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ACOUSTIC RELEASE SYSTEMS

by

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TECHNICAL REPORT

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Acoustic Release Systems

Ocean Research Equipment Corp., Acoustic Release Device - Previous Use and Testing
Raytheon Corp., Acoustically Controlled Actuator - Tests
American Machine and Foundry Co., Acoustic Coded Command System - Tests

R. H. Heinmiller

Introduction

In the fall of 1967 an extended program of tests was begun to evaluate several types of acoustic anchor release devices available on the market. This program was prompted by a need to isolate and correct problems which came to light after several years of use of the O.R.E. system. Two other systems, one made by Raytheon and the other by American Machine and Foundry Co., were tested. This report deals with previous use of O.R.E.'s system by the W.H.O.I. Buoy Project and the testing program in 1968 and with the Raytheon and A.M.F. test series. Detailed description of these systems and their operation will not be undertaken in this report. Reference is made to data published by the respective manufacturers.

Acoustic Release Systems, General

Comparison of these systems is complicated by different modes of operation in each case. However, all the systems must meet certain basic criteria in their operation. The first consideration is reliability. That is, does the device perform its basic function, i.e. mechanical release, when commanded to? This question, because of the statistical nature of the acoustic process, must be approached statistically. This implies large numbers of trials. The second consideration is security, or what is the susceptibility of the device to triggering from sources of noise, either natural or man-made in the ocean, when no command has been given. No effort was made to try to evaluate security. Three approaches are possible in this area. First, noise sources may be simulated in the laboratory. Second, the device may be put in the ocean. The third approach is the theoretical one. Most of the manufacturers involved have done this last type of analysis. The second approach involves long exposure times in the ocean.

Each of the release devices tested includes, at least as an optional feature, provision for transmitting information as to whether the device has been released. In the case of the Raytheon system, an additional channel also transmits information on the attitude (horizontal or vertical) of the underwater unit. A third consideration, then, is how reliable (or useful) are these functions?

O.R.E. Release - Previous Use

The O.R.E. release system employs a double-sideband, supressed-carrier signal. Coding is provided by carrier frequency, modulation frequency, and signal duration.[1] A 12-KHz. pinger is available as an optional feature to provide confirmation of firing. This pinger was not used by the Buoy Project previous to 1968. The system was used by the Buoy Project between January 1965 and October 1967 on sixty-seven occasions at sea. On thirty-one of these occasions, no conclusions can be drawn about release performance, usually because of the loss of the mooring. The other thirty-six are listed in Table I.

On twenty-three occasions, the release performed its function on command, although on two of these (255 and 257), only after a considerable number of commands. This includes 214 and 216 which were fitted with oversize sling rings and thus failed to release mechanically, although they fired their squibs on command. There were three known cases

(254, 258a, and M.I.T. Exp. #1) of units refusing to release due to a mixup in the piston O-rings. These also had apparently fired but not released. Two cases (195 and 231) involved a release which functioned on its timer, no attempt having been made to release it on command. Three subsurface moorings (234, 235, and 246) refused to surface even though acoustic-beacon signals indicated that the moorings were intact. These are considered release failures.

A single instance of pre-tripping of an O.R.E. release has been identified by W. R. Wright. A series of subsurface moorings was set in the Denmark Straits in March of 1967. One of these refused to come up on command and was later recovered by dragging. The record from two depth recorders on the mooring is shown in Figure 1. At "A" the mooring is supported by six steel floats. At "B" the release apparently tripped letting the buoyancy section surface. At "C", one day later, the lower recorder dropped to the bottom. It is supposed that at this point one ball broke loose and two flooded. At "D" the mooring surfaced again, apparently after the flooded balls broke off. At "E" one more ball broke loose and the gear sank. The gear, when recovered, had only two balls on it, both badly battered. Pack ice in the area accounted for the loss of the balls. Ice noise has been suggested as a possible source of noise to actuate the release.

The most serious cases are those in which the release worked successfully on its backup timer after it had refused to work on command. The eventual functioning of the unit on the timer indicated that there was no mechanical problem with the unit, such as O-ring reversal. This happened on four occasions (193, 251, 252b, and 258b). There were enough of these malfunctions to prompt the initiation of a testing program on the O.R.E. system.

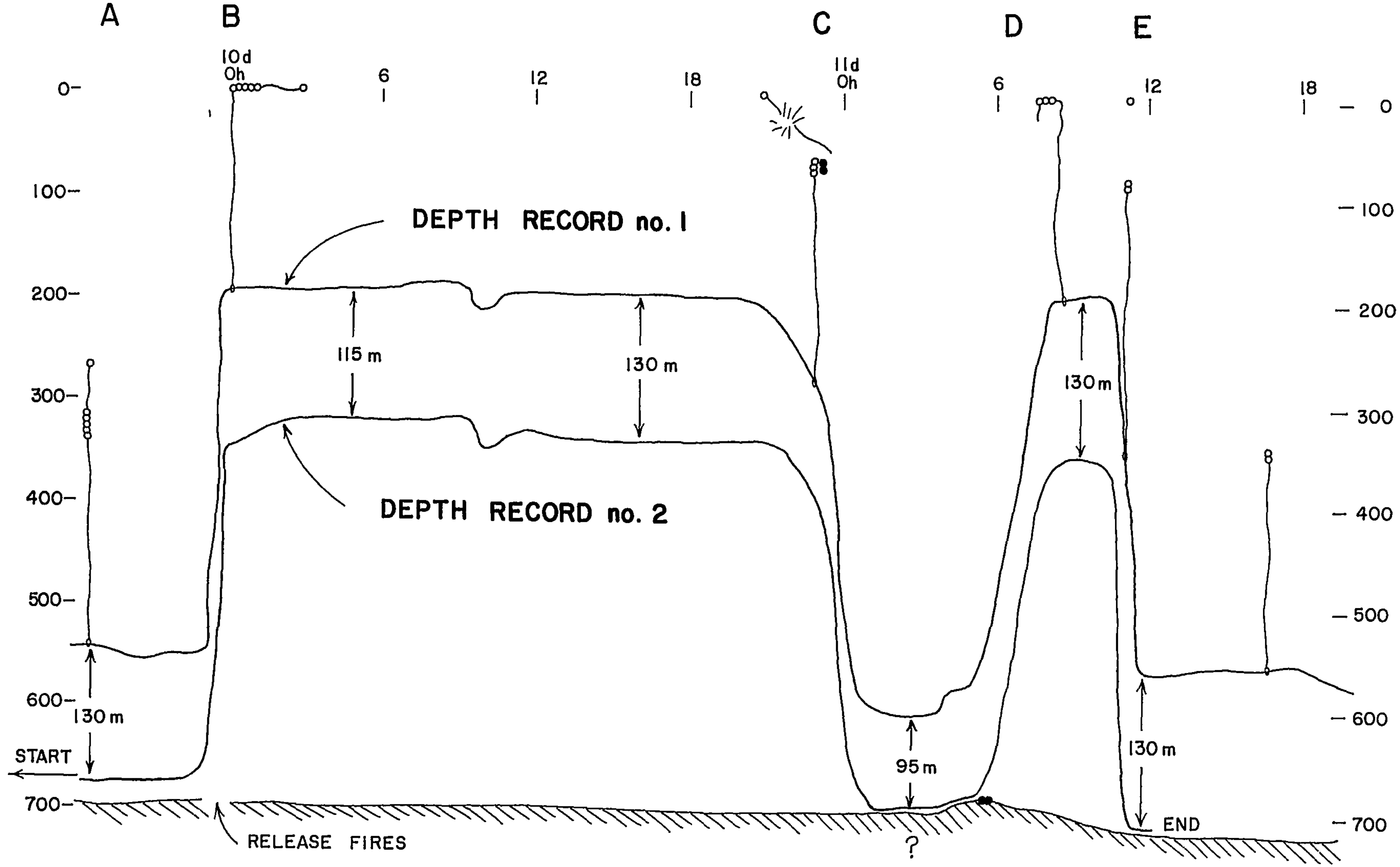

A
B
C
D
E
10d
0h
6
12
18
11d
0h
6
12
18
0
100
200
300
400
500
600
700
800
DEPTH RECORD no. 1
DEPTH RECORD no. 2
115 m
130 m
130 m
130 m
95 m
130 m
START
END
RELEASE FIRES
?

FIG. 1

Table I

Station #	Location	Days at Sea	Surface or Subsurface	Release #	Response Command	Response Timer	Notes
179	D	27	SS	13	yes	---	
183	D	2	SS	17	yes	---	
184	D	56	SS	17	yes	---	
189	D	56	SS	17	yes	---	
192	D	43	SS	16	yes	---	
193	D	139	S	28	no	yes	
195	J	77	S	28	---	yes	
201	D	32	S	32	yes	---	
203	D	67	SS	32	yes	---	
205	H	44	SS	30	yes	---	
208	D	2	S	40	yes	---	
210	D	38	S	30	yes	---	
212	D	61	SS	43	yes	---	
214	D	2	S	49	yes	---	Release fitted with wrong-size sling rings
216	D	2	S	47	yes	---	" " " "
220	D	59	S	47	yes	---	
231	D	1	S	49	---	yes	

Table I (Continued)

Station #	Location	Days at Sea	Surface or Subsurface	Release #	Response Command	Response Timer	Notes
234	G	55 (lost)	SS	17	no	---	Beacon signal indicates mooring intact
235	H	54 (lost)	SS	71	no	---	" " "
239	SS1	50	S	69	yes	---	
242	D	50	S	69	yes	---	
243	D	51	SS	72	yes	---	
244	SS3	9	S	49	yes	---	
246	H	51	SS	77	no	no	
249	D	8	SS	47	yes	---	
250	D	8	SS	78	yes	---	
251	D	8	SS	79	no	yes	
252	D	8	SS	81	no	no	(Two releases on mooring)
				82	no	yes	
254	D	7	SS	79	no	no	Piston o-rings reversed
255	D	1	SS	82	yes	---	Took numerous tries to fire
257	Gulf of Maine	1	S	80	yes	---	Refused to fire until hauled up just under ship
258	D	1	S	80	no	no	(Two releases on moorings)
				82	no	yes	O-rings reversed
M.I.T. "Anchor Drop Exp. #1"					no	---	O-rings reversed
M.I.T. "Anchor Drop Exp. #2"					yes	---	O-rings reversed

O.R.E. Release Tests

October 1967-CHAIN 74

Tests were carried out by D. Ketchum from O.R.E. using a specially modified release unit. Release #83 was wired to provide an outside connection to the output of the receiver detector. The incoming, detected signal could then be monitored via a hardwire connection. A D.C.-level shift indicated when the squib relay had closed.

Lowerings were made on the conducting wire on the acoustic winch. A 12-KHz. pinger was attached below the unit. It was immediately found that the one-second repetition rate pinger pulses were shutting off the Automatic Gain Control in the receiver, thus preventing the necessary 2.5 seconds of signal from getting through. Even after the removal of the pinger, however, it was impossible to trigger the unit due to the presence of noise of undetermined origin.

Bermuda Tests

A set of tests was carried out by O.R.E. in Bermuda in November of 1967. The tests were carried out over a two-day period using two vessels: R/V PANULIRUS from the Bermuda Biological Station, and the BAY QUEEN, a fishing boat. The interrogator and its transducer were put on the BAY QUEEN and the release was lowered on a conducting wire from the PANULIRUS. The only modification to the release after the October CHAIN tests was to reduce the integration time to 1.5 seconds. The interrogator used was a portable, battery-powered unit.

A single lowering was made on the first day. Several series of interrogations were made at various depths and source ranges. After approximately seventy interrogations, the command signal began to sound distorted and the release failed to respond. It was decided that the batteries in the interrogator were getting low, so operations were terminated.

On the second day a battery charger was carried on the

the BAY QUEEN and used between series of interrogations. Seventeen series of about ten interrogations each were made at varying depths and ranges. The batteries again gave out on the last series.

On all lowerings on both days a 3.8 KHz. acoustic beacon was attached to the wire above the release. This beacon had a two-second repetition rate and a timing circuit that shut it off for approximately thirty seconds at one-minute intervals. At each interrogation it was determined whether the beacon was on or off by listening on a hydrophone. The beacon stopped working during the seventh series.

Table II shows the results of the interrogations for both days disregarding preliminary interrogations made to adjust equipment at the beginning of each day and the series when the batteries were low.

Putting the release on the bottom seemed to have no effect on its performance. Series of interrogations made at two-meter intervals near the bottom and at ten-meter intervals near the surface gave no indication of multipath problems. Transducer depth was also varied with no apparent effect.

Considerable amounts of reverberation were noted as distorted signals continued to come in for several seconds after stopping the interrogation. The water depth was approximately 950 fathoms. Once the release fired a second time on the reverberating signal. Typical firing times on the direct signal, even with considerable distortion, were about four to five seconds.

Table II

	Attempts	Not Fired	Fired	% Success
Beacon ON	55	5	50	91 %
Beacon OFF	160	4	156	97.5%
Totals	215	9	206	93 %

Considerable noise was observed at approximately 8 KHz. It seemed to have little effect on performance. The beacon could be seen shutting down the AGC and cutting off the signal every two seconds and seemed to have some effect, as may be seen from Table II.

December 1967 - ATLANTIS II 41

The integration time of the lowered unit was increased to 2.5 seconds for this cruise. The object was to investigate the performance of the release with the longer integration time and with beacon (3.8-KHz.) interference. The first lowering was made with a beacon (two-second rep-rate) above the release and a standard release (#47) with a 1.5 second integration time and confirmation 12-KHz. pinger below the monitored release. (See Table III.)

A number of preliminary interrogations made at 10 m. before the beacon was attached indicated the release was working properly. After attaching the beacon, a total of nineteen interrogations were made at various source depths and release depths to 1,000 m. All failed to fire the unit.

Release #47 was then fired with a single command at 1,000 m. It fired immediately as confirmed by the pinger, which turned on. The gear was hauled up and the 3.8-KHz. beacon removed. The unit was sent down with the 12-KHz. beacon still operating.

Forty-five interrogations were made at various release depths and source depths with only twelve successes before the pinger stopped. It was found in this series that the release responded quite well with the source at twenty-six feet depth, but poorly with other source depths.

After the pinger stopped, twenty-five attempts were made of which nineteen were successful, with ten straight successes with the transducer at twenty-six feet.

TABLE III

Series	Unit Depth m.	Source Depth m.	Attempts	Successes	Interference
1	75	30	3	0	3.8 KHz.
2	300	30	3	0	"
3	300	20	4	0	"
4	300	40	3	0	"
5	1000	40	6	0	"
6	75	50	6	0	12 KHz.
7	300	50	9	0	"
8	1000	50	6	0	"
9	1000	26	9	6	"
10	1000	50	6	0	"
11	1000	26	6	6	"
12	1000	38	3	0	"
13	1000	32	3	3	None
14	1000	35	5	2	"
15	1000	32	7	4	"
16	1000	22	10	10	"
17	1000	26	3	0	"
18	1000	32	4	4	"
19	1000	29	8	6	"
20	1000	32	4	2	"
21	1000	100	3	0	"
22	500	100	6	0	"
23	500	26	7	7	"
24	500	100	2	0	"

Table IV

25	500	26	17	14	"
26	500	100	12	12	"
27	500	26	7	7	"

The gear was brought up and release #47 with the 12-KHz. pinger removed. #83 was sent back down. A series of interrogations was made at a constant release depth, while varying the source depths. Results were mixed. The gear was then re-rigged with release #47 with confirmation pinger below the test unit. The unit responded well to signals from a source depth of twenty-six feet, but not from 100 feet. #47 was then fired with the source at 100 feet.

The test unit was hauled up and modified to have a 1.8-second integration time and sent down to 500 m. It worked well at both twenty-six feet and 100 feet source depths. (See Table IV.)

Conclusion

The decreased integration time drastically reduces the effects of interfering signals which shut down the release AGC circuit and of multipath interference from varying source depth. The effect of the shorter integration time on the security of the system has not been evaluated.

Raytheon Acoustically Controlled Actuator

A series of tests of the Raytheon ACA was carried out on several cruises. The units tested were two prototypes, the first built by Raytheon. The ACA system uses a four-frequency coded system.[2] Each part involves the simultaneous absence or presence of various frequency combinations and the two parts are transmitted one after the other. Two frequencies are used for replies by the unit to interrogation from shipboard. Four channels are available in each release unit, each with its own unique four-frequency, two-part code. The quick-reply channel simply provides a single-frequency reply for location purposes. An attitude-monitor channel replies on either of the two reply frequencies depending on whether the unit is horizontal or vertical. The squib-interrogation channel indicates whether the squib-firing circuit has continuity and thus whether the squib has fired. The fourth channel is used to fire the squib.

June 1967 - CHAIN 68

ACA unit #1 was deck tested and lowered on the hydrowire to 2,500 m. All functions except actual firing of the squib were checked out. Unit seemed to be operating properly.

While setting a mooring one day later on which it was intended to place the ACA as anchor release, Unit #1 fired prematurely as it was being paid out over the stern. The mooring was hauled from the upper end and the release inspected. It was two-thirds to three-quarters full of water. It was rinsed and the batteries were removed but no repairs were possible on shipboard. Unit #2 was then lowered to 2,450 m. on the hydrowire, brought up and checked. It had not leaked. A second lowering of #2 was made several days later to 3,000 m. Mixed results were obtained with various interrogations and two squib-firing commands sent while it was at 3,000 m. failed to fire it. The release operated properly on deck the next day.

Three more lowerings were made. On the first, ship noise prevented identification of release replies. Five firing commands were sent and when the release was brought up, it had fired. On the second lowering to 250 m., the unit worked well and was fired on command. A third lowering was similar.

August 1967 - CHAIN 71

ACA unit #2 was placed on mooring station 253 at a depth of 2,000 m. The unit was not inserted into the mooring as the anchor release, but rather was placed off-line, shackled to a piece of chain in the mooring. A series of range tests were made by interrogating the unit in each of its three reply modes. Results are shown in Table V.

Table V

Interrogation	Number of Interrogations	Number of Received replies	Range (horiz.) Miles
Quick reply	7	6	2-4 miles
Attitude	5	4	
Squib cond.	5	5	
Quick reply	10	10	1.4 miles
Attitude	10	10	
Squib	12	10	
Quick reply	8	6	2.9 miles
Quick reply	7	5	5.3 miles
Quick reply	∿15	0	7.1 miles

ACA #1 was then lowered on the hydrowire to 1,000 m. and further tests were made (See Table VI.)

Table VI

Mode	No. of Interrogations	No. of Replies	Depth
Quick reply	50	50	
Attitude	13	12	100 - 1,000 m.
Squib	7	6	
Quick reply	4	4	
Attitude	1	1	Less than 100 m.
Squib	1	1	

During these tests, it was found that when the ACA was asked for a quick reply, it sometimes replied at the wrong frequency. Near the surface, it replied in the quick-reply mode without command. In this particular unit, the quick-reply interrogation used a low-order security code with a single frequency and half part code. Apparently ship's noise was causing the quick replies.

In later range tests, replies could not be heard at ranges greater than two miles, apparently due to noise. ACA #2 was later fired. Two commands were necessary and upon recovery of the mooring the mechanism was observed to have worked.

A test lowering on the hydrowire of ACA #1 was made to investigate the performance of the unit while lying on the bottom. A certain amount of difficulty was found in attempting to fire it while in the mud.

Raytheon later reported a shipboard unit code spacing error which they feel accounted for the difficulty in firing the #1 unit. This would seem to be confirmed by the fact that the quick reply, a one-part code, worked while the two-part code (attitude and squib) did not.

October 1967 - CHAIN 74

In October the equipment was primarily operated by W.H.O.I. personnel. Unit #1 had been modified. The squib-interrogation channel was changed to monitor a magnetic switch on the inside of the case. A small magnet in a holder on the outside of the case kept the switch closed. This magnet was connected by a string to the weight to be tripped by the release mechanism. When the weight was released, the magnet pulled off and let the switch open. The squib-interrogation chanel thus monitored the actual mechanical functioning of the release instead of squib continuity. A number of lowerings were made using both units. Results were mixed. In the first lowering, a number of interrogations were made at mid-depth. The unit (#1) was then laid on the bottom, interrogated and commanded to fire. Further interrogations indicated the magnet was still in place so the squib presumably had not fired. The release was lifted off the bottom and again interrogated. After two firing commands, the unit indicated that the magnet was gone. This was confirmed upon hauling the unit to the surface.

After rearming, the unit was again lowered to the bottom. A number of interrogations were made on the way down. When the unit was on the bottom, firing commands were given. Interrogating the unit as to whether the magnet was still on brought several inconsistent replies. The unit was then lifted off the bottom and interrogated again. Replies as to condition of magnet were still inconsistent. The unit was dropped to the bottom and raised three times. When hauled to the surface it had not released.

The unit was then lowered to 2,400 m., interrogated and commanded to fire. Further interrogation indicated that the magnet was still on. When the unit was hauled aboard, it was found that the weight had been released but the string connected to the magnet had broken, leaving the magnet in its holder.

On the final lowering, unit #2 was placed on the bottom and commanded to fire. Replies to subsequent interrogation indicated the squib had fired. Numerous interrogations at mid-depth were made on the way down and on the way up. When the unit was brought aboard it had fired.

Results of all interrogations made on these lowerings, as shown in Table VII, indicate that in the "quick reply" mode replies were received 81% of the time. In the "interrogate squib" (or magnet) mode replies (of either indication) were received only 67% of the time, and in the "attitude interrogate" mode, 52% of the time. Furthermore, the replies in the latter two modes were not always consistent. For instance, at one point after a firing command, a series of ten interrogations gave seven "noes" and three "yeses". Including all interrogations of both units in all three modes, replies were heard in 206 out of 309 attempts for an average of 67%.

Table VII

Mode	Interrogations	F1 Replies	F2 Replies
Quick Reply	121	---	98
Squib (Magnet)	66	32	12
Attitude	122	43	21

Some difficulty was encountered in attempting to fire the unit while it was lying on the bottom. Results here were also inconsistent.

Conclusions

Results with this system were inconsistent. Successive replies to interrogations were often contradictory. For identification of the reply frequency, the operator must rely on two indicator lights on the shipboard unit. These replies are single pulses. If repetitive signals were used, a graphic detection and recording system could be used.

The weight of the underwater unit (195 pounds) made it difficult to handle over the side of the ship. Raytheon reports they are building a production version of this unit, using smaller transducer and integrated circuits, which will be considerably lighter. However, this substantially different unit would require further testing.

* * *

AMF Acoustic Coded Command System

Tests of the American Machine and Foundry Acoustic Coded Command System were carried out on the December 1967 Buoy Project cruise (ATLANTIS II, 41). The AMF system uses a pulsed, amplitude modulated double sideband supressed carrier signal[3]. The signal employs a code of five levels: carrier frequency, modulation frequency, pulse width, pulse repetition frequency, and time duration. In the model tested, three channels were available, all using all five code levels. The first channel turned on a 12-KHz, one-second repetition rate, pinger for a preset length of time. The second channel fired the release. Release actuation turns on the pinger, which then remains on. The third channel can be used for actuation of external devices. Only the first two channels were used in these tests.

The tests were divided into two parts. In the first part the release was lowered on the hydrowire. In the second, it was placed on a mooring. For the first lowered tests, a 3.8-KHz. acoustic beacon was attached to the wire ten meters above the release unit in an attempt to look at interference problems. An attenuation box was put on the output of the shipboard command unit which allowed steps of attenuation of up to 50 db. to be put in. At each depth a series of up to twenty-five interrogations would be made at varying attenuations to determine the threshold level at which the unit began to respond. After each interrogation the 12-KHz. pinger would be listened for. (A series of interrogations were also made at each depth with a new type of shipboard command unit being tested by AMF. Data from this unit is ignored for the purpose of this report.) With the release near the bottom the squib was then fired and firing confirmed by the pinger.

On the second lowering, a separate 12-KHz. pinger was attached ten meters above the unit as a bottom finder. Several series of interrogations were made at various intermediate depths and near the bottom. The unit was then laid on the bottom and a series of interrogations made. It was then fired while on the bottom and firing confirmed. The only effect of putting the unit on the bottom seemed to be to increase the threshold attenuation by about fifteen db. In other words, it took fifteen db. more power to fire it in the mud than at the same range hanging on the wire. The power required to fire it when on the bottom, however, was still ten db. down from the maximum power available from the shipboard unit.

The release was then put on a mooring eighteen meters above the anchor in about 2,600 m. of water. Range tests were made starting at eight miles horizontal range. No response could be gotten until the range had been reduced to four miles. Thresholds were then determined at one-mile intervals up to the mooring. Later the release was successfully fired to retrieve the mooring.

In Fig. 2 the threshold attenuation in db. is shown as a function of slant range, both for lowered and moored tests. The thresholds for each series (at a particular depth or range) were estimated from the data.

In Fig. 3 the percentage of successful interrogations is plotted as a function of percentage of power-attenuation threshold. Each trial was assigned a percentage based on the

A.M.F. RELEASE

THRESHOLD vs. RANGE

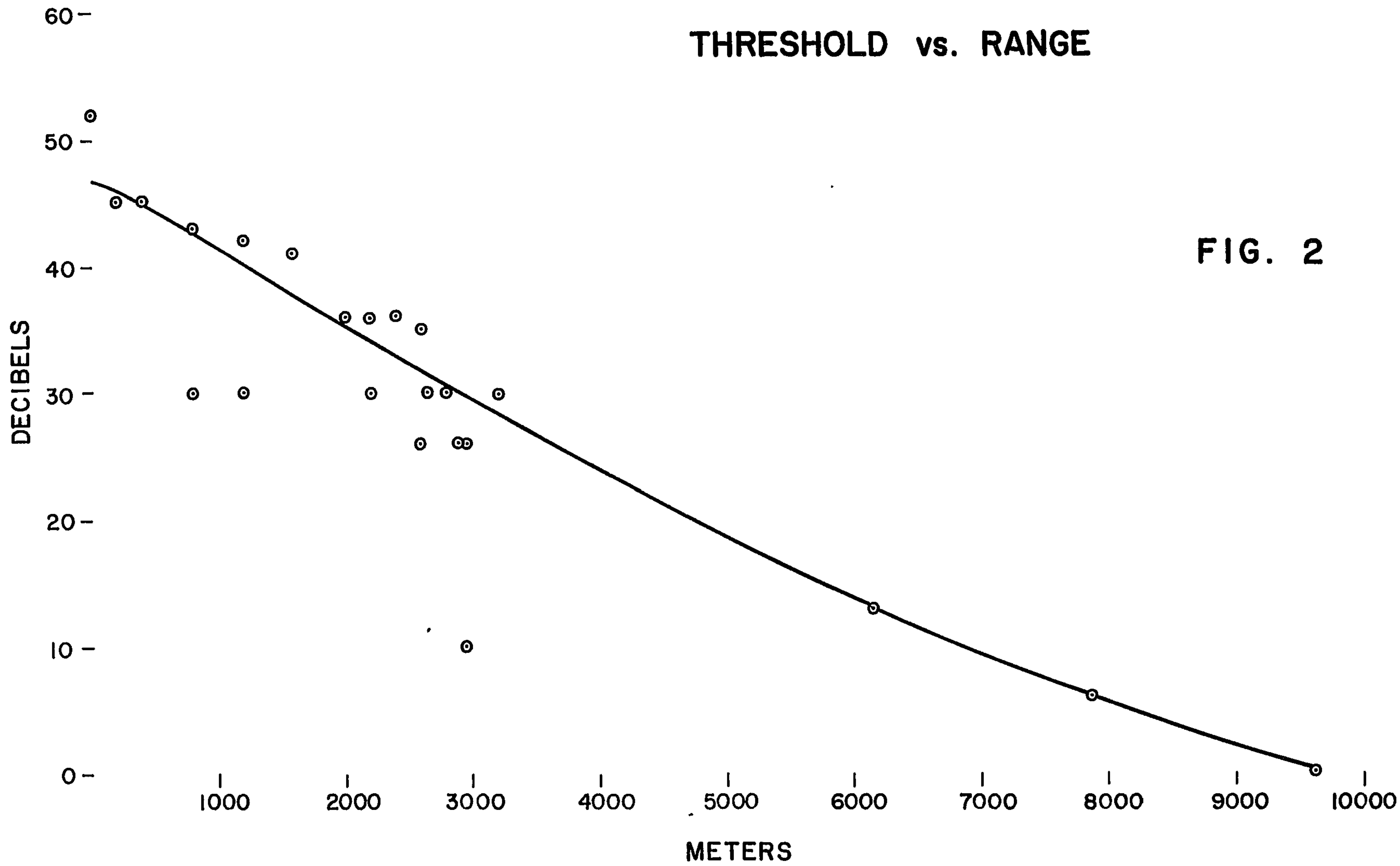
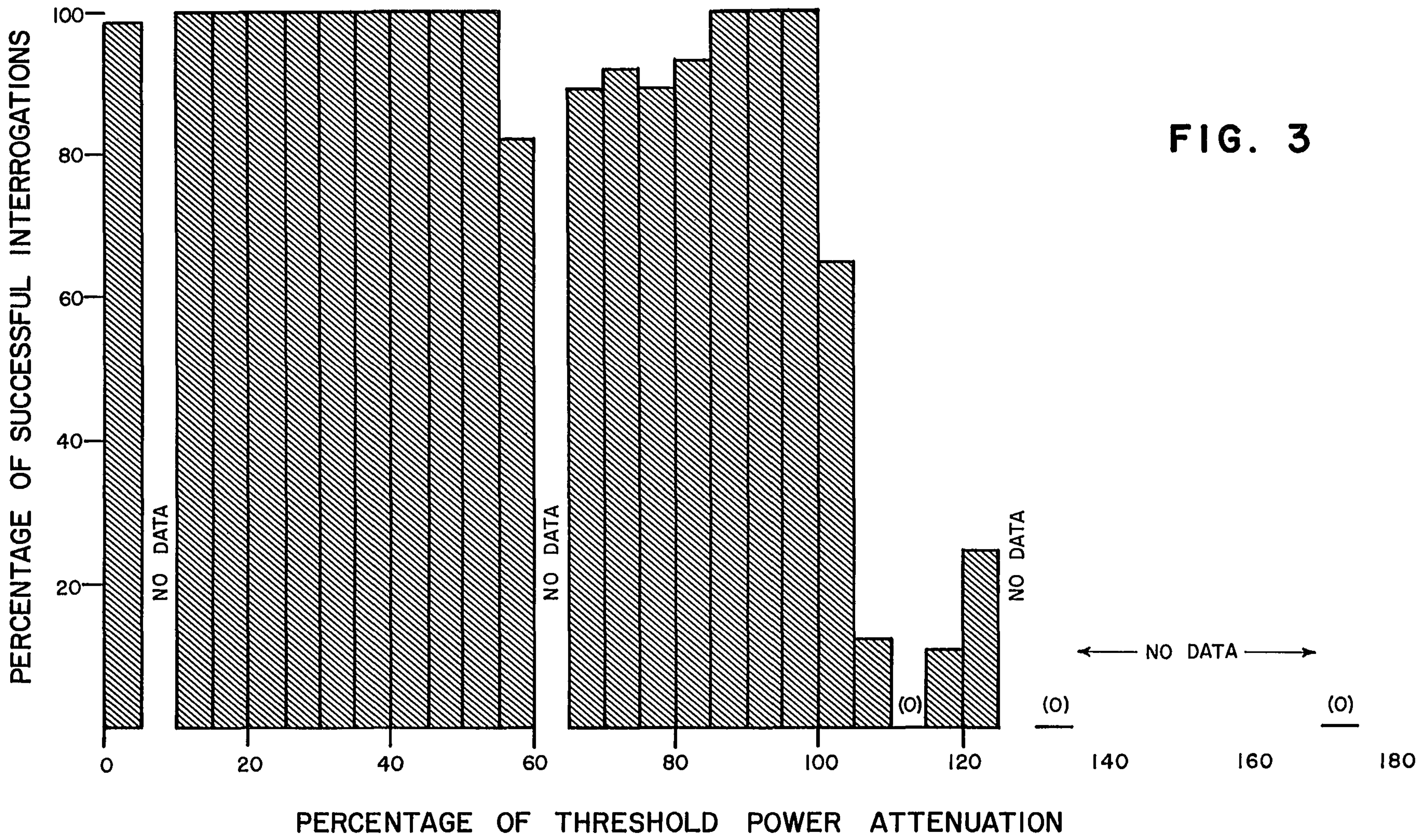


FIG. 2



PERCENTAGE OF SUCCESSFUL INTERROGATIONS
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180
NO DATA
NO DATA
NO DATA
(O)
(O)
NO DATA
(O)
PERCENTAGE OF THRESHOLD POWER ATTENUATION

FIG. 3

threshold for its series. Then all trials in each threshold interval, regardless of conditions (depth, etc.) were collected and the percentage of successes plotted.

In many cases, the total number of trials in an interval was very small. Therefore, the percentage successes for those intervals are not very meaningful. Taking cumulative figures, of all trials between 0 and 50% of threshold, 98.2% were successful. Of all trials up to 99% of threshold, 95.6 % were successful. No difficulty was found in hearing the reply signal. The presence of the 12-KHz. pinger on the wire during one lowering did not seem to affect the functioning of the release.

One anomalous effect was noted on one lowering. Three series of interrogations were made at 800 m., 850 m. and back at 800 m. The thresholds for the series were respectively 30 db., 43 db., and 43 db. The threshold at 800 m. seemed to change by 13 db. No explanation has been given for this but, in any case, the thresholds found were well below the peak source power available.

Conclusions

The system worked consistently, both in the lowered tests and in the moored tests. The 12KHz. pinger in the release could be heard quite easily. The receiver in the shipboard unit simply uses an audio (loudspeaker) output. The repetitive reply signal could be recorded, although the clock controlling the pinger repetition rate is not very accurate or stable, so that it might be difficult to use this pinger as a homing beacon.

It should be noted that the firing confirmation function in this system actually monitors the retraction of the piston in the release mechanism. This is contrasted to the O.R.E. system where the voltage at the squib is monitored, or the Raytheon system, which (in the standard model) monitors squib continuity. The A.M.F. mechanism is probably more positive.

References

[1] Ocean Research Equipment Corp.; Report #08652, Instruction Manual, O.R.E. Acoustic Release Device Model #210BT; February, 1967

[2] Raytheon Corp.; Preliminary Specifications, Acoustically Controlled Actuator System, Model ACA-1120

[3] American Machine and Foundry Company, Alexandria Division; AMF Model 200 Acoustic Command System Description; October, 1967