新方式音波発生装置の効果試験

Test of new-type sound generator

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1984年5月の生捕りイシイルカへの音波発射実験、7月のベーリング海における実験、8月の北海道沿岸オホーツク海における実験から、イシイルカに対する威嚇効果が確められた20～50 kHzの超音波パルスとFM波をランダムに発生する装置を4台試作し、サケマス操業海域と日本近海で効果試験を行った。北海道沿岸オホーツク海で8月28日に行った実験については、今年度の他のドキュメント（No.2995）に述べられている。

1. 装置の仕様

1984年に使用した音波発生装置（擬似エコーロケーションクリックス発生装置）より更に複雑な組合せで音波を発射させるため、パルス波の周波数（f）、パルス巾（r）、間隔（t）及びFM波の変調間隔（T′）を16通りとし、その組合せをランダムに選定できるようにした。

主な仕様は以下の通りである。

1.1　周波数範囲　20～50 kHz

1.2　送波器　送波感度：35 dB以上（図1参照）

指向性：水平方向無指向性

垂直方向　60°（半減半角50 kHz）無指向性（30 kHz以下）

1.3　最大送波音圧　86 dB re 1 μbar at 1 m 図1参照

1.4　送波モード

A．パルス波（図2）

f：20、22、24、26、28、30、32、34、36、38、40、42、44、46、48、50 kHz

r：0.9、8.1、15.3、22.5、29.7、37.0、44.2、51.4、58.6、65.8、73.0、80.2、87.4、94.7、101.9、109.1 mS

t：9.9、24.3、38.8、53.2、67.6、82.0、96.5、110.9、125.3、139.7、

154.1、168.6、183.0、197.4、211.8、226.3 mS

f、r、tは以上の値から無作為に選択される。

B. FM波（図3）

f_1：20 KHz

f_2：50 KHz

T′：9.0、15.7、22.5、29.2、35.9、42.7、49.4、56.1、62.9、69.6、76.3、83.1、89.8、96.5、103.3、110.0 mS

T′は以上の値から無作為に選択される。

1.5 周期　図4のようにパルス波を5個、FM波を5周期だけ送波し、休止時間後同じことを繰り返す。

1.6 電源　12 Vの小型密閉鉛蓄電池（寸法93×65×152 ㎜、重量2.6 Kg、容量6.5 Ah）を2個直列接続して24 Vで使用している。12時間放電、12時間充電で年60回使用するとしても5～6年間使えるので乾電池に比べ経済的であり、操業1回毎の音波発射エネルギーも大きくとれる。

1.7 使用温度　0～40° C

1.8 ブイ　寸法　最大直径380 ㎜、高さ797 ㎜、（図5）、中型ラジオブイの中に電池、電子回路を収納し、外部のスイッチによりOFF→TEST→ONと切換えて作動させ、TESTではランプの点灯により作動を確認する。総合重量は1人でも持ち運びできるように20 Kgとした。

1.9 作動時間　流網が海に入っている間の約12時間音波が発射され、しかも休止時間ができるだけ短いことが望ましい。図4の休止時間をディップスイッチの選定値（D）により調整し、電池が充分充電されている場合装置の作動時間（H）を次式で大まかに求められるようにした。

$$H = 1.5 \frac{D \cdot C}{I}$$

C：電池の容量（6.5 Ah）

I：最大消費電流（6.5 A）

ディップスイッチは8個（D_0～D_7）あり、それをONにした時「1」とし、OFFの時「0」とするとDは次式で示される。

$$D = \sum_{n=0}^{7} Dn \cdot 2^n$$

D_3を1、それ以外を0とするとD＝8でH＝12となり、1回の操業中音波を発射できる。D＝8では1秒音波発射、4～5秒停止位の送波モードである。実際の使用にあたっては揚網時にランプ点灯と空中発射音を確認し、それらが暗かったり弱かったりした場合にD＝10に設定し直すことにしたが、独航船による効果試験では2個のブイについてその調整を行った。

2. 独航船による効果試験

明洋丸船団所属の独航船第31福荷丸に新方式の音波発生装置4台を積み込み、米国側へ提出する報告書をそのまま利用して、混獲イルカの水平垂直位置のデータを日本人オブザーバー（山下氏）に採集して戴いた。

図6に示すように流網の両端から20反目と90反目の計4カ所にブイを取付けた。6月12日から7月29日の間に40回操業し、35回音響ブイを投入した。ブイ投入前と揚網時に空中の発振音を確認したが、全部作動良好であった。

船速をストップかスローの状態でブイを投入するので風の強い日には網成りを悪くする原因となるが、敢えて船速を下げて投入し実験回数を増やした。

音響ブイにはレーダブイやラジオブイのようにアンテナが無いため、少し波があるとその存在がはっきりせず、揚網舷の反対側へブイが行き船底から引揚げたり、プロペラの方へ行く危険が生じた。ブイの取付位置の前後1反目に赤い布で目印を付け、それが接近してきたら笛を吹いて甲板員に知らせ舷側でのトラブルを避けた。

ブイを網より風上側に投入した場合、ブイが網にからみ横になっていることが数回あった。その原因はブイ下部のナットに網糸がからむためであり、次の実験からは改造する必要がある。海水がついた手でさわったり、海水の飛沫がかかる所で操作しないように注意しておいたが、返送されたブイを調べてみると電池側コネクタ端子の1カ所に腐触が見られ、接点復活剤や予備の電池を持たせる必要があることがわかった。

今回の実験期間中のイシイルカの混獲状況を表1に示した。混獲イシイルカの水平垂直分布とブイ取付位置との関係を図6に示した。

水平を9区分、垂直を3区分に分けて4個のブイを使用している時のイシイルカの混獲分布を計算し、1985年の一般網のデータと対比させながら表2と3に示した。

一般網に比べるとブイを取付けた両端側は混獲が少く、音波の弱い中央部（水平区分4～6）に約80％が集中している。投網時に風波が強くブイ2個のみを使用した時には、ブイを取付けなかった方の網端に親子と思われるイシイルカが2頭羅網していた。

垂直方向の区分別混獲分布はブイ試験網と一般網でほぼ同じ結果となっている。ブイ試験網のＣＰＵＥは0.325で1985年の一般網のＣＰＵＥ（0.445　や他の試験網のＣＰＵＥ（0.354～0.421）に比べ小さいが、明洋丸船団の臨接船と比べると似た値であった。

ブイ試験船は1隻であり、実験回数とイシイルカ混獲数が少いので統計的な効果判断ができないか、音波の到達しにくい中央部の混獲数が多い傾向が見られるので今後とも検討していく必要がある。

3. サンマ漁船による効果試験

前述の独航船第31稲荷丸は6～7月のサケマス漁業が終ると8～11月の期間にサンマ棒受け網漁業を行い、北海道の東側海域から三陸沖へと南下してくる。夜間に多い時では50マイル位移動しながら約10回操業するが、イルカが接近してきて集魚灯に集まったサンマの回遊が乱れ、徐々に魚群が薄くなる被害が漁期中に10回位発生する。昼間、漂泊している時にもイルカが寄ってくることがあるので、音響ブイの効果試験をやって貰うことにした。

1985年度は、イルカの群が少く、音響ブイの実験は以下のように3回しか行えなかった。

① 8月22日14時33分、天候晴、水温13.2°C、無風、操業中にイルカ2頭(種不明)が接近してきたのでブイを船尾後方へ投入すると1,000 m位の所にいたイルカは徐々に遠ざかった。

② 8月23日15時37分、天候曇、水温14.0°C、風向風力SSW－1、漂泊中にリクゼンイルカ7頭が接近してきたので船尾後方へブイを投入すると、700～800 mの所にいたイルカは徐々に遠ざかった。

③ 8月26日15時30分、天候霧雨、水温15.8°C、風向風力ENE－3、漂泊中にリクゼンイルカ2頭が接近してきたので船尾右側へブイを投入すると、20 mの距離のイルカは約2分後に急速に逃げた。

各実験位置を図7に示した。音響ブイの作動時間を調整するディップスイッチは左から3番目をONとし、作動時間は6時間で短いが音波発射回数を多くした。

③の約2分後というのは、音響ブイのスイッチをONにしても電子回路内のコンデンサーを充電するのに時間がかかるためである。今回の実験から20 mの近距離では強烈な威嚇効果があり、1,000 m位の遠距離では音波の存在を嫌って徐々に遠ざかることが分った。

表1. イシイルカの混獲状況

使用ブイの数	操業回数	混獲回数		総混獲頭数
		1頭	2頭	
4	34	7	2	11
2	1	0	1	2
0	5	0	0	0
合計	40	7	3	13

表2. 網の水平方向の区分別混獲分布（%）

水平区分	1	2	3	4	5	6	7	8	9
一般網（1985）	12.1	11.2	11.6	9.4	9.4	9.4	10.3	12.4	14.4
ブイ試験網	0	9.1（1）	0	36.4（4）	36.4（4）	9.1（1）	0	0	9.1（1）

試験網……ブイ4個　　（ ）……頭数

表3. 網の垂直方向の区分別混獲分布（%）

垂直区分	上	中	下
一般網（1985）	48	42	10
ブイ試験網	46（5）	36（4）	18（2）

試験網……ブイ4個　　（ ）……頭数

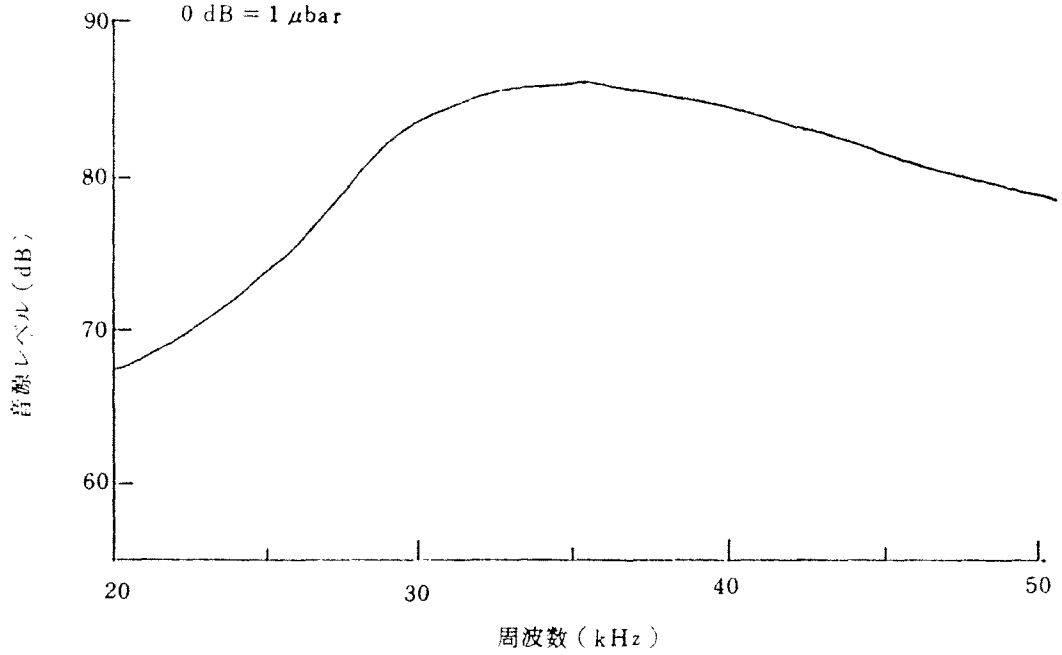


図1. 送波器の出力特性

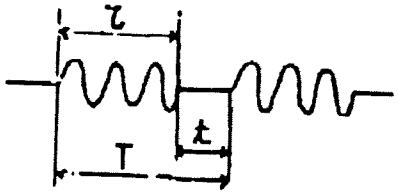


図2　送波モード（パルス波）

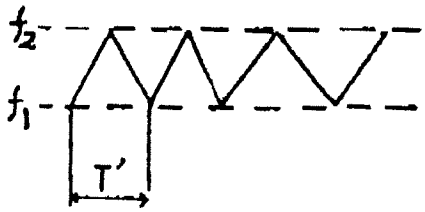


図3.　送波モード（FM波）

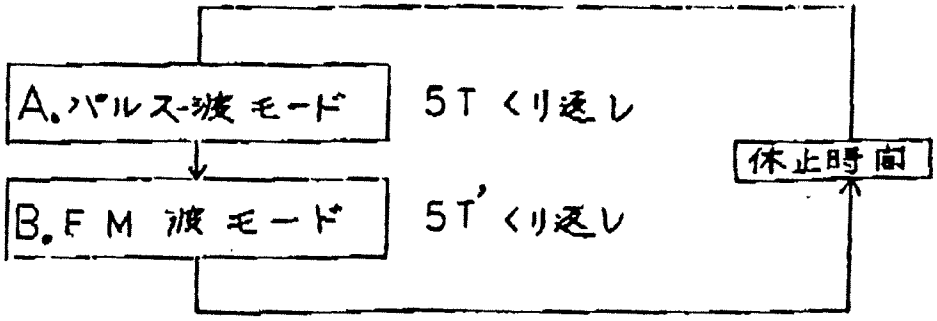
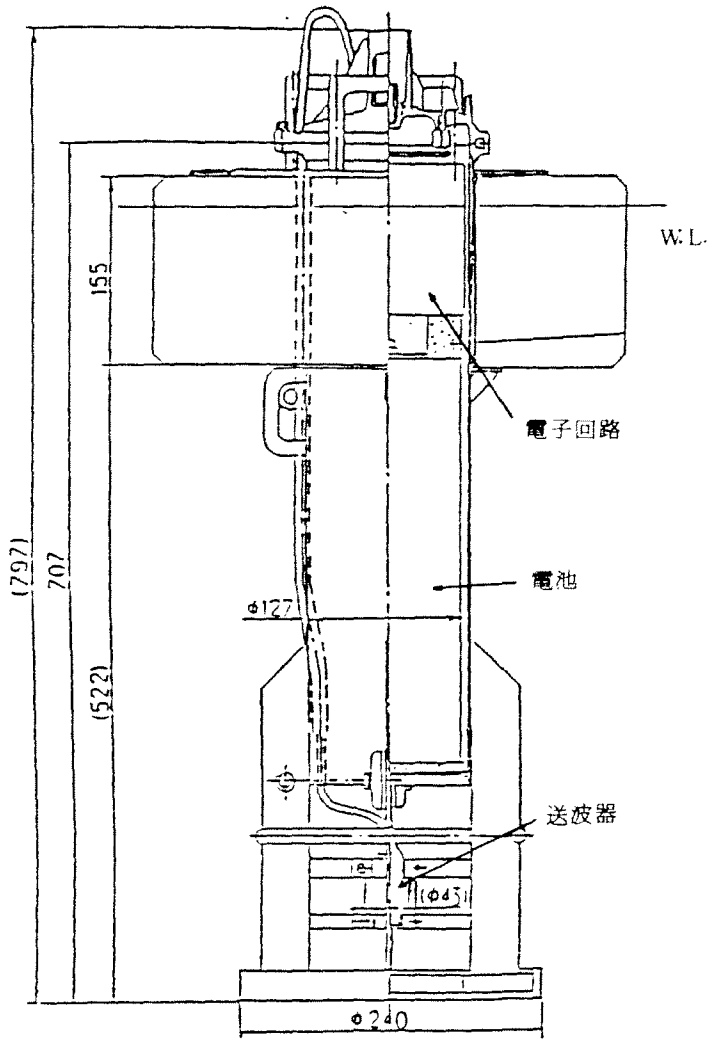
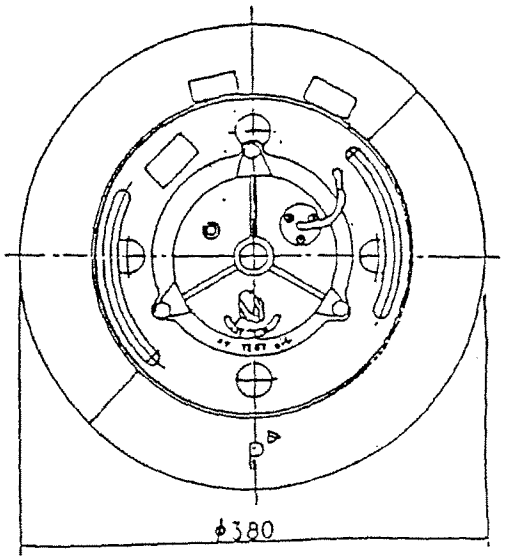


図4　　送波周期





20 Kg

図5　音波発生装置

(a) ブイ4個

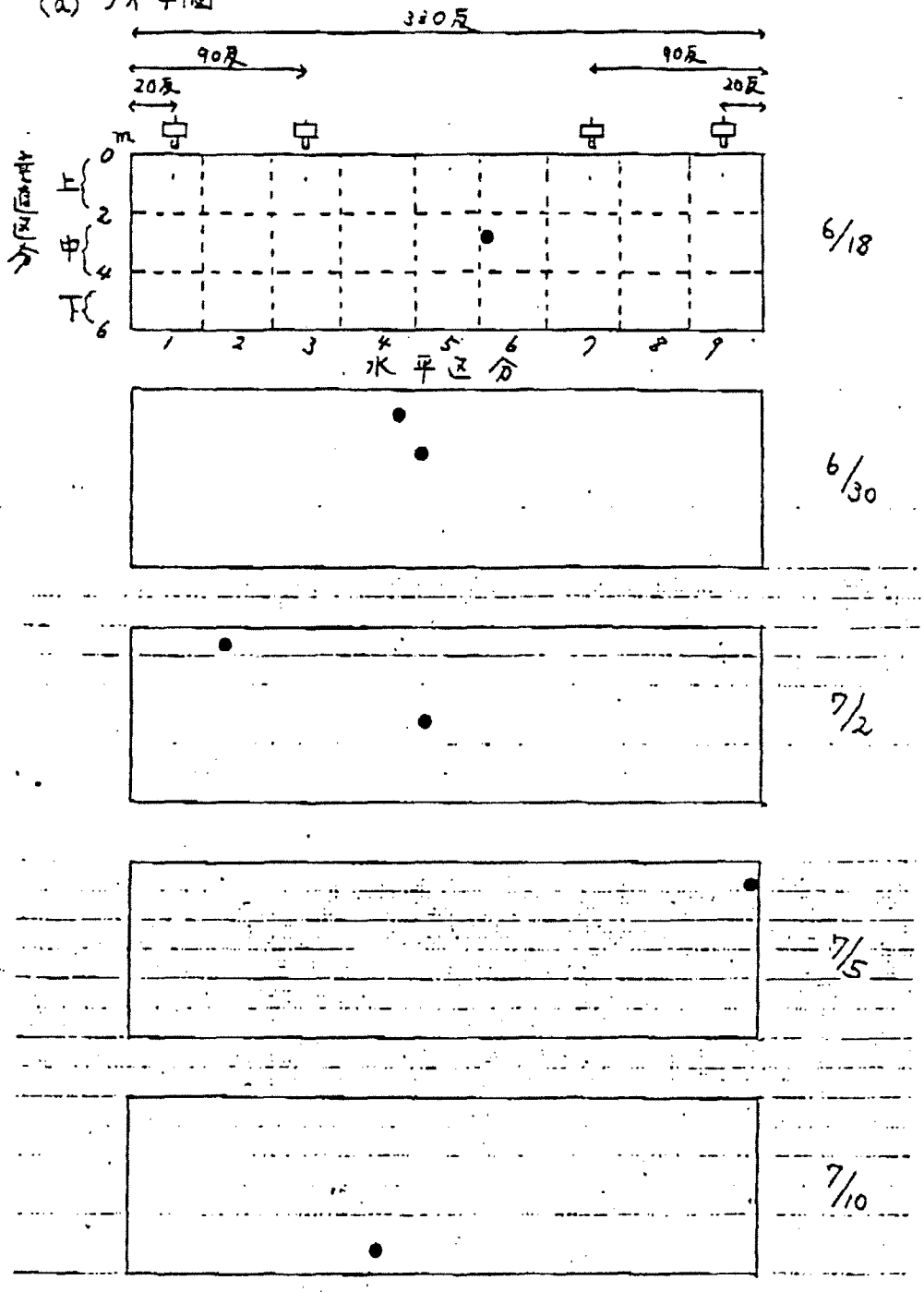


図1 ブイの取付位置と
→ブイ試験海の水平・垂直方向の混濁状況
● …… 混濁化力, ⊕ …… 音響ブイ

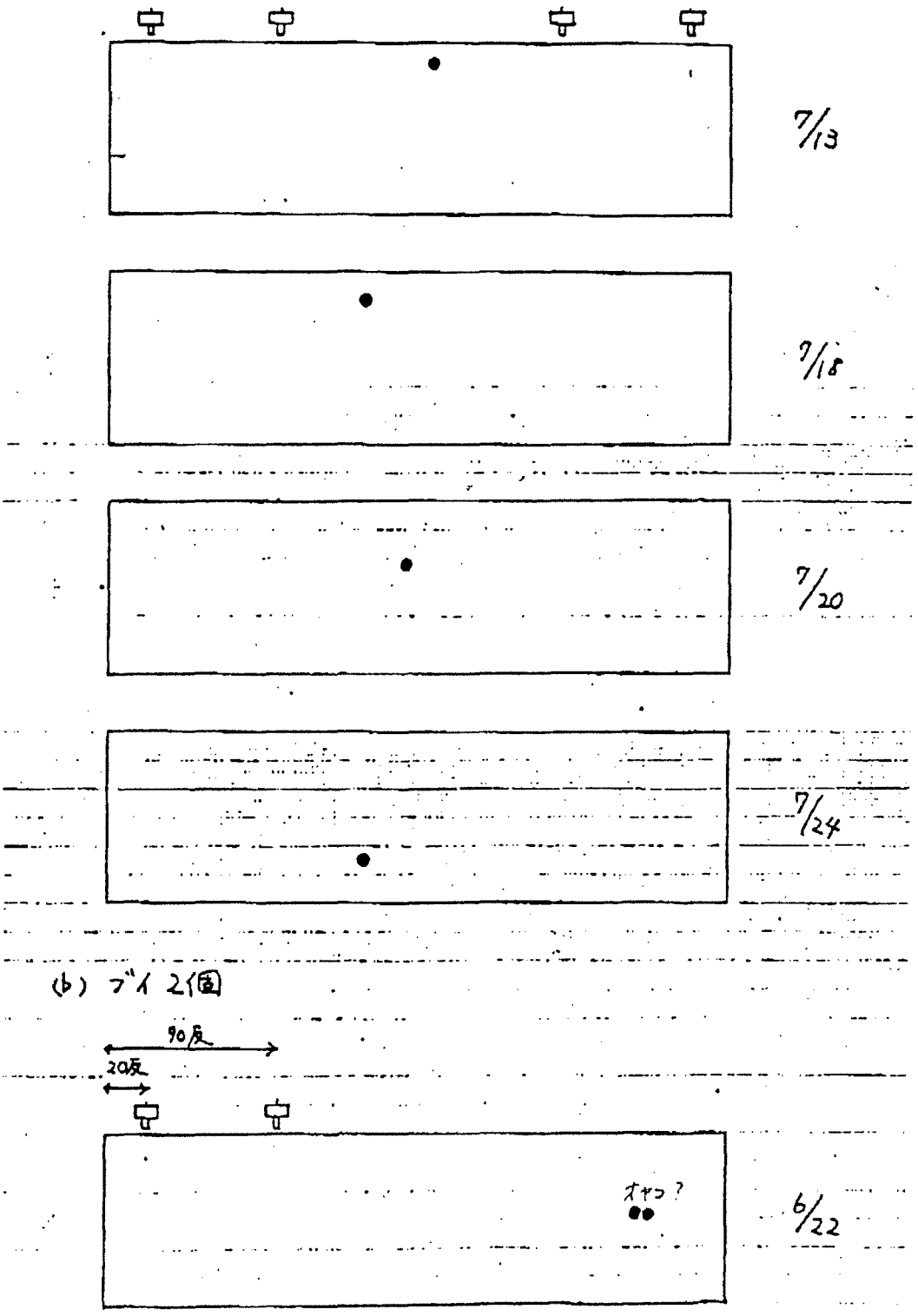


図6. ブイの取付け位置とブイ試験網の水平・主直方向の浸漬状況

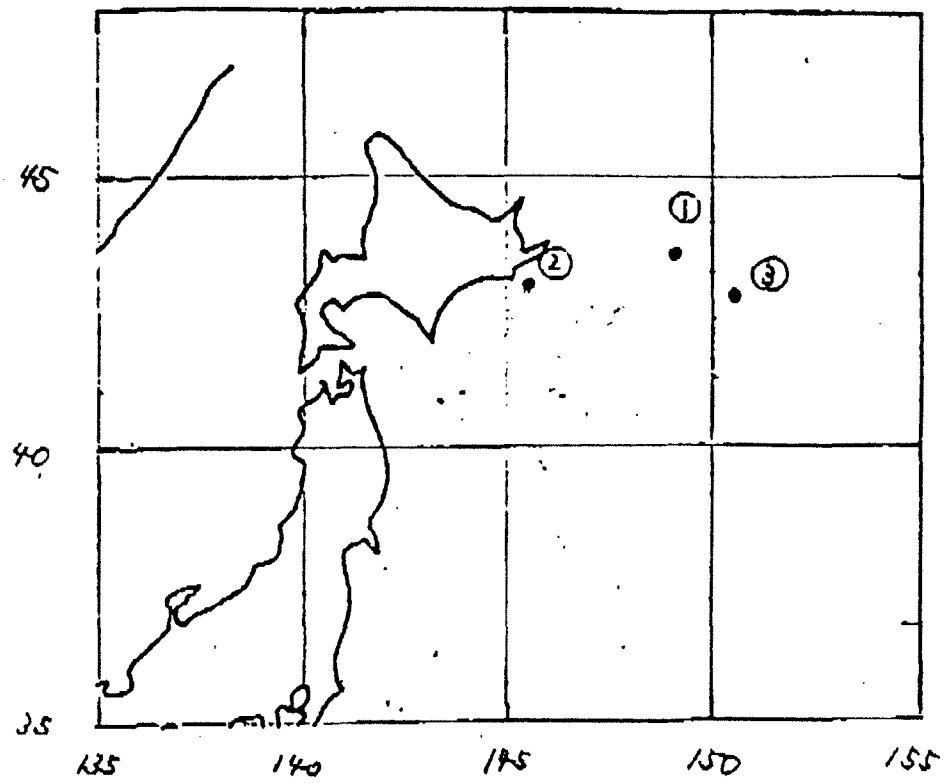


図7　サニマ丸船による実験地点

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TRANSLATION

TEST OF NEW TYPE SOUND GENERATORS

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Four generators were manufactured that produce random supersonic pulses and Frequency Modulation (FM) waves of 20 to 50 kHz which were determined to have alarming effects on Dall's porpoise in a series of three acoustic experiments. The three experiments conducted were: that where sound waves projected towards a Dall's porpoise in captivity (conducted in 1984 May), that conducted in the Bering Sea (in 1984 July), and that conducted off the Okhotsk coast of Hokkaido (in 1984 August). Tests of effect of this type of sound generator were made in the areas for salmon fisheries and in Japanese waters. The experiment, which was conducted off the Okhotsk coast of Hokkaido on 1985 August 28, is described in a INPFC document (Doc. 2995) submitted this year.

1. Specifications of the sound generators

The sound generators were designed to select random combinations of frequency (f), pulse width (τ), and pulse interval (t) of pulse waves, and modulation period (T') of FM waves, each of which has 16 options, in order to emit supersonic waves with more complicated combinations of these factors compared to the sound generators used in 1984 (equipment which generate false echolocation clicks).

Main specifications of the sound generators used are as follows:

1.1 Frequency range

20 to 50 kHz

1.2 Transmitter

Transmitting sensitivity		35 dB or more
Directivity	Horizontal	omnidirectional
	Vertical	60° (3 db down half angle at 50 kHz)
		omnidirectional ($\leq$ 30 kHz or less)

1.3 Maximum sound pressure

86 dB re 1 μbar at 1 m distance (see Fig. 1)

1.4 Transmitting mode

A. Pulse waves (Fig. 2)

f = 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50 kHz

τ = 0.9, 8.1, 15.3, 22.5, 29.7, 37.0, 44.2, 51.4, 58.6, 65.8, 73.0, 80.2, 87.4, 94.7, 101.9, 109.1 ms

t = 9.9, 24.3, 38.8, 53.2, 67.6, 82.0, 96.5, 110.9, 125.3, 139.7, 154.1, 168.6, 183.0, 197.4, 211.8, 226.3 ms

f, τ , and t are selected randomly among these values

B. FM waves (Fig. 3)

f_1 = 20 kHz

f_2 = 50 kHz

T' = 9.0, 15.7, 22.5, 29.2, 35.9, 42.7, 49.4, 56.1, 62.9, 69.6, 76.3, 83.1, 89.8, 96.5, 103.3, 110.0 ms

T' is selected randomly among these values.

1.5 Period

As shown in Fig. 4, five pulse waves and FM waves in five cycles were transmitted. After an interval, the same is repeated.

1.6 Power supply

Two compact sealed lead storage batteries (dimensions: 93x65x152 mm, weight: 2.6 kg, capacity: 6.5 Ah) of 12 V are used by connecting in series to obtain 24 V. This power source is usable for 5 to 6 years under the condition of 60 times (12 hour discharge - 12 hour charge) a year. They are more economical than dry cells and potentially more useful for larger emissions of sound waves.

1.7 Temperature at use

0 to 40°C

1.8 Buoy

Dimensions: maximum diameter: 380 x height: 797 mm (Fig. 5)

Batteries and electronic circuits are put in the middle-sized radio buoy. Shifting the external switch from OFF, TEST, to ON positions starts the generator's operation. At TEST position its operation can be confirmed by means of a light on the monitor lamp. Overall weight of the buoy was limited to 20 kg in order to be carried by one person.

1.9 Operation time

It is desirable that sound waves be projected over 12 hours while the gillnets are set in the sea and that the interval be as short as possible. When the interval can be adjusted with selected values (D) of the dip switch and the batteries are amply charged, operation time (H) of equipment can be roughly calculated by the following formula:

$$H = 1.5 \frac{DC}{I}$$

C = Battery capacity (6.5 Ah)

I = Maximum current (6.5 A)

There are eight dip switches (D0 to D7). If [1] = ON and [O] = OFF, D will be calculated by the following formula:

$$D = \sum_{n=0}^{7} Dn \cdot 2^n$$

If D_3 = 1 and Dn's other than D_3 = 0, H will be 12 at D = 8 and the sound waves can be projected throughout a gillnet operation. At D = 8, the transmitting mode will be approximately one second sound projection and 4 to 5 second interval. It had been determined that in actual use brightness of the light on the monitor lamp and the projected sound in the air should be examined on retrieval and that the value of D should be readjusted to 10 if the examination indicated that the light became darker or the sound pressure became weaker. In the testing of effect made by one catcher boat, two buoys were thus readjusted.

2. Test of effect made by a catcher boat

Four newly designed sound generators were placed on board the Inari maru No. 31, one of the catcher boats attached to the Meiyo maru. Data on horizontal and vertical positions where entanglement of Dall's porpoise occurred were collected by Mr. Yamashita, a Japanese marine mammal observer, who used the data included in the report to be submitted to the United States.

As shown in Fig. 6, the buoys were attached to the nets at four locations, the 20th and 90th tan from both ends of a set of gillnets. During 1985 June 12 to July 29, the catcher boat conducted fishing operations 40 times and of these 35 times with acoustic buoys. Sound projected in the air were examined for each generator before setting and upon retrieval. All examinations showed the sound generators to be in good operating condition.

Since the casting of buoys was conducted at the vessel speed mode of "Stop" or "Slow", this might result in a poor set of the nets set in the sea with windy conditions. However, even under such conditions vessel speed was reduced while setting nets in order to increase the number of experimental operations.

Since the acoustic buoys lacked antenna differing from radar buoys and radio buoys, their location could not be determined easily when the sea became even slightly rough. Under such conditions, the following difficulty or danger was observed: buoys appeared on the side of the vessel opposite to where the nets were retrieved, were recovered around the bottom of the vessel, or moved toward the propeller. Pieces of red cloth were attached to the nets before and after the buoy in intervals of one tan. When the cloth approached, a whistle was blown to alert the crew that the buoy was coming. In this way trouble on the ship sides was avoided.

When the buoys were set on the windward side of the net, it was observed several times that they fell sideways becoming entangled in the net. The entanglement was caused by threads of the net catching on the nut mounted at the lower portion of the buoy. It will be necessary to redesign the buoy structure to eliminate these defects in further experiments.

Although the crew had been advised that the sound generators should not be handled, by hands wet with seawater or where seawater might spray on them, upon examination, one of the buoys when returned from the catcher boat was seen to have erosion on one of the battery connecter terminals. It was found necessary that a rapid contact recoverer and a spare battery should be carried on the catcher boat.

The incidental catch of Dall's porpoise during this experiment is shown in Table 1. Relationship between horizontal-vertical distribution of the entanglement of Dall's porpoise and the locations where the buoys were equipped is also illustrated in Fig. 6.

The set of gillnets was divided into nine areas horizontally and into three areas vertically and the distribution of the entanglement which for the experiments where four buoys were used are shown in Tables 2 and 3 comparing the data from the 1985 operations with standard nets.

Comparing the result for the standard net operations, a small amount of entanglement was observed in both ends where equipped with buoys and 80% of the entanglement was concentrated in the central portion (horizontal area 4 to 6) of the set of gillnets where the sound waves from the buoys are weak. When only two buoys were used because of strong wind and waves, two Dall's porpoise, which seemed to be a cow/calf pair, got entangled in the end of the set of gillnet not equipped with buoys. With respect to the distribution by vertical area, almost the same results were obtained from the experimental nets with buoys and the standard nets.

Although CPUE of the experimental nets with buoys is 0.325 and smaller than that (0.445) for the standard net operations and those (0.354 to 0.421) of operation with the other types of experimental nets conducted in 1985, it is similar to CPUEs obtained from the vessels which were attached to the Meiyo maru and operated side by side with the Inari maru No. 31.

No statistical conclusion can be made on the experimental net with the buoys since only one catcher boat was used for this experiment and the small number of Dall's porpoise incidentally caught. However, distribution of entanglement of Dall's porpoise in this experimental

net shows a tendency to concentrate in the central portion where the sound waves emitted from the buoys are weak. Therefore, further studies are required.

3. Test of effect made by a Pacific saury fishing vessel

The Inari maru No. 31, mentioned earlier as a catcher boat of the mothership salmon fishery, conducts a Pacific saury stick-held dip net fishing operation for a period from August to November after the salmon fishery (June to July) is closed. It moves southward from waters off the eastern coast of Hokkaido to waters off the Sanriku coast according to migration of that species. Up to about ten operations are conducted in one night shifting about 50 nautical miles. Damage took place about ten times during the fishing season when the porpoise approached the vessel and disturbed the migration pattern of Pacific saury attracted to fish lamps was disturbed and the school of fish gradually became less concentrated. In addition, porpoise also approached vessels while they are stationary in the daytime. Therefore, test of effect of the acoustic buoys were asked to be made.

In the 1985 fishing season, since a smaller number of schools of porpoise appeared, experiments with the acoustic buoys were conducted only three times as follows:

Experiment 1

Time	August 22, 1433
Weather	Clear sky
Water temperature	13.2°C
Wind direction/class	Windless

When two porpoise of unknown species were approaching the vessel during the fishing operation, a buoy was cast in the rear of the stern. The porpoise appeared from a distance of 1,000 m then moved gradually away from the vessel.

Experiment 2

Time	August 23, 1537
Weather	Overcast sky
Water temperature	14.0°C
Wind direction/class	SSW-1

When seven truei type Dall's porpoise were seen approaching the stationary vessel, a buoy was cast also off the stern. The porpoise were seen from a distance of 700 to 800 m from the vessel then gradually moved away from it.

Experiment 3

Time	August 26, 1530
Weather	Misting rain
Water temperature	15.8°C
Wind direction/class	ENE-3

When two truei type Dall's porpoise approached the vessel, a buoy was cast to the right side of the stern and after two minutes the porpoise seen from a distance of 20 m rushed away from the vessel.

Locations of the experiments is shown in Fig. 7. By setting the third dip switch from the left in the ON position for adjustment of operation time it was planned to increase the times of emissions of sound waves while the operation time would decrease to six hours.

The reason for the two minute interval between casting the buoy and flight of the porpoise is that it takes a certain time to charge condensers in the electronic circuit after switching on the acoustic buoy. From these experiments, it was found that the acoustic buoys had a strong intimidating effect toward porpoises in a shorter range where the distance between the buoy and porpoise is 20 m and that the porpoise got away from the buoy disliking the sound waves where the porpoise appeared in a longer range of about 1,000 m from the buoy.

TABLES 1 TO 3 AND FIGS. 1 TO 7 ARE ATTACHED

Table 1. State of incidental catch of Dall's porpoise.

Number of buoys used	Number of sets	Frequency of incidental catch		Number of Dall s porpoise incidentally caught in total
		One porpoise	Two porpoises	
4	34	7	2	11
2	1	0	1	2
0	5	0	0	0
Total	40	7	3	13

Table 2. Distribution of entanglement by horizontally divided section of net

		Horizontal section								
		1	2	3	4	5	6	7	8	9
% of porpoises entangled	Standard net	12.1	11.2	11.6	9.4	9.4	9.4	10.3	12.4	14.4
	Trial net	0	9.1 (1)	0	36.4 (4)	36.4 (4)	9.1 (1)	0	0	9.1 (1)

Trial net: A set of gillnets equipped with four buoys

( ): Number of porpoises entangled

Table 3. Distribution of entanglement by vertically divided section of net

		Vertical section		
		Upper	Middle	Lower
% of porpoises entangled	Standard net	48	42	10
	Trial net	46 (5)	36 (4)	18 (2)

Trial net: A set of gillnets equipped with four buoys.

( ): Number of porpoises entangled

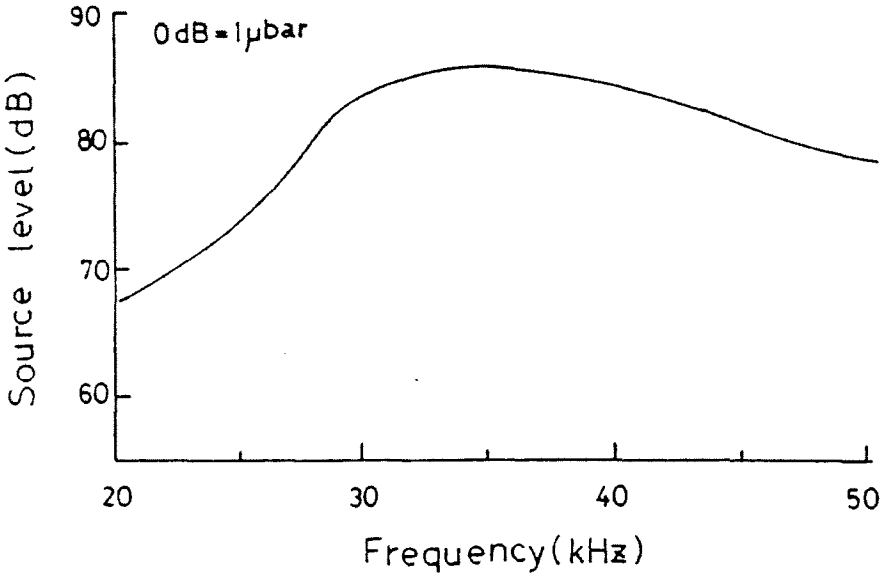


Fig.1. Source level of transmitter

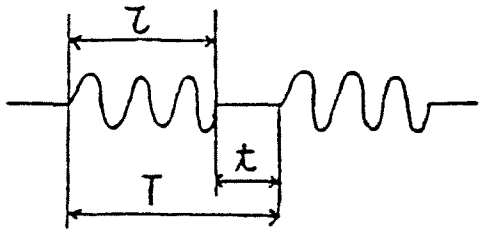


Fig.2. Transmitting mode (pulse wave)

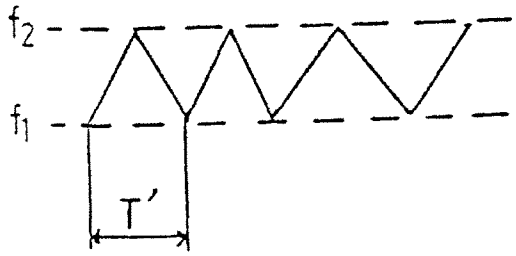


Fig.3. Transmitting mode (FM wave)

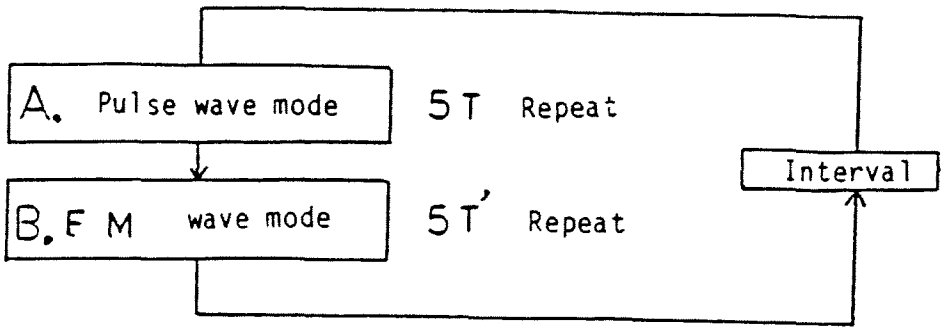


Fig.4. Transmitting period

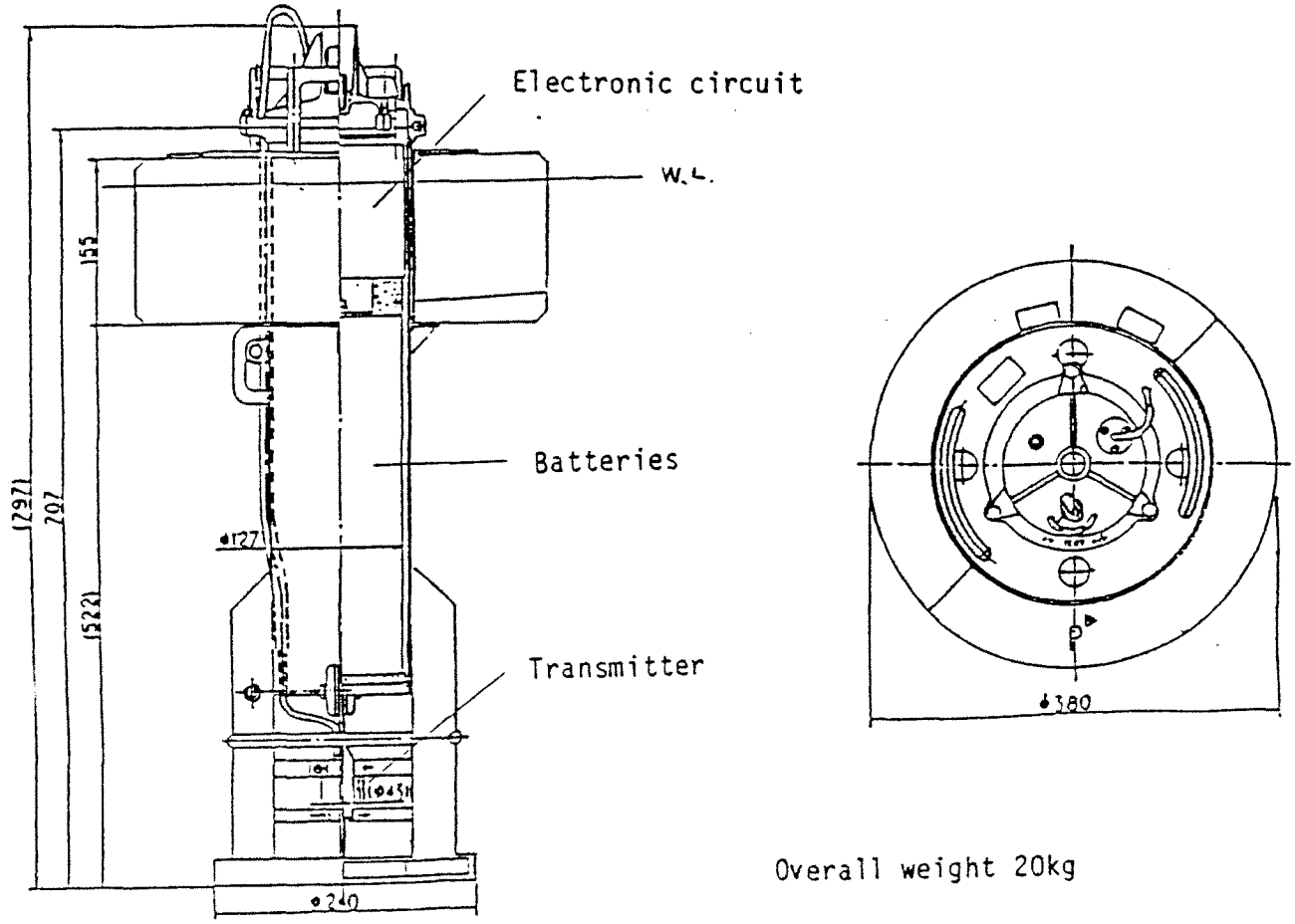


Fig.5. Sound generator

(a) Four buoy operations

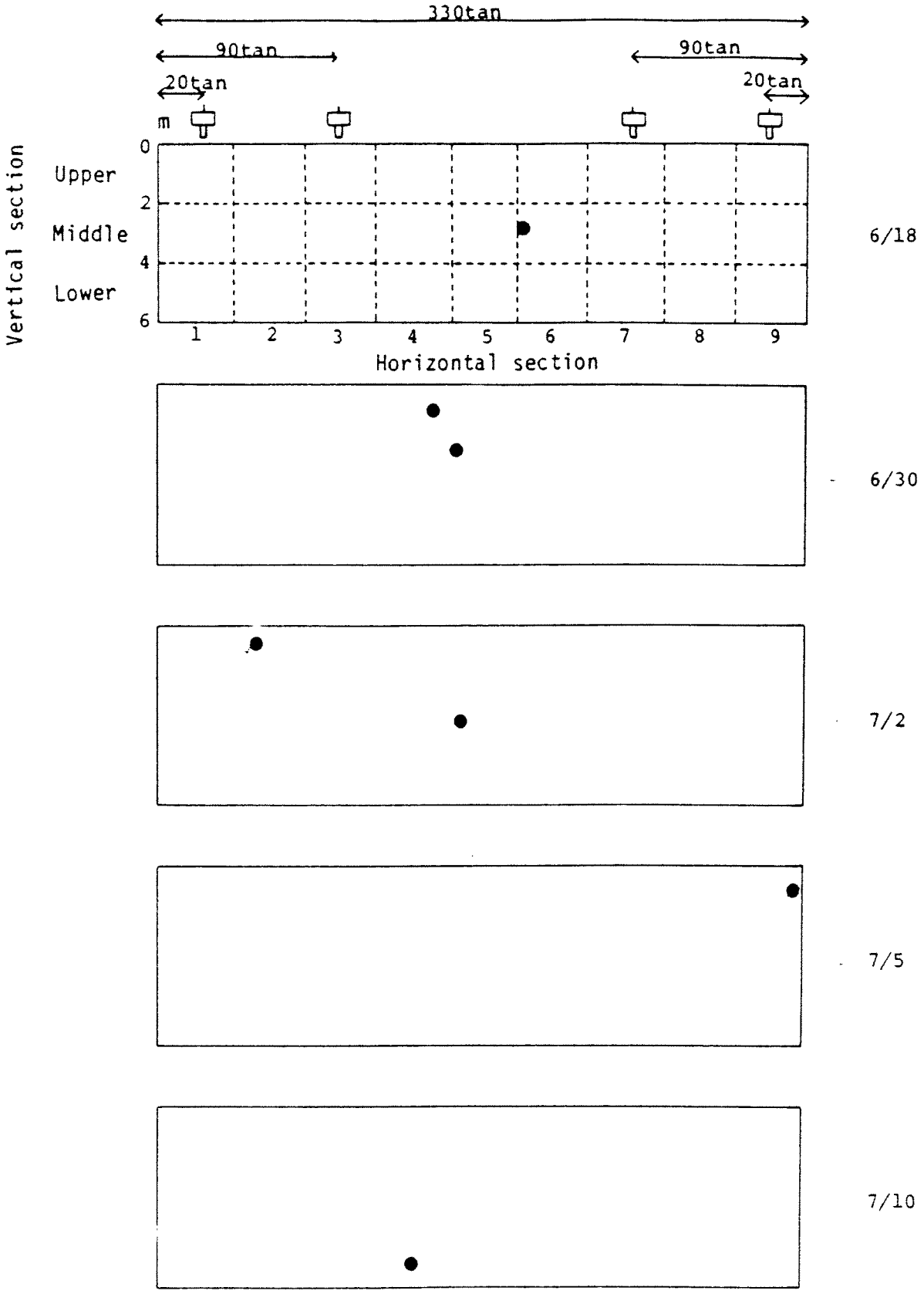
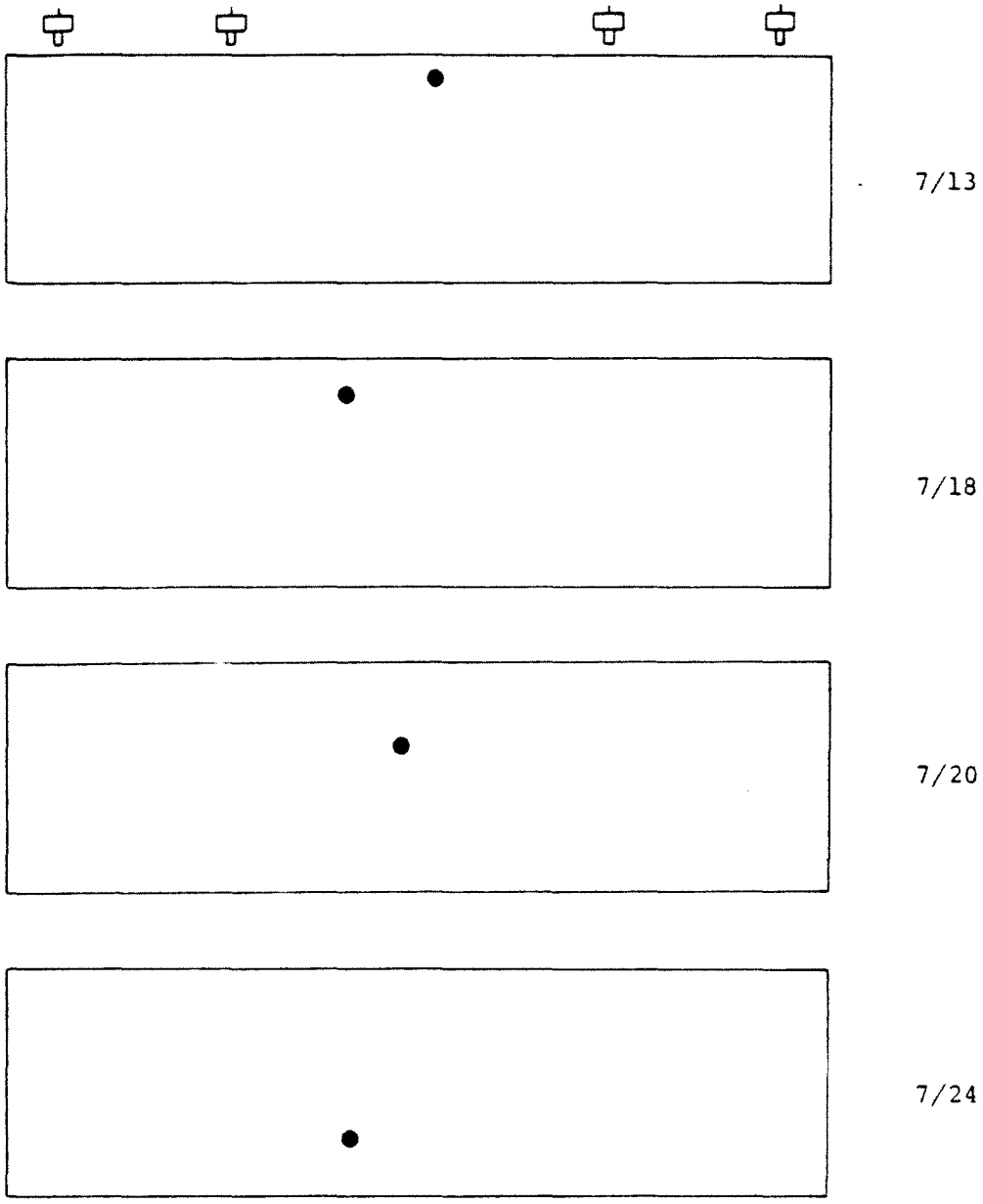


Fig.6. Position of the buoys and horizontal and vertical distribution of entanglement in the trial net.

●---Porpoise become entangled ⊕---Acoustic buoy



(b) Two buoy operation

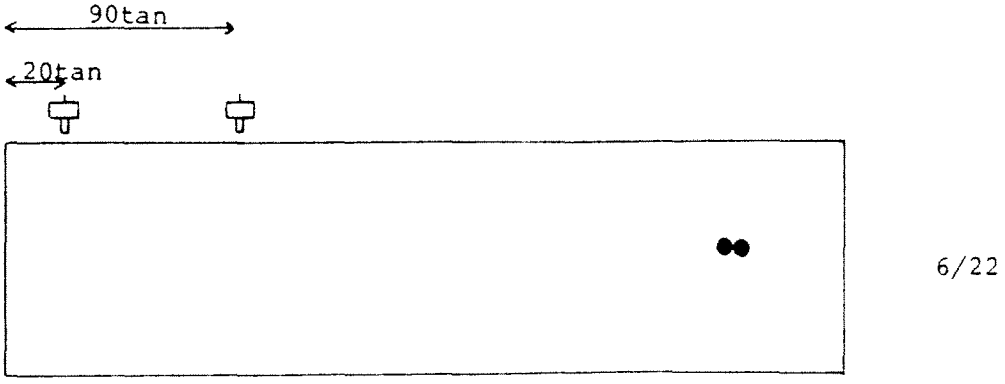


Fig 6 continued

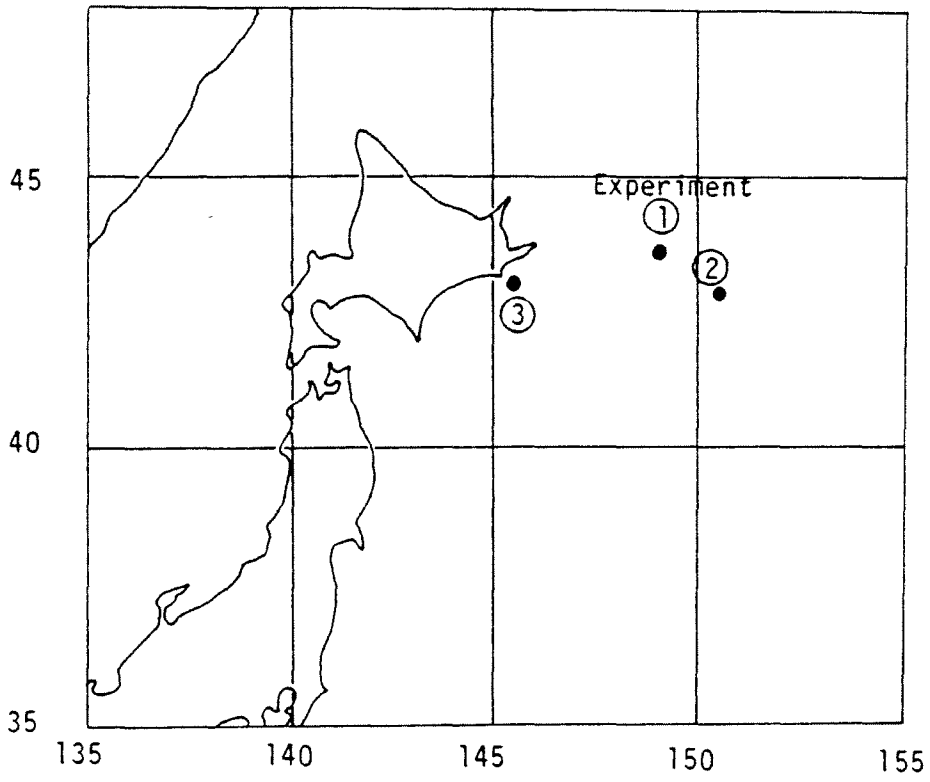


Fig.7. Locations at which the experiments were conducted by a Pacific saury fishing vessel.