Echo Sounder, Sonar, Radar Operations and Navigation Course

FINAL REPORT

1981-070

NSW Department of Primary Industries

CONTENTS

ECHO SOUNDER, ELEMENTARY SONAR AND RADAR OPERATION

1982

The 1982 Radar, Navigation, Echo Sounder and Sonar Course was held from April 27 to May 7. This years course for professional fishermen was attended by 11 students. It was felt that the smaller number was easier to handle in the compact training areas.

The first week of the course consisted of four (4) days at the Sydney Technical College learning and implementing navigational skills and mastering radar techniques. The College is being remodelled and the smaller number of students was easier to accommodate.

The second week was held at our training centre at Gore Bay and on board our research vessel "Kapala". Two nights of relevant films were also staged.

The course this year included two interstate lecturers and once again students came from all over N.S.W. A syllabus and list of lecturers is attached.

ECHO SOUNDER, ELEMENTARY SONAR AND RADAR OPERATION

APRIL 27 - MAY 8, 1982

Mr. C. L. Fountain	6 Sunnyside Street, Gladesville, 2111.
Mr. L. J. McIntosh	3 Lobb Street, Churchill, 4305.
Mr. J. E. Davis	10 O'Haras Creek Road, Middle Dural, 2158.
Mr. W. H. Lackey	P.O. Box 59, Caringbah, 2229.
Mr. B. I. McAteer	56 Junction Road, Moorebank, 2170.
Mr. G. Kuznetsoff	Lot 6, Collingridge Street, Berowra Waters, 2082.
Ms. L. Petryszyn	P.O. Box 29, Berowra Heights, 2082.
Mr. R. Ruzianczuk	P.O. Box 29, Berowra Heights, 2082.
Mr. R. E. Bennett	44 Burlington Street, Montery, 2217.
Mr. C. Saunders	42 Robert Garrett Street, Coffs Harbour, 2450.
Mr. R. S. L. Davis,	4 Jones Road, Kenthurst, 2154.

ECHO SOUNDER, SONAR, RADAR AND NAVIGATION COURSE

LIST OF LECTURERS

BILL OWEN:	Group Marketing Manager, Marine and Aviation Division, A.W.A. Ltd., will be lecturing on the following topics:- Factors affecting the echogramme Special features of echo sounders Sonar: the echogramme
JOHN HILL:	Consultant, Department of Electrical Engineering, University of Melbourne, will be lecturing on the following topics:- How an echo sounder works Sonar: the echogramme Stages in fishing operations
BRIAN McDONALD:	A Director of Marine Navaid Systems Aust. Pty. Ltd., will be lecturing on the following topics:- The Echo Sounder - The echogramme Factors affecting the echogramme The major components of an echo sounder
REINHOLDT WAWORWSKI:	Lecturer at the Maritime College in Launceston, Tasmania, will be lecturing on the following topics:- Factors affecting the echogramme Use of Netsondes in South Eastern Australia
TERRY GORMAN:	Senior Biologist, Marine Exploration, N.S.W. State Fisheries, will be lecturing on the following topics:- The netsounder programme Principal types of netsounders and their applications.
KEN GRAHAM:	Biologist, Marine Exploration, N.S.W. State Fisheries, will be lecturing on the following topics:- Use of Netsondes in New South Wales

SYLLABUS

ECHO SOUNDER AND SONAR OPERATIONS COURSE

12 SHIRLEY ROAD, WOLLSTONECRAFT, SYDNEY.

DAY 1

TIME	UNIT	SUBJECT HEADING	SYNOPSIS	LECTURER
9.30 am			OFFICIAL OPENING OF THE COURSE	
10.00 am	1.0	<u>THE ECHO SOUNDER</u> THE ECHOGRAMME	A detailed description of the echo sounder picture giving the reasons for the characteristic appearance of the features found on an echogramme. The differences between wet and dry paper.	BRIAN McDONALD
11.00 am	2.0	FACTORS AFFECTING THE ECHOGRAMME	Frequency, pulse length, beam width, paper speed, stylus speed, rough seas, aeration, pitching, rolling, nature of the sea bed - rocky, soft, uneven, undulating, sloping, level, ghosting, false echoes. Interference from ship and propeller noise and other echo sounders.	John [illegible] BRIAN McDONALD
11.45 am	3.1	FACTORS AFFECTING THE ECHOGRAMME	Fish schools, dense schools above the bottom, isolated schools above the bottom, dense schools on the bottom, individual fish close to the bottom. Appearance of single fish in the centre and edge of the beam. Ship passing over stationary fish. Fish and ship in motion.	REINHOLDT WAWORWSKI
12.30			LUNCH	
2.00 pm to 4.00 pm			Practical echo sounder training on board "Kapala".	

DAY 2

TIME	UNIT	SUBJECT HEADING	SYNOPSIS	LECTURER
9.00 am	5.0	HOW AN ECHO SOUNDER WORKS	What is sound, propogation of sound, wave length, frequency, ultra sound, velocity of sound in water, method of measuring distance by sound, common frequencies used by echo sounders; weakness of returning echo, absorbtion and dispersion, amplification, transmitting power, beam width, pulse lengths, side lobes, reverberation, resolution.	JOHN HILL
9.45 am	6.0	THE MAJOR COMPONENTS OF AN ECHO SOUNDER	Types of transducers. Size in relation to: frequency, power, beam width, pulse length. Cavitation. Selecting transducers. Amplifier: its function and intelligent use of gain. Transmitter: its function. Display units: description of various types, i.e. paper C.R.T., flashing light, digital, meter, and their advantages and disadvantages for commercial fishing.	BRIAN McDONALD
10.30 am	7.0	SPECIAL FEATURES OF ECHO SOUNDERS	White line, grey line, bottom lock, "memory" in C.R.T., narrow, medium and wide beam sounders and their application in fishing and bottom discrimination. Side lobes and their use. Phased scales. Transducer systems including phased away and stabilised units. "Colour" displays.	BILL OWEN
11.15 am	8.0	GENERAL DISCUSSION	Examples of local recordings discussed and explained. General question and answers.	REINHOLDT WAWORWSKI
12.00			LUNCH	
2.00 pm to 4.00 pm			Practical echo sounder training on board "Kapala"	
5.30 pm to 8.00 pm		FILM NIGHT	General fishing films.	

TIME	UNIT	SUBJECT HEADING	SYNOPSIS	LECTURER
9.00 am	9.0	THE NETSOUNDER ECHOGRAMME 40 mins	A description of the echo sounder picture as displayed by the netsounder. The base line, i.e. headrope, the footrope, the sea bed, the sea surface. Fish echoes: signal loss. Trawl track displays on echo sounders - difference in time in such displays.	TERRY GORMAN
9.45 am	10.0	PRINCIPAL TYPES OF NETSOUNDERS AND THEIR APPLICATION	Simple netsonds displays, multi-netsonds displays. Types of transmission, their advantages and disadvantages. Development of fishing tactics using information from netsonds and echo sounders. The development of fishing tactics. The combined use of sonar, echo sounder and netsounder - where to aim the net. Use of temperature read out.	TERRY GORMAN
10.30 am	11.0	USE OF NETSONDES IN SOUTH EASTERN AUSTRALIA	Local examples of netsounder recording on Jack mackeral, pilchards, lightfish and nannygai.	KEN GRAHAM & REINHOLDT WAWORWSKI
11.15 am	12.0	<u>SONAR</u> THE ECHOGRAMME	A detailed description of the echogramme from a sonar set giving the reasons for the characteristics of the recording. The difference between it and an echo sounder recording. Changing scales, sounding vertically, interference noises, ships wake, fish echoes, bottom echoes.	JOHN HILL
12.00			LUNCH	
2.00 pm to 4.00 pm			Practical training on board "Kapala" with netsond and sonar.	
5.30 pm to 8.00 pm		FILM NIGHT	General fishing films.	

TIME	UNIT	SUBJECT HEADING	SYNOPSIS	LECTURER
9.00 am	13.0	FACTORS AFFECTING THE ECHOGRAMME	Frequency, pulse length, beam width, output power, behaviour of the sound beam in water, i.e. refraction. Effect of heavy idling and pitching. Correct positioning of the transducer.	BILL OWEN
9.45 am	14.0	STAGES IN THE FISHING OPERATION	Methods of searching, use of high power long pulse. Automatic searching target location, use of audio signal: doppler effect. Estimation of target size, observation of target movement. Catching phase - use of low power short pulse, rapid scanning, wide sonar beam, rapid transmission.	JOHN HILL
10.30 am	15.0	DISCUSSION OF LOCAL SITUATION	Slides of echo recordings and discussion of tactics using sonar to catch fish off South Eastern Austra.ia.	KEN GRAHAM REINHOLDT WAWORWSKI
11.00 am			Practical sonar training on board "Kapala".	
5.30 pm		BARBECUE	A barbecue will be held at Gore Bay.	

DAY 5

TIME	UNIT	SUBJECT HEADING	SYNPOSIS	LECTURER
7.00 am to 7.00 pm			At sea on board "Kapala" deep water trawling	

Attachment 1

Echosounding Notes

Introduction

Echosounders work by sending out a beam of sound in short bursts or pulses. Each pulse travels down through the water and is reflected back to the surface from the sea bed or from any objects in the path of the beam. The beam and a pulse of sound are shown in fig 1. When the echo reaches the surface it is picked up by the echosounder which registers the depth of the water and any objects between the vessel and the ocean floor.

Basic Principles

Sound

As echosounders and sonar operate on sound waves, we will begin with an examination of this phenomenon. Sound is a process of vibration and is produced by any vibrating object such as the diaphragm of a loud speaker, a bell or the strings of a musical instrument. If a bell is struck it sides vibrate, moving rapidly in and out and a ringing sound is heard.

The tone of the ringing depends on how fast the sides of the bell vibrate. A small bell produces more vibrations per second than a larger one and the sound from it is therefore higher in pitch. The rate of vibration of a sound source is known as its frequency and is measured in cycles per second. The faster the frequency, the higher the sound.

Propagation of Sound

As the sides of the bell vibrate, they hit the air molecules around the bell, pushing them outwards and then pulling them back in again. These molecules in turn have a similar effect on their neighbours causing them to vibrate back and forth at the same rate as the sides of the bell. By this process vibrations from a sound source are transmitted in all directions through a medium. Such vibrations move in the form of waves, in much the same way that ripples in a pool radiate out from where a stone has been dropped into it. When the vibrations from a sound source reach our ears, we hear the sound.

Frequency and Wavelength

Two aspects of sound are important for our purposes. These are the frequency and the wavelength. The frequency, as we have seen, is the rate at which the sound source vibrates and the wavelength is the distance between each sound wave traveling out from the source. Sounds with high frequencies have short wavelengths and those with low frequencies have long wavelengths.

Frequencies used in echosounders are quite high and generally very between 30,000 and 200,000 vibrations or cycles per second. As the human ear can only detect sounds below 20,000 cycles per second, sounds with frequencies above this level are known as ultrasonic sounds or simply as ultrasound.

Benefits of Ultrasound

Ultrasound is used in echosounding for a number of reasons:

- it gives a stronger echo from small objects such as fish
- it has greater power to discriminate between two objects which are close together
- it is more readily concentrated into a beam
- it is less affected by interference from shipboard noises

Echoes from small objects

A small object such as a fish will not be detected unless the sound waves from the echosounder are being reflected from it. As ultrasound has a high frequency, it has a short wavelength and these small waves are reflected well by small objects such as fish. Lower frequencies with their larger waves are not well reflected by fish. This can be illustrated by the following example. If ocean waves hit against a breakwall or vertical cliff they will be reflected back again. However if the same waves hit a wharf pylon they will go around it and very little of the wave will be reflected. This is pretty obvious but it does show that it is the relationship of the size of the wave to the object it hits which determines how much of the wave will be reflected.

Discrimination

The amount of detail shown by an echosounder is affected by the duration of each sound pulse (termed pulse length). In situations where one target is beneath another and the two are close together, such as when a school of fish is close to the sea bed the two objects will not show up separately, unless the length of pulse can be made very short. With longer pulse lengths, the start of the echo from the sea bed will arrive at the echosounder before the echo from the school of fish has finished. This means that the two echoes will be fused together and the school of fish will appear as a lump on the sea bed and may not be detected (fig 2). A short pulse length means a short echo mark and a long pulse length, a long mark.

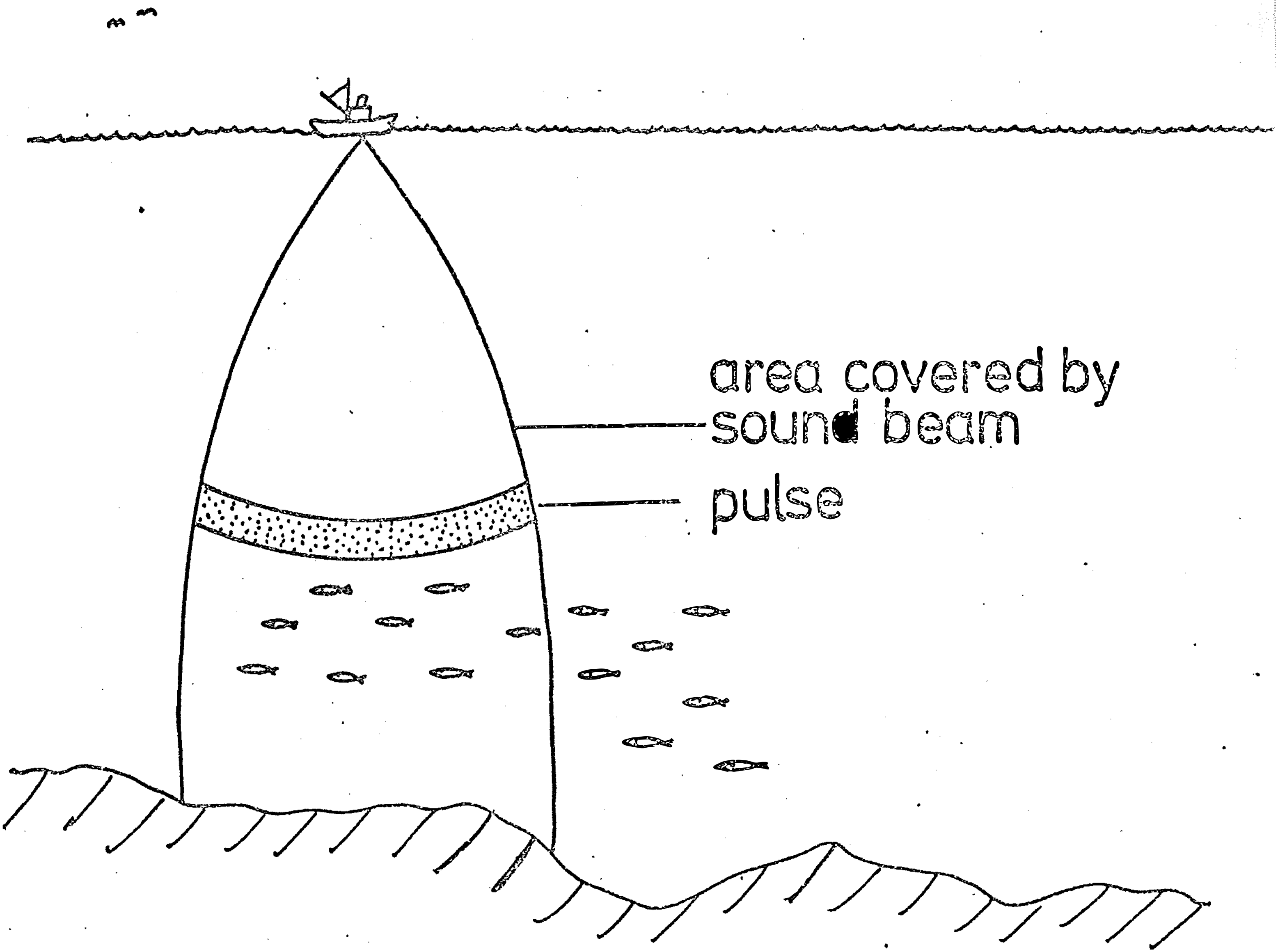
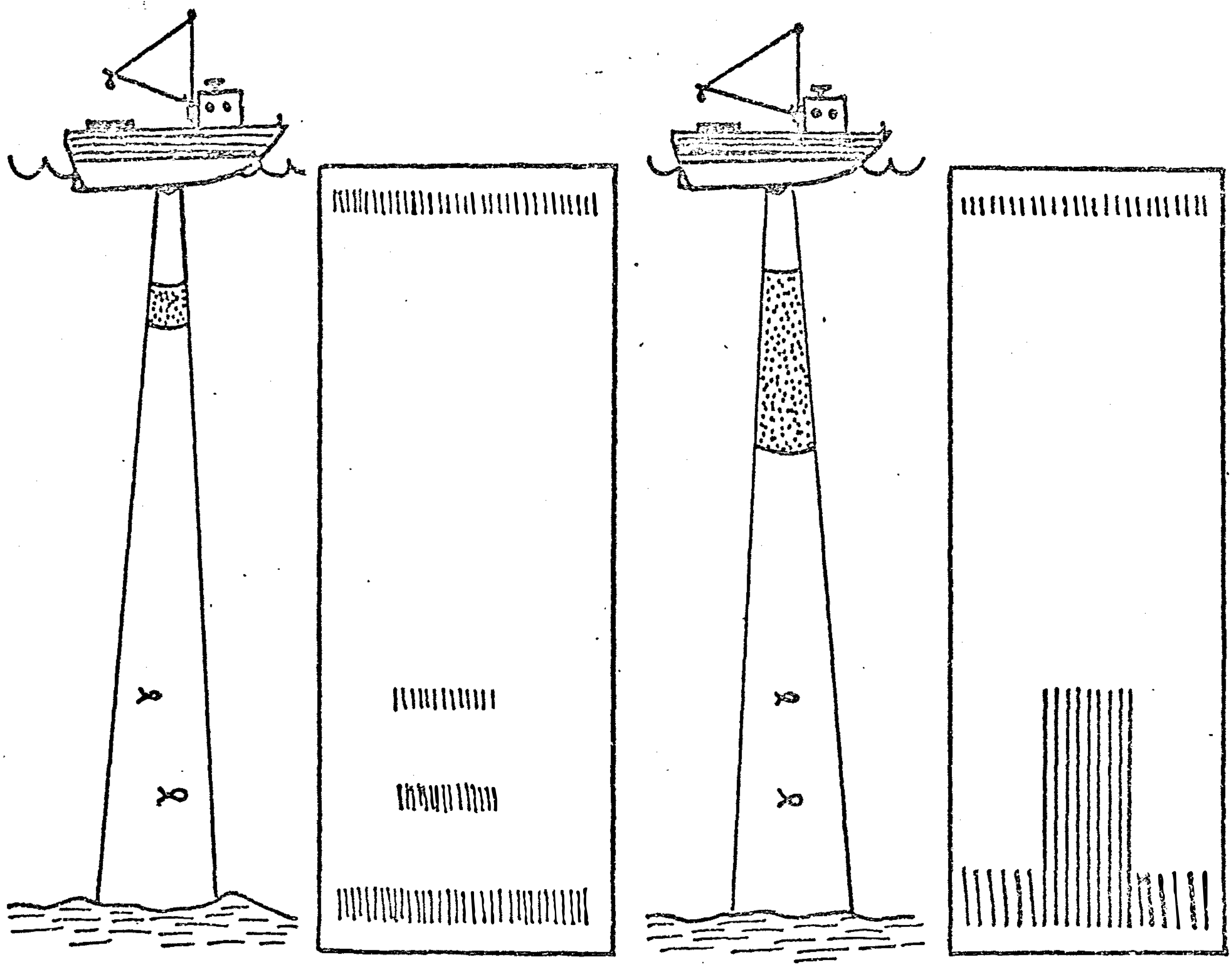


fig.1
ECHO SOUNDING



short

long

fig. 2 PULSE LENGTH

Each pulse must be made up of a minimum number of vibrations or waves. We have seen that the waves in ultrasound are smaller than those in normal sound and this means that the pulses can be made very short using ultrasound.

Concentration into a beam

Unlike the bell in our earlier example, an echosounder does not send out sound waves in all directions but rather in a concentrated beam. To send out a beam of sound underwater, the diameter of the transducer must be larger than the wavelength of the sound used. Using ultrasound, with its short wavelengths, a suitable transducer can be easily constructed. However, if lower frequencies were to be used, their larger wavelenghts would mean that transducers would have to be very large to concentrate the beam sufficiently. For technical reasons, such large transducers cannot be made to vibrate properly and so ultrasound is more suitable.

Interference

Noises created by the ship, such as turbulence or engine noise, can sometimes be picked up by echosounders. This is minimised in sounders using ultrasound as most ships' noises are in the audible range of frequencies and therefore will not be detected.

Ultrasound does have one drawback, however, it does not penetrate through the water as well as low frequency sound. However, all this means is that the initial transmitting power must be a bit higher than for lower frequencies. This is easily achieved in modern sounders.

Measuring Distance Using Echoes

Echosounders measure the depth of water beneath them by sending out a sound pulse towards the sea bed and measuring the time the echo from the seabed takes to return. This process is just the same as when a person shouts at a distant mountain and hears the echo return after a few moments. The further away the mountain, or the deeper the sea bottom, the longer the echo will take to come back. If any objects such as schools of fish are in the path of the sound beam, they too will produce echoes and will be shown by the echosounder at the appropriate depth.

Accuracy of time measurement is very important if the echosounder is to show depths correctly. Sound in water travels at about 1500 m/sec (820 fathoms/sec). If the ocean is 150 m (82 fathoms) deep the echo will take only 0.2 seconds to return. Obviously, a very small error in time measurement will result in a large error in depth indication. We will see how such accurate time measurement is achieved under the section in the depth indication.

Components

Transducer

Function

The transducer is responsible for producing the sound pulses sent out by the echosounder and for picking up echoes returning from the bottom or from fish.

Types

There are two types of transducers, magnetostrictive and electrostrictive. Both types vibrate rapidly each time a pulse is sent out, much like the sides of the bell which we discussed earlier. However, the sound produced by the transducer is much higher than that of the bell.

Magnetostrictive transducers are made of metallic alloys which can be made to contract and expand very rapidly when an alternating magnetic field is applied to them. The magnetic field is produced by electric wires running through the transducer. When current flows through the wires, the transducer vibrates rapidly, producing the sound pulse on which the echosounder relies. For the sound pulse to be efficiently sent out and for the echo to be efficiently picked up, the transducer face must be in good acoustic contact with the water below it. This is why marine growths must be carefully removed from the transducer face and why it must not be painted. Both painting and fouling will reduce the sensitivity of the echosounder.

Magnetostrictive transducers are used for frequencies up to about 100 kilohertz (100,000 cycles per second). For frequencies above this level, electrostrictive transducers are used. These vibrate when an electric field rather than a magnetic field is applied to them but tend to be somewhat brittle.

Earlier we saw that electrical currents in the transducer give rise to vibrations. This process is reversed when echoes hit the transducer and cause it to vibrate. This vibration generates electrical currents which are passed through an amplifier to the display unit.

Pulse characteristics

Each pulse produced by the transducer is very short. Pulse lengths are generally less than 2 milliseconds (2/1000 seconds) and are composed of a number of sound waves. A 75 KHz (kilohertz) sound has 75,000 waves (or cycles) per second. If a 75 KHz transducer sends out a 1 millisecond pulse, the pulse will contain 75,000 x 1/1000 = 75 sound waves. The sound produced is quite sharp; rising rapidly to maximum volume and cutting off quickly. The shorter and sharper the pulse, the better the definition that will be shown by the display unit (fig 2). However, short pulses do not penetrate deep water as well as long ones.

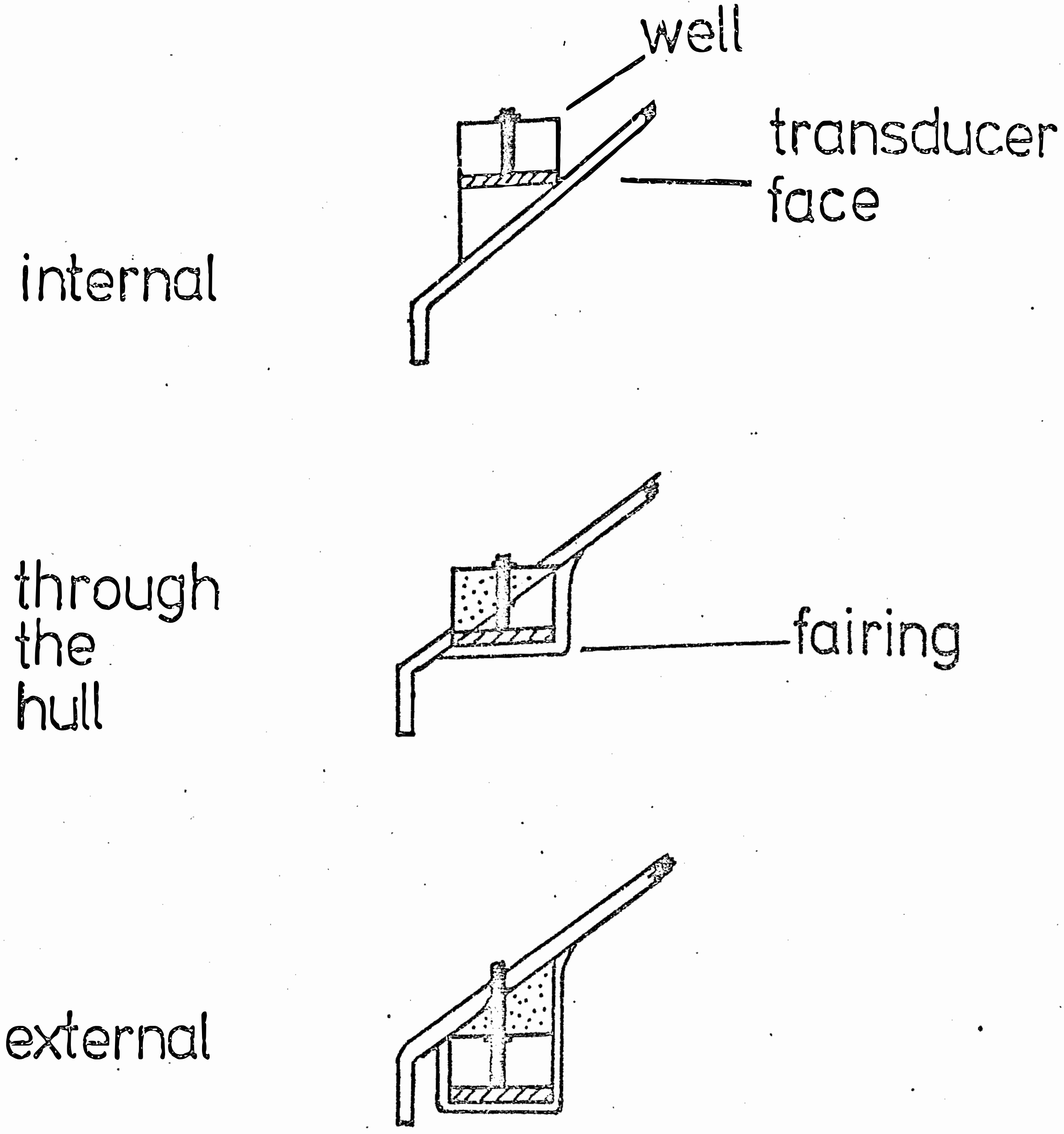


fig. 3
TRANSDUCER MOUNTINGS

Selectivity of Transducers

Transducers are built so that they vibrate most easily at the frequency of the echosounder for which they are designed. If you took the transducer from a 50 KHz sounder and put it on a 30 KHz unit it would not vibrate properly. Although the electrical impulses applied to it would be at the frequency of 30 KHz, the physical dimensions of the transducer would be such that it would tend to vibrate at 50 KHz with the result that very few vibrations would be produced. This aspect of the transducer is known as resonance. Each transducer has a frequency at which it vibrates most easily, known as the resonant frequency. Echsounders and their transducers must therefore be carefully matched for best results.

The fact that transducers tend to vibrate over a narrow range of frequencies makes them quite selective. If interfering noises strike the transducer they will only be picked up if their frequency is close to the resonant frequency of the transducer. This is why interference is not a great problem with echosounders. The exception to this is when two sounding instruments such as an echosounder and sonar are operating on similar frequencies. In this situation, interference can be noticed.

Mounting

Transducers can be mounted outside the hull, through it, or in a well on the inside. The first two are the most common and give the best results. Ways of mounting transducers are shown in fig 3. With outside or limpet mounting, the transducer assembly is entirely outside the hull with only wires passing through a gland in the hull. This allows a wider choice of positioning and may avoid interfering bubbles and turbulence associated with the hull surface.

With this type of mounting, a fairing dome is added to reduce turbulence around the transducer face.

If the transducer is positioned through the hull a housing is used which has walls as thick, or thicker than the ship's hull at that point.

Internal mounting is rarely used in fishing vessels. With this method a well is constructed on the inside of the hull and the transducer placed in it.

Location

The transducer should be located away from the propeller and from machinery, both of which can cause interfering noise. It should be placed so as to avoid any bubbles which can block transmission almost completely. If there is a choice of sides, the transducer should be located on the side of the vessel on which the propeller blades move downwards. When the blades move upwards, they splash water against the hull, causing considerable noise. If the transducer is on the other side of the hull, it is shielded from this noise by the keel. Propellor noise can also be reduced by aiming the transducer slightly forward (usually about 3°). The hull in front of the fairing dome should be as smooth as possible so that interfering turbulence is not created.

Amplifier

Echoes returning to the transducer may be very weak and may need amplifying up to 100,000,000 times before they can be used by the display unit. Amplification is varied by the gain control in much the same way as the volume of a radio set can be varied. In addition to a manual control, many sounders now have an automatic form of gain control known as time varied gain (TVG). With this system, the amplification at the instant of transmission is very low so that echoes returning from close targets receive reduced amplification. The amplification gradually rises again until echoes returning from distant targets receive full amplification. The result of this system is that distant and close targets of the same size will be shown in their true relative sizes. Without the system, close targets would be shown as being larger than they really are.

Transmitter

The transmitter sends electrical power to the transducer and determines when each pulse is to be sent out. It is composed of a number of components which determine the pulse length and frequency. Once a signal of the right pulse length and frequency is generated, it is amplified and then sent to the transducer which bursts into vibration. Of course, the frequency of the transmitter must be matched to the resanant frequency of the transducer for best results.

Where vacuum tubes are used in the transmitter circuit, high voltages of 1000 volts or more are used which are very dangerous if touched.

Depth Indicator

There are three main types of indicator, flashing light, cathode-ray tube (or scope) and graph. Each of these will now be dealt with separately.

Flashing light

This type of display indicates depth by a light which flashes at different points along a circular depth scale according to the depth of water. The light is carried on the edge of a disk (shown in fig 4) which rotates behind a circular window, around which is placed a depth scale.

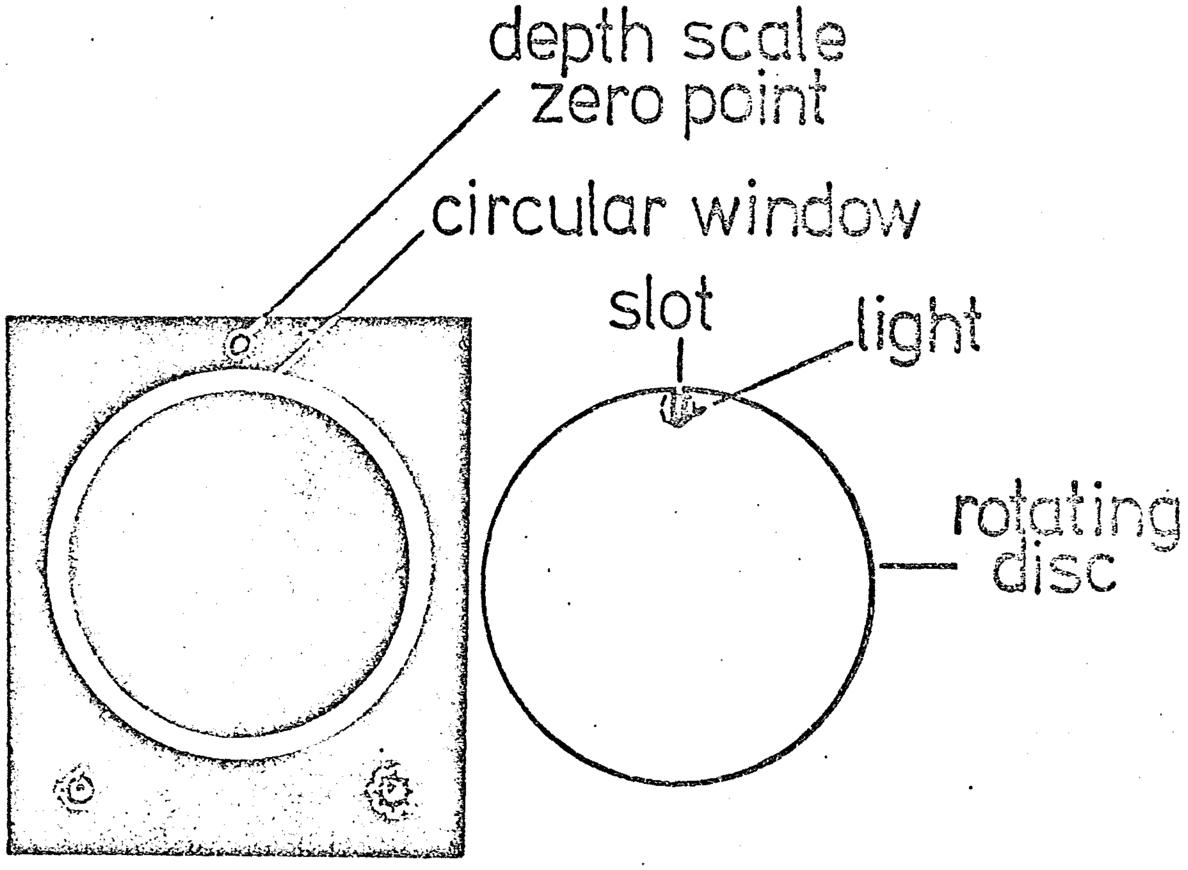


fig. 4 FLASHING LIGHT INDICATOR

fig. 5·1

no echoes

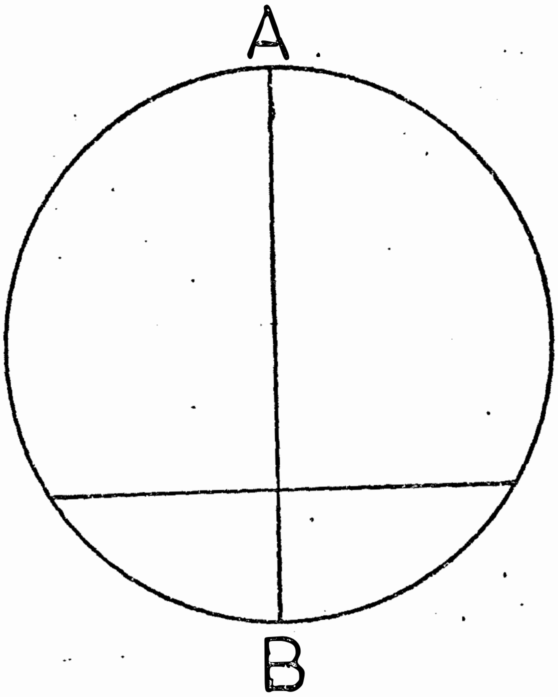


fig. 5·2

echo received

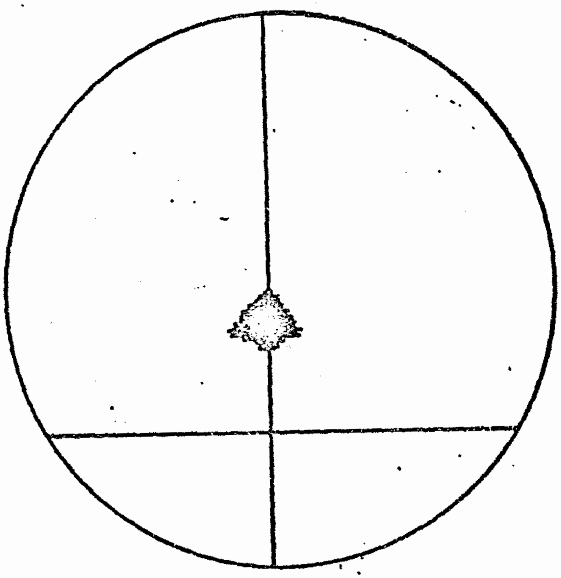


fig. 5 CRT INDICATION

As the light passes the zero point on the depth scale, a sound pulse is sent out by the transducer. When the echoes from the bottom return, the light immediately flashes at whatever point it has reached around the depth scale. The depth is generally read from the edge of the flash closest to the zero mark. The speed of the disk is such that when the echo returns, the light will be alongside the appropriate point on the depth scale. The light is placed on the back of the rotating disk and is only visible through a narrow slot. This makes a fairly precise indication when the light flashes. One pulse is sent out each time the light passes the zero point on the depth scale.

We know that the speed of sound in water is 820 fathoms/sec., so that echoes from an object 410 fathoms away will return in exactly one second. If we assume that the disk makes one rotation per second and that a sound pulse is sent out as the light passes the zero point on the scale, then echoes from an object at 410 fathoms would return just as the light reached the zero point again. If we made 410 equal divisions around the depth scale we could then read off the depth of any echo- producing objects between 0 and 410 fathoms. If the disk was made to rotate twice as fast, the depth scale would have to be changed to read 0 to 205 fathoms. If it rotates more slowly, the maximum depth on the scale could be increased. Many sets have several depth ranges with the disk rotating at a different speed for each range.

As only one pulse can be sent out per rotation of the disk, the pulse repetition rate (no. of pulses per minute) is fairly low with this type of sounder. However, its only function is to indicate depth so the low pulse repetition rate is not a disadvantage. This type of sounder is used generally for locating reefs or for navigation. It will only rarely detect schools of fish and its accuracy is generally not sufficient for trawling.

Cathode ray tube

This type of indication is based on a cathode ray tube (CRT) much like those used in television sets or radar equipment. When no echoes are being received, the screen appears as in fig 5.1. As as echo is received, the vertical line (AB) on the tube face will zig zag momentarily as in figure 5.2. The further down the vertical line the echoes appear, the deeper will be the object producing them.

One important advantage of CRT indication is that it shows echo strength. As shown in fig. 6, a strong echo, such as that from a large school of fish will deflect the beam sideways further than a weak echo from only a few fish. With flash indication this is very difficult and with graph indication it is not as accurate. Further, CRT indicators can show a school of fish at a single sounding whereas graph indicators require several soundings to build up a picture. Strong but very short echoes will be shown on a CRT indicator but may be missed on a graph recorder.

The timing technique is as follows:
The vertical line AB is not a constant line but is produced by a beam of electrons coming from inside the set, striking the inside of the tube face at the top and then moving rapidly down until it is striking at the bottom. The tube is coated on the inside with a phosphor coating which glows momentarily when an electron beam strikes it. The beam is constantly moving from the top of the tube at position A, down to position B so that it appears as a firm line. Once it reaches B it immediately flicks back to begin another trace at A.

As the beam returns to position A, a sound pulse is sent out from the transducer. As the sound pulse travels down through the sea, so the electron beam travels down the tube face. When an echo is received by the transducer it causes the trace to momentarily brighten and to zig-zag rapidly, causing an image as shown in fig 6.

For the depth to be read straight from the tube face, the speed of movement of the beam must be regulated in much the same way as the speed of the disk in the flashing light indicator. For instance, if the beam takes one second to move from A to B then during that time the sound pulse will be able to travel 820 fathoms. This means that the maximum range at which a target can be picked up would be 410 fathoms. The sound pulse would take 1/2 second to reach the target and 1/2 second to return. The faster the beam moves the shallower will be the maximum depth at which an object can be detected.

Phased Ranges

Phased ranges are sections of the water beneath a ship such as 60 to 90 fathoms or 40 to 60 fathoms. This type of range can be easily shown on CRT indicators by delaying the beginning of the beam's movement until after the sound pulse has been transmitted. This means that the indication does not begin until a particular depth is reached. It may also be possible to adjust the speed of the beam's movement so that either a long or a short section of water is investigated. For trawling, the section of water immediately above the bottom can be expanded to give a better indication of any fish present. If the fisherman is midwater trawling and knows at what depth his net is fishing, he can select that particular depth on the CRT and investigate it in detail.

When the indicator is not operating on phased ranges and the depth changes, the bottom echo can be brought back onto the same part of the screen by a control knob which also moves a depth scale indicator. This means that the depth can be read directly from the scale.

When the area next to the bottom is being examined, many CRT sounders are capable of producing a display where the bottom is always at the same level in the screen, even if the depth is changing. This makes reading easier. Many sounders also have a digital depth display so the fisherman can keep track of depth as well as investigate any fish close to the bottom.

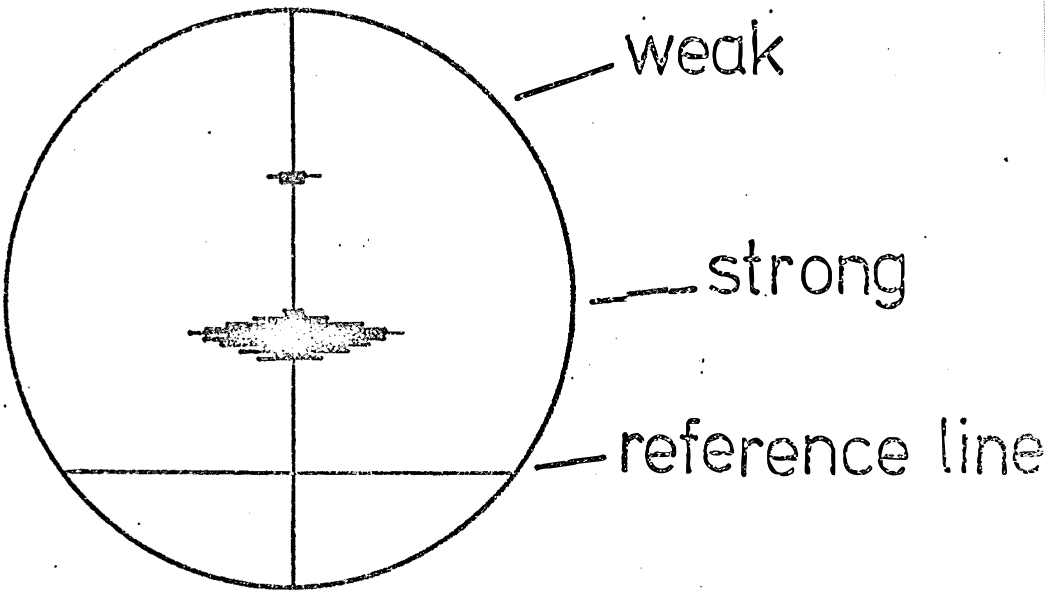


fig.6

ECHO STRENGTH ON CRT INDICATOR

Graph indication

Like flashing light and CRT indication, a graph indicator relies on uniform movement to measure depth. This job, which is done by the rotating disk or moving electron beam in the first two indicators, is carried out by a stylus or pen which moves from top to bottom of the chart. When the sounder is operating on a range beginning at the water surface, a sound pulse is sent out the moment the stylus passes the zero point on the scale. At this point, the stylus marks the paper to represent the surface. The stylus then travels down the paper until the echo is received. When this happens the electrical pulse from the echo is amplified and sent to the stylus which marks the paper at whatever point is has reached. The chart is marked with a depth scale from which the depth of the object producing the echo can be read.

When the indicator is being run on different ranges, the speed of the stylus is changed accordingly. While the sounder is in operation the paper is being slowly moved along under the stylus so that each successive echo mark is alongside the previous one and a picture is gradually built up.

Chart recorders use two types of paper, moist and dry. Moist paper is more sensitive but requires more careful storage. Dry paper is a little less sensitive but is generally easier to work with.

Wet paper is impregnated with a solution of potassium iodide and starch. It becomes discoloured when an electric current passes through it. Dry paper has a carbon base which is exposed when electric current flows through it. Wet paper is more sensitive and shows echo strength in more detail. However, the echo mark on it is wider so that the paper speed must be increased to avoid overlapping the echoes. Wet paper is therefore used up faster than dry. It is however, cheaper.

Dry paper can be run through a recorder several times, provided it has not been marked too heavily on the first run but wet paper can be used only once. Markings on wet paper will fade if you don't dry it out and store it in a dark place whereas markings on dry paper are permanent.

Dry paper can be kept as long as you like before being used but wet paper will only last about a year.

Stylus wear is greater with dry paper and if a moving stylus is being used, it will need adjusting and replacing more often with dry paper.

With graph indication it is possible to select ranges which include midwater areas, as can be done with CRT indication. Midwater or phased ranges, show a small area in greater detail and, like the phased ranges in CRT indication, are very useful for trawling. The size of the display is generally the same in both CRT and graph recorders. Both can be used to show an overall picture of the water beneath a vessel or to show a selected range of depths.

An important difference between graph indication and other types of display is that it relies on a number of soundings to build up a picture. Flashing light and CRT indicators give all their information at each sounding. This means that if the vessel is rolling a lot in a heavy sea, graph indication will be at a disadvantage compared to CRT indication. As the vessel rolls, only one sounding in perhaps 4 may be directed towards the bottom. The other three will be sent to one side or another of the vessel at an angle to the sea bottom. Very few echoes will return from these soundings. This results in a very sketchy picture on graph indicators which may be difficult to interpret. CRT indicators will also show very weak echoes but will show an accurate picture once every couple of soundings. As this indicator gives accurate information from each sounding, the operator can detect fish from the good soundings. Graph indicators give less information from single sounding and so are less useful in stormy weather.

A graph will however, provide a record of soundings which CRT indications do not. This may be most useful in detecting projecting rocks or wrecks which could damage nets. A glance every minute or so will tell the skipper if he has passed over any such objects and needs to change course to avoid them with the net. With With CRT indication, constant attention by the skipper is needed to detect this danger. Graphs may also be used for keeping records and comparing fishing grounds.

Graph indicators used to suffer from the disadvantage of a slower pulse repetition rate compared to CRT displays. The more sound pulses a unit sends out per minute, the more information it can gather. Only one pulse can be sent out per movement of the pen across the chart. With a mechanical system, the time taken for the pen to return to the start of the chart was equal to the time it spent moving down it. This meant that for half the time the sounder was in operation, it was merely waiting for the pen to return to its starting point. CRT indicators had no such trouble. The electron beam was generated electrically and could be made to flick back to the starting point instantly. This problem can also be overcome by having two pens such that while one is returning to the starting point, another is beginning its travel down the front of the chart. However, in very shallow depths or when using short phased ranges, the pen must travel across the chart at a very fast rate. For instance, for a phased range 8 fathoms deep to be shown across the full width of the chart, the pen would need to cover the width of the chart in 2/100 sec. It is difficult to get a mechanical stylus to move this quickly and many units use a multiple stylus system.

This is comprised of several hundred individual styli or pens. These pens don't move and are arranged from the top of the graph down to the bottom. They are scanned electrically so that no time is lost between the end of one scan and the start of another. The principle of operation is the same as for the movable pen type. After a pulse is transmitted, the scanner moves rapidly from the top stylus towards the bottom one. When an echo is received, the resulting current is passed to whichever styli are being scanned at that moment and the graph is marked in the appropriate place.

Multiple stylus systems are available which have the same range facilities as mechanical stylus and CRT systems. It has also been possible to provide chart recorders which show a recording of the entire depth of water beneath a vessel on the upper 2/3 of the chart and a phased range on the lower 1/3. This system is generally designed for trawling and the phased range usually consists of the several fathoms closest to the sea bed. Single stylus systems can be made to show a similar level of detail to multiple stylus ones by the use of an electronic shift register which stores the echo signals then releases them at a slower rate. With this system the pen need not move as fast to show the same amount of detail as the usual mechanical stylus system.

Graph recorders are most suitable for trawling, general fish finding and navigation.

Interpretation of Recordings

Sound beam characteristics

Echosounders do not emit sound in all directions but in a concentrated beam. As the width of the beam has a considerable bearing on interpretation of echograms we will examine some of the factors which affect beam width.

Directivity

The directivity, or narrowness of the sound beam is determined by the relationship between the size of the face of the transducer and the wavelength of the sound used. The sound beam will be narrower if the transducer face is enlarged or if the wavelength of the sound is shortened (i.e. the frequency is raised).

Transducers are generally oblong rather than square. This results in a sound beam which is narrower along the long axis of the transducer and wider along the transducer's short axis.

The area of the sea bed covered by the sound beam is known as the effective zone and is oval in shape with the long diameter of the oval lying in the same direction as the short diameter of the transducer face.

Transducers are mounted on a ship with the long axis lying in the fore and aft direction. This means that the beam is wider from port to starboard and narrower in the fore and aft direction.

It has been found that this system functions better in a heavy sea. It is well known that most vessels roll more than they pitch. If the vessel rolls too far, the echosounder beam may strike the sea bed at an angle and be reflected away from the ship. When this happens the bottom echo is lost and the sounder is of little use. With the beam being wider from port to starboard, the vessel can roll considerably and one edge or another of the beam will still strike the bottom so as to give an echo (see fig 7). If the beam is too narrow, it will hit the bottom at an angle and be reflected away from the sounder.

As vessels generally don't pitch as much as they roll, the beam can be more concentrated in the fore an aft direction to give better penetration and definition.

Apart from the main beam, the transducer also sends out a number of smaller side lobes as shown in fig 8. Side lobes can be used to tell whether the bottom is hard or soft. As well as reflecting more of the main beam, the harder bottom will reflect more side lobe energy and give a longer echo length (beard length) to the trace on a graph recorder. This effect is not so prounounced with very small side lobes.

Size of Effective Zone

A number of factors affect the size of the area covered by the sound beam. The most important of these concerns the power of transmission.

As you can see from the cross section of the sound beam, the sound pulse will be strongest in the middle of the effective zone. As the edge of the beam is approached, the pulse gets weaker. Obviously, the stronger the pulse, the more echoes will return from areas near the edge of the beam. This increases the size of the effective zone.

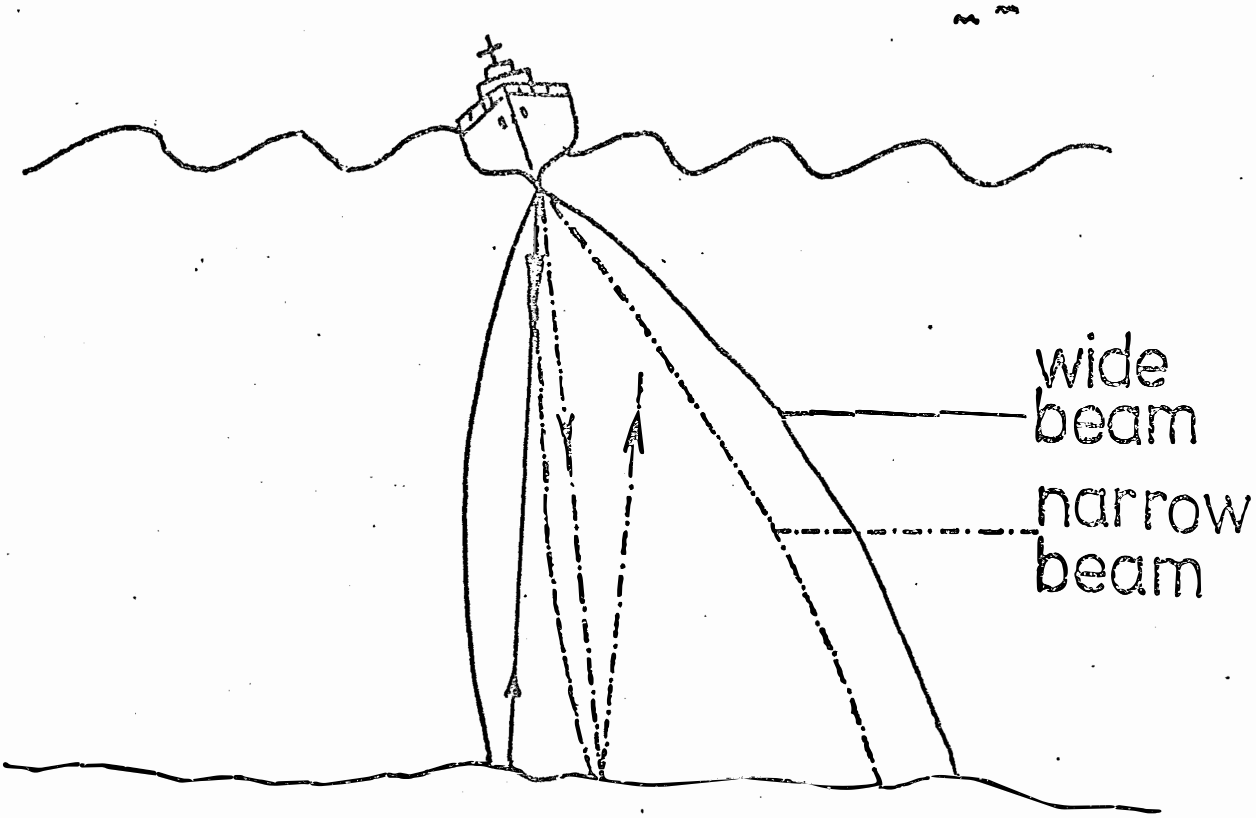


fig. 7

EFFECT OF ROLL AND BEAMWIDTH

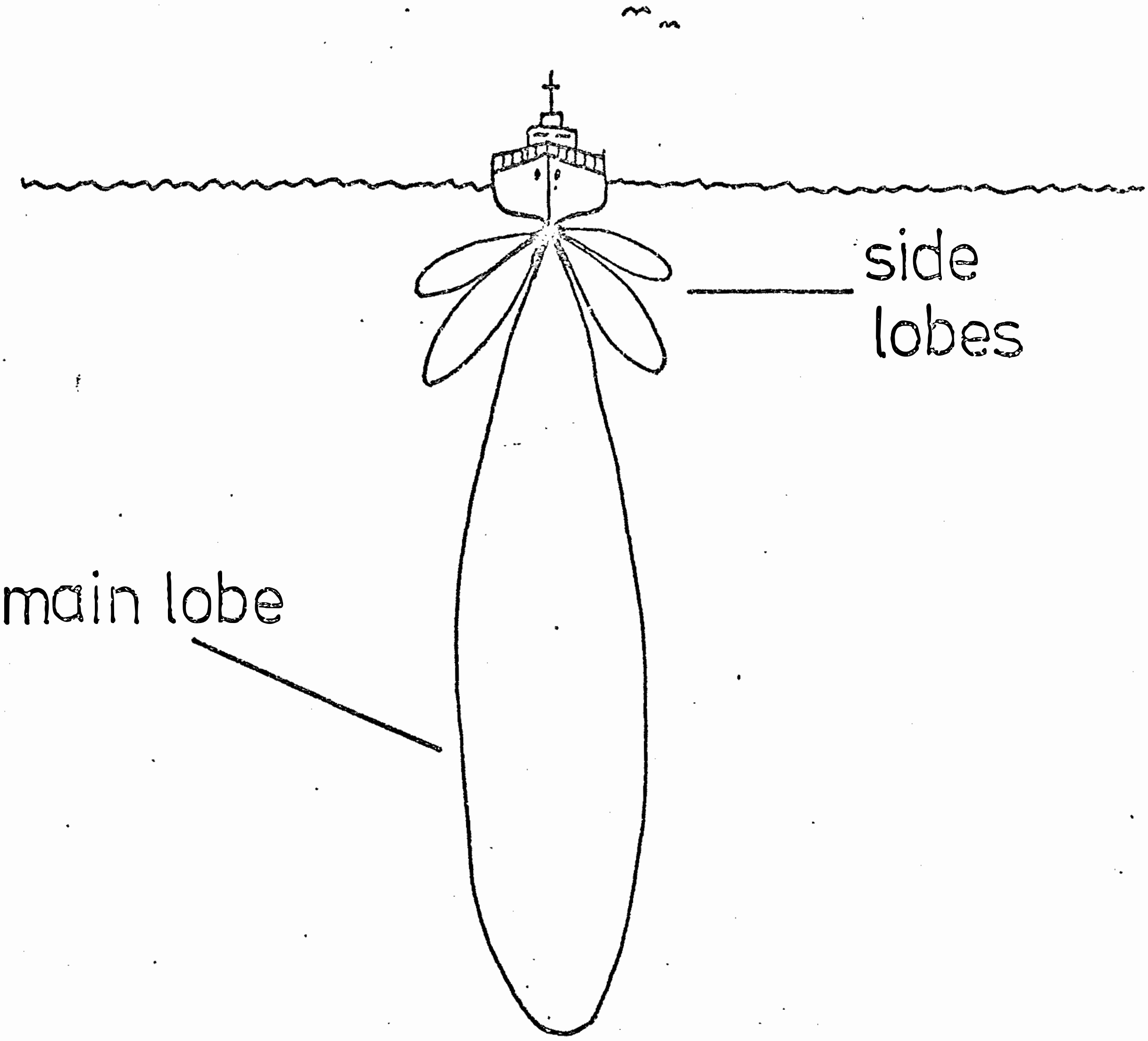


fig.8 CROSS SECTION OF BEAM

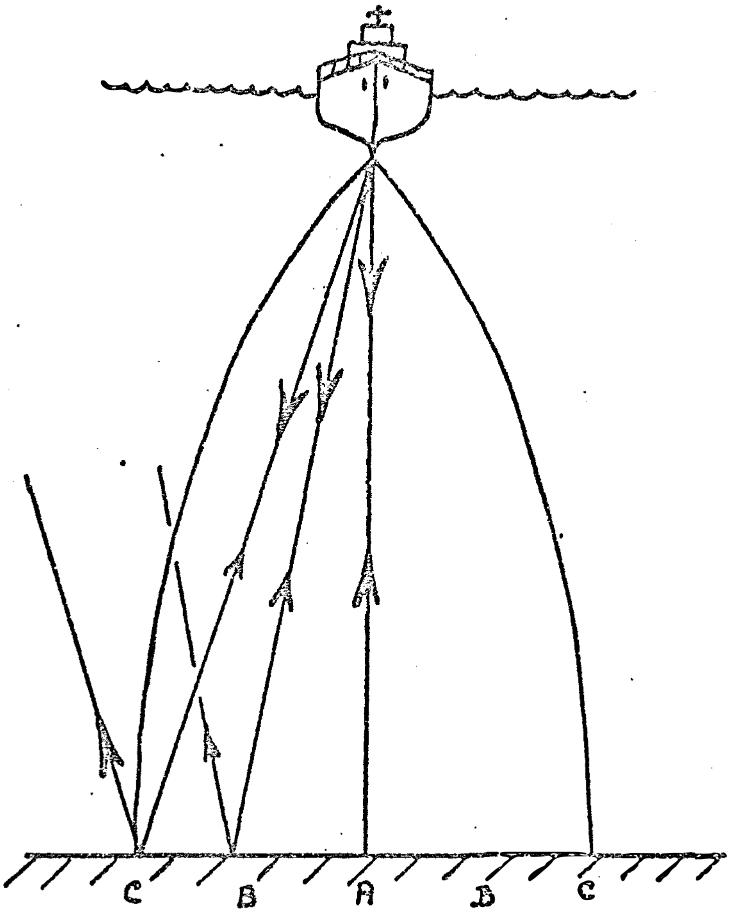


fig.9 EFFECTIVE ZONE

The next most important factor is the nature of the object reflecting the sound pulses. Hard objects like rocky bottoms give a better echo from the edges of the beam than soft objects such as fish or mud. The harder the bottom the greater the effective zone. Shape is also important and an object may be so shaped as to give a better echo from the edge of the beam than from the centre.

Amplification also affects the size of the effective zone. Weak echoes will return from the edges of the sound beam and from the side lobes. These echoes will not be registered unless the amplification is high. If this is so, then the effective zone will be increased and the echoes will be detected.

We can see from this brief discussion that the factors affecting the size of the effective zone are fairly complex and interrelated. This makes it especially difficult to accurately estimate fish numbers from echsoundings. Unless the operator has a good idea of the size of the effective zone and knows how much this varies from one set of conditions to the next, it will be very difficult to estimate fish numbers accurately.

Echo Length

When a vessel is on an even keel, sounding a level sea bed, the first echoes to return will be those from the centre of the effective zone (point A in fig 9). These are also the strongest. They produce the sharply defined top edge of the overall echo on both CRT and graph indicators. Echoes which return from areas next to the centre of the effective zone (area B) will be received after the initial ones as the sound pulse has further to travel. They are also weaker as the sound does not strike the bottom perpendicularly but rather at an angle. This means that less sound will be reflected back to the vessel. These echoes produce a weaker indication on the display, attached to the initial sharp echo. Finally echoes will return from the edge of the effective zone (point C). These will be the weakest of all. They will only make a grey mark on a graph recorder and will produce only a small deflection of the electron beam in a CRT display. They will be at the bottom of the echo mark. The result of this process is a strong initial echo which fades out fairly quickly. The larger the effective zone, the longer the echo will take to fade away and the longer will be the echo length.

All other things being equal, a hard bottom will give a longer echo than a soft bottom. This can be used to advantage to get a fairly good idea of the bottom and whether it would be suitable for trawling.

Echoes from the sea bed

Multiple echoes

Sound pulses are reflected from any surface separating two very different media, such as between rock and water or water and air. This means that echoes travelling up from the bottom will be reflected just as well from the surface of the sea as they were initially reflected from the bottom. After a sound pulse has been sent out, a small proportion of the echoes returning from the bottom will reach the transducer and be recorded on the display unit. However, most of the echoes will hit the surface of the water around the vessel and he reflected downwards again. If the initial transmission was powerful enough, the sound pulse will continue down to the bottom and be reflected back a second time. As it reaches the surface for the second time it will again be detected by the transducer and will produce a second mark on the chart. As the sound which made the second mark has traveled twice as far as that which made the first one, the second echo will appear at twice the depth of the first one. If the initial transmission has enough power a number of multiple echoes may be detected. This may be complicated slightly by the echoes returning to the surface being reflected by the bottom of the hull, as well as by the surrounding surface waters. This results in the double echo being composed of two distinct bands. The first one being reflected from the ship's hull and the second from the sea surface. The distance between these two bands represents the depth at which the transducer is mounted.

Multiple echoes are favoured by shallow water, high amplification or a hard bottom. Shallow water reduces loss of echo strength as the echoes have only a short distance to travel. High amplification picks up weak multiple echoes which would otherwise go unnoticed and a hard bottom gives a stronger echo with more chance of making the journey from surface to bottom twice. With some practice, an operator may be able to distinguish between a hard bottom such as rock and a softer one like sand or mud by observing the number and intensity of multiple images. However, as we have seen, the nature of the button is only one factor affecting the number of multiple images. As we saw earlier echo length (beard length) is also used for bottom discrimination.

Multiple echoes in flash indicators

Multiple echoes in flash indicators cannot be distinguished by their appearance. They are of no use in this type of indication and are best removed. As the multiple echoes are much weaker than the first bottom echo, they can be removed by reducing the gain setting until only the first echo is left. Changing the range will also remove double echoes.

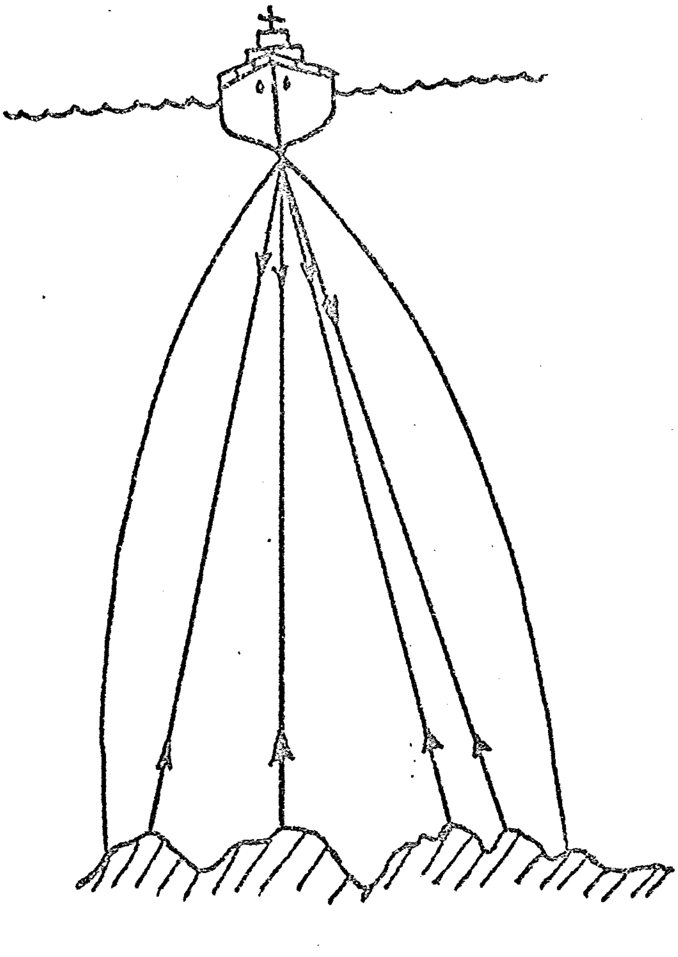


fig.10 UNEVEN BOTTOM

Multiple echoes in CRT indicators

In CRT indicators, multiple echoes only occur when depth ranges which begin at the surface are used. When using phased ranges, the double echo is very rarely encountered. On the fixed range, the double echo will occur at twice the depth of the first echo and will be much weaker. It will therefore cause a much smaller deflection of the electron beam. As with flash indication, multiple echoes are of little or no use in CRT indicators. They can be removed by reducing the gain or selecting another range. CRT indicators will be rarely used on the fixed range while fishing so multiple echoes will rarely be encountered.

Multiple echoes in graph indicators

Multiple echoes are most obvious in graph indicators. Their appearance has been previously described. One use of multiple echoes in graph indication is that fish will not be indicated in the second echo. When fish are close to the sea bed it is often difficult to distinguish between them and projecting rocks. The fish echo is considerably weaker than that from rocks and will not be represented on the double echo. However, since the advent of white and grey line systems, little use is made of this fact.

Effect of bottom type

Normal echosounders will not detect a rough or undulating sea bed when the undulations are small compared to the size of the effective zone. In fig 10 we can see that echoes from the peaks will be the first to be picked up. Echoes from the low areas will return later and will merely form part of the echolength. The graph will give an indication which is much smoother than the bottom really is. The only indication that the bottom is uneven may be a slightly increased echolength.

Echosounders could be manufactured with very narrow beams which could detect such irregularities in the sea bed. However they would be very seriously affected by the rolling of the vessel and would require expensive stabilisation systems which would make them too costly for everyday use. One simple solution is to reduce the gain as far as possible without losing the picture. As we saw earlier, this narrows down the effective zone and a more accurate picture will be built up. Conversely, heavy handed use of the gain will mask some bottom features which would otherwise be detected. This may be necessary, however, to pick up smaller targets. The gain setting should always be appropriate to the task in hand. Periodically varying the gain may show up features the operator was not previously aware of.

Slope

Errors in depth measurement are likely to be greatest where the bottom is sloping. We can see from fig.11 that the strong central beam from the sounder will not be the first one to return. The first echoes will be those from the edge of the beam on the highest point on the slope as they have the shortest distance to travel and a favourable aspect. The sounder will therefore indicate depth as distance A rather than distance B which is the true depth vertically below the vessel.

Fish on sloping ground can be very hard to detect. A school at position C will not be shown separately in the graph but will appear at the lower end of the bottom echo.

Errors will be exaggerated if the ship is rolling in a heavy sea. Fig. 12 shows how different depths can be indicated on successive soundings as the ship rolls. Depths A and B can be indicated within a few seconds of each other.

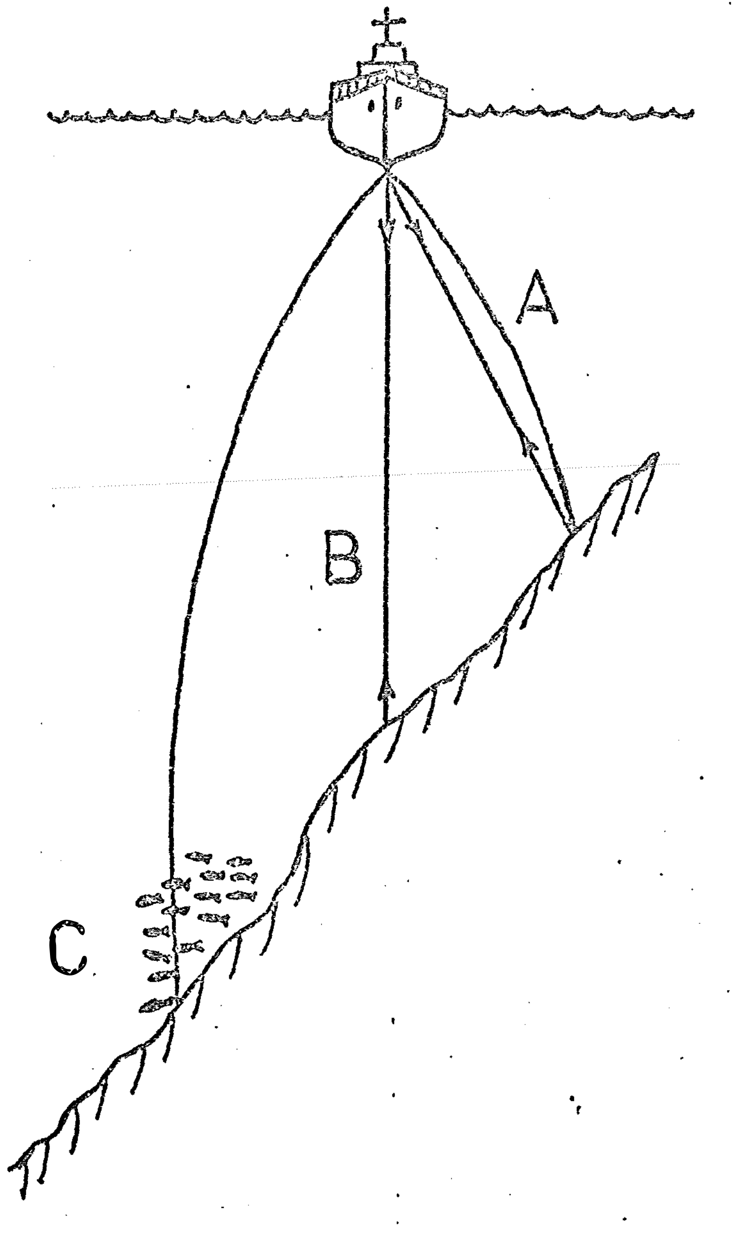
Trawling along sloping ground will require very careful steering of the vessel and it is important for the skipper to be able to recognise sloping ground on the echosounder.

Indications of slope

Flash indications do not show the details of the echo sufficiently for any indication of slope to be apparent in the display. Unless the vessel turns away from the slope and the rapidly changing depth is noticed, slope will not be detected by flash indicators.

CRT indicators show details of echoes very well. Earlier, we saw that on a sloping bottom, the first echoes to be received are often weak ones from the side of the effective zone whereas on a level bottom, the first echoes are the strong ones from the centre of the beam. This results in a difference between echoes from sloping and level bottoms. We saw earlier that echoes from a level bottom begin with a sharp deflection of the electron beam which gradually fades away. Echoes from a sloping bottom often begin gradually as the weak echoes from the edge of the effective zone reach the transducer first. The strong echoes from the centre of the effective area then reach the echosounder and the echo reaches its maximum extent. Finally the weak echoes from the distant edge of the effective area reach the transducer forming weak deflections which fade away rapidly. "Ideal" echoes from sloping and level bottoms are shown diagramatically in fig 13. A further indication will come from the fact that CRT indications of slope are constantly changing as the vessel rolls, even in a small swell. Schools of fish may give a similar echo to that from a sloping bottom but they can be distinguished by the fact that the echo from a sloping bottom is constantly changing whereas fish echoes are fairly constant.

fig.11 SLOPING BOTTOM



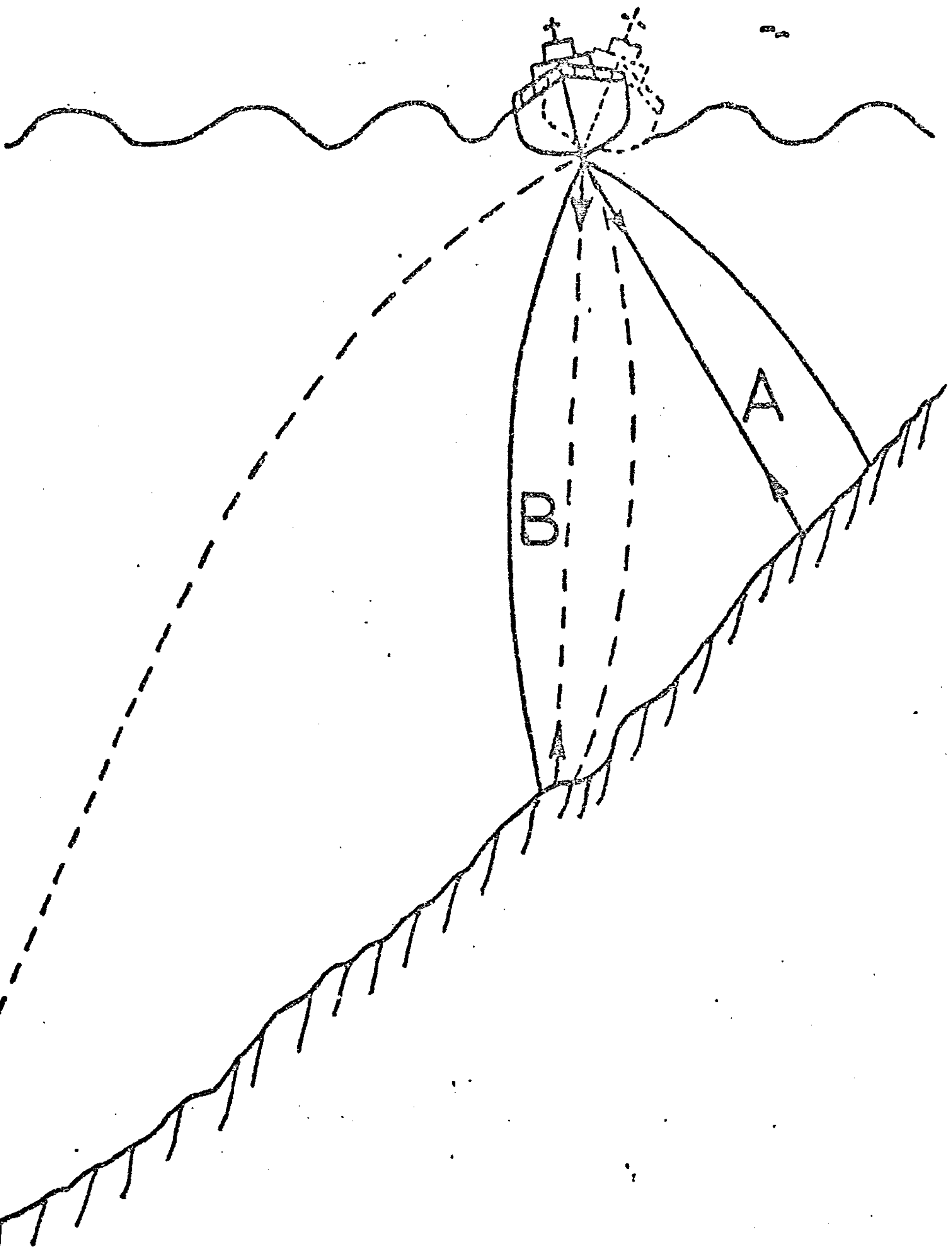


fig.12

EFFECT OF WAVE ACTION & SLOPE

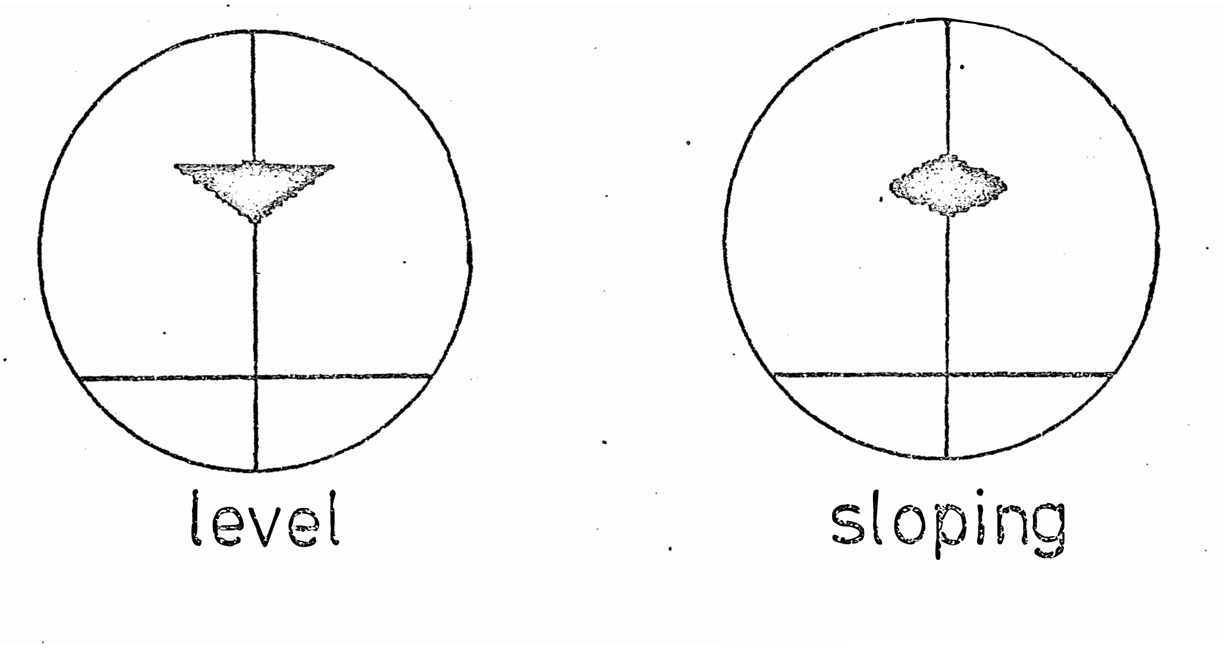


fig.13 BOTTOM INCLINATION
CRT INDICATOR

With graph indications, slope is not shown so clearly as with CRT indicators. This is because details of the echo are not shown as well by graph indicators. However some indications are present. As the first echoes received are weak ones, the top edge of the echo will not be sharp and black but rather, grey and a bit blurred. As the ship rolls from wave action, each successive sounding will probably be directed at a slightly different part of the slope and this will give the recording a jagged appearance similar to that produced by a heavy sea over a level bottom.

Ghosting and ambiguous depth indication

When the depth of water under a vessel is fairly great and is deeper than the maximum figure on the recorder being used, a ghost bottom may appear. After a sound pulse is transmitted, the pen starts its movement across the chart. If no echoes are received during this movement, the pen returns to the zero mark and another cycle begins. In some cases, the echo from the first pulse will then arrive after the pen has begun its movement for the second pulse. The pen may only move the equivalent of a few fathoms when the echo arrives. The sounder cannot tell that this is an echo from a previous pulse and it marks the paper as usual at a depth much less than it really is. The mark, however is often quite weak, due to the great distance travelled by the sound and the white line, if it is being used, often disappears. An experienced operator usually has little trouble with ghost bottoms.

At shallower depths, this process can give rise to ambiguous depth indication. If a sounder is being used at a range of say 0-100 fathoms and a ghost image appears, it can easily be detected by switching to a longer range, say 0-200 fathoms. Provided the true depth lies within this range, the bottom will show up at its true position. If the depth is greater than this figure, the change in range will move the false indication to another point in the depth scale showing the indication to be false.

Echoes from fish

Noise

Unwanted sound can have a substantial effect on an echosounder's ability to detect fish and for this reason we will begin our discussion of fish echoes with an examination of it. Sound, other than the echsounder pulse is generally known as noise. It can be detected and indicated by echosounders, especially on the higher gain settings. This can give rise to false echoes and to dark areas in the chart which can obscure wanted fish echoes. Interference can often be recognised as it continues below the sea bed on the chart and is often constant with depth. It can sometimes be removed, or at least reduced by reducing the gain setting.

Most noise comes from the vessel in which the echosounder is installed. Noise can also come from nearby vessels and from the sea itself.

Ship noises can be divided into machinery noise, flow noise, propeller noise, electrical noise and interference from other acoustic instruments.

Machinery noise is generated mostly by the main engine but may also come from auxiliary machinery, especially if it is in poor condition. Machinery noises can be transmitted through the hull to the transducer mountings or into the water and then to the transducer. It is generally dominant over other noises when the vessel is proceeding at low speed. This type of noise can be reduced by:

- rigidly fixing all engines and fittings to avoid rattling and vibrations
- providing shock absorbing devices between the engines and the hull or between the hull and the transducer

Flow noise is caused by the flow of water past the hull as the vessel proceeds (as shown in fig 14). Flow may be laminar or turbulent. Laminar flow is a thin, nicely ordered layer flowing along the hull. Turbulent flow is a wider layer of disordered water full of eddies, generally outside the area of laminar flow.

If the turbulence is great enough cavitation occurs and small voids or cavities will momentarily form in the water especially towards the rear of the hull. The cavities collapse again soon after they are formed creating considerable noise. Cavitation also occurs at the propeller or near any protuding objects at high speed.

Flow noise may also be caused by air bubbles being carried under the transducer face or by the splash from the vessel's bow waves. In some cases a hole in the hull may set up a resonant noise with a discrete frequency. Other flow noise will have a wide range of frequencies.

Flow noise can be reduced by:

- making sure that the transducer or dome is as streamlined as possible. It is often useful to angle the fairing slightly in towards the point of the bow, rather than pointing it straight ahead
- ensuring that the transducer projects out through the layers of laminar and turbulent flow. This is most easily done by mounting the transducer towards the front of the vessel where these layers are thinner

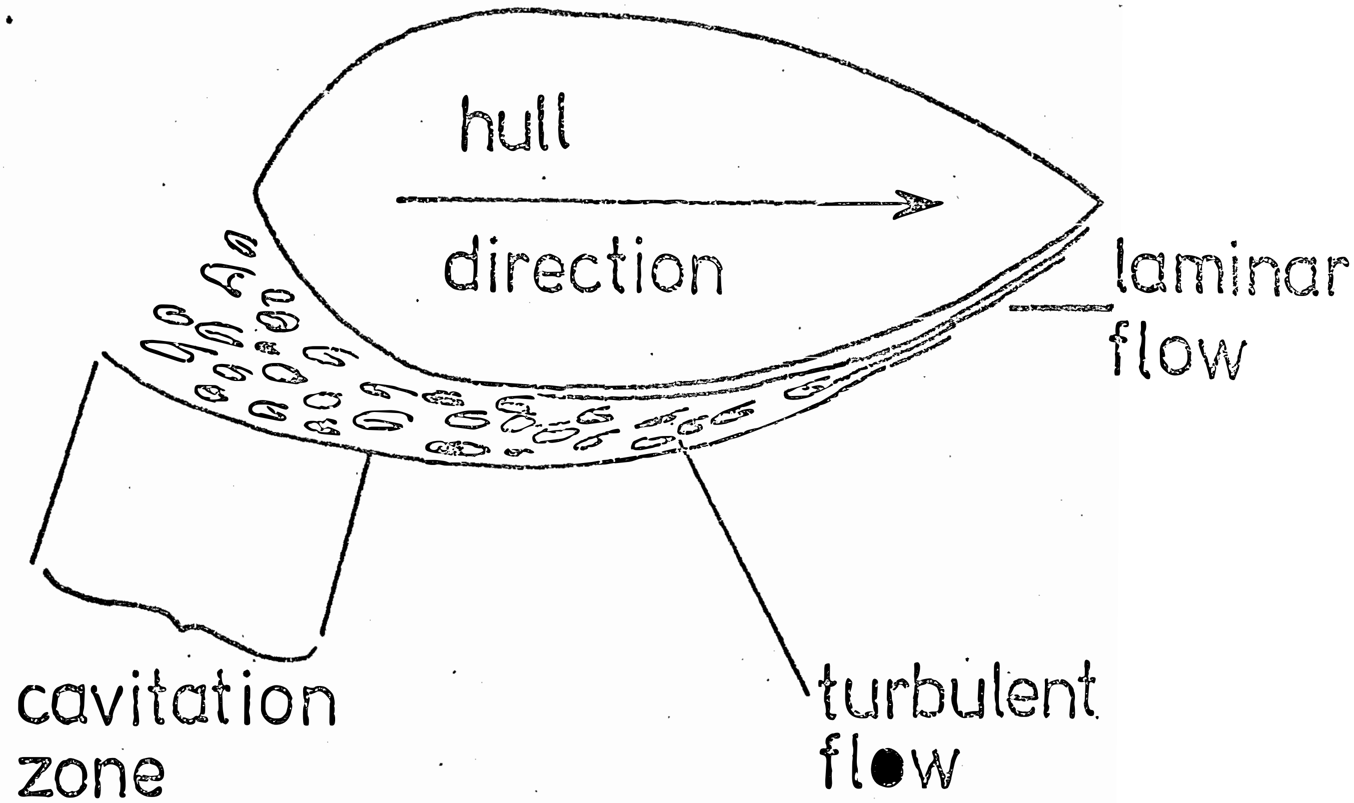

hull
direction
laminar
flow
cavitation
zone
turbulent
flow

fig. 14 FLOW

- making the hull in front of the transducer as smooth as possible. No protuding objects or rapid changes in hull shape should occur. Keels, especially bilge keels and zinc anodes (if used) should be rounded off with no sharp edges.

Propeller noise is generally water-borne but shaft vibrations may be transmitted through the hull. Static electricity can be built up on the propeller shaft. This can cause sparks which are another source of noise. Propeller noise usually dominates other noises at high speeds. It is greatest from variable pitch or fast moving propellers. Cavitation (the formation of bubbles) by propellers is especially noisy and even when this is not occurring, noise is generated by the propeller forcing water against the hull or the rudder. Propeller interference is most noticeable when reversing. In this situation, a stream of bubbles may be projected forwards under the transducer, blocking its transmission almost completely.

Propeller noise can be reduced by:

- locating the transducer as far away from the propeller as practical and on the side of the hull on which the propeller blades are moving downwards
- providing sufficient clearance between the propeller and the hull and between the propeller and the rudder
- using zinc anodes which are streamlined and parallel to the flow of water
- replacing damaged propellers
- Angling the transducer so that the beam points a few degrees forward, rather than being exactly vertical
- properly grounding the propeller shaft to stop discharges of static electricity

Electrical noise can be produced or picked up in any of the echosounder parts other than the transducer. Noise is most commonly picked up by transducer cables and comes from the ship's voltage supply. At higher frequencies electrical components are more prone to electrical interference and this may be a limiting factor in echosounders using high frequencies.

Electrical noise can be reduced by:

- proper grounding of all units
- separating echosounder cables from others carrying heavy currents
- using a voltage supply which does not have disturbances such as from other machinery

Other acoustic instruments such as sonar or net-sondes can cause interference if the frequency used is close to that of the vessel's echosounder. This type of interference is often seen as a series of dots running from the top to the bottom of the chart on graph indicators.

Other vessels in the vicinity can cause unwanted noise but they are generally not close enough to do so.

Noise from the sea is caused largely from wave action. It is not usually very important except in the use of sonar when the sound beam, being reflected back from waves on the surface can cause considerable interference.

Soundings from single fish

With a vessel stationary in a calm sea, a single fish swimming along at a constant depth will initially appear as a weak echo as it gets to the edge of the effective zone. As we can see from the fig. 15 the display will show the fish to be slightly deeper than it is. This is because it is at the edge of the beam and the sound pulse has to travel along distance A which is longer than the fish's true depth, distance B. When the fish reaches the centre of the beam, the sound now travels along the shorter distance B so that the fish now appears on the display at its true depth. It also gives a stronger echo when it is in the centre of the beam as the sound pulse is strongest here.

On a chart recorder, the echo produced by a single fish is therefore crescent shaped, stronger in the middle and weaker at the edges. A diagram of this is included as fig. 16.

On a CRT recorder the echo initially appears low on the screen and fairly weak. As the fish enters the centre of the beam the echo rises to its true depth and increases to its proper strength as the fish leaves the beam the echo is lowered and becomes weaker. Fig. 17 shows this type of record.

Similar records can be produced when the fish is stationary and the vessel is moving.

When the crescent shaped echoes become asymetrical, the fish will be moving around in different directions and different speeds. This is the more usual situation. Although fishermen are not generally looking for individual fish, those looking for tuna will often encounter them in groups which give echoes from each individual fish but which are still economically important.

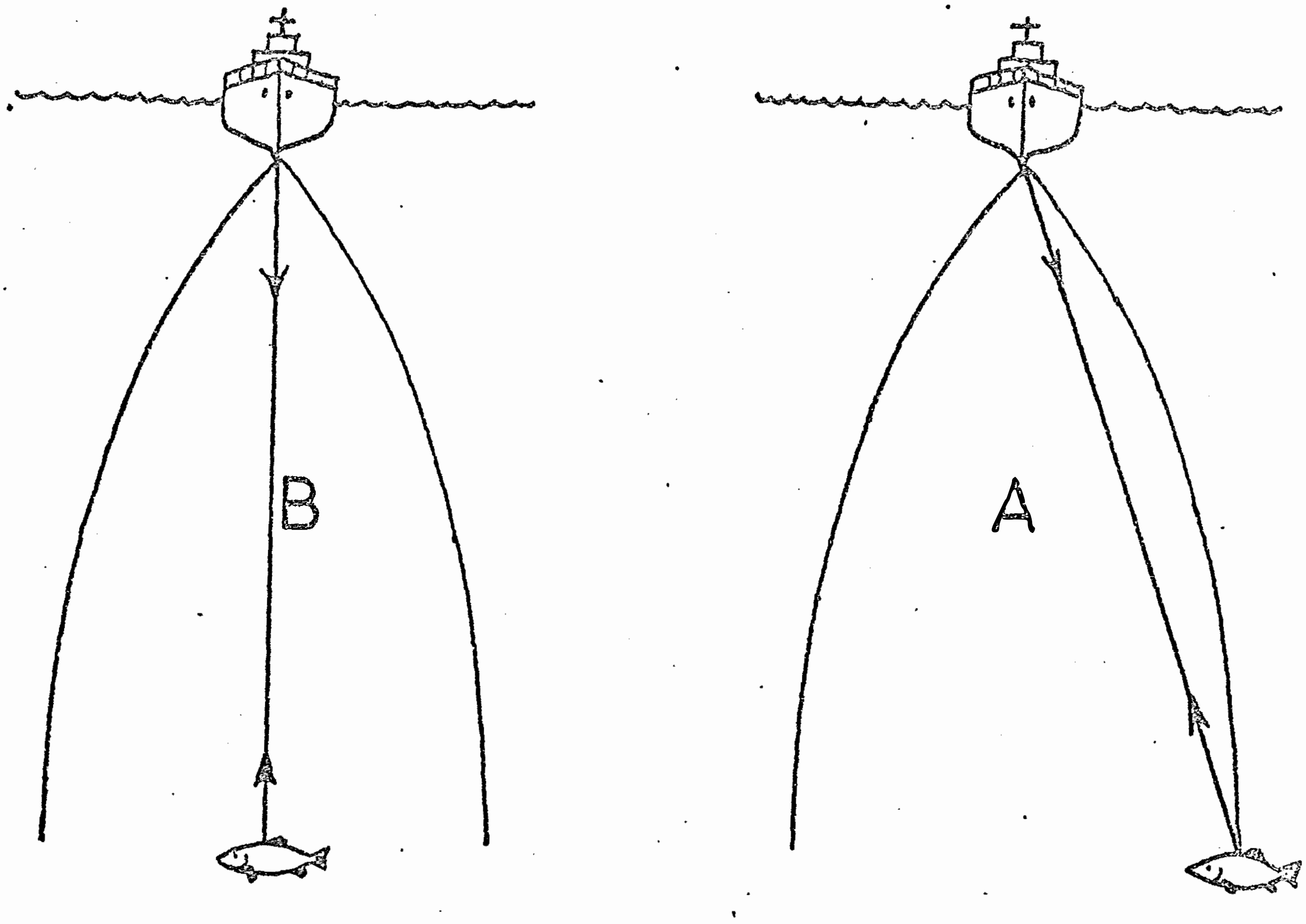


fig.15 FISH CROSSING BEAM

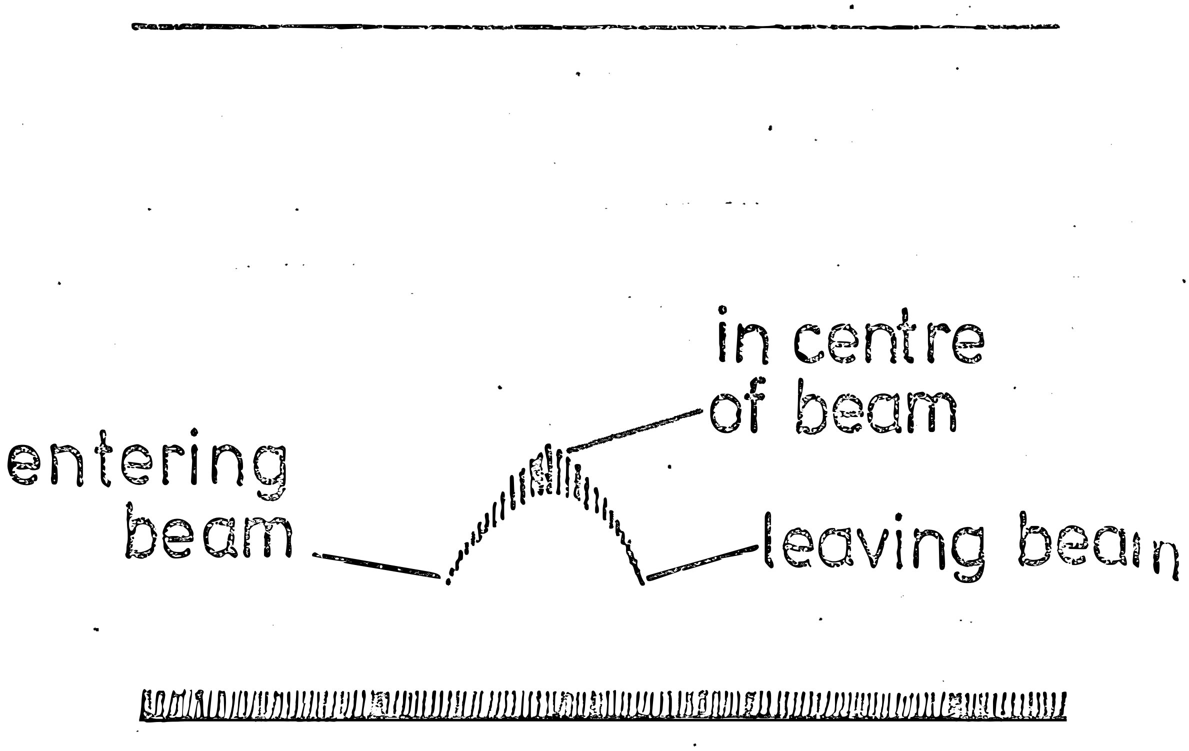


fig. 16
FISH CROSSING SOUND BEAM
GRAPH DISPLAY

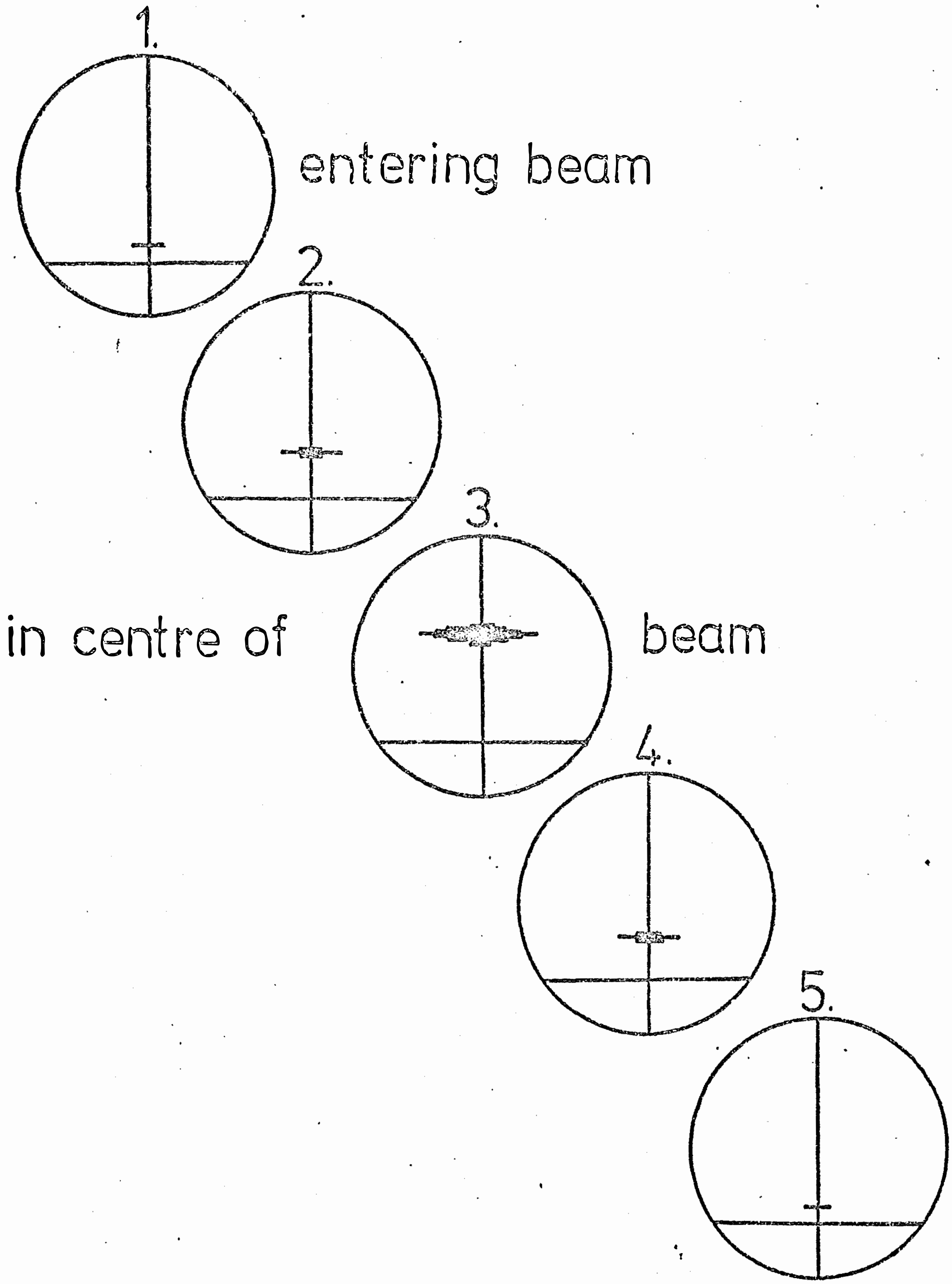


fig.17 FISH CROSSING SOUND BEAM ON CRT DISPLAY

Soundings from schools of fish

Echoes from schools of fish are made up of the sum of all the individual echoes. As CRT indications give a more accurate indication of echo strength, they show the density of a fish school more accurately than graph indications can. On graph indications schools of fish show up as dark areas which may be small and separated or joined together in a ribbon-like band.

Depth of fish school

In most cases, the school of fish will be considerably larger than the area covered by the sounder beam. When this is the case, the top of the echo in the chart will represent the true depth of the school, just as the top of the sea bed echo is the true depth at that point. If the school is smaller than the area covered by the beam and is located at the edge of it, the depth indicated will be deeper than the true depth of the school. We saw earlier how objects at the edge of the sounder beam are indicated at greater than their true depth.

Thickness of schools-reverberation

It is sometimes thought that the thickness of a fish school corresponds to the thickness of the echo mark on the display. This is not true, however, due to the phenomenon of reverberation and to the echoes from the edge of the sound beam. Reverberation occurs when the sound pulse bounces around inside a school of fish for a while before returning to the surface. When a sound pulse strikes the top fish in a school, some of it is reflected to the surface and picked up by the echosounder. The rest of the energy misses the top fish and penetrates into the school. The sound can then be reflected from one fish to another or from the fish to the bottom before it is reflected upwards to the transducer. This means that some of the sound is delayed in returnig to the transducer and so the pen has moved further down the chart before the echo is finished, making the school appear to be thicker from top to bottom, than it really is. The fact that echoes from the edge of the beam take longer to return than echoes from the beam's centre also tends to make fish schools appear thicker than they really are.

In mid-water trawling, the net must be lowered to the depth of the top of a school rather than to the bottom of it. In using ground trawls, a skipper must be careful with fish schools which appear to come close to the bottom. The echosounder may show that the bottom of the school is below the headline but this may not be so due to the factors outlined above.

It is difficult to prescribe any rules concerning allowances for reverberation. Beam width, pulse length and gain settings all affect how thick the school will appear. As a general rule, an allowance of 10% can be made for the depth of the lower edge of the school. For instance, if the lower edge of the school appears to be at 100 fathoms, a more realistic estimate would be 100-10% = 90 fathoms.

False indications of school thickness can be reduced by having the lowest gain setting, shortest pulse length and narrowest beam width possible.

Fishermen who fail to take note of the need to correct the apparent depth of the bottom edge of a school will be disappointed to find that they have been trawling in vain.

Length of the School

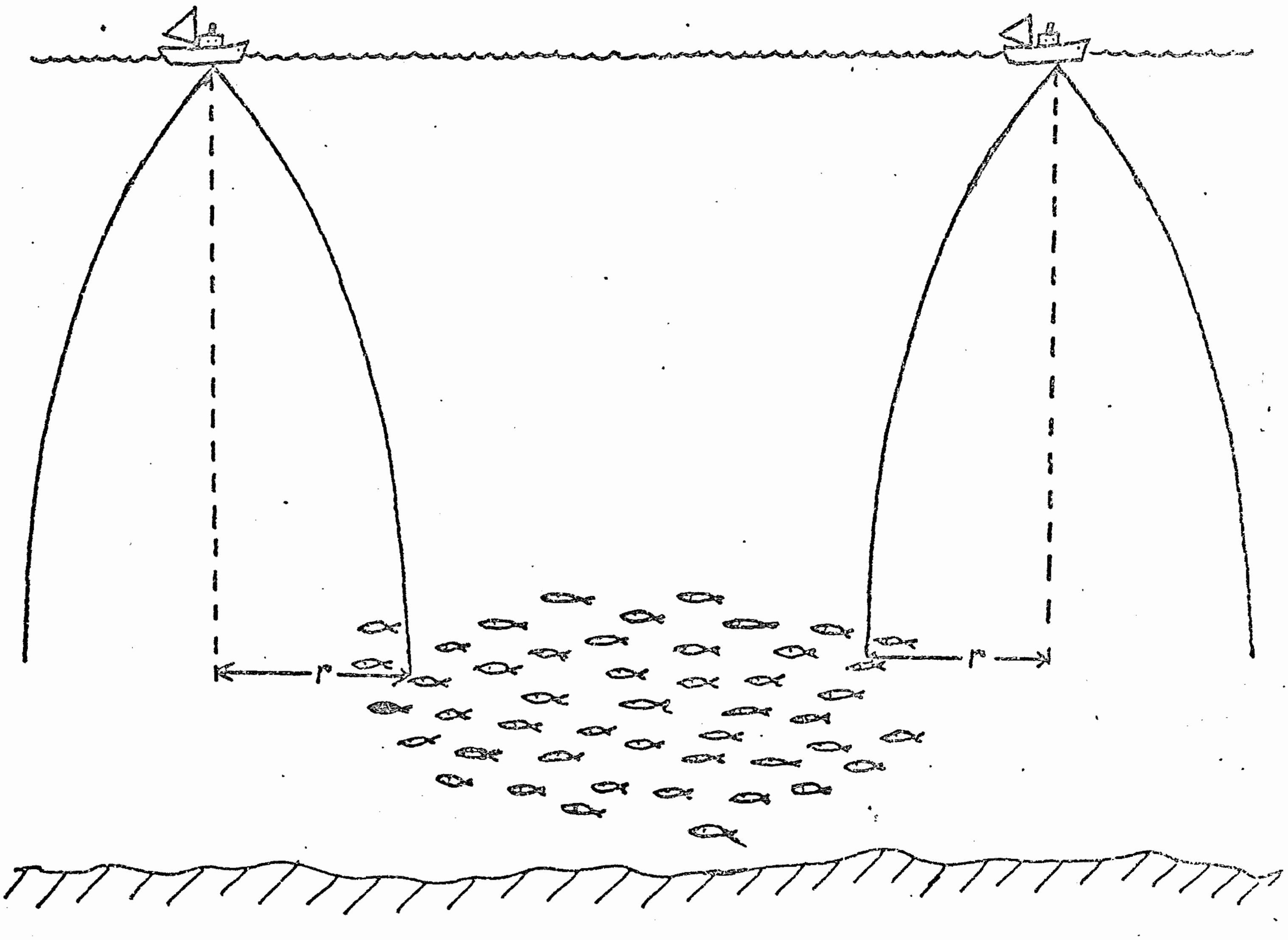
The length of a school can be calculated fairly easily provided the speed of the vessel and the length of time that the school can be seen are known. If we suppose that the vessel is going 3 knots or 49.8 fathoms per min and a school is being indicated for 5 minutes then it will be 49.8 x 5 = 249 fathoms long.

This is complicated slightly by the fact that the sounder will begin indicating the school before it is exactly beneath the ship and continue to indicate it so long as the school is within the sound beam, even after the ship has passed over it. This is shown in fig. 18. We can see from this diagram that the length of the school will be over-estimated by the radius of the sounder beam at each end (distance r in the diagram). However, this distance is difficult to calculate. We saw earlier that a large number of factors affect the diameter of the sound beam. An approximate estimate of the radius of the beam is 1/6 of the sounded depth. Therefore, to obtain an estimate of the length of a school, we must subtract from the apparent length twice the radius of the sound beam or 1/3 of the sounded depth. If we presume that in our previous example the depth was 75 fathoms we have to deduct 75/3 from 249 = 226 fathoms.

This type of correction factor is important only for small schools. With larger ones, the correction factor may only account for a few percent of the total length of the school. Many sounders have time marks on the chart to assist with estimation of fish schools. Obviously, chart recorders are more suitable for estimating fish stocks as they produce a record which can be used later. A CRT indicator, on the other hand, must be watched constantly.

Estimating the quantity of fish in the net

Having an accurate estimation of the number of fish in the net would be extremely useful to trawl fishermen. Time and money would not be wasted hauling a half empty net or trawling with one which is already full. However, at the moment, accurate fish counting systems are still experimental. The quantity of fish in the net depends on the length and density of the school and how effective the net is in catching it. The fisherman can get an idea of the size and position of the fish school from the echosounder. However we have already fig.18 LENGTH OF SCHOOL



sounder beginning
to indicate fish

sounder ceasing
to indicate fish

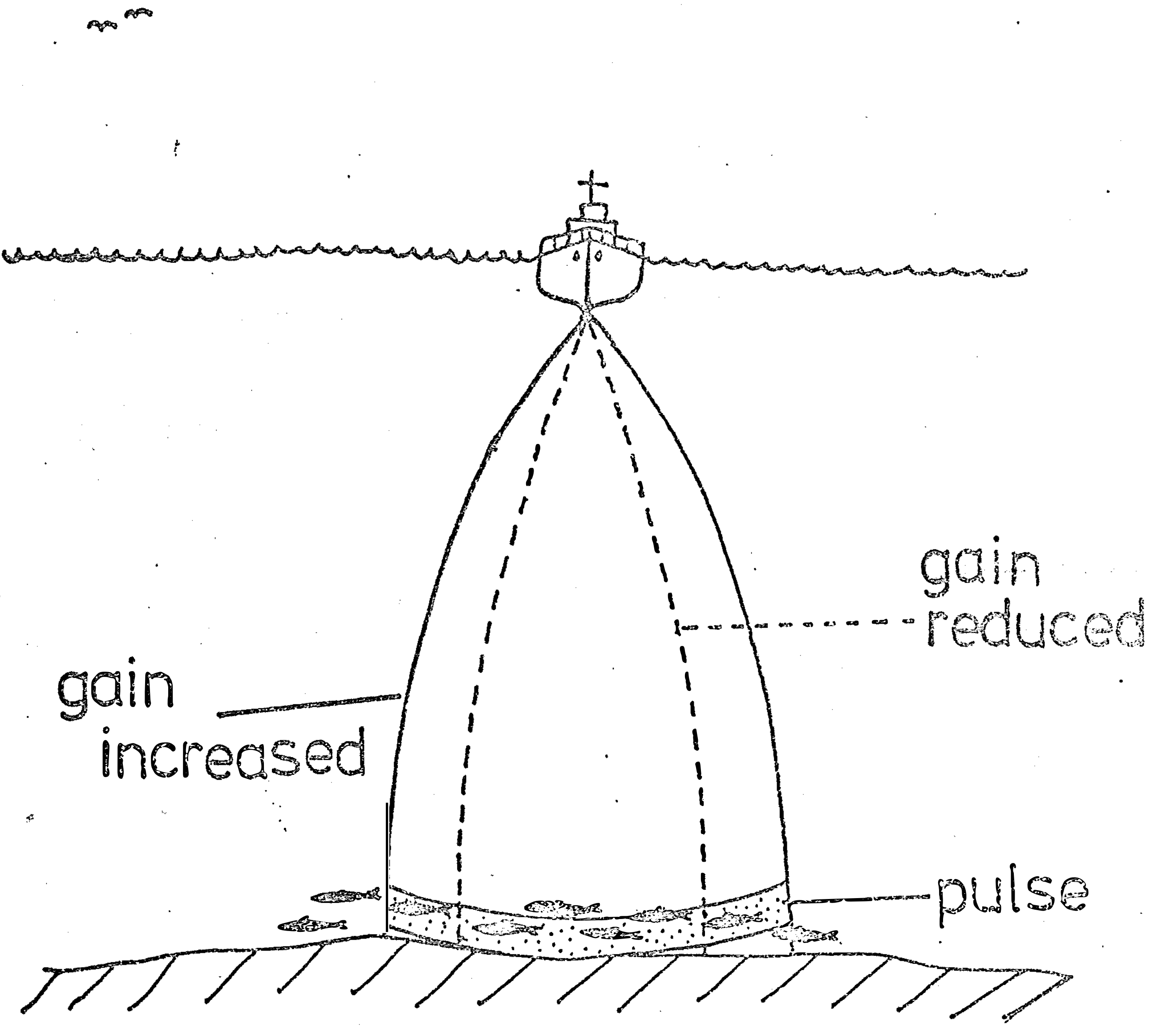


fig.19

GAIN AND BEAM WIDTH

seen how a large number of factors such as pulse length, gain setting and overall condition of the unit will affect how dense a school appears to be. When we come to the efficiency of the net we begin dealing with fish behaviour about which little is understood. Similarly, a net may fish differently under different circumstances, currents, depth, slope and composition of the bottom may all affect how a net fishes. Furthermore, the fish shown on an echosounder may be a considerable distance in front of the net. A vessel fishing at 100 fathoms will be about 300 fathoms in front of the net. At a speed of 3 knots it will take about 6 minutes for the net to reach the fish. If they happen to be moving they may easily move out of the path of the net before it reaches them. Net monitors may be used to give a better indication of fish entering the net but they are not completely effective and are expensive to purchase and operate.

Although a large number of factors affect the relationship between what is shown on the echosounder and what is caught in the net, skippers can gain valuable experience in judging net contents from echosounder records. Fishermen must constantly compare the echosounder record with the catch. Some overseas skippers have developed considerable expertise in this area. Although our conditions and equipment are not as suitable for this it may still be a worthwhile exercise.

Fish Close to the sea bed

Fish that are lying close to the sea bed are the most difficult to detect. This is especially important in Australia as a considerable proporiton of our fish are caught with bottom trawls.

We can see from Fig. 19 that the fish and the bottom will both be hit by the sound pulse at the same time. This means that the echoes returning from the fish will be fused with the bottom echoes, unless the pulse length is very short or the beam width very narrow. Fish are most likely to be shown as separate from the bottom if the gain is set on the minimum setting that will give an adequate fish echo. This reduces the diameter of the effective zone by not picking up echoes from the edge of the beam. It is shown by the dotted beam in fig. 19.

The shortest pulse length should also be selected, however, if the fish are very close to the bottom the pulse would have to be so short that it would not be able to penetrate to the bottom and back again.

The difficulty of detecting fish close to the bottom has lead to the development of white and grey line systems. Both of these systems rely on the fact that the amplifier can distinguish between bottom echoes (which are usually fairly strong) and fish echoes (which are generally much weaker). However, this ability is not shared by chart display units which can't show the difference between the two echo strengths. Many fish echoes are strong enough to make a strong black mark on the chart. Bottom echoes although much stronger are also black and the two echoes appear identical in strength. You can't get blacker than black.

The white line system overcomes this problem. In this system, the amplifier passes all weak echoes, such as those from fish to the display unit and they are marked on the chart in the usual fashion. However, when the strong bottom echo is received the amplifier shuts off so that the pen moving along the chart leaves no trace. As soon as the echo strength falls below the cut-off level, the amplifier resumes functioning and the tail of the bottom echo is shown. The point at which the amplifier cuts off can be varied to suit different fishing conditions.

With this system, fish echoes appear as a thickening of the thin black line on top of the white line. They are much easier to see this way. Some systems have a white line of pre-determined thickness whereas in others, the amplifier remains shut off as long as echoes above the cut-off level are being received. This means that on a hard bottom where even the weaker echoes from the edge of the sound beam are strong, the amplifier will remain shut-off longer as echoes from the edge of the beam take longer to return to the transducer. This results in the white line getting wider on hard ground and narrower on a soft bottom. Together with echo length, this is a good way to tell what type of bottom you're over.

The grey line system was invented to show more bottom information by cutting off for as long as bottom echoes were being received, rather than for a preset period. This was the first system to vary the width of the line with bottom hardness. In this respect many modern white and grey line systems are the same. One advantage that the grey line does have is that the fish echoes are marked in black on a grey line. This makes the echoes easier to see than on white line systems, which mark fish as a thickening of the thin black line which runs along the top of the white line.

A further way of getting improved discrimination of fish close to the ground is using a display in which the bottom few fathoms can be shown in an expanded form and bottom-locked. This latter term means that although the bottom may be jagged and the vessel may be moving up and down with the swell, the expanded bottom echo is always shown on the same part of the chart. This makes reading much easier, especially in a heavy swell. Both CRT and the more advanced chart indicators have this ability.

As shown in fig. 20, dead areas exist on each side of the sound beam. Due to the curved nature of the sound pulse, echoes from fish in dead areas will be mixed up with the bottom echoes and can not be separated because they arrive at the transducer simultaneously. However, the fish at position A will be indicated as their echoes will arrive at the transducer before the bottom echoes.

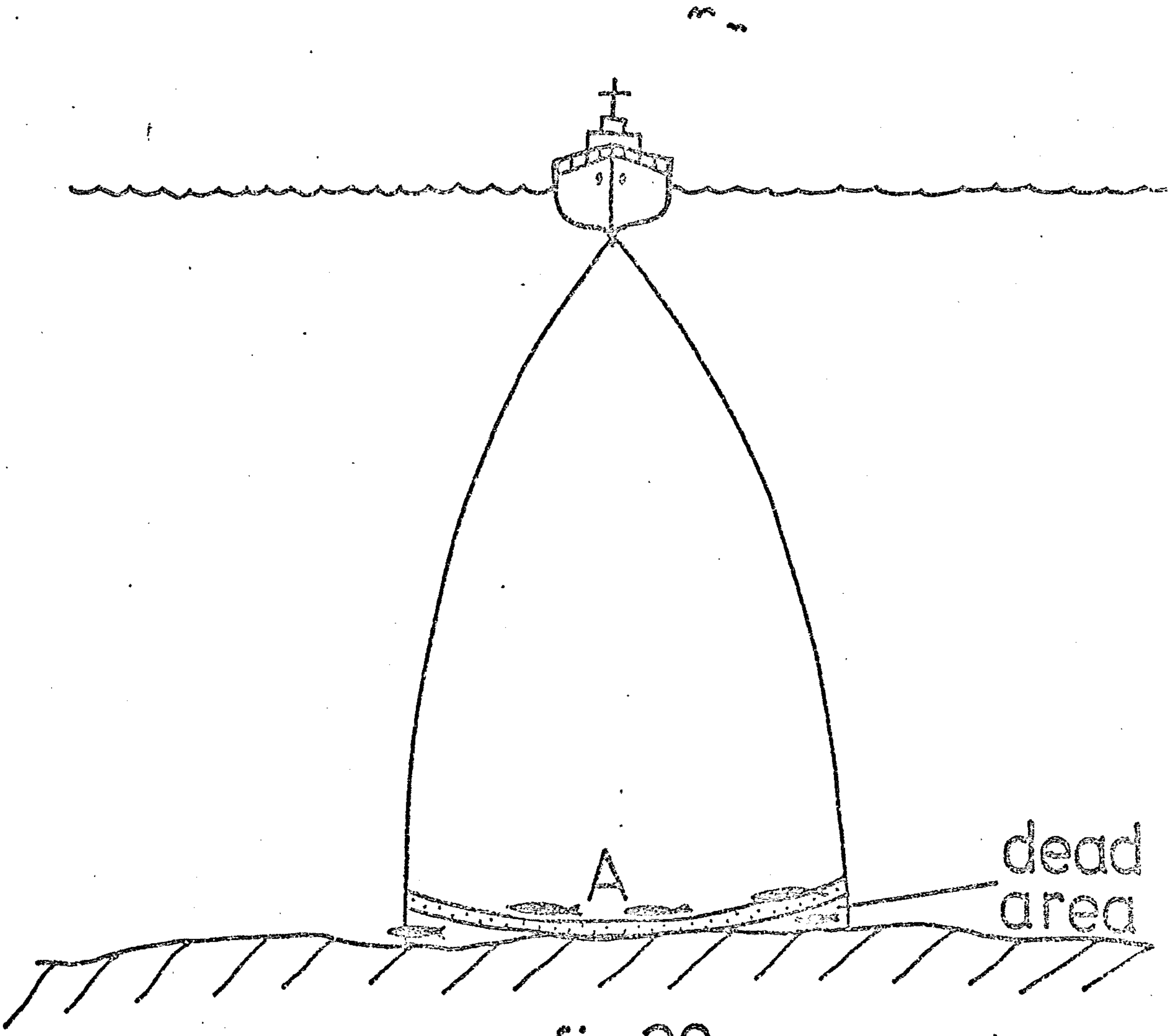


fig.20
DEAD AREAS

Time varied gain

One problem with comparing fish schools at different depths is that schools close to the transducer give a stronger echo and therefore appear larger than schools which are deeper and therefore further from the transducer. In situations where a layer of plankton or a similar target is located at a shallow depth, it may produce such strong echoes that any small schools of fish below it are obscured. Similarly, a school which is worth catching may appear too small merely because it is located a bit deeper than usual.

This sort of problem can be overcome using a device known as time varied gain or time sensitivity control. This system automatically reduces the degree of amplification the instant a sound pulse is transmitted. This means that echoes returning from close targets are reduced. As echoes from objects further away return, the amplification gradually rises until echoes from objects near maximum range receive maximum amplification. This means that all targets are shown at their true size rather than close objects appearing larger than distant ones.

Attachment 2

ECHO SOUNDER COURSE 1982

THE NETSONDE ECHOGRAMME

The netsonde is a specialised development of the echo sounder which enables fishermen to tow midwater trawls at any depth, and to vary this depth rapidly by changes in towing speed and or warp length, in order to catch schools of fish swimming between the surface and the sea bed. The netsonde provides the following information about the net and its surroundings:-

- The headline
- The footrope
- The sea bed
- The sea surface
- The depth to the sea bed from the headline and footrope
- The depth of the headline and footrope from the surface
- Schools of fish above the headline, in the mouth of the net, and below the footrope

If you refer to the first figure you will see a typical echogramme of scattered fish schools close to the bottom in quite shallow water. The scale is 0-50 fathoms and at the left hand side of the recording at the third minute mark, the depth is 32 fathoms; between the 7th and 8th minute mark there is a low reef and the bottom depth has increased to about 40 fathoms; the bottom then remains fairly level until the end of the recording.

Referring next to the fish schools, there is a distinct layer between the 3rd and 8th minute. From this point onwards the fish are more scattered and are in small schools, most of which are within seven fathoms of the bottom. This echogramme was made off Bate Bay just south of Sydney in August 1974, and the fish were a mixture of jack mackerel and nannygai which were schooled up in this area for several weeks.

We will examine next the echogramme from the netsonde which was recorded simultaneously with that from the echo sounder during the actual fishing operation, and we will follow the path of the net as it was manoeuvered through the fish schools.

The objective was to tow the net close to the sea bed without damaging it by sustained contact with the bottom and to catch as many fish as we could. If we refer to the netsonde echogramme this shows the complete operation which lasted 35 minutes. The transducer is mounted on the headline of the net in which position it is analogous to the transducer on the hull of a fishing vessel. The difference is of course that as the fishing boat moves through the water the sea bed rises or falls as the depth varies, whereas with the netsonde the net may be moving up and down in the water and the depth may be varying also. On the echogramme of the netsonde, the headline is the baseline and all the recordings relating to the sea bed and fish etc., are measured from this point. Therefore, as the net sinks down from the surface towards the sea bed, the bottom appears to rise to meet the net as the distance between them decreases.

The echogramme of the netsonde is divided into two halves. The top half shows the recording from the headline to the sea bed while the lower half shows the recording from the headline to the surface. Referring to the top half of the recording first; at the extreme left hand edge, shooting the net has been completed, and the vertical opening of the net is only about four fathoms due to the speed at which the net is being towed through the water. There is a momentary check as the winch stopped, then the net mouth opened up quickly to about seven fathoms and continued to open until it reached about ten fathoms and continued to open until it reached about ten fathoms as the ship alowed down to allow the net to sink to the bottom. The sea bed is shown rising to meet the footrope and the reef referred in the 7th and 8th minute of the echogramme is clearly visible. As the footrope of the net appeared to be approaching the bottom too rapidly, and remembering that these nets are very fragile, its descent was checked by increasing speed. Two things happened as a result of this action; the vertical opening of the net decreased by one or two fathoms and the net ascended quickly until it was about four fathoms off the bottom. The towing speed was then reduced more slowly than previously, the net mouth opening increased gradually and the net slowly descended until the footrop commenced skimming the bottom. The towing speed was then allowed to creep up so that instead of the net continuing to skin the bottom as intended, it rose slowly so that in all probability most of the intended catch escaped under the footrope; however, fish can be seen entering the net during most of the tow. A conservative estimate of the catch was about half a tonne for the 35 minute trawl but because of the scattered nature of the fish schools very little was detected in the way of fish recordings in the vicinity of the net mouth, which is quite normal in these situations.

Turning now to the lower half of the recording, the surface is represented by the very thick line at the bottom of the paper. This recording is in many ways a mirror image of the bottom recording in the upper half of the paper, but the recording is less sharp than the one of the sea bed, because the beam angle of the upper transducer is wide and the sea surface consists of continuously moving waves of various heights. The check on completion of shooting can be seen just as clearly as in the top half of the paper as the net descends and the range between the sea surface and the headline increases. The descent was checked at about 26 fathoms and the net lifted until the headline was at 24 fathoms, then the towing speed was adjusted to allow the net to sink more slowly towards the bottom. There is an additional recording on the paper which is quite common in shallow water and it represents a reflected echo from the sea surface of the sea bed as it appeared in the echo recording referred to in the beginning. This conveniently shows a true profile of the sea bed including the reef in the left hand side of the recording. This echo recording is relatively faint because there have been significant losses in signal strength as the signal is reflected between the sea bed and the surface.

The second figure shows an echo sounder recording of mixed nannygai and jack mackerel beginning to disperse upwards into the water coloum as sunset approaches. This recording was also made off Bate Bay but was later in the afternoon of the next day. The typical small schools shown in the first figure are beginning to break up and the fish are rising upwards. The sea bed is level and the depth is 35 fathoms. The scale is 25-75 fathoms, the bulk of the fish are about 30-40 fathoms below the surface, therefore we aimed to tow the net up and down through the fish over this depth range. Turning to the netsonde recording for this operation the net was allowed to sink rapidly until the headline was about 32 fathoms off the bottom. The winch was stopped causing the vertical opening of the net to be reduced quite rapidly, and the net continued to sink until the headline was 25-26 fathoms off the bottom. The net was then towed at this depth for some time before power was applied decreasing the opening and causing the net to rise rapidly until the headline was at 50 fathoms. Power was then reduced allowing the net to sink until it was only 20 fathoms. Power was then reduced allowing the net to sink until it was only 20 fathoms off the bottom; finally towing was increased and the net was lifted slowly off the bottom at first, and then very rapidly as the trawl was completed. The trawling speed in this operation was 4.5 knots whereas in the previous one it had been 3.0 knots. There are a lot more fish echoes inside the net compared with the previous trawl and the fish are evidently passing straight to the codend. The total catch was just over 2.3 tonnes for a 30 minute tow.

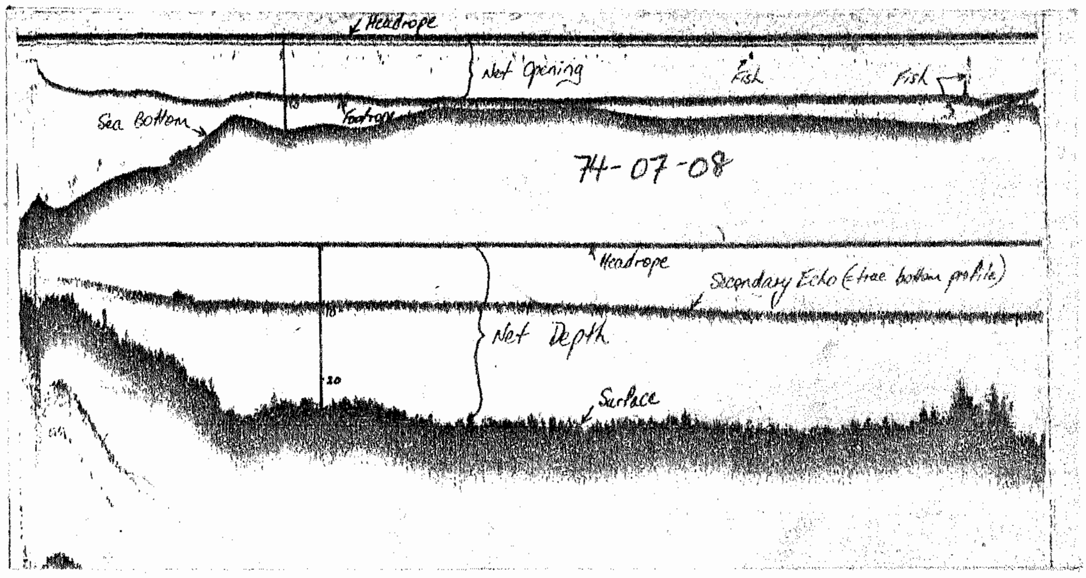
The third figure shows what happens when the net comes in contact with the sea bed, luckily in this instance without damage. This time the net was towed at an appropriate speed enabling the footrope skim the bottom. The quantity of fish underneath the headline is much larger than shown in either of the two previous recordings but the catch for the 30 minute tow was less than half a tonne. Evidently the fish were swimming along maintaining station underneath the headline, and therefore were being continuously recorded by the headline transducer. Fish echoes above and below the headline appear quite clearly in all three echogrammes but because the transducer sounding upwards is the least important of the two it is usually more heavily suppressed and the echoes above the headline will be weaker and fewer.

If acoustic transmission is used between the net and the ship, the acoustic connection can be broken if the sound waves are bent by water temperature layers, or if there is poor alignment of the transmitter and receiver. This type of failure would only occur in a cable transmission unit if the cable itself was broken.

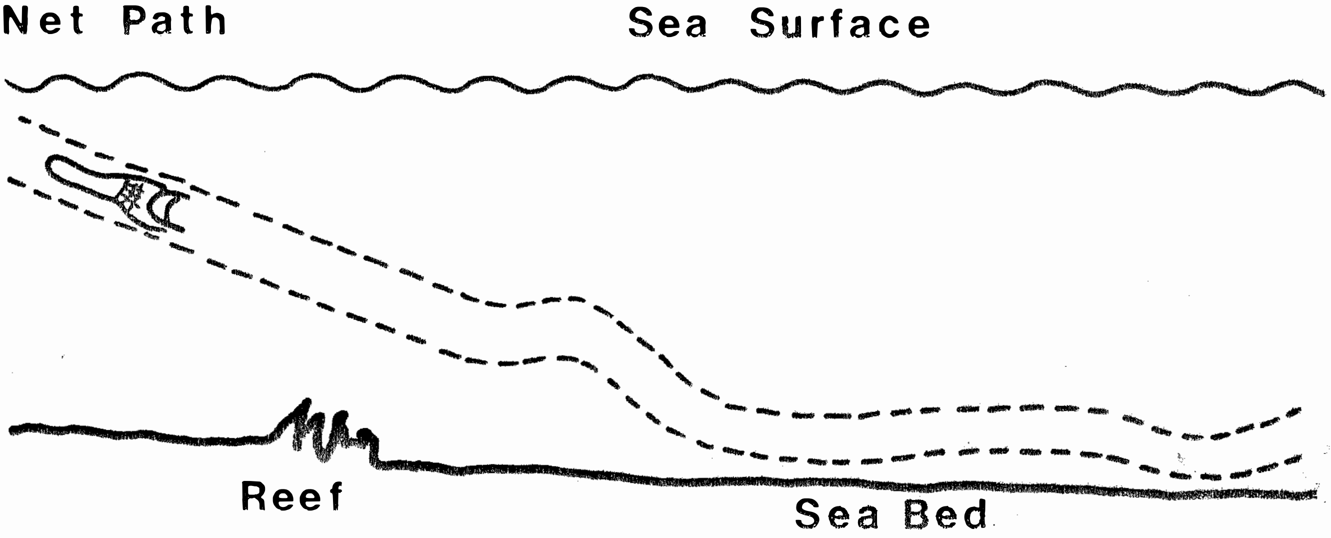
In some netsonde displays, the surface, headline, footrope and sea bed are shown in proper sequence, i.e., with the sea surface at the top of the paper and the sea bed at the bottom, but because of depth considerations either could be off the scale at any given period of the trawling operation.

Netsonde equipment is available which displays the trawl track on the echo sounder paper but this has to be interpreted with care because the net is travelling some distance behind the ship on which the recording is made so that there is a significant time difference between the two lots of information. Therefore, some adjustment has to be made to superimpose the trawl track to its correct position on the echo sounder recording. For example, if the net is being towed at 50 fathoms using 150 fathoms of warp and the ship's towing speed is 3.0 knots, then the time delay will be about three minutes from the time the fish leave the echo sounder beam until they are picked up by the netsonde.

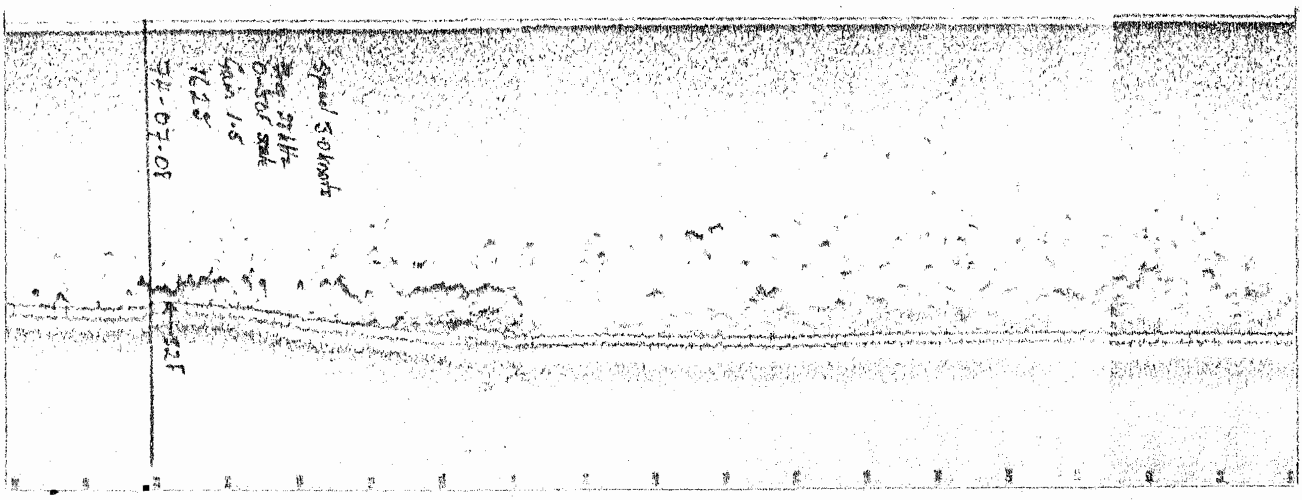
Netsonde Recording



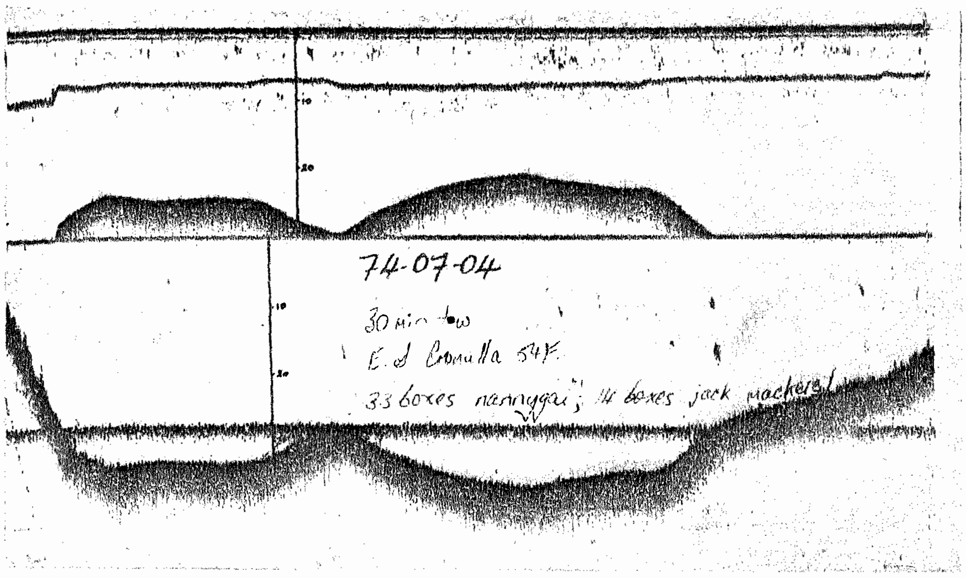
Net Path



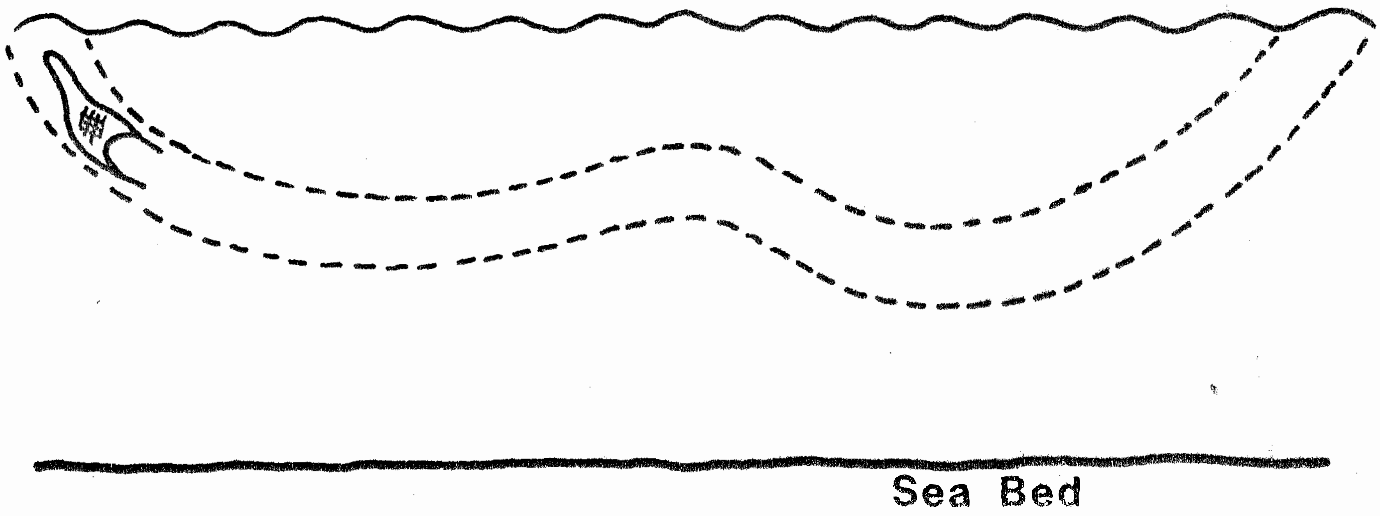
Echosounder Recording



Netsonde Recording



Net Path



Echosounder Recording

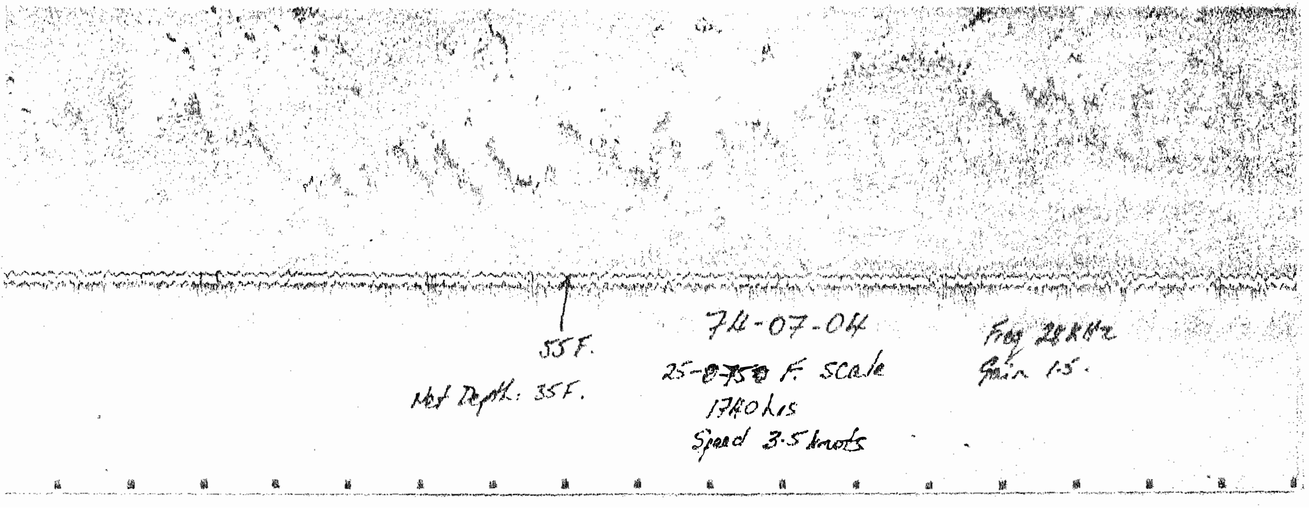
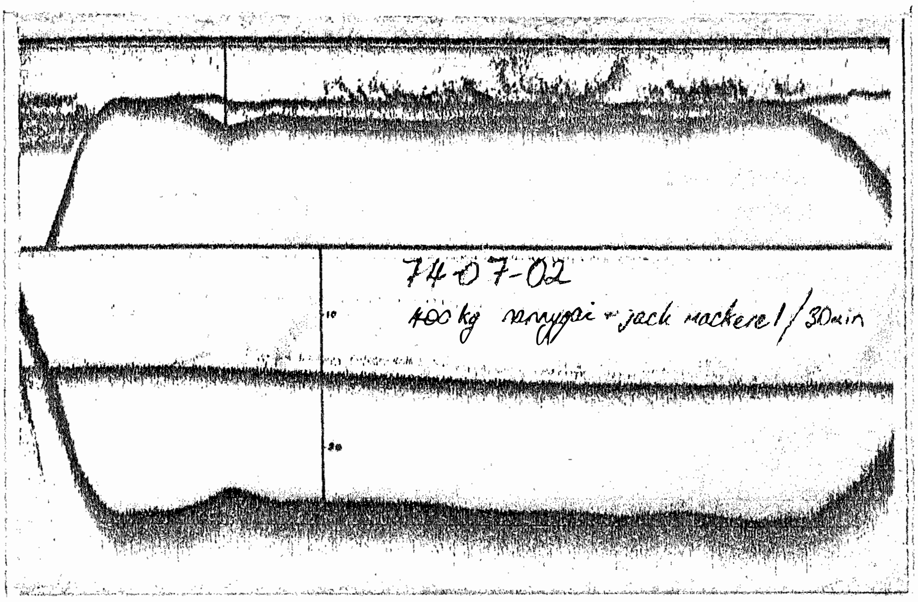


Fig 2

Netsonde Recording



Net Path

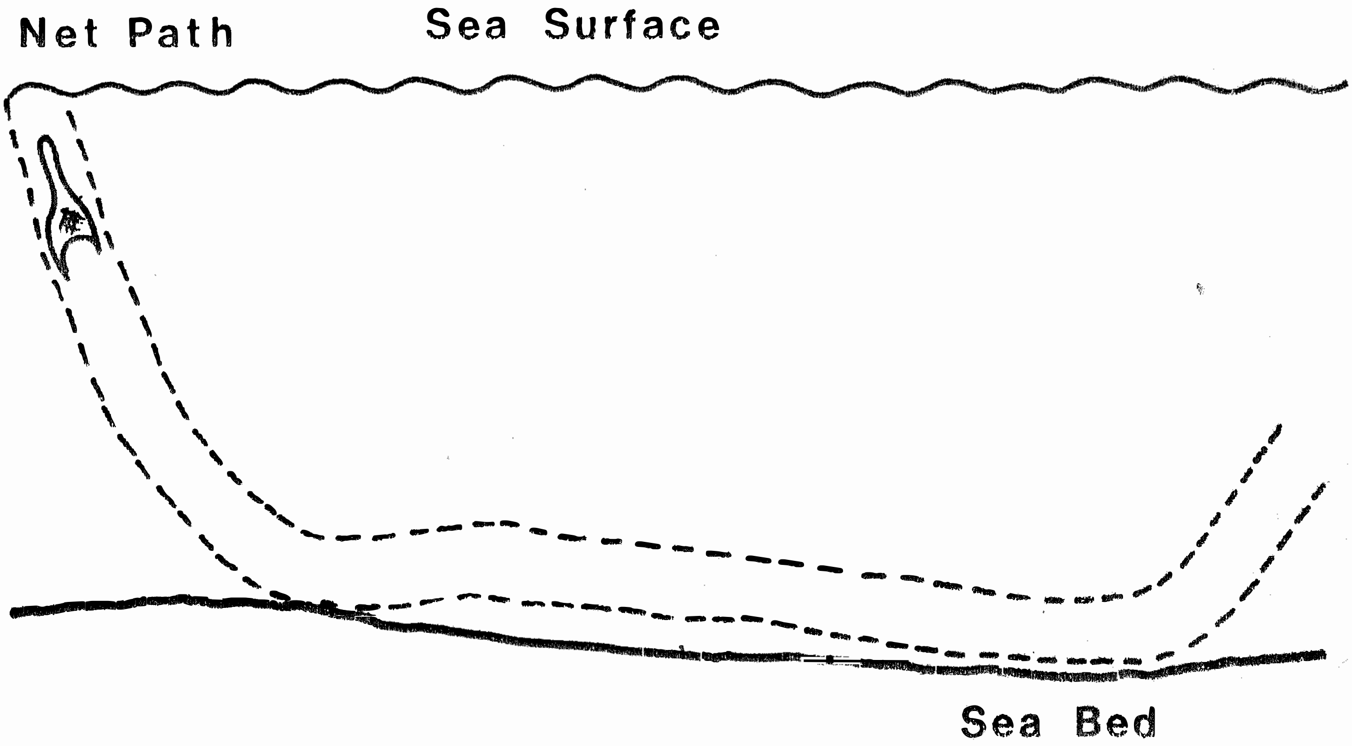


Fig 3

Attachment 3

NETSONDES OR NETSOUNDERS

There are two basic types of netsonde: Depth Sensors and Headline Mounted Transducers.

1. Depth Sensors (see figure 1)

These units have been largely rendered obsolete by the development of headline mounted transducers and are rarely used in commercial trawling. They can only transmit information on depth, and they cannot detect fish around the trawl mouth. Consequently, their application is fairly limited as fishermen cannot develop fishing tactics with their gear because they are unable to observe the reaction of fish to the net. They do have, however, some application in purse seining, and research trawling in very deep water with midwater trawls where only the net depth is required. They are still used for gear research for measuring certain gear parameters.

They operate by varying their transmission frequency according to depth, and thus require to be calibrated periodically to ensure that their readings are accurate.

2. Headline Mounted Transducers

The operation of the headline mounted transducer is identical to that of a hull mounted one. Depending on the system in use, it is capable of showing the sea surface, the headline, the footrope, the sea bed and fish echoes above, below and inside the mouth of the net.

3. Transmission systems

Transmission of the signal from the net to the ship can be either by a cable or by acoustic signal through the water.

3.1. Cable Transmission

Cable transmission can be by means of a third cable or via special conducting trawl warps.

3.1.1. Third cable (see figure 2)

This has almost completely replaced conducting trawl warp because it is cheaper and more efficient. It does however require an automatic electric or hydraulic self tensioning winch for handling the cable (see figure 3). This cable has to be tough, capable of rapid repair at sea in the event of breakage, and as thin as possible to reduce drag.

3.1.2. Conducting trawl warp (see figure 4)

This has to be specially manufactured with separate concentric cores for conducting wires, insulation, and strength, and special connections have been developed to by pass trawl doors and other fittings. The warp is not easy to repair and breaks in the transmitting core are difficult to locate; also the cost of manufacture is quite high. These considerations have precluded the widespread adoption of this method of transmission. In addition, the system was developed to work with depth sensors rather than headline transducers and this limitation further restricted its application in commercial fisheries.

3.2. Acoustic transmission (see figure 5)

The advantage of this system is that it dispenses with the cable between the net and the ship and the selftensioning winch. It does however require a small winch, which need only be manually operated, to shoot and retrieve the light weight receiving paravane that is towed on a short cable beneath the surface immediately astern of the ship (see figure 6).

The units may be either simple depth sensors or headline transducer types. The transmitter on the net is automatically switched on by a pressure switch at a preset depth, and continues to operate until the net is hauled to the surface where it automatically switches off again. These sets have a manual on/off switch also, either for testing or for use in very shallow water.

As a rule, acoustic transmission units are better suited to small trawlers where space limiation and cost are important factors to be considered. In this regard, the cost of the selftensioning winch alone is often greater than a complete acoustic transmission system.

The principal disadvantage of acoustic transmission systems is signal loss caused by poor alignment of the receiver and paravane, or refraction of the signal by variations in seawater density or temperature. Poor alignment occurs in a variety of conditions; for example in strong surface currents if the vessel is towing with or across the set. In the former case it may be necessary to reduce surface speed in order to maintain the correct net depth, this can result in the receiving paravane hanging vertically below the ship resulting in signal loss. In the latter case the ship may be pushed so far to one side as to lie outside the receiving range of the towed paravane.

4. Methods of Display

The methods used to display the netsonde signal are chiefly paper recordings, and/or cathode ray tube presentation (C.R.T.), but meters are used in some depth sensing units.

In paper recorders the baseline or zero point on the scale is the headline, and the scales are calibrated up or down from this point to measure directly the depth of the net from the surface, the vertical opening of the net, and the height of the headline above the sea bed. Fish echoes are displayed above and below the headline and between the headline and footrope. The recording may be complicated by the presence of secondary echoes of the sea bed, sea surface, and even of the net itself. These secondary echoes are the result of signals bouncing back and forth between the seabed and sea surface but because of the greater distance they have to travel, and the resultant losses in signal strength they produce a relatively weak recording on the echogramme. It is usually easy therefore to distinguish these signals from the primary recordings on the paper.

Cathode ray tube presentation has some advantages over paper displays in that it allows greater flexibility of both scale position, and size, however, it suffers the disadvantage of not having a continous record, so if desired it can be used in conjunction with a paper printout. One system developed in Canada used an omnidirectional 360° display on a C.R.T. but it apparently has not gone into production.

On the echogramme (see figure 7) the position of the transducer on the headline is analogous to the transducer on the hull of a fishing vessel. The difference is of course that as the fishing boat moves through the water the sea bed rises or falls as the depth varies, whereas with the netsonde, the net may be moving up or down in the water and the depth may be varying also. On the echogramme of the netsonde therefore the headline is the baseline and all recordings relating to the sea bed and fish etc., are measured from this point. As the net sinks from the surface to the sea bed the bottom therefore appears to rise to meet the net as the distance between them decreases. Conversely as the net ascends the sea bed falls away from the net.

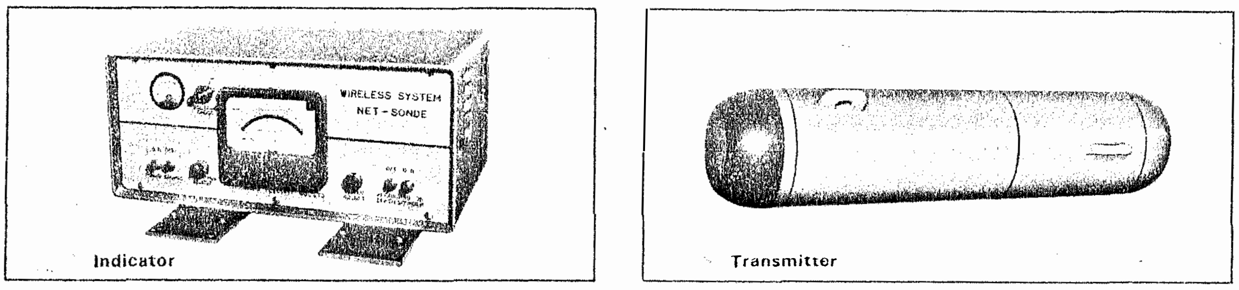
Some manufacturers arrange their recording displays in the 'correct' sequence i.e., sea surface at the top of the paper, then headline, footrope and sea bed. However, as most fish sound as the net approaches, other manufacturers give greater priority to the soundings downwards from the headline. This is given prominence at the top half of the paper while the upwards sounding transducer is displayed on the lower half. In practice both methods of display work equally well, although the latter takes some getting used to in the beginning.

<u>Simple and Multi Netsondes</u> (see figure 8)

Simple netsondes comprise a single transducer sounding downwards, and in some models an upwards sounding transducer as well. The operation of these is wholly automatic e.g., both transducers operate on different frequencies, if the lower transducer operates first, it emits a sound pulse, waits momentarily for the returning echo then transmits this back to the ship. Then the upper transducer in its turn emits a sound pulse and so the sequence continues. Netsondes are often used in conjunction with sonar and always with the ship's echo sounder. Simple netsondes provide the skipper with the means of developing fishing tactics based on the behaviour of the fish at the approach of the net. However, because of the wary nature of some species, and the large 'blind' spot caused once the fish leave the beam of the ship's echo sounder until they are detected by the netsonde, some manufacturers have developed multinetsondes in which forward looking transducers are used to provide information on the movements of the fish during the period when they would normally be 'invisible' to the captain of the fishing vessel. This period of 'invisibility' can last for several agonising minutes depending on warp length and ship's speed. In multinetsondes the transducers are usually all on the same frequency and they are operated by independent switches which may be controlled by a timing selector so that any transducer or series of transducers can be switched on in any sequence for the amount of time the operator needs to detect the movements of the fish ahead of or around the net e.g., the forward looking transducer can be switched on for say 30 seconds then the downwards and upwards transducers for 10 seconds each in that sequence. This sequence can be altered by the operator as the fish approach the net and the forward looking transducer can be switched off altogether when the fish are at or very close to the headline.

The problem with a single forward facing transducer is that only the distance to the fish is known and no decisions can be made as to whether the fish are moving up or down, or to the left or right relative to the mouth of the approaching net. One solution was to arrange two transducers facing forward, one of which has a horizontal beam while the other is inclined 15-25 degrees downwards. These two transducers can detect fish about 200 metres ahead of the advancing net and if only the horizontal transducer shows fish the net is too deep. Conversely if only the inclined transducer shows fish the net is too high. The net is at the correct depth, only if both transducers show about equal quantities of fish.

The drawback with the multinetsonde was that the blind area betwen the echo sounder and net was still inadequately covered by the forward facing transducers, which only worked effectively if the net was being towed directly behind the ship. In the event of cross currents or side winds the net is usually to one side, therefore the supermultinetsonde was developed with four forward scanning transducers. The display is on a large C.R.T. screen with the zero point in the middle, which corresponds with the position of the netsonde on the headline. The coverage of the forward looking transducers corresponds to the four sectors on the screen, i.e., above and below the headline and to port and sharboard. The beams overlap slightly to ensure that there are no gaps and the correct position of the fish school is an equal distribution about the zero position in the centre of the screen.



Indicator

Transmitter

NET-SONDE FNZ-5N

Fig1

New trawl equipment for small trawlers

■ Excellent and reliable information with cable lengths of 1600 feet or more ■ Specially prepared to fit on small pair trawlers ■ For connection to standard Simrad echo sounders for 38 kHz ■ Gives new opportunities for valuable information at low cost.

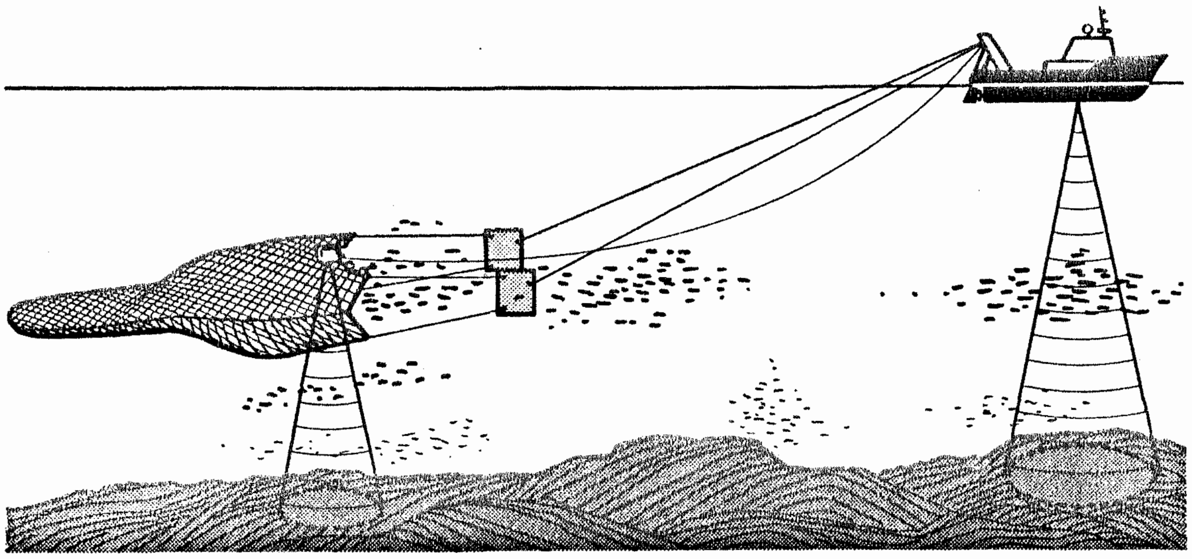


Fig2

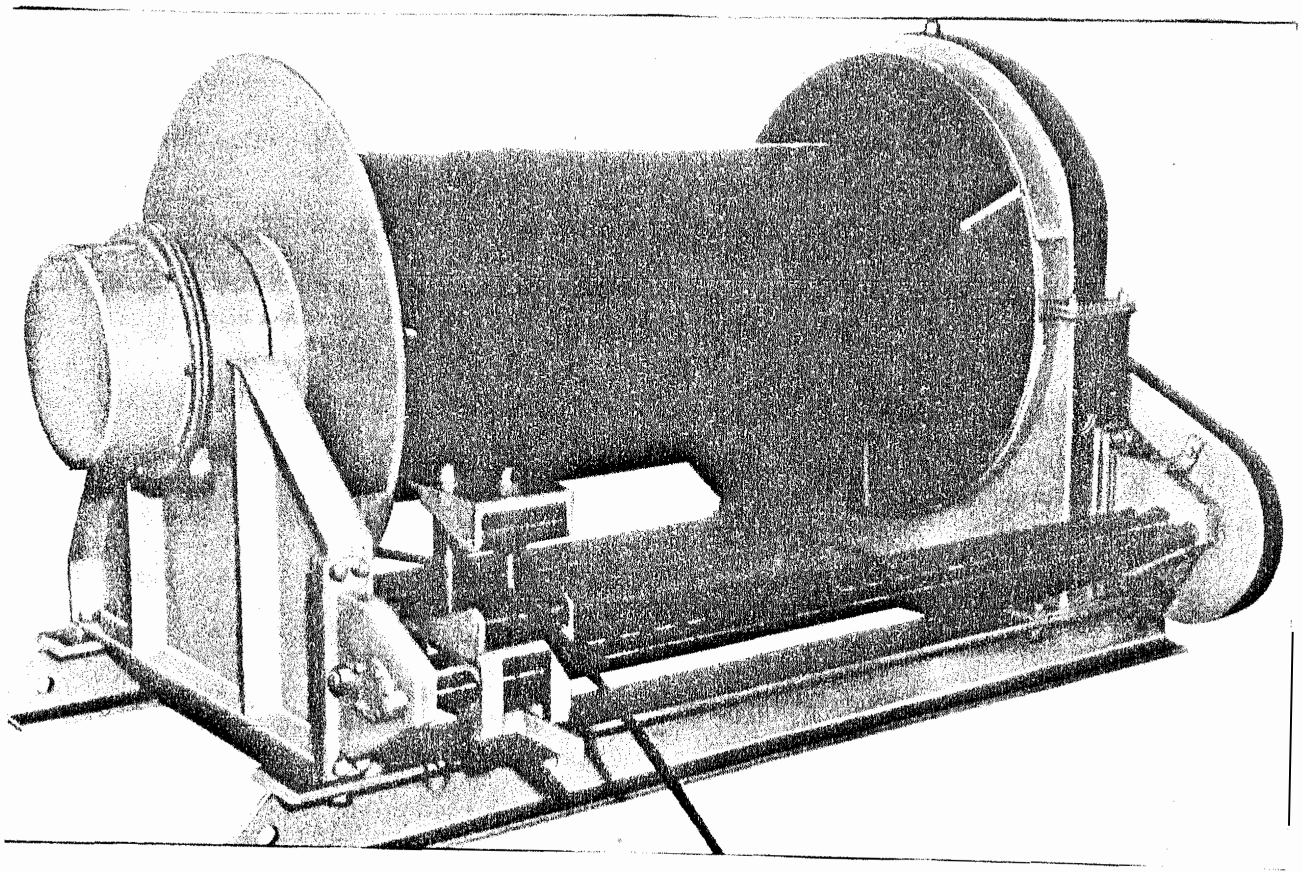


Fig3

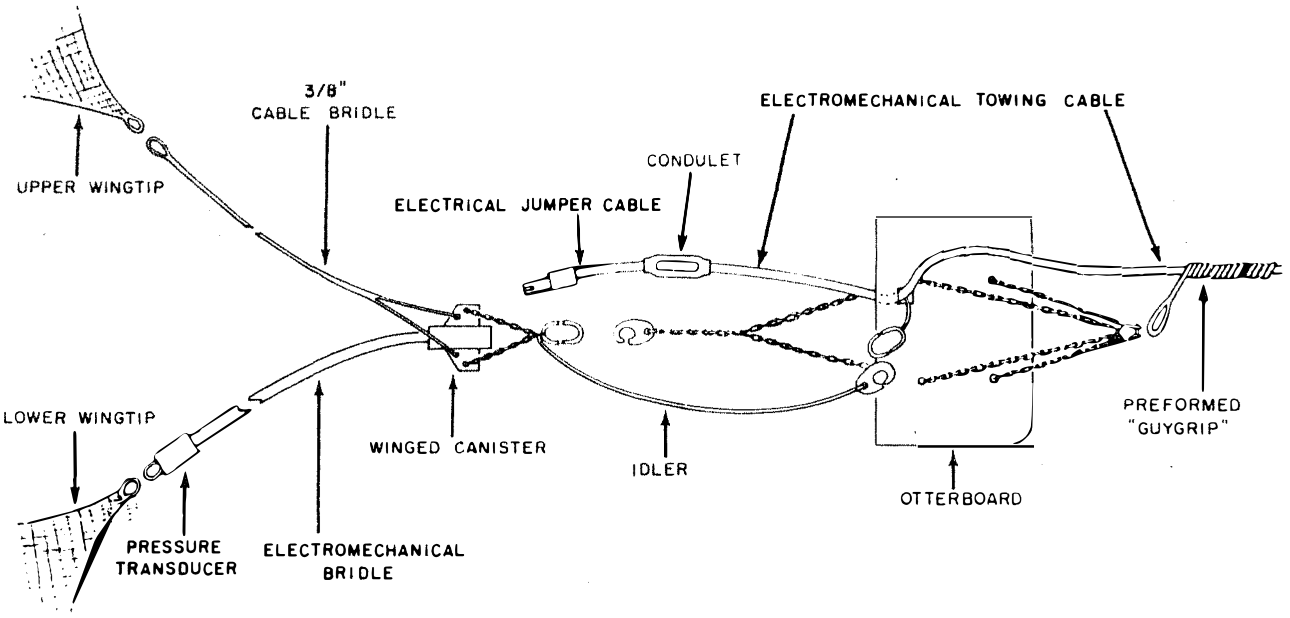
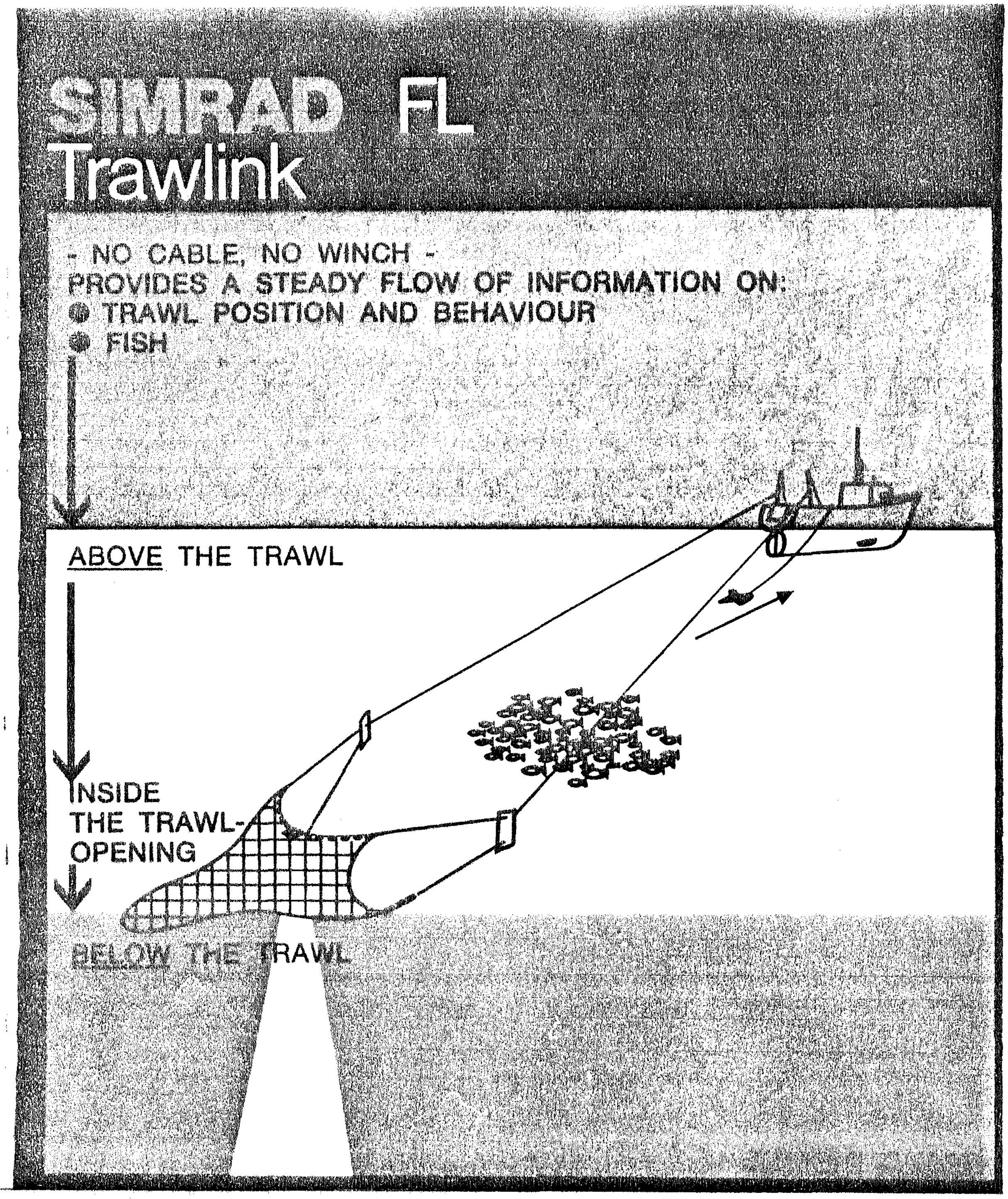


Fig 2. Otterboard by-pass system

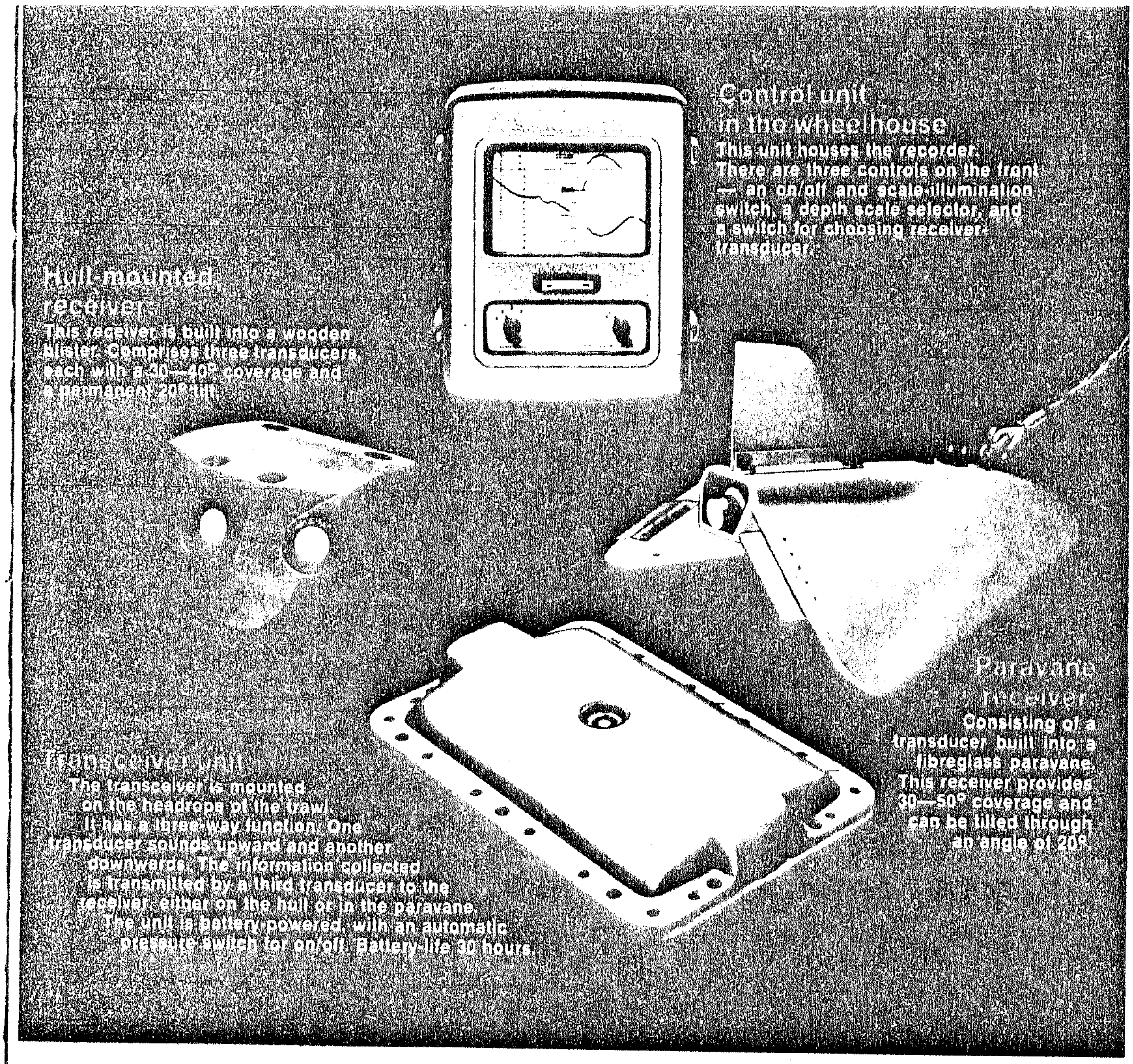
Fig4



SIMRAD FL
Trawlink

- NO CABLE, NO WINCH -
PROVIDES A STEADY FLOW OF INFORMATION ON:
● TRAWL POSITION AND BEHAVIOUR
● FISH

Fig5



Control unit in the wheelhouse

This unit houses the recorder. There are three controls on the front — an on/off and scale-illumination switch, a depth scale selector, and a switch for choosing receiver-transducer.

Hull-mounted receiver

This receiver is built into a wooden blister. Comprises three transducers, each with a 30—40° coverage and a permanent 20° tilt.

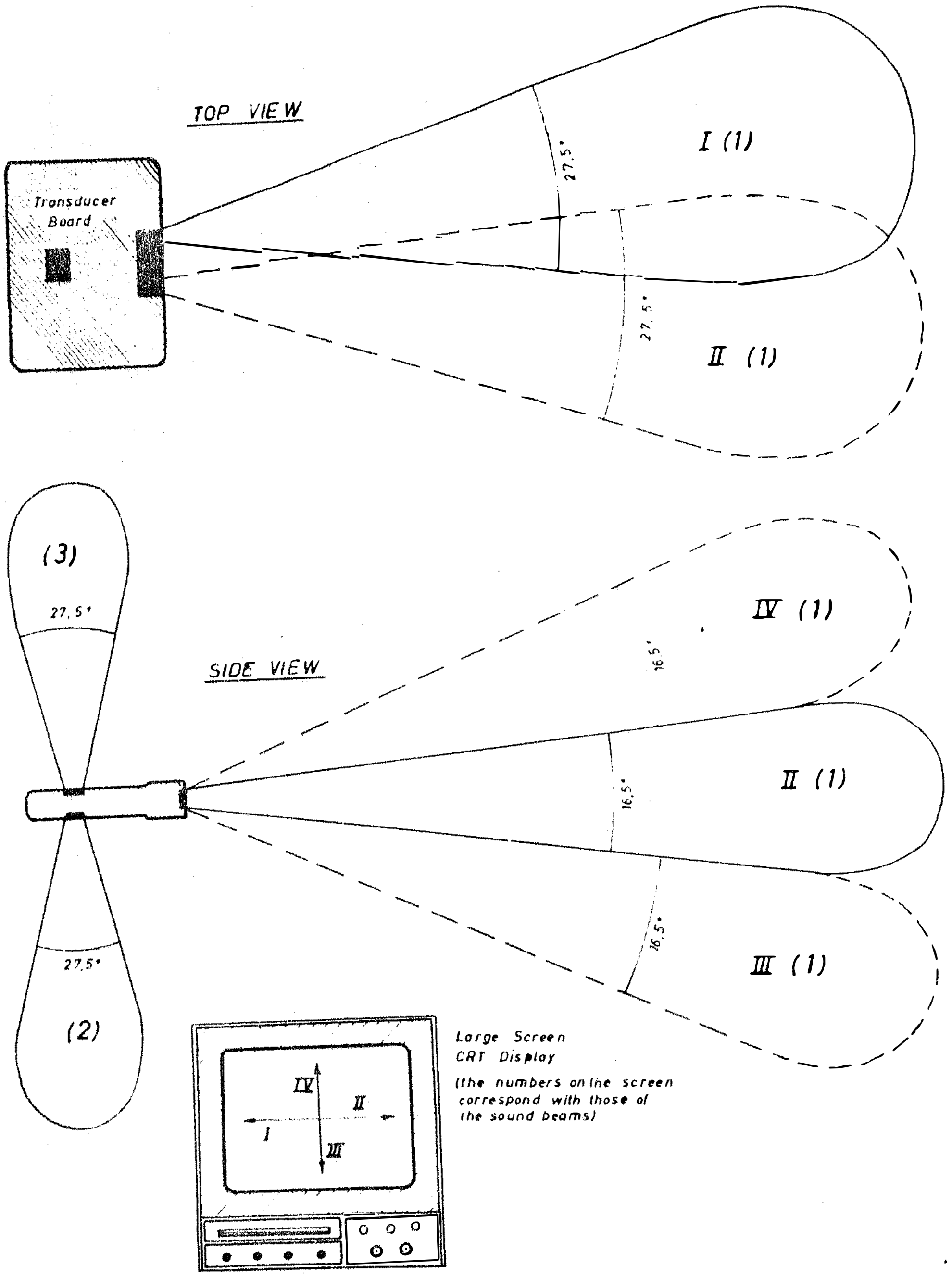
Paravane receiver

Consisting of a transducer built into a fibreglass paravane. This receiver provides 30—50° coverage and can be tilted through an angle of 20°.

Transceiver unit

The transceiver is mounted on the headrope of the trawl. It has a three-way function. One transducer sounds upward and another downwards. The information collected is transmitted by a third transducer to the receiver, either on the hull or in the paravane. The unit is battery-powered, with an automatic pressure switch for on/off. Battery-life 30 hours.

Fig6



Large Screen CRT Display (the numbers on the screen correspond with those of the sound beams)

Fig7

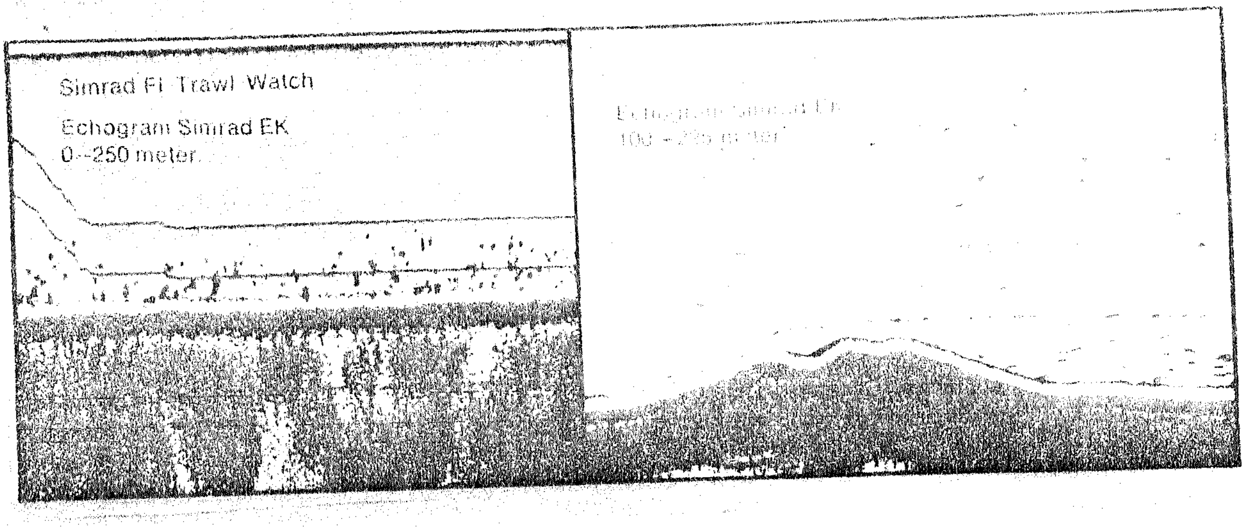


Fig8

Attachment 4

KRUPP

REPORT

BL 9090 A 002

ECHOSOUNDERS AND RADARS
FOR
FISHING VESSELS

NETSOUNDERS
FOR
MID-WATER TRAWLING

MARINE NAVAID SYSTEMS (AUSTRALIA) PTY. LTD.
100 ELLIOTT STREET BALMAIN 2041

KRUPP ATLAS-ELEKTRONIK

Order No.: BL 9090 A 002

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KRUPP ATLAS-ELEKTRONIK BREMEN
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ECHOSOUNDERS AND RADARS FOR FISHING VESSELS

1. INTRODUCTION

The intention of this paper is to provide the fisherman with a basic understanding of the operation of echosounders and radars, and the interpretation of echosounder recordings and radar PPI pictures. This paper will explain in a simple manner through extensive use of diagrams and echosounder recordings how ultrasonic waves behave in water and electromagnetic pulses behave in air. It is hoped that this information will help the fisherman to select the correct equipment for his special type of fishing.

2. OPERATING PRINCIPLES OF ECHOSOUNDERS AND RADARS

Since the basic operating principles of echosounders for depth measurement and radar for range measuring are the same, we are able to describe both at the same time.

For depth finding, the echosounder uses sound pulses travelling downwards through water. These sound pulses are reflected from the bottom back to the surface as echoes and are picked up by the ship that propagated them. Since the velocity of sound through water can be regarded as being constant, it is only necessary to measure the time interval between the start of each pulse and the return of its echo in order to calculate the depth.

A radar transmits electromagnetic pulses, which travel through air at a known constant speed. The pulses are reflected back from an object, and again time measuring has to be done in order to calculate range.

The difference in design of these two equipments is necessitated not only by their different applications, but also by their different working media (water or air), and the rate at which time intervals have to be measured.

The speed of sound in water is approximately 4,920 feet per second. An echo received one second after transmission of the pulse would indicate a depth of 2,460 feet, or approximately 413 fathoms, thus allowing for the time required for the pulse to travel to the seabed and back to the surface. Just for comparison, the speed of an electromagnetic pulse through the air is approximately 186,000 statute miles per second. This means that the time measuring in a radar has to be approximately 200,000 times faster than in an echosounder.

Time measuring in radars and echosounders is done in a similar way, for example: in an echosounder by driving the stylus at a certain speed over the paper; or, on a radar screen, by driving an electronic beam over the cathode ray tube. Let's take an example. The speed of sound in water is approximately 4,920 feet per second and the stylus is moving across the paper at 6 inches per second. If initially the vessel is in 820 feet of water, the returning echo from each transmission will take one third of a second to come back. The pen will have moved two inches from its starting point the zero line, and the pen will burn a mark on the paper. The distance of this mark from the zero line will correspond to the water depth. Thus, sounders are calibrated by matching the speed of the recording device, stylus or flasher or time base of a scope, to the propagation speed of the transmitted pulse and returning echo.

The same procedure is done in a radar set. Because of the high speed of time measuring, the deflection of the electronic beam from the center towards the rim of the CRT (which corresponds to the moving pen of the sounder) is so fast that the human eye has the impression of a constant line being painted on the screen.

Our first picture shows a block diagram of the main operating functions of an echosounder.

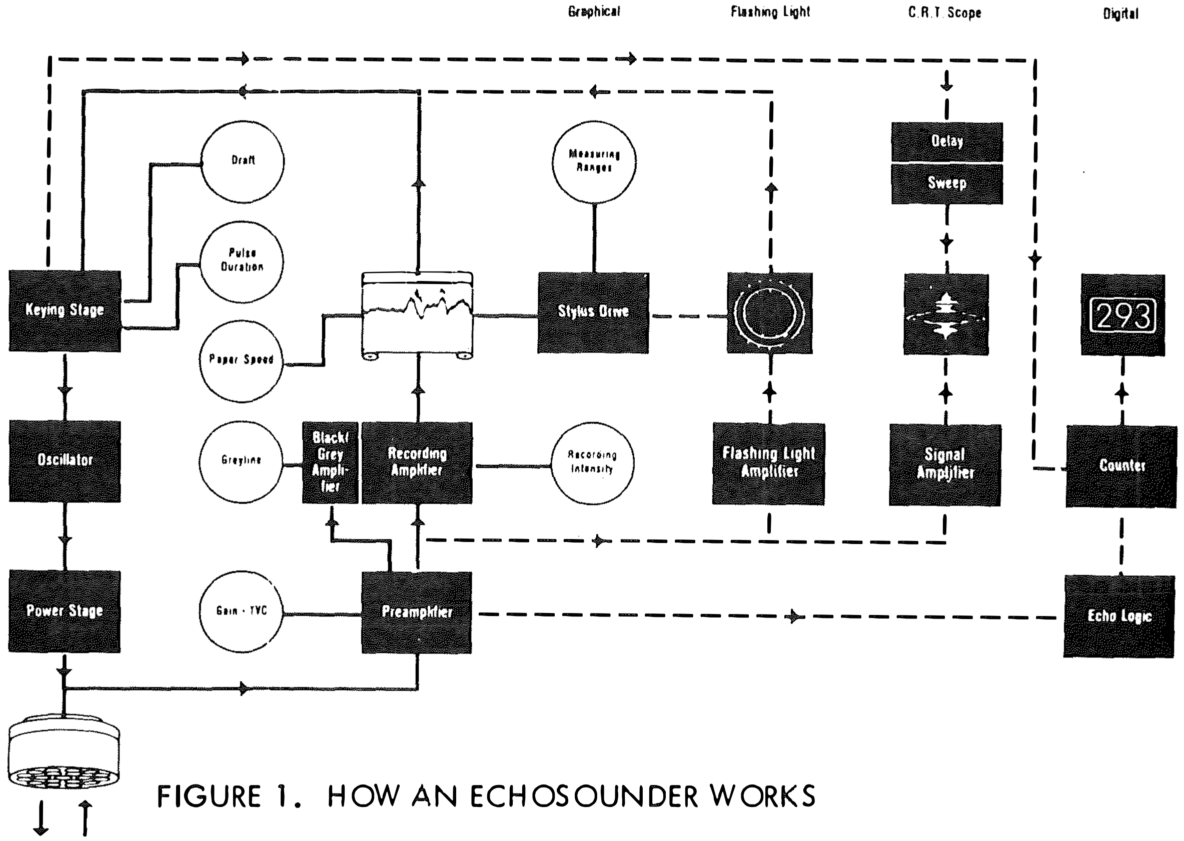


FIGURE 1. HOW AN ECHOSOUNDER WORKS

These functions can be divided into different parts: transmitting, receiving and signal processing, and displaying.

On the transmitting side we see the "keying stage" triggering the "oscillator", which drives the "power stage". The power stage generates certain electronic pulses which are fed to the transducer. In the transducer, these electrical pulses are converted into mechanical vibrations of the transducer and these vibrations cause an ultrasonic or sound pulse in the water. Echoes from these sound pulses are picked up by the transducer and converted back into electrical signals. These are fed into the receiver and signal processing stages where they are amplified and processed so they can be displayed. Presently there are four ways to display echo signals:

1. Graphical mode (recorder)
2. Cathode ray tube or scope presentation
3. Red light indicator (commonly known as a flasher)
4. Digital readouts

In the fishing industry the first two modes are the most widely used because the fisherman is not only interested in the water depth but also in various other information, such as fish, fish behaviour, bottom structure, etc. This information can only be shown on a recorder or scope presentation.

All commercial echosounders perform these basic functions, but the design of certain parts may differ considerably, and consequently the performance of the sounders are different. Therefore, let's have a closer look at certain functions and their influence on the performance of a sounder.

2.1 TRANSDUCER

One of the most important parts of a sounder is the transducer which converts electrical energy into sound waves (transmission) and reverses this procedure when hit by an echo (reception). There are several materials available which are able to perform these conversions. Nickel is the oldest and most commonly used one. Ceramic transducers are gaining more and more importance, because they have a higher "degree of efficiency". "Degree of efficiency" is a factor which measures in percentage the conversion from electrical energy to sound energy (during transmission) or the conversion from sound energy into electrical energy (during reception). Because of the conversion from one form of energy into another, a reduction of output power is encountered. The "degree of efficiency" for transducer materials is as follows:

Nickel	- 10% to 20%
Ferrite ceramics	- 30% to 40%
Barium titanate ceramics	- 40% to 50%
Lead-zirconate-titanate	- approximately 75%

This means that only the above mentioned percentage of the total electrical output power is converted into ultrasonic energy. The conversion of the echo energy back into an electrical signal during reception is done with the same efficiency factor. Because of their higher efficiency, the ceramic transducers are used more and more for fishfinding purposes. KRUPP ATLAS ELEKTRONIK has pioneered the development of the lead-zirconate-titanate transducer which has the highest efficiency of 75%.

The next picture shows different types of transducers.

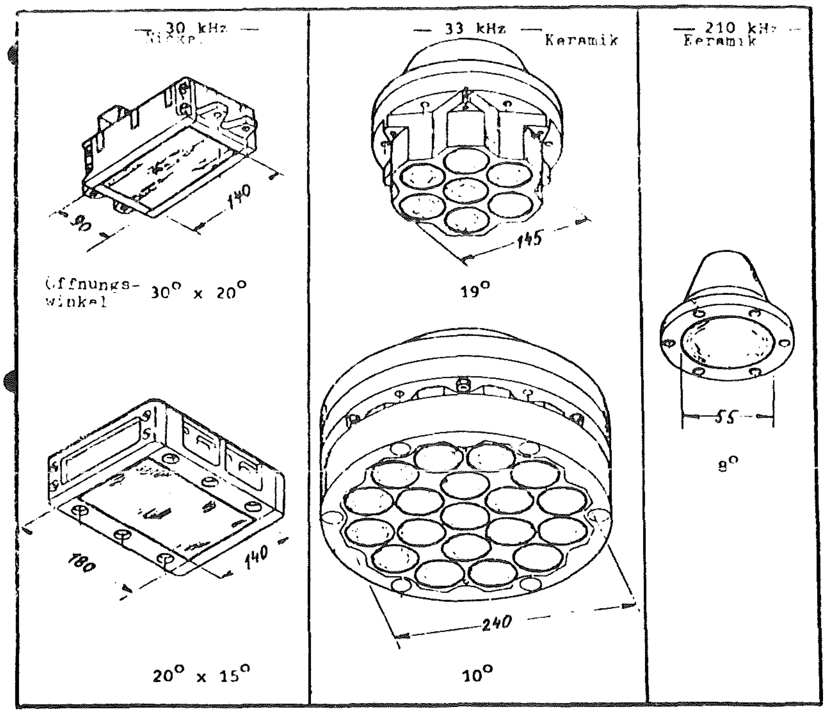


FIGURE 2. TRANSDUCER CONFIGURATIONS

On the left side the conventional "Nickel packs" are shown. The center picture shows transducers built by using high efficiency lead-zirconate-titanate elements. On the right is a transducer made from barium titanate ceramic. As you can see, they differ in shape and thickness. The reason for this is the "beamwidth" which has to be achieved (which will be explained later), and the "resonance frequency" at which they have to work.

At the resonance frequency, a transducer will produce the highest level of sound from an electrical input signal. Correspondingly, any echo returning at the resonance frequency will cause maximum vibration in the transducer and therefore high amplitude electrical signals will be fed back to the amplifier. This allows the transducer to select only signals it transmits as opposed to general acoustic noise. It works similar to tuning a radio to a certain station. The working frequencies of sounders are carefully chosen by the manufacturer because the frequency, at a given transmitting power and beamwidth, determines the reachable depth. This is due to the attenuation or absorption of sound waves in water which is related to the frequency. For example: the following depths can be reached with the below listed frequencies at the same transmitting power levels and the same beamwidths.

5 kHz down to approximately 27,000 feet
30 kHz down to approximately 9,600 feet
100 kHz down to approximately 2,000 feet

The output power of a sounder cannot be increased indefinitely, therefore selection of the frequency is a determining factor for the depth performance of a sounder.

We are now coming to a very important factor for the performance of a sounder - the installation of the sounder transducer into the vessel's hull.

Beside the above mentioned limitations of sound conversion and frequency, we may encounter further acoustical problems. The transducer, in order to create sound waves, needs good contact to acoustically 'clean' water. By 'clean' water we understand water which is not mixed with air bubbles. Air is another media and will prevent the proper build-up of ultrasonic pulses. It will also prevent smaller echo signals from arriving at the transducer. In addition to the air bubble problem, we find quite a lot of acoustical noise in the water created by the engine and the propeller of the vessel. The frequencies of these noises may be in the vicinity of the resonance frequency or its harmonics and may produce interference on the display. Another problem may arise when the cabling between the transducer and the recorder is not installed properly. For instance, this happens when unshielded cables are used in the vicinity of AC motors, generators or AC cables. Then so called 'over speaking' of interfering signals may occur.

To avoid these problems, keep in mind these points when installing an echosounder transducer:

1. Pick a location with the least possible water turbulence
2. Try to avoid noise generating machines (far away from engine room)
3. Use properly shielded transducer cables

On the next three pictures we show the recommended transducer locations for different types of fishing vessels.

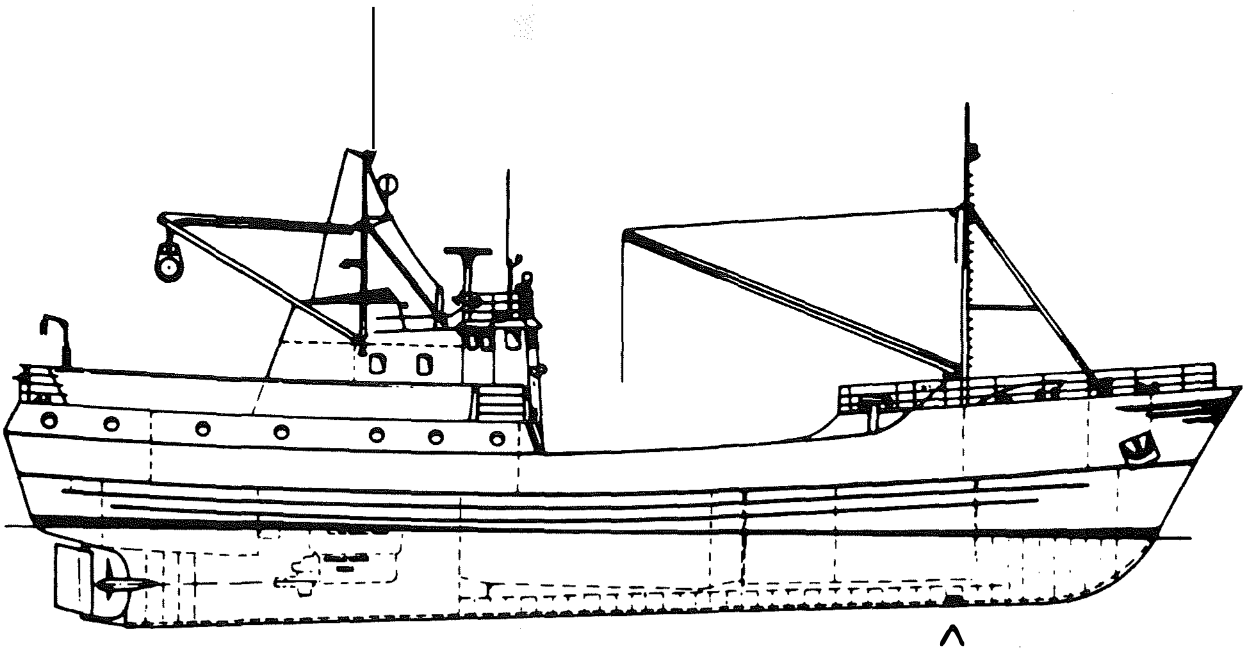


FIGURE 3. TRANSDUCER LOCATION

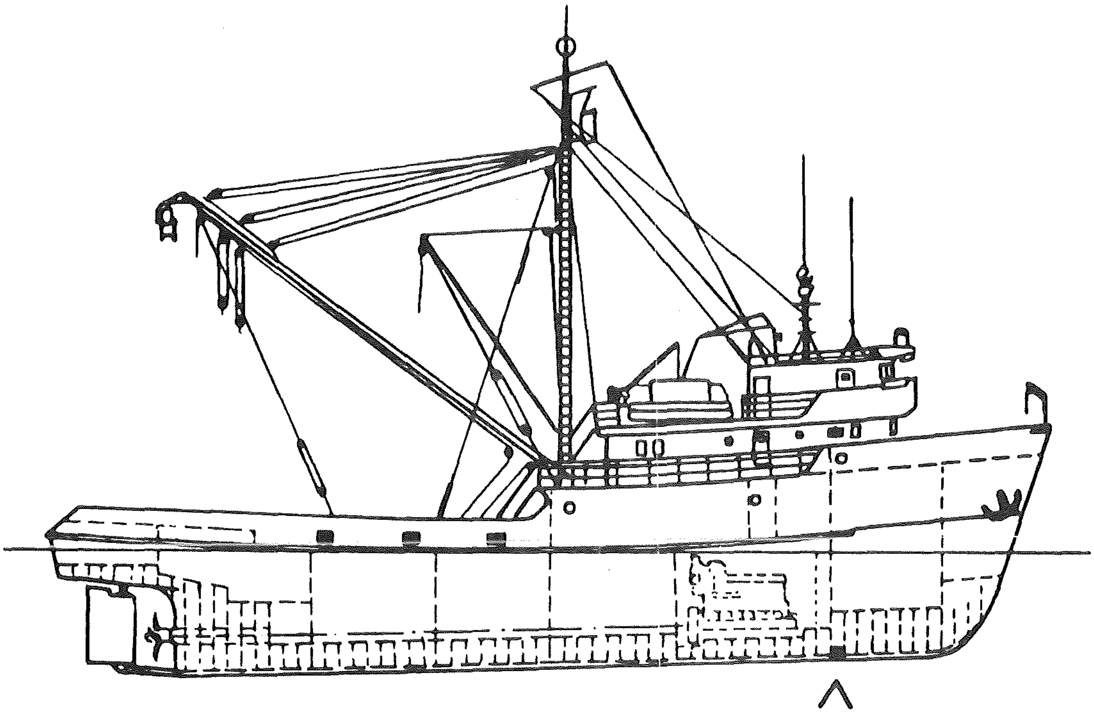


FIGURE 4. TRANSDUCER LOCATION

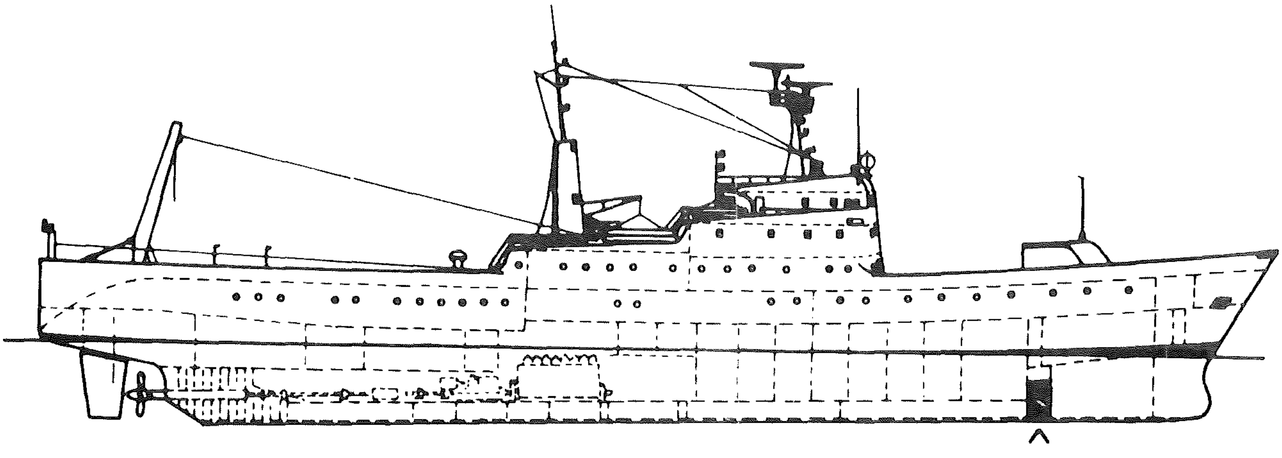


FIGURE 4A. TRANSDUCER LOCATION

The transducer should be located in the first third of the ship's length (from the bow) and as close to the keel as possible, or preferably in the keel, as is done on big stern trawlers. Obstructions which may cause turbulences like sonar domes, bow thruster, outstanding rivets, etc. should be located behind the transducer and a streamlining fairing should be used. The vicinity of the engine room should be avoided. If this is not possible, shift the transducer as far forward as possible. Since not all aspects and problems of transducer installation can be properly discussed in this paper, in case of doubt the manufacturer's advice should be taken into consideration. We at KRUPP ATLAS ELEKTRONIK offer a free service to obtain the best possible position for the transducer.

Before ending this short description of transducers, let's return to the expression 'beamwidth'. The beamwidth is the concentration of the radiated energy in one definite direction or area. By this the radiated energy is not wasted into all directions, but focuses into one direction (flash light effect) which increases the maximum reachable depth. The next picture shows a typical beam pattern diagram of an echosounding transducer.

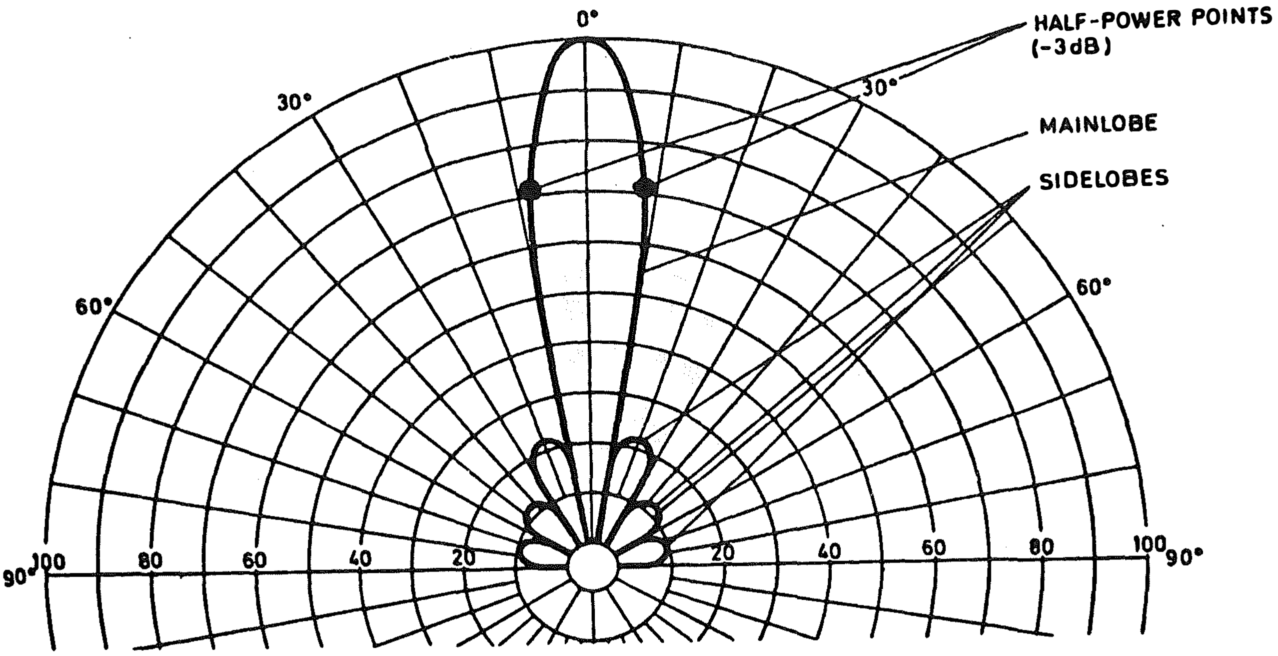


FIGURE 5. BEAM PATTERN OF A TRANSDUCER

The center of this diagram represents the transducer's face and our picture shows that the main part of the energy is concentrated in an area of ± 10°, or as commonly expressed a beamwidth of 20°. This concentration is called the 'main lobe'. The so called 'half power points' are defined as the limits of the main lobe at which point the radiated energy is reduced to half power. Some energy, but at a much reduced level, is radiated outside these limits. These are the so called 'side lobes'. Since they transmit into and receive from unwanted directions, false echoes may occur. On the other hand, when side lobe echoes are interpreted in the right way, quite a lot of useful information for fishermen can be obtained. This subject will be explained in detail later. In order to achieve a good sounder performance, certain compromises have to be made when the beamwidth of a transducer is being fixed. On one hand a wide beamwidth is wanted in order to collect as much information as possible with one pulse and to avoid sounding failures due to rolling and/or pitching of the boat. This last point is rather important. Vessels, especially small ones, tend to roll heavily, and as the vessel lists to one side, transmits a signal and then rolls immediately to the other side, quite a lot of the echo signals will be lost because the main lobe is now pointed away from most of the returning echo. On the other hand, a narrow beamwidth has the advantage of increasing the reachable depth by concentrating the radiated energy in a smaller area. A narrow beamwidth will also reduce inaccuracies in recordings (see the following example).

In our next picture, we see a vessel with a transducer of a certain beamwidth.

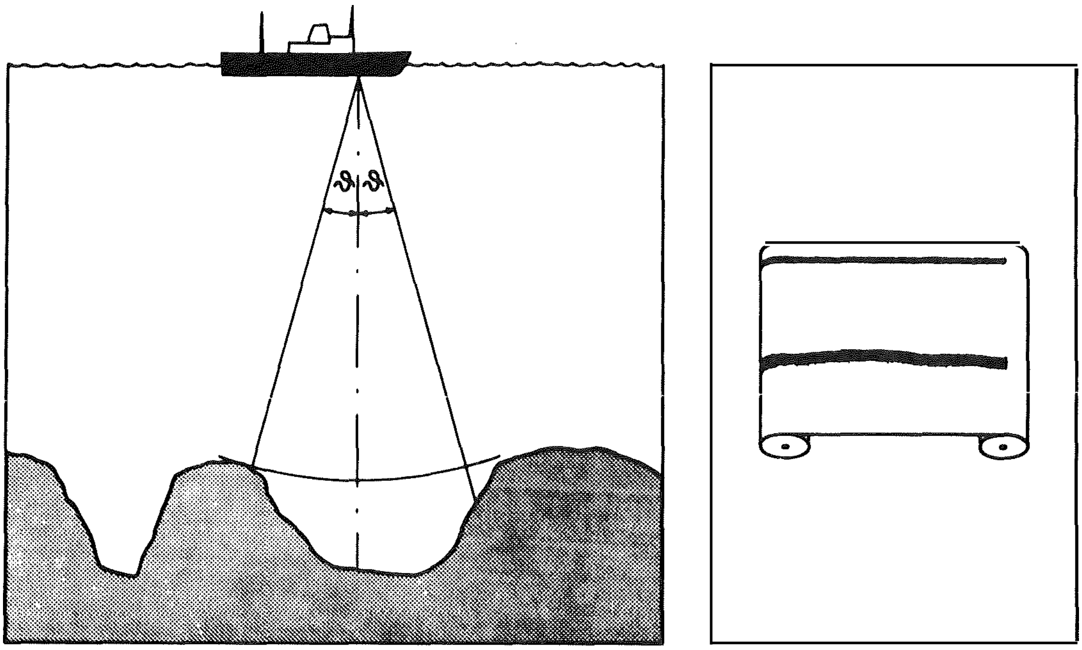


FIGURE 6. BEAMWIDTH AND ANGULAR DEFINITION

If the vessel is sailing over a trench or a hole in the seabed and the area covered by the main lobe is wider than the trench, the following will happen. The transmitted pulse will be reflected first from the edges of the trench and received before the reflections of the bottom of the trench. This will result in a straight line recording on the echosounder paper (see right of our sketch) because the bottom reflections which arrive later will be masked by the reflections of the edges. Therefore a trawl may be damaged quite easily on what appears to be a flat bottom. The ability of a sounder to show hazards like these is called "angular definition". As previously mentioned certain compromises have to be made to achieve a good angular definition. We at KRUPP ATLAS ELEKTRONIK think that a transducer should have a beamwidth between 10° and 20°. For smaller vessels which don't require great depths and which roll more often, a wide beamwidth will do the job. On bigger vessels, 10° would be more suitable. In order to offer the optimum, transducers with a switchable beamwidth are available (for instance, KAE high efficiency ceramic transducer, type SW 6020 with switchable beamwidth 19° - 10°). If the beamwidth has to be less than 10°, the transducer has to be stabilized against rolling and pitching. This is only possible by means of complicated and very expensive gyro controlled or electronically controlled devices, which are now used on hydrographic vessels.

Now we will take a close look at the behaviour of the ultrasonic pulse in water. As mentioned earlier, the pulse of alternating current causes the face of the transducer to oscillate. This in turn sends a series of sound waves into the sea and since the transducer is in direct contact with the water, the series of waves moves away from the transducer at a speed of

4,920 feet per second. In practice, sound is generated in short bursts with longer listening gaps in between. This is done so that echoes, which are always smaller in amplitude than the transmitted pulse are detected instead of being completely swamped by the large transmission signal. The generated pulse or wave now takes a special form in the water with a specific thickness. During propagation through the water it forms a conical beam. The thickness of the sound pulse which compares to a slice of a cone, is called the pulse length. The pulse length determines the so called 'radial definition' of a sounder. This means, the ability to distinguish between two objects which are situated one behind the other. The pulse length depends upon transmission time or the duration of the short bursts from the transducer. It can be easily calculated in the following manner. Let's assume the transducer works for 1 millisecond (one thousandth of a second). We know that sound waves travel at 4,920 feet/second and our transducer works for one thousandth of a second. During that time a pulse of approximately 5 feet (4,920 divided by 1000) has been generated. A series of waves, or better still, ultrasonic pulses, move through the water and are going to hit two objects. The expression 'radial definition' will be explained in the next picture.

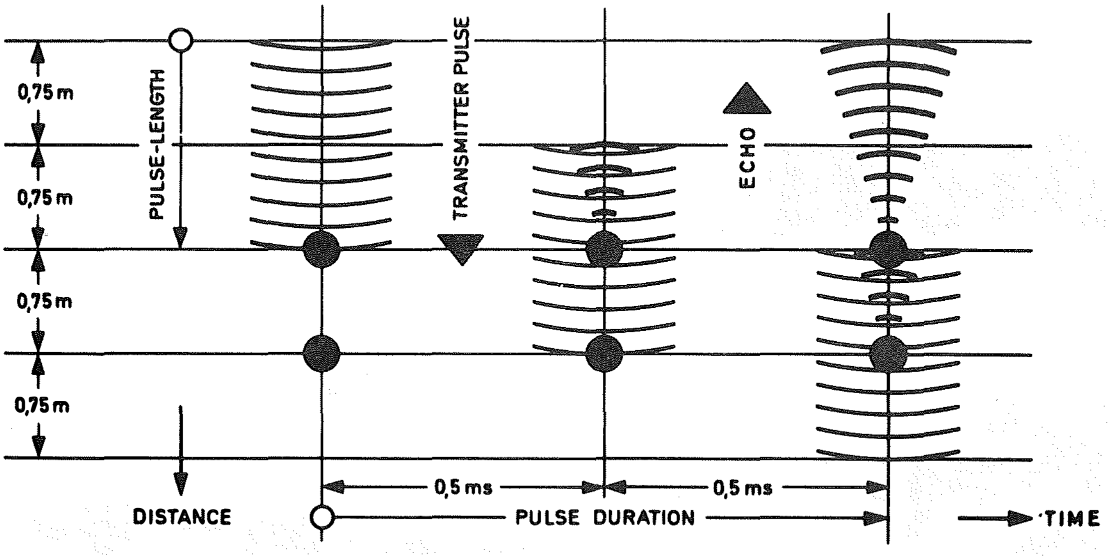


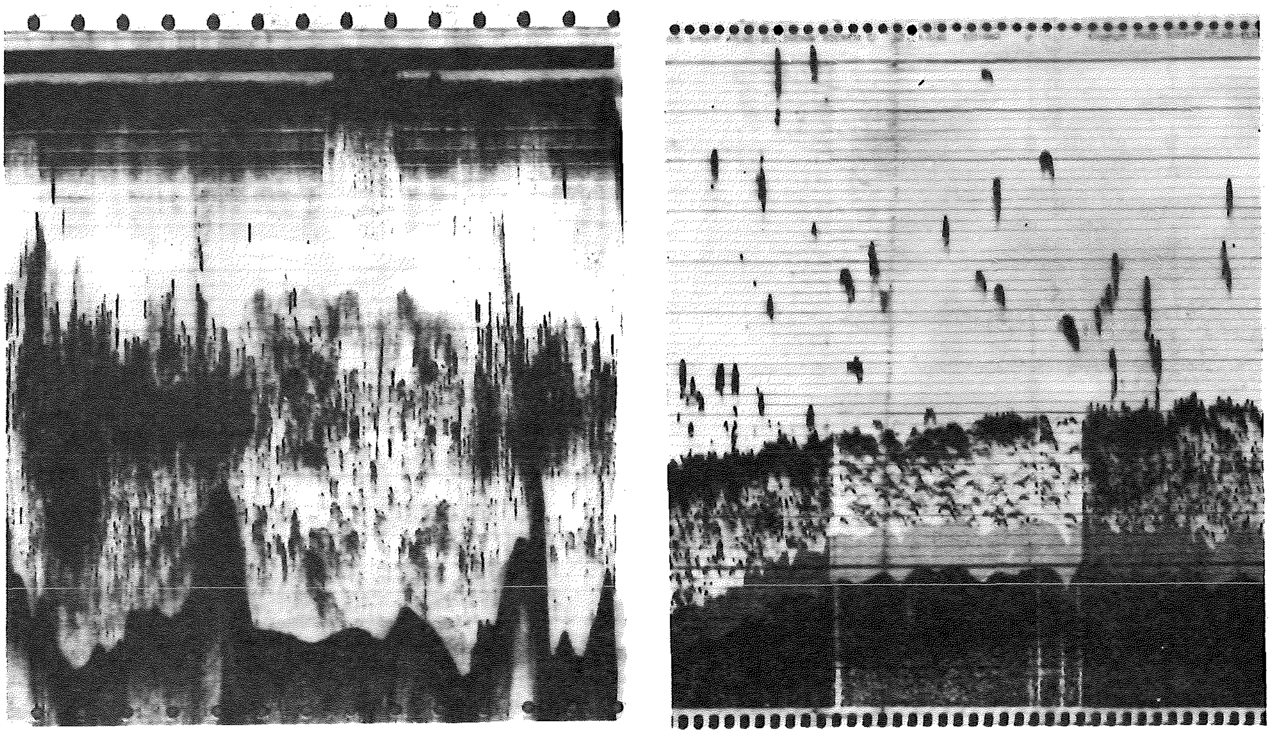
FIGURE 7. RADIAL DEFINITION

On the left side we see a pulse of 5 feet or 1.5 m length hitting the first object with its front. Now this object causes reflection of energy back to the transducer. In the center of the picture the pulse has moved on and has passed by the first object, constant reflections of energy occur, furthermore the front end of the pulse has now reached the second object, which is 2.5 feet or 0.75 m behind the first one. Here also a reflection is created. In the figure on the right, the situation has changed again. Now the back end of the pulse has passed over the first object and the reflections have ceased, but the front end of the echo caused by the second object is almost reaching the first one. Now two separate echo signals are moving back together towards the transducer. This example shows that in order for two objects to be recognized as such, they have to be separated by at least half a pulse length. Therefore in order to achieve a good radial definition, a very short pulse length should be used. But on the other hand, the limitation exists that a transducer needs a certain number of vibrations in order to form a pulse. The most commonly used pulse durations and the resulting pulse lengths and radial definitions are listed below.

Pulse duration (in milliseconds)	0.1	0.3	1.0	3.0	10
Pulse Length (in feet)	0.5	1.5	5.	15.	45
Radial Definition (in feet)	0.2	0.75	2.5	7.5	22.5

In most of the KRUPP ATLAS ELEKTRONIK sounders pulse lengths of 1.5 feet are used on the first basic ranges and phasings, resulting in a radial definition of approximately .8 ft.

The next picture shows the effect of a long and a short pulse recording.



The left picture shows massive black recordings caused by long pulse operation which does not allow any details (temperature layers, plankton, fish etc.). To the right we see a detailed recording obtained by using short pulses, showing single fish. With this recording the fisherman will be able to judge where the core of this shoal is and hopefully, able to take appropriate actions.

2.2 ECHOES

On the way through the water, the transmitted sound pulses hit different objects and part of their energy is reflected. The ability to cause reflections depends on three main parameters:

1. Nature of the target material
2. Size of the target
3. Depth of a target below the ship

Generally speaking, a reflection occurs as soon as the density of the media in which the pulse moves changes by certain degrees. A small change in density as often happens in water when the water temperature changes, results in the recording of a so called 'thermocline'. Rapid changes in density may be caused by another material, for instance rock. These density differences in relation to the ability of reflecting sound waves are called 'sound hardness'. The greater the difference in density between the transport media and the target, the greater will be the reflection. This reflection decreases with the following targets in the indicated order:

Rock, sand, wood, mud, fish, plankton, water layers

A similar phenomenon occurs with radar targets. Every experienced radar operator knows that steel boats produce better blips than comparable wooden vessels.

The size of a target also plays a very important role because it determines the amount of energy which will be reflected. We distinguish between 'point targets' and 'area targets'. Area targets are the seabed or large, dense layers of fish, or targets where the area being hit by the sound cone is bigger than the sound cone and therefore a great portion of energy is reflected. Point targets are single fish or other objects which are smaller than the area covered by the pulse. In this case only a fraction of the pulse will hit the target and consequently the reflection will be considerably smaller than that of an area target.

The power of the transmitted sound pulse decreases with greater depth. The echo strength derived from different targets with different reflection behaviour or 'sound hardness' therefore depends greatly on the depth at which the target is located. For example, the echosounder ATLAS 620 will detect a single cod at a depth of 150 fathoms and record the seabed at a depth of 1100 fathoms. These figures are just to illustrate the big difference in reflection behaviour.

The following pictures show several typical recordings which the fisherman will encounter often. Figure 9 shows a recording of two temperature layers, or thermoclines.

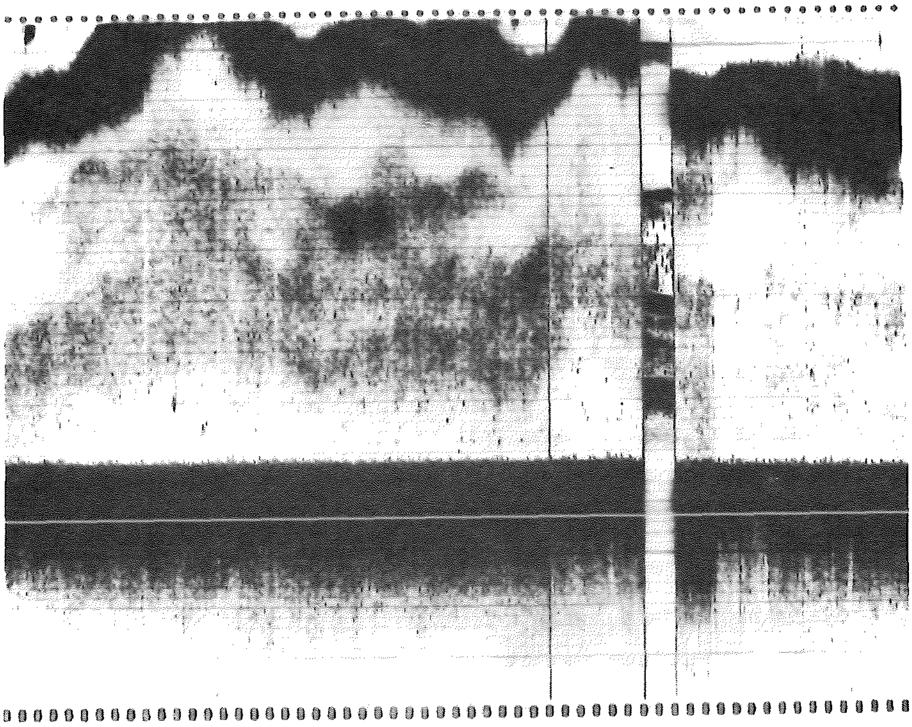


FIGURE 9. THERMOCLINE

The strong black recordings on the upper part are reflections of the thermocline. The lower straight line represents the bottom. The rather diffused marks in between are caused by plankton. To the right of center of Figure 9, the skipper has changed the range and since an overall view of the total depth is shown, two thermoclines in the area can be recognized.

The next picture shows how a mound will be marked.

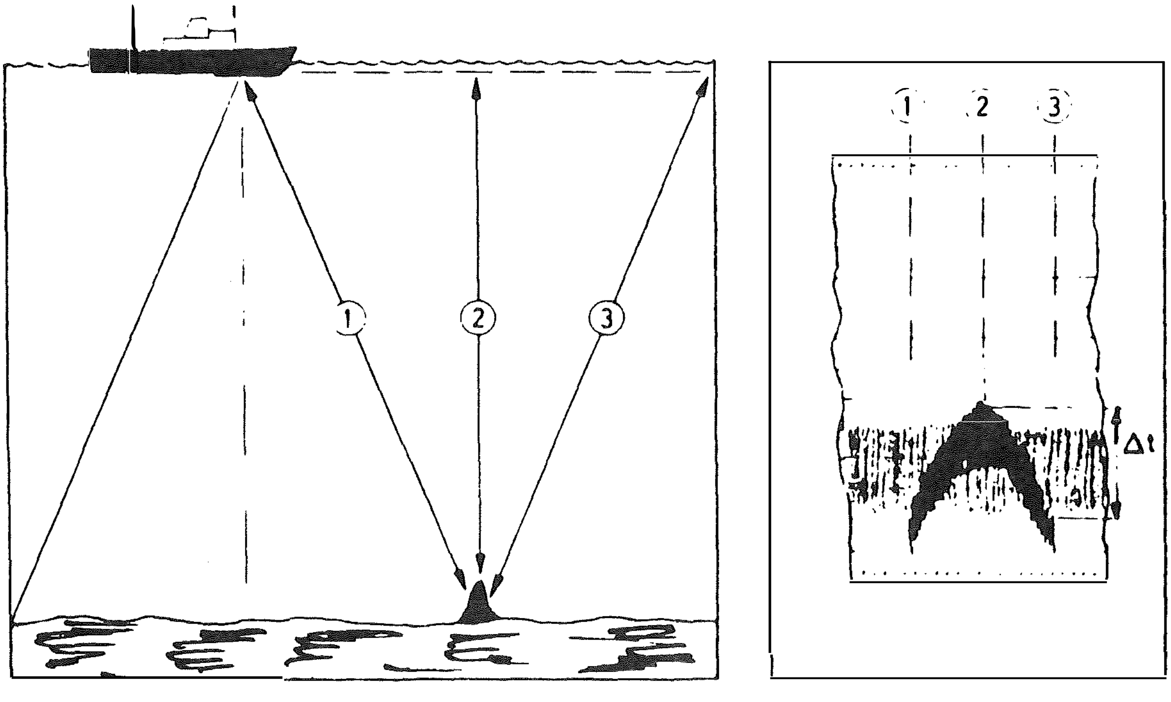


FIGURE 10. BUILD UP OF A MOUND RECORDING

In position 1, the leading edge of the sound beam is illuminating the mound. Since the distance at this position between transducer and mound is greater than the distance from transducer to seabed (indicated by the perpendicular line from the boat), the echo from the mound will arrive later than the seabed echo and will be recorded as shown under Figure 1 on the chart sketch. The vessel moves into position 2. It is now positioned directly over the mound and its true depth will be recorded. In position 3 the trailing edge of the beam receives echoes from the mound and the same misreading will occur as in position 1.

Figure 11 shows actual mound recordings taken with an Atlas recorder.

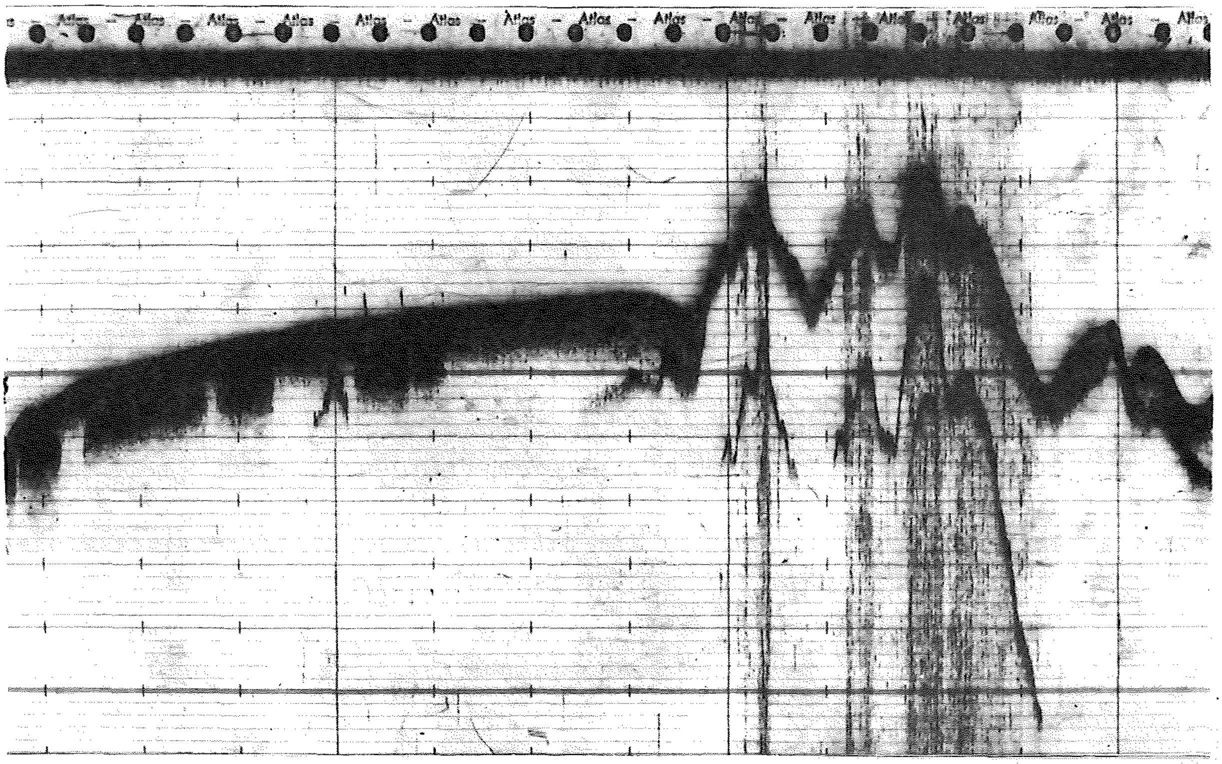


FIGURE 11. MOUND RECORDING

These mounds can be very dangerous to a trawl. But by correctly interpreting the recordings obtained with the proper recorder, a fisherman can take action to avoid a 'fastener', whereas a masked depression in the seabed due to improper beamwidth wouldn't give him any warning at all!!

With the next picture the build up of a single fish mark will be explained.

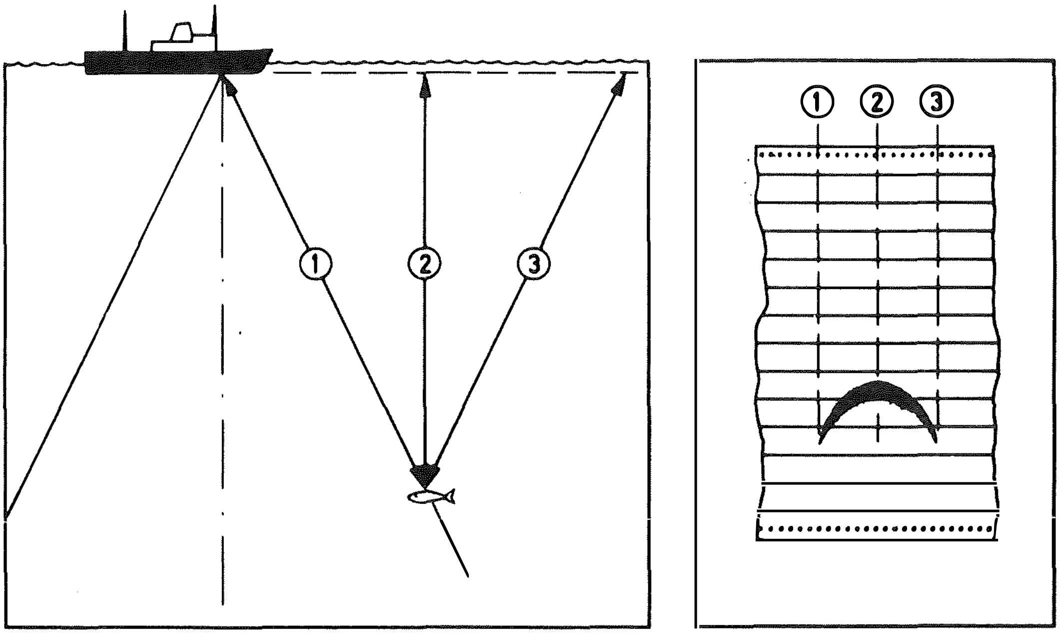


FIGURE 12. BUILD UP OF A FISH MARK

It actually happens in the same way as a mound recording. The leading edge of the beam picks up the fish and a recording in a wrong depth occurs. Only when the vessel is directly over the fish is its true depth measured. In position 3, the trailing edge again measures too great a depth and during that pass over the fish the characteristic inverted 'V' or comet shape is produced.

The next recording shows these inverted 'V's' and other forms of marks which provide the fisherman with considerable information about the movement of the fish under his vessel.

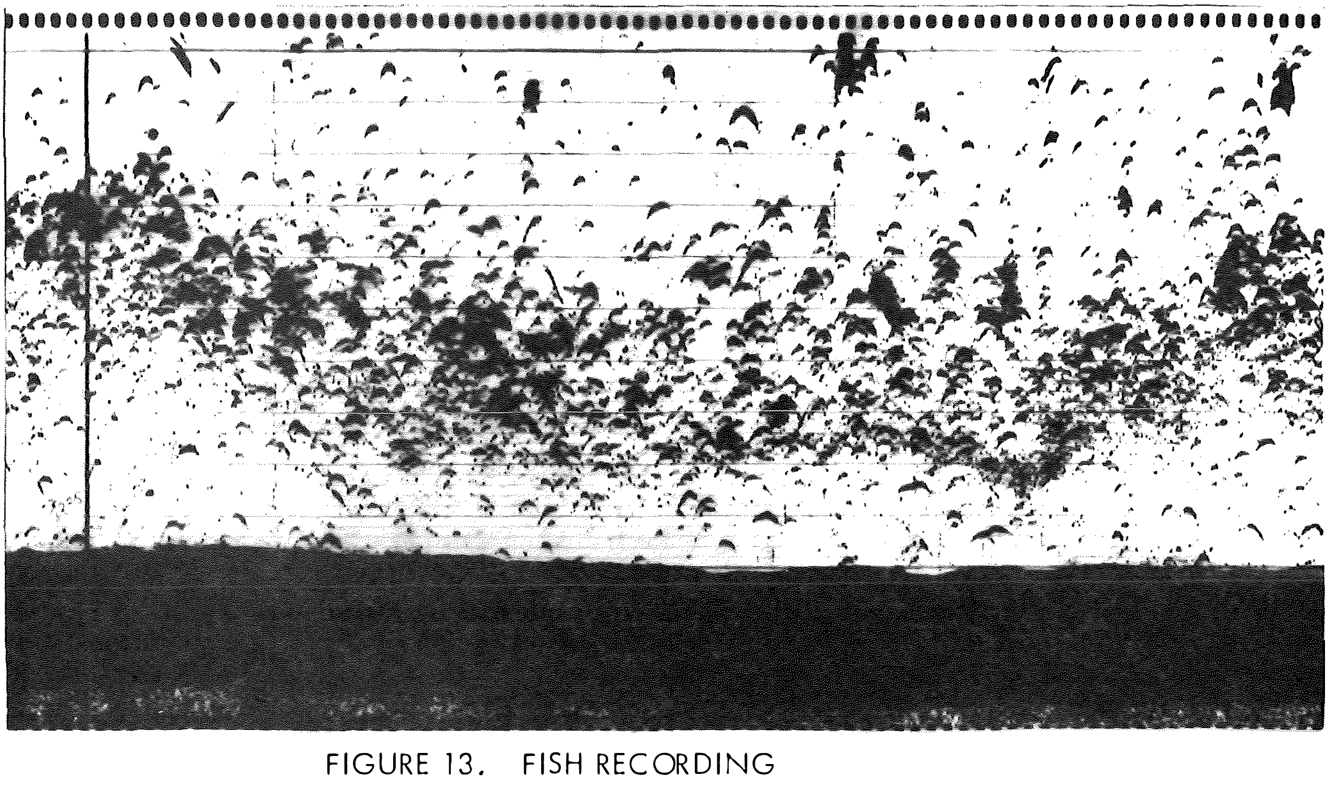


FIGURE 13. FISH RECORDING

If a completely inverted 'V' is recorded, the classical passing over has occurred. 'M' shaped marks indicate that the fish has moved inside the main beam, most probably swimming in the same direction as the vessel. The most alarming marks are those where the inverted 'V' is incomplete. This means that the recording stops at or near the top of the comet trace. This indicates a reaction of the fish most probably to the vessel's noise and that it has left the sound beam very rapidly, a typical flight indication. There are numerous other forms of fish marks possible, but it takes too long to describe them in detail.

The seabed can cause a confusing echo called 'second seabed' or 'double echo'. The ground reflects a very large area of sound back towards the transducer. A great deal of this sound will strike the water surface around the vessel, which acts as an excellent reflector. This causes the waves to return to the seabed which again reflects the sound back to the vessel, marking the paper at exactly twice the true depth.

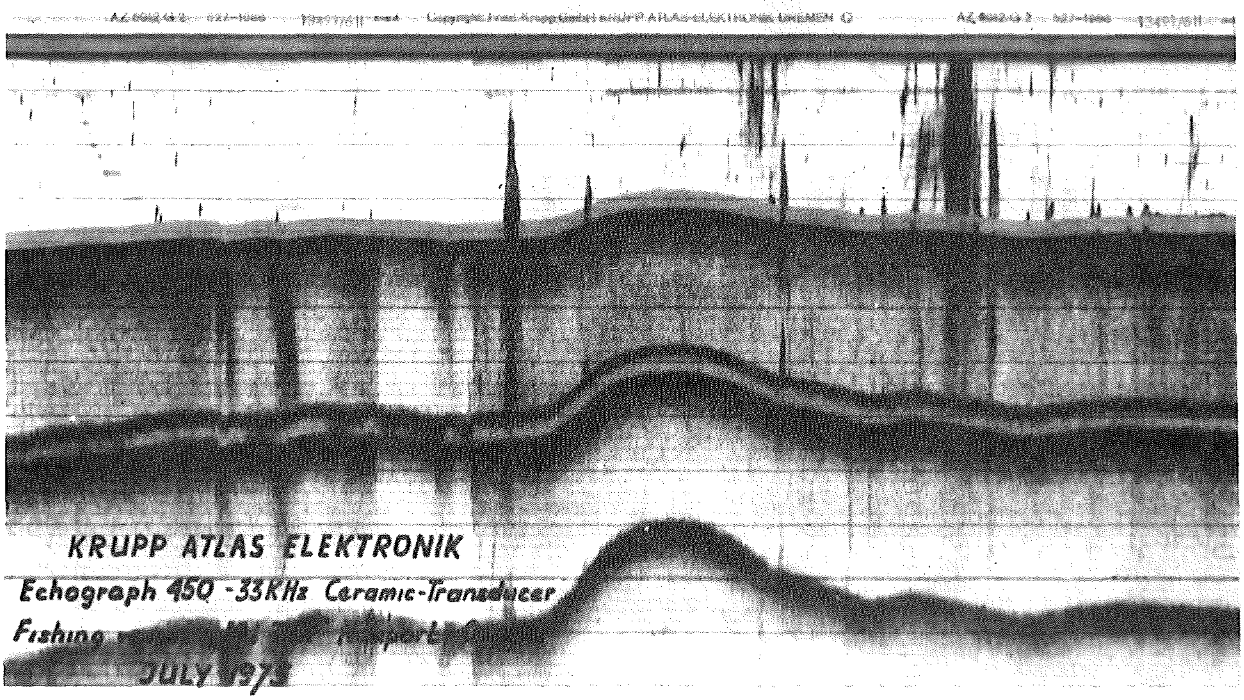


FIGURE 14. DOUBLE ECHO AND GROUND DISCRIMINATION

Figure 14 shows this effect. Here not only the second, but also the third reflection of the seabed is recorded. Furthermore, this recording has additional information for the fisherman.

First of all, it shows that the sensitivity of the set is correctly adjusted and is working perfectly, so that he is sure of picking up even weak echoes, because of the third seabed echo.

Second, the draft of the vessel is shown. The sound waves from the seabed are not only striking the surface but also the hull of the ship. This also causes a reflection back to the bottom, which again reflects towards the transducer. In the picture the draft of the vessel "MITOI" is represented by the thin black line on the top of the grey line of the second echo.

Third, the bottom structure, hard or soft bottom, is shown. This feature, also called 'Ground Discrimination' will be explained next. The hard bottom is indicated by the long black **tails** of the first and second seabed recording. Figure 15 shows the build up of a 'Ground Discrimination' or G.D. recording.

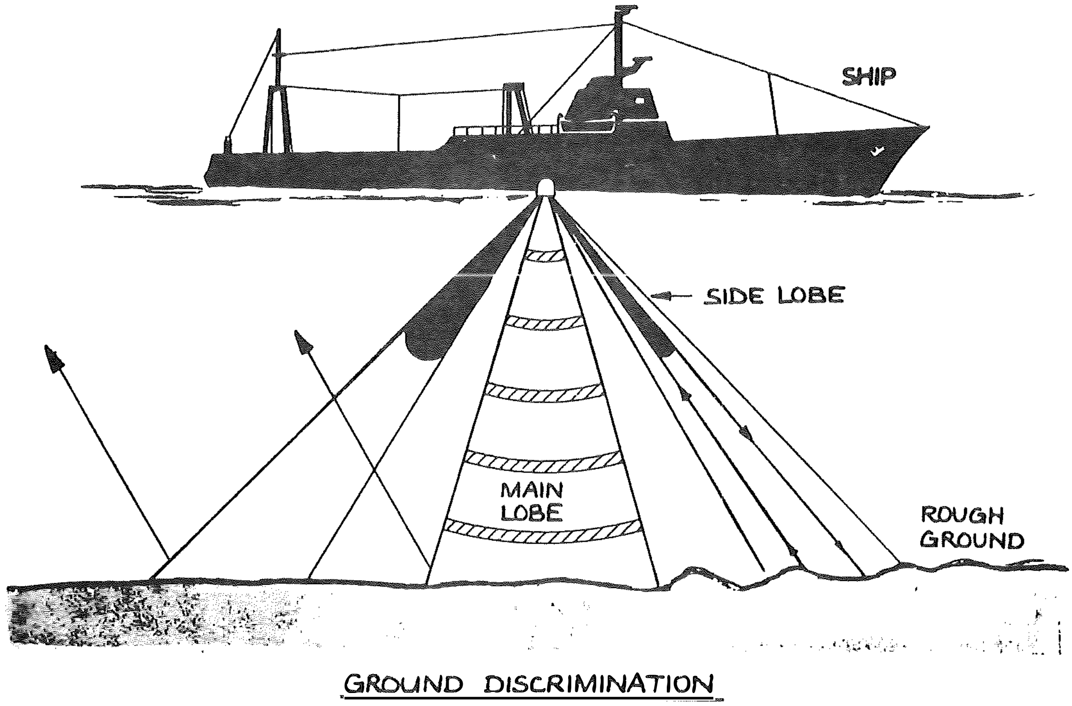


FIGURE 15. EXPLANATION OF GROUND DISCRIMINATION

As mentioned in the transducer description, a certain amount of energy is transmitted via the side lobes and echoes are received in this manner. When working over smooth ground part of the energy from the main and the side lobes is reflected away from the transducer, as indicated by the arrows on the left side of the picture. When the ship approaches rough ground, the reflections from the side lobes are directed more towards the transducer due to a change of the angle at which the bottom is hit. These echoes have travelled further than the returns of the main lobe, and will therefore show up as tails under the normal ground echo. Such tails can be seen in Figure 16.

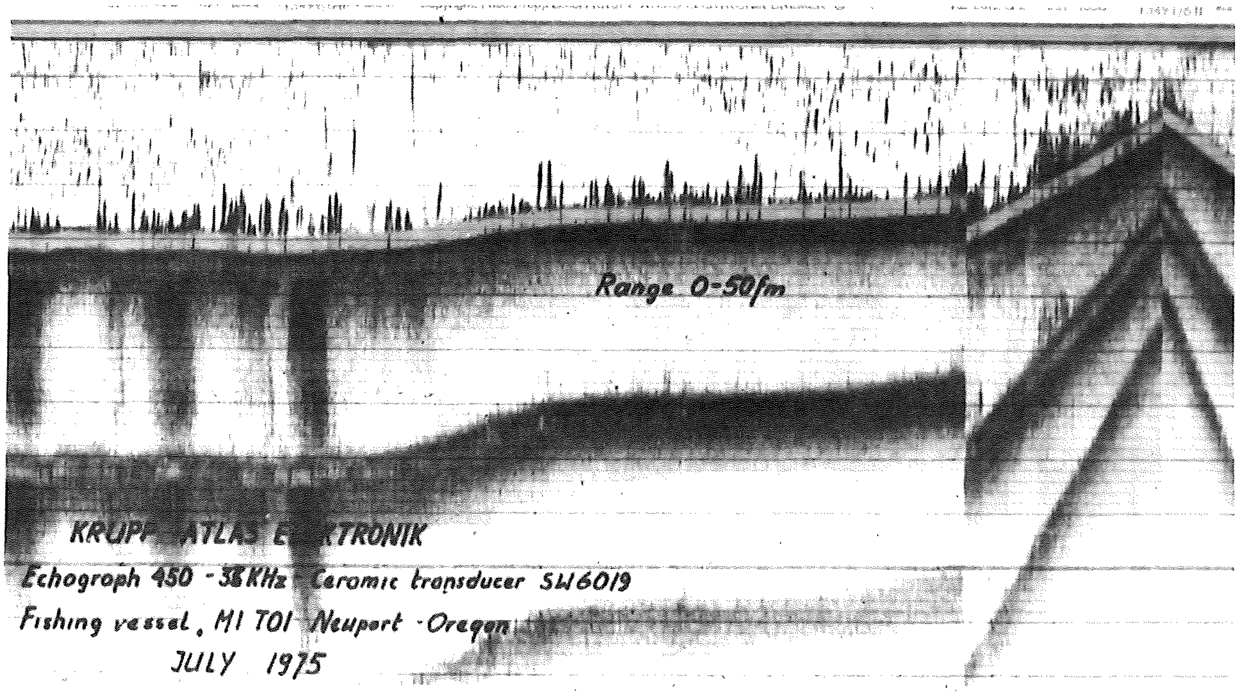
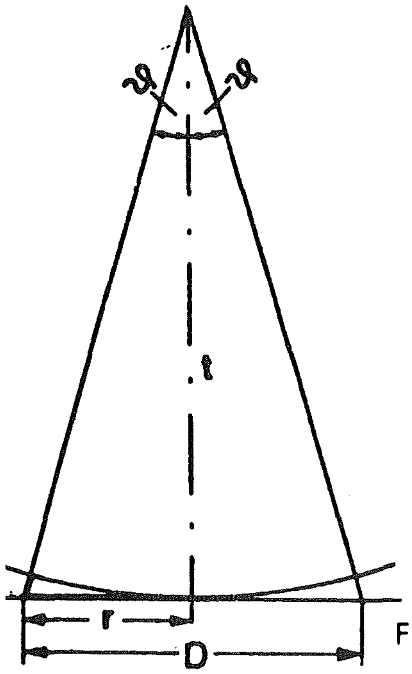


FIGURE 16. GROUND DISCRIMINATION RECORDING

In order to obtain such recordings one needs a highly efficient transducer, with the correct side lobe pattern. In order to achieve an optimum performance KRUPP ATLAS ELEKTRONIK has designed the '7 element PZT transducer' which has an efficiency of approximately 75% (transducer Type SW6019 is available with the Atlas Recorders 450, 600 and 700) and offers high sensitivity in the main direction for fish detection, and good sensitivity in the side lobes for ground discrimination.

2.3 BOTTOM TRAWLING AND ECHOSOUNDER PERFORMANCE

Now we will describe how fish recordings near the bottom depend on certain sounder characteristics. The term beamwidth has already been explained. Now its effect on fish recording will be discussed. Figure 17 shows the area covered by the sound cone in relation to beamwidth and water depth.



ϑ	r	Beamwidth	D
2,5°	t/24	5°	t/12
5°	t/12	10°	t/6
7,5°	t/8	15°	t/4
10°	t/6	20°	t/3
15°	t/4	30°	t/2

FIGURE 17. AREA COVERED BY SOUND CONE IN RELATION TO BEAMWIDTH AND WATER DEPTH

At the left of the sketch the main lobe can be seen. The letter 't' represents the water depth, and 'D' stands for the diameter of area hit by the sound beam. In the last two columns on the right the relationship between beamwidth, depth and sound area can be seen. For example, a beamwidth of 5° will cause a diameter of one-twelfth of the water depth. A 30° angle creates a sound cone of half of the water depth. The consequence of these figures is shown in Figure 18.

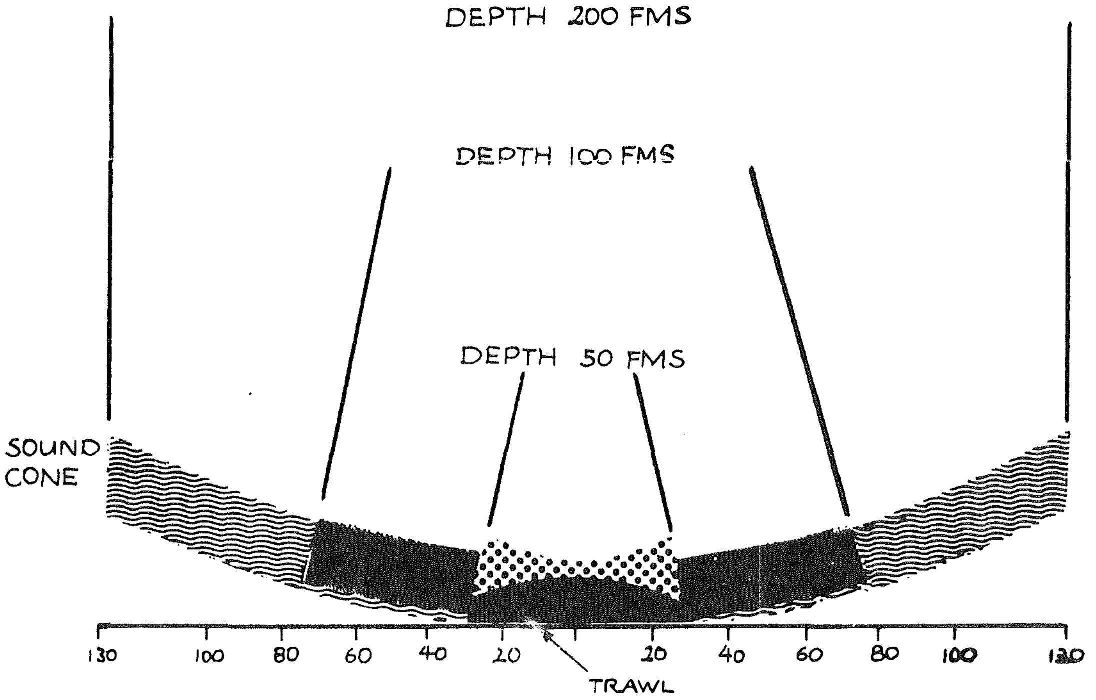


FIGURE 18. TRAWLING AREA AND SOUND CONE

In the picture the covered area for a 13° beam angle is shown for several depths. At a depth of 50 fathoms the cone covers an area of approximately 60 feet in diameter, which is roughly the working area of a bottom trawl. With 100 fathoms of water the illuminated diameter increases to approximately 150 feet, and at 200 fathoms to approximately 260 feet. Therefore, with increasing diameter of the sound cone, the number of fish marks will increase providing that the fish are evenly distributed. The catch however will not increase, because of the trawl size. The catch may even decrease in the event the sounder picks up echoes coming from one side of the cone and the trawl, due to a current, works on the other side of the cone. The masking of trenches due to the beamwidth has already been described.

The next picture (Figure 19) shows how fish will be obscured.

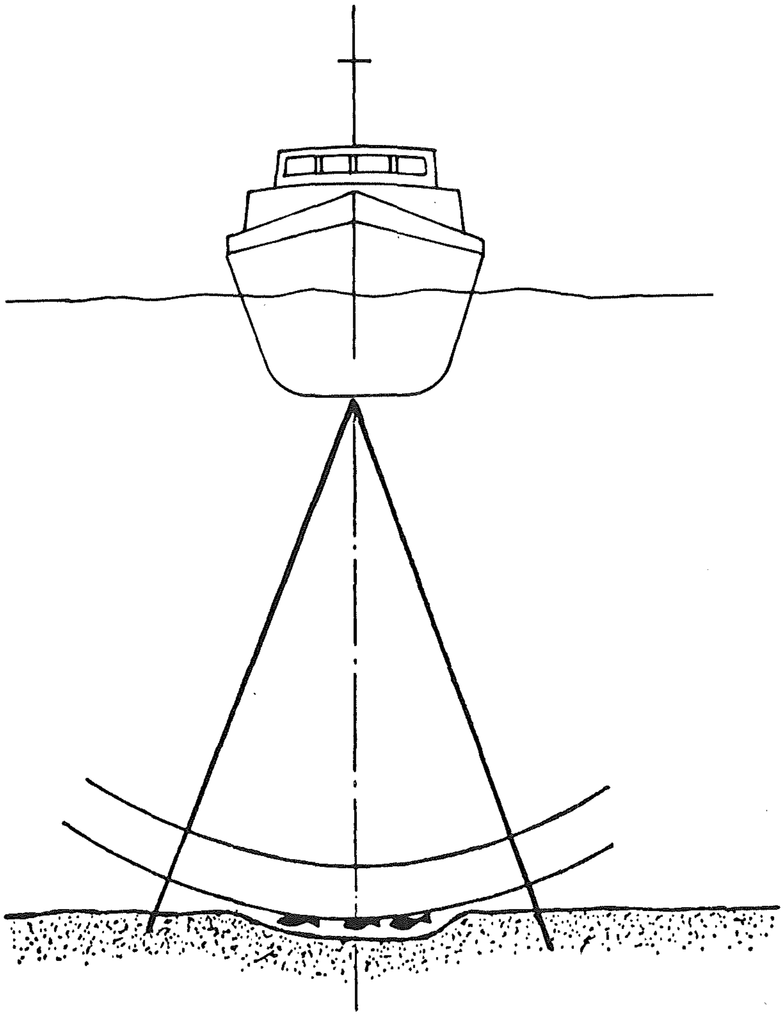


FIGURE 19. FISH OBSCURED BY TRENCH

The reflections of the trench edges will arrive at the same time as the fish echoes at the sounder. Since the bottom echoes are considerably stronger than the fish echoes, the latter will be lost. A similar effect will occur when contour fishing, or when trawling on a slope. The following picture (Figure 20) shows that the beam's edge will hit the bottom before the center of the beam hits the fish, result - no fish mark.

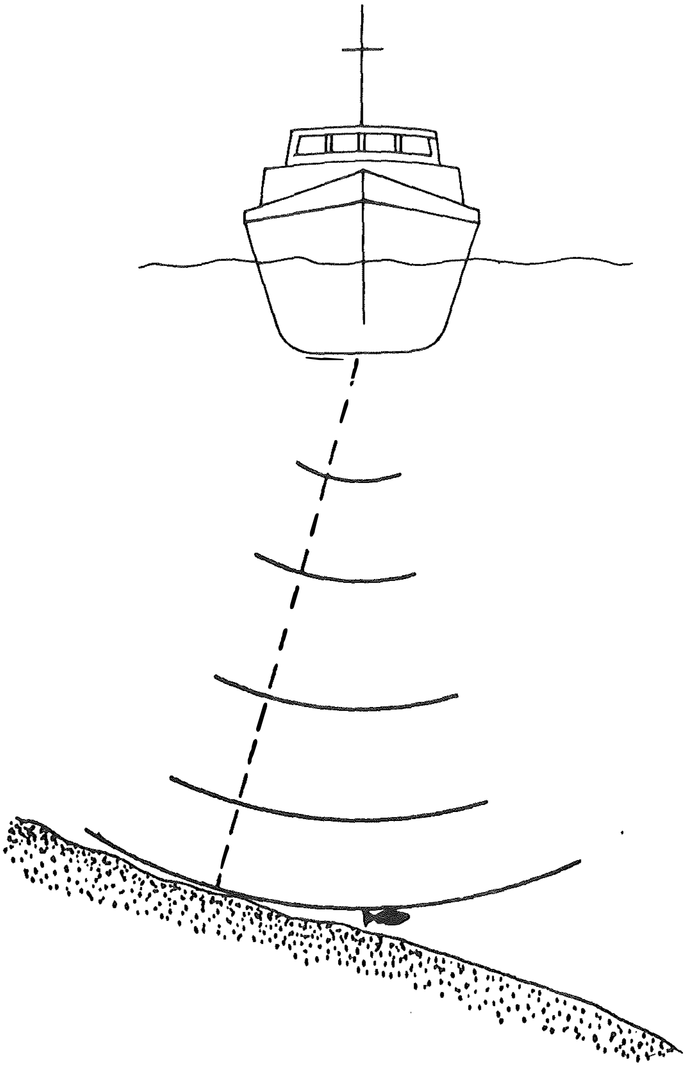
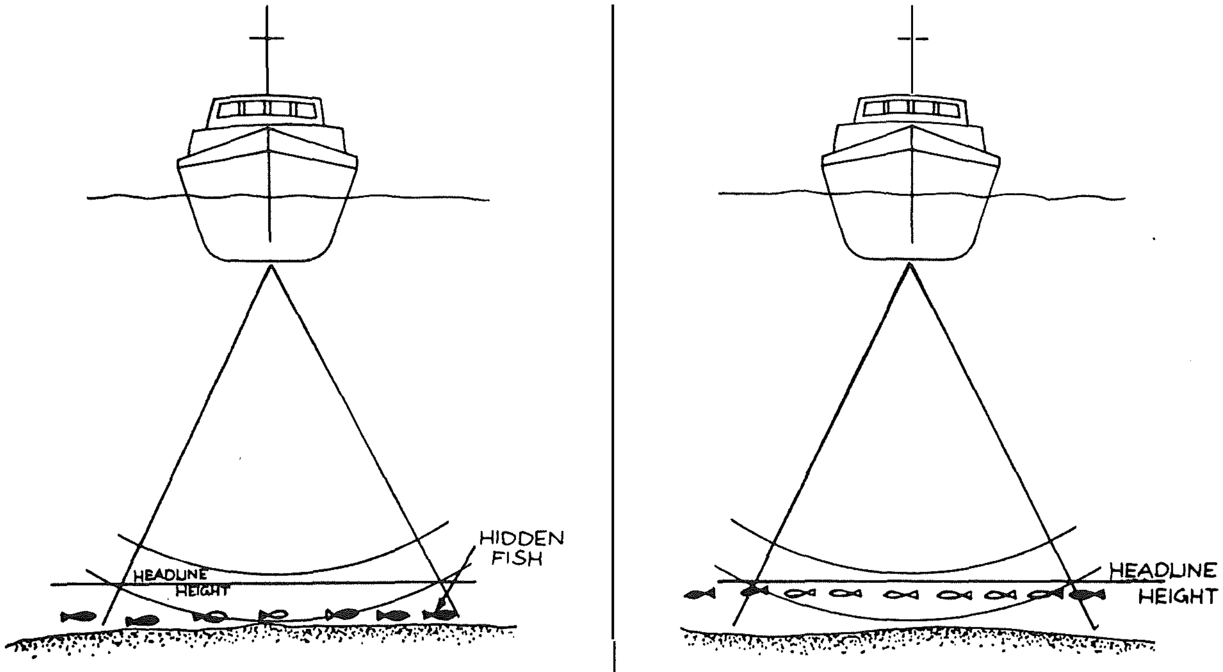


FIGURE 20. SLOPING GROUND MASKING FISH

Even on smooth and rather flat grounds fish may be hidden from the sounder. Here the height of the fish over the ground in relation to the beamwidth is important.

Figure 21 shows the difficulties of recording fish very near or right down on the bottom.



HIDDEN FISH FOR TIGHT DOWN CASE

OFF THE BOTTOM FISH NOT HIDDEN

FIGURE 21. FISH RECORDING NEAR THE BOTTOM

The dark drawn fish will be hidden from the sounder because the center of the beam will hit the bottom first. To improve indications of fish situated like this, the scope presentation is used (this will be described later). The catch, however, will be the same because in both cases the fish are below the headline. Another effect, which influences the relation between fish recordings and actual catch has to be mentioned, also, that is the false indication of fish height over ground. The next sketch clarifies this phenomenon.

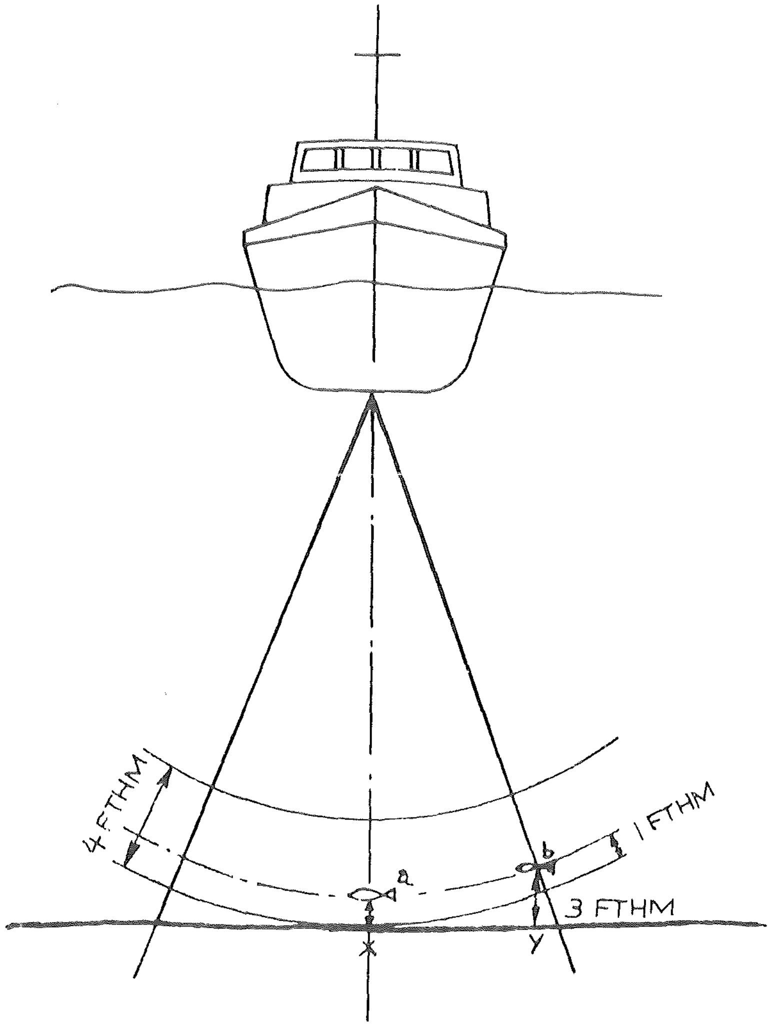


FIGURE 22. FALSE INDICATION OF FISH HEIGHT

The sound pulse spreads out in a conical form, the fish at point 'a' will be recorded at their true height - one fathom over ground. The fish at point 'b' will be hit at the same time, because the distance from the transducer to point 'a' and point 'b' is the same. The fish at point 'b' however will be recorded at the same height of one fathom, although its real position is three fathoms over the ground. If, theoretically speaking, a ship would meet fish only on the beam's edges whereas the trawl works in the beam's center, the catch would be next to nothing although fish marks are recorded at the proper height over ground.

It is hoped that these remarks have shown how difficult it is to estimate what is going on below the vessel, and how certain sounder specifications such as beamwidth and pulse length influence the performance of the sounder.

2.4 DISPLAY MODES

As mentioned at the beginning, there are four display modes used in echosounding. The ones most widely used for fish detection are the graphical mode and the CRT or scope presentation. The great advantage of the chart recorder is that it provides a memory. Successive echoes of fish shoals and seabed build up into echo traces which keep numerous informations available for the fisherman over a long period. The advantage of the CRT presentation is its high resolution of single targets and the presentation of the real target size. The disadvantage is that no permanent record can be kept. The combination of both chart recording and scope presentation is therefore successfully used by European fisheries.

Let us now consider the influence of the chart recorder to the performance of the sounder. Remember, an echosounder is a measuring instrument. The information gained by design features such as good radial definition for single fish detection, correct beamwidth of the transducer or excellent sensitivity of the amplifier has to be displayed in a proper manner. Otherwise, these informations are lost and the value of the sounder for the fisherman is diminished.

The term 'depth to scale ratio' describes the ability of a recorder to show small echoes on the paper. Let's take an example. The next sketch shows five partial recordings.

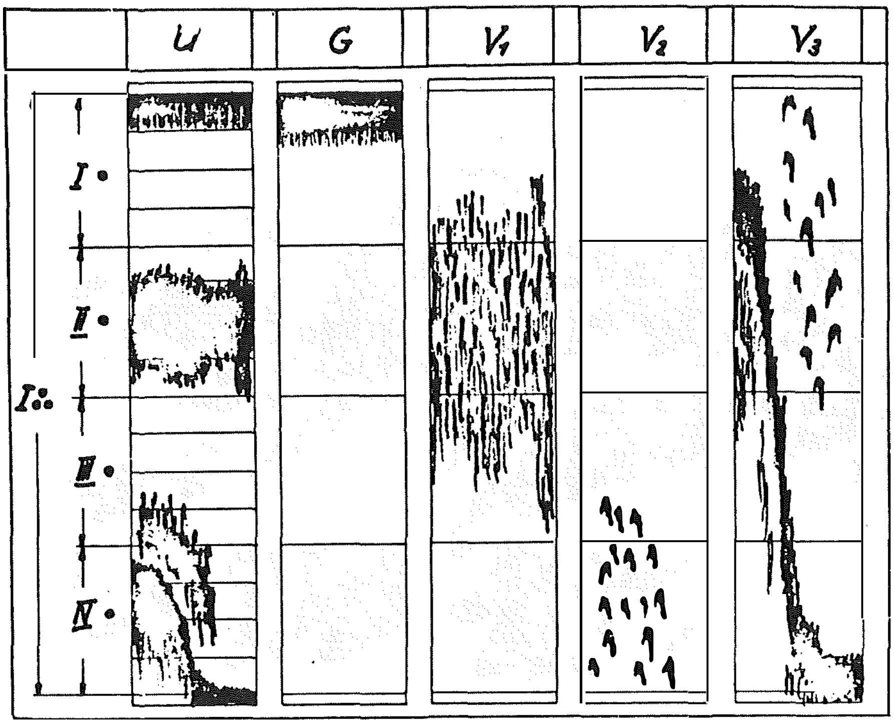


FIGURE 23. DEPTH TO SCALE RATIO

On the left under the title 'U' a normal recording is shown. On top the zero line can be seen; in the middle are some black recordings; further down obviously shows some fish marks and the seabed. Let's assume this recording represents a scale of 0 - 100 fathoms and the paper is 10 inches. In this case the depth to scale ratio will be one-tenth of an inch per fathom of depth, or better, the paperwidth divided by the scale used. Now, let's assume the sounder has a radial definition of one foot - that means it is able to distinguish 6 fish in one fathom of depth, if they are all one foot apart. The sounder however only has one-tenth of an inch of paper available to reproduce these 6 echoes, consequently it would show just one black mark, and valuable information is lost. To solve this problem, a different calibration system is used - basic ranges and phased ranges. Let's return to our example. If we divide the recording 'U' into four parts, the following ranges would be achieved. A basic range of zero to 25 fathoms as shown under title 'G', and three phased ranges: V 1 = 25 ... 50 fathoms; V 2 = 50 ...75 fathoms; and V 3 = 75...100 fathoms. The basic range (basic because it extends from the transducer or zero line downwards) has a depth to scale ratio of four tenths of an inch per fathom of depth. That means four times greater than range 'U'. But the three phased ranges also have this good depth to scale ratio, resulting in a picture with definition. Generally speaking, the versatility of a sounder can be recognized by the number of basic ranges, their phasings and their depth to scale ratio. More sophisticated machines even incorporate 'intermediate ranges' which cover 50% of two neighboring ranges. For example, the intermediate range of the ranges 50...100 fathoms and 100...150 fathoms would be 75...125 fathoms. This allows the skipper to shift the interesting recordings to the most suitable spot on the paper. The next picture shows a good example of how the proper use of ranges available and gain control will result in a good picture.

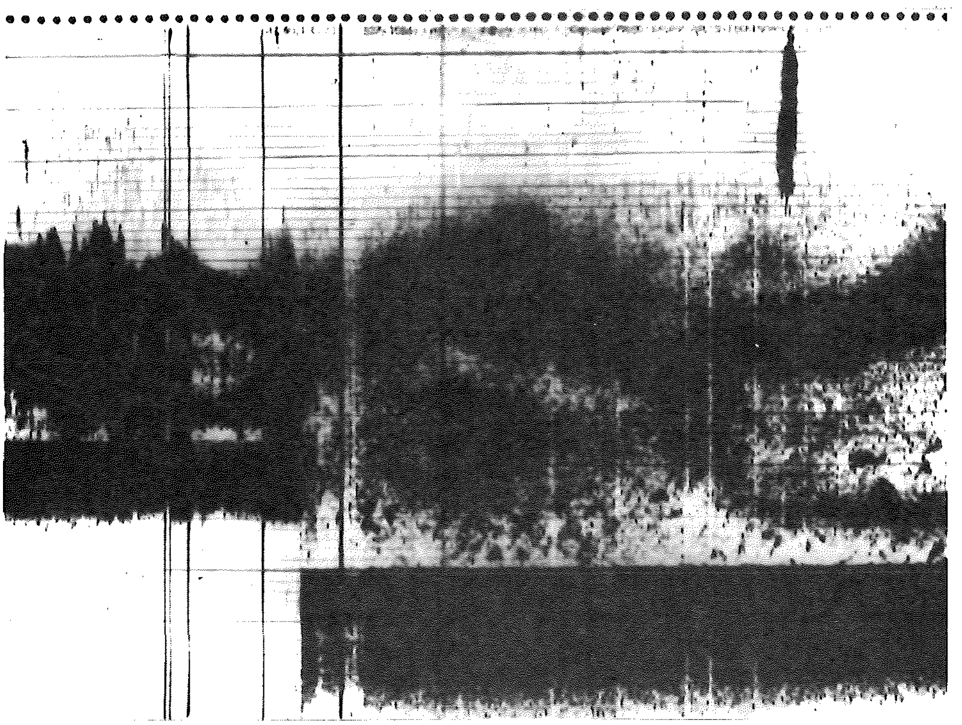


FIGURE 24. PROPER USE OF RANGES

To the left the skipper uses the 100 to 200 fathom scale to search for fish. All he achieved was a strong black recording which showed no details. Even when he reduced the gain (recognizable in this photo by the better greyline recording) no more details were shown. Then he switched to the range 125 to 175 fathoms which doubled the depth to scale ratio, and also reduced the pulse length. Now the massive black recordings broke up into details. A strong thermocline showed up and underneath it, typical comet traces of single fish (in this case, hake) mixed with trash fish.

To improve fish recordings close to the seabed, 'Grey Line' or 'White Line' circuits are incorporated in most fish detecting sounders. These circuits apply the fact that the seabed echo is normally many times stronger than a fish echo. By means of a control the operator will activate a threshold; any echo arriving which is smaller than this preset threshold value is regarded as a fish echo, and will be fully amplified and recorded in black. The seabed echo being greater than the threshold value causes a cut off in amplification and the stylus is unable to burn the paper for a certain time. After a while the amplifier is opened up again in order to record the rest of the bottom echo. The following Figure 25 shows the effectiveness of 'Grey Line' or 'White Line'.

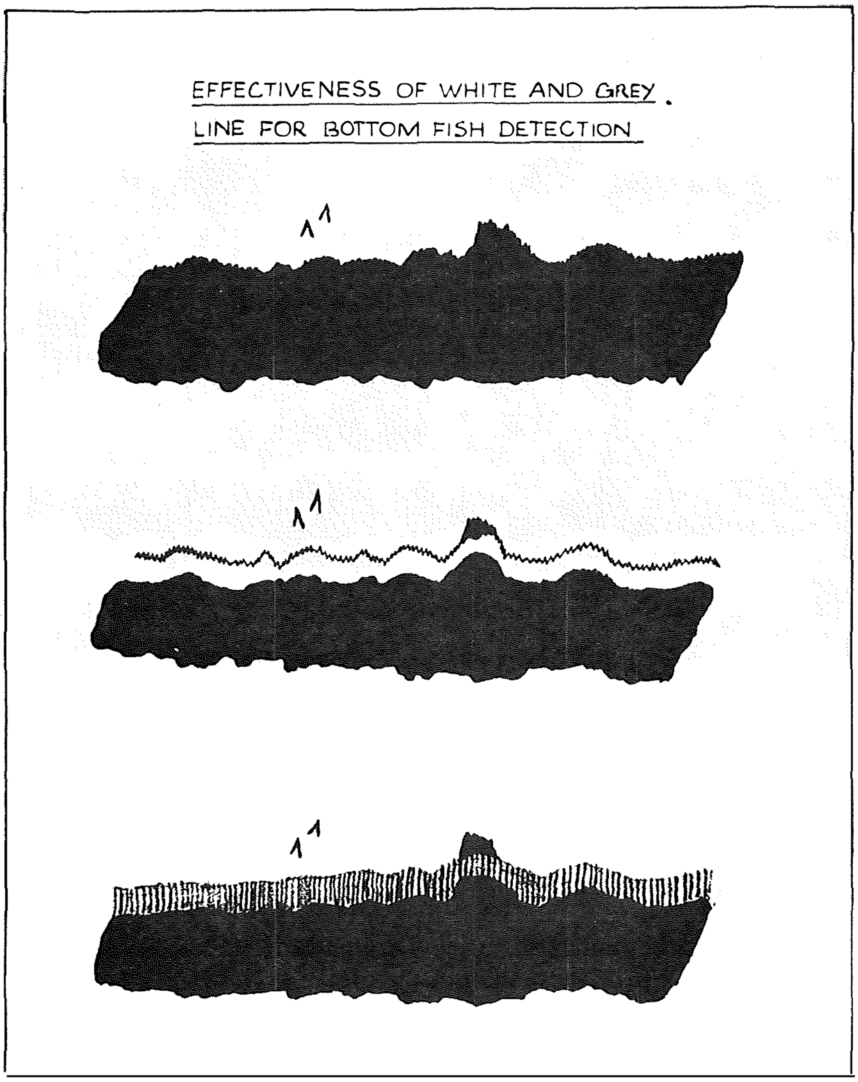


FIGURE 25. EFFECTIVENESS OF GREY LINE OR WHITE LINE

At the top, a recording without this feature is seen. Only two single fish can be recognized. In the center a corresponding 'White Line' recording is reproduced. The actual seabed is represented by the tiny black line on top of the white line. But suddenly fish near to the bottom can be discovered. The 'Grey Line' recording is shown at the bottom of the sketch. To produce the grey impression the amplifier is not completely cut off, but only its' performance reduced, so that the stylus can't burn through the paper. When comparing both systems, the Grey Line has the advantage that single fish will be clearly seen, whereas on a White Line sounder they tend to merge with the tiny black line, especially in bad weather when the bottom contour is not clearly reproduced. KRUPP ATLAS ELEKTRONIK, whose predecessor ATLAS WERKE first brought out the Black/Grey amplifier, has continued to improve this feature. In the more sophisticated sounders 'Black/Grey Automatics' are incorporated. Here the fisherman doesn't have to adjust the threshold to the varying conditions under water, this is done automatically by the machine. Figure 26 shows how fish marks are recorded right down to the Grey Line.

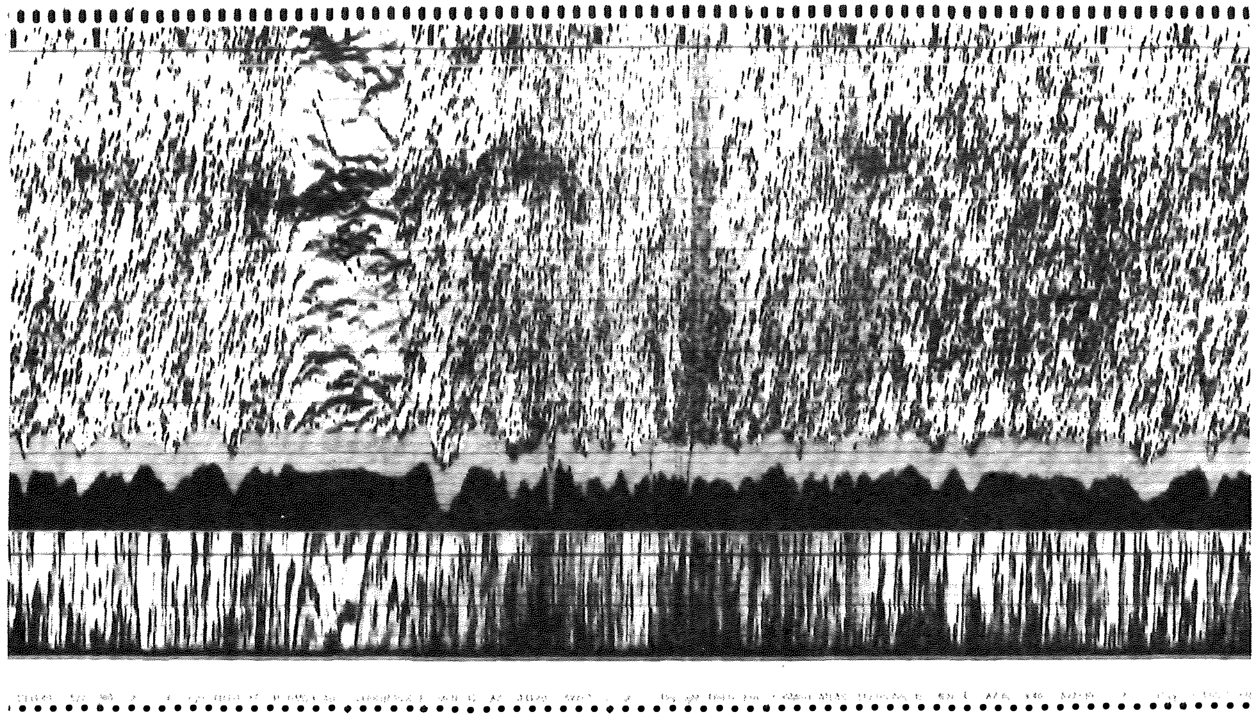


FIGURE 26. EFFECT OF PAPER SPEED

It also shows how different paper speeds will effect the recording. On the left side the normal economical speed is used. The fish marks can be clearly seen. Then the paper speed has been doubled. The fish marks are stretched and the movement of the fish is now more easily recognizable. More to the right the speed has been slowed down to half of the economical speed. The recording is now too compressed and the picture loses its' detailed impression. Later the normal paper speed is used again. Normally the paper speed is automatically adjusted to the range selected. In KRUPP ATLAS ELEKTRONIK sounders the speed is adjusted to an economical rate. In special cases, when more information is wanted, this speed can be doubled. In order to save paper, the fisherman is able to reduce the paper speed when he is only searching for fish, until he has found a shoal.

Another improvement of the recording system made possible by modern electronic technology is the graphic scale expander. Figure 27 shows a simplified explanation of a digital store expander.

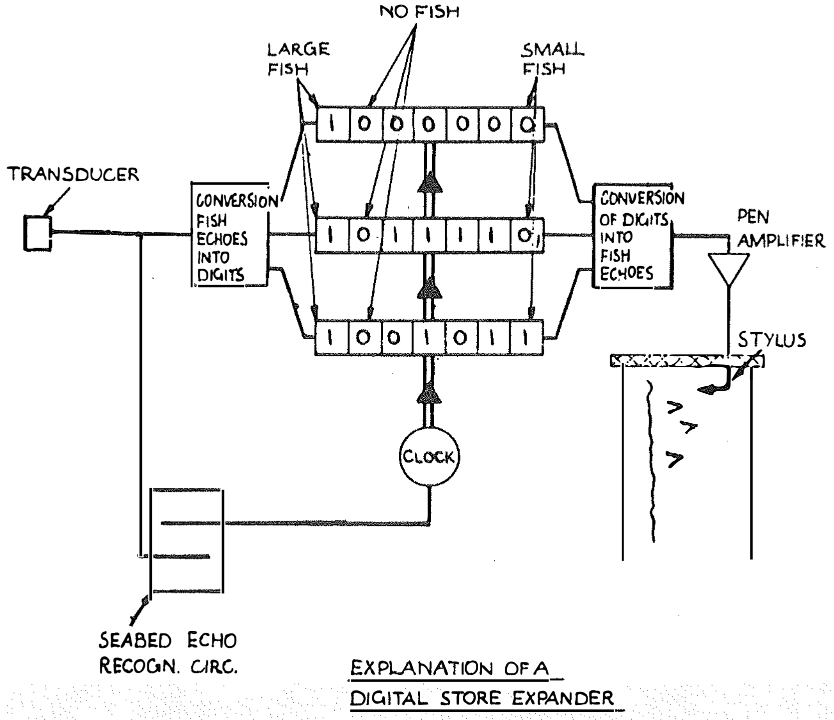


FIGURE 27. DIGITAL STORE EXPANDER

Echoes received are converted into digits ('zeroes' and 'ones') and stored in electronic stores at their true depth in this form. Three 'ones' represent a large fish. Three 'zeroes' represent no echo. Small fish are a combination of 'zero' and 'one'. The clock moves these digit columns from left to right, one store at a time, and each column represents a certain depth of water. The detection of the seabed which is performed by a special circuit triggers clock and stylus. The clock moves the digits into a converter where they are reconverted into analogue signals again and then moved to the stylus to be recorded at the correct depth position. The use of digital storage and clock controllong of recordings has opened new ways to improve the depth to scale ratio. Figure 28 shows both bottom locked scale expansion and normal recording.

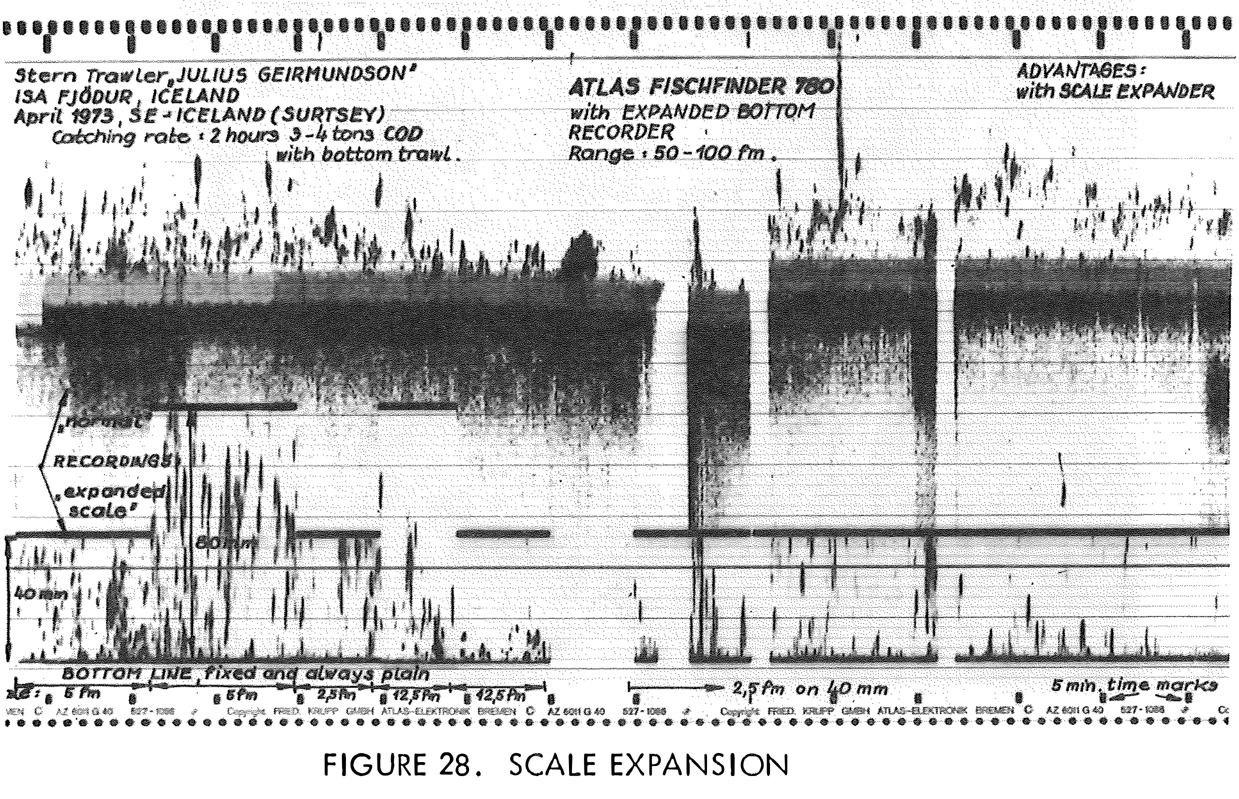


FIGURE 28. SCALE EXPANSION

Here certain sections of the normal recording are enlarged and repeated on the lower part of the chart paper. The bottom line is fixed and is always straight. The range which the skipper wants to see enlarged can be adjusted to headline height, so that he has a better view of the area at which his bottom trawl is working. By means of this feature a depth to scale ratio of one inch per fathom of depth is possible.

The scope is another mode of presentation with excellent depth to scale ratio. The advantage of this equipment is the presentation of the real target size. It works in the following manner. An electronic line is generated on a CRT. The line moves in the middle of the tube from top to bottom. Since the electronic beam has no mass or weight, its' speed can easily be adjusted to any specific rate, and ranges as small as 5 fathoms can be achieved. The beam will vary in width depending on the size of the targets received. If there is no target, the beam is a straight line from top to bottom. Any target deflects the beam and the degree of deflection depends on the size of the target (small deflection - small fish; larger deflection - several fish or fish school; very large deflection - bottom echo).

Figure 29 shows deflections caused by single fish and shoals.

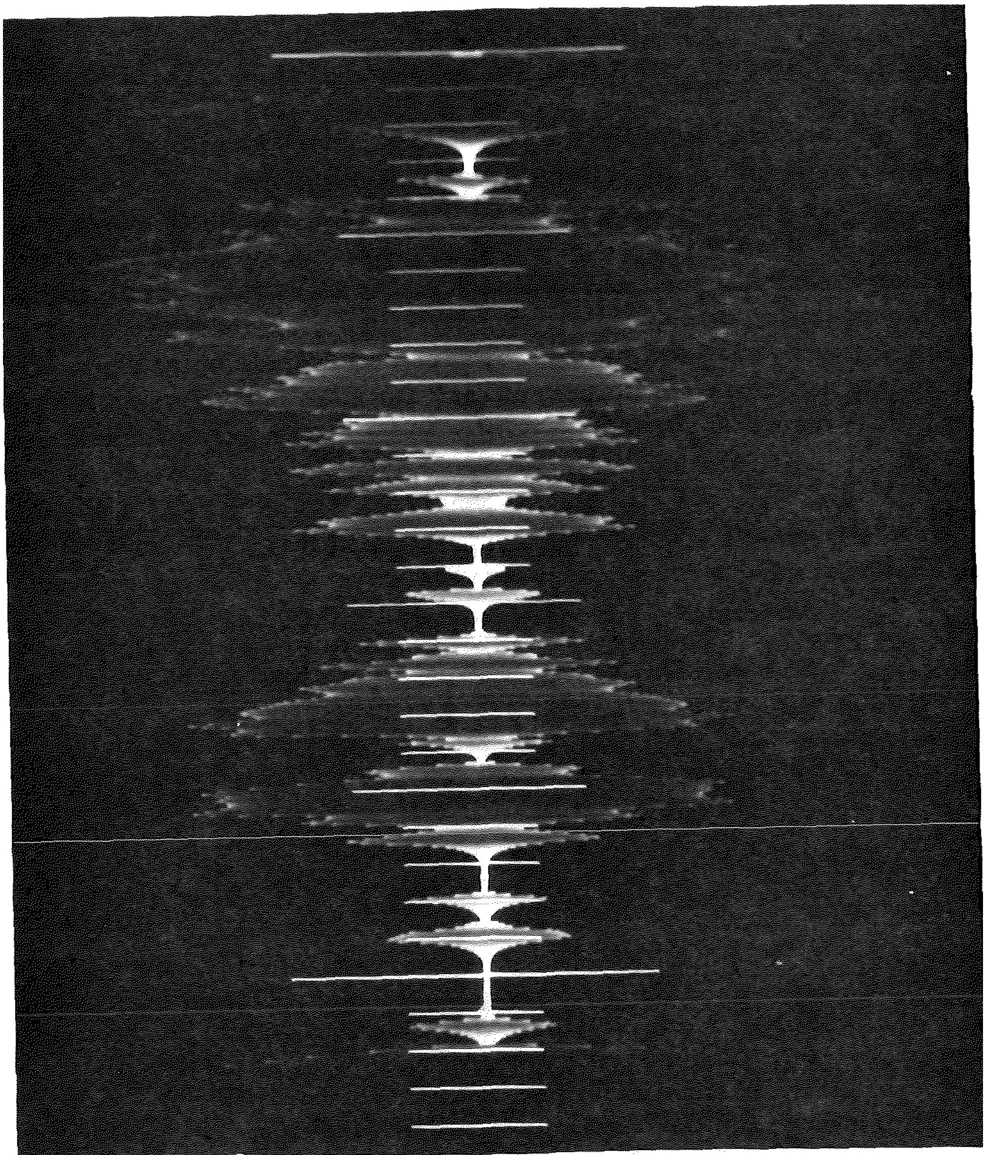


FIGURE 29. CRT PRESENTATION OF FISH ECHOES

At the bottom of the picture the wide deflection of the seabed can be seen. By means of CRT presentation the radial definition ability of an echosounder can be shown. Every white mark in that picture represents half a fathom of depth and every single fish can clearly be distinguished. Beside this high definition representation, the scope offers another advantage.
Fish close to the bottom can be seen on the scope by means of the 'automatic brilliance modulation'. This feature is comparable to the black/grey automatic in the recorder. This brilliance of weak echoes (single fish) is amplified in order to obtain a better contrast between single fish and shoals. The bottom represents the strongest echo and will cause the greatest deflection of the beam. Bottom echoes will be displayed on the scope rather dimly. Weak fish echoes arriving only fractions before the strong bottom echo will cause a brightening up of the contour line of the bottom echo. This indicates fish close to the bottom. It has occurred that good catches were made although no fish marks were seen on the chart paper. Figure 30 shows very clearly bright marks caused by fish directly above bottom.

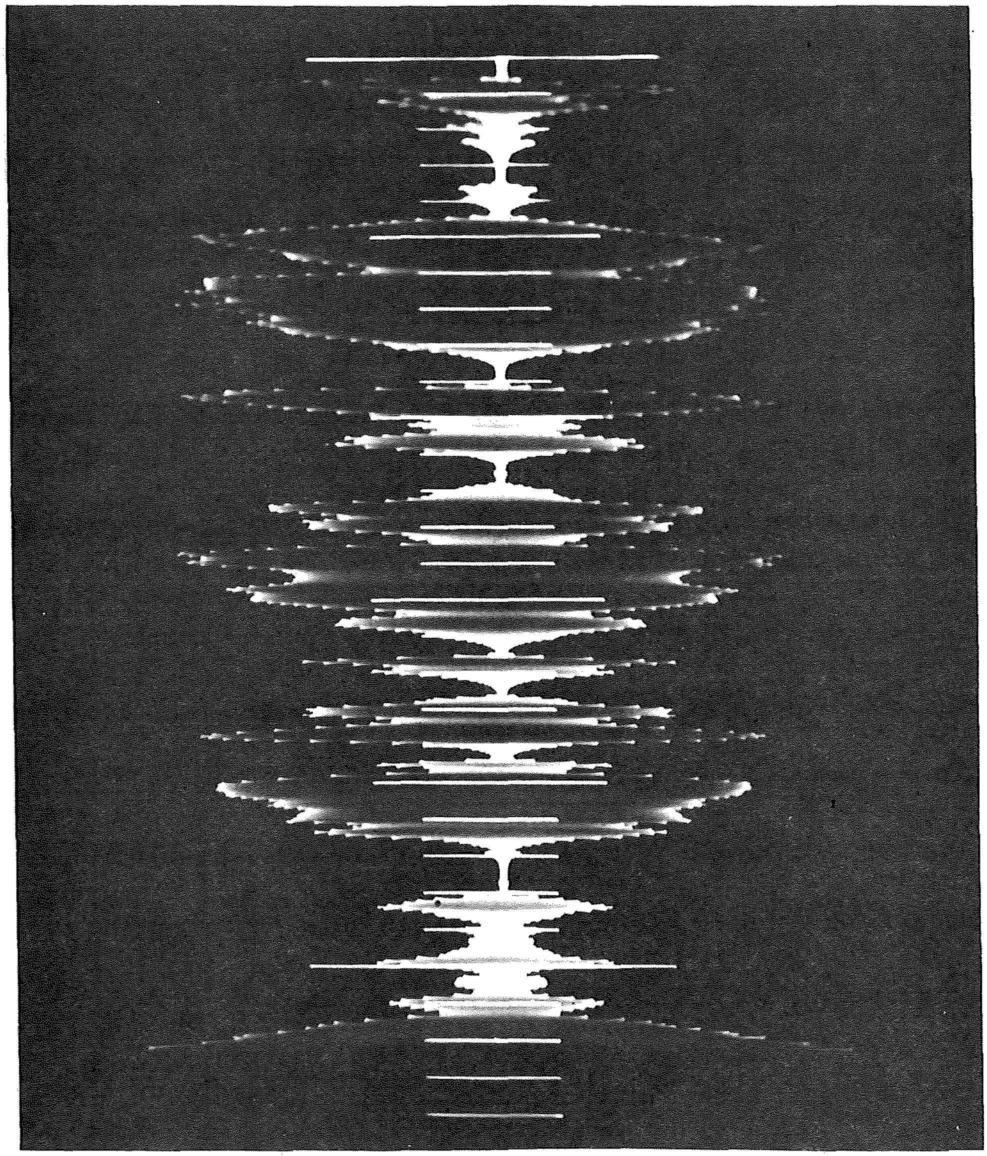


FIGURE 30. BRILLIANCE MODULATION OF SMALL TARGETS

The disadvantage of the scope presentation, rather fast pictures interrupted by long pauses due to slow return of echoes, lead to the development of the 'steady picture'. The steady picture works in a similar way as the digital scale expander. The whole picture is converted into digits and stored. During the long pauses between two soundings the store contents are constantly replayed so that the human eye has the impression of a standing picture, which only changes when a new array of echo signals arrives.

2.5 HOW TO SELECT AN ECHO SOUNDER

In order to summarize all the points which determine the performance of a sounder and to give the fisherman hints on how to select equipment for his specific requirements, the following twelve highlights are listed:

1. The number of ranges (basic, phased and intermediate ones) indicate the versatility of the sounder
2. Look for the best depth to scale ratio (chart paper width divided by range selected)
3. Look for variable paper speed
4. Is Grey Line, White Line, or better yet, black/grey automatics, included in the sounder?
5. Select the sounder which has a high efficiency transducer, which is more important than high output power.
6. Select the transducer beamwidth which is suitable for your vessel. Determine if you need a switchable beamwidth.
7. Look for the best possible radial definition (short transmit pulse widths)
8. If you need ground discrimination, select the proper transducer
9. Decide whether a graphic scale expander is needed.
10. Could you use the advantages of a scope presentation for your type of fishing?
11. Is the brilliance modulation feature available on your scope?
12. Is a steady picture possible, to ease interpretation problems?

NETSOUNDERS FOR MID-WATER TRAWLING

2.6. INTRODUCTION

The development of mid-water trawling showed the necessity for a new instrument, the so called "netsounder". Since the mid-water trawl can be aimed at a specific shoal of fish, the trawls exact depth (or better, height over ground) must be known to the skipper. Normally the skipper locates fish with his echosounder. Then he adjusts his trawl to the same depth in order to get a successful haul. This positioning and catch control is done with the "netsounder". As the name implies, the netsounder is nothing but an echosounder with the recorder unit mounted in the wheelhouse and the transducer lashed to the headline of the trawl.

2.7. OPERATING PRINCIPLE

Figure 1 shows a block diagram of the main operating functions of a netsounder.

ATLAS NETZSONDE – the key for success in pelagic trawling

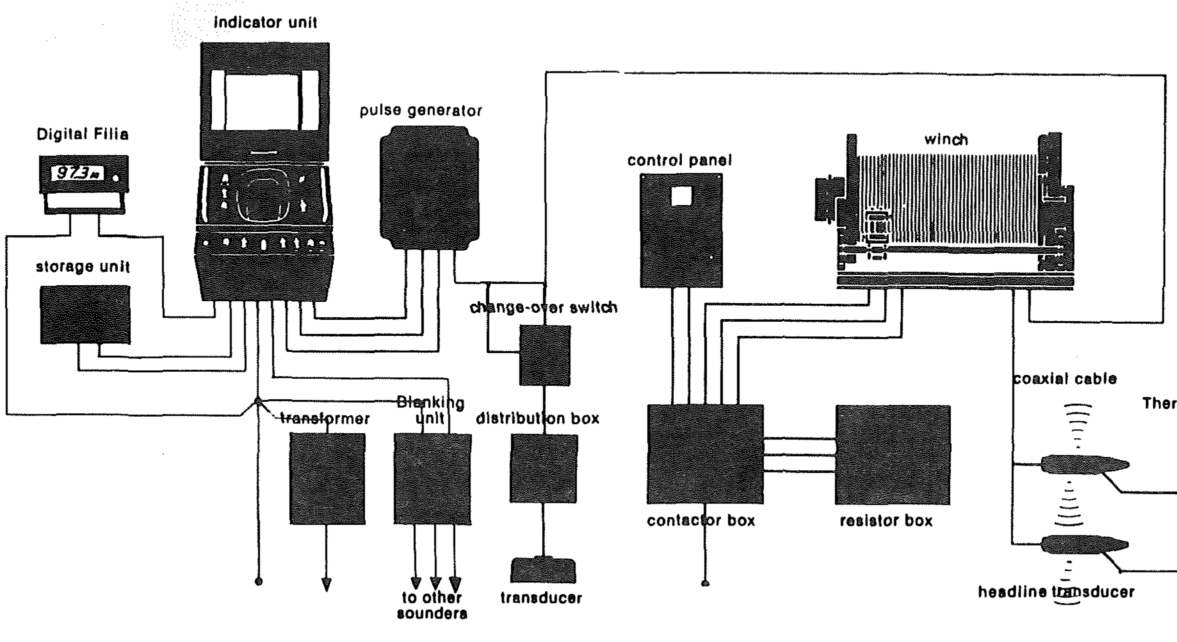


FIGURE 1. OPERATING FUNCTIONS OF A NETSOUNDER

To the left side of the picture is the echosounder (recorder unit, transmitter, and accessories like digital readouts and storage unit). To the right side is the winch, the necessary controls for the winch, the transducer and the thermosonde. The winch is needed to carry the cable, which is used as electrical link between recorder and transducer on the trawl. (There are also cableless systems on the market, which will be described later.) Normally two different transducer types are offered, the "down transducer", or the "up/down transducer".

The down transducer is used for mid-water trawling in medium depths. If the vessel has to fish in real deep waters, where bottom contact might be lost, the up/down transducer should be used. The thermosonde is needed to measure the water temperature at the working area of the trawl net. Certain species of fish prefer certain temperature ranges. The knowledge of the temperature below may save a lot of "dead" trawling time. These features will be described in detail in the next chapter.

Figure 2 shows a single mid-water trawler in operation.

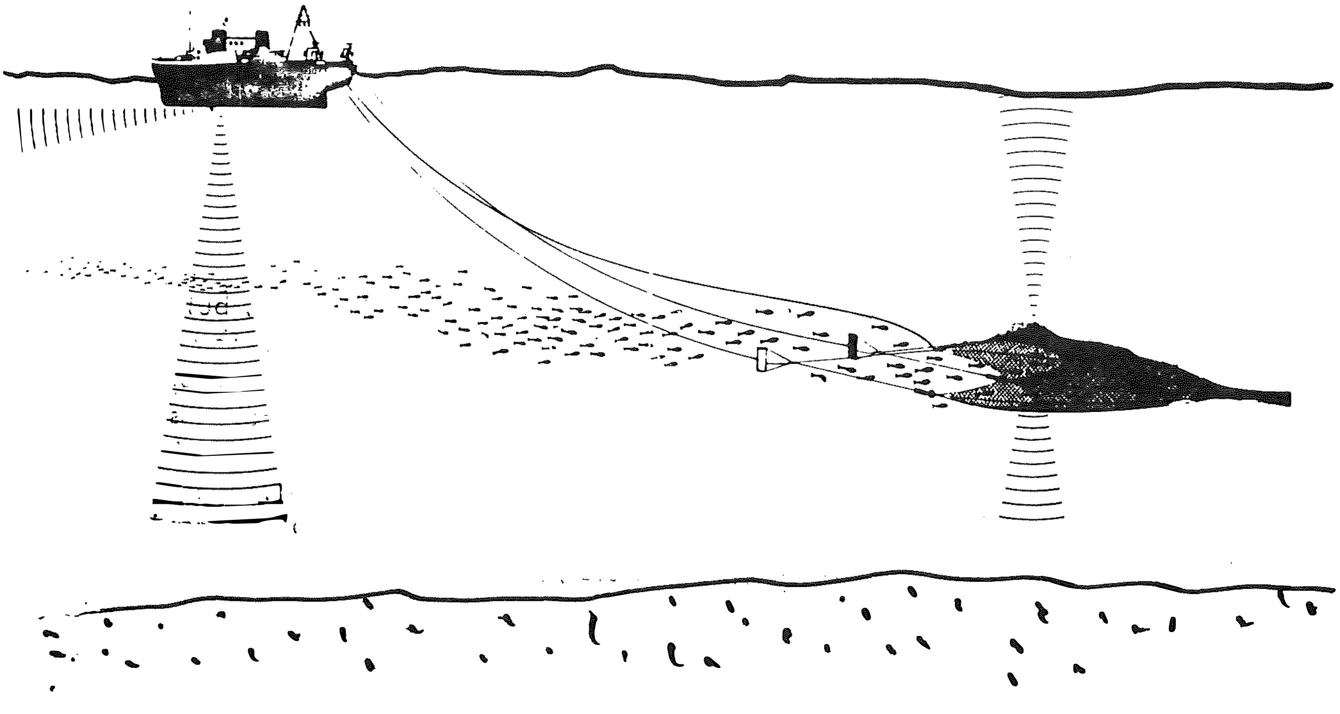


FIGURE 2. SINGLE MID-WATER TRAWLING

The up/down transducer mounted on the headrope can be seen. The two sound beams are indicated, as is the connecting cable.

Figure 3 shows the principle of the cableless system.

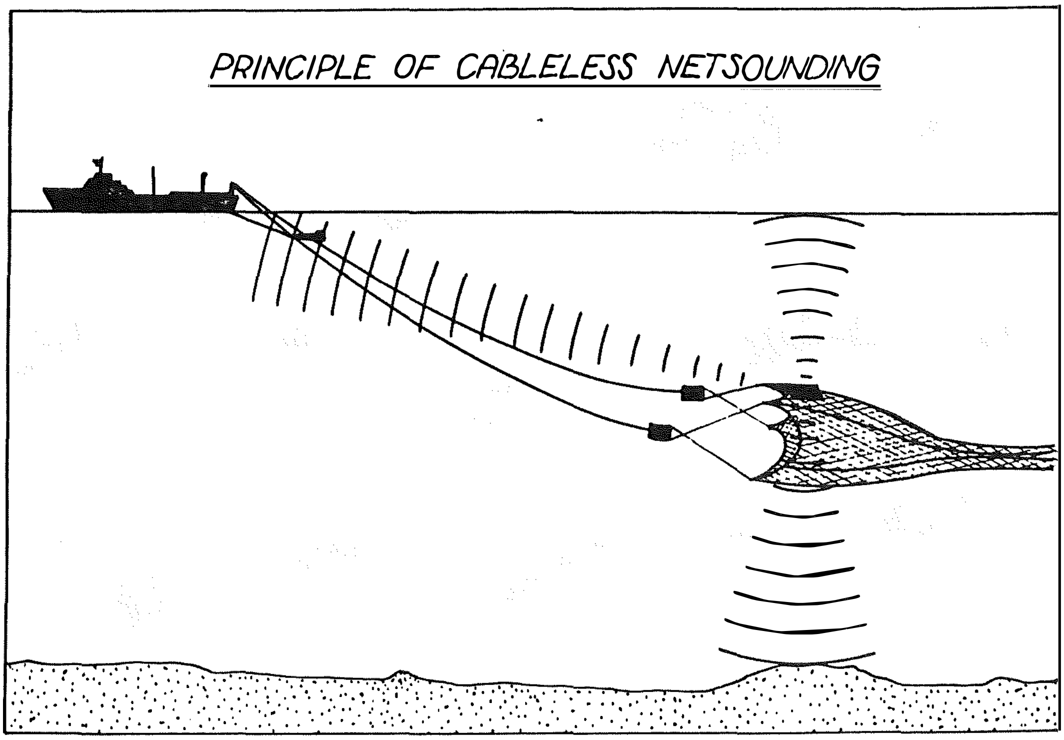


FIGURE 3. PRINCIPLE OF CABLELESS NETSOUNDER SYSTEM

Here the information from the trawl is not transported to the ship via cable, but by a so called "acoustic link". At the headline of the trawl net a housing is mounted which carries the transducers for up/down soundings, the sounder transmitter/receiver, and a power supply. The echosignals received are transformed in a special way and then transmitted towards the vessel by means of a third transducer situated in the front section of the housing. These signals are picked up by another housing (towed body) which is towed behind the vessel. This has to be done in order to avoid the wake of the ship. The wake consists of air bubbles and disturbed water and blocks the reception of sonar signals completely. The pros and cons of both systems are discussed in Chapter 2.9.

2.8. INTERPRETATIONS OF RECORDINGS

Everything which has already been mentioned in the echosounder part of the booklet "Echosounders and Radars for Fishing Vessels" regarding interpretation of recordings like definition, depth to scale ratio, etc., applies also for netsounder recordings. Furthermore, there are certain aspects which have to be kept in mind by the skipper in order to draw the right conclusions.

Figure 4 shows a comparison between a normal echosounder recording and a netsounder recording.

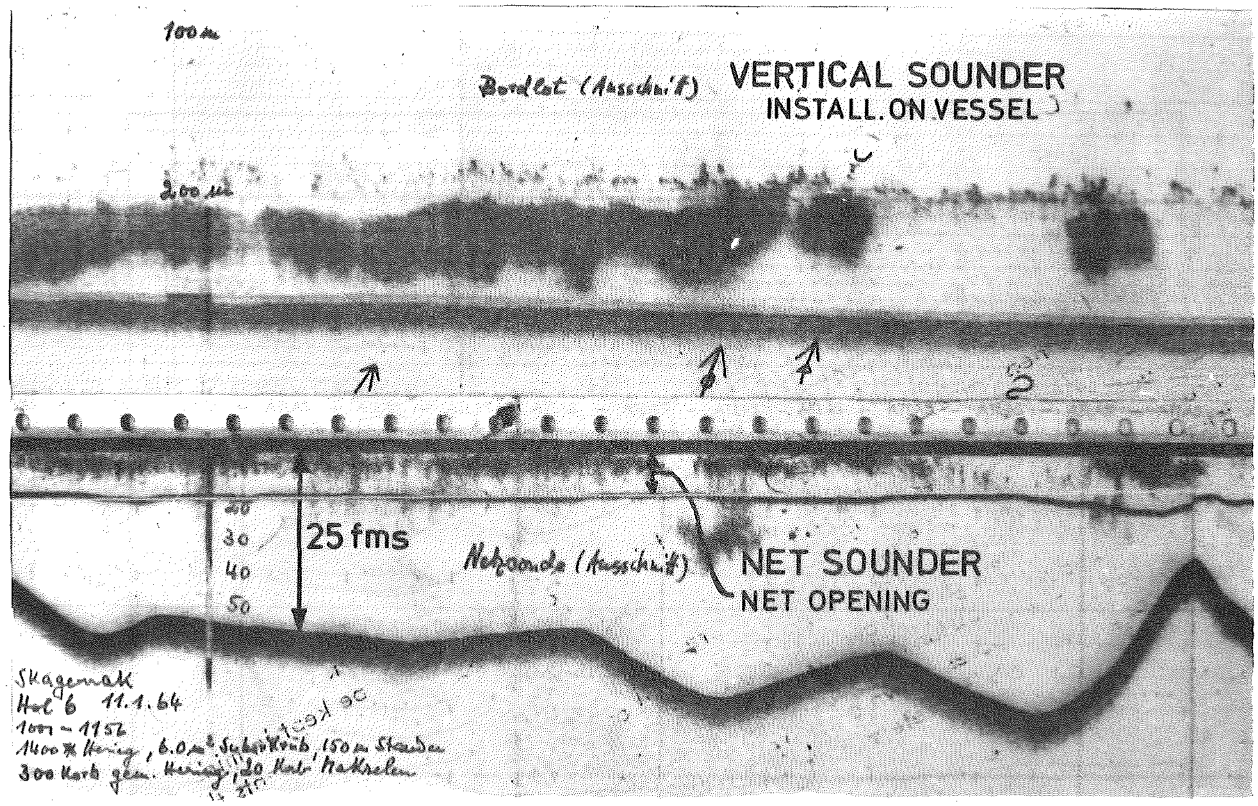


FIGURE 4. COMPARISON ECHOSOUNDER RECORDING - NETSOUNDER RECORDING

A rather smooth bottom can be seen on the echosounder recording. Furthermore a strong fish concentration, beginning approximately 25 fathoms over ground (mid-depth of approximately 100 fathoms - 200 meters) and ending approximately 3 - 4 fathoms over ground, is shown. The appropriate netsounder graph shows quite a different picture. It has to be kept in mind that the transducer is mounted at the headline, therefore the zero line, which represents the the transducer position also represents the headline of the trawl. The second line on the paper which runs almost parallel to the zero line at a certain distance, is the echo of the ground rope. The distance between these two lines is the vertical trawl opening. The recordings between these two lines are fish entering the trawl. The third line further down (which is curved) is the echo of the sea bed. The distance read between zero line and seabed is the height of the headline over seabed. The figures drawn on the left side of the chart show that the headline at that position is approximately 50 meters (or 25 fathoms) over ground. As shown on the echosounder recording, that is exactly the height of the shoal. The skipper has steered his trawl into the same depth. The vertical sounder chart shows a smooth flat bottom, but the netsounder recording presents the seabed moving up and down. An explanation for this difference follows. The zero line represents the transducer position, i.e. headline of the trawl. This line can't be moved on the paper, it is fixed to the beginning of the recorder paper due to the mechanical design of the sounder. In reality, however, the trawl moves up and down in the water. On the chart this trawl movement can be seen as a relative movement of the seabed. If a trawl would be towed at a height of, let's say, 25 fathoms over the ground, the seabed would be recorded as a straight line at a distance of 25 fathoms. If the trawl would be lowered to a height of only 15 fathoms, the seabed recording would move up toward the net. The chart shows these movements exactly. On the left side the skipper has brought the trawl to a height of approximately 25 fathoms over seabed and is trawling almost parallel to it. In the center of the recording he decided to lift the trawl a bit; this is shown by the dropping seabed. Now the fish are recorded under the ground rope, i.e., the trawl is too high. It is therefore lowered again, recognizeable by the upward trend of the seabed curve. On the right side of the picture, the trawl is lowered rather near to the seabed. The distance headline - seabed decreases very much.

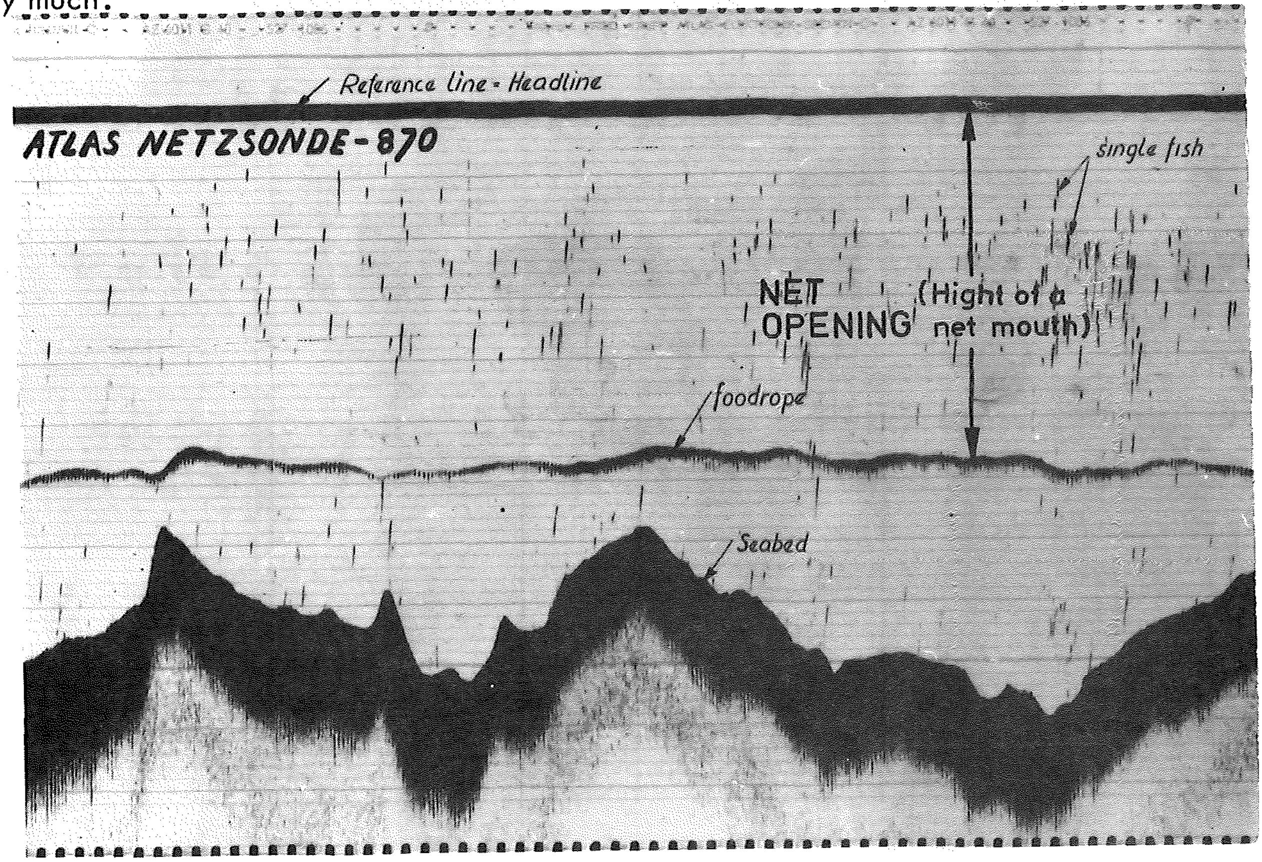


FIGURE 5. NETSOUNDER RECORDING

Reality has brought up another problem. Sometimes the skipper has to fish rather high over ground, for instance 50 fathoms or more. Since he has to watch the catch and the trawl height at the same time, he is forced to use a rather large scale (0 - 50 fathoms). When using these large scales, the recording of the trawl opening will be rather small and quite a lot of definition is lost. This led to the use of additional scopes for netsounding. The trawl opening, regardless of the fishing depth, is always shown on the scope with its high definition picture. The recorder is used for height control of the trawl.

Sometimes mid-water trawling has to be done over deep water of 500 fathoms and more. At these depths no bottom contact will be possible, therefore the above mentioned up/down transducer has to be used. The up/down transducer is a plastic case which houses two transducers. It is lashed to the headline so that one transducer faces upwards to the surface and the other one downwards. Since no bottom contact will be possible, the water surface will be used as a depth reference. Figure 6 shows a recording made with an up/down transducer.

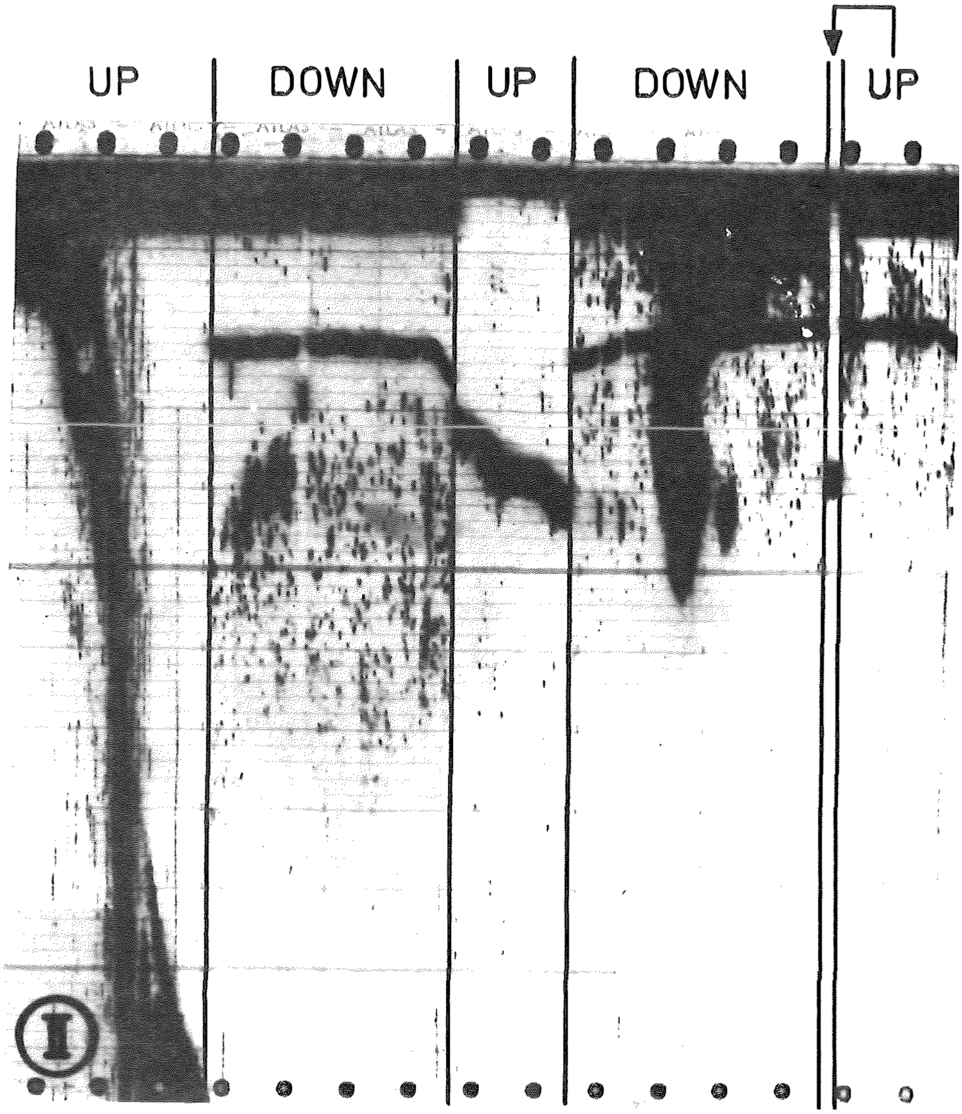


FIGURE 6. UP/DOWN TRANSDUCER IN OPERATION

On the left side of the recording the "up transducer" is used. First, the zero line and surface recording form one line. Then they part, and the distance towards the surface increases rapidly. This means that the trawl is sinking fast. (It might be clearer if one imagined this part of the recording upside down). Then the skipper switches on the "down transducer". The ground rope recording can now be seen and underneath it are several fish marks. The trawl obviously has not reached the right depth. Again the "up transducer" is used for depth control. The ground rope goes off, the surface echo comes on and the distance transducer - surface is still increasing, i.e., the trawl is still sinking. After a while the skipper switches back to the down sounding. The ground rope echo comes up again, and then a heavy fish concentration is shown, partly entering the trawl and partly escaping underneath the ground rope.

Figure 7 shows another example of successful mid-water trawling.

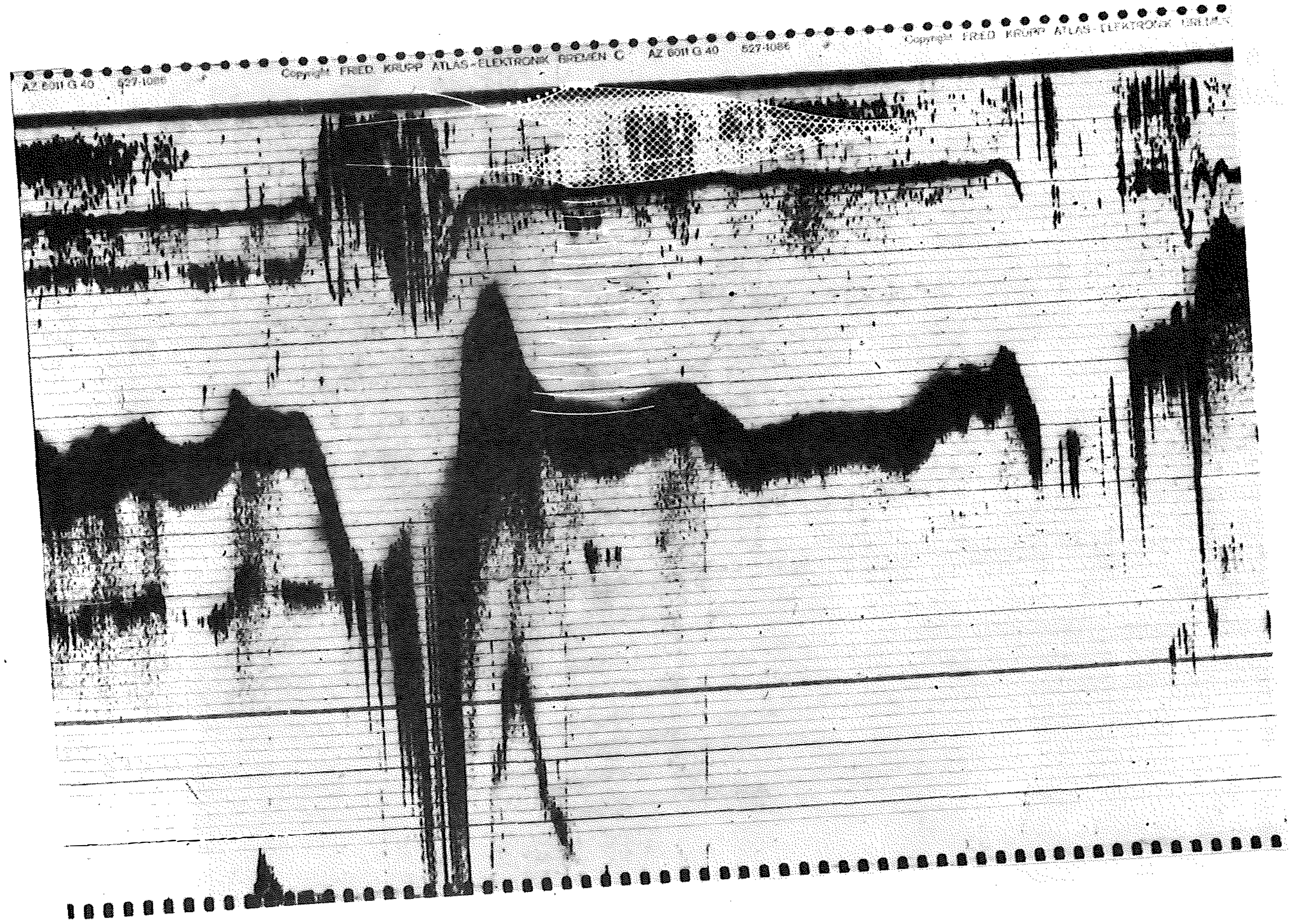


FIGURE 7. SUCCESSFUL NETSOUNDER FISHING

In this picture only the "down transducer" is used. On the left side we see the shooting of the gear, and after reaching a certain height, how the trawl opens (ground rope recording stabilizes) and how the fish enters the trawl. In the center, the skipper decides to turn and to fish the same shoal again. Since turning with huge mid-water trawls is very critical, he heaves until the doors are to the blocks, the rest stays in the water. He then turns the vessel and shoots again. This maneuver can be seen on the recording, because the ground rope closes in on the head line and the bottom drops off. The black recording underneath the head line is disturbances caused by the ship's wake, because the trawl is almost at the vessel's stern for the turn. After turning he shoots again, stabilizes his trawl at the right depth, and drags through the same shoal again. On the right side we see the repetition of this maneuver.

Last but not least, another feature of netsounder operation should be explained, the already mentioned thermosonde. This is a temperature measuring device which is also mounted to the head rope. It is triggered by the transmitting pulse of the netsounder and sends its temperature signals to the vessel via the same cable. The temperature will be recorded as a dotted line on the same paper as the netsounder echoes and can be read by means of a special scale.

Figure 8 shows a temperature recording.

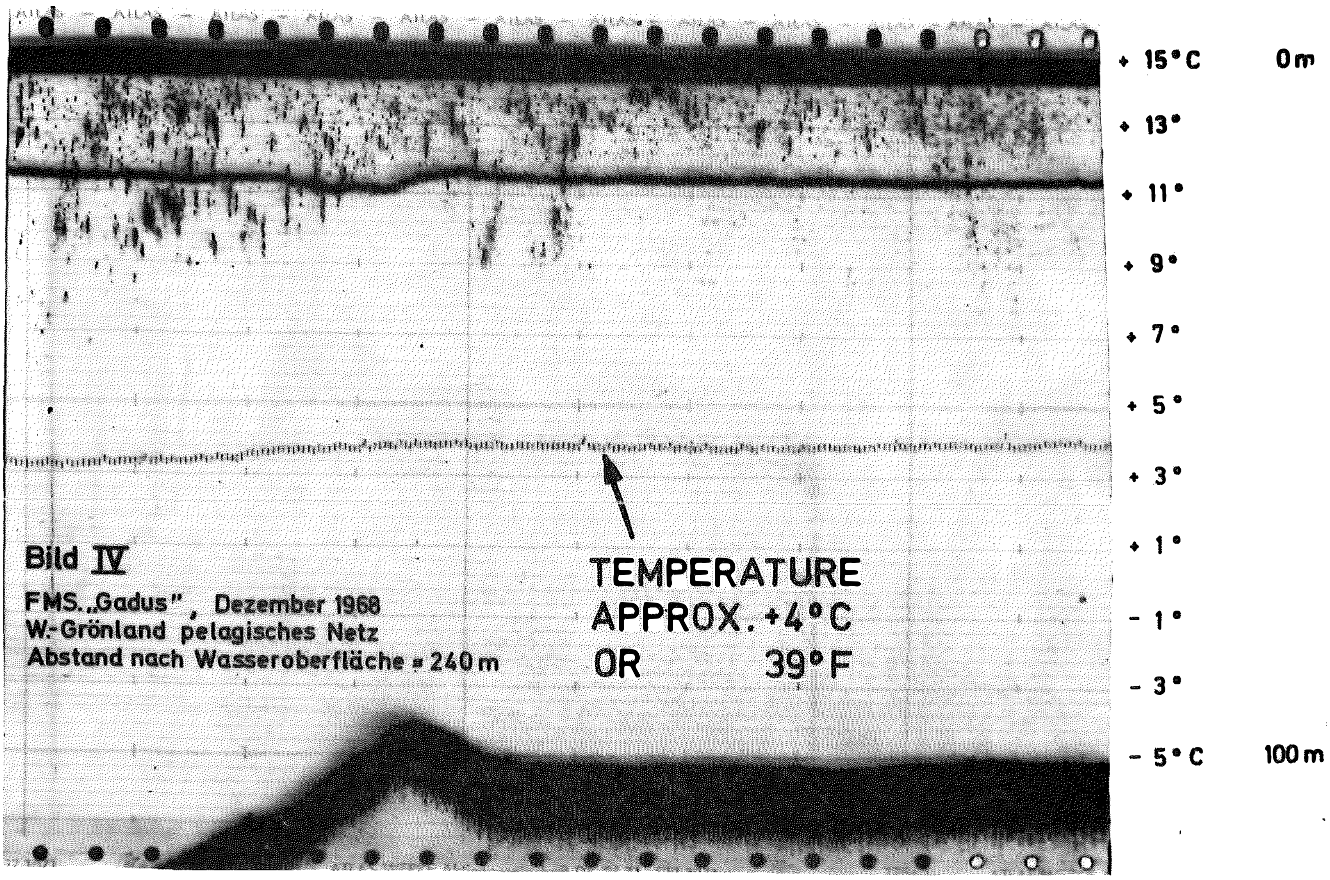


FIGURE 8. TEMPERATURE FISHING

The temperature is rather steady at approximately 4° Centigrade, which corresponds to 39° F. It also shows that no fish echoes are to be seen under the trawl – the skipper has found the right temperature layer. The advantage of the thermosonde is obvious. When, for example, cod fishing is done, temperature readings under approximately 2° Centigrade (approximately 36° F) or over 10° Centigrade (approximately 50° F) indicate that no cod can be expected. Another fishing area should be selected, thus saving valuable trawling time.

2.9. CABLE SYSTEMS AND CABLELESS SYSTEMS

In this chapter, the pros and cons of both systems will be considered. Both have advantages and disadvantages. Which system is best suited depends on the kind of fishing, the area, and the capability of the ship.

The cable system offers the following advantages:

- Constant contact with the trawl, regardless of the acoustic conditions in the water
- Almost no problems with acoustic interference
- No expensive electronic parts on the trawl

The main advantage of the cable system is the constant contact with the trawl during the fishing operation. (With the cableless system this contact may be interrupted or disturbed due to the underwater conditions.)

The cable used today is a shielded steel core cable with a breaking strength of 1.5 tons to 2 tons. The repair of a broken cable has been simplified and can be done in minutes. On bigger ships so called self tensioning winches are used which minimize the danger of breaking the cable and ease handling problems. The cable is kept at a constant tension. When the dragging force from the trawl is greater, cable will be paid out; if it slacks off, cable will be heaved in. On smaller vessels which only need a limited amount of cable (200 - 300 fathoms), hand winches are often used.

Furthermore, the cable will not pick up signals from other acoustic sources like sonars or echosounders working on the same frequency. Only if a sonar with the same frequency is trained directly on the netsounder transducer might interfering signals be picked up. In case of gear troubles or a complete loss of gear, only a transducer is lost - not a complete electronic unit.

The disadvantages of the cable system are as follows. The self tensioning winches require quite a lot of electrical power. Hand winches are uncomfortable and tiresome. The use of hydraulic winches has been successful, but again, power is needed. The transmitted signal and the received echo are attenuated quite strongly due to the long cable, but this problem has been solved by using a highly efficient PZT ceramic transducer. The disadvantages of the cable system are naturally the advantages of the cableless system.

The main advantages of the cableless system are as follows:

- Less power requirements aboard because no winch is used
- Less initial cost (no winch, no control unit)
- Certain advantage when pair trawling

Since the cableless system works without a winch, no special power requirements from the vessel are needed, and naturally the price for such a system will be lower.

Figure 9 shows an example of pair trawling with a cableless system.

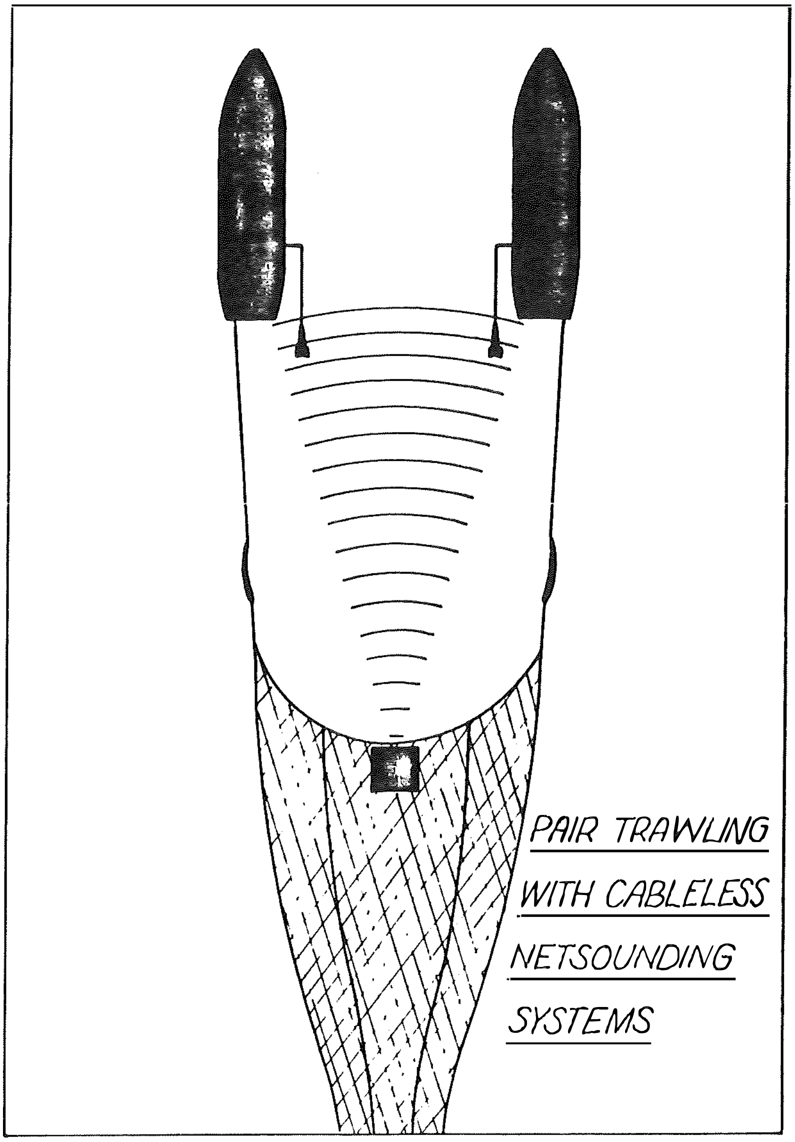


FIGURE 9. PAIR TRAWLING WITH CABLELESS NETSOUNDER

When pair mid-water trawling is done, both ships can pick up signals from the trawl, if the distance between them is not too great and the beam angle of the transmitter is wide enough. Both skippers have access to the situation below and can decide quickly what actions are to be taken.

The cableless system also has quite a number of disadvantages:

- Liable to fail due to environmental conditions
- Maneuvers can interrupt the contact to the trawl
- Interference from other acoustic sources will cause disturbances
- Rather expensive electronic parts are used at the trawl

The main disadvantages of the cableless systems are problems caused by the underwater acoustic conditions. Similar problems are encountered when using sonar. The next picture, Figure 10, shows the influence of a thermocline when using a cableless system.

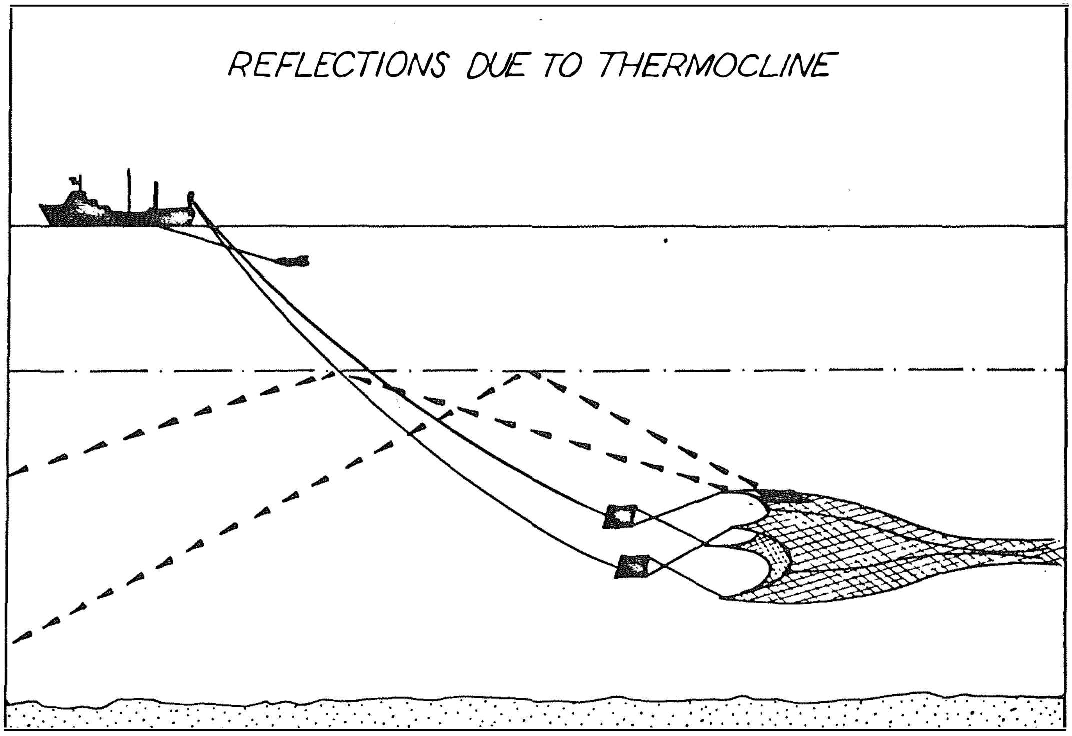


FIGURE 10. REFLECTIONS DUE TO THERMOCLINE

The signal is hitting the thermocline at a slant, and part (or in the worst case, the complete signal) will be reflected towards the seabed, causing a weakening or complete interruption of the recording aboard.

Mid-water trawling in shallow water or near the seabed or surface can cause wrong indications.

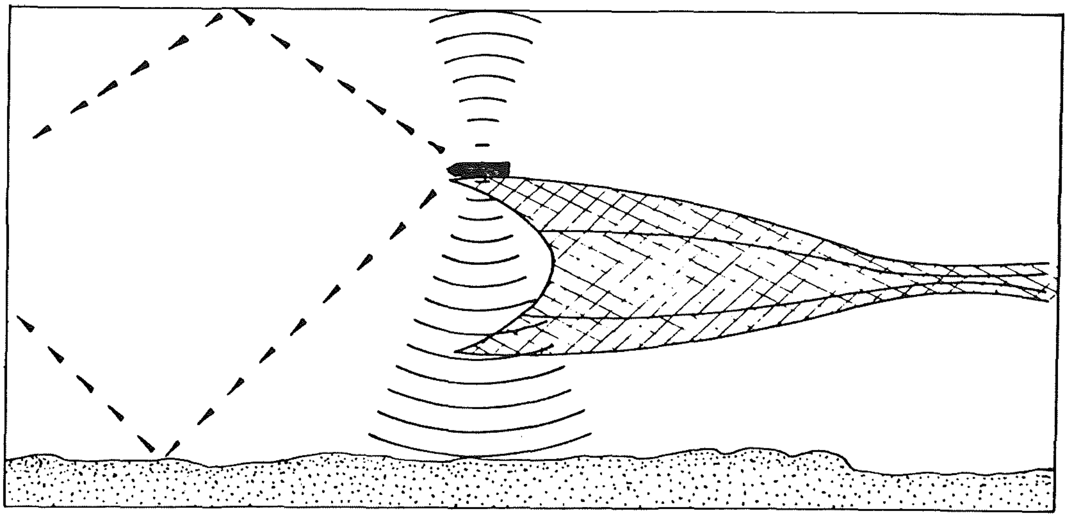


FIGURE 11. MID-WATER TRAWLING IN SHALLOW WATERS, REFLECTION FROM SURFACE AND/OR SEABED

Parts of an emitted pulse will reach the receiving transducer directly, and parts of the pulse will hit the seabed and/or the surface (or be reflected between both) and will reach the receiver later than the direct running pulse. This will cause wrong and irritating recordings.

Furthermore, course changes as shown in Figure 12 may lead to an interrupted contact. Since the trawl does not react as fast as the ship, the net transmitter will point in another direction than the receiver. This is very critical, because course changes cause a loss of speed and the trawl loses height during that time.

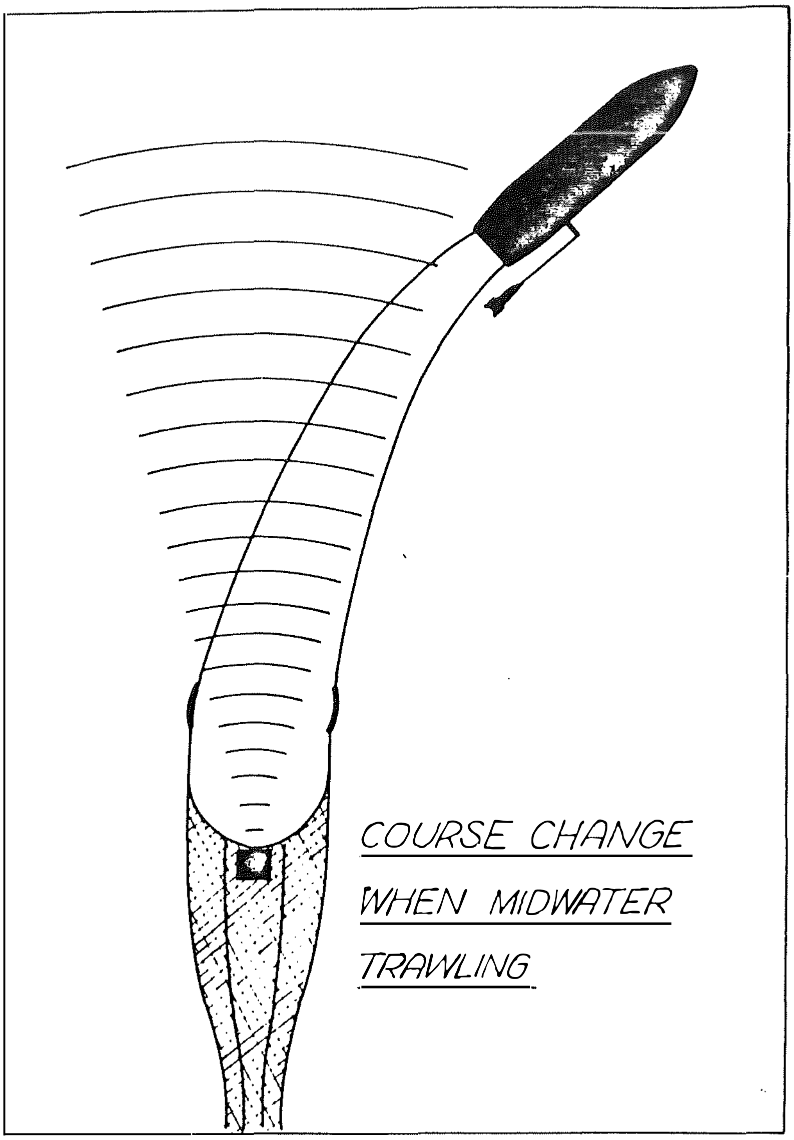


FIGURE 12. COURSE CHANGES WITH CABLELESS SYSTEMS

Problems also arise when several cableless systems work on the same crowded fishing grounds. 'Overspeaking' from one system to the other may occur. Also, sonars working in that frequency range may cause acoustic disturbances.

As mentioned earlier, the danger of losing the complete electronic unit has to be taken into consideration as a disadvantage.

2.10. HIGHLIGHTS OF NETSOUNDER OPERATION

In order to summarize the points covered regarding netsounder operation, the following highlights are repeated:

1. When mid-water trawling, the use of a netsounder is essential. Fishing without one means fishing blindly and risking the loss of gear, especially over rough grounds.

2. If you go mid-water trawling, determine at which depth you are most likely to be working

3. Decide which transducer you are going to need (down or up/down)

4. Consider the use of a scope for better definition, if working in relatively deep water

5. Would a thermosonde help in saving trawling time?

6. Consider the pros and cons of the cable and cableless systems before deciding which way to go!

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3. RADAR

Radar is a very important tool for the fisherman for safety and navigation. In the beginning of this paper we briefly discussed the similar basic operating principles of radars and echosounders, and there are also quite a number of other similiarities. For instance the definition of a radar depends also on antenna beamwidth and transmitter pulse length.

3.1 ANTENNAS

The radar antenna, which compares to an echosounder transducer, has two beamwidths - a rather narrow horizontal beamwidth (in order to obtain a good horizontal or 'angular' definition) and a wide vertical beamwidth (in order to compensate for the movement of the vessel).

Typical beamwidths for X-band radars are:

4 ft. antenna, approximately 2° horizontal beamwidth
5 ft. antenna, approximately 1.5° horizontal beamwidth
8 ft. antenna, approximately 0.9° horizontal beamwidth

The vertical beamwidth for all these antennas is in the order of approximately 20°.

Figure 1 shows the horizontal definition of a 2° beamwidth antenna.

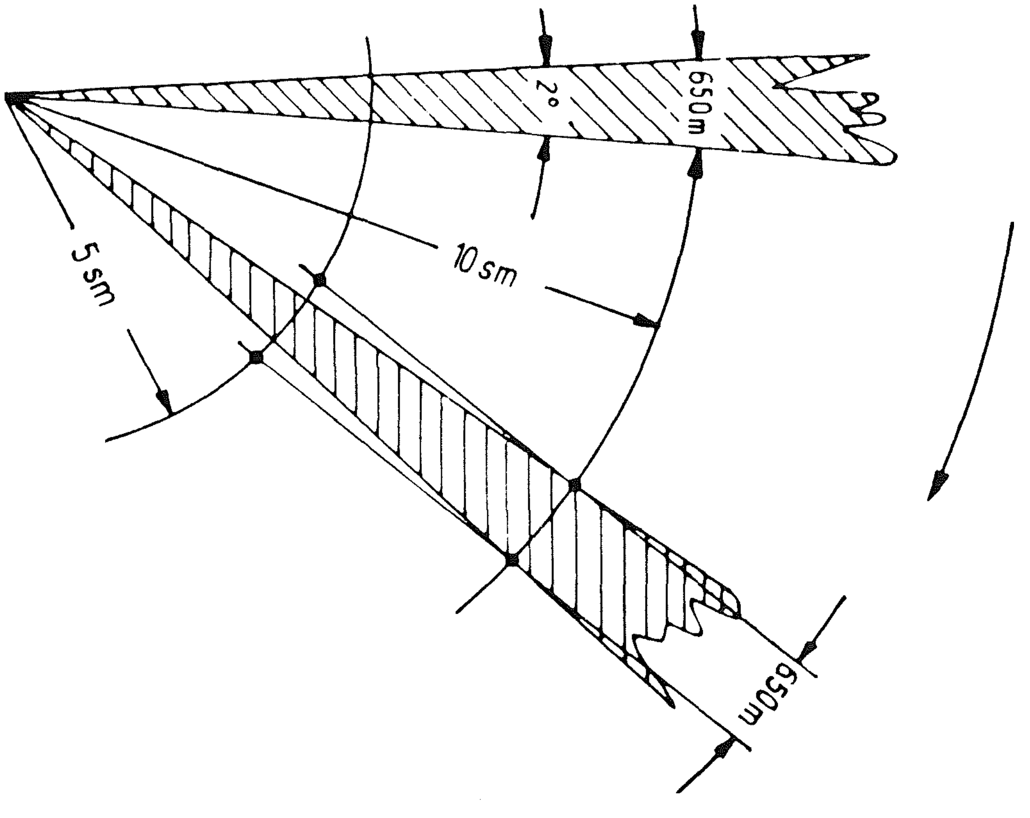


FIGURE 1. ANGULAR DEFINITION OF A RADAR ANTENNA

Figure 1 shows that two objects at a distance of 10 nm have to be at least 650 m (approximately 2000 feet) apart in order to be displayed as two separate targets. The radial definition is determined by the pulse length, as explained in Figure 7 on Page 9. Since propagation speed of electromagnetic pulses is approximately 200,000 times faster than that of sound waves, much shorter pulsedurations have to be used. One typical value is 0.07 microsecond, that means one-millionth of a second, results in a resolution of 15 m, or approximately 45 feet.

3.2 DISTORTION OF RADAR PICTURE

Both horizontal beamwidth and pulse length distort the radar picture to a certain extent. Because a target reflects for as long as it is hit by the radar pulse, radial distortion results (refer to Page 9, Figure 7). It is important to keep this in mind when measuring distance to a target, whether by means of the VRM or with the fixed range rings. The true measurement of target distance is from the center of the PPI to the leading edge of the echo (closest point of target towards center of PPI). Horizontal distortion is caused by a horizontal beamwidth and has already been described.

Figure 2 shows a comparison between a true situation and how it would be shown on a radar.

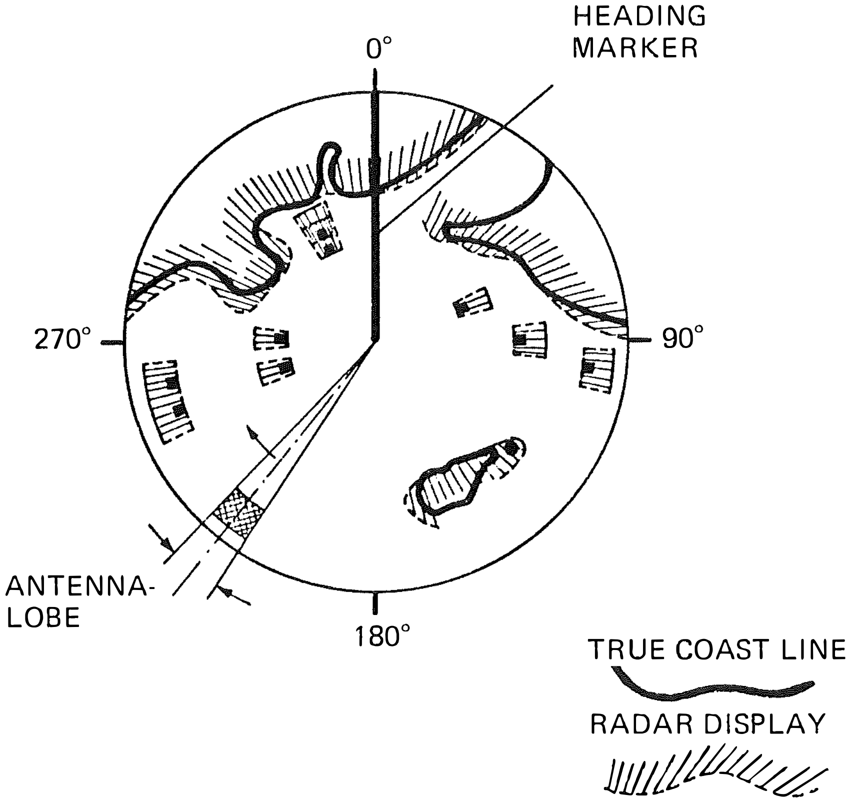


FIGURE 2. COMPARISON TRUE SITUATION - RADAR PICTURE

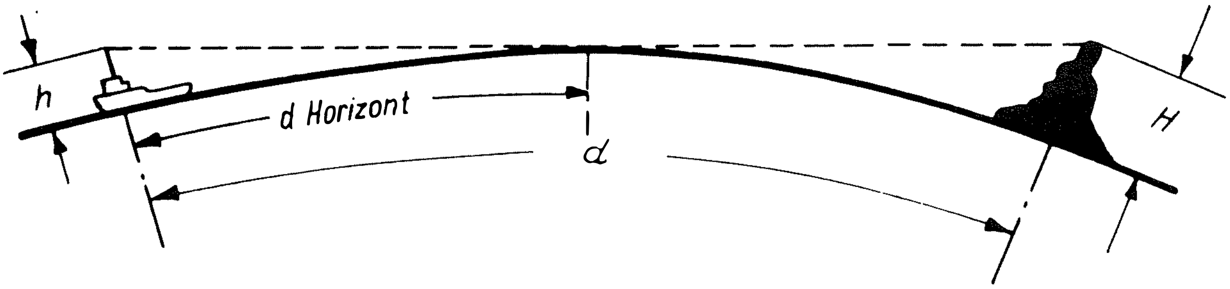
Figure 2 shows how different targets are changed in their presentation. Small targets appear wider (see four targets at bearing approximately 250° to 270°). It also shows how the definition decreases towards the rim of the CRT due to the greater arc of the horizontal beam of the antenna. Inlets and estuaries appear smaller or disappear completely from the picture. (This is the same effect as already described on Page 8, Figure 9 in the Echosounder Section)

Close-together targets which are at the same distance from the center of the PPI can appear as one because of the distortion caused by the horizontal beamwidth of the antenna (see Figure 32 - small target and island at bearing 140°). The target beside the island, either single rock, buoy or small vessel will not be seen. The fisherman using radar should be aware of these facts and should know that horizontal beamwidth, which again depends on the size of the antenna, and pulse length are causing these distortions. In order to obtain a well defined picture the horizontal beamwidth should be as narrow as possible and the pulse length as short as possible.

3.3 LONG RANGE PERFORMANCE

The long range performance of a radar set depends on several factors. These are: beamwidth, height of target and the noise figure of the receiver. As described in the echosounder section, a narrower beamwidth will concentrate more energy into a small area, thus increasing the distance a pulse travels. Naturally the transmitter power influences the reachable range, but it has to be kept in mind that a four-fold increase in power is needed to increase the detection range by 40%. Factors like antenna gain, target height and antenna height have far greater influences on the long range performance.

The radar pulses when leaving the antenna will propagate in a straight line away from the antenna and will not follow the earth's curve. Figure 3 shows the propagation of the radar pulse.



$$d = 2{,}23 \sqrt{h} + 2{,}23 \sqrt{H}$$

FIGURE 3. PROPAGATION OF RADAR PULSES

Figure 4 explains how antenna height and target height influence the detection range. Generally, the higher both are, the better the long range performance.

The following picture gives some typical figures.

TARGET HEIGHT (in meters) $d = 2.23\sqrt{h} + 2.23\sqrt{H}$
depending on Radar Range d (in n.m.) and Antenna Height h (in meter)

Radar horizon n m	Antenna height meter	RADAR RANGE IN N.M. 5	6	8	10	20	24	30	36	40	48	50	60	64	70
4,5	4		0,5	2,5	6,1	48,2	76	130	199	252	379	414	616	708	858
5,0	5		0,2	1,8	5	45	72	125	192	245	370	405	605	696	845
5,5	6			1,3	4	42,5	69	121	187	238	362	395	595	686	833
6,3	8			0,5	3	37	62	112	176	227	347	381	576	665	810
7,1	10			0,1	1,7	33	57	105	167	217	335	368	560	648	791
8,6	15				0,3	26	47	91	149	196	309	341	527	612	752
10,0	20					20	39	80	135	180	288	319	499	583	719
11,2	25					15	33	70	123	166	271	301	475	557	691
12,2	30					12	27	63	112	154	255	285	455	535	666
13,2	35					9	23	56	103	143	241	270	437	515	644

FIGURE 4. RANGE IN RELATION TO ANTENNA AND TARGET HEIGHT

With an antenna height of 12 feet or 4 m, a target at 24 miles must be at least approximately 230 feet or 76 m high before it will be detected. The equivalent figures for a 15 feet high antenna is 220 feet. And last but not least, the so called 'noise figure' influences the radar performance. This noise is electronic noise in the amplifier being generated by its' components. In a transistor radio, for instance, this noise can be heard as a humming sound. The weak echoes returning to the amplifier must be greater than the noise, otherwise they are lost. A number of manufacturers are publishing the noise figure of their equipments. The lower it is, the better; a typical value is 9 dB.

3.4 TRANSCEIVER AND DISPLAY

When comparing the construction of radar equipments, two significant differences will be observed, the transceiver up and transceiver down versions. How do these two versions influence the radar performance? The first one is constructed in such a way that the transmitter and receiver are mounted directly under the antenna. This offers the advantage that very little output power is lost due to the short way from the magnetron to the antenna, and naturally the same applies to the returning echo. Furthermore, the installation is simpler and cheaper. On the other hand it has to be kept in mind that the transceiver has to be serviced, and this can be difficult in adverse weather conditions.

The transceiver down version eases the service problem, but the outgoing pulse and returning echoes have to be transported from the transmitter to the antenna by means of a waveguide or coaxial cable, and energy losses will occur. In order to give a typical figure again, a waveguide run of approximately 45 feet will cause a 50% loss in output power. Therefore the transmitter down versions must have a greater output power.

When looking at the display side, we find the same problems as in an echosounder display – the range to scale ratio. Here it depends on the tube diameter and the smallest usable range. In modern radars, the smallest range is approximately 0.25 of a mile, and the CRT size is at least 9" or larger.

3.5 DISTURBANCES AND IRREGULARITIES

Distrubances and irregularities in radar performance are caused by the following factors:

- Meteorological effects (rain, snow, hail)
- Reflections caused by the sea (sea clutter)
- Other radars working on the same frequency
- Propagation irregularities
- Obstructions on the vessel

Meteorological effects (rain, snow or hail) reflect the radar pulses and appear as milky areas on the radar PPI. Figure 5 shows radar presentation of a rain shower.

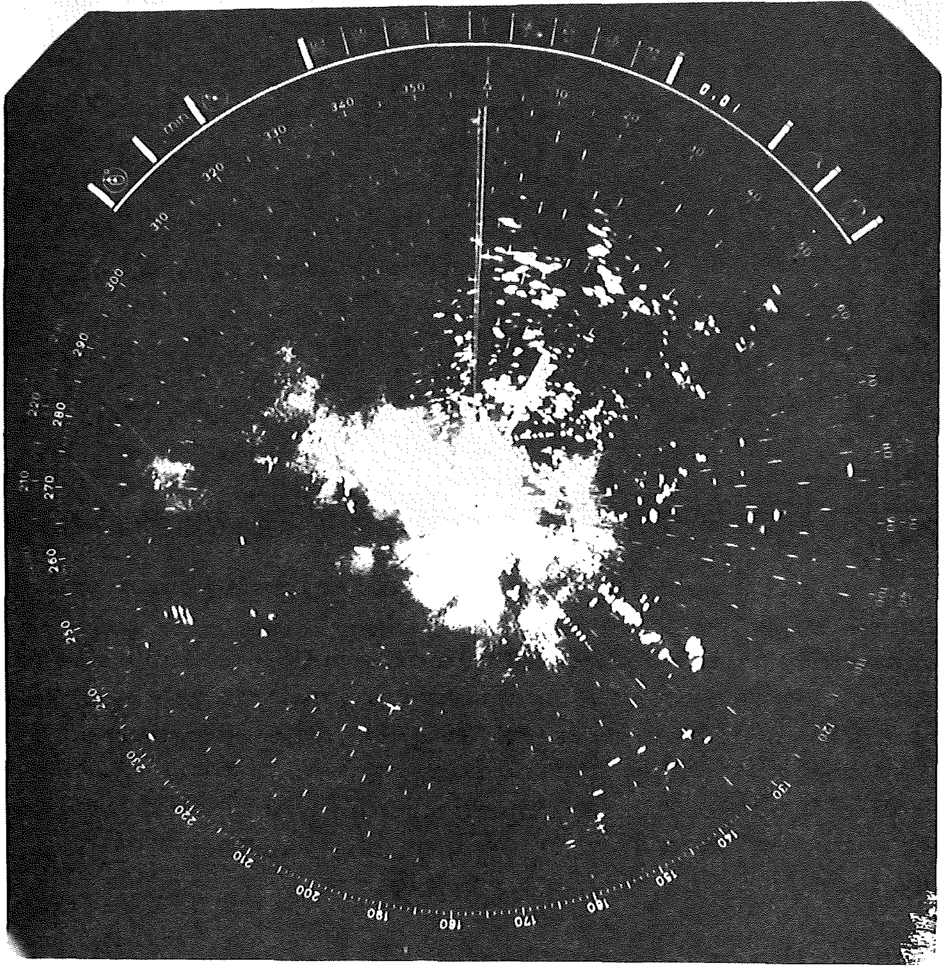


FIGURE 5. RAIN INDICATION ON A PPI

Since quite a lot of the radiated energy is absorbed by the surrounding rain, small targets like buoys, spars or even small boats which are in the shower or behind it might be lost. Almost all radars have a control by which this disturbance can be reduced to a certain extent, without suppressing wanted echoes (FTC - anti-rain clutter control). Reflections by the sea, or "sea clutter", can be recognized as an area of varying echoes in the center of the PPI, as shown in Figure 6.

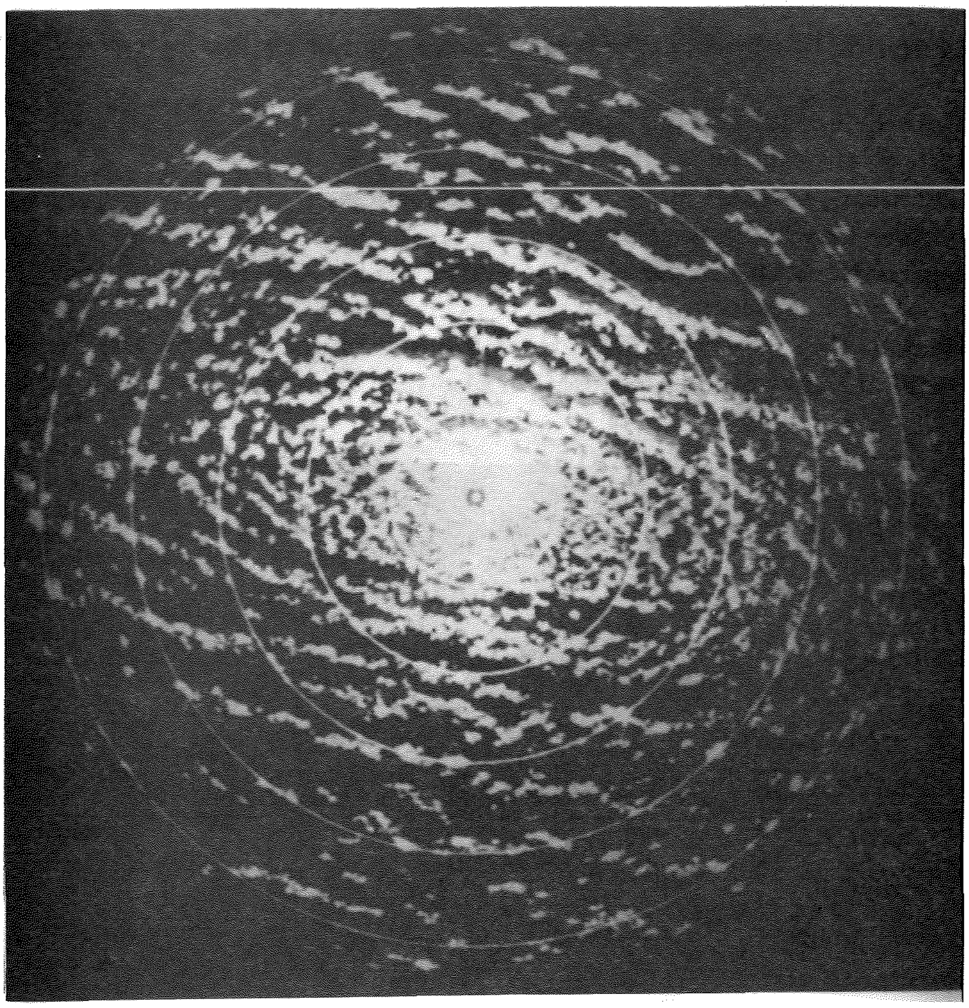


FIGURE 6. SEA CLUTTER PRESENTATION

These echoes normally have a circular shape around the center, but sometimes the direction of wind and/or swell can be recognized by an extension of these echoes in a particular direction. The intensity of these disturbances depends upon the roughness of the sea and the height of the antenna. The higher the antenna is mounted on the vessel, the more sea clutter will be picked up. The so called "STC" (or anti-sea clutter control) will suppress these unwanted echoes. It has to be used with care, especially on small ranges, because small targets (which the skipper actually wants to detect) might also be suppressed.

Other radar sets working on the same frequency will cause very typical interferences. Figure 7 shows this effect.

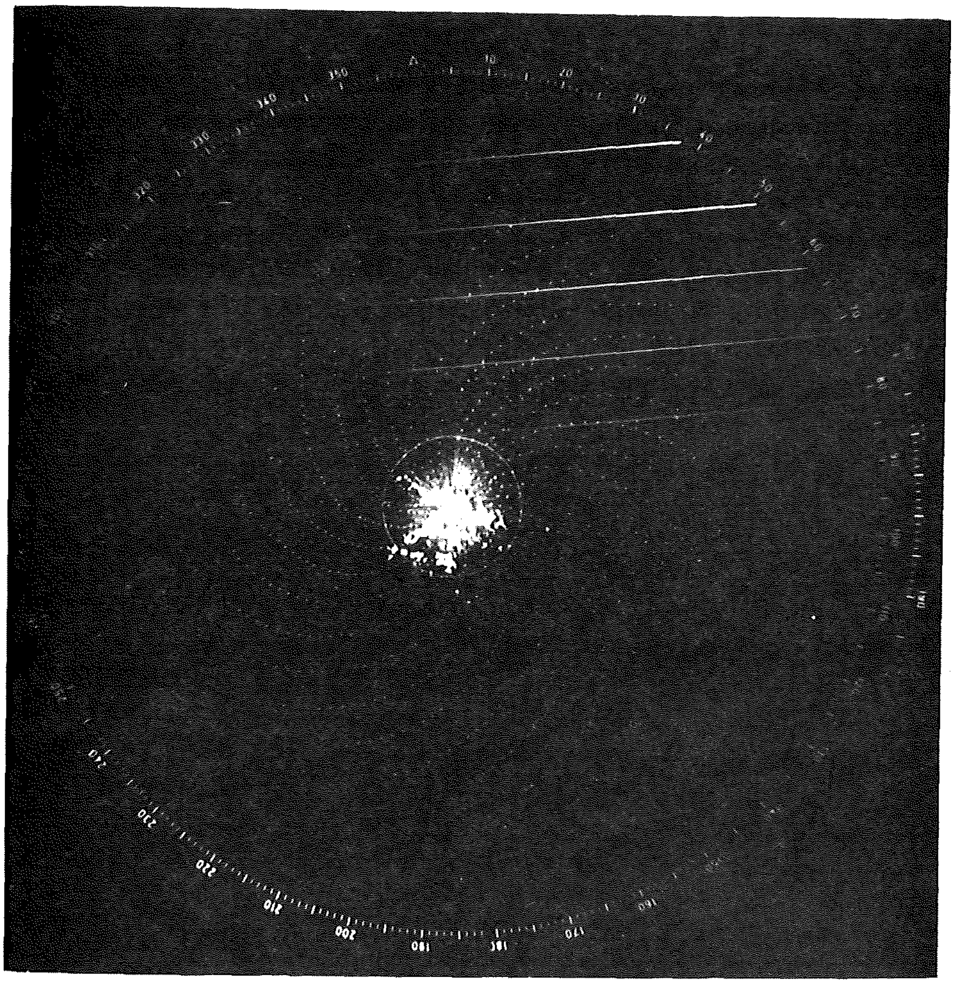


FIGURE 7. RADAR INTERFERENCE

Small dots will be painted on the screen traveling either straight or in a curve towards or out of the center of the PPI.

Propagation irregularities are caused by special meteorological conditions. Special atmospheric layers may cause a diffraction of the radar beam either upward and away from the surface, thus reducing the obtainable radar range; or diffracting the beam towards the earth, resulting in extended ranges. These phenomenon occur very seldom, and don't last too long.

Obstructions on the vessel (funnels, super structures, masts, etc.) may cause so called 'ghost echoes' and/or sectors of reduced radar visibility. Sectors with reduced visibility are easy to recognize. On a day with 'good' sea clutter reception, the STC control should be switched off. These sectors will then be shown as shadows on the screen, beginning in the center of the PPI. A check like this should be done as soon as possible after the installation of a radar because the skipper should be aware of the following fact; when navigating in a fog, dangerous targets may 'suddenly' appear on the PPI, because the own vessel made a course change. These targets could be hidden by a shadow sector and become visible only after the course change of the own vessel. Another irritating factor is the so called 'ghost echoes'. Here one target may produce two echoes on the screen at completely different bearings. Let's assume a ship is picked up as a target at a bearing of 10°. The antenna turns and is pointing aft, and for example, part of the radar energy now emitted is hitting the crossbar of the aftermast or a superstructure. These radar pulses are now reflected forward, are caused to travel through the air, hitting this particular ship and are reflected back to the crossbar or superstructure and then back into the antenna (remember - radar pulses travel with the speed of light!). This will cause another echo of the same ship, but at a bearing of approximately 170°! The distance to both echoes will be the same. Now, let's assume the located vessel is approaching on a parallel course. On the radar the true blip will move parallel to the headflasher towards the center, the ghost echo will also move towards the center from aft with the same speed. When the vessel is abeam, both true and ghost echo will merge and only the true echo will move on, and the ghost echo will disappear. The ghost echo may even move forward if there is more than one reflector available on the vessel. This can be very irritating and may result in navigational errors, if the radar is not observed constantly. The only solution to this problem is to identify these reflecting areas and change their angles toward the radar antenna, or shift the antenna to another place. Since large reflecting areas like superstructures, crossbars, etc., are only found on larger ships, this problem will most likely not occur on small vessels.

3.6 SUMMARY, RADAR SECTION

To summarize the radar section, the following highlights are repeated:

1. The range to scale ratio indicates the versatility of the radar - it depends upon the smallest range and the CRT size.

2. Beamwidth and pulse length determine the resolution. If frequently navigating in narrow waters - look for the highest possible definition.

3. Long range performance does not rely only on output power. Before installing high power equipment, look at your antenna height, the height of targets which often will be used as navigational aids (the coastline), and look at the noise figure.

4. Serviceability should decide whether a transmitter up or transmitter down version is chose, not the initial installation costs.

4. FINAL REMARKS

Finally, a remark on the performance of all electronic equipment on board fishing vessels, and especially on small ones, has to be made. No matter how good and sophisticated the equipment may be, its' performance is also very much influenced by these two factors:

1. The installation

2. The power supply of the vessel

A great deal of good equipment has been spoiled due to mistakes made during the installation, and it has proved very expensive to correct them later.

Lack of electrical power is common in older vessels. The power consumption has increased over the years by installing more and more equipment, however the electrical potential has not been increased accordingly. Also, many vessels have inadequate wiring.

Every fisherman should be aware of these facts, otherwise he will lose money and time in unnecessary service and repairs.

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Attachment 5

New South Wales State Fisheries

THE KAPALA MIDWATER TRAWLING SURVEY IN NEW SOUTH WALES

T. B. Gorman & K. J. Graham

THE KAPA MIDWATER TRAWLING SURVEY IN NEW SOUTH WALES—1973-76

by T. B. Gorman and K. J. Graham
New South Wales State Fisheries
Sydney, N.S.W.

1. ABSTRACT

A midwater-trawl resources survey was carried out in southeastern Australian waters during 1973–74 and for short periods during 1975 and 1976 by the New South Wales State Fisheries research vessel *Kapala*.

The application of this technique for catching fish was tested for local conditions and fish stocks. Large catches were made periodically of such species as nannygai, jack mackerel, anchovy and pilchards. However the availability of species vulnerable to midwater trawling in New South Wales was found to be unpredictable and it was concluded that any future commercial use of the method would have to be on an opportunistic basis.

2. INTRODUCTION

The establishment of a viable pelagic fishery is dependent upon the development of suitable fishing methods. Purse seining and poling can be used to capture pelagic fish, and midwater trawling can substantially increase the catch by exploiting pelagic and semi-pelagic species schooling below the surface.

Although data accumulated over many years recorded the presence of large unexploited stocks of pelagic fish in New South Wales waters, large scale fishing had, however, been virtually confined to a few species which were vulnerable to purse seining or pole fishing.

Incidental observations by F.R.V. *Kapala* in New South Wales waters indicated that there were stocks of fish occurring in midwater or just off the sea bed over a depth range from 20 to 200 fathoms. It was believed that some or all of these fish could be caught by midwater trawling.

In New South Wales, midwater trawling has several possible economic and technical advantages over purse seining.

(1) The basic principles of trawling are already well known. Fishermen could, therefore, easily adapt their existing vessels to midwater fishing.

(2) Midwater gear is relatively simple and its use would not normally affect the handling and stability of existing vessels, nor their operation as conventional bottom trawlers.

(3) The overall cost of outfitting for midwater trawling is about $7,000–$8,000; probably about 7 to 8 per cent of that for purse seining.

(4) Midwater trawling is less affected by weather conditions than is purse seining. Therefore, the trawlers would have the advantage of an increased number of fishing days.

More recently the high capital outlay, operational costs and the uncertain catches by purse seining have precluded any real continuity of development of this method of fishing in Australian waters. In view of this and the apparent economy and effectiveness of modern midwater trawling, it was considered that this method of fishing should be tested and adapted if necessary for use under local conditions and for local stocks. This testing would then be followed by exploratory fishing to obtain data on the prospects of establishing fisheries for the more likely species.

3. GEAR

3.1 Vessel

The New South Wales State Fisheries research vessel *Kapala* is 25 m l.o.a. and approximately 240 tonnes displacement.

The main engine is a 16 cylinder 71 series GM driving a Liaaen AG45 C.P. propeller through a 4.76:1 gearbox. The maximum bollard pull is 6 400 kg (14 000 lb) at 460 h.p.

The main winch is a Marco model 1750 with a line pull ranging from 16 000 kg (35 000 lb) bare drum, to 5 600 kg (11 800 lb) full drum with the motors in parallel. In midwater trawling the main winch must have sufficient power to heave in the net at normal towing speeds, otherwise, the vertical manoeuvreability of the net is much reduced.

The *Kapala* net drum has the following dimensions: the outer flanges have a diameter of 1.5 m (5 ft); the original inner flanges were portable and had the same diameter; the core of the drum is 46 cm (1 ft 6 in) in diameter and the distance between the outer flanges is 2.2 m (7 ft). The capacity of the drum is 3.6 cu m (128 cu ft), which is more than adequate to handle the nets used so far. Although the drum was recently divided by split flanges to carry two trawls during bottom trawling, the 140 cm (4 ft 6 in) wide section to port still has sufficient capacity to carry the 800 mm midwater trawl.

3.2 Nets

The net plan of the 400 mm x 434 mesh circumference Hermann Engel midwater trawl used initially by *Kapala* is shown in figure 1.

This particular net is an improved version of earlier Hermann Engel designs and was at that time (1973–74) being used by Scottish fishermen as either a single boat trawl, or a pair trawl to catch herring and sprats.

It is a four panel net and is made entirely from high tenacity nylon (polyamide). To reduce towing resistance, the wings and forward panels are constructed of large meshes of fine twine and the body of the net is very long to obtain smooth water flow characteristics through the netting.

The headline length is 34.5 m (112 ft) and the footrope length 41 m (133 ft). The theoretical horizontal opening of this net is approximately 20 m (66 ft) while the vertical opening is about 15 m (49 ft).

The headline, winglines, and footrope are of 18 mm ($\frac{3}{4}$ in) diameter braided nylon, which is formed into hard eyes by a "Talurit" splice at each of the four wing ends. 45 x 20 cm (8 in) floats of a special design are attached to the headline in nine groups of five. These floats are attached through a central hole to one another and to the net. Each group of five floats is encased in a cover of strong netting to prevent the floats from becoming entangled in the large meshes (figure 3).

45 kg (100 lb) of 6 mm ($\frac{1}{4}$ in) diameter chain wrapped in strips of 40 mm ($1\frac{1}{2}$ in) mesh netting is seized to the lower bosom and adjacent footrope sections of each lower wing. It is necessary for the chain to be enclosed in either netting or fire hose to prevent it tangling in the net.

The 400 mm trawl was found to be not really suitable for the *Kapala*:

(1) The net was too small to take advantage of the power available on *Kapala* and since the success of midwater trawling depends largely on using the biggest possible net, this was considered to be its most important drawback.

(2) The headline and footrope were braided nylon, and they tangled too easily during shooting and hauling.

(3) The 210/72 ply nylon twine used in the 400 mm mesh sections was not strong enough (breaking strength 97.5 kg) for many working conditions.

(4) Originally, there was no small mesh section at the centre of the headline within which to mount the netsonde.

The second net incorporated all the modifications found necessary as a result of previous experiences since commencing the programme. This model is a standard Engel 308 mesh by 800 mm circumference net used by European pelagic trawlers (figure 2). It is considerably larger, i.e, its stretched mesh circumference is 42 per cent greater than the smaller net; the 800 mm mesh sections are made from 210/180 ply nylon which has a breaking strain of 210 kg; the headline and footrope are made from combination wire rope; the centre of the headline is without floats and is fitted with a small mesh panel for the netsonde; and generally the net is of stronger construction all round. Its vertical opening is between 12 to 16 m (40 to 55 ft) depending on towing speed.

3.3 Weights

Unlike bottom trawls, pelagic trawls are "suspended" from the headline, therefore the main ballast weights of 150 kg (320 lb) each, are located at the lower wing tips. The function of these weights is to obtain the vertical opening of the net by pulling the footrope away from the headline. On conventional stern ramp trawlers without a drum, these weights usually consist of rectangular steel blocks shackled together in series between the lower leg of the bridle and the lower wing tip. Alternatively, each weight may consist of a single detachable block of steel.

When using a net drum the weights may be either detachable or specially designed to wrap around the core of the drum with the net.

For each lower wing of our net we initially used 4 oval shaped lead weights, each measuring 28 cm x 15 cm (11 in x 6 in) in diameter cast directly onto 12 mm ($\frac{1}{2}$ in) galvanized chain. The length of chain was 3.5 m (11 ft 6 in). Of this 1.4 m (4 ft 7 in) was left clear of weights so that the chain would slip easily into the slots on the inner flanges when winding on the net. The spacing between each weight was 5 links of chain.

The original oval-shaped lead weights were found to be individually too heavy for convenience during shooting, and too closely spaced on the chain for proper storage on the drum. The drum was thrown out of balance by the close concentration of heavy weights on one side. As a result, the drum got out of control on occasions and the resulting slack weights caused serious tangles.

Two new sets of weights consisting of 15 cm (6 in) diameter lead spheres were cast directly onto 12 mm ($\frac{1}{2}$ in) chain and distributed evenly over the full length of the chain. This solved both problems of drum imbalance and handling during shooting. A tarpaulin was wound onto the drum immediately following the weights to ensure complete separation between them and the net.

3.4 Trawl Doors

The pelagic Suberkrub trawl doors (figure 4) supplied with the net are fabricated entirely from steel and measure 2.5 m (8 ft 4 in) in height by 1.2 m (3 ft 11 in) in length. The weight of each door is about 300 kg (660 lb) and the towing brackets are above centre so that any increase in towing speed results in positive lift.

The upper bracket is best suited for trawling in deep water as the additional lift is very useful for quickly raising the net. The lower bracket is essential for trawling in shallow water as it reduces the likelihood of the doors broaching the surface and planing along the top.

The characteristic curved cross-section of these doors gives much greater shearing power and reduced drag compared with conventional designs.

3.5 Bridles

As delivered, the bridles and hook-up arrangements between the sweeps and the doors were not intended for operation with a net drum and had to be modified. All connections between the various components were made with "Hammerlock" shackles which have no protrusions and are less likely to tangle in the net.

3.6 Netsonde

The original netsonde was a Furuno FNZ6.B. This model is a depth sensor with a temperature indicator, and transmits data acoustically to a towed paravane receiver. The display is by a meter readout and by a line of dashes printed on the recording paper of the Furuno New-Videograph echo sounder (see figure 13). This netsonde does not provide a dynamic display of the fish in relation to the position of the trawl net, as do more recent models of the echo sounder type, but simply enables the net to be manoeuvred to the depth at which the fish were first detected by echo sounder.

During 1974 the Simrad FL Trawlink was installed. This was a recently developed netsonde using acoustic transmission between the net and the trawler. The signal can be received by either a hull mounted receiver or towed paravane. Our netsonde used the latter (figure 5).

The net mounted transceiver unit of the Trawlink (figure 6) possesses three separate transducers; one sounds upwards, another downwards, while the third transmits the collected data back to the towed receiver. Figure 7 shows a typical printout from the display.

This unit has considerable operational advantages over the depth sensing system we had used previously.

(1) The depth sensor requires to be calibrated regularly by being lowered down to a range of preselected depths. This is time consuming and often inconvenient.

In the case of the trawl link the calibration is affected by a control on the cabinet and takes only seconds.

(2) With the Trawlink, the vertical mouth opening of the trawl net can be read directly off the recording, and fish traces are recorded relative to the mouth of the net, i.e., above the headline, below the footrope or inside the mouth of the net. This feature is particularly important as it enables the development of fishing tactics to counter any apparent avoiding action by fish. It also enables an assessment to be made of the quantity of fish entering the net.

(3) The net can be trawled at a specific depth with greater precision, e.g., it can be towed so that the footrope just skims the bottom. This was impossible with the depth sensor as the mouth opening was not known precisely although it was assumed to be about 7 fathoms.

(4) The transceiver unit is contained in a very compact faired fibreglass housing which does not tangle in the large meshes of the midwater trawl mouth. (A similar housing was made for the Furuno transmitter for this purpose.)

3.7 Fish Detection Equipment

Kapala is equipped with a Simrad SB2 sonar which has a maximum working range of 2 500 metres. Two echosounders are also fitted, these are:

(1) Koden multi-stylus SR7-871A dual frequency sounder operating on 50 and 200 kHz.

(2) Furuno New Videograph FNV.2500 operating on 28 and 200 kHz.

4. METHODS

4.1 Location of Fish

Searching for fish was conducted randomly over the continental shelf and upper continental slopes along the whole of the New South Wales coast and into eastern Bass Strait. As the programme progressed, however, more effort was directed towards areas where fish had previously been found. A ship's speed of about 8 knots was maintained and as well as a visual lookout for surface fish; the sonar and echosounders were operated continuously for subsurface fish detection.

4.2 Fishing Tactics

Sonar was essential for locating schooling species such as jack mackerel, yellowtail and pilchards. After detecting a school by sonar, its size and depth was determined by echosounder. We then steamed away from the fish until there was enough sea room to come about, shoot and settle the gear at the depth of the school. During this phase, the school's position was continuously tracked by sonar.

As the *Kapala* passed over the school last minute adjustments could be made to the net depth if the position of the fish was shown by the sounders to have altered, and after the net had passed through the fish it was hauled. Sonar was not essential for scattered fish such as nannygai or light fish which cover wide areas and are readily detected by echosounder.

4.3 Aerial Surveillance

An aerial survey for pelagic fish over the continental shelf between Sydney and Queensland was conducted in conjunction with the midwater trawling programme from November, 1973 to March, 1975. During this period CSIRO surveyed southern New South Wales waters as part of their "Jack Mackerel Programme".

5. RESULTS

5.1 Aerial Surveillance

The aerial surveillance flights during the summer were badly disrupted by cyclonic storms and their effectiveness was considerably reduced. However, even when conditions were favourable we found no evidence of large quantities of small pelagic fish which had been recorded in the past.

During the winter large stocks of frigate mackerel were sighted off the mid-north coast with the main concentrations being around the Solitary Islands and between Cape Hawke and Port Macquarie. Several tonnes were subsequently caught by the purse-seiner *Maria Luisa*. However it is unlikely that these fish could be caught by midwater trawling.

5.2 Midwater Trawling Catches

Full details for all cruises have been published by "Kapala Cruise Reports" (Nos 15, 16, 19–23, 27, 29).

Three species, nannygai, jack mackerel and anchovy were caught in quantity during the programme, while smaller catches were also taken of light fish, yellowtail, pilchards. blue sprats and gemfish. Each species is discussed separately with respect to distribution and the catches made by midwater trawl.

5.2.1 *Nannygai*

Sizeable concentrations of this species were found in two main areas:

(i) Bate Bay.

(ii) Jervis Bay—Montagu Island.

During August, 1974, nine trawls were made through scattered nannygai and jack mackerel off Bate Bay. About 12 tonnes of nannygai and 3 tonnes of jack mackerel were caught with an average total catch-rate of approximately 2.7 tonnes per hour. These fish were easily caught by aiming the headline at the densest concentrations, and it was found that the catch rate rose with increased towing speed. Although the netsonde showed heavy recordings of fish at the mouth of the net when towing at 2 knots, the relatively small catch indicated that the fish recorded were in fact simply swimming along beneath the headline. Later tows at about 3 knots caught larger quantities of fish but gave a much lighter netsonde recording as the fish were apparently passing quickly into the net. Figure 8 shows a typical echotrace of the mixed nannygai-jack mackerel schools in the area.

In March–April, 1976 we found similar concentrations of nannygai off Bate Bay. On the first day the fish were scattered and only 700 kg of fish were caught from four shots totalling 145 minutes trawling time. This comparatively low catch rate was probably because the small 400 mm net was in use, whereas the 800 mm net had been used previously off Bate Bay.

At nightfall the fish rose up in the water column and dispersed, and towards dawn began to reschool and descend towards the bottom. At dawn we made a 3 tonne haul for 1 hour's trawling, and later at dusk, a comparative trawl with the CSIRO research vessel *Courageous* on apparently scattered fish resulted in 1.2 tonne catch for *Kapala's* 400 mm net and about 3 tonnes for *Courageous* using the larger 800 mm net. It would seem therefore that these supposedly dispersed schools warrant further investigation.

Heavy concentrations of nannygai were also found early in the programme along the edge of the shelf between Jervis Bay and Montagu Island. Some good catches were made with short tows when the fish were schooling close to the bottom during the day. These schools were often found associated with what appeared to be dense schools of small "krill" (figure 9).

On several cruises nannygai were found at night widely scattered in midwater over much of the shelf in the Ulladulla-Batemans Bay region and they appear to be one of the most prolific species along the south coast. It became apparent that by adopting the strategy of shooting on nannygai after they had schooled closer to the bottom during the day, more consistent catch rates could be attained. This was demonstrated in April, 1976 when we took 5 tonnes of large nannygai in a 25 minute early-morning shot east of Brush Island (figure 10).

It is also probable that very large catches of nannygai could be taken by a high opening bottom trawl when they are schooled close to the bottom.

5.2.2 *Jack Mackerel*

This species was found in several schooling patterns. These included dense plume shaped schools, a cloud-like school near the bottom, scattered fish through the water column, and scattered small schools or individuals mixed with other species.

Dense plume-shaped schools of jack mackerel were found off Jervis Bay in 1973 and just to the south of the mixed nannygai/jack mackerel concentrations off Bate Bay during August, 1974 (see above). This type of school is quite distinctive on the echosounder with its shape and long "tail" caused by reverberation (figure 11). Several schools were detected by sonar south of Bate Bay, but we only managed one successful shot of 4 tonnes from a single school. At the other attempts, fish avoided capture by sounding beneath the footrope or moving off to one side. Undoubtedly the success rate could be improved with practice.

A very large but less dense school of mackerel (figure 12) was found off Cape Howe in September, 1974 from which 2.5 tonnes were taken for 30 minutes' trawling. On several cruises, jack mackerel were found scattered in midwater (figure 13) but we failed to catch any quantity and the netsonde showed the fish actively actively avoiding the net.

Jack mackerel were often found mixed with other species. Up to 40 per cent of the total catch in the trawls off Bate Bay in August, 1974 were jack mackerel.

Significant quantities were also caught from anchovy schools, and comprised about half of a 0.5 tonne catch of juvenile jack mackerel and yellowtail taken in Twofold Bay in late 1975.

5.2.3 *Anchovy*

Heavy concentrations of anchovies were found at the entrance of Twofold Bay in October-November, 1974, and like nannygai they proved very easy to catch. The fish were in shallow water (14–25 fathoms) and extended upwards to within a few fathoms of the surface (figure 14).

The fish sounded as the net approached, so the trawl was fished with the footrope very close to the bottom. Very good catches were made despite the fact that only the last 12 metres of the net consisted of 20 mm mesh and escapement through the 80 mm mesh which preceded it was obviously high. The catches ranged in size from 400 kg to an estimated 6 tonnes and averaged just over 5 tonnes per hour. This was the only locality where anchovies were found in quantity although several small schools were found inshore south from Twofold Bay, and also wider out on the shelf in eastern Bass Strait. However, these schools moved too quickly to be caught by midwater trawl.

Anchovy failed to appear the following season which coincided also with a poor season at Lakes Entrance where purse-seining for this species has been conducted for some years.

5.2.4 *Pilchards*

Small catches of pilchards were taken along the whole New South Wales coast. In Byron Bay some pilchards were taken with yellowtail. Mixed catches of pilchards and blue sprats were caught in Stockton Bight from small schools found inshore; the catch rate ranged from 4 kg to 1 000 kg for 30 minutes' trawling. The largest catch of pilchards was taken well out on the shelf east of Cape Howe when 550 kg of pilchards and 250 kg of anchovy were caught from a single school.

5.2.5 *Yellowtail*

Evidence of large quantities of yellowtail in Byron Bay were seen during two cruises to that area in July/August, 1973 and 1974. On the first cruise some yellowtail were mixed with the pilchard catches. However in 1974, yellowtail were found dispersed over a wide area at night and catches of 280 and 400 kg per hour were made. Quite dense pyramid shaped schools were also found by sonar during the day (figure 15) but a gear malfunction prevented us fishing these schools.

A mixed catch of 850 kg of juvenile jack mackerel and yellowtail was taken in Twofold Bay in December, 1975.

5.2.6 *Light Fish*

Probably one of the most important discoveries during the programme was the positive identification of large stocks of light fish along the edge of the continental shelf from at least as far north as Newcastle, south into Bass Strait. Echo recordings had been made of these fish as far back as 1971 and because of their continuous distribution southwards it was important that their identity be established. Our surveys and subsequent ones by the CSIRO research vessel *Courageous* off S.E. Victoria and Tasmania, appear to indicate that light fish may constitute the biggest and most consistently available pelagic fish resource in South East Australia. They are small, measuring 25–40 mm in length and with a body depth of only 5–10 mm (figure 16). They are usually found during daylight at the edge of the shelf and out over the upper continental slope, extending upwards in the water column sometimes to the 60 fathom level. They can occur as a continuous distribution or may be broken up into discrete schools and some layering may be evident (figures 17, 18). Our catches have been small because of the relatively large size of our codend mesh (20 mm). However, further investigations on the vulnerability of these fish to midwater trawling will be carried out when we take delivery of a special codend section for the 400 mm net.

5.2.7 *Gemfish*

Gemfish have been caught on the continental slope off N.S.W. since 1972. The fishery is a winter one and was originally confined to a small area between Sydney and Wollongong, but by 1976 had extended south to Ulladulla. Currently these fish are caught by bottom trawl during daylight, because at night they tend to disperse into the water column.

A single trawl for gemfish was made at night in July, 1974 through fish detected near the bottom in 135 to 145 fathoms. About 250 kg of gemfish were landed but the fish had severely damaged the codend and many were seen floating away from the net as it was hauled. A special codend has since arrived and with the acquisition of a new Koden netsonde which has a greater depth range than the Simrad Trawlink, further experimental trawling will be conducted during subsequent gemfish seasons.

The significance of this operation was that it proved that gemfish could be detected and caught in midwater, so if the additional trials are successful, it is possible that the fishery could be conducted on a 24 hour basis rather than confined to daylight as at present.

6. SUMMARY

The failure of jack mackerel to appear in quantity in southern N.S.W. for three successive seasons (1973–74–75) was a big disappointment not only to ourselves but to the other government departments and private fishing companies who were engaged jointly in the programme. The total effort involved in terms of vessels and aircraft was probably one of the biggest operations ever mounted in Australia, but it only succeeded in demonstrating how little is really known about our fish resources. However, we did make large catches of mackerel when suitable concentrations were found indicating that significant quantities of this species could be caught off N.S.W. by midwater trawl during good seasons.

So far we have succeeded in catching nannygai and anchovies in commercial quantities, but only the former species seems to be consistently available. Light fish could almost certainly be caught in large quantities with the appropriate trawls and their wide distribution and apparent abundance indicate to us that they are worth more investigation. Gemfish have proved to be widely distributed and are now an important species in N.S.W., so further investigation of the vulnerability of this species to midwater trawling is certainly warranted.

Midwater trawl fisheries overseas are frequently seasonal and often opportunistic, which necessitates that vessels need to carry other fishing gear as well as a midwater trawl. The most usual combination is bottom and midwater trawls. The situation in N.S.W. waters appears similar and there are periods when large catches of pelagic and semi-pelagic fish could be made if vessels were equipped to take advantage of these occurrences.

While gemfish and large nannygai are in demand as table fish, most other species caught while midwater trawling, including the smaller nannygai, would be more appropriately used as industrial fish. In this regard the problems associated with trying to establish a fishmeal industry in Australia are well known. The logical alternative therefore is fish silage production or liquid fish protein (L.F.P.). Unlike fishmeal, L.F.P. does not require high capital investment in plant nor does it require trained engineers and skilled technical staff to supervise production. There are also no problems with storage or smell. L.F.P. is well suited to trawl fisheries where supplies tend to be fairly low in volume and erratic. Experience overseas, particularly in Denmark, have shown that L.F.P. can be used to advantage as animal feed. We intend therefore to continue our midwater trawl investigations and examine the nutritional value and likely economics of L.F.P. production from the various species.

APPENDIX

Species referred to in the text are:

Jack mackerel	*Trachurus declivis*
Yellowtail	*T. mccullochi*
Nannygai (red fish)	*Centroberyx affinis*
Light fish	*Maurolicus meulleri*
Anchovy	*Engraulis australis*
Pilchard	*Sardinops neopilchardus*
Blue sprat	*Spratelloides robustus*
Gemfish	*Rexea solandri*
Frigate mackerel	*Auxis thazard*
Krill	fam. Euphausiidae

FIGURE 1 — ENGEL PELAGIC TRAWL — 434 MESHES CIRC. BY 400 M/M STRETCHED MESH

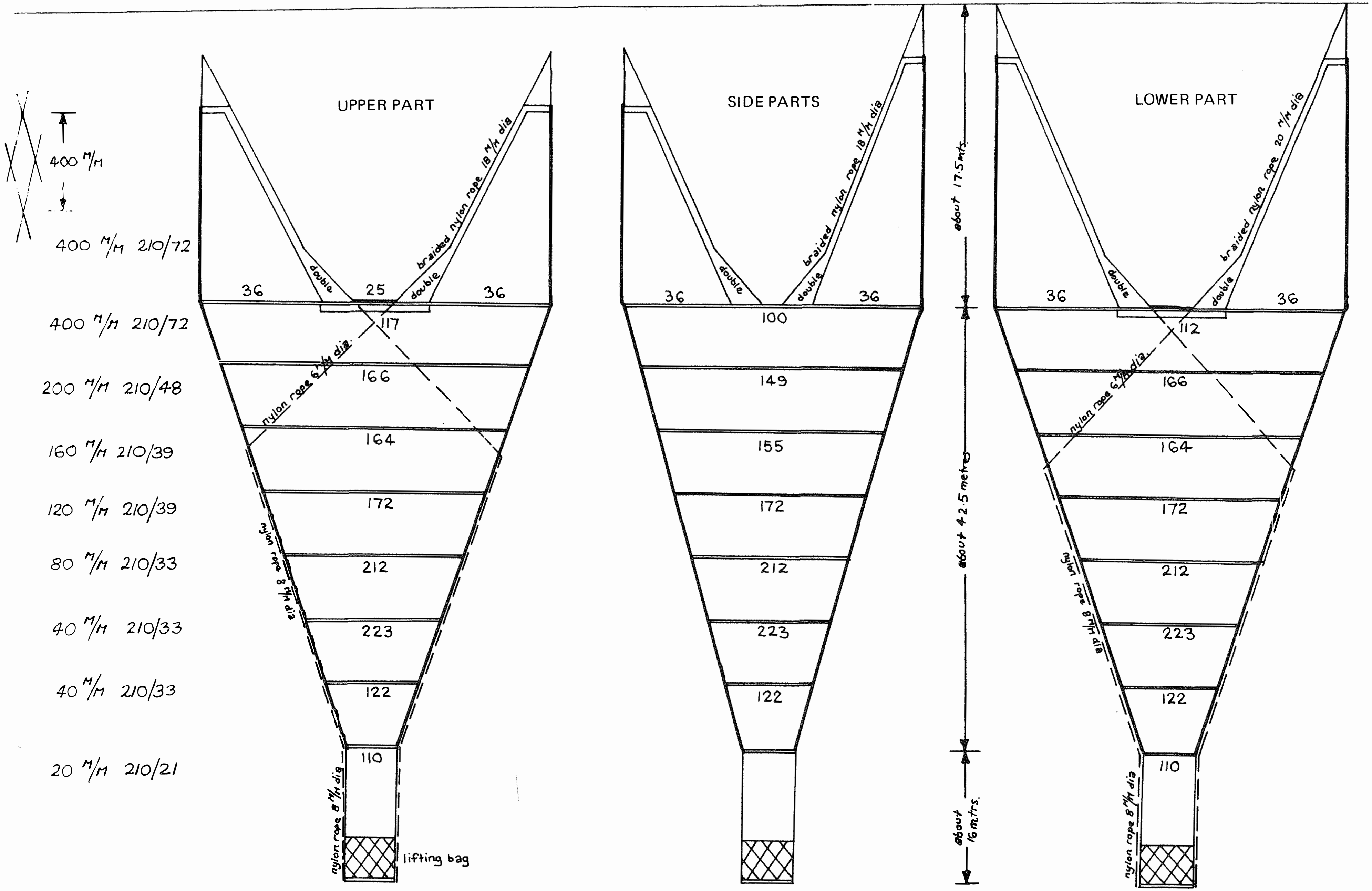
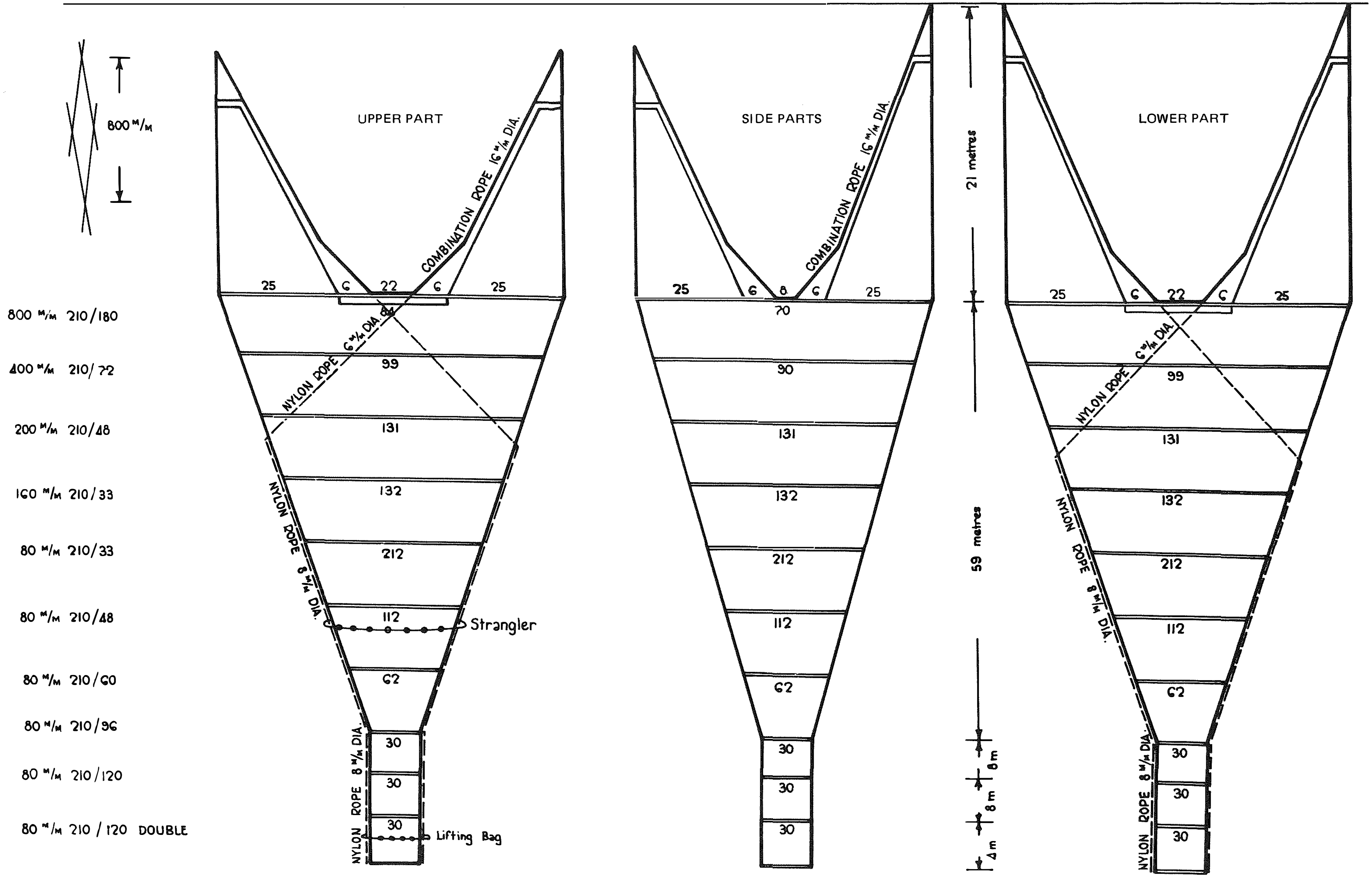


FIGURE 2 — ENGEL PELAGIC TRAWL — 308 MESHES CIRC. BY 800 M/M STRETCHED MESH



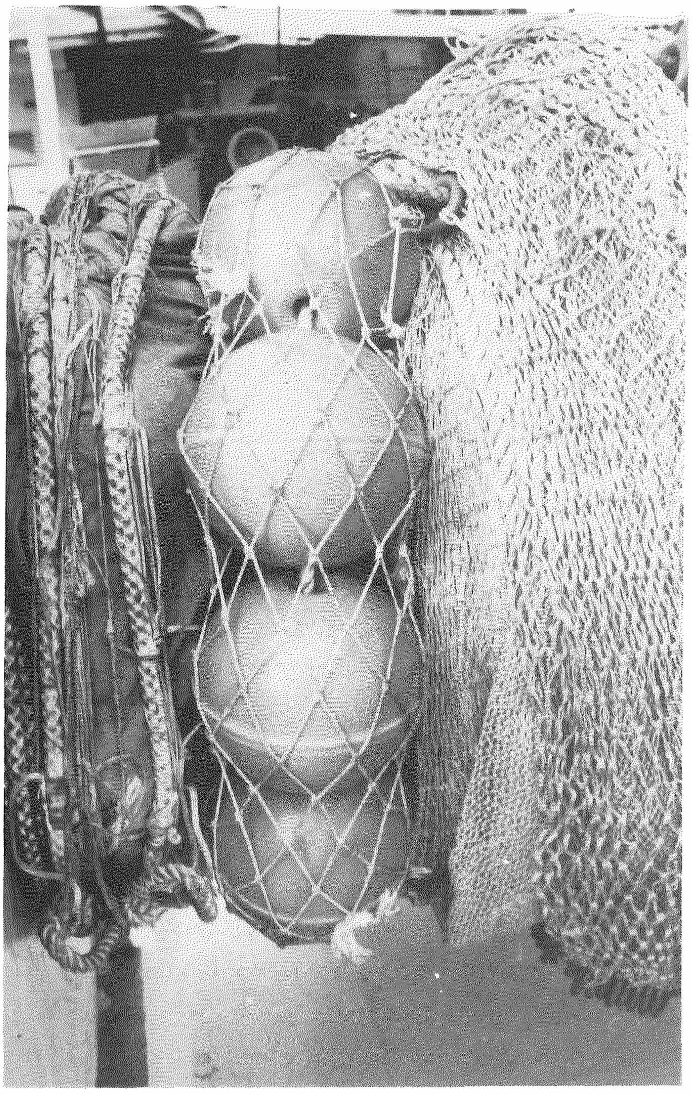
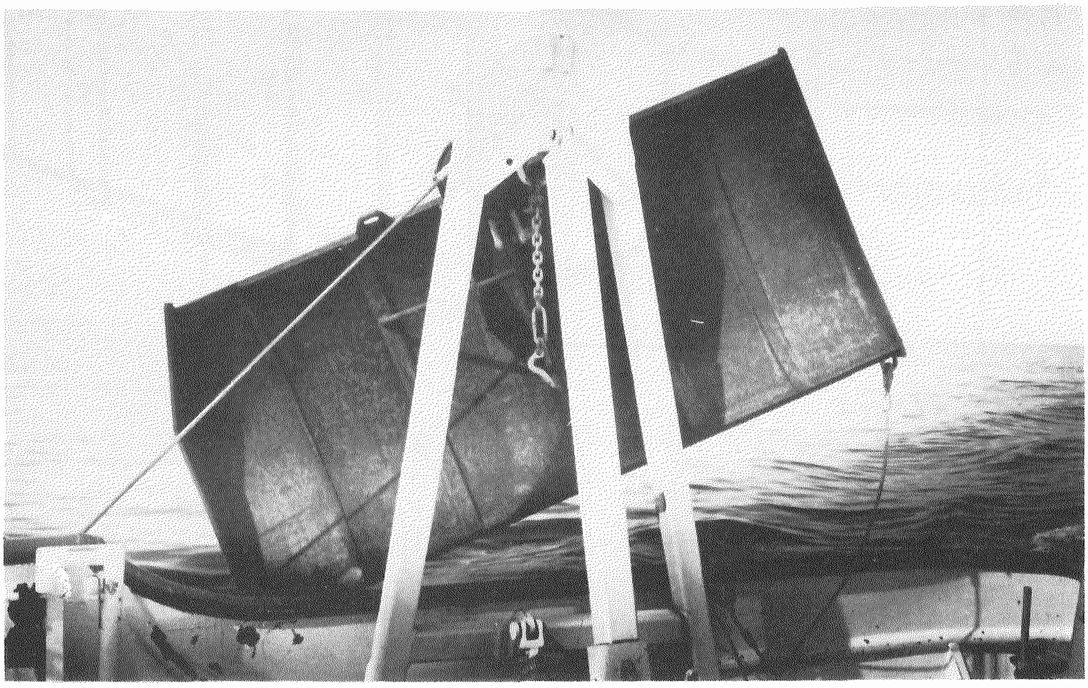


FIGURE 3—Section of the midwater trawl on the net-drum showing the headline floats enclosed in netting.

FIGURE 4—Süberkrüb midwater trawl door.



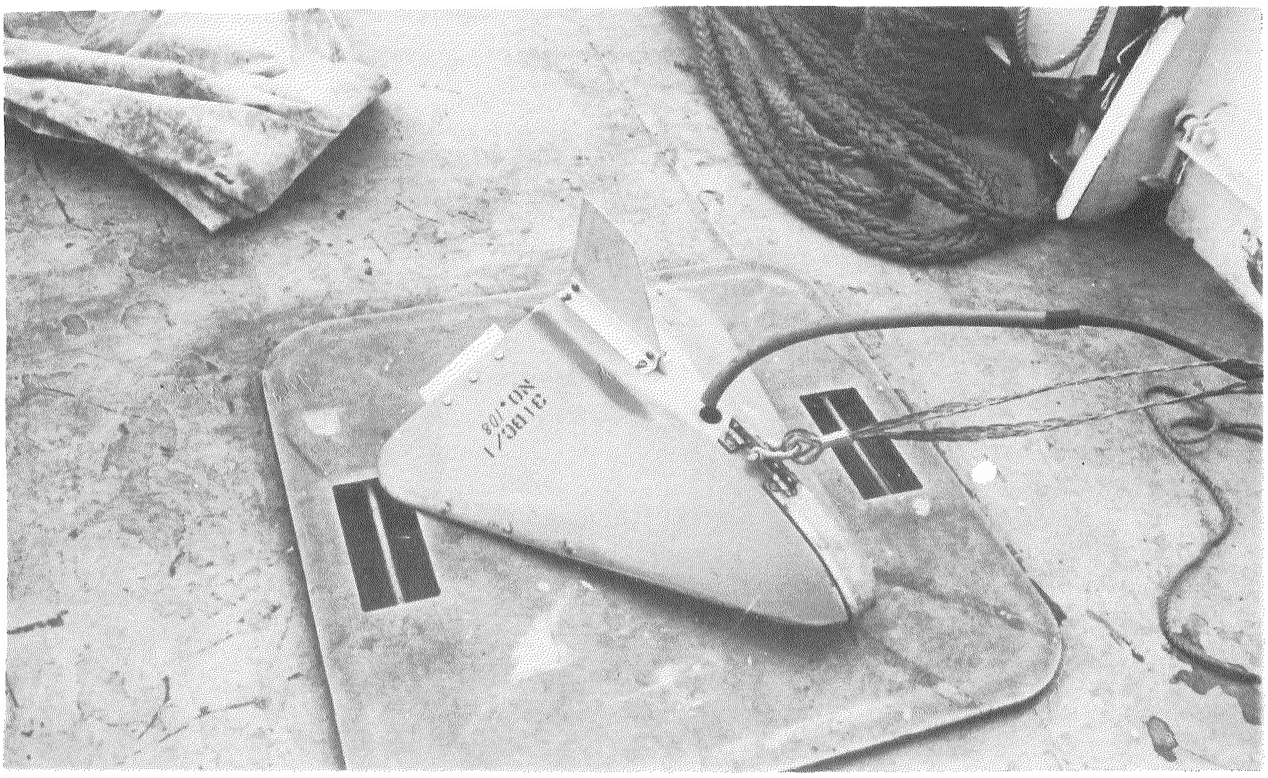
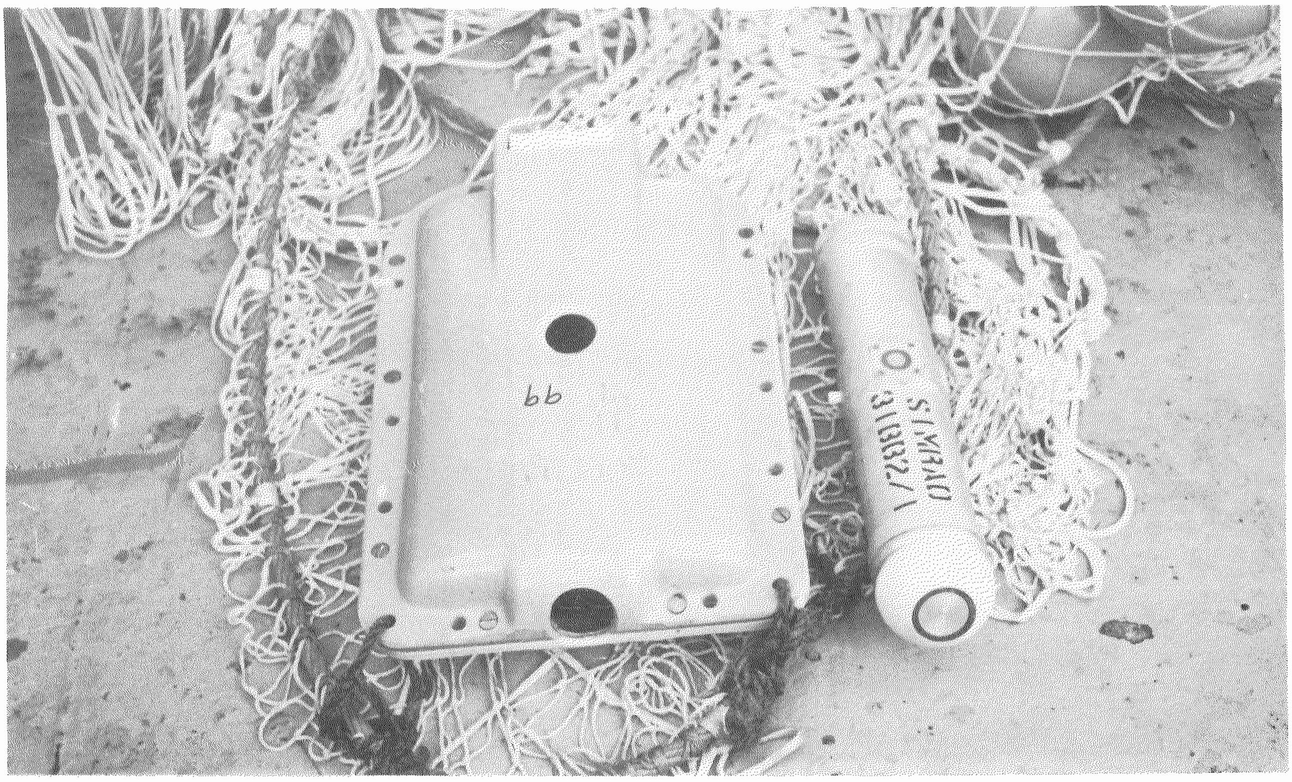


FIGURE 5—Towed paravane enclosing the Trawlink receiver.

FIGURE 6—Trawlink fibreglass transceiver housing mounted on the headline; alongside is the transceiver showing the upward and forward transmitting transducers.



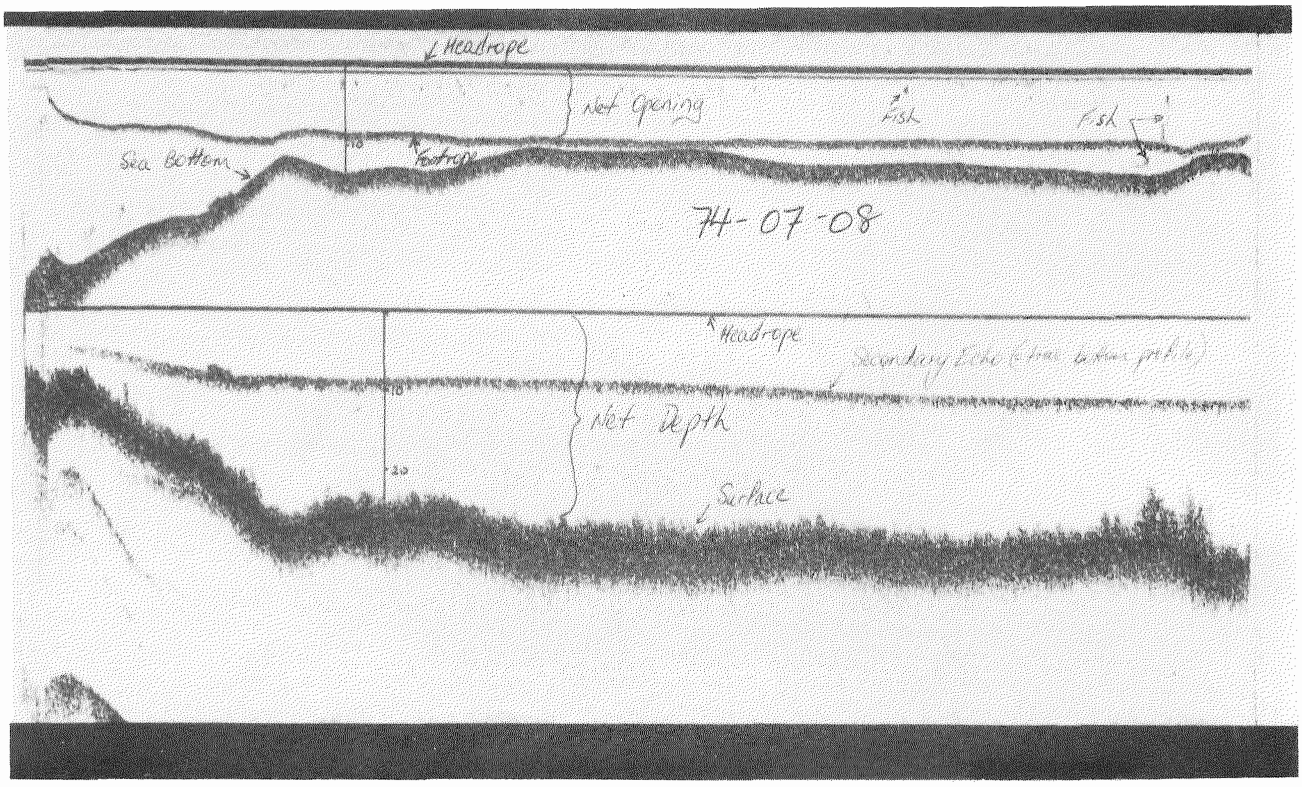
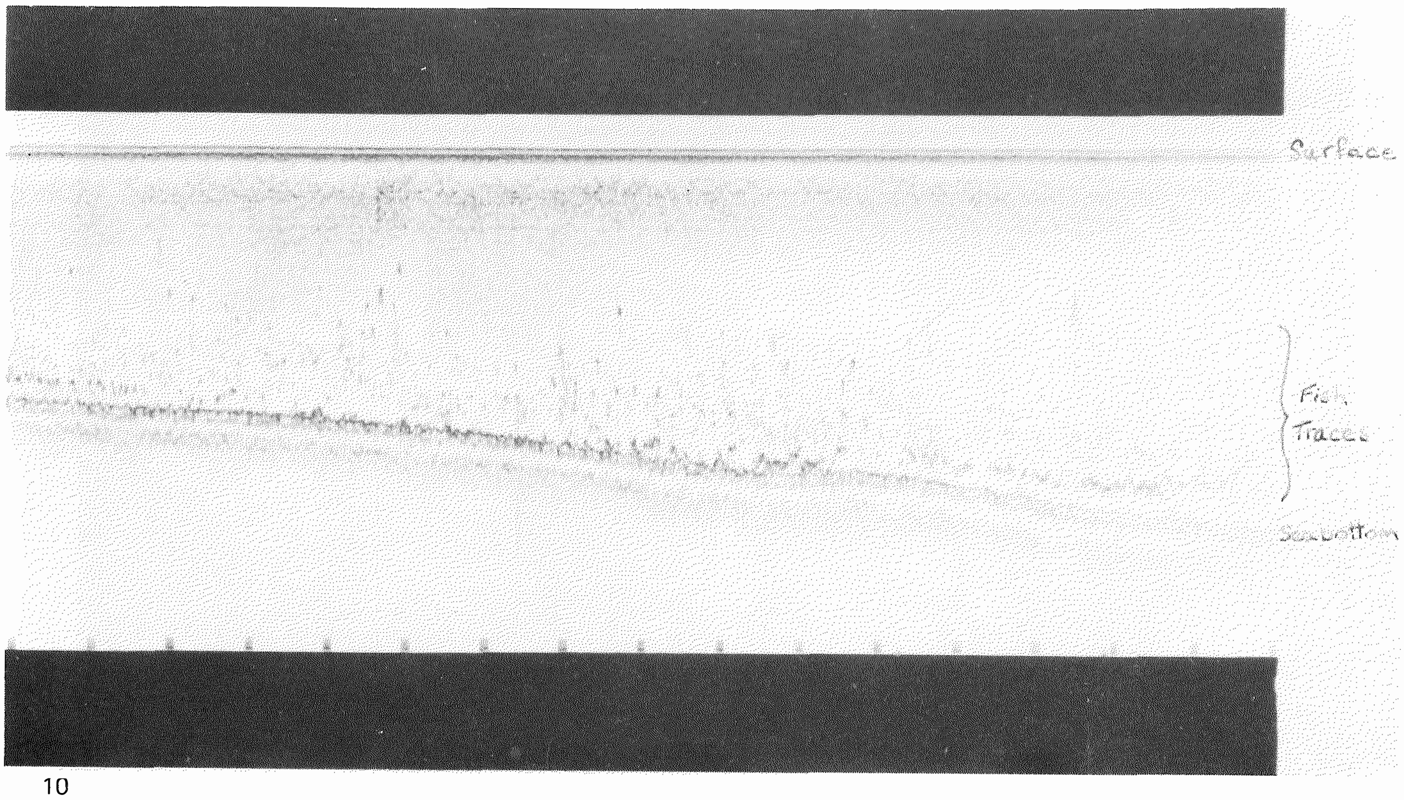


FIGURE 7—A typical Trawlink record showing the footrope of the net being towed close to the bottom. The net opening is about 8 fathoms and traces of fish are evident between the headrope and footrope, and below the footrope.

FIGURE 8—Echogram of scattered nannygai and jack mackerel recorded off Bate Bay in August, 1973. (Furuno 28 kHz; scale 0–50 F.)



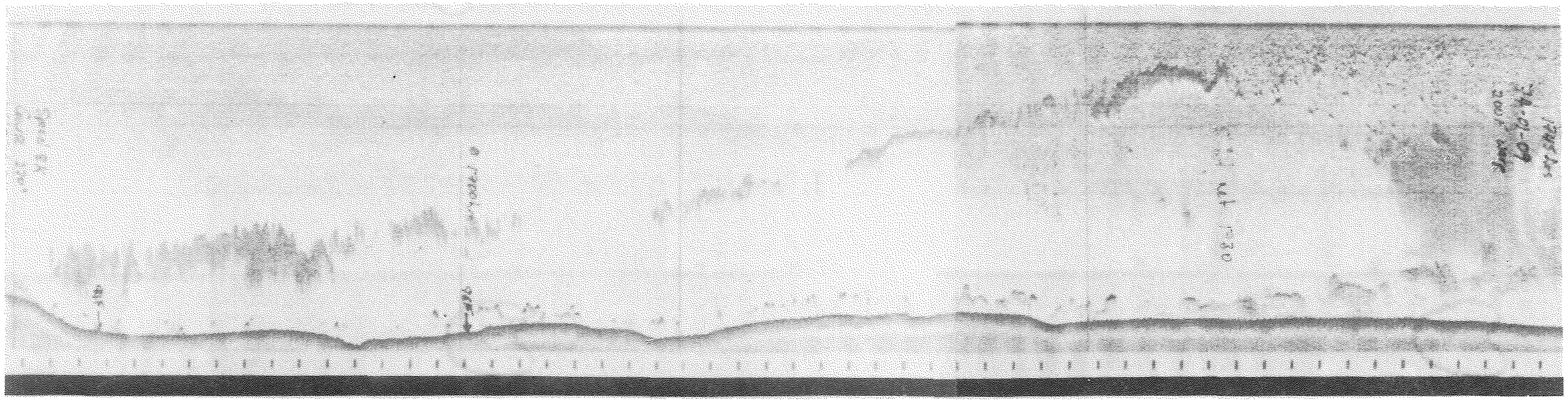


FIGURE 9—Echogram of nannygai and krill schools recorded at the edge of the shelf off Ulladulla. The cloud-like schools of krill can be seen rising off the bottom and dispersing as dark approaches; the smaller nannygai schools are close to the bottom and also eventually disperse. (Furuno 28 kHz; scale 0–100 F.)

FIGURE 10—Echogram of nannygai recorded near the edge of the shelf southeast of Ulladulla in April, 1976. As dawn approaches the fish are descending to form dense schools close to bottom. About 5 tonnes of nannygai were caught from the school at the right of the trace. (Furuno 28 kHz; scale 0–100 F.)

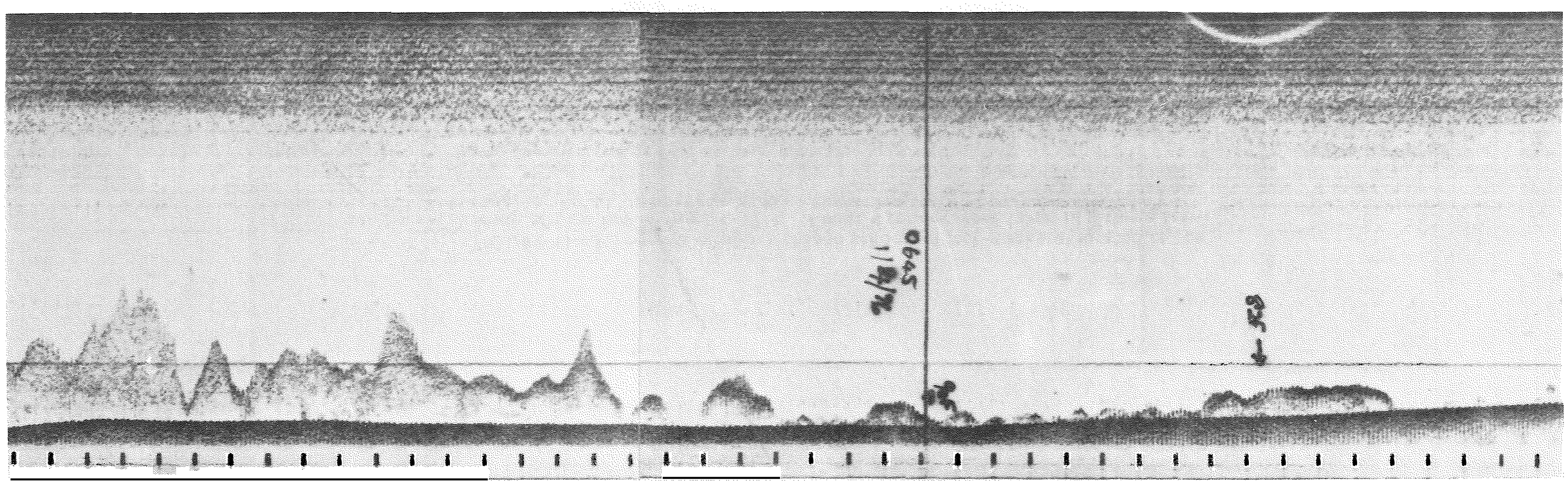
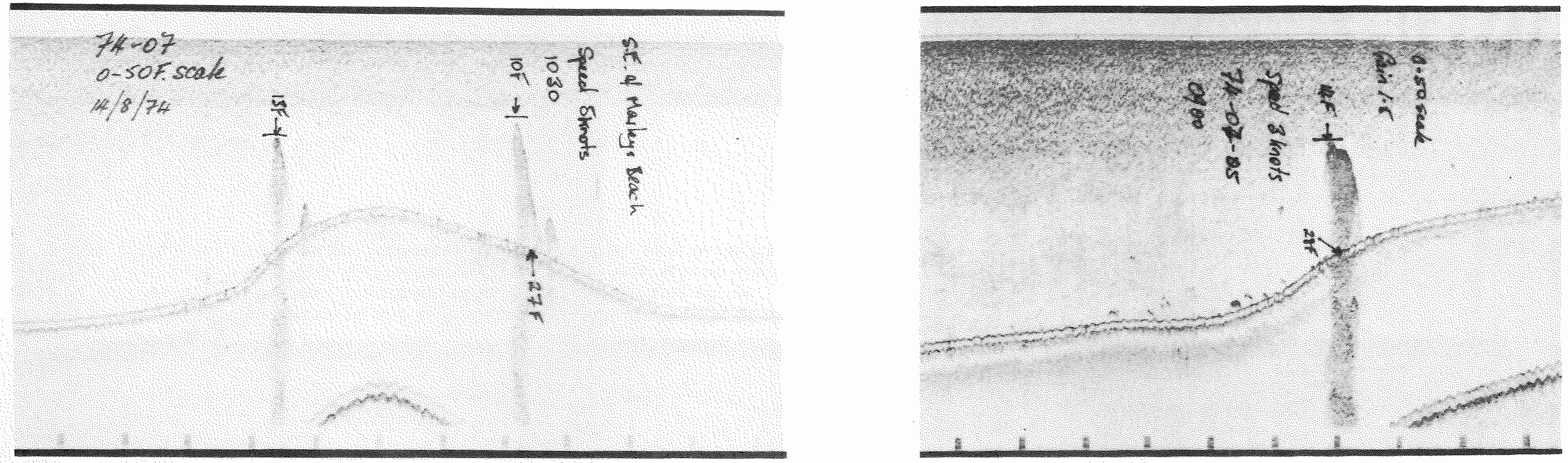


FIGURE 11—Echograms of plume shaped schools of jack-mackerel located to the south of Bate Bay in August, 1974. About 4 tonnes were taken in a single trawl through the school in the right-hand trace. (Furuno 28 kHz; scale 0–50 F.)



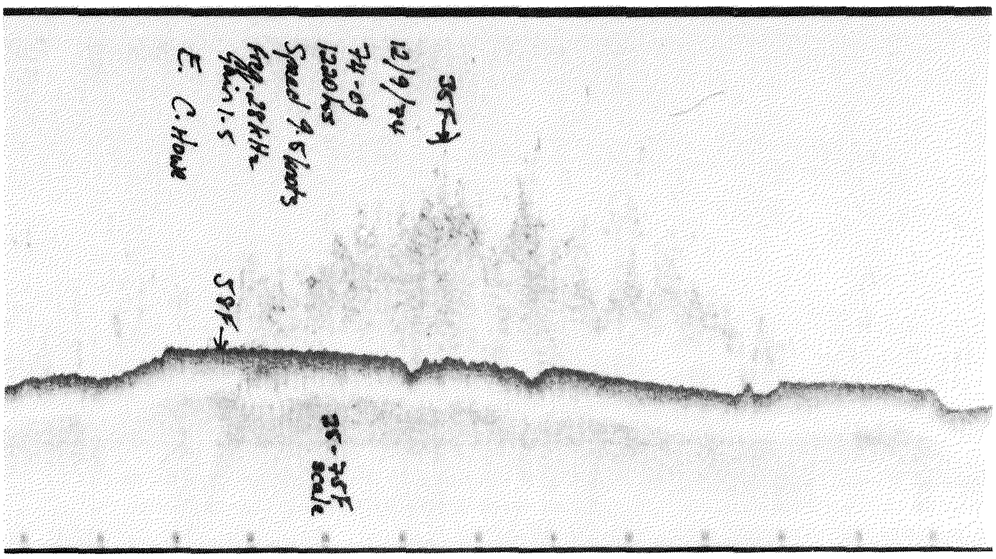
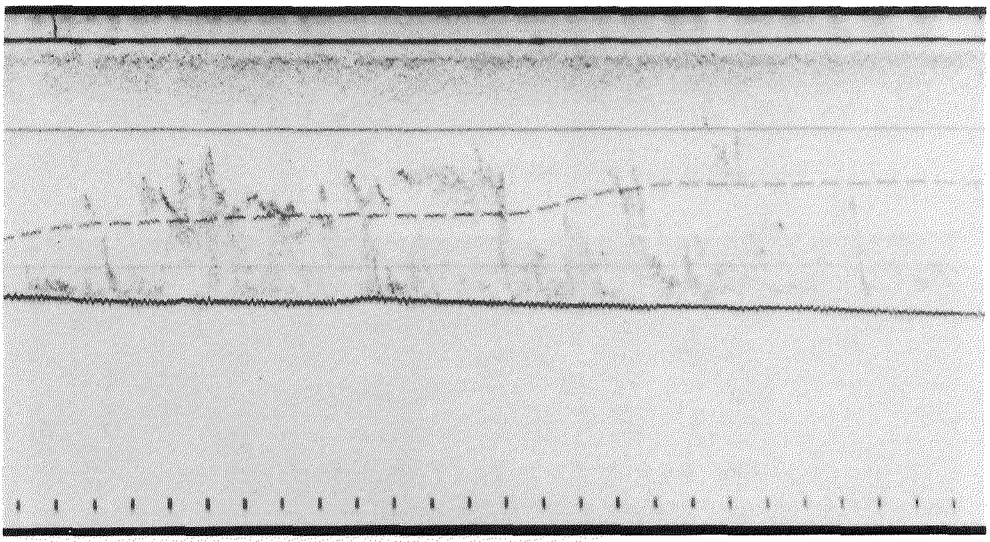


FIGURE 12—School of jack-mackerel recorded in about 60 fathoms east of Cape Howe. About 2.5 tonnes were caught during a 30-minute trawl through this school. (Furuno 28 kHz; scale 25–75 F.)

FIGURE 13—Echogram of scattered jack-mackerel recorded in about 60 fathoms south of Montagu Island. The dotted line is the record of the headline depth from the Furuno netsonde (see section 3.6). Very small catches were taken when trawling through scattered fish as shown, and subsequent trawls with the Simrad Trawlink netsonde through similar mackerel schools showed the fish actively avoiding the net. (Furuno 28 kHz; scale 0–100 F.)



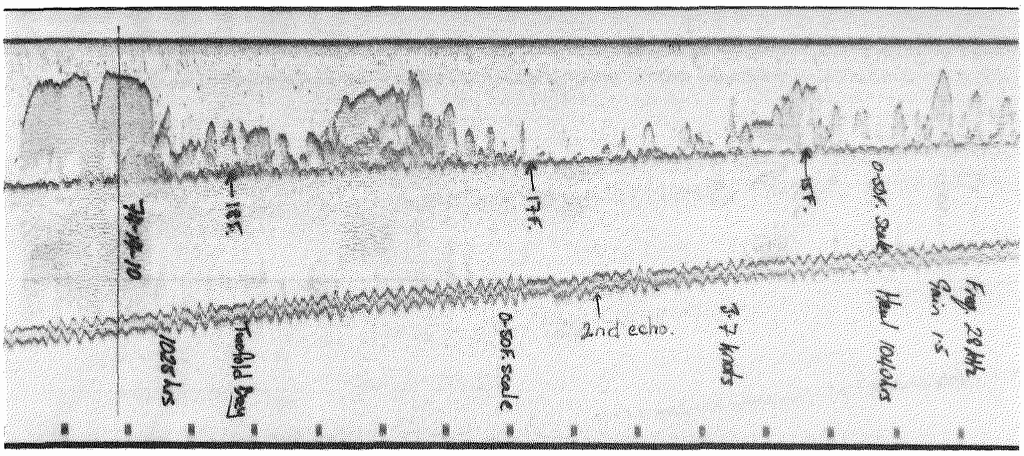


FIGURE 14—Echogram of dense schools of anchovy in 15 to 20 fathoms at the entrance to Twofold Bay. Large catches were made by towing the net close to the bottom. (Furuno 28 kHz: scale 0–50 F.)

FIGURE 15—Pyramid-shaped school of yellowtail recorded in 19 fathoms north of Byron Bay. (Furuno 28 kHz; scale 0–50 F.)

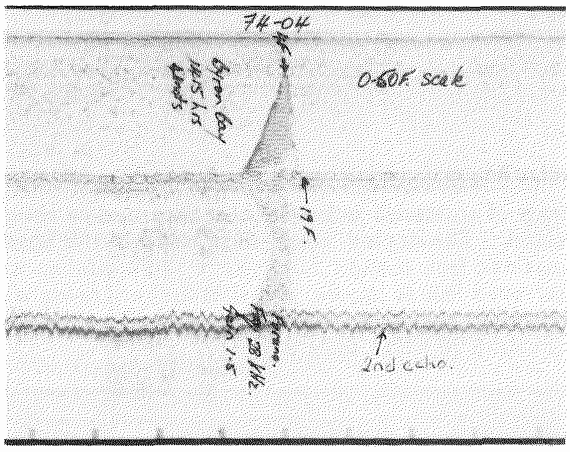
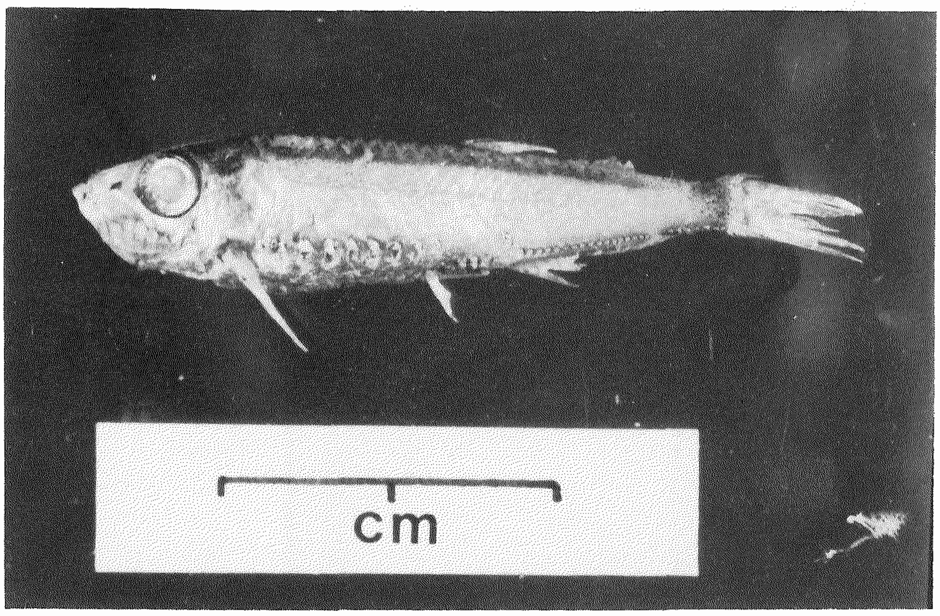


FIGURE 16—Photograph of a light-fish (*Maurolicus meulleri*).



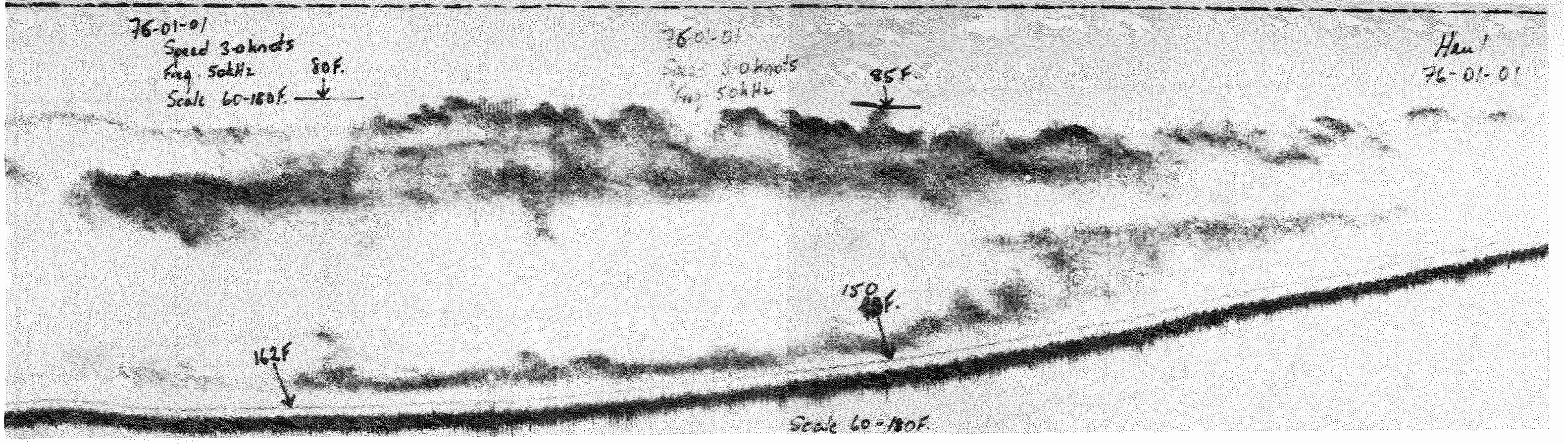
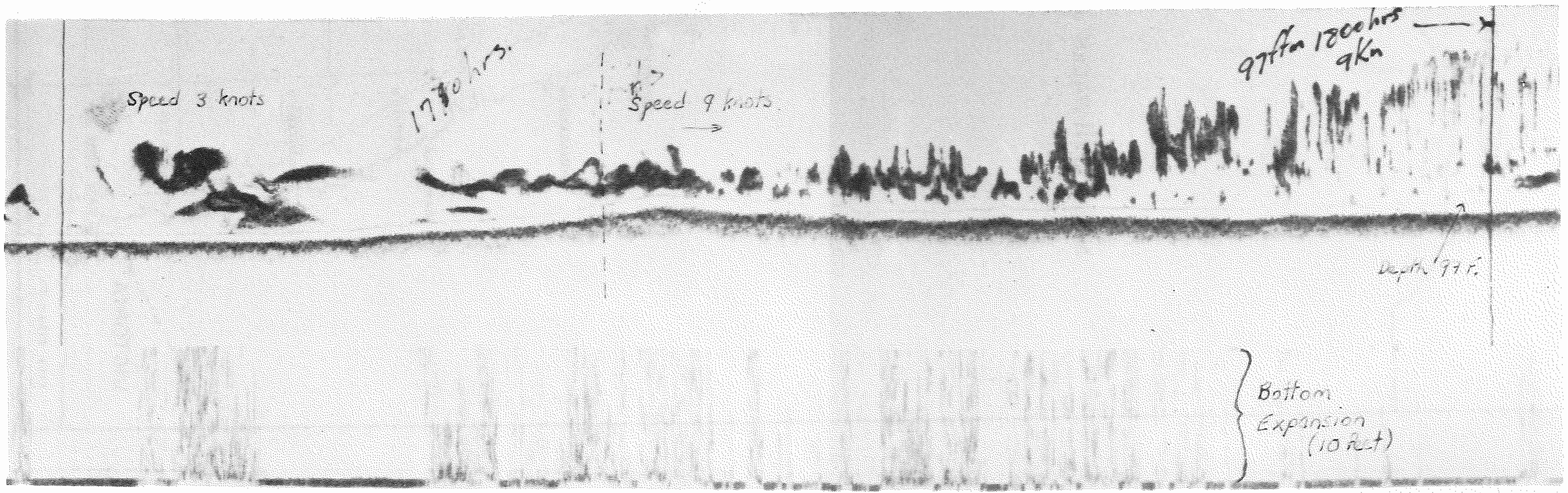
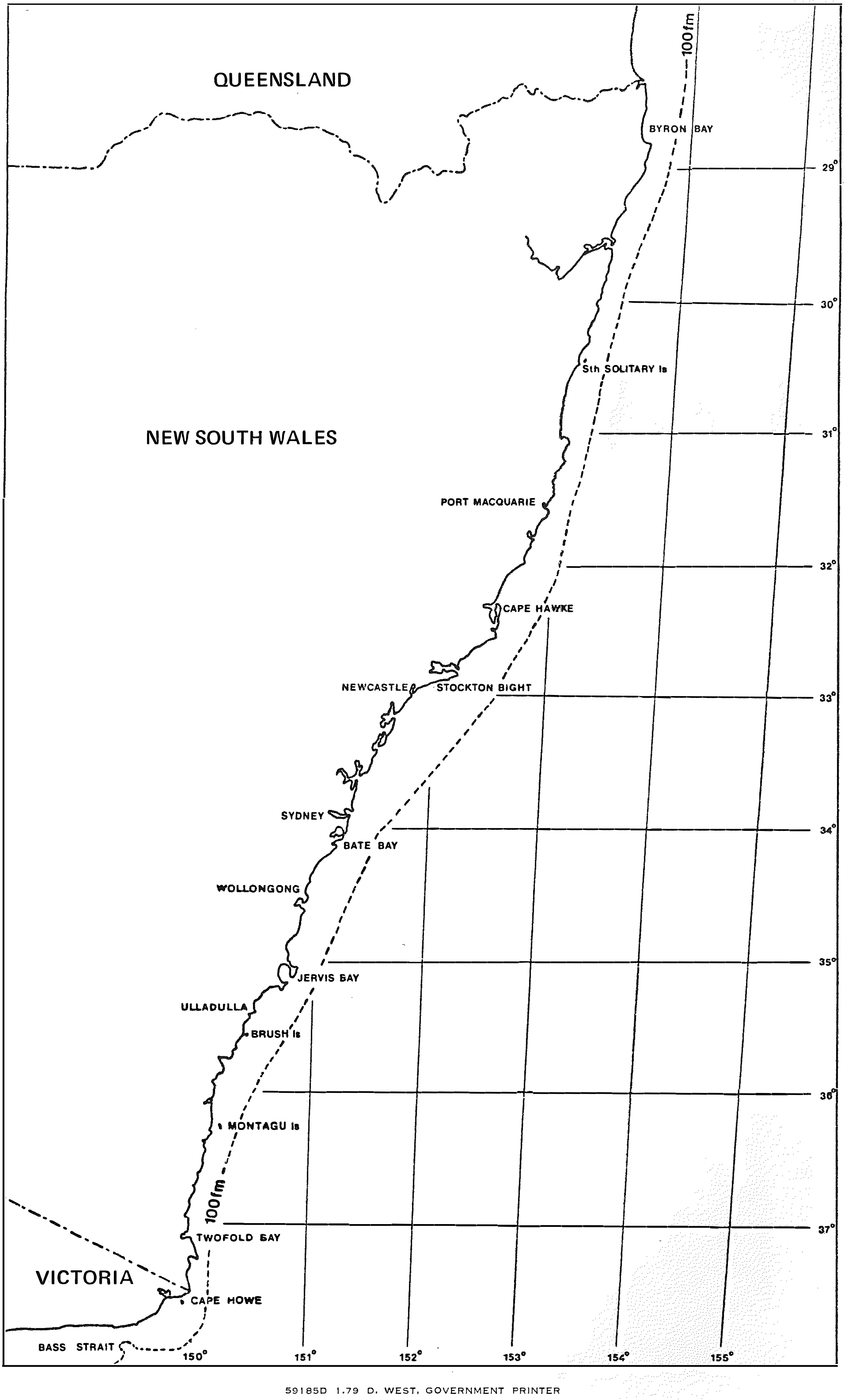


FIGURE 17—Echogram of cloud-like schools of light-fish recorded over the upper continental slope in eastern Bass Strait. (Koden 50 kHz; scale 60–180 F.)

FIGURE 18—Continuous schools of light-fish recorded at the edge of shelf (110 fathoms) north of Montagu Island. The left side of the figure was recorded at trawling speed (3 knots), and the latter half at 9 knots. Again the pattern of the fish rising and dispersing as night approaches is evident. (Koden 50 kHz; scale 0–240 F.)





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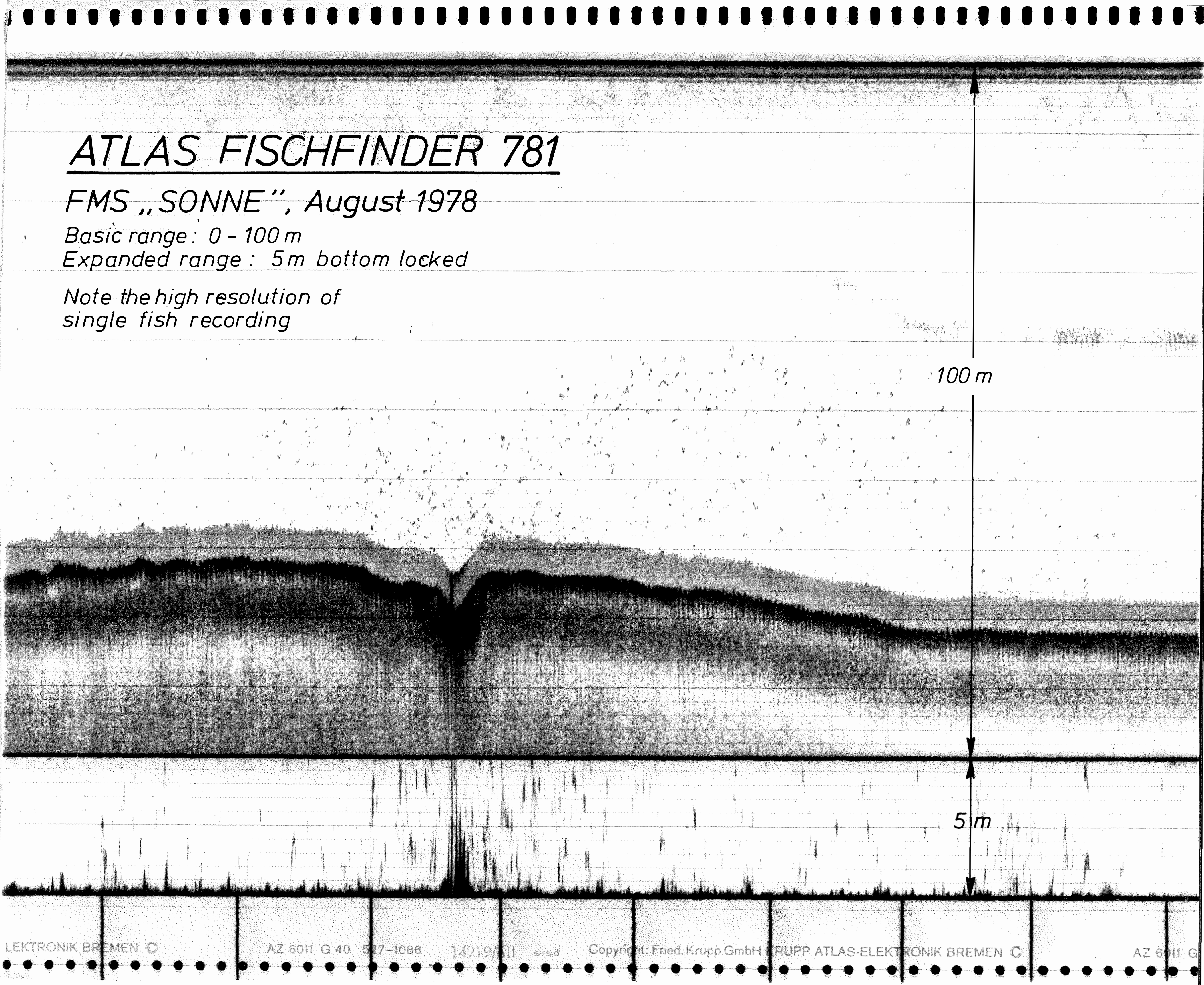
Attachment 6

ATLAS FISCHFINDER 781

FMS „SONNE", August 1978

Basic range: 0 – 100 m
Expanded range: 5 m bottom locked

Note the high resolution of
single fish recording



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