MINISTERIE VAN LANDBOUW

Bestuur voor Landbouwkundig Onderzoek

Kommissie voor Toegepast Wetenschappelijk

Onderzoek in de Zeevisserij (T.W.O.Z.)

(Voorzitter : **F. Lievens**, directeur-generaal)

PRELIMINARY RESULTS OF HYDROACOUSTIC MEASUREMENTS

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ONDERWERP «TECHNIEK IN DE ZEEVISSERIJ»

Mededelingen van het Rijksstation voor Zeevisserij (CLO Gent)
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INTRODUCTION.

Within the scope of the investigations on the influence of noises produced by fishing vessels and their gear on catches, some preliminary measurements were carried out in Belgium.

In this paper, the first results of a number of underwater noise measurements are given. These measurements are the first in a series of freefield noise measurements which aim at finding a relation between the catch performance of vessels and gear and their hydroacoustic characteristics.

An effort was made to carry out the measurements in accordance with the proposals of the ICES Working Group on "Underwater sound in relation to fish capture" (Anon., 1972).

EXPERIMENTAL CONDITIONS.

The hydroacoustic freefield recordings took place near the Belgian coast in March 1973. The depth at the measuring ranges varied between 11 and 18 m. The bottom consisted of mud and sand. Wind speed varied between 1 and 2 Beaufort. The overall background noise level was found to be 16 dB and the index value of spectrum level varied from 0 dB at 25 Hz to -55 dB at 10.000 Hz.

The technical specifications of the fishing vessel, the R.V. "Hinders", are given in table 1. During the fishing operations the ship towed a bottom trawl with the characteristics as mentioned in table 2.

INSTRUMENTATION AND METHODS.

The block diagrams of the recording and analysing instrumentation are shown in figures 1 and 2. All instruments used in the freefield recordings were battery operated so that all machinery on board the measuring vessel could be stopped. The omnidirectional hydrophone, mounted in a metal frame, was lowered to the sea bottom. The sensitivity as given by the constructor's weighing curve, is -70 dB/1V/1 μ Bar $\pm$ 1dB from 10 Hz to 30 KHz. A reference signal of 100 mV/1000 Hz, corresponding to an acoustic pressure of 50 dB re 1 μBar at the hydrophone input, was recorded on each tape before the measurements started.

The recorded noises were analysed in 1/3 octave bands covering the frequency band from 25 to 10.000 Hz. Besides, each recording was examined on the occurence of spectrum lines in a frequency band from 40 to 10.000 Hz. The used selectivity of the frequency analyser was 35 dB/octave, for which the 3 dB bandwidth was 1/24 of the octave. The noise levels are given as index values of noise spectrum level in dB referred to 1 μBar, 1 Hz and a distance of 1 meter from the vessel. Spherical spreading was assumed.

The following recordings were performed :

- propeller disconnected, motor idleing at 400, 750 and 1150 rpm ; distance 58 to 60 m
- main engine turned off, auxiliary engine on ; distance 56 m
- free running at 750 rpm (rpm during fishing) and 1150 rpm (full speed) ; distance 35 to 46 m
- fishing at 750 rpm ;distance 110 to 140 m
- shooting the gear ; distance 85 to 160 m.

The distances were measured with a telemeter (Wild). The instrument showed an error of less than 5 % for distances under 200 m.

RESULTS AND DISCUSSION.

The results of the frequency analysis of the noise generated by the main engine idle-running and of the auxiliary engine are grouped in table 3. The frequency and sound spectrum level of the spectrum lines are recorded in table 4. The diagrams of the noise pressure levels vs frequency are given in figures 3 to 6.

The spectra of the main engine with disconnected propeller, figures 3, 4 and 5, showed the highest noise pressure levels at the lower frequencies, where the spectrum lines were found as well. With growing rpm, the sound levels increase and the spectrum lines tend to shift towards higher frequencies. This shifting of the spectrum lines is due to the fact that they are generated by rotating and reciprocating machine parts. It can be calculated that the lines at 74 Hz (400 rpm), 48 Hz and 97 Hz (750 rpm) and 76 Hz and 149 Hz (1150 rpm) occur at the fundamental and first harmonic frequency of the firing rate.

The peak in sound pressure level at 500 Hz, which is also noticed in other operating conditions, could not be explained. No spectrum lines were found in the corresponding 1/3 octave band. Accelerometer measurements, to be performed in a leter phase of the programme will probably elucidate this problem.

The spectrum of the auxiliary engine shows a peak at 31,5 and 50 Hz. Spectrum lines are found between 57 and 129 Hz. With the exception of the values found at the beginning of the frequency band, the noise level of the auxiliary engine is much lower than that of the main engine so that its contribution to the total noise generated by the ship tends to be rather small.

Table 5 mentions the sound pressure levels of the vessel free running at 750 and 1150 rpm and fishing. Spectrum lines are given in table 6. The diagrams of the frequency analysis are given in figures 7 to 9. The values given are the means of 3 runs. The spreading between the results is shown by the range.

The noise generated by the propeller, and particularly by the cavitation which is the most important component of propeller noise, results in a broad analytical plain from the beginning of the spectrum up to 500 Hz and in a considerable increase of the sound pressure levels at the higher frequencies.

At an engine speed of 750 rpm the noise pressure levels from the free running ship are lower than those generated by the idleing engine in the frequency band up to 80 Hz. From 100 Hz on however, much higher levels are obtained, reaching a maximum at 160 Hz (42 dB) and at 500 Hz (43 dB). Between 500 and 2500 Hz the increase in sound pressure level is 7 dB for most 1/3 octave bands. From 3150 Hz on a much greater difference is obtained, reaching 16 dB at 5000 and 10.000 Hz.

At 1150 rpm all values measured in free running conditions lie at a higher level than with the propeller disconnected, except the significantly lower value found at 31.5 Hz. The most important increase in sound pressure level is noticed in the frequency band from 160 Hz to 500 Hz. The highest levels were also obtained at these frequencies : 53 dB at 160 Hz and 51 dB at 500 Hz. From 630 to 2500 Hz, when free running at 1150 rpm, the difference was 10 to 13 dB. The difference in sound pressure level reaches a maximum at 10.000 Hz, the sound pressure level of the free running vessel being 23 dB higher than that of the idleing engine.

The most important spectrum lines reach a noise pressure level of 50 dB at 74 Hz for 750 rpm and 61 dB at 150 Hz for 1150 rpm.

From tables 5 and 6 and figure 9 the effect on the spectrum of towing a trawl can be deduced. The noise generated by the gear and the different load situation of the ship result in a totaly different spectrum. When comparing the values free running and trawling, both at 750 rpm, an increase of 15 dB is noticed at 31,5 Hz. At 80 and 100 Hz a smaller increase in sound pressure level is found, at 250 Hz the difference increases again to 12 dB. At these frequencies and at 500 Hz peaks of respectively 58, 43 and 44 dB occur. From 500 Hz on there is a continuous increase in sound pressure level with reference to the free running vessel. From 2500 Hz the difference remains constant at about 13 dB. All spectrum lines (table 8) are found in a small frequency band of 24 Hz. The highest value, 53 dB, is obtained at 97 Hz.

Figure 10 shows the sound pressure level vs time for 40, 160 and 630 Hz while shooting the gear. The following phases can easily be distinguished :

(1) the propeller is disconnected

(2) the propeller is reversed in order to stop the ship completely

(3) the net having been paid out, the engine speed is increased, and while the ship describes a circle the otterboards are shot

(4) at the end of the shooting routine the ship is on course of the haul and fishing can start.

The figure shows clearly that sudden changes in course and rpm cause heavy changes in sound pressure level.

Table 7 gives the frequency range of hearing and the pure tone auditory threshold, obtained in free field conditions, of some commercial fish species. Comparing these data with the results of our measurements shows that the frequency range where we found the highest sound pressure levels coincides with the lowest hearing thresholds. The auditory thresholds lie at a level of 70 to 80 dB lower than the highest noise pressure levels in the same frequency band. This implies a detection range of 3 to 10 km.

Comparison of pure tone thresholds with measured sound pressure levels of fishing boats seems however rather doubtful. Thresholds obtained by a band of noise appear to be 3-4 dB lower than pure tone thresholds (Enger, 1969). This means that fish may be able to detect fishing vessels at even greater distances than these stated above. On the other hand it is generally accepted that fish react very strongly to sudden changes in noise level, but that they soon become accustomed to stationary noises (MacLennan and Hawkins, 1973).

The significance of spectral lines in relation to fish behaviour is, up to now, not fully understood. Masking of pure tones by background noise does exist for fishes (Buerkle, 1968 ; Chapman, 1973) and it remains an open question if the spectrum lines as found in the analyses, will be of any influence on fishing operations.

SUMMARY.

Hydroacoustic freefield measurements on R.V. Hinders were performed for different operation conditions so that the influence of engine speed, cavitation, load etc. on the sound spectrum could be evaluated. The following conclusions can be drawn from these analyses :

1. regardless the operation condition, the highest noise pressure levels occur at the lower frequencies, up to 500 Hz ;
2. noise pressure levels increase with increasing engine speed ;
3. due to cavitation noise a broad analytical plain up to 500 Hz is created and a considerable increase of the sound pressure level for the higher frequencies is obtained ;
4. while towing a gear, high additional peaks are generated in the region below 400 Hz ;
5. while shooting the gear, changes in rpm and course cause sudden changes in sound pressure levels ;
6. almost all spectrum lines are found in the region below 100 Hz ;
7. comparison between the spectra obtained and the hearing threshold of some commercial fish species indicate that fish may hear a fishing vessel over considerable distances.

REFERENCES.

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Buerkle (U.), 1968 - Relation of pure tone thresholds to background noise level in the Atlantic cod (Gadus morhua) - J. Fish. Res. Bd. Can. 25, no. 6, 1155-1160.

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Enger (P.S.), 1969 - Nervous responses in the fish brain to pure tones and to noise - ICES, C.M. 1969/B:7.

Hawkins (A.D.) and Chapman (C.J.), 1969 - A field determination of hearing thresholds for the cod, Gadus morhua L. - Report of the 8th IF Meeting.

MacLennan (D.N.) and Hawkins (A.D.), 1973 - Sound in fishing - Fish Industry Review vol. 3, no. 1, 2-6.

Olsen (K.), 1969 - Directional hearing in cod (Gadus morhua L.) - Report of the 8th IF Meeting.

Table 1 - Technical specifications of R.V. "Hinders".

Type : combined side and beam trawler

Hull construction : iron frames, wooden hull

Main dimensions : L.O.A. : 23,15 m
Moulded breadth : 6,44 m
Moulded depth : 2,89 m
Gross tonnage : 78

Main engine : Type : MWM, 4- stroke
Power : 250 hp
Max. rpm : 1150
No. of cylinders : 8
Mounting : fix

Auxiliary engine : type : Enfield, 4-stroke
Power : 5,5 hp
Rpm : 1500
No. of cylinders : 1
Mounting : fix

Propeller : Pitch : fixed
Diameter : 1,25 m
No. of blades : 4
Reduction gear : 1/3

Table 2 - Characteristics of the gear.

Type : shrimp net½

Headline : 10,5 m

Groundrope : 12,8 m rigged with wooden bobbins of 12,5 x 12,5 cm

Legs : 4,9 m

Otter boards : rectangular, 2 x 1 m

The material of the net is polyamide with a tex number of 630 R tex.
Mesh sizes : 19, 18, 16, 14 and 12 mm.
All parts of the net are tapered by the ratio 1/2.

Table 3 - Index value of noise pressure levels of R.V. Hinders-propeller disconnected.

fc (Hz)	Noise level for main engine rpm			Auxiliary engine L_{is} (dB)
	400 L_{is}(dB)	750 L_{is}(dB)	1150 L_{is}(dB)	
25	31	33	32	29
31,5	43	44	44	36
40	40	40	46	28
50	38	44	45	35
63	37	41	45	30
80	35	37	39	27
100	30	33	39	26
125	30	35	40	25
160	28	32	45	19
200	29	29	35	14
250	29	32	34	12
315	27	30	35	12
400	22	24	27	8
500	27	29	37	9
630	21	23	30	6
800	15	19	26	-3
1 000	12	18	24	-4
1 250	7	12	17	-8
1 600	12	9	13	-11
2 000	1	10	10	-11
2 500	-4	3	5	-13
3 150	-9	-3	3	-14
4 000	-12	-7	-3	-15
5 000	-12	-11	-7	-17
6 300	-12	-12	-7	-20
8 000	-13	-13	-9	-22
10 000	-15	-15	-12	-26

Table 4 - Frequency and index value of noise pressure level of spectral lines - propeller disconnected.

Main engine rpm						Auxiliary engine	
400		750		1150			
f(Hz)	L_{is}(dB)	f(Hz)	L_{is}(dB)	f(Hz)	L_{is}(dB)	f(Hz)	L_{is}(dB)
55	45	48	47	51	53	57	40
63	42	55	55	60	53	84	33
74	41	62	48	68	55	112	36
				76	49		
		82	46	85	46	129	31
		89	39	93	45		
		97	38	149	42		

Table 5 - Index of noise pressure levels of RVS Hinders-free running and fishing.

fc (Hz)	Noise level for main engine rpm					
	750		1150		750-fishing	
	L_{is}(dB)	Range(dB)	L_{is}(dB)	Range(dB)	L_{is}(dB)	Range(dB)
25	28	1	38	2	39	4
31,5	33	2	36	1	48	4
40	40	1	45	3	45	3
50	39	5	46	4	38	3
63	36	3	47	2	38	2
80	36	3	45	3	43	1
100	39	3	43	0	43	1
125	36	7	46	2	37	5
160	42	2	53	1	39	1
200	35	4	51	4	41	5
250	32	2	50	2	44	5
315	34	2	50	2	42	7
400	30	2	45	2	35	3
500	43	3	51	1	44	5
630	31	2	42	3	37	3
800	29	4	36	2	33	6
1 000	24	4	35	0	28	1
1 250	19	2	30	2	25	2
1 600	16	3	24	2	25	4
2 000	13	3	22	2	23	3
2 500	9	4	18	1	22	2
3 150	8	2	18	1	21	3
4 000	6	1	18	2	19	2
5 000	5	4	15	1	16	1
6 300	2	1	12	2	16	2
8 000	1	6	10	1	14	1
10 000	1	4	11	2	13	1

Table 6 - Frequency and index value of noise pressure level of spectral lines - free running and fishing.

Main engine rpm								
750			1150			750-fishing		
f(Hz)	L_{is}(dB)	Range(dB)	f(Hz)	L_{is}(dB)	Range(dB)	f(Hz)	L_{is}(dB)	Range(dB)
58	49	4	51	54	1	73	48	3
74	50	1	67	55	4	84	52	1
83	43	2	85	54	0	90	51	4
			150	61	2	97	53	0

Table 7 - Hearing abilities of some commercial fish species.

Species	Frequency range of hearing (Hz)	Hearing threshold (dBre 1 μBar)	Author
Cod Gadus morhua	40-400 20-400	-27 dB at 200 Hz -28 dB at 160 Hz	Hawkins and Chapman, 1969 Olsen, 1969
Haddock Melanogrammus aeglefinus	30-470	-15 to -20 dB from 110 to 310 Hz	Chapman, 1973
Leng Molva molva	40-550	-19dB at 200 Hz	Chapman, 1973
Pollack Pollachius pollachius	40-470	-22 to -24 dB from 100 to 200 Hz	Chapman, 1973

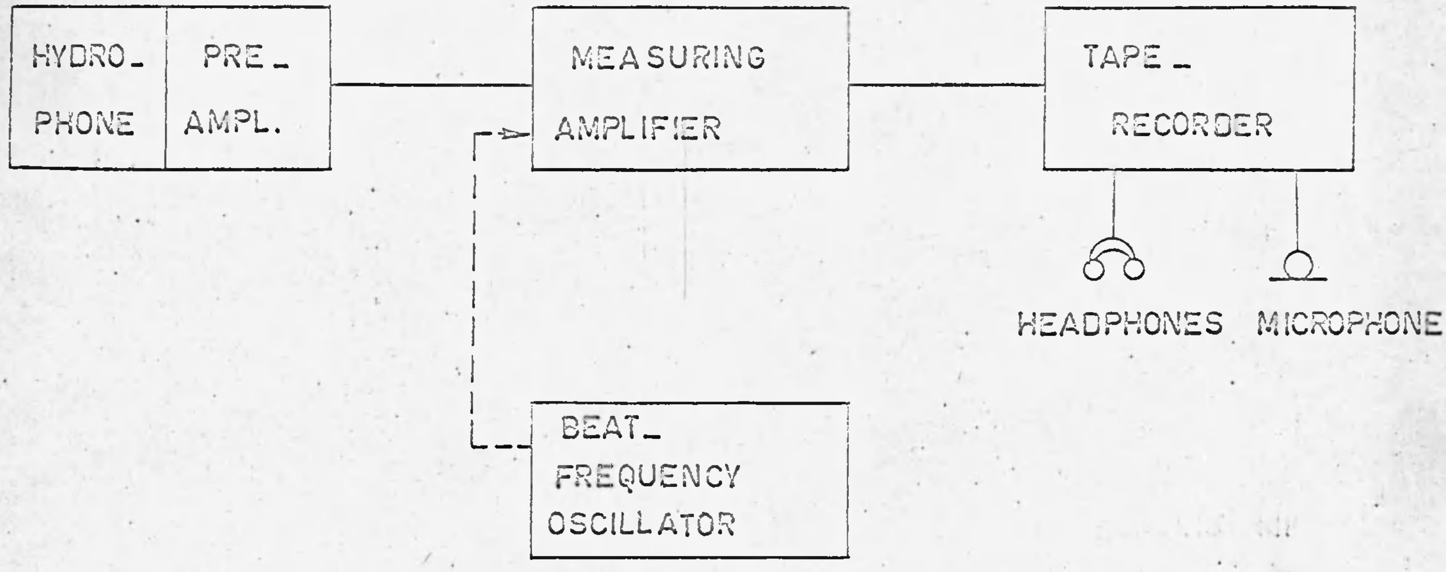

Figure 1 — Block diagram of the recording instrumentation

Hydrophone : Thomson-CSF, type TSM 6.120.

Measuring amplifier : Brüel & Kjaer, type 2606.

Tape recorder : Nagra III.

Beat frequency oscillater : Brüel & Kjaer, type 1014.

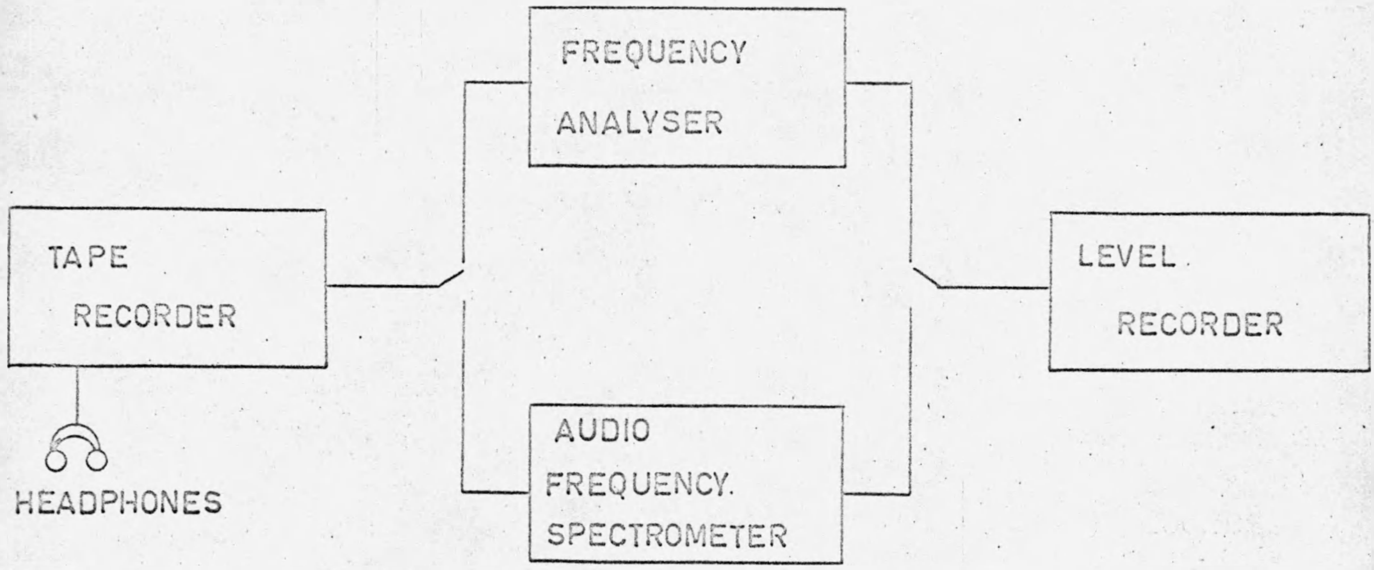

Figure 2 – Block diagram of the analysing instrumentation

Tape recorder : Nagra III.

Frequency analyser : Brüel & Kjaer, type 2105.

Audio frequency spectrometer : Brüel & Kjaer, type 2112.

Level recorder : Brüel & Kjaer, type 2305.

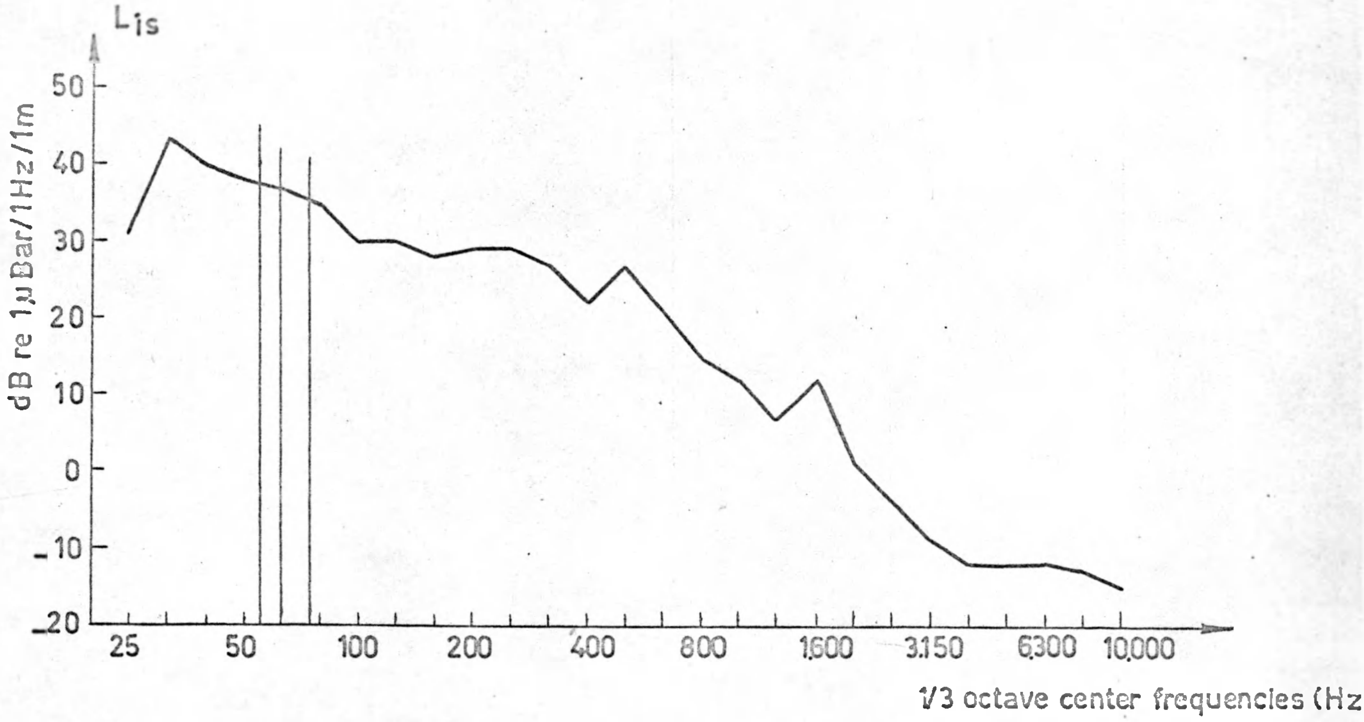

Figure 3 – Sound spectrum of the main engine idleing at 400 rpm

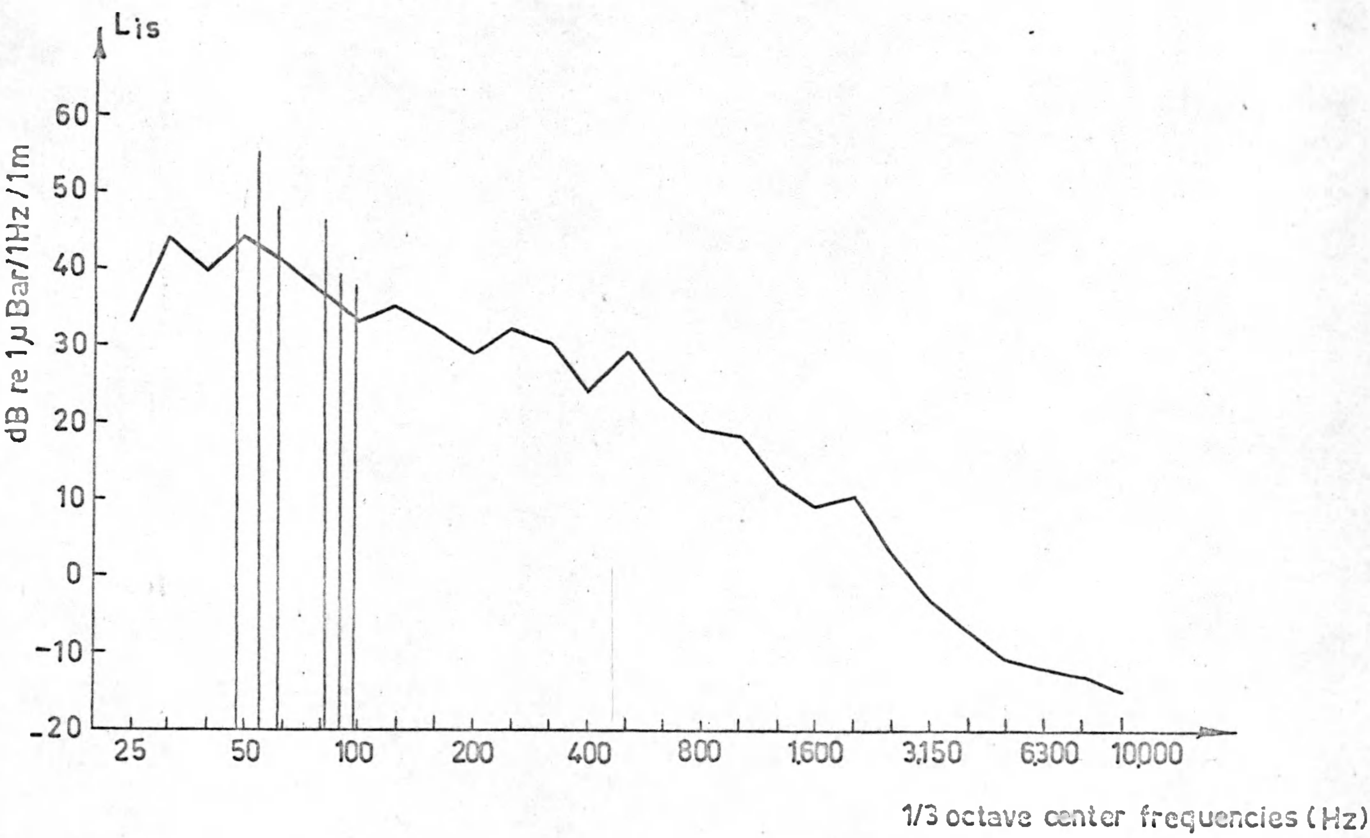

Figure 4 – Sound spectrum of the main engine idleing at 750 rpm

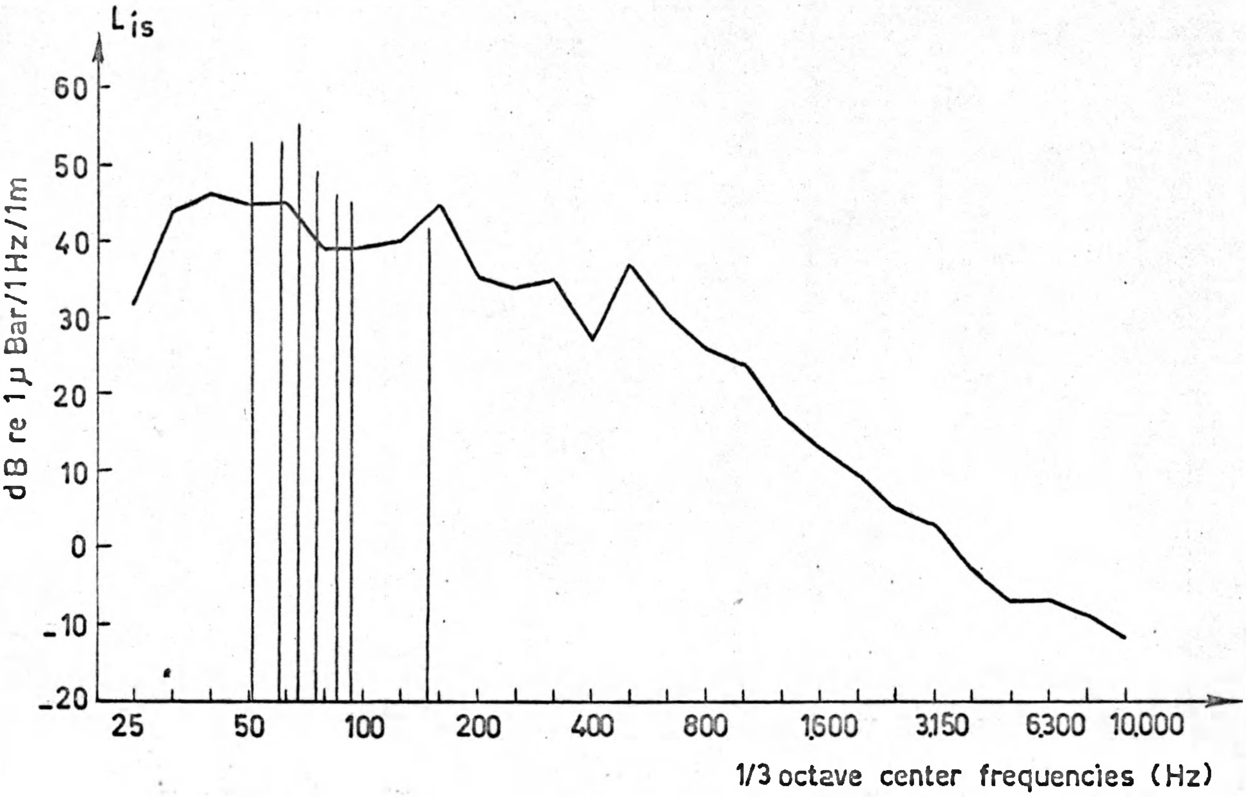

Figure 5 – Sound spectrum of the main engine idleing at 1150 rpm

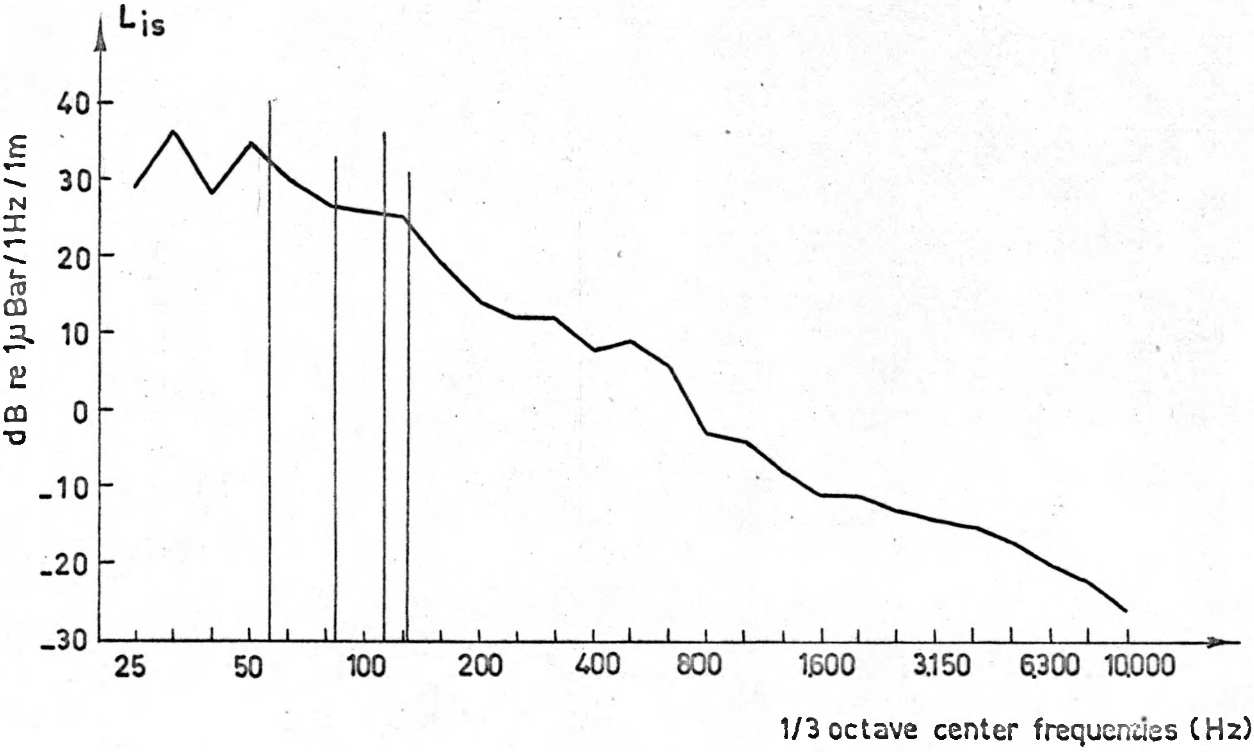

Figure 6 – Sound spectrum of the auxiliary engine

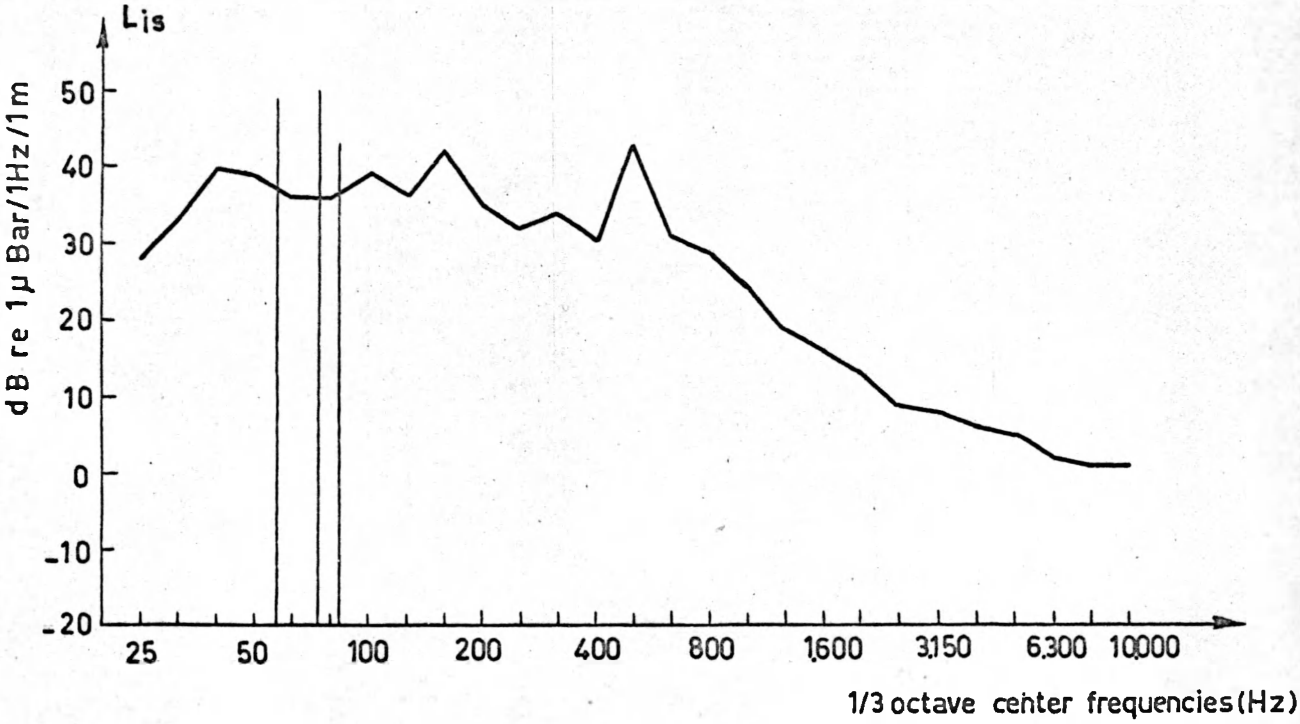

Figure 7 _ Sound spectrum of the free running vessel at 750 rpm

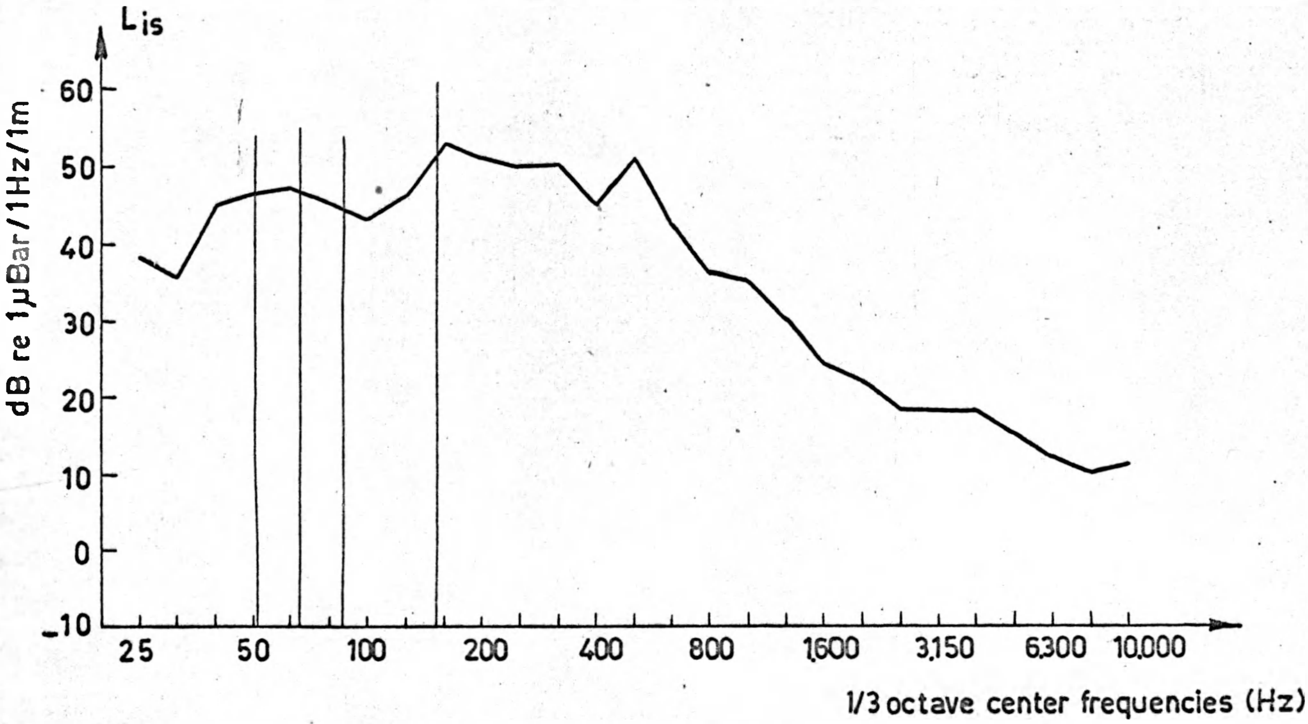

Figure 8 _ Sound spectrum of the free running vessel at 1150 rpm

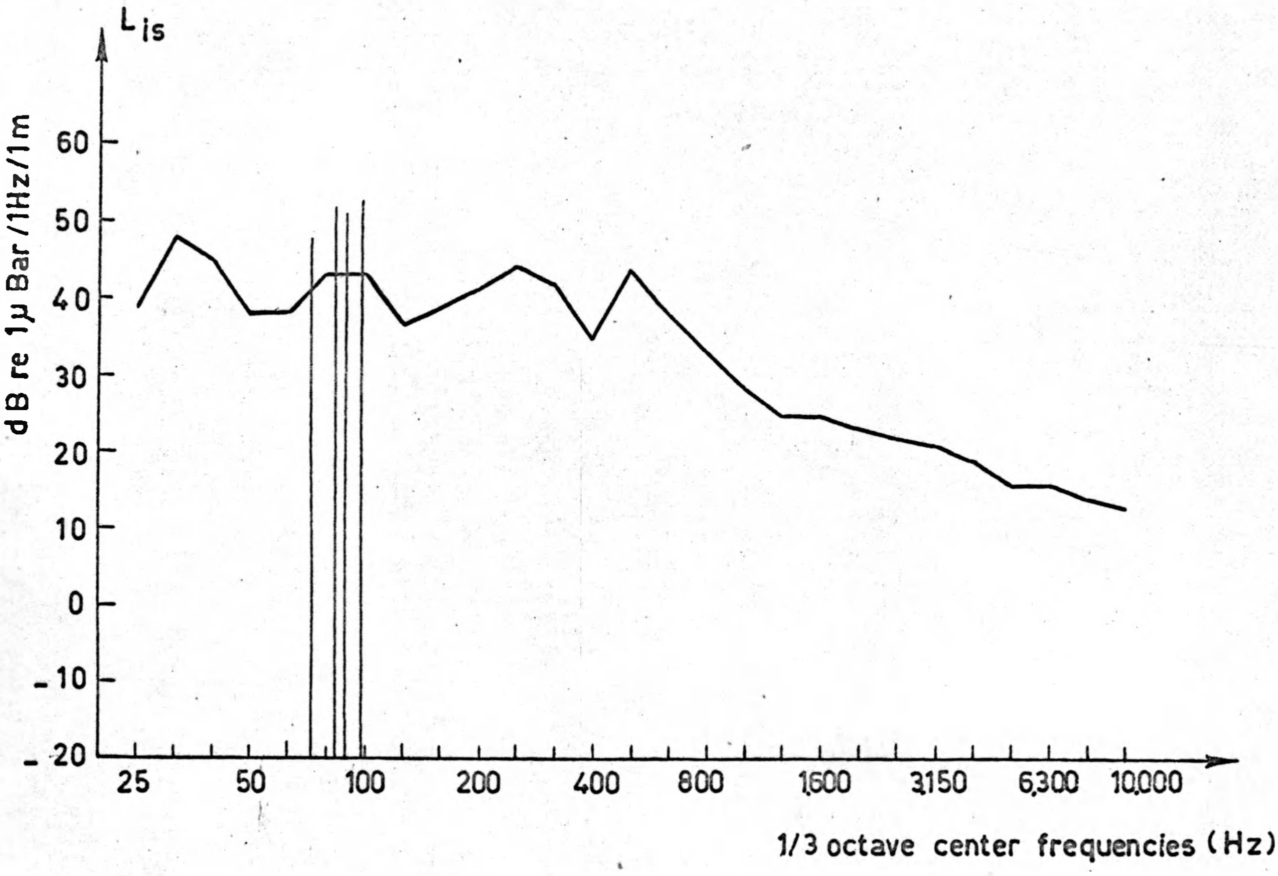

Figure 9 _ Sound spectrum of the vessel trawling at 750 rpm

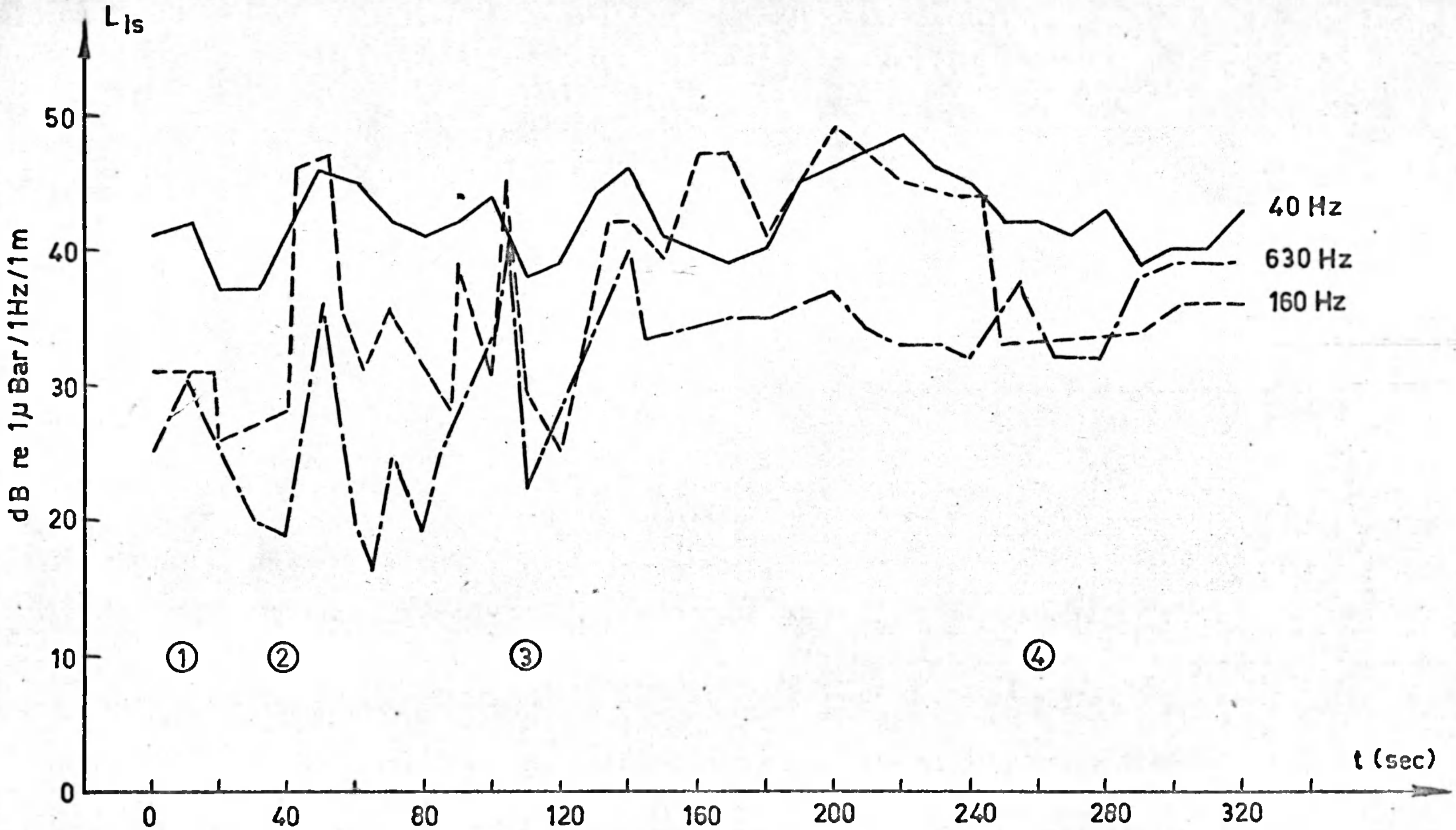

Figure 10 — Sound pressure levels while shooting the gear.