INSTITUUT VIR MARITIEME TEGNOLOGIE
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Titel:/Title:

ENVIRONMENTAL IMPACT STUDY: UNDERWATER RADIATED NOISE

Dokument Nr:/Document No:
TV0010-000003-730

Skrywer(s)/Author(s)
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TITLE PAGE
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Lêernaam:/File Name:
SHE00047.S01

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Issue/Uitgawe	Date/Datum	Pg/Bl	Of/Van	Document No/Dokument No
1	8/7/94	1	30	TV0010-000003-730

IMT 0058/1

GOEDKEURINGSBLAD
APPROVAL SHEET

	Handtekening/Signature	Datum/Date
GOEDKEURING/APPROVAL:		
Uitvoerende Bestuurder, IMT Executive Manager, IMT	T. de [illegible]	24.7.94
AANVAARDING/ACCEPTANCE:		
Groepbestuurder Group Manager	[signature]	20-07-1994
OPGESTEL DEUR:/COMPILED BY:		
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Konfigurasiebestuur Configuration Management	[signature]	27/7/94

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AMENDMENT HISTORY

Dok Uitg Doc Issue	Datum Date	Seksie/Hoofstuk/Bladsy verander Section/Chapter/Page altered	IVV Nr ECP No	Handtekening Signature
1	8/7/94	INITIAL ISSUE		

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OPSOMMING / SUMMARY

This report documents the process and subsequent results of measurements conducted on the underwater noise radiated by off-shore mining operations. Contained are the spectra and noise amplitudes of two types of mining processes i.e. Drill and Crawler. The results indicate that the levels of radiated noise produced are mainly broadband between 100 Hz and 2 500 Hz and have the same amplitude as a typical noisy merchant vessel.

SLEUTELWOORDE / KEYWORDS

Off-shore mining, underwater radiated noise, De Beers mining, Environmental noise, crawler, drill, Louis G Murray, Grand Banks.

1. INTRODUCTION

IMT received a request from the Environmental Evaluation Unit (EEU), University of Cape Town (UCT), on behalf of De Beers Marine, to evaluate the acoustic noise radiated by vessels mining at sea. This work forms part of a larger project to study the effects that off-shore mining operations have on marine mammals and local sea life.

2. OBJECTIVES

The objective of this study is to provide EEU with a comprehensive report on the underwater radiated noise characteristics of the various mining methods.

This is to be achieved by:

a. Establishing the noise levels during mining by measurement.

b. Quantifying the noise levels in terms of other noise (eg. ship, ambient noise).

c. Identify the frequency content and its spectral contribution by analysis.

It is not our objective to assess the impact of the measured noise level on marine life.

3. TRIAL CONFIGURATION

Two mining vessels were to be monitored to establish the normal underwater noise levels radiated by the different mining processes. These being the Louis G Murray and the Grand Banks, which were stationed 3 miles apart, 30 miles off the Namibian coast.

The planned measurement procedure was to record the underwater noise levels at the four cardinal points at a distance of 100 metres from the vessel. Then further measurements at 500 meters and 1 000 metres if required. This was to be repeated for both vessels.

4. MEASUREMENT SYSTEM

The noise monitoring system consisted of a broadband hydrophone with integral preamplifier/ line driver, a low frequency noise cancellation system (to reduce the effect of the wave motion), a receiver/demodulator and a digital tape recorder (all battery powered).

4.1 Technical specifications

Hydrophone — Type: IMT measurement
Sensitivity: -165 dB re 1V/μPa (with pre-amp)
Directionality: omni-directional
Frequency Band: 6 Hz to 12.5 kHz (3 dB cut-off points)

The hydrophone calibration chart is included in the appendix.

Recorder — Type: AIWA DAT HD-S1
Frequency Range: 2 Hz to 22.5 kHz

The low frequency noise cancellation system was custom built to reduce the amount of noise produced by wave action on the hydrophone's flotation.

Analysis

Type:	HP 3582A spectrum analyzer
Averaging:	rms (32)
Window:	Hanning

5. RESULTS

For the duration of the trial period the weather varied between sea state 4 and 8 on the Beaufort scale. This was outside of normal safety limits for operating monitoring equipment from a small boat. Fortunately there were two short windows in the weather allowing IMT personnel time to record the required radiated noise levels.

The original trial plan, to monitor the noise levels at 4 points around each vessel had to be modified. Acceptable recordings were made by deploying the hydrophone 100 meters from the bow of each vessel (on the lee-ward side) then drifting out to 300 meters. During this time the relative position of the monitoring boat was announced every 50 metres by the target vessel and logged to aid later analysis.

The results produced are of the vessel LGM, the LGM preparing to deploy the crawler and LGM plus the crawler operating. The levels from the other vessel, the Grand Banks are of the vessel and the vessel plus the drill operating. No ambient records were available due to the unfavourable weather conditions.

6. LGM

6.1 LGM 100 Hz spectrum

The basic tonal structure has a predominant peak at 15 Hz with harmonics at 30 Hz, 45 Hz, 60 Hz and 75 Hz. The 15 Hz tonal could be fundamental but there is a possibility that there is a 7.5 Hz tonal at a lower level. The 15 Hz tonal could be the product of a machine rotating at 900 rpm, or more likely the second harmonic of the 7.5 Hz component (450 rpm).

Figure 1 below is a combined spectrum of all the LGM measurements (6) in the low frequency band i.e. 100 Hz for the vessel and the vessel plus the crawler operating. The noise level variations were due to poor measurement conditions i.e. bad weather, suspect positioning and that the recordings were made on different days. There was no definite change in this spectrum due to the crawler working. Attached in the Appendix are examples of the individual spectra (figures 13 to 30).

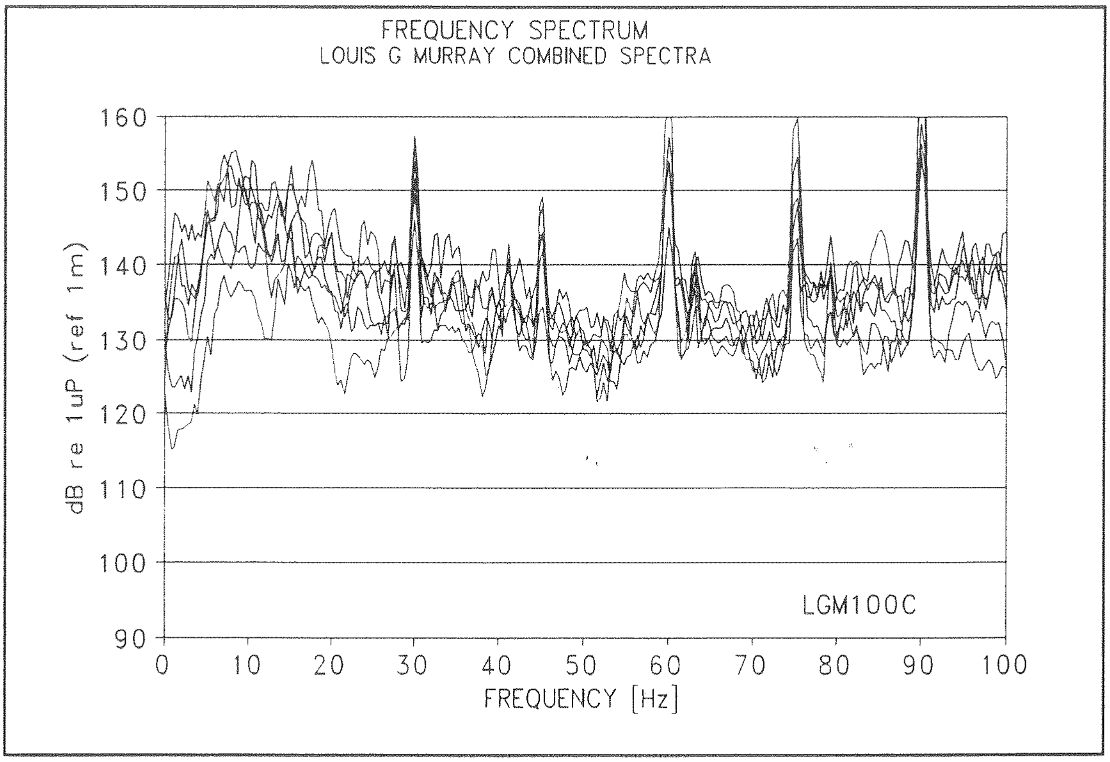

Figure 1: LGM combined spectra (Δf = 400 mHz).

6.2 LGM 1 000 Hz spectrum

Analysis of the recordings show that the underwater radiated noise level of just the LGM was higher in the first recording (recorded on day 2) than the measurement taken on day 3. (Day 2, the crawler was non-operational, Day 3 the crawler was operational but not deployed.)

The difference in the broadband levels (not due to the crawler) is due to the sea state (day 2 sea state 5, day 3 sea state 3).

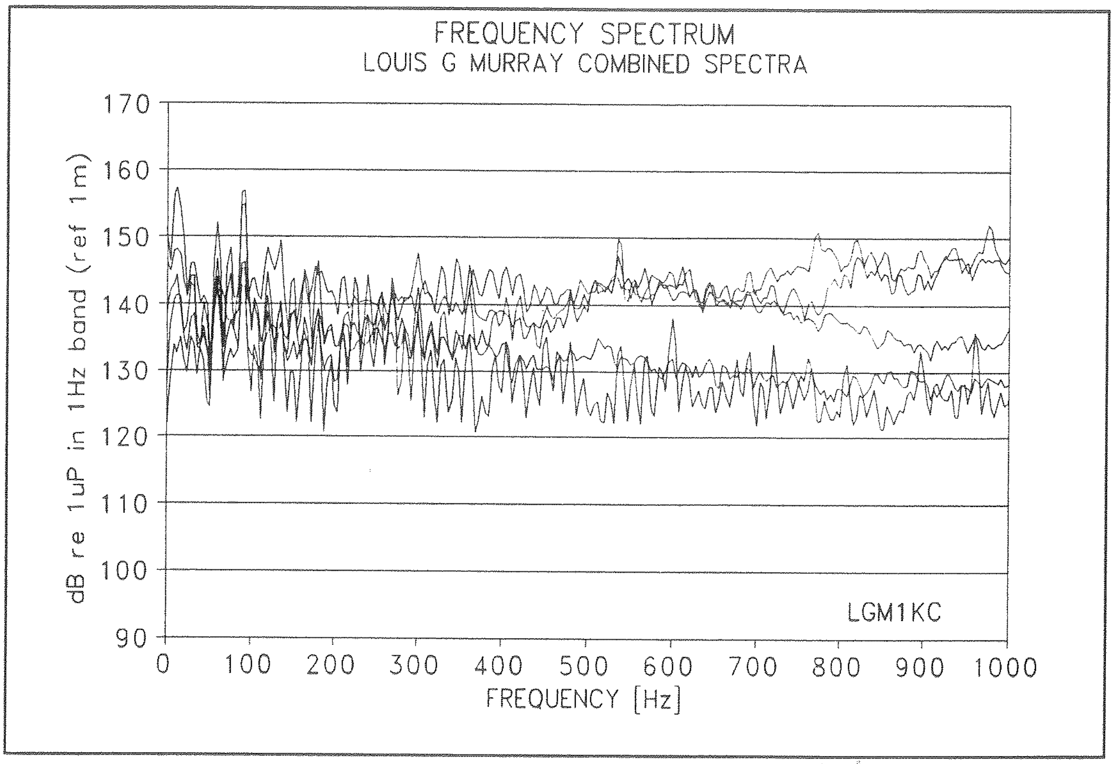

Figure 2: LGM 1 kHz combined spectrum.

Noise levels from the crawler:

Between 0 and 400 Hz the spectrum is dominated by a tonal structure produced by the vessel and possibly the crawler (unable to distinguish). Above 500 Hz there is a gradual increase in the broadband level (as much as 20 dB at 1 000 Hz) caused by the crawler operation.

6.3 LGM 10 kHz spectrum

When the crawler is operating there is a marked level increase between 1 kHz and 10 kHz, with an identifiable peak at 2 600 Hz. The difference between the two modes of operation is between 20 and 25 dB. Figure 3 illustrates the combined noise levels.

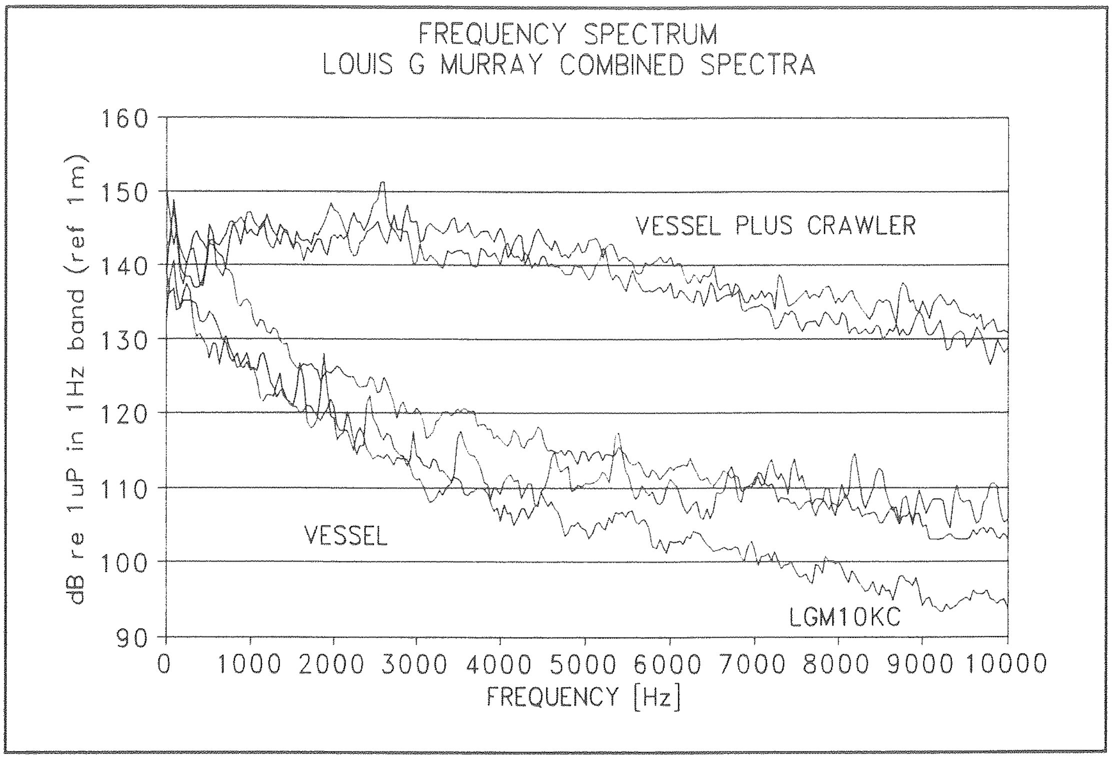

Figure 3: LGM 10 kHz combined noise levels.

6.4 LGM 25 kHz spectrum

The comparison between just the vessel and the vessel with the crawler operating indicates a constant broadband noise level increase across the measured spectrum of between 20 and 25 dB. The increase in noise level is produced by the movement of air and rocks up the suction pipes.

NOTE:

The measurement system i.e. the hydrophone and amplifier have a flat response between 6 Hz and 12.5 kHz. After which there is a steady decrease in sensitivity. The DAT tape recorder has a frequency response up to 22.5 kHz after which it drops dramatically.

Observation

The crawler produces a broadband noise level increase between 500 Hz and 22.5 kHz* (* DAT recorder limitation). The approximate band level is 167 dB re 1 μPa in the 25 kHz band (referred to 1 meter).

A "ping" of 2 250 Hz was monitored while the crawler was operating. This is outside of the equipment measurement range, therefore a source level estimation is not possible.

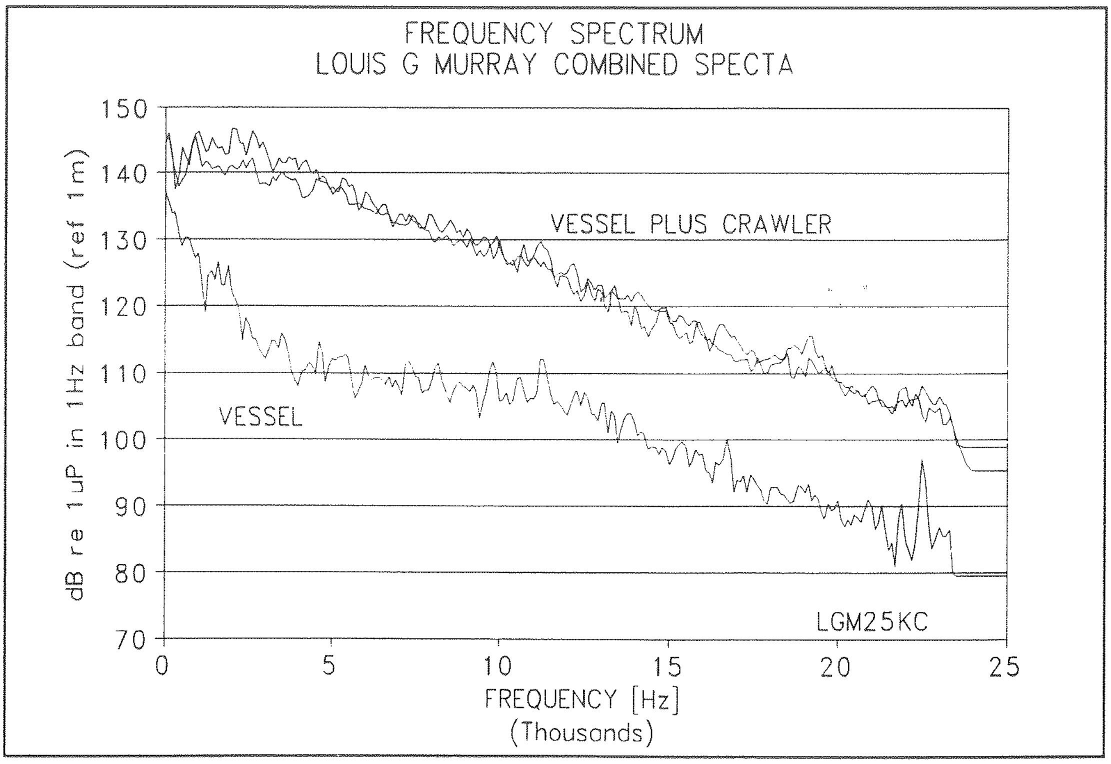

Figure 4: LGM 25 kHz combined spectrum.

7. GB SPECTRUM

All the GB measurements were conducted on the same day. The measurements started at 100 meters from the vessel, inline with the bow, and concluded at 300 metres from the vessel. This drift method of measurement was used as the strong wind and sea motion limited the scope of these measurements. This measurement was repeated for comparison.

7.1 GB 100 Hz spectrum

This spectrum is dominated by tonals produced by the rotating machinery. The drill and the vessel's operating noise levels cannot be distinguished from each other. There is a large variation in the noise level at 10 Hz the reason for this is unknown. This higher level is both present in the vessel recording and the vessel plus the drill. It is also absent from one of the vessel recordings. This noise component is significantly large and is therefore worth further study.

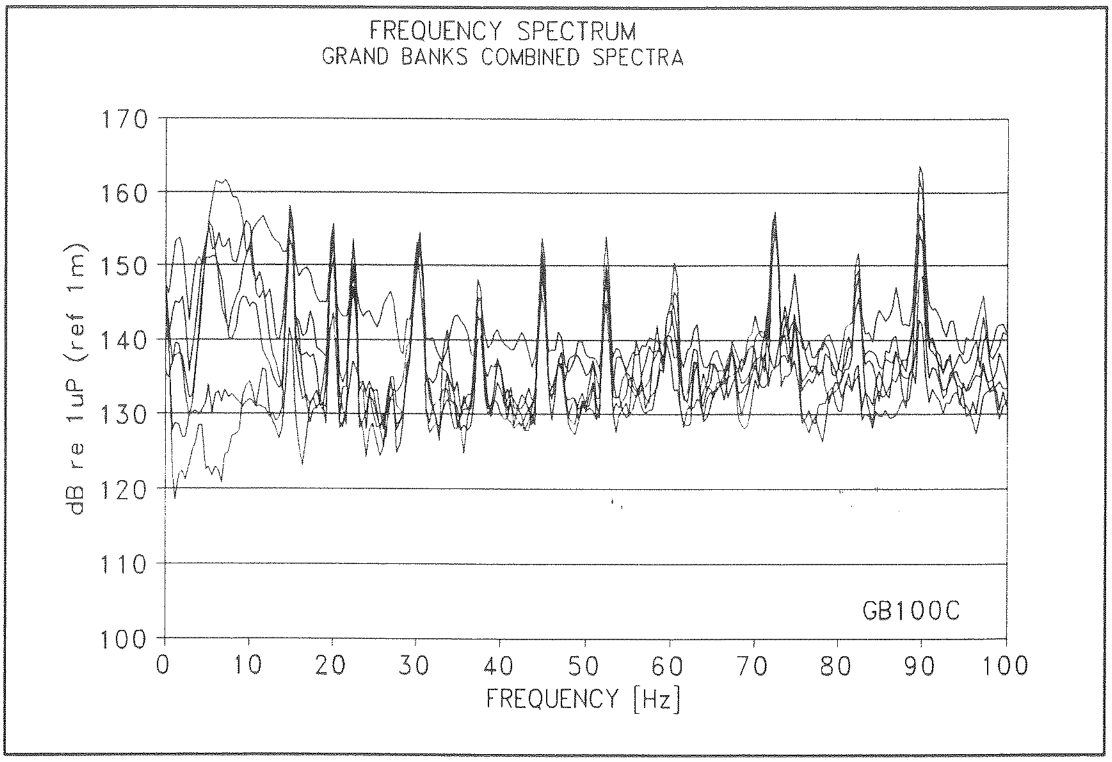

Figure 5: LGM 100 Hz combined spectra (Δf = 400 mHz).

7.2 GB 1 000 Hz combined spectrum

As with the LGM crawler the drill noise is only noticeable above 400 Hz. This increase in noise level is broadband and is approximately 10 to 15 dB above the vessel noise at 1 kHz.

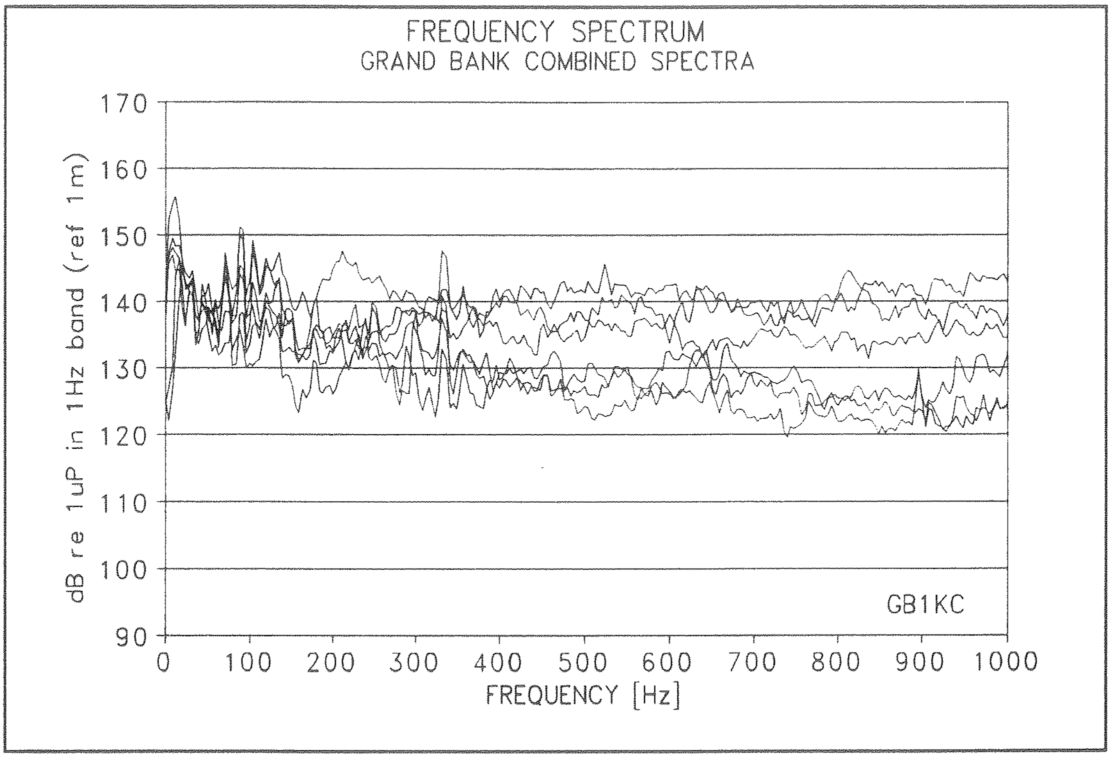

Figure 6: Grand Banks 1 000 Hz combined spectrum.

7.3 GB 10 kHz spectrum combined spctrum

The broadband noise level increase is similar to that of the LGM being 20 - 25 dB higher across the 1 kHz to 10 kHz spectrum.

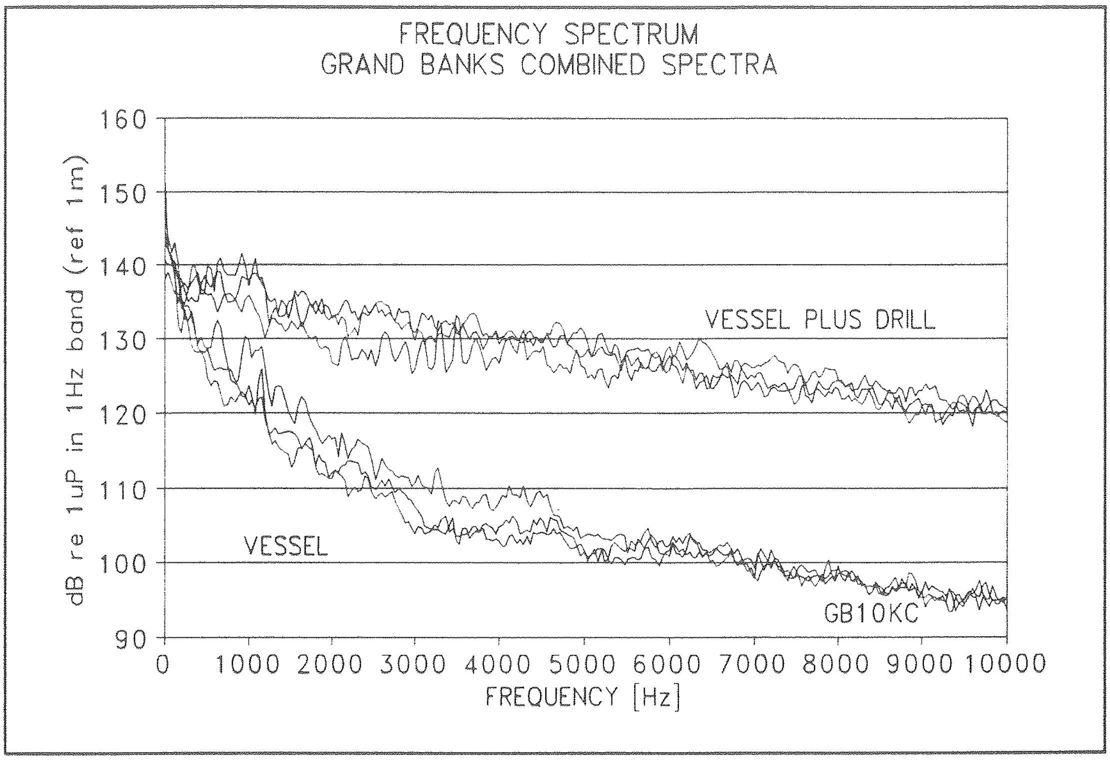

Figure 7: Grand Banks 10 kHz combined spectrum.

7.4 GB 25 kHz spectrum and general

The drill and crawler methods of mining have very similar increases in broadband noise level, above the vessel's self-noise levels. Like the crawler the drill used by the GB has a broadband level increase of 20 to 25 dB from 500 Hz up to 22.5 kHz* (*DAT recorder limitation). The major difference between the two mining vessels is that the GB is overall more quiet by 6 dB than the LGM.

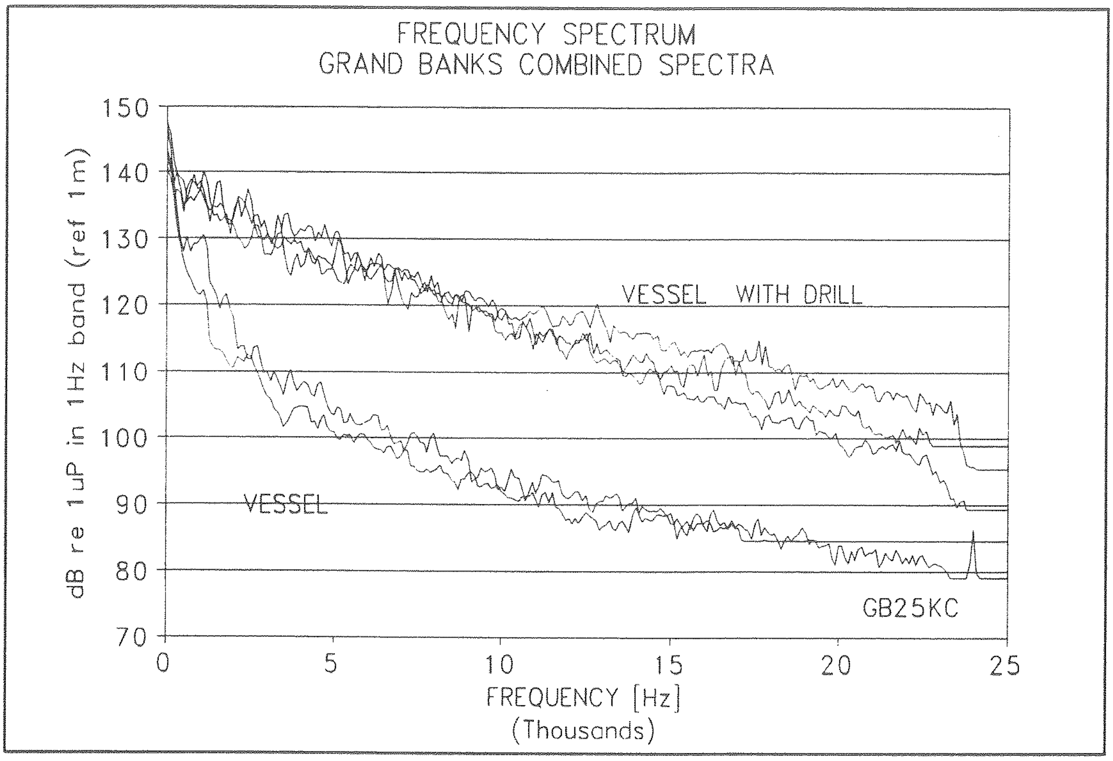

Figure 8: GB 25 kHz dB combined spectrum.

8. RELATIVE LEVELS

8.1 Mining operations

Illustrated below in figure 9 is the estimated levels of the mining vessels compared with the two different types of mining process. The graph starts at 100 Hz as below this frequency the radiated noise levels are mainly due to the mining vessel's rotating machinery. From this graph it can be clearly seen that the noise generated by the two mining processes is broadband i.e. between 100 and 25 000 Hz, with peak levels at 1 000 and 3 000 Hz.

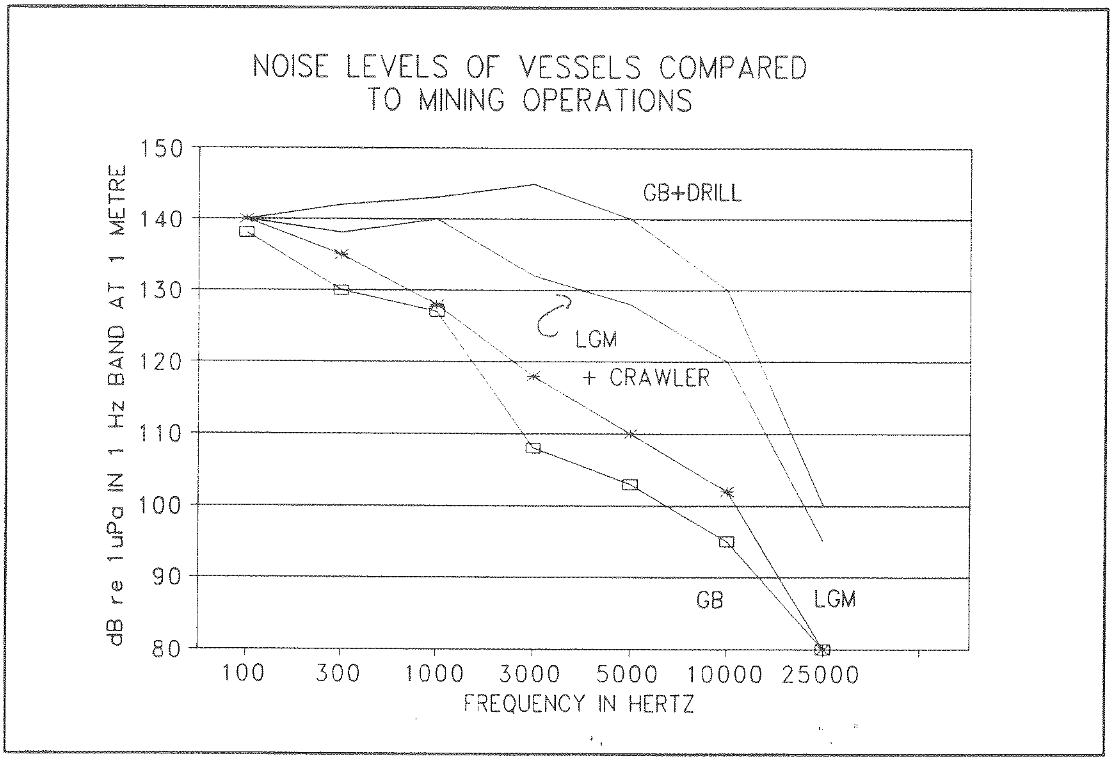

Figure 9: Noise level comparison.

8.2 Merchant vessels

To understand the significance of the radiated noise, the levels produced by the mining operations are compared with a maximum predicted merchant vessel source level (Sonar Handbook - Ref. 1). The vessel indicated in figure 10 is a merchant vessel moving at 20 knots. From this one can see that the radiated noise produced by the mining operations is equal to the merchant levels, depending upon the mining process.

Note:

The fall-off in amplitude of the high frequencies are due to system constraints.

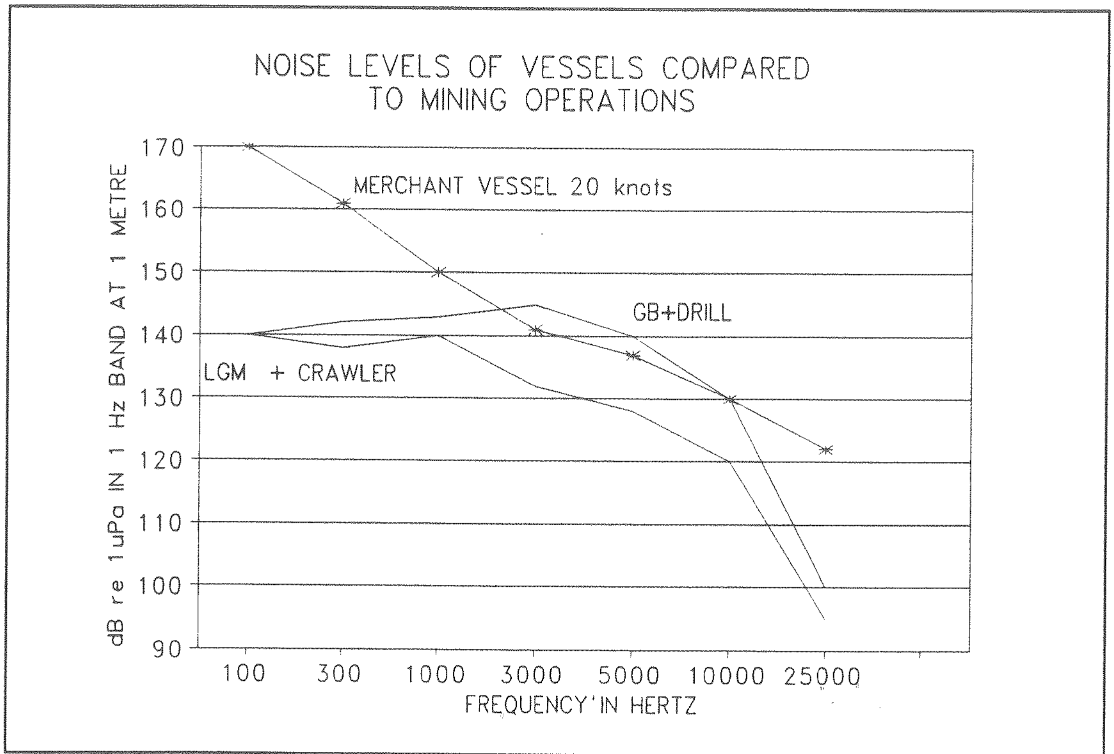

Figure 10: Mining operations versus typical shipping noise levels.

8.3 Ambient levels

In figure 11 the level of mining related noise is compared to the ambient noise level produced by a sea state 3. The mining vessel's noise level is then modified to illustrate the attenuation as a function of range. From this one can see that the noise produced by the mining operations (worst case) can be detected above the ambient noise level for well over 1 000 metres. This is only a guideline as there are many factors that can modify the expected range i.e. variation in salinity, temperature, conductivity, water depth bottom type and the absorption of energy at the higher frequencies.

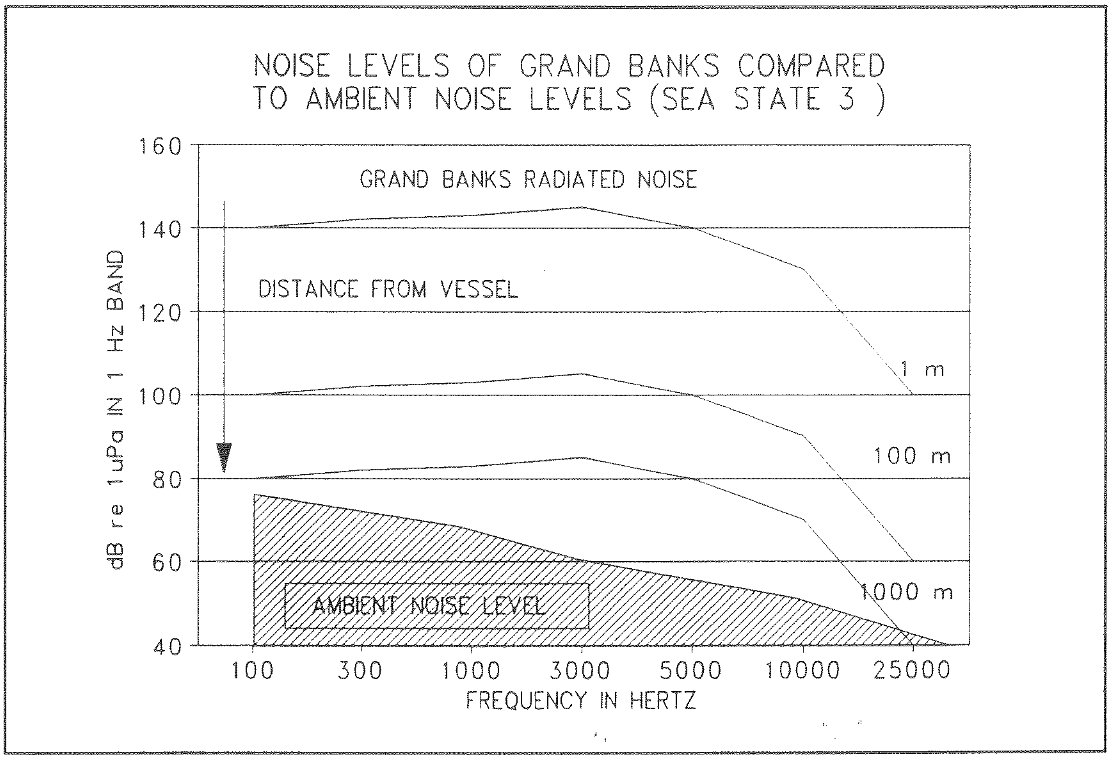

Figure 11: Ambient noise comparison.

9. CONCLUSION

The results produced by analysis of the noise radiated from the Louis G Murray and the Grand Banks indicate that the overall worst case (Grand Banks) levels are no louder than the predicted maximum levels of a merchant vessel. The only uncertainty being the sub 10 Hz levels produced by the Grand Banks.

This area of the spectrum needs further study as this type of noise can propagate long distances, under the right conditions. The other type of noise that has not been measured by this study is that of the underwater positioning system i.e. Sonar Dyne. This is because of the limited frequency range of the recording equipment. Typically the Sonar Dyne system operates between 20 and 40 kHz. The system used to record the radiating noise levels was limited to 22 kHz.

10. RECOMMENDATIONS

To complete this study it will be necessary to make a few more recordings covering ambient noise (at least 5 km from any vessel), low frequency noise (noise between 1 Hz and 10 Hz) and high frequency noise (above 22.5 kHz) to detect the positioning transponders. This must be done under more suitable weather conditions.

11. REFERENCES

1. La Grange, P.L., Sonar Handbook. IMT Report KT076-060000-731001, Issue No 5. February 1993.

APPENDIX A

Hydrophone calibration chart.

Examples of individual noise spectra.

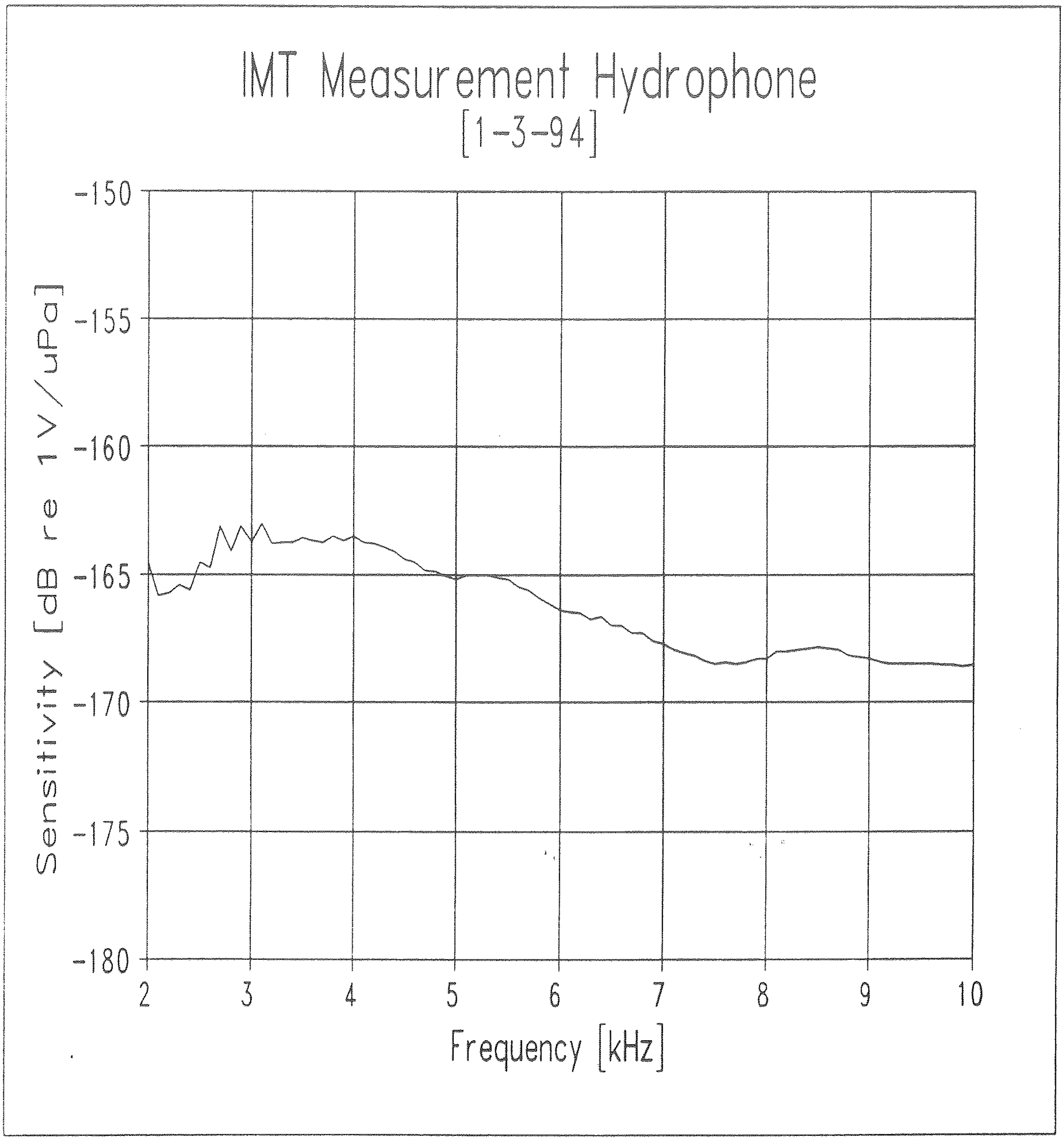

Figure 12: Hydrophone calibration chart.

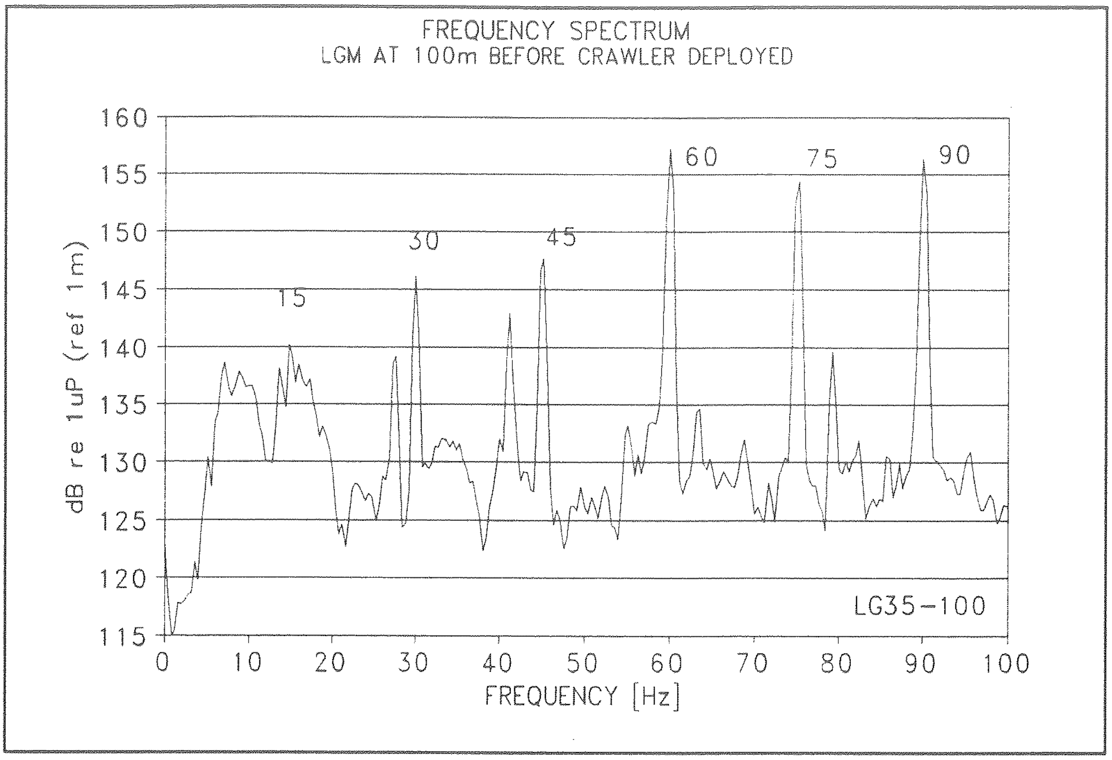

Figure 13: LGM before crawler (100 Hz Δf = 400 mHz).

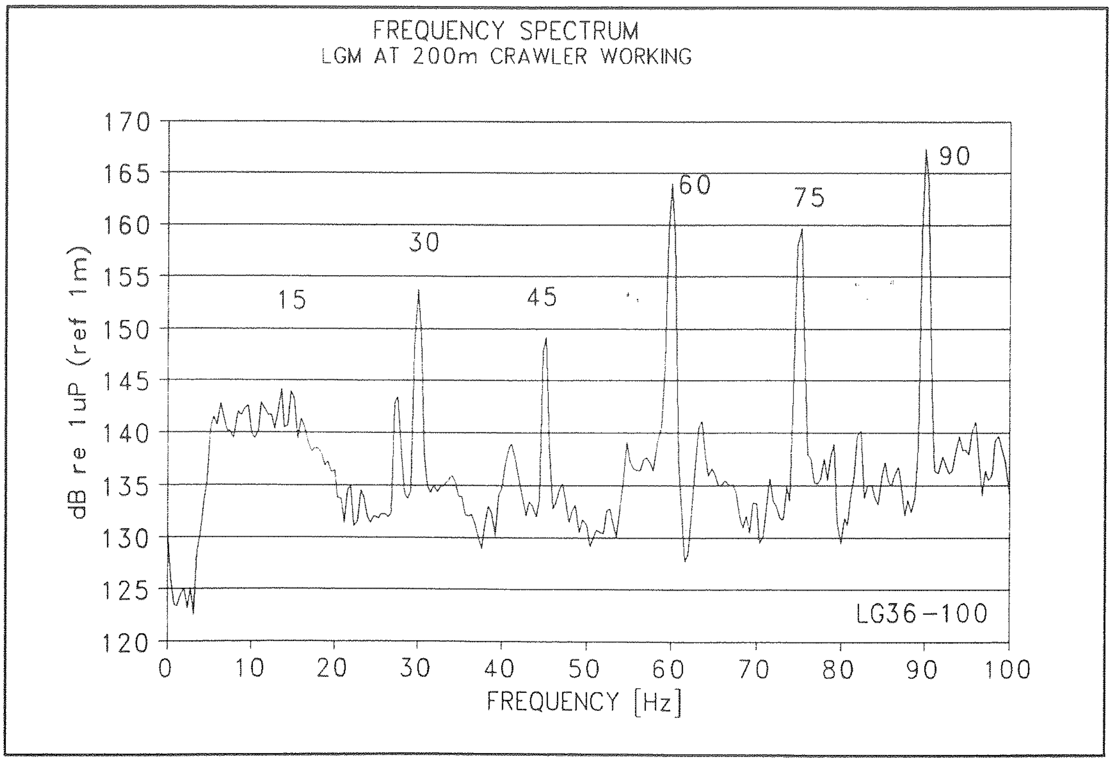

Figure 14: LGM crawler working (100 Hz Δf = 400 mHz).

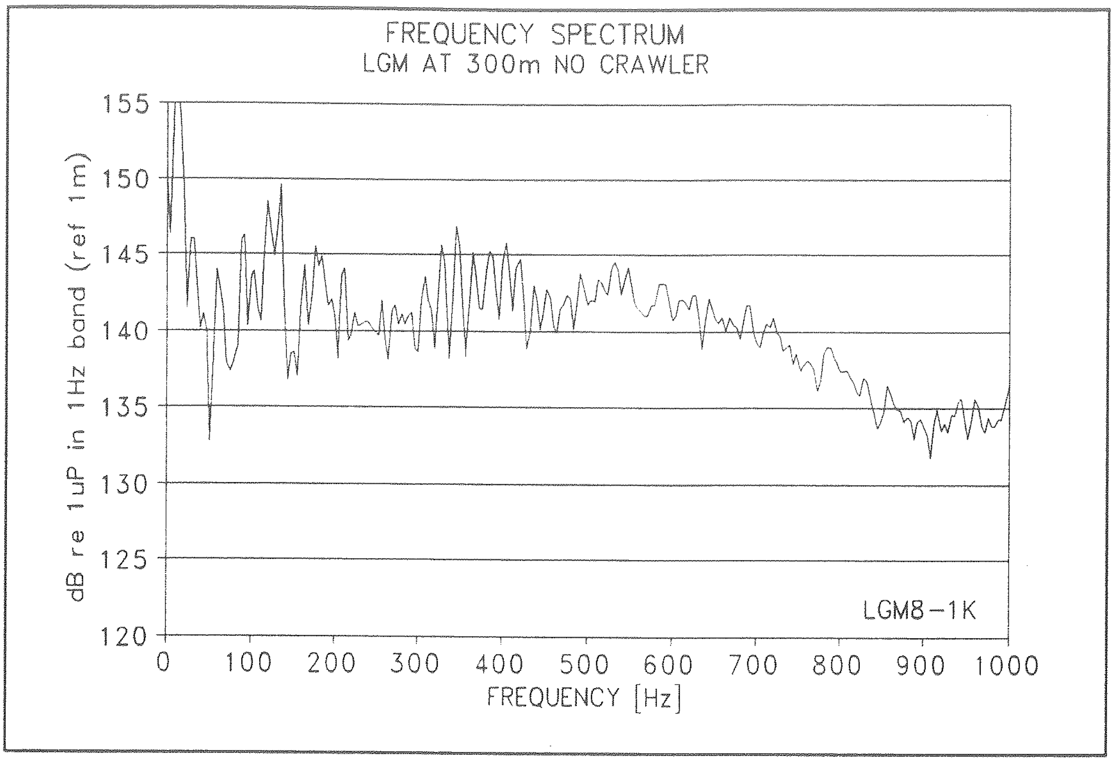

Figure 15: LGM crawler working (1 000 Hz).

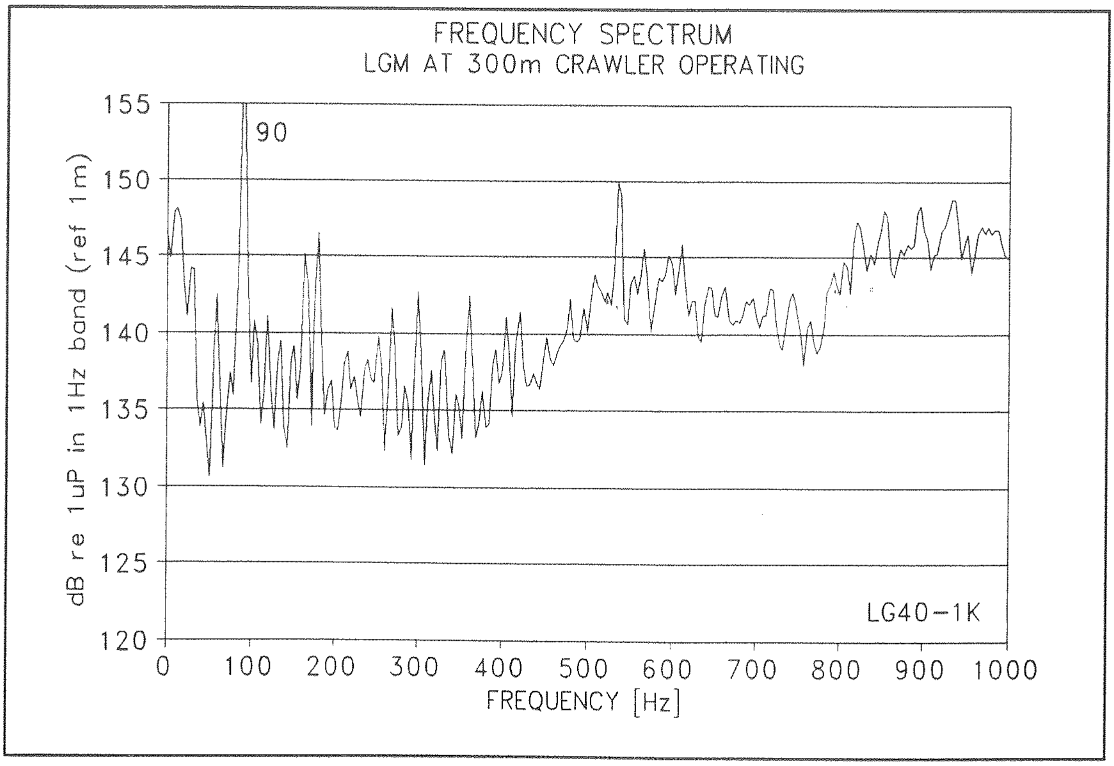

Figure 16: LGM no crawler (1 000 Hz).

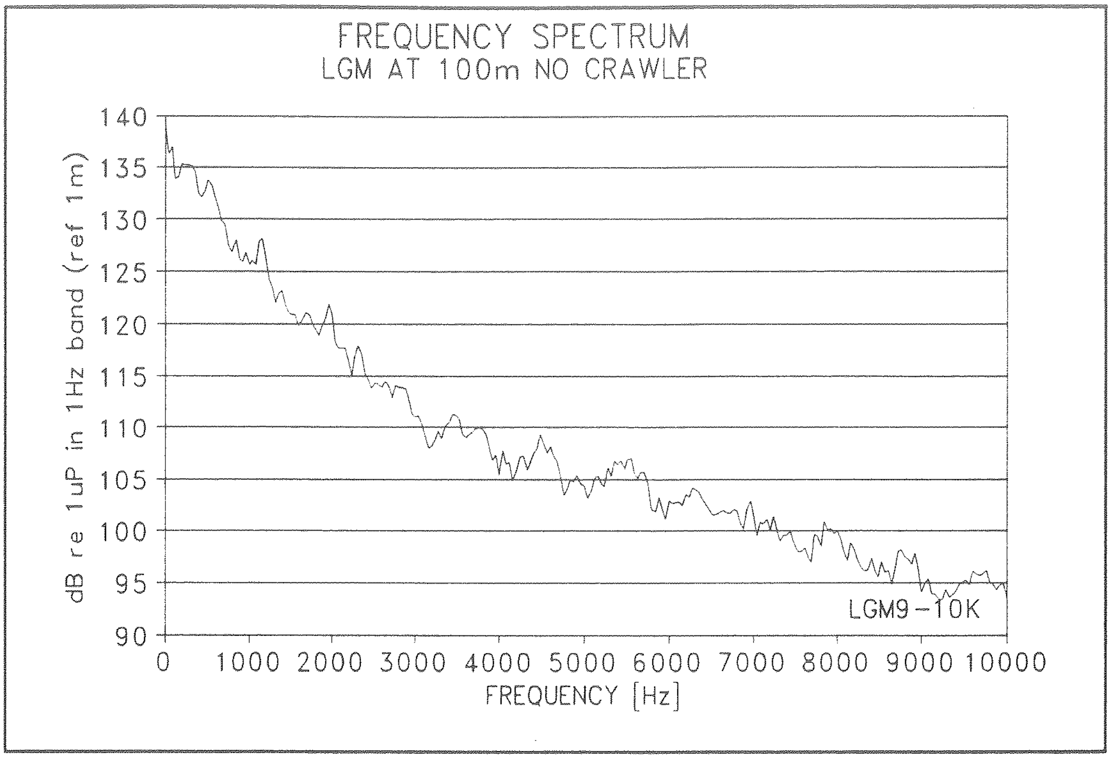

Figure 17: LGM no crawler (10 kHz).

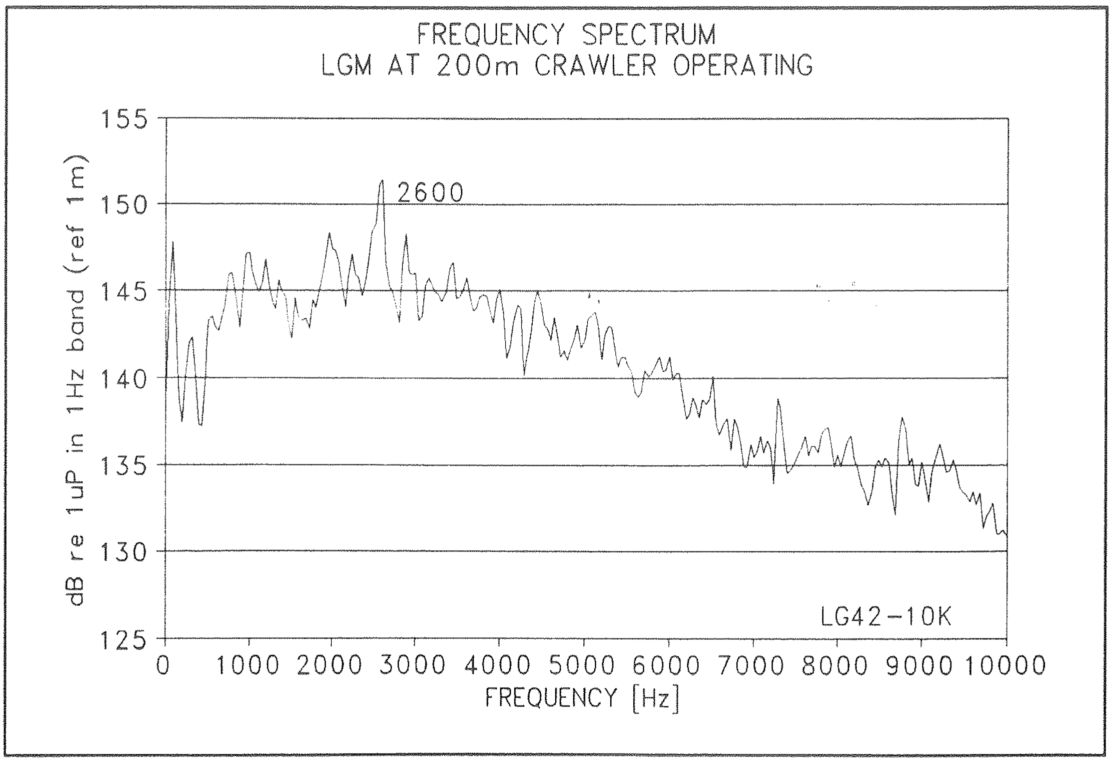

Figure 18: LGM crawler working (10 kHz).

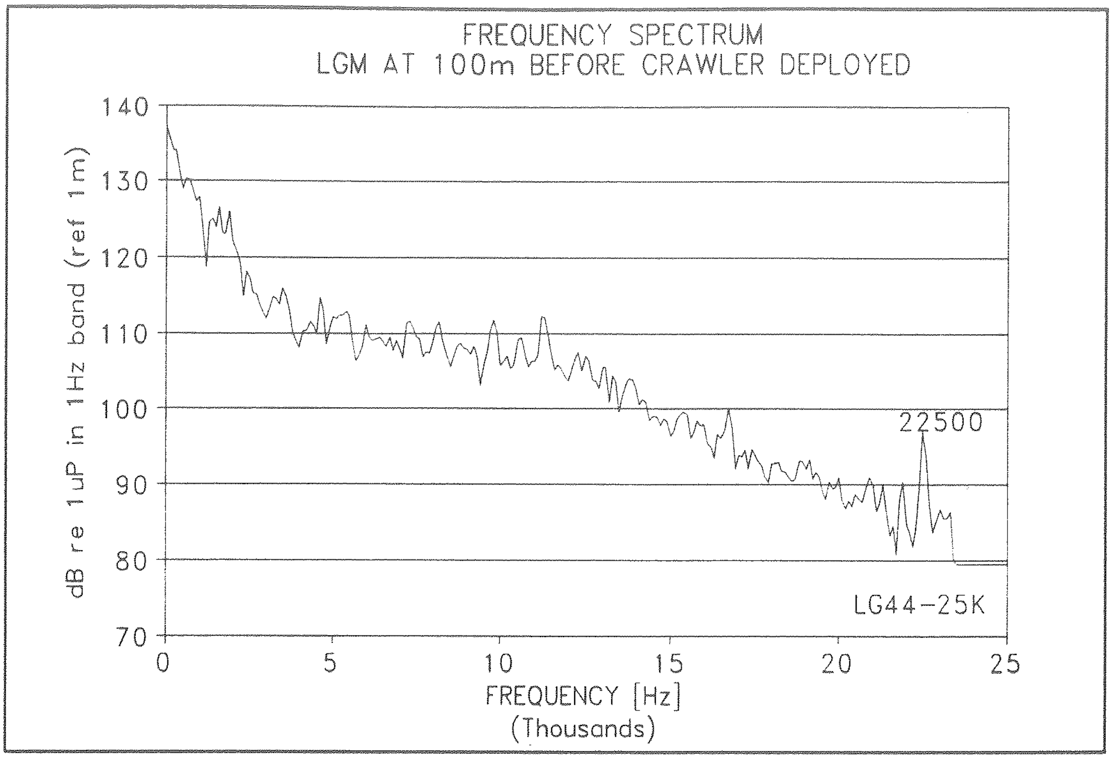

Figure 19: LGM before crawler (25 k).

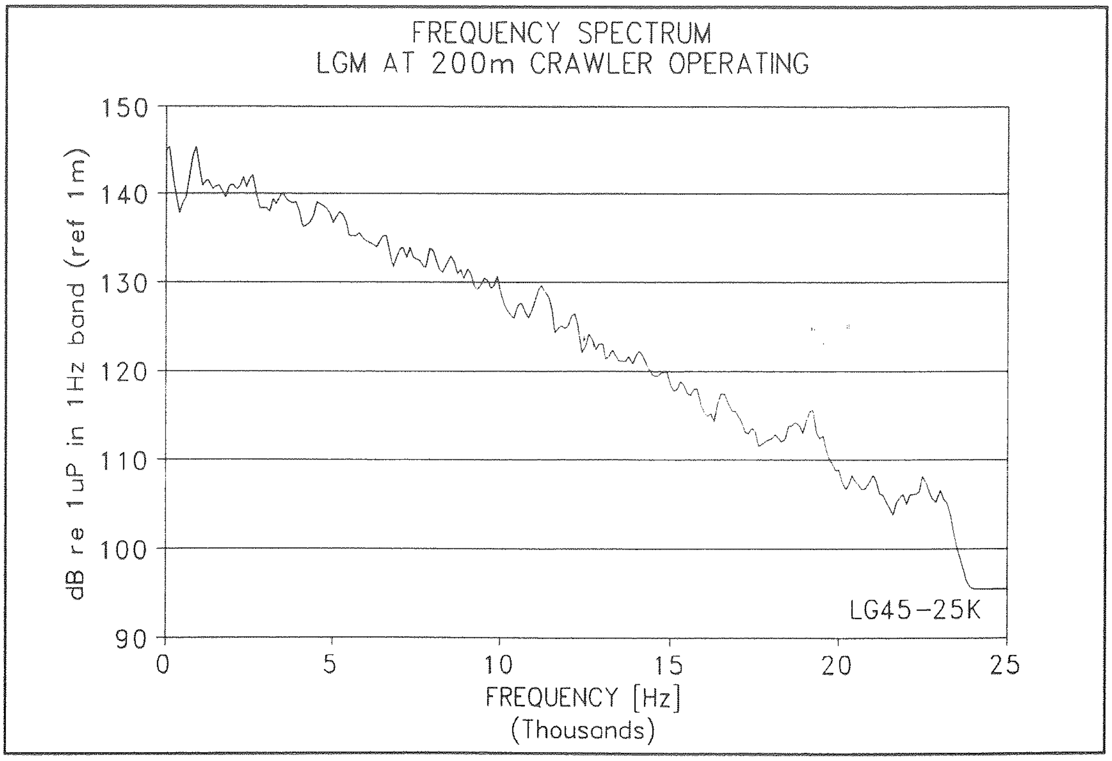

Figure 20: LGM crawler operating (25 k).

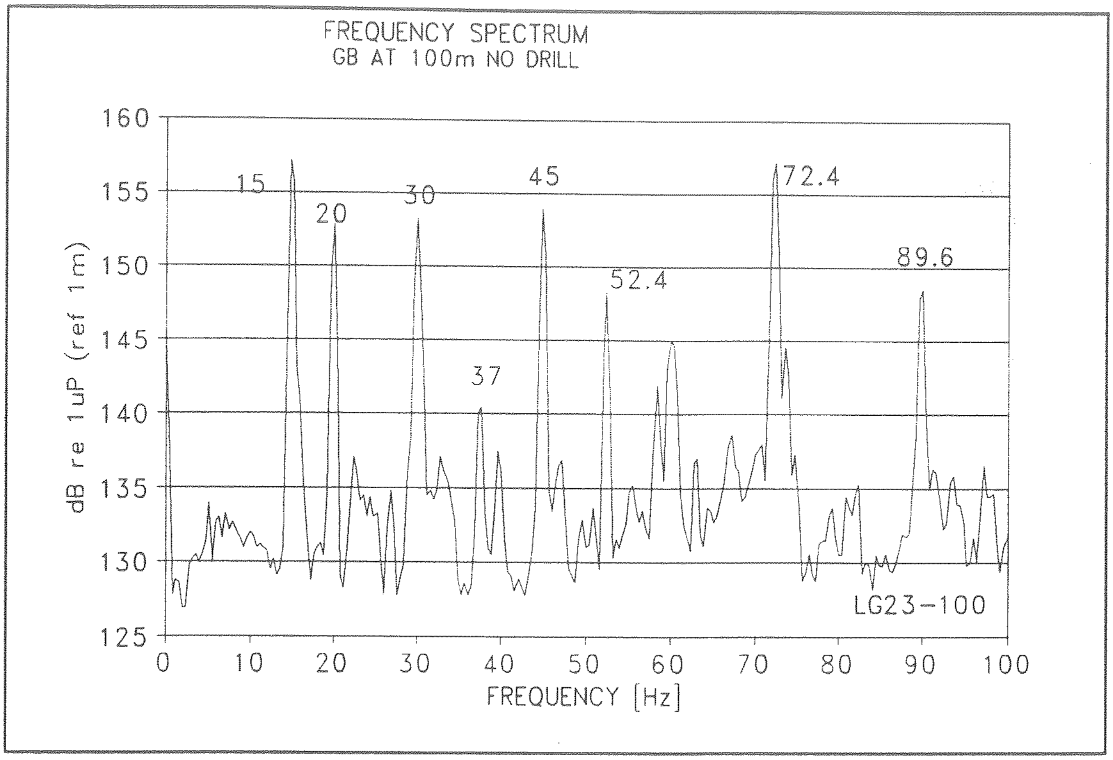

Figure 21: GB no drill (100 Hz).

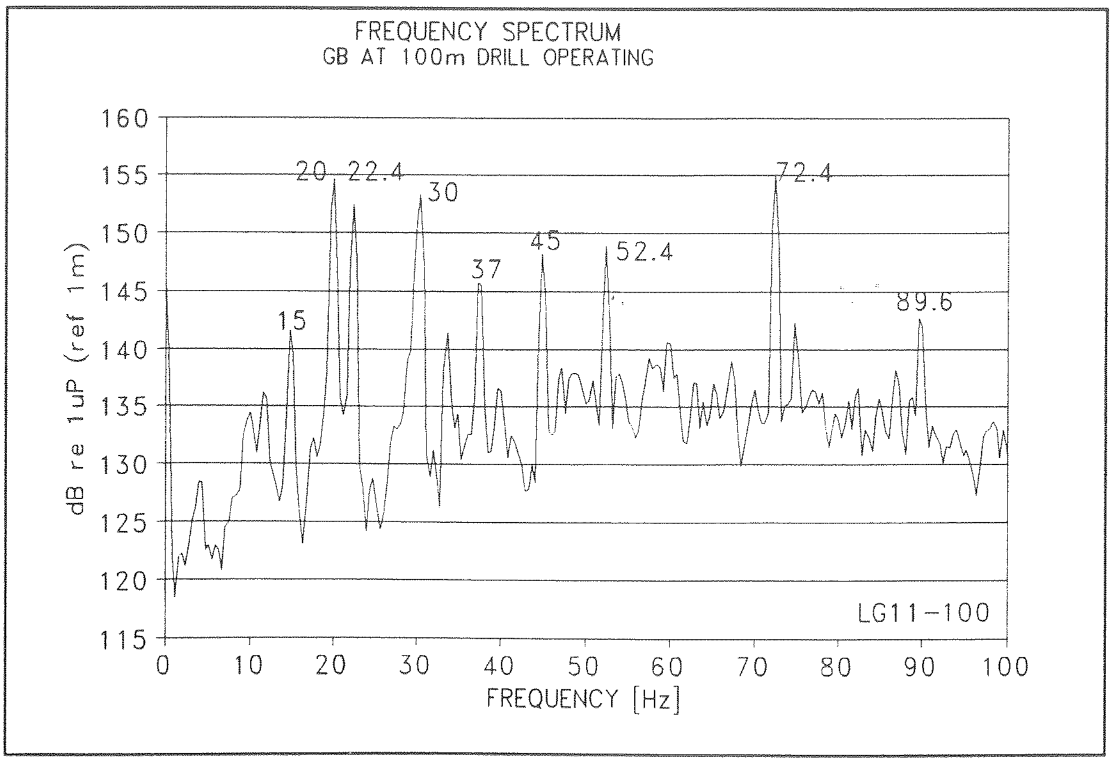

Figure 22: GB drill operating (100 Hz).

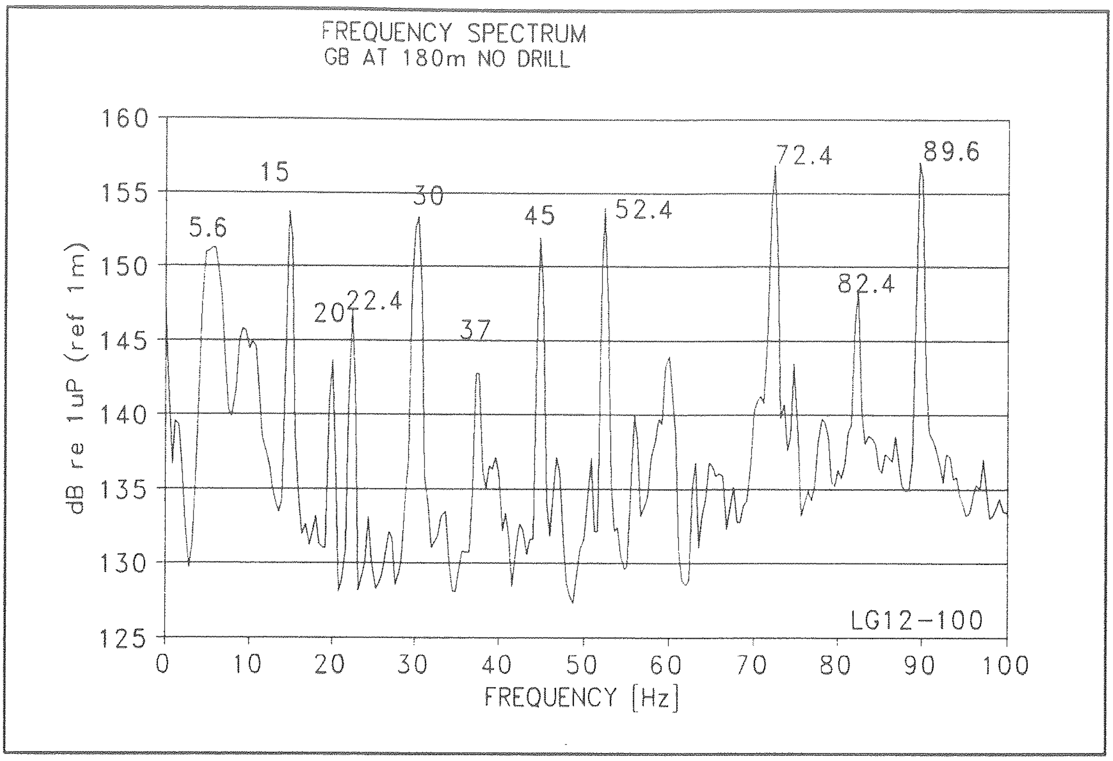

Figure 23: GB no drill (100 Hz).

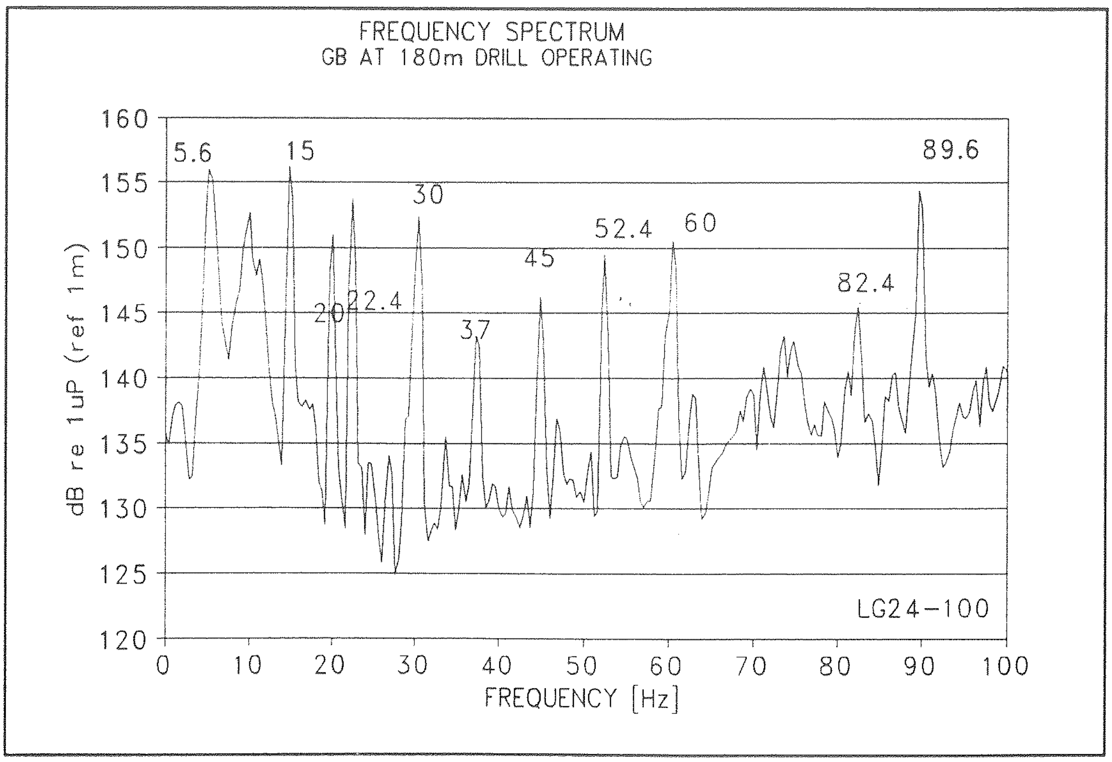

Figure 24: GB drill operating (100 Hz).

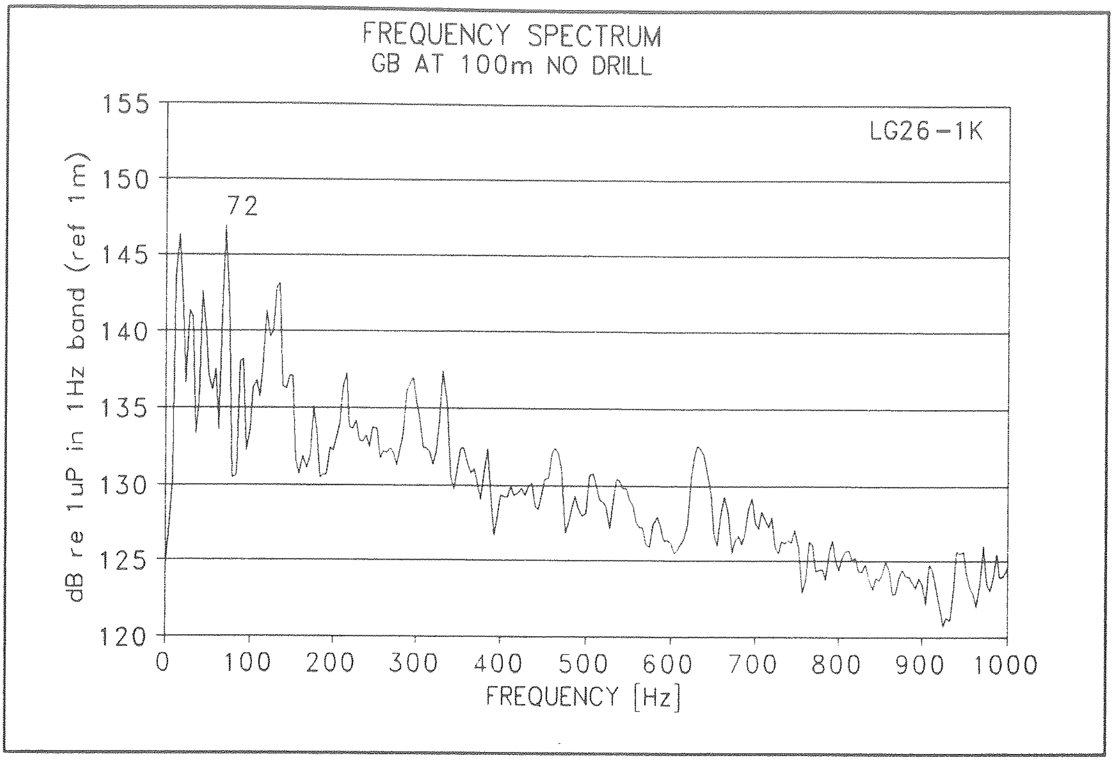

Figure 25: GB no drill (1 kHz).

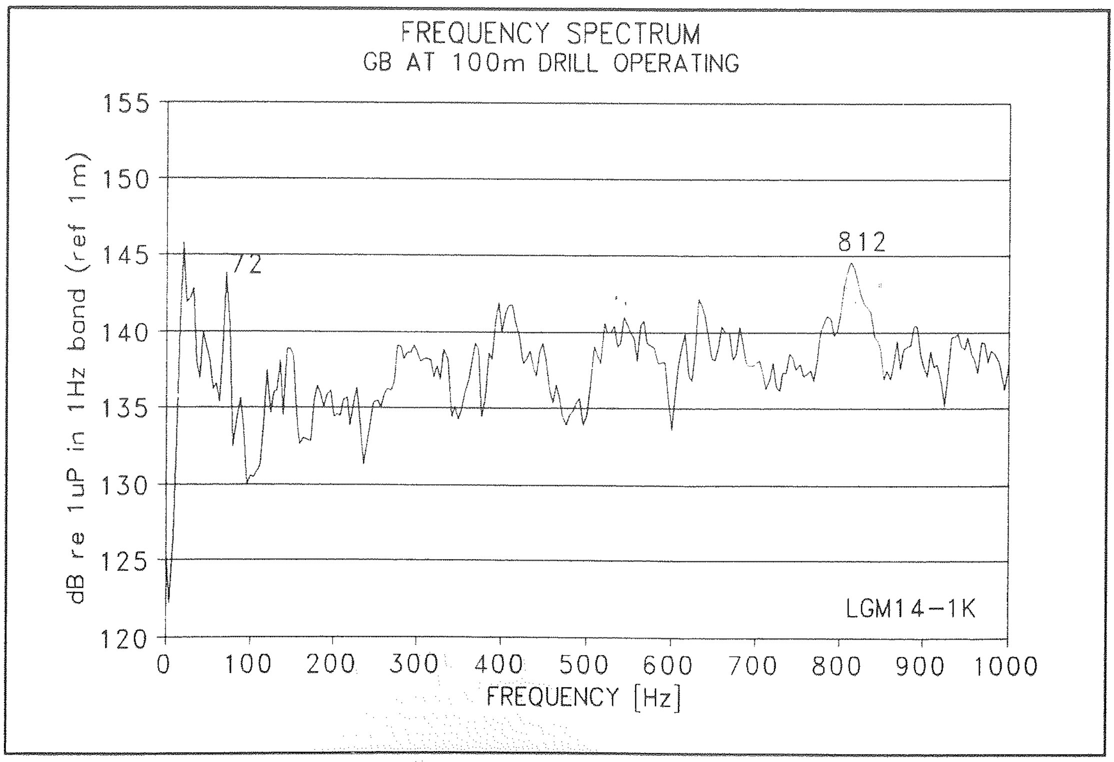

Figure 26: GB drill operating (1 kHz).

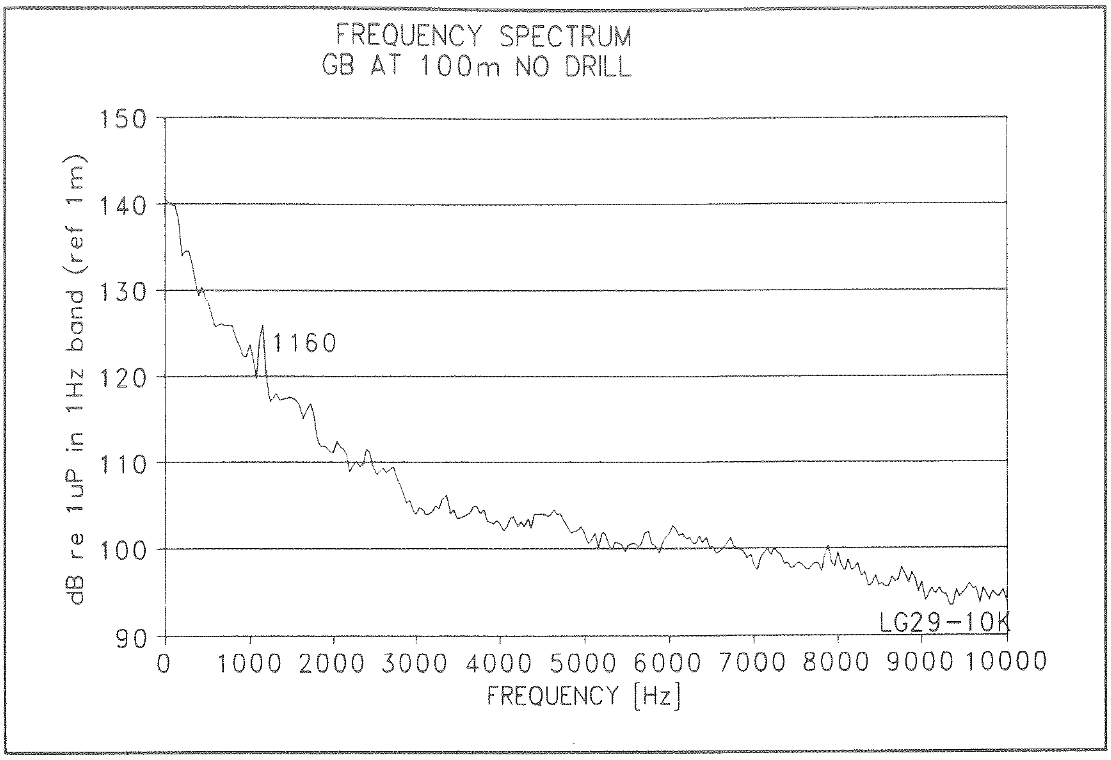

Figure 27: GB no drill (10 kHz).

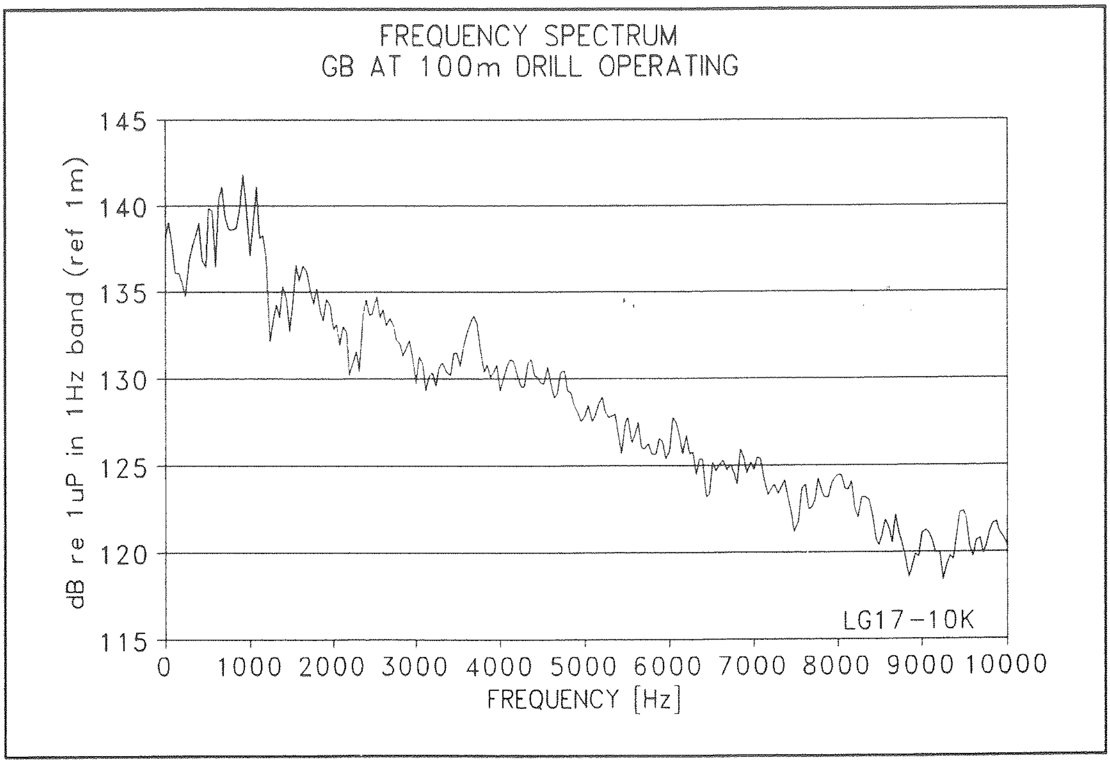

Figure 28: GB drill operating (10 kHz).

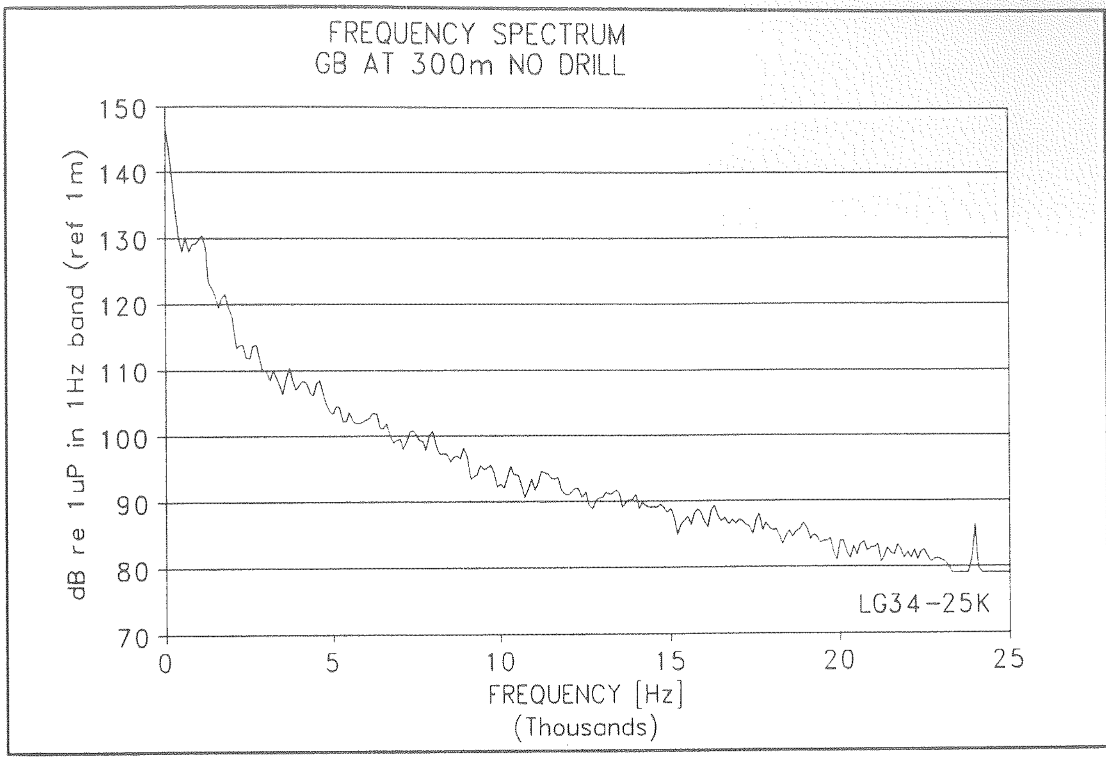

Figure 29: GB no drill 25 kHz.

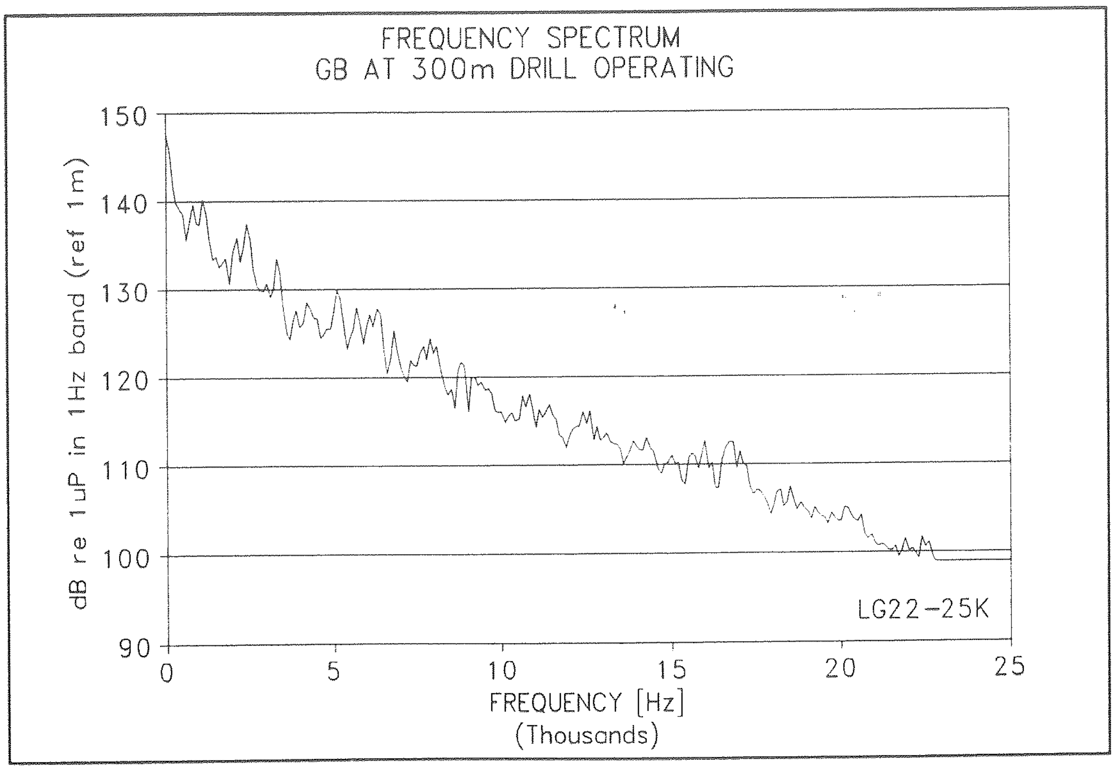

Figure 30: GB drill operating 25 kHz.