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Les enjeux liés aux levés sismiques dans
l'estuaire et le golfe du Saint-Laurent

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The marine vibrator

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As the geophysical industry enters the 21st century, it is undergoing several fundamental changes. One challenge involves the requirement to perform marine surveys in ways that are less intrusive to the environments in which we operate. Many oil and gas producing areas in shallow water and transition zones remain unsurveyed as a result of environmental restrictions. In the United States the Marine Mammal Protection Act is now raising issues regarding operations of conventional air-gun source vessels. These kinds of challenges are not new to our industry. An early Conoco land vibrator crew made possible a survey in Los Angeles when dynamite was thought the only solution. The concept of using swept signal sources as a more environmentally friendly alternative to impulse sources is a solution that our industry has been familiar with for a long time. This article contends that a similar solution for marine environments already exists—the marine vibrator.

The swept signal source generates an amplitude output spread over several seconds. The impulsive source releases its output in milliseconds, not seconds. As a result of this fundamentally different approach, the impulsive source will project higher instantaneous pressures than the swept signal source. Yet, as we know when we compare land vibrators to dynamite, the data results can be considered reasonably similar. In the marine environment, the situations are different but comparable. As a result of the introduction by the U.S. Navy of the SURTASS LFA system, the Navy has funded various research projects into the effects of high sound pressure levels on ocean mammals. This research, summarized in an environmental impact statement published in January 2001, set 180 dB as the threshold limit for marine mammals. A typical air-gun array will generate 255 dB. A deepwater array of four marine vibrators will generate approximately 223 dB. This information allows calculation of the exposure level (EL) at a given distance from the source. This calculation is based upon spherical spreading. The source level (SL) is the output that would be measured by a hydrophone located 1 m from the acoustic center of the source array and referenced to 1 µPa.

$$\text{The distance (m) to reach an EL of 180 dB} = 10^{\left(\frac{SL-EL}{20}\right)}$$

According to this formula, the 180 dB exposure level is reached 5.6 km from the air-gun array and 141 m from the marine vibrator array.

$$\text{Air gun array} \quad 5.6\ \text{km} = 10^{\left(\frac{255-180}{20}\right)}$$

$$\text{Marine vibrator} \quad 141\ \text{m} = 10^{\left(\frac{223-180}{20}\right)}$$

This is a dramatic demonstration of the relative sound pressure advantages of swept sources versus impulsive sources. The determination of the safe exposure level for marine mammals is still being investigated.

In shallow water areas, the environmental concerns are different. One issue is the impact of the pressure wave on the bottom living organisms. To be effective an impulsive source must be at a depth of several meters in the water to minimize surface loss of energy. Marine vibrators are able to produce full output in as little as 1 m of water depth. In 5 m of water, a 500 inch^3 air-gun array producing 6.4 Bar, located 2.5 m from the surface, will generate a 1.024 bar pressure wave on the bottom. A marine vibrator in 5 m of water, located 1 m from the surface, and producing 0.4 bar will generate a 0.025 bar pressure wave on the bottom—a pressure 40 times smaller than a typical shallow water air-gun array.

Historically, the marine vibrator project started in late 1981 with the signing of an agreement between Industrial Vehicles International (IVI) and Britoil. IVI began evaluation testing in July 1982 of an existing transducer developed by Raytheon. These tests were carried out in an Oklahoma lake and were completed in January 1983.

However, this design had a number of performance and reliability problems and in August 1983 IVI started development of a marine source capable of generating a high-amplitude, broad-band, modulating frequency output. This resulted in several designs for the transducer. Both source performance evaluation and endurance testing were performed during this process.

In 1985 the first HUP-101 marine vibrators were commercially produced. This model was subsequently improved to version HUP-104, which offered higher amplitude output at low frequencies with reduced harmonics. Other support equipment such as the marine vibrator power unit were also commercialized during this period.

Subsequent to this introduction a number of shallow water and deepwater surveys were executed. One shallow water survey in the Gulf of Mexico made some comparisons between dynamite and marine vibrators. Frequency analysis of the data showed that the marine vibrator energy returning from the target zone contained higher frequencies than the dynamite data (Figure 1).

Geco ran the initial deepwater test in the Gulf of Mexico in 1984. This test ran a line with a single marine vibrator. Figure 2 shows the data.

Geco ran additional surveys in 1987 using an array of six marine vibrators. Figure 3 is an example of these results.

In 1993 IVI signed an agreement granting Schlumberger exclusive use of the marine vibrator. During the next seven years, Geco-Prakla directed the marine vibrator project. Various surveys and tests were done during this period.

In 2000, the exclusivity agreement between IVI and Schlumberger expired. With the expiration of this agreement IVI has refocused on this project. A general review has been completed to update all aspects of the product to reflect new technologies and processes. A complete shallow water marine vibrator system was marketed in the first quarter of 2003. This system consists of marine vibrator modules, power units, and the associated controllers with GPS. It is capable of operating and generating full source output in as little as 1 m of water. With the environmental pressures on our industry growing, IVI is committed to offering the marine vibrator as a marine source acceptable to industry, government, and environmental groups.

Suggested reading. "Development of a hydraulic transducer for marine seismic" by Bird et al. (SEG 1984 *Expanded Abstracts*). "Marine vibrator field tests in the Gulf of Mexico" by Haldorsen et al. (SEG 1985 *Expanded Abstracts*). "Marine vibrators and the Doppler effect" by Dragoset (SEG 1988 *Expanded Abstracts*). "Shallow water use of marine vibrators" by Christensen (51st EAGE Conference and Technical Exhibition, 1989). "The effects of source and receiver motion on seismic data" by Hampson and Jakubowicz (*Geophysical Prospecting*, 1995). "The acoustic output

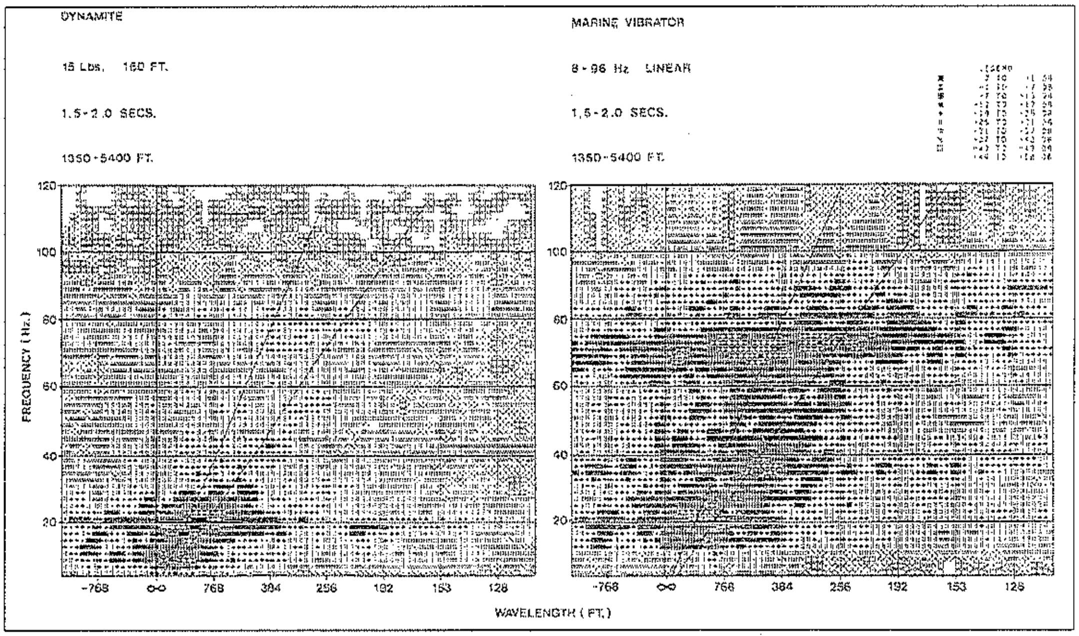

Figure 1. F-k plots showing frequency results of a dynamite and marine vibrator comparison.

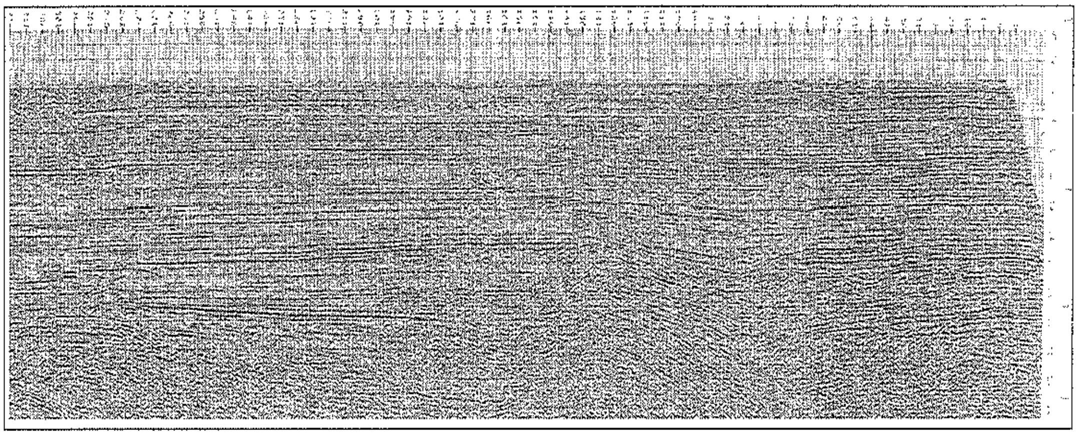

Figure 2. Results from initial 1984 test using a single marine vibrator.

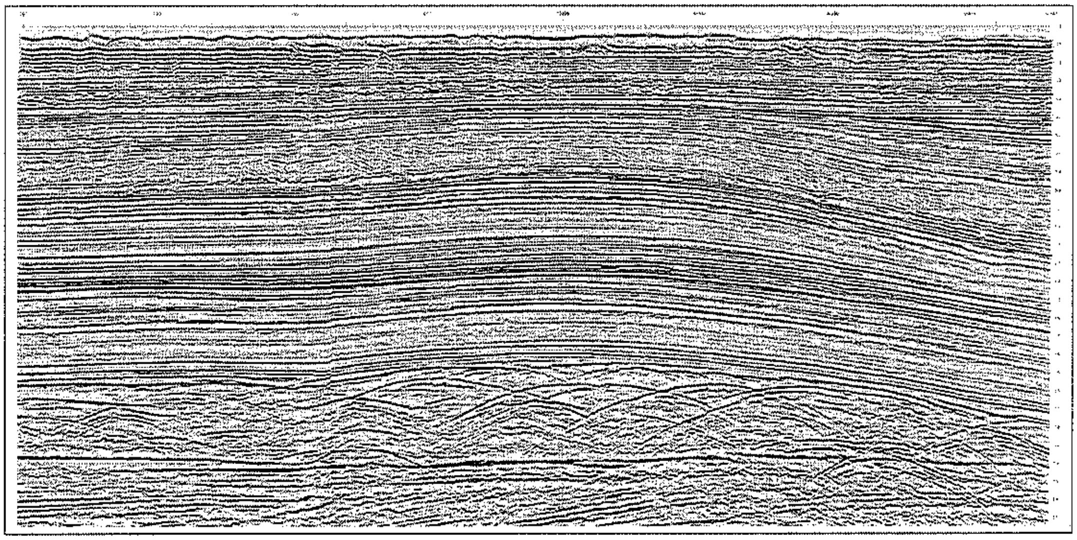

Figure 3. Results from 1987 North Sea survey.

of a marine vibrator" by Walker et al. (SEG 1996 *Expanded Abstracts*). "Comparison of marine vibrator, dynamite, and airgun sources in the transition zone" by Potter et al. (59th EAGE Conference and Technical Exhibition, 1997). "Seismic data acquisition in deepwater using a marine vibrator source" by Johnson et al. (1997 SEG *Expanded Abstracts*). "High fidelity vibratory seismic (HFVS) method for acquiring seismic data" by Allen et al. (1998 SEG *Expanded Abstracts*). "Marine vibrator motion correction in the frequency space domain" by Noss et al. (SEG 1999 *Expanded Abstracts*). TLE

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