

New vibrator system holds promise

A newly designed system offers vast improvements over conventional technology.

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An advanced compressional (P)-wave seismic vibrator under development by scientists at ION Geophysical Corp. performed up to expectations in a series of recent field tests by producing high-quality ground-force energy beyond the low- and high-frequency limits of conventional seismic vibrators.

During engineering acceptance testing, the advanced vibrator system generated highly synchronous sweeps exhibiting bandwidth frequencies ranging from 1 to 250 Hz; the vibrator also maintained high force output from 4 to 160 Hz while reducing harmonic distortion of the signal by as much as 50%. Most sweeps with conventional vibrators begin at 5 Hz or higher; most conventional seismic vibrators can maintain a stable ground-force output to a maximum frequency of less than 100 Hz. Harmonic distortions can create false return signals that can mask authentic reflection events.

At low frequencies, the energy produced by a seismic vibrator can be degraded by such factors as reaction mass stroke, hydraulic pump flow, pump response time, servo valve stroke, accumulator size, engine horsepower, peak-decoupling force, harmonic distortion, and vehicle chassis isolation. Simulations of vibrator dynamics revealed that the reaction mass stroke and peak-decoupling force are key parameters for setting the fundamental force envelop at low frequencies.

Modeling by ION researchers also has shown that key factors limiting vibrator performance at high frequencies are

the narrow frequency bandwidth of the servo valve system, flexure and weight of the baseplate, and coupling conditions between the baseplate and the ground. Based upon these findings, ION designed a new high-frequency controller, integrated with Pelton DR valve technology, that allows the bandwidth of usable ground-force energy to be extended up to 250 Hz.

The advanced vibrator system subjected to testing was a prototype incorporating a redesigned reaction mass system, a newly designed baseplate that is 2.5 times stiffer and slightly heavier than a conventional baseplate, and the new high-frequency controller.

Optimizing seismic imaging

To support the optimization of seismic imaging, a vibrator must generate synchronous, repeatable ground-force energy sweeps over a broad frequency range and sustain a usable signal for a prescribed time interval with minimal harmonic distortion. The ability to gener-

ate a usable vibrator signal beyond current low- and high-frequency limits and to output the chosen frequency range during the prescribed sweep period affords a major advantage in the process of finding and delineating oil and gas reservoirs.

Extending the usable low-frequency bandwidth of a vibrator signal can enhance the vertical resolution of seismic data and dramatically improve the accuracy of surface-derived velocity sections. High frequencies are most useful for enhancing spatial and temporal resolution, notably in shallow seismic or vertical seismic profile surveys.

Current seismic interpretive capabilities can resolve vibrator data to about a quarter wavelength at best. Because higher frequencies have shorter wavelengths, geologists typically are able to see finer details in seismic images with some high frequency. In general, the earth attenuates high frequencies much faster than low frequencies, so it is very important to generate high-level forces at higher fre-

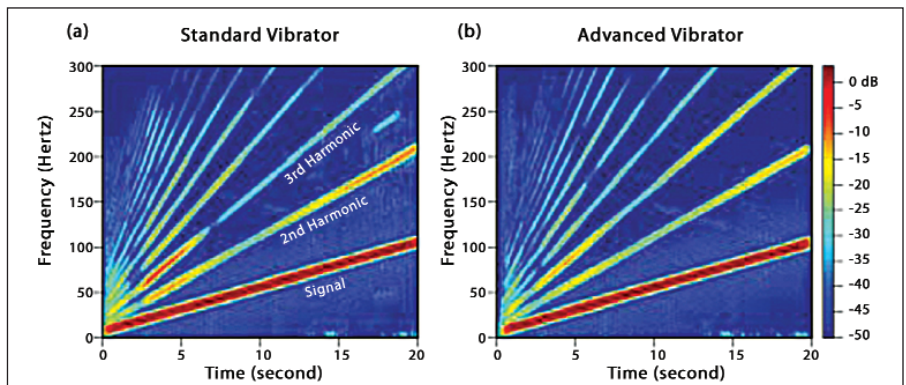


Figure 1. Frequency-time representation of the weighted-sum ground force; (a) standard AHV vibrator, and (b) AHV-IV vibrator with the new mass and baseplate system. On the gravel track, with the AH V-IV vibrator equipped with the new mass and baseplate, a significant reduction in the harmonic distortion at low- to mid-range frequencies was measured. The fundamental content in the ground force was more uniform and consistent. (Images courtesy of ION Geophysical Corp.)

frequencies in order to get some high-frequency reflection back.

Harmonics contribute to the peaks on the ground-force waveform. So by reducing harmonic distortion, it might be possible to shake the vibrator harder and produce more fundamental force, thereby improving the signal-to-noise ratio. Acquisition methods proven to mitigate harmonics introduce added complexity to the acquisition process and frequently require more sweep time, which can impair productivity.

Baseplate basics

Maintaining good coupling between a vibrator's baseplate and the ground over a wide range of sweep frequencies is key to acquiring high-quality return signals. Nonlinear forces in a vibrator's hydraulic system and the ground's response can cause the baseplate to generate harmonic distortion. Variable surface conditions heighten the challenge of compensating for nonlinear forces.

In a conventional vibrator, poor baseplate coupling can cause uneven loading and fluid-flow conditions that can both interfere with the generation of a usable vibrator signal and create harmonic distortions at low and high frequencies. For frequencies below 10 Hz, a conventional vibrator cannot produce sufficient force due to mechanical and hydraulic constraints and suffers severe harmonic distortion, while output energy generates correlation noise rather than enhancing the signal.

When a conventional vibrator shakes at high frequencies, the baseplate bends, flexes, and rocks in a complex manner, causing different parts of the mechanism to move independently in response to ground-related nonlinearities. This, in turn, causes turbulent flow in the hydraulic system and instability in the servo valve assembly, resulting in inaccurate estimates of the actual ground-force being generated and creating a risk that the amount of energy being pushed into the ground will be overestimated, especially at high frequency. High-frequency pressure spikes occur which, if large enough, can cause bubbles (cavitations)

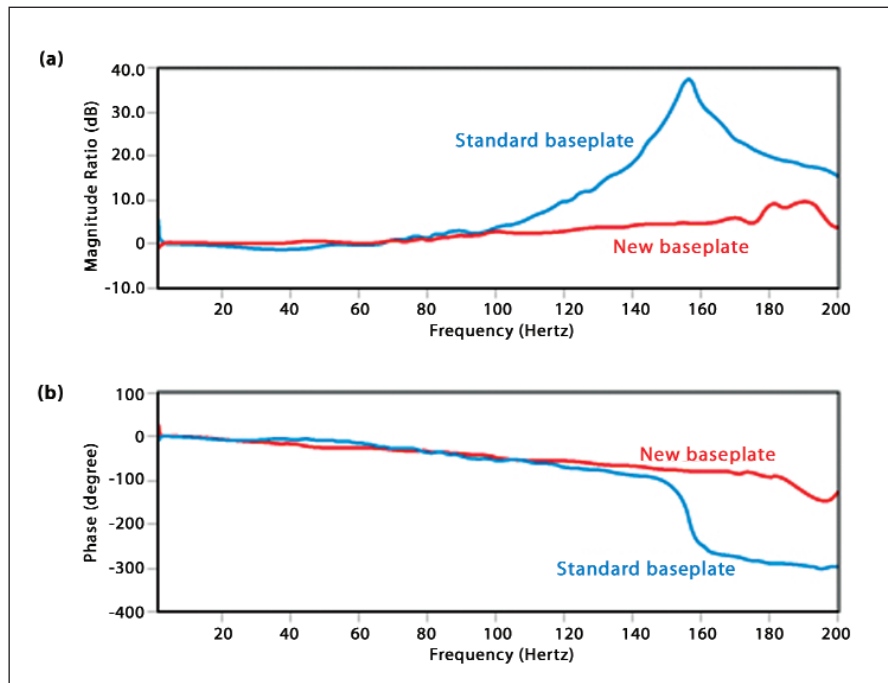


Figure 2. (a) The weighted-sum ground force response in the frequency domain is used to evaluate the baseplate's rigidity. If the baseplate acts as a true rigid body, the weight-sum ground force should be equal to the actual ground force, and a zero dB and zero phase will be seen in frequency response plots.

to form in servo valve fluids; when these bubbles collapse, they can severely damage servo valve assembly components.

Advanced vibrator design

These issues and many others were resolved in the design of the advanced vibrator system, the AHV-IV. To overcome problems in the hydraulic systems, ION designed a new reaction-mass system with shorter supply lines for the hydraulic fluid-flow hoses and for flow passages in the reaction mass. In addition, the sizes of passageways were altered to minimize flow restrictions, and accumulators were repositioned to increase the supply of pressurized fluid during peak flows.

To overcome issues raised by baseplate flexing, ION designed a new baseplate that is 2.5 times stiffer than conventional baseplates and about 5% heavier. The fundamental changes involved changing the structural shapes of baseplate mechanical components.

In field tests, the design changes implemented in the new reaction mass and new vibrator baseplate achieved measur-

able improvements in vibrator output-signal quality across the full bandwidth and beyond the low- and high-frequency limits of conventional seismic vibrators. Data quality appeared capable of generating seismic images of high resolution for delineating small hydrocarbon traps.

The new reaction mass design almost completely eliminated supply-pressure ripples and the longstanding problem of cavitations in the vibrator hydraulic system. This advancement will help extend the performance lives of hydraulic and mechanical components and reduce required maintenance.

The new baseplate extends the bandwidth frequency of usable ground-force energy up to 160 Hz and suppresses even-order harmonics, producing a pronounced reduction of output signal distortion under variable loading conditions.

Taken together, these advances can be expected to spur improvements in data quality and bring new operating efficiency to the process of gathering seismic data as well as to the oil and gas exploration and delineation process. **ION**