| Nomad 15 Specifications | |
|---|---|
| Peak force output | 17,364 lbf (7,724 daN) |
| Hold down weight | 16,135 lbf (7,177 daN) |
| Frequency range | 1 - 400 Hz * |
| Length | 6566 mm |
| Width | 2441 mm |
| Height | 3110 mm |
| Gradeability | 55% (29°) |
| Turning circle (curb to curb) | 7814 mm |
| Turning circle (wall to wall) | 9860 mm |
| Gross Vehicle Weight | 9 T |

* Full drive from 7 Hz

Table 1: main specifications of the compact vibrator

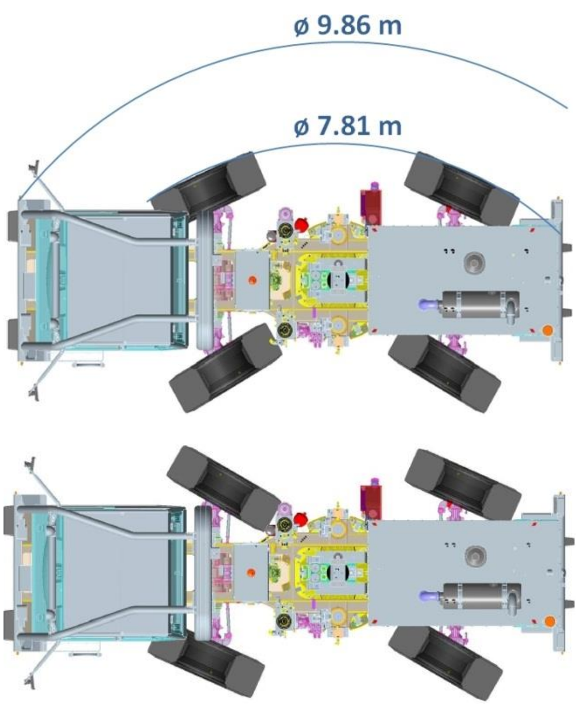


Figure 1: Directional modes: in addition to the standard mode, where only the front wheels are directional, the compact vibrator has two special directional modes to ease access to difficult areas: (top) coordinated mode, wheels in opposition offering an unequalled turning radius, and (bottom) synchronized mode, vibrator moving as a "crab".

## Broadband performances

To foster the strong development of broadband acquisition, performance at both low and high frequencies has been a major concern when designing the source. Sweeping is possible from 1 Hz with a reduced drive, with full drive reached at 7 Hz. High frequency vibration of up to 400 Hz is possible, depending on ground characteristics (Figure 2). This high frequency performance is made possible by an extra stiff circular baseplate, and a hydraulic peak force (17,364 lbf) higher than the hold-down weight (16,135 lbf). The latter compensates for the mass-to-baseplate phase shift above the ground cutoff frequency (Tellier, 2015). High frequencies are particularly beneficial when imaging shallow targets.

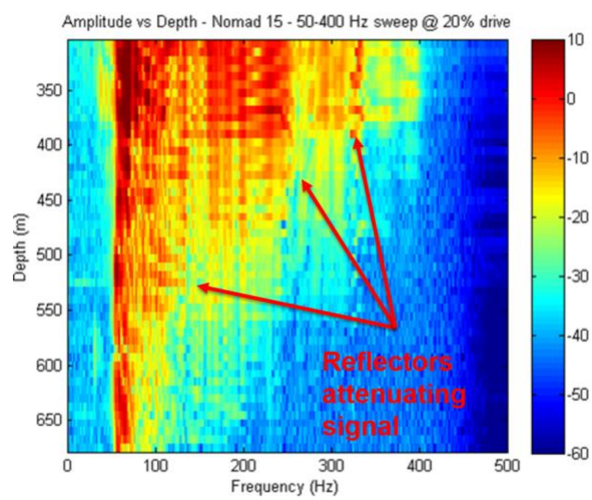


Figure 2: high-frequency capability of the compact source. Signal up to 400 Hz can be generated and recorded on a well. On this example, the 400 Hz signal can be observed down to 380 m. High frequencies are then progressively attenuated by the strong reflectors at 380, 430, 520 and 580 m. Note also that the vibration drive level used for this experiment was low (20% of vibrator full capability).

## Mitigation of shooting environmental impact

To answer increasing concerns about the seismic operations environmental footprint, the compact vibrator design has focused on maximum reduction of the vibrator's environmental impact:

- Noise reduction is maximized by a soundproof engine housing. The 77 dB measured 7 m from the vibrator side makes the Nomad 15 highly suitable for operations in populated areas.

- The Nomad 15 engine complies with Stage 3b and Tier 4i emission standards, European Union and United States regulations that define the acceptable limits of exhaust emissions - mainly nitrogen oxides ($NO_x$) and particulate matter (PM). Standard motorizations are also available.
- The Intelligent Power Management (IPM) measures the engine load and adapts the engine RPM (Revolutions Per Minute) accordingly. While vibrators usually operate at a constant RPM, this IPM significantly reduces fuel consumption, as well as noise and exhaust emissions. A field test carried out by a seismic crew using five vibrators, each working more than 2000 hours, showed fuel savings of up to 15% on the two vibrators equipped with IPM.

### Field experience: mining

A field test was led in 2015 to evaluate the potential of the compact vibrator for potash mining, at depth around 650 m (Martinez Garcia, 2016). This 1.2 km 2D test line intended to demonstrate the compliancy of light vibrators for future 3D seismic investigations as an alternative to explosives, owing to increasing concerns over public relations and environmental issues. Despite a rough mountainous terrain (Figure 3) with more than 250 m difference of elevation over the 1.2 km line, an excellent dataset could be acquired with a single Nomad 15, sweep 4-125 Hz, 16 s, 70 % (Figure 4). Though the sweep was repeated 4 times at each shot location, a single vibration was underlined to be enough to illuminate the 300~700 ms twt target (i.e., 500~1100 m), while imaging quality remain excellent at much deeper targets (1.4 s twt, i.e., 2200 m).

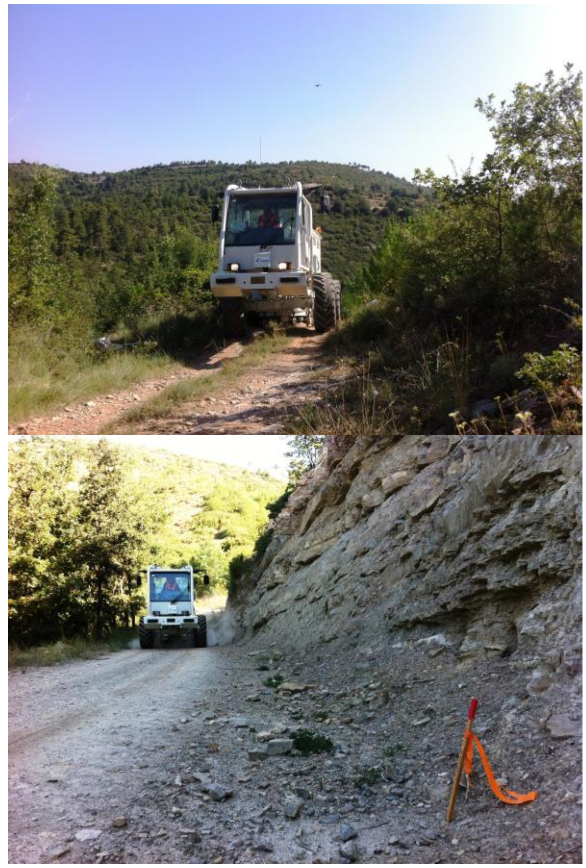

Figure 3: typical terrain conditions for potash mining in Spain, with the compact Nomad 15 vibrator in operation.

### Field experience: Smart Cities

Smart Cities are developing rapidly and are closely related to geosciences, as witnessed by the first workshops organized by the SEG on the topic in 2019, in Beijing and Singapore. For this application, a detailed identification of the near surface structures is required, in order to optimize the installation of infrastructures, ensure their robustness over time, and prevent any unexpected geology related problem during construction. High-resolution seismic reflection is a powerful method to acquire the detailed information required. For this purpose, the compact vibrator was selected on several projects for its accessibility and ability to emit the broadband signal required for high-resolution imaging, as well as its low noise disturbance to local residents and minimized impact to existing infrastructures.

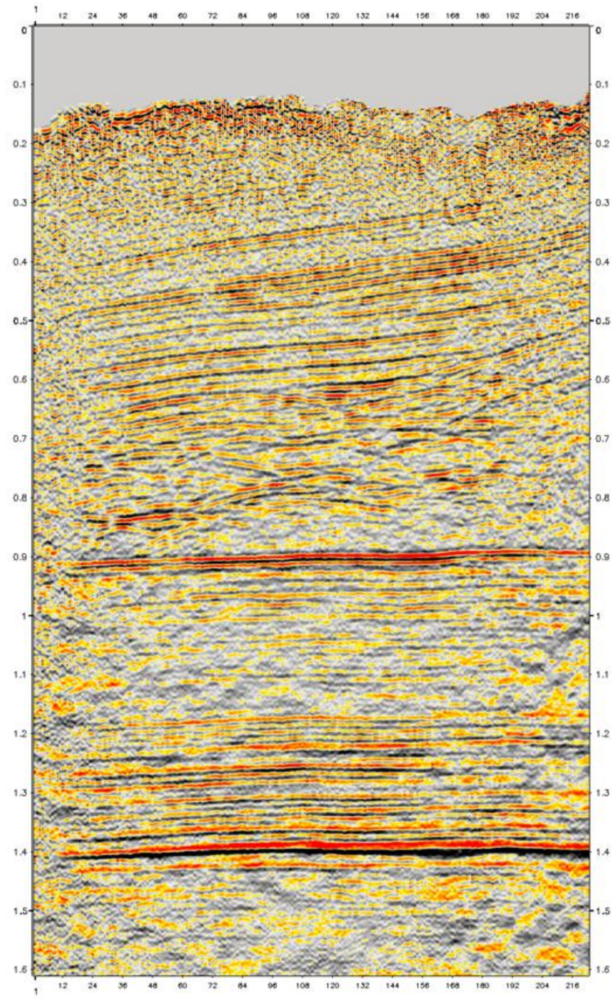


Figure 4: Stack obtained with a single Nomad 15, 4 sweeps per vibration point, after full pre-processing (elevation statics, spherical divergence, denoising, spike deconvolution, residual statics, AGC). From Martinez Garcia, 2016.

For such shallow applications (investigation depth < 100 m), special care must be observed when processing the seismic data. Data processing is indeed expected to deliver high SNR and resolution for the imaging of shallow layers that may be highly heterogeneous due to the combined effect of geology and infrastructures. Seismic propagation is perturbed by significant energy dispersion that complicates processing and hence interpretation. Great care has to be paid to the selection of accurate processing parameters, such as mute and associated tapers, statics and velocity analysis. Noise attenuation based on analysis in different domains takes the greatest role in improving SNR and final imaging. Statics and velocity analysis also impact the subsurface image, especially for the ultra-shallow layers. If the processing workflow is not defined accordingly, the resulting image may be misleading (Figure 5): the great difference observed on final stack sections as a result of different processing workflows and parameters is obvious.

## Conclusion

The compact design, low ground impact and high accessibility of the proposed compact vibrator makes it an ideal seismic source for miscellaneous applications:

- Imaging of shallow targets with high frequencies, such as mines, gas storage, tar sands or Smart Cities.
- Limited access areas, such as cities, wooded or agricultural areas. The low level of noise is a plus in populated areas for the acceptance of seismic works by the local population.
- Mixed source shooting, where large and small vibrators operate according to terrain type for optimal productivity.
- Complete or partial replacement of explosives by safer and more productive sources: the compact vibrator can indeed efficiently complement explosives, by shooting the large associated exclusion areas.

This new source then appears as a good candidate to introduce the benefits of Vibroseis (productivity, bandwidth, HSE exposure) to large parts of India, where relief of rough terrain conditions usually limit the possibilities of seismic operation and subsequent imaging.

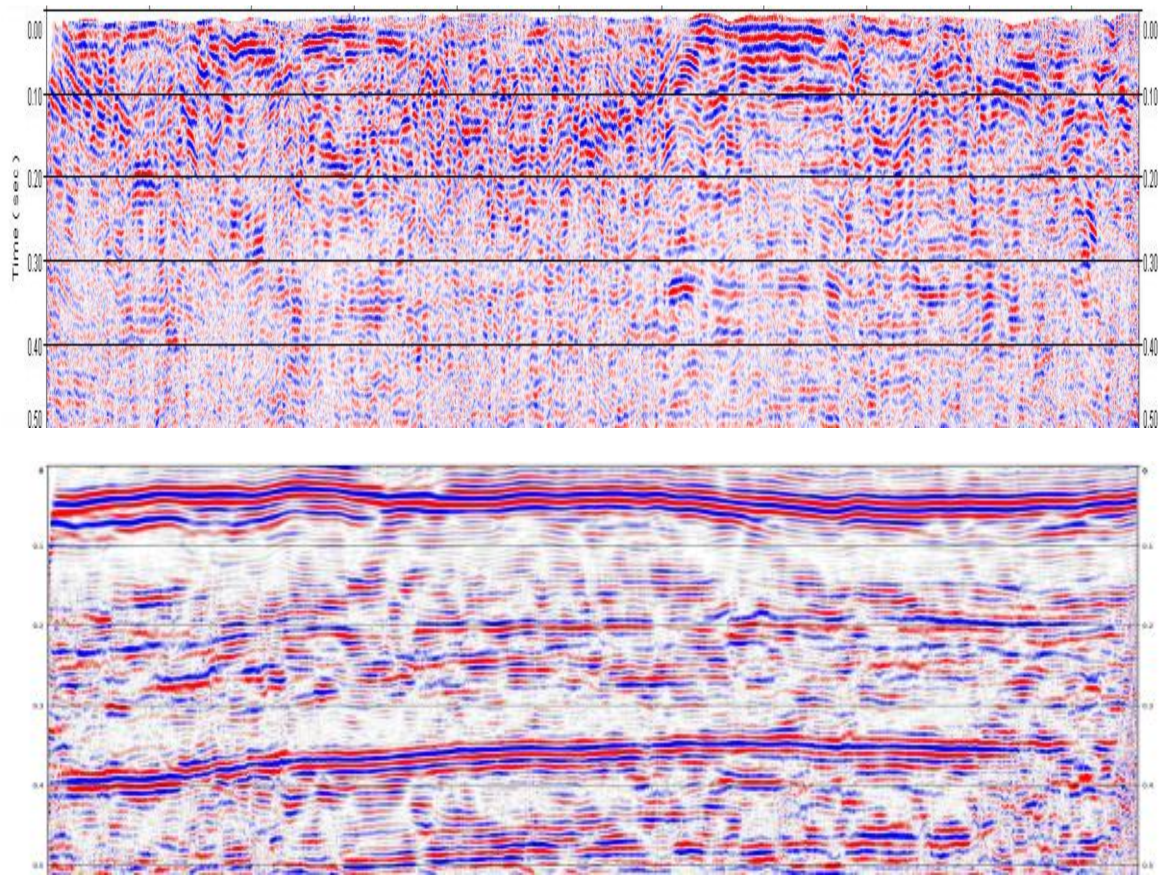


Figure 5: stack sections from the a Smart City project, with standard (top) and optimized (bottom) parameters.

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