Making Waves - Towards a New Era of Seismic Recording Equipment

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SUMMARY

Seismic recording equipment engineering and manufacturing has experienced an evolutionary change in the past 20 years. In addition to great strides in channel count and flexibility, the cost per channel has also dropped steadily. Seismic contractors utilizing modern equipment can economically shoot in virtually any region that can be accessed with little or no lasting impact on the land and at the same time the quality and utility of the recorded data has increased inversely to the cost.

These evolutionary strides are supported by higher channel counts; lighter more flexible equipment and advances in source technology including operational strategies which produce 20,000 or more source points in a single day of shooting. The growing trend of high density single point sources combined with single point sensors is yielding high fold data of unprecedented quality.

This presentation will explore the more recent advances in seismic equipment development and the operational changes they have enabled to deliver this evolutionary change in the quality and cost of seismic data.

Key words: seismic, equipment, vibroseis, sensors, cableless

INTRODUCTION

Research and development in seismic recording equipment is often taken for granted since it has always just seemed to happen independently from the rest of the industry. Driven by a competitive market for equipment sales, the advances and milestones along the way may seem insignificant to the explorationist, however, looking back at the individual strides in R&D and their impact on current recording a clear picture emerges of the forces that have driven the changes which yield the current results. In some cases with consequences that were never part of the plan outlined by the original efforts.

Vibroseis development has made great strides in the previous 10 years. The current "off the shelf" vibrator can sweep broader band, with better phase control and lower distortion than source units only 10 years old. These improvements are the result of the application of modern engineering methods applied to proven technology. Production sweeps starting as low as 1.5Hz have been successfully employed in multiple regions of the world while frequencies as high as 300 Hz have been swept in other areas.

Ultra-high channel count recording systems and cableless technology are providing a further degree of flexibility in survey design which is also unprecedented. Traditional group intervals and trace densities are yielding to high density single point acquisitions with group spacing as small as 10 meters. Contractors routinely deploy 20,000 to 40,000 live channels in many parts of the world. Discussions regarding the use of wide or narrow azimuth geometries and stacking fold have become obsolete, overwhelmed by the sheer numbers of traces delivered by a modern seismic crew, at lower costs.

THE MODERN VIBRATOR

Vibroseis technology was first proposed and introduced to the industry by Conoco in the 1950s. R&D since can be summarized by efforts to increase the energy delivered over a broader frequency range and to control and understand the energy that is delivered. These efforts yielded bigger, heavier vehicles, better controllers with real time feedback and operational patterns that often had multiple units sweeping simultaneously. Research from a small group of industry experts expanded the understanding of the complexities involved in a seemingly simple process. Yet the production parameters seemed all too familiar and all too common. An 8-60Hz, 10-12 second linear sweep with standard cosine tapers or something nearly identical was the norm. A few mavericks attempted to push the frequency envelope but little in the way of lasting paradigm changes prevailed.

Then in the early 2000s things started to change more quickly. Modern engineering and computer modelling methods began to enlighten developers. Building on the works of earlier researchers, the behaviour of individual vibrator components could be analysed, understood and corrections implemented. Among those advances are software and firmware controls to the servo valve, improvements to the hydraulic controls and a better understanding of the baseplate-earth coupling that has prompted stiffer more rigid baseplates. Combined, these improvements created a vibrator which sweeps the common 8-60Hz sweep with better control, but more importantly, better consistency across a broad range of surface types. The key to better vibroseis data will always be a better understanding of what energy the vibrator puts into the ground.

Understanding the mechanics and hydraulics of the modern vibrator have led to other advancements like better control electronics and sweep design. Source controllers play a key role since they interface with the vibrator through firmware and respond to feedback loops in real-time attempting to adapt to changes and drive the vibrator to achieve specific energy delivery goals. The feedback is supplied by accelerometers usually on the baseplate and mass of the vibrator shaker assembly, and current engineering has even demonstrated optimal placement for those accelerometers.

In the past 2 years it has become common to start sweeps as low as 1.5-2Hz extending the energy by multiple octaves in the low frequencies. This was enabled because of the engineering improvements outlined above and also the dramatic improvement that these additional octaves began to make to inversions. Designing custom sweeps which drive a vibrator within its theoretical performance profiles has made it possible to start sweeps in these very low frequencies and perhaps more importantly, to understand the potential outcome and set the expectations for what is possible.

Figure 1 shows a small sized vibrator working in a national park in Uganda. Picture courtesy of Total

Higher frequencies have also benefited from these advancements. Small-sized vibrators which can sweep as high as 300-400Hz while maintaining phase and energy goals are growing in demand for programs with shallow targets or VSP operations.

Higher density shooting with single, better controlled and understood vibrators is changing the way seismic data is shot. Desert operations in the Middle East employ huge fleets of vibrators and high productivity shooting methods to achieve fantastic source production rates, but more importantly better seismic data. The observed trend is that those technologies and operational methods will eventually find their way into every region of the world and produce similar improvements in data quality. We already see signs of these trends in areas like the oil sands of Athabasca which 10 years ago was believed to be a dynamite-only region.

RECORDING SYSTEMS

In the early 1990's when 3D seismic was picking up, distributed cable systems could field 2,000-4,000 channels live. As demands for wide azimuth and denser receiver geometries increased, channel counts on crews began to grow. A second, simultaneous technology was 3C sensors and the prospect of full wave field recording which increased the demand on channel count threefold. While 3C recording today remains a special case, recording system development has delivered. Channel counts of 20,000 to 40,000 live are now common and 200,000 channels and beyond are now possible. System components have grown lighter, are less power hungry, more reliable and most importantly, cheaper. Old issues like system timing and filter response have taken a back seat to channel count because high fidelity, low noise systems with precision timing is a standard capability of the currently available systems.

Figure 2 shows a compact cableless node with a connected battery and 3C sensor.

In the early 2000s cableless system technology was introduced. Today in North America, cableless equipment has all but totally replaced cabled seismic equipment as the method for collecting data. This evolutionary change was driven by two main factors. The primary reason is development and availability of cost-effective reliable hardware. The second reason is because modern cableless systems are comprised of remotely deployable nodes, each of which is a standalone recording system. By virtue of this architecture, the systems are fully scalable and can be deployed at any group interval and in virtually any setting where access is possible. It is this flexibility of the equipment which has made the concept popular with the contractors and explorationists alike. Survey design is no longer constrained by cable lengths or connections and virtually any geometry is possible with any type of sensor configuration.

The future direction of this technology also looks encouraging as improvements in energy density, GPS performance, wireless technology, sensors and manufacturing all converge to offer the prospect of higher trace densities, improved visibility and lower cost.

CONCLUSION

Many changes in source and system development have led to the current level of modern seismic equipment. Improvements in vibrator technology have led to more powerful and more accurate source which can sweep a very broad range of frequencies. Recording systems now provide a level of flexibility and capability which is unprecedented and the operational benefits of all these technology changes can now be applied to other regions of the world, leading to better quality data at a lower cost.