Land Geophysical Equipment and Operation Management

Fan Huiwen, Wu Yongsheng, Han Shanfeng, Wang Meng, Wang Yongfang, Shang Yongsheng, He Yongqing, and Li Jia, BGP, CNPC

Summary

This paper analyzes the general and specific requirements for geophysical equipment in contemporary geophysical exploration， and reviews BGP Equipment's research & development, manufacturing, and full supply chain capability. BGP land geophysical equipment spectrum is introduced. Several new advances of land equipment including large-tonnage EV80 vibrator and AHV480 vibrator are introduced. To expand the seismic node application scenes and fields, BGP Xi'an developed three new kinds of seismic nodes including eSeis Mini, eSeis GEM, and iEdot 5G node. All these newly developed nodes are applied well in the exploration operations. The Intelligent Seismic Operation System developed by BGP is also introduced. It promotes BGP's intelligent management to a new level.

Introduction

Rapid development of geophysical exploration has provided urgent requirements and expectations to the advanced geophysical equipment. The complexity of geological structures and complex surface terrains, deep-buried reservoirs, and subtle lithological changes requires energy sources to excite more powerful energy to penetrate ultra-deep layers, and receiving equipment have the ability to capture weak signals, maintain high-quality data acquisition in various environments, and support large-scale, high-density data acquisition. This article introduces several typical equipment achievements in BGP equipment sector in the past two years. Large-tonnage AHV480 vibrator and EV80 vibrator are introduced. Three new kinds of seismic nodes such as eSeis Mini, eSeis GEM and iEdot 5G are developed to expand the seismic node application fields. The intelligent seismic operation system is upgraded and widely promoted in BGP's seismic operation. This will promote the operational mode change and greatly improve the operation efficiency. [1]

Requirements & Expectations

Geophysical exploration operation covers a series of working processes such as surveying, drilling, spread deploying, shooting, receiving, and recording. As far as the geophysical exploration equipment is concerned, there are some specific and technical requirements to be considered in each working process.

Traffic ability: Geophysical exploration areas include different types of terrain such as desert, TZ swamp, jungle, and mountain. To ensure the equipment and working staff get to the target areas is a basic requirement for the next-step explorations.

Strong Energy Source: The exploration target layers are going to deeper reservoirs in most exploration areas. The more powerful energy source is required to transmit the excitation signal to the deeper layers.

High-sensitivity sensor: Capturing the subtle and weak signals reflected from deep underground layers is crucial to the geological image quality. High-sensitivity geophones and MEMS digital sensors are going to be pursued in the exploration projects by more and more companies.

Multi-field Seismic nodes ： Seismic nodes have demonstrated their advantages in seismic exploration and

will be gradually- adopted by more and more companies. The expansion of nodal technology into the EM field is an inevitable trend that will further drive the development and application of seismic nodes.

High productivity: To increase productivity of geophysical exploration is the common desire of both oil companies and geophysical service companies.

Smart, digital, and HSE compliance: Equipment development is now going toward greener, smarter, and more efficient solutions that prioritize automation and environmental protection. This shift is driven by growing emphasis on health, safety, and environmental compliance, pushing designs to minimize ecological impact while ensuring maximum operator safety.

BGP Equipment Product Spectrum

Over nearly 60 years of development, BGP has formed a series of geophysical equipment products covering special vehicles, drilling rigs, vibrators, geophones, and acquisition systems.

Desert vehicles: WTC desert vehicle series is designed and manufactured to provide logistic transportation in desert areas. These vehicles are widely used in the Middle East, Africa, and Western China operations.

Vibrators: BGP has EV series vibrators and AHV series vibrators -Till now, more than 2,500 vibrators have been manufactured and sold worldwide.

Drill rigs: BGP has manufactured WTZ series drill rigs. The WTZ drill rigs cover truck-mounted, tractor-mounted, and amphibious vehicle-mounted series. The maximum drilling capacity is 500 meters deep. The portable drilling rigs are widely used in Mountainous areas.

G3i cable system & Seismic Node: G3i cable system has been designed and manufactured in INOVA Calgary. It has been widely used in exploration projects both domestically and globally. BGP now has two series seismic nodes, including the eSeis Node and the Quantum Node. Over the past 5 years, one million plus seismic nodes have been put into operations.

Geophone and digital sensor: BGP Xi'an is originally a professional manufacturer of Geophone and acquisition instrument with 70 years' history. More than 20 million SN and SD geophones have been produced and used. INOVA is advanced in MEMS digital sensor design and manufacturing. 240,000 units of SL11 digital sensors have been successfully used in a KOC seismic project.

Achievements & Applications

- **EV80 large-tonnage Vibrator**

More and more oil companies are interested in applying large-tonnage vibrators to address ultra-deep exploration issues. BGP's newly developed EV80 vibrator provides a good solution.

Before we started to develop the EV80 vibrator, we analyzed and studied the technical performance of nearly all vibrators currently in use on the market and found two issues that needed to be focused on: first, most vibrators have insufficient low-frequency excitation performance; second, in the high-frequency range, vibrators tend to experience output force attenuation and increased distortion. So the key design points of the EV80 vibrator are to enhance the low-frequency excitation and stabilize the high-frequency excitation.

The EV80 vibrator is equipped with 760HP high-power engine, with 8-inch mass stroke, 7000kg mass weight, high-volume stable-flow hydraulic system, and increased hydraulic system pressure. All these designs ensure that EV80 Vibrator has stronger low-frequency excitation capacity. The EV80 vibrator can theoretically achieve a full drive output force 80,000 pounds at a low- frequency of 3.5Hz shown in Figure 1. outperforming other vibrators in low-frequency excitation.

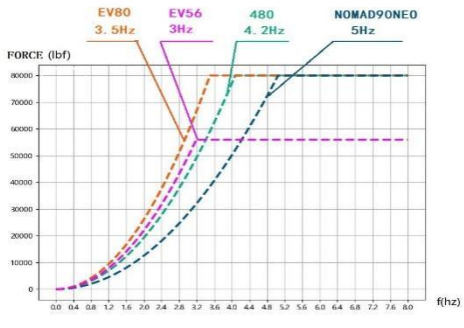

Figure 1 EV80 vibrator output force curve

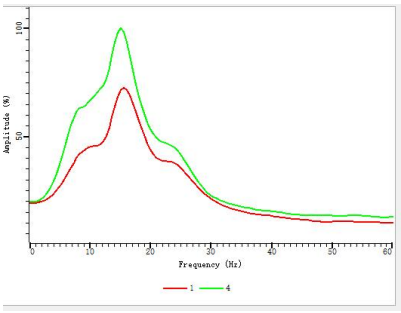

Figure 2 Comparison of output force of EV80 with conventional 60,000-pound vibrator

In order to stabilize the high frequency band excitation and control the output force attenuation, and signal distortion. The EV80 vibrator has enhanced high-strength base-plate, pre-stressed top frame design, the base frame structure and, optimize piston oil passage balance design and 8 airbags buffer design. All these designs ensure that EV80 vibrator has a stable output force in the high-frequency band and low signal distortion.

The excitation capacity of EV80 is 20% higher than that of a conventional 60,000-pound vibrator, as shown in Figure 2. EV80 vibrator has advantages in ultra-deep layer exploration. For ultra-deep layers with a depth of more than 6,000m, the low-frequency signal-to-noise ratio of the EV80 profile is higher, and there are still relatively good data available at a depth of over 15,000 meters, as shown in Figure 3.

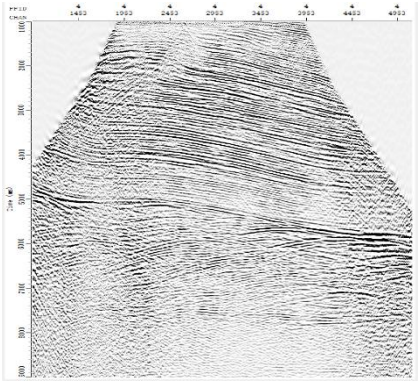

Figure 3 Seismic section using EV80 vibrators

- **AHV V480 TITAN Vibrator**

The AHV V480 TITAN vibrator was launched in 2019 to meet the ultra-deep exploration globally. It was rapidly accepted by customers. Its main design objectives are to improve geophysical performance, create a powerful, accurate and stable signal for ultra-deep geophysical exploration, to decrease source-generated noise, to reduce the operation impact on ambient environments and operating costs, and to provide easy maintenance and ergonomically-friendly operations.

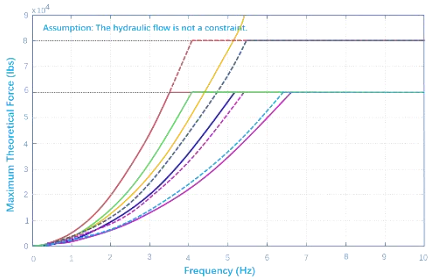

Figure 4 Maximum Theoretical Force Comparison at Low Frequencies

The AHV V480 TITAN vibrator is equipped with Cummins 589BHP diesel engine to provide enough power. The hydraulic system is designed with two 2.5gallon internal bladder-type accumulators and two 10 in^3 external serve accumulators, and two 5gallon system accumulators to absorb hydraulic system pressure turbulence. Three P7 hydraulic pumps are equipped to provide high volume super-fast hydraulic flow. The shaker has 7inch usable stroke with a 13,369 lbs reaction mass. Redesigned dual fan cooling system keeps the engine noise at a low level while ensuring good heat dispersion. Super-stiff base-plate design, field proven chassis design, and 12-airbag suspension system ensure the stable low frequency and high frequency excitation performance, as shown in Figure 4.

- **eSeis Mini Node**

BGP has two series of nodes, eSeis Node and Quantum Node. Both are very successfully promoted. More than 600,000 eSeis nodes have been promoted and used nodes, mainly in domestic exploration operations. While more than 500,000 Quantum nodes have been promoted and used mainly in North and South America exploration projects.

Like all other nodal systems, the eSeis Node system mainly consists of four parts: nodal units, harvest and charge racks, data processing systems, and QC units. Now eSeis Node and Quantum Node are technically

mature and are stably produced according to the market demands. BGP- tried to expand and diversify the Node product spectrum to meet the different needs of geophysical exploration. BGP has also developed three new types of seismic nodes.

The first kind is eSeis Mini Node including eSeis iL1-M and eSeis iL1-P specifically to meet the needs of ultra-high density seismic acquisition of millions of channels. The node has 8 key features: integrated design, tilt test function, optimized CPU clock speed to save power, large storage, compact size, lighter weight, Bluetooth Low Energy communication, and multi-functional quality control.

Compared with the traditional nodal devices, eSeis Mini piezoelectric geophone weighs only approximately 230g while its magnet-electrical velocity geophone, weights about 350g. To guarantee the acquisition accuracy, eSeis Mini is equipped with a 24-bit ADC chip, by reconstructing the acquisition logic, it can realize intelligent adjustment of operating frequency of MCU main control chip—it automatically reduces the frequency to save power when in idle status, and instantly increases the frequency to ensure accuracy during acquisition; By choosing high-capacity lithium batteries, eSeis iL1-P node equipped with 1 set of 21700 type battery, eSeis iL1-M node equipped with 2 sets of 21700 batteries, the working time of the eSeis Mini can reach up to 35 days. Shown in Figure 5.

Figure 5 eSeis-iL1 Node Unit

- **eSeis GEM**

The second newly developed node is the eSeis GEM. BGP expanded its node technology into the GEM field and developed eSeis GEM, which can collect signals from three kinds of sensors simultaneously — geophone, magnetic nod, and electrode, realizing the multi-physical field synchronous detection. It is compatible with multiple levels of channel gains and sampling rates, flexibly adapting to different exploration scenes. It can operate continuously for 25 days with a power consumption of 700mW. Its GPS clock accuracy reaches ±20μs, ensuring the temporal synchronization of data. It is mainly used in seismic-electromagnetic joint reservoir evaluation. The eSeis GEM Node is shown in Figure 5.

- **iEdot 5G Node**

The iEdot Node is consisted of node, remote monitoring platform, interactive monitoring software, and charging and downloading rack. Equipped with Huawei 5G communication module, the system is compatible with mainstream 4G/5G frequency band, and can operate stably in different network environments to support real-time and efficient data transmission. Its core functions include remote real-time data transmission and status monitoring, which overcomes the time and space limitation of traditional acquisition mode. The iEdot 5G Node is shown in Figure 6.

The architecture of "5G node + cloud server +KL Noise Monitor software" is adopted to realize real-time data receiving, spread status monitoring, and interference warning. A complete data link is constructed by integrating USMand intelligent seismic operation system to support the generation of real-time single-shot records and effectively ensure the seismic data quality.

Figure 6 eSeis GEM and iEdot 5G Node

Intelligent Seismic Operation System

BGP has taken the lead in developing the world's first Intelligent Seismic Operation System, focusing on the reshaping field acquisition processes and workflow reconstruction to achieve the digital transformation of traditional seismic exploration and acquisition operations.

The Intelligent Seismic Operation System serves as the platform for the digital transformation of field seismic

exploration, and acquisition operations. It deeply integrates work processes, such as acquisition design, surveying and staking, spread management, drilling, dynamite shooting, vibroseis operation, and acquisition recording. It optimizes the management of quality control, safety, operation, personnel and equipment management, forming an intelligent system that integrates acquisition technology and project management.

Its overall architecture, as shown in Figure 7, consists of one platform and two systems. The platform includes a cloud service platform, an integrated communication network and a production operation map. The two systems are the technology application system and the project management system.

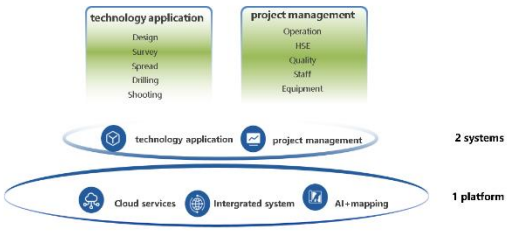

Figure 7 Architecture of Intelligent Seismic Operation System

The intelligent seismic operation system includes the following four main functions: 1) Intelligent design; 2) Efficient operation; 3) Intelligent quality control; 4) Intelligent management. Based on the real-time data-driven whole-process proactive management mechanism, the Intelligent Seismic Operation System utilizes technologies such as the Internet of Things, artificial intelligence, and digital twin to achieve instant sensing, intelligent analysis, and dynamic intervention of personnel, equipment, and workflow progress. [2]

The first function is to realize an intelligent design. The surface image of the working areas is obtained through satellite photos, lidar image, and UAV photography. Using GIS image processing technology, the ground object recognition, 3D modeling, AI-based obstacle extraction and simulation survey are carried out.

By loading the seismic acquisition observation system, the operator can implement an optimization design, inspection of shot and receiver points, path planning of vehicles, vibrators, and bulldozers, and marking the dangerous obstacles and restricted areas. Currently, the compliance rate of acquisition scheme exceeds 90%.

BGP has also developed a Seismic Acquisition Virtual Reality System by leveraging GIS and VR technologies. By using 3D surface image data obtained before, this VR system can highly reproduce the exploration operation scenes in complex surface environments and realize indoor cloud survey, and acquisition operation simulation. In the future, by applying digital twin technology and through real-time data collection, and high-speed transmission, the system will truly display the current status of real time seismic exploration operations, allowing managers to conduct immersive production command.

The second function is to realize intelligent and efficient operation. The seismic cloud platform connects all teams and operational personnel. The production information is shared by all. Work task assignment can be directly sent to each person's mobile phone and the work tasks completed by each team are automatically uploaded to the cloud platform by the work terminals, and the operation progress of each team will also be updated in real time on the platform. This model reduces the mutual restrictions among different teams and significantly improves the operational efficiency. Marker-free operation technology is introduced, which integrates the surveying process into spread management, drilling, and shooting processes. Therefore, no red or blue flag marks are needed any more.

USM supports multiple excitation sources such as vibrators, dynamites and seamless switches among different excitation operation sources. [3] It supports dynamic time, distance, and setup priority rules. It transforms the traditional manual control into the core algorithm of the command machine, reducing human errors, improving efficiency and reshaping the operational process, shown in Figure 8.

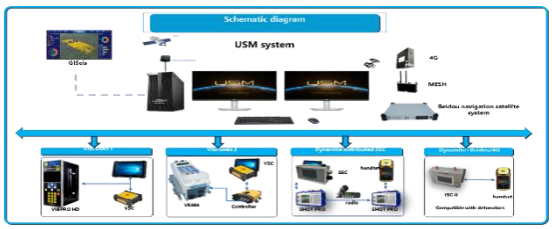

Figure 8 Ultimate Source Management System

The third function is the intelligent quality control. It has developed multiple quality-control methods, including UAV quality control, train, and noise interference monitoring. Quality control data can be automatically collected by cruising drones along the spread lines. Train and noise interference monitoring can identify the interference noise within the receiving spread and its affected areas in real time, reducing the impact of noise on data quality.

The fourth function is intelligent and dynamic management: BGP has established an intelligent production command center at its headquarters. It can conduct real-time monitoring, intelligent analysis, and online technical support for all seismic operations and obtain the real time progress of key operation processes such as surveying, drilling, shooting, and recording. Key equipment and personnel equipped with HSE Tags can send the real-time locations to the command center to enhance the QHSE management in working areas. [4] In case an excitation malfunction occurs in a field operation, the HQ command center can take over and carry out remote excitation operation.

Key equipment management is also an important part of intelligent management. The system can realize real time perception and intelligent analyses of equipment status, and implement dynamic intervention. BGP has developed a “t Vibrator Digital Management Platform”, which can collect and display the vibrators’ position, working status (such as engine temperature, and hydraulic pressure), performance indicators (such as peak output force, distortion and phase) and other information collected by different intelligent sensors installed on the vibrators. The predictive models are established to analyze the data, identify the potential failures, and implement preventive maintenance and online technical support.

By the end of September 2025, the Intelligent Seismic Operation System will be widely applied in 400 application projects and there will be more than 50,000 users.

Conclusions

BGP has strong equipment R&D, manufacturing capability, and full-supply-chain capacity to provide the best services to our clients.

The EV and AHV series vibrators provide customers with diverse solutions and also keep BGP’s vibrator technology at the leading position in the industry.

eSeis Mini, eSeis GEM, and 5G iEdot nodes have expanded their application fields.

The Intelligent geophysical exploration operation is an inevitable trend in the future and will play a crucial role in enhancing operational efficiency, reducing costs, and minimizing HSE risks.

The combination of intelligence and AI in exploration equipment will promote the operation mode change of geophysical exploration.

Acknowledgments

We would like to thank BGP and all parties for the permission to publish this paper. We would also like to thank the experts of BGP for their valuable suggestions.

References

1. E.W. Hammer, Introduction to geophysical prospecting by Milton B. Dobrin, Journal of the Franklin Institute 253.5(1952):522-523
2. Yi Changhua, Li Chunfen, Han Shanfeng, Huang Lei, Liu Xiaofeng. Design and Application of the Intelligent Seismic Team System[J]. Geophysical Exploration Equipment, 2024, 34(4): 211-214, 217.
3. Cao Xinjiang, Yang Liqing, Ma Tierong. Construction Technology and Application of the Efficient Simultaneous Excitation Management System (USM)[C]. The Second China Petroleum Geophysical Exploration Academic Annual Meeting, 2024, 04: 515-518.
4. Yan Wei. The History and Current Status of Efficient Excitation Systems for Well Shots[J]. Geophysical Exploration Equipment, 2025, 35(2): 71-74, 79.