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SUPER ENGINEERING

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West-East Gas Pipeline Project

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1 Overview

The West-East Gas Pipeline Project is a landmark project of China's Western Development. In February 2000, the State Council approved the launch of the West-East Gas Pipeline Project, which was constructed by the China National Petroleum Corporation to transport natural gas from the Tarim Basin in Xinjiang to the eastern region. The designed transmission volume is 17 billion m^3 per year, which was completed and put into production at the end of 2004. The second and third lines of the West-East Gas Pipeline Project were successively built to meet the gas import needs of Central Asia, forming a West-East Gas Pipeline System with a total length of 14520 km. The lines covered 16 provinces (cities and districts) and the Hong Kong Special Administrative Region. The project has realized the pipeline network pattern of Tarim, Qaidam, Changqing, Sichuan, and Chongqing, and imported liquefied natural gas (LNG) to Central Asia, China, and Myanmar. Accordingly, gas supply has reached Northwest China, Central Plains, East China, Central China, and South China regions, and natural gas has been transferred to North China and Southwest China. This network pattern has become the most important part of China's natural gas pipeline network.

The West-East Gas Pipeline Project has passed through the most complex terrain, geomorphology, geology, and cultural environment conditions in the world. Such high-capacity natural gas pipelines must adopt high-pressure, high-grade, and high-caliber technical routes. New systems need to be established for the pipelines, which include material equipment, construction technology, and project management. With the world's most advanced technical specifications that include 10/12 MPa delivery pressure, X70/80 steel grade, and 1016/1219 mm diameter pipe, the system has opened up a comprehensive innovation process in the history of China's pipeline construction.

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2 Engineering technologies and management innovations

2.1 Creating a "1 + *N*" collaborative innovation industrialization model

Faced with many technical problems, a "1 + *N*" collaborative innovation industrialization model has been proposed after analyzing the advantages of various domestic industries. The model relies on engineering, where the owner leads the engineering design and defines engineering construction goals. It works together with technologically advanced companies to develop engineering goals and work on innovative breakthroughs.

This model uses PetroChina as the main subject and organizes the domestic metallurgy, steel, machinery manufacturing, and other related industries. It focuses on certain technical indicators to carry out a comprehensive joint research from every aspect of steel making, steel rolling, pipe making, and welding to pipeline materials and equipment. After achieving breakthroughs in the main technical specifications of the first line of West-East Gas Pipeline Project (X70 steel, 1016 mm, and 10 MPa pressures), its second line was accomplished by applying independent technology and utilizing X80, 1219 mm, and 12 MPa pipelines.

The model focuses on core technology breakthroughs, pipeline fracture control indicators, China's steel rolling and pipe-making capacity, and engineering technical and economic requirements. It is the first to carry out a full-

scale gas blasting test of the X80 spiral steel pipe, and it has verified the fracture strength level of spiral welded steel pipe. Independent technology was used to build the most advanced full-scale gas blasting test site for steel, which laid the foundation for establishing the leading position of China in pipeline cracking toughness research (Fig. 1). This study developed the standards for steel pipes and fittings, and simultaneously, conducted researches on pipe making and equipment used for on-site welding process to ensure optimal strength and toughness matching in high-grade steel pipes.

The model centers on project management and adopts an open, inclusive, and flexible organization mode. It also uses contract management tools to carry out joint research with more than 200 companies to form an integrated organizational guarantee system. At the same time, the parallel engineering management method is adopted, and the latest technical achievements are applied to engineering under an open design platform.

2.2 Creating a high-pressure, high-steel-grade, large-diameter pipeline construction technology system

In large-scale pipeline construction technology, pipeline design and construction standards for special areas, such as strong earthquake fault zones, mountain valleys, rivers, lakes, and seas, have been established. As a result, a new generation of construction technology with digital design, efficient construction, and non-excavation crossing has been formed. In accordance with the characteristics of special geological features and geological disasters, the pipeline strain design and reliability calculation method have been studied. Standards, such as the determination of parallel pipeline spacing based on the failure crater and fault tree model, have been established. Multi-constrained factor self-identification algorithm and databases of constraint factors, such as design standards, geographic information, cultural environment, and construction technology, have also been constructed. An open platform of standardized design and multi-professional collaborative digital design that adapts to concurrent engineering management has been created, starting from the pipeline life cycle.

Internal and external welding machines and self-adjusting counterparts with independent intellectual property rights have been developed. Meanwhile, various welding techniques and supporting technologies for large-diameter and X70/80 high-steel-grade pipes have been developed, and the welding efficiency and quality have been greatly improved. A series of construction technologies and construction methods have been developed for China's unique topography of mountainous areas, loess ridges, deserts, water networks, and other special landforms. As a result, the large-scale construction capacity of large-caliber pipelines has been formed (Fig. 2).

High-tensile, torsion-reaming drilling rigs and magnetic signal precision control docking technology have been developed for directional drilling across the Yellow River, Yangtze River, and Qiantang River. Using the mud-water balance shield method, it has successfully crossed the 62.5-meter-high water pressure and soft and hard interlaced strata of the Yangtze River, which has repeatedly set world records for non-excavation pipeline crossing. Under the complex geological conditions of directional drilling, shield tunneling, and pipe jacking as the core, a series of non-excavation crossing technology of large diameter pipelines have been formed.

2.3 Creating a large-scale natural gas pipeline network operation technology system

The construction of the West-East Gas Pipeline Project has promoted the formation of China's natural gas pipeline network. Due to the difficulty in resource allocation and high operational risk, the problem of centralized control and the risk of pre-controlling the pipeline network should be solved.

On the basis of the single pipeline's Supervisory Control and Data Acquisition (SCADA) system in the West-East Gas Pipeline Project, a physical model of the independent pipeline network operation and single pipeline has been established. The single-pipe control interlock and the real-

Fig. 1 Full-scale pipeline blasting test.

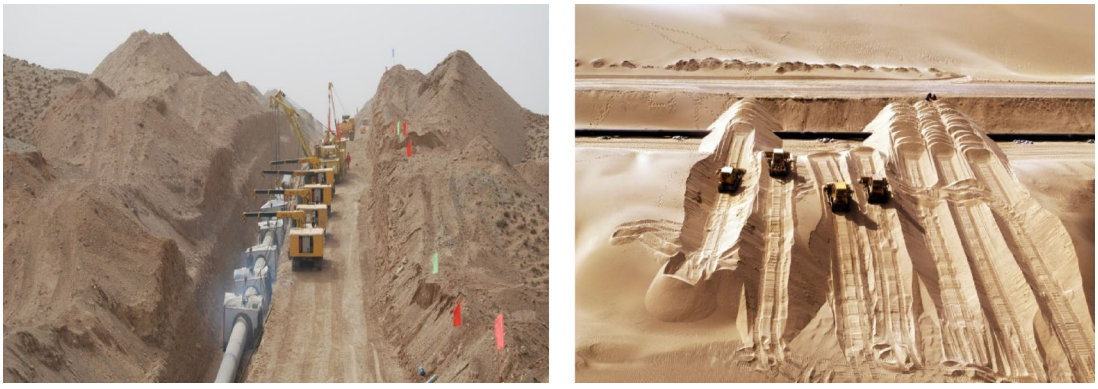

Fig. 2 Pipeline mechanized construction.

time synchronization technology of active and standby control centers have been developed to build a centralized management and integration platform for natural gas pipeline networks (Fig. 3). The self-developed SCADA system has been widely used in China's natural gas pipeline networks.

Based on the concept of risk control, life-cycle pipeline integrity management has been implemented. Monitoring and testing standards for geological hazards, third-party damages, and pipeline body defects have been established. Research on the integration of risk management and risk assessment methods in areas with high pipeline impact has been carried out to establish a pipeline integrity management technology system suitable for complex environments and to achieve a transition from passive response to active prevention.

Specialized emergency repair forces have been laid out for high-impact areas, high incidence of geological disaster regions, and high-intensity seismic zones. Emergency repair equipment and technology adapted for deserts, mountains, water networks, rivers, and other nine kinds of special scenes have been developed, forming a complete technical system for pipeline emergency repair.

2.4 Creating a technical system for the localization of pipeline equipment and materials

The localization of natural gas pipeline materials and equipment is attributed to China's guaranteed capability of oil and gas supply security. With the support and assistance of relevant state ministries and commissions, the National Engineering Laboratory has been established for the West-East Gas Pipeline Project, and the localization of materials and equipment has been realized.

Through the research and development on the low residual stress forming process of high-grade steel spiral pipe and the high-energy welding process of large-

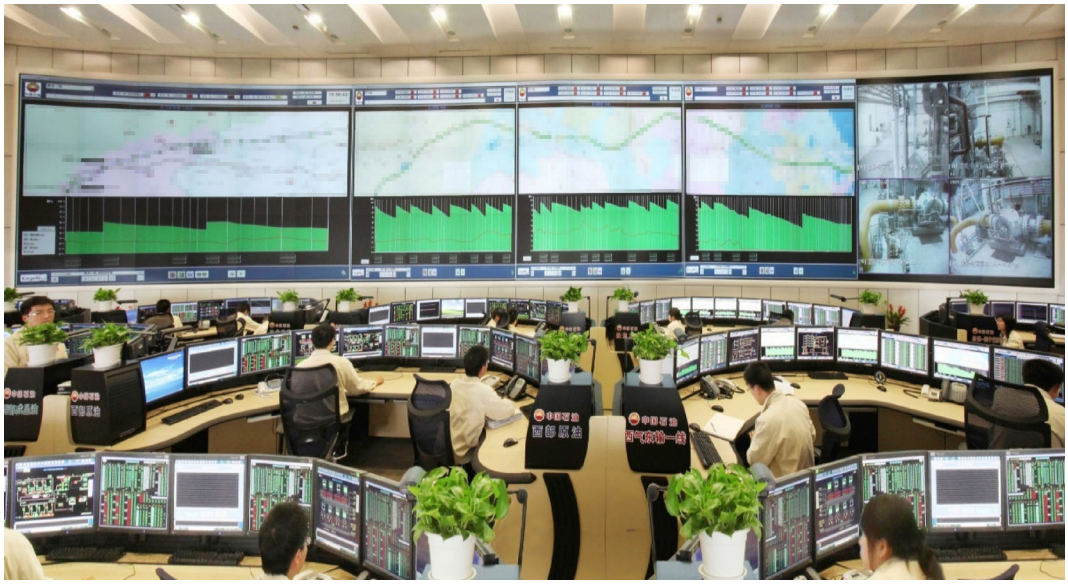

Fig. 3 PetroChina Oil and Gas Pipeline Control Center.

diameter, thick-wall submerged arc welded pipe, upgrade of the spiral welded pipe industry has been realized. By developing the JCOE forming process of high-steel straight seam pipelines and establishing a steel pipe strength prediction model, the yield strength of steel pipe after expansion has been effectively controlled, which greatly reduces the production cost as compared with the UOE forming process.

A class 900 40"/48" high-pressure large-diameter ball valve, 20 MW electric drive compressor unit (Fig. 4), 30 MW class combustion drive compressor set, and other domestic developments have been carried out, and the industrial application of all products has been completed. The performance parameter indicators have reached the international advanced level, which has promoted the technological advancement of the related equipment manufacturing industry.

2.5 Creating a new social responsibility system for large-scale engineering

The natural and cultural environments in the areas through which the West-East Gas Pipeline Project passes are diverse. Once the natural gas pipeline fails, it not only affects users' gas supply safety but also public safety. To strive for the understanding and support from all people, we need to establish a new social responsibility system.

For the first time in China, the gas supplier and users have implemented a risk-sharing mechanism for take or pay long-term contracts and have established a dynamic sales management of "monthly plan, weekly balance, and daily appointment" to reduce the risk of customers' excessive gas consumption. The supplier can flexibly arrange the purchase and sales plan to ensure stable gas supply.

We have conducted social relationship impact assessment, and hired professional institutions to delve into communities along the pipeline network and investigate the impacts of resource utilization, cultural education, and social environment. We have also invited reporters from mainstream media to conduct in-depth, on-site tracking reports to ensure the public's right to know about the project and to regularly release news. We have publicized pipeline protection to the people along the routes and jointly conducted emergency drills to enhance mutual understanding and trust.

On the basis of the systematic special assessment of environmental impact as well as soil and water conservation, an expert-support system for environmental protection has been established for the first time to avoid harming natural reserves, such as wild camels, and develop every inch of cultivated and forest land. Meanwhile, pipeline engineering and environmental protection system was first established in China. A cultural heritage protection model was established, and dozens of ancient Great Wall sites, famous ancient sites, and accidentally discovered cultural relics have been properly protected, realizing a peaceful coexistence of national projects and cultural relics.

3 Conclusions

The completion of the West-East Gas Pipeline Project marks the development of China's oil and gas pipeline construction and operation technology and management in the world's advanced ranks, achieving a historical leap. The engineering developments in the country have won numerous awards, such as the first National Environmental Friendly Engineering, National Development and Construction Project Soil, Water Conservation Demonstration

Fig. 4 20 MW electric drive compressor unit.

Project, One Hundred Classic and Quality Engineering during the 60th anniversary of the founding of the PRC, National Excellent Engineering Survey and Design Gold Award, and the first prize of National Science and Technology Progress Award (won twice).

The gas supply system of the West-East Gas Pipeline Project has become one of the largest pipeline systems in the world, bearing more than 50% of China's natural gas supply capacity. It greatly increased the proportion of natural gas in China's primary energy consumption structure, covering more than 160 cities and more than 3000 enterprises, and benefiting nearly 400 million people. It also plays an important role in improving the air environment and people's living quality.

The collaborative innovation industrialization model as well as its achievements of the West-East Gas Pipeline Project will not only be applied and developed in China's future oil and gas pipeline projects, it will also play a positive role in promoting the technological and industrial progress of China's related industries.