KERUI PETROLEUM TECHNOLOGY

Integrated Solutions and Services for Oil & Gas Production Enhancement

KERUI PETROLEUM TECHNOLOGY

TO MAKE ENERGY EXTRACTION CLEANER AND MORE EFFICIENT

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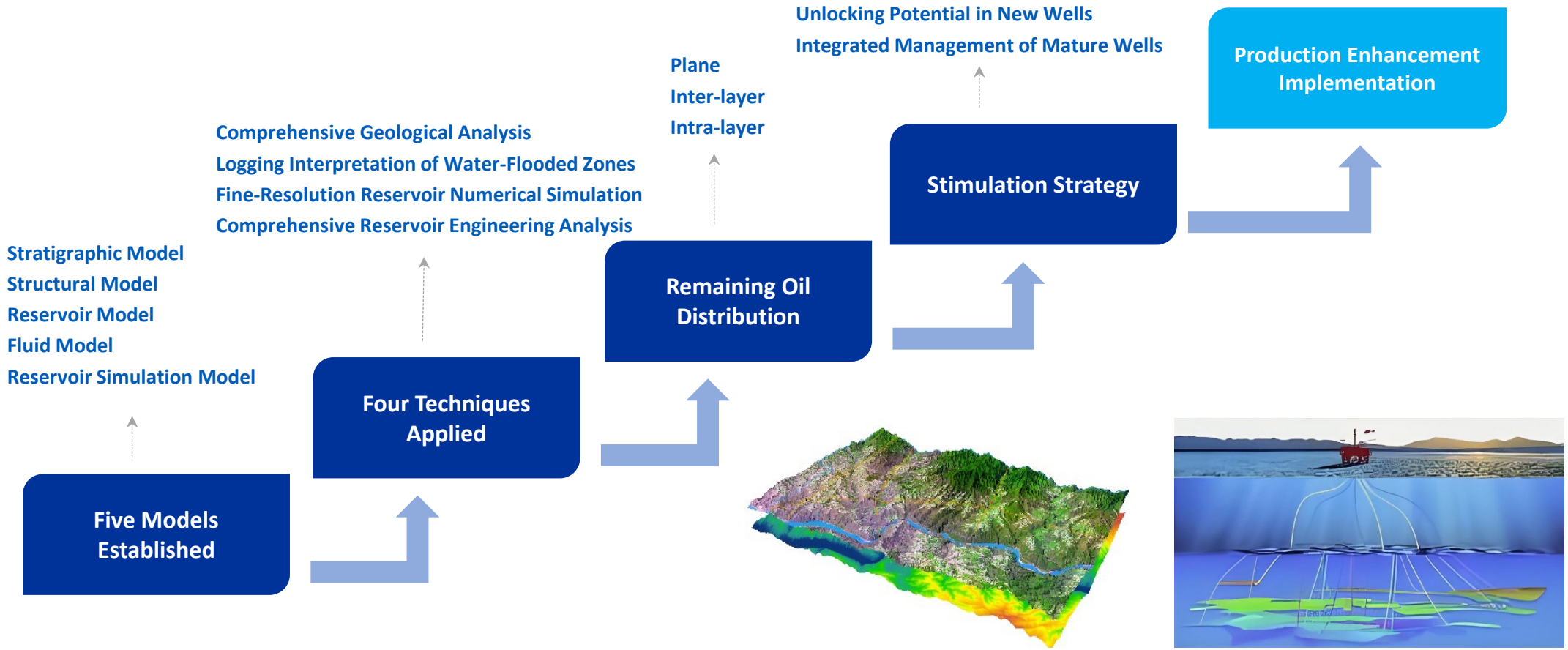
Contents

After years of development, mature oilfields shows **highly dispersed** and **localized oil enrichment**. To enhance production, five models (e.g. stratigraphic and structural models) and four technical approaches (e.g. integrated geological analysis and comprehensive reservoir engineering study) are applied characterize the distribution of remaining oil and maximize residual oil recovery.



Reservoir Description Technology: Reservoirs formed by different **genetic mechanisms** and **geological settings** show significant differences in reservoir characterization and development practices, necessitating the establishment of targeted research approaches and technical methods.

Different Types of Reservoirs	01 Integrated Reservoirs	02 Fault-Block Reservoirs	03 Special Lithologic Reservoirs
	• Reservoir Architecture Profiling • High Water-Cut Zone Mapping • Rhythmite Stratification Modeling	• Fine-Scale Characterization of Fault Tips and Fault Planes • Description and Correlation of Low-Order Faults • Geological Modeling of Complex Fault Systems	• Study on the Spatial Distribution of Reservoir Rocks • Spatial Distribution and Attribute Characteristics of Fractures
Technical Focus	Rhythm Stratification Technology for Thick Oil Zones High-Resolution Intraformational Barrier Prediction	Precision Characterization of Minor Fault Systems	Characterization Technique for Reservoir Spaces and Fractures

Contents

Kerui Unconventional Oil and Gas Research Institute is equipped with high-performance **experimental equipment** and **internationally advanced software systems**. Based on comprehensive geological and reservoir engineering research, it develops technically and economically feasible oil and gas production enhancement plans for target reservoirs.

Research Capability

Comprehensive Geological Study

- Fine Structural Interpretation of Complex Structural Belts
- Sedimentary System Analysis and Reservoir Characterization
- Comprehensive Analysis of Hydrocarbon Accumulation
- Fine Geological Modeling of Oil and Gas Reservoirs
- Reserve Calculation and Evaluation

Reservoir Engineering Study

- Research on Development Policies and Technologies for Complex Oil and Gas Reservoirs
- Study on Reservoir Numerical Simulation and Remaining Oil Distribution
- Formulation of Oil and Gas Production Enhancement Plans
- Economic Evaluation of Complex Oil and Gas Reservoirs

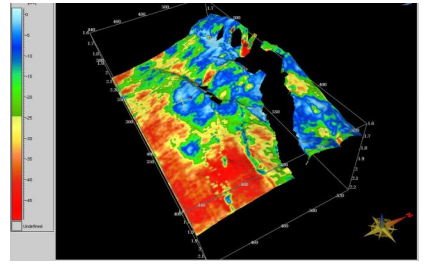
Hardware and Software

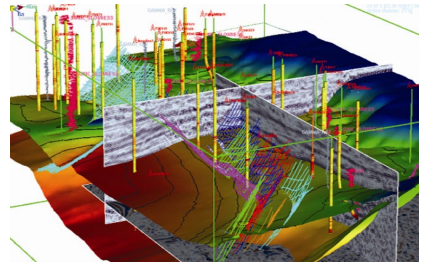
Software

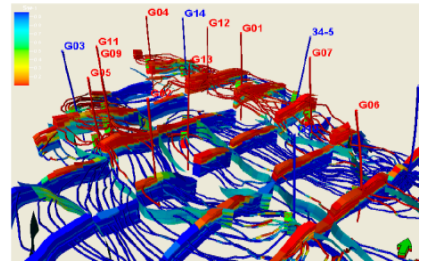
- CYCLOG Stratigraphic Correlation Software
- Jason, Strata and other seismic inversion software
- Geoframe and Landmark Comprehensive Seismic Interpretation Software
- Petrel Geological Modeling Software
- Eclipse and CMG Reservoir Simulation Software

Hardware

- HP Xw9400 and DELL 7910 Series Workstations, High-Performance Microcomputers and Other Main Equipment
- Printers, Plotters, Scanners and Other Supporting Equipment







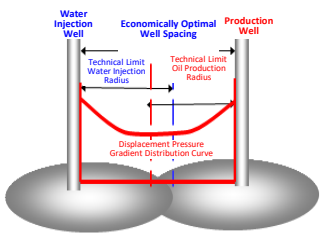
Contents

Precision Waterflooding Technology

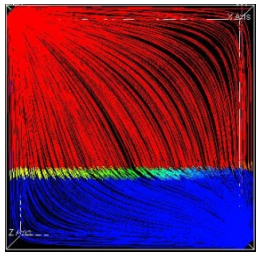
Technical Introduction

For reservoirs with **depleted formation energy** and **poor waterflood performance**, integrate multiple technologies - **well-pattern waterflooding optimization, fine-grained zonal injection and water quality classification management** to supplement energy and achieve an effective swept volume and displacement efficiency in water injection.

Technical Advantages



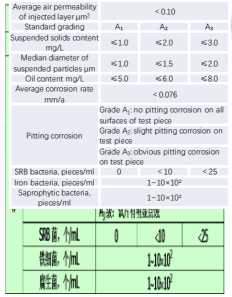
Displacement Pattern Efficiency Model



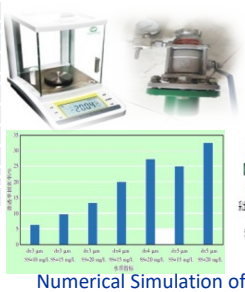
Effective Waterflooding Simulation Model

Well Pattern Waterflood Optimization Technology

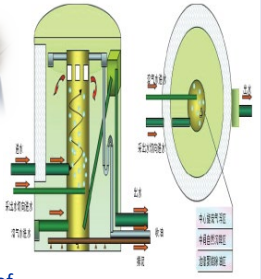
- Optimize the design of efficient displacement well patterns
- Supplement energy
- Enhance displacement efficiency



Water Quality Tiered Control



Numerical Simulation of Reservoir Damage from Water Quality Parameters



Water Quality Improvement Technology

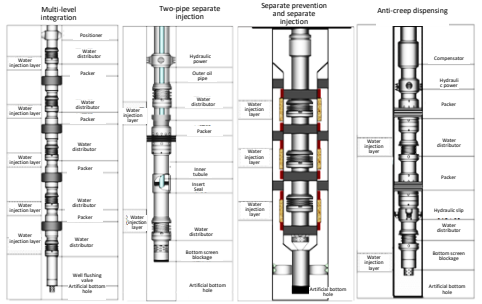
Tiered Water Quality Management Technology

- Tiered water quality control
- Integrated optimization package for water quality parameters
- Ensure adequate and high-quality water injection

Precision Layered Water Injection Technology

- A series of tailored fine-grained injection techniques and testing methods for different reservoir types, supported by independently designed and matched injection tools.

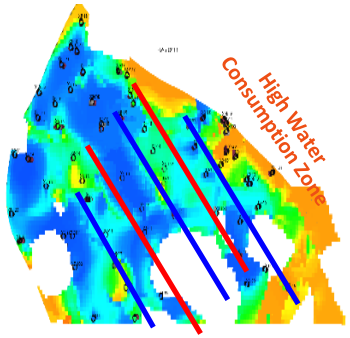
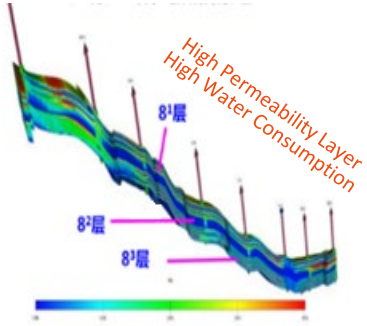
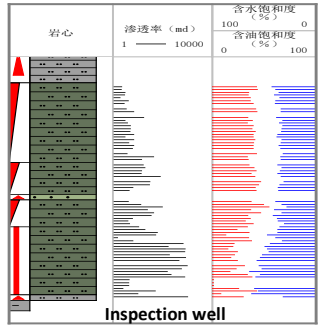
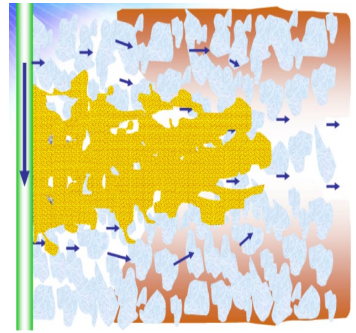
Fine Injection Technology Measurement and Adjustment with Tool Support



Fine Zonal Injection Technology Series

Flow Field Vector Adjustment /Quantitative Description Technology of High Water Consumption Zones

For high-water-cut mature oilfields with established preferential water injection channels, based on the identification of high water-consuming zones, flow field adjustments are implemented to reduce water cut and improve the development effect.

	Planar High Water-Consumption Belt	Inter-layer High Water-Consumption Layers	Intra-layer Rhythmic Section	High Water Consumption Section Within the Layer
Water Breakthrough Characteristics	GD West Area Beiguan 3^5  Saturation Difference 26.4%	T11 Nansha II 8  Saturation Difference 15.1%	GD Oilfield $Ng5^{2+3}$  Difference 12.3%	Water Blocking and Profile Adjustment in Deep Reservoir 
Remaining Oil Distribution	Enrichment in Non-Mainstream Lines and Other Weakly-Driven Areas	High Remaining Oil Saturation in Potential Layers	Enrichment of Remaining Oil in the Middle & Upper Part of Layer	Remaining Oil Enrichment at Both Ends of the High Water Consumption Section Within the Layer
Technology Series	**Well Pattern Adjustment for Flow Field**	**Layered Waterflooding for Profile Control**	**Precise Adjustment Leads to Effectiveness**	**Fine Profile Control for Sweep Efficiency**

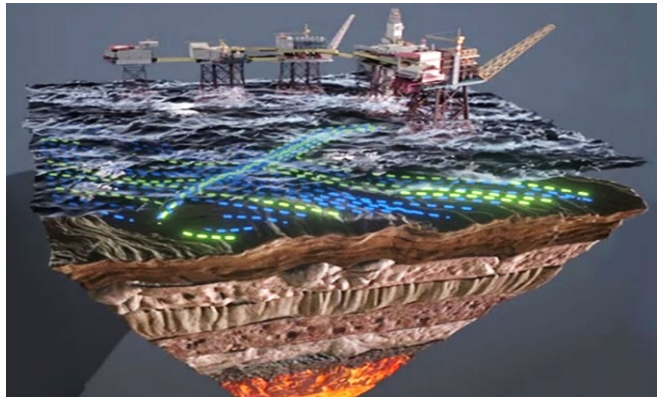
Polymer Flooding Development Technology

Technical Introduction

By adding high-molecular-weight polymers into the injection water to increase the viscosity of the water phase and reduce its permeability through adsorption and retention, thereby reducing the water-oil mobility ratio, enhancing sweep efficiency and improving the recovery factor.

Technical Advantages

- **Fit for different types of reservoirs:** the oil displacement mechanism is simple and stable, with no complex chemical reactions involved, low reservoir condition requirements and wide applicability.
- **High chemical stability:** modern polymer formula has strong thermal and salt resistance, and can maintain oil displacement performance under different geological conditions.



Based on reservoir properties and formation water mineralization, reservoirs suitable for polymer flooding are classified into three types, supported by a mature product system tailored to varying requirements.

Type of Reservoir		Permeability mD	Formation Temperature ℃	Water Mineralization 10^4mg/L	Ca^{2+}/Mg^{2+} mg/L	Formation Crude Oil Viscosity mPa·s
Class I		> 500	< 70	< 1.0	< 200	< 150
Class II		> 500	70-80	1.0-3.0	< 400	< 150
Class III	1	> 100	< 95	< 3.0	> 400	< 150
	2	> 500	< 70	< 3.0	> 400	< 500

Water Shut-off, Profile Control and Flooding Adjustment Technology

Technical Introduction

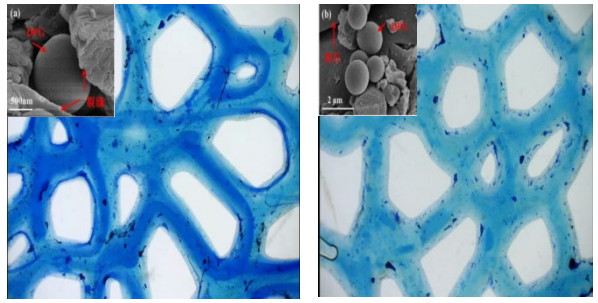
- Aiming at the problems of poor water injection sweep and low water flooding efficiency of the reservoir, this technical series provides integrated solutions to improve planar and inter-layer profile control and injection effects;
- According to the requirements of different reservoir water flooding processes, water shut-off and profile control, nitrogen foam, three-phase flooding and other processes are provided;
- Improve the energy supplement and effective sweep volume and displacement efficiency of water flooding reservoir, greatly enhancing the recovery factor of secondary oil recovery.

Technical Advantages

Water Shutoff and Profile Control Agent System

Water-Blocking and Profile Adjustment Technology

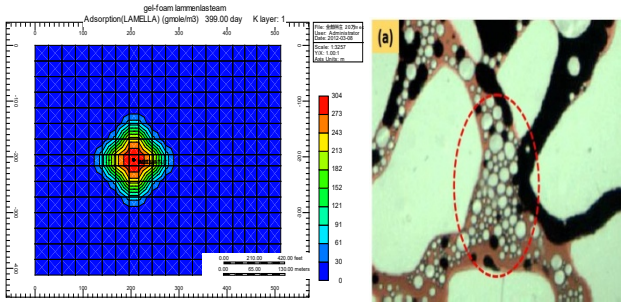
- Systematized plugging agent systems
- Addressing problems of temperature resistance, salt resistance, etc.



Microscopic State of Flexible Particles in Pores

Three-Phase Compound Flooding Technology

- Nitrogen foam plugging
- Flexible particle bridging
- Water phase energy enhancement
- Widely applicable for water control and oil enhancement



Adsorption Concentration Distribution in the Foam Flooding Reservoir

Microscopic Visualization of Foam Plugging

Nitrogen Foam Technology

- Nitrogen pressurization energy supplement
- Foam plugging and profile control
- Dynamic plugging of pores with high water content.

Compound Water Injection for Low-Permeability Reservoirs

Technical Introduction

The compound water injection oil recovery technology was developed by combing conventional booster pumps with chemical agents. The injection pressure is slightly higher than the reservoir's fracture pressure, leading to the formation of micro and short fractures around the water injection well. This not only increases water injection volume but also effectively controls water breakthrough. The daily injection rate per well can reach several hundred cubic meters.

Technical Advantages

Significant Pressure Drawdown and Strong Water Injectivity in Formation	Pressurized Water Injection Technology	Replenishment of Reservoir Energy
Poor Reservoir Properties and Limited Water Injectivity	Permeation and Drag Reduction Technology	Reducing Water Injection Resistance by Chemical Agents
Thick Formation Horizontal Wells with Remaining Oil Concentrated at the Top	Nitrogen Energy Accumulation Technology	Replacement of the Remaining Oil at the Top
Reservoir Heterogeneity and High Water Cut in Oil Wells	Foam Foam Water Shutoff Technology	Controlling the Speed of Water Breakthrough

High-Pressure Water Injection Equipment

Pressurized Water Injection Equipment

Gas Stimulation Technology for Carbonate Reservoirs

Technical Introduction

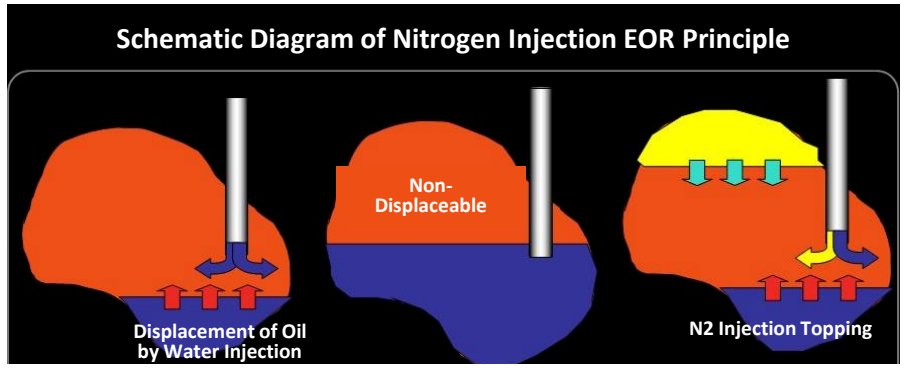
- High-purity nitrogen is separated from air by nitrogen production equipment and injected into the formation after compression, rapidly replenishing formation energy, displacing remaining oil in the reservoir and enhance oil well production.
- Two application modes: single-well huff and puff and nitrogen flooding.

Nitrogen Advantages

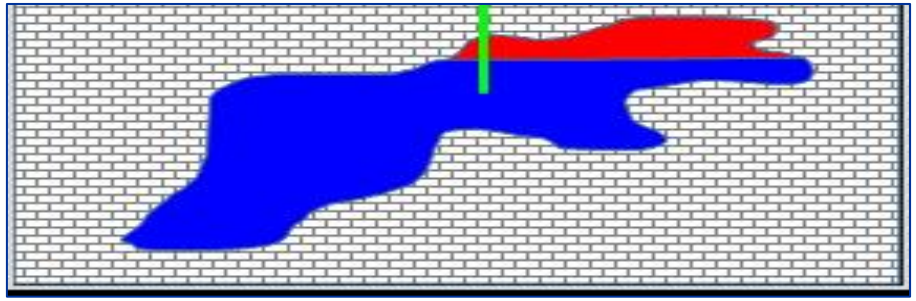
- Abundant gas source, with locally available materials
- Stable chemical properties and no damage to the strata
- Odorless, non-toxic, non-combustible, non-explosive and safe for injection

Application Scenario

- **Fracture-Vuggy Carbonate Reservoirs:** widely applied at scale in northwest China oilfields, becoming the leading EOR technology.
- **Fractured-Porous Carbonate Reservoirs:** mainly applied in oilfields in eastern China, achieving an integrated well selection and operation service, enabling redevelopment of shut-in and abandoned wells.



Schematic Diagram of Fractured-Porous Carbonate Reservoir



Schematic Diagram of Fracture-Vuggy Carbonate Reservoir

Integrated Heavy Oil Production Technologies

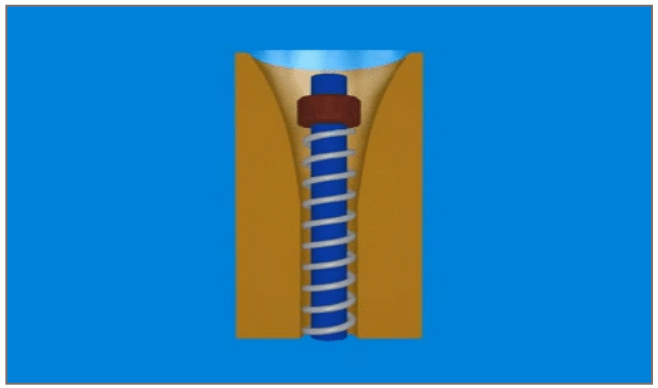
Technical Introduction

- A series of technologies specifically for systematic development of **high viscosity heavy oil reservoirs**;
- **The whole-process dry-keeping** technology combines **nitrogen foam, steam huff and puff, thermal recovery and oil displacement;**
- Enhances reservoir displacement efficiency, reduces oil viscosity and increases heavy oil recovery.

Technical Advantages

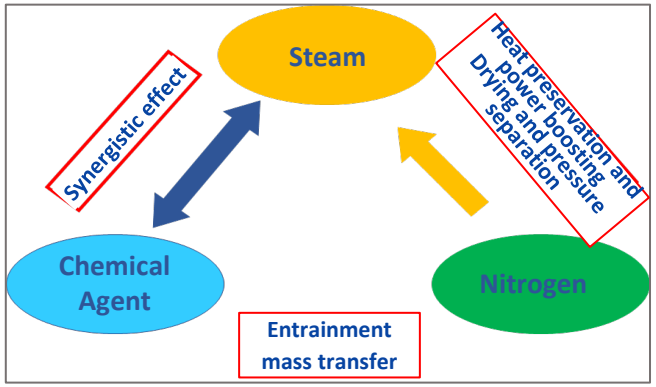
Whole Process Thermal Management Technology

✓ Equipment and processes throughout steam generation, transmission, and injection ensure bottom-hole dryness above 63%.



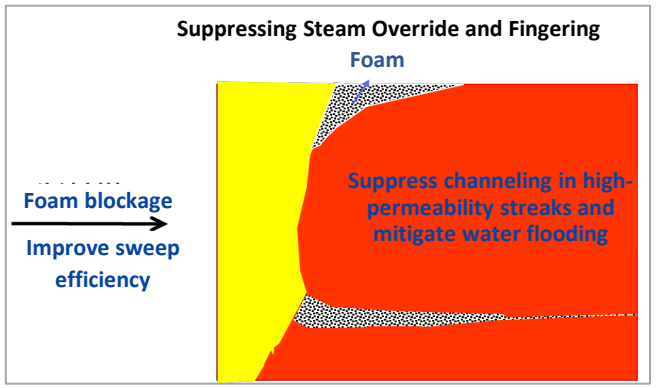
Uniform Steam Injection and Production Technology

✓ Balanced production allocator: solves the problems of uneven steam absorption and large difference in reserve production.



Nitrogen+ Chemical Assisted Thermal Recovery Technology

✓ Nitrogen forms a gas cap for heat insulation and energy transfer; Chemical agents enhance foam stability and block steam channeling.



Treatment Technology for High Water-Cut Well

✓ Nitrogen foam profile control: utilize foam plugging to improve the steam sweep efficiency.

Case I: Fine Water Injection Technology for Well Pattern Interchange Flow Field Adjustment in G Area

Technical Adjustments

- Interchange of upper and lower strata well pattern to change injection-production flow line by 40°
- Oil well sidetracking for water avoidance in high water consumption area
- Blocking and adjustment of deep thick oil layer in the water well
- Multi-stage plugging of tubing, workload for old wells changing strata: 89 Wells

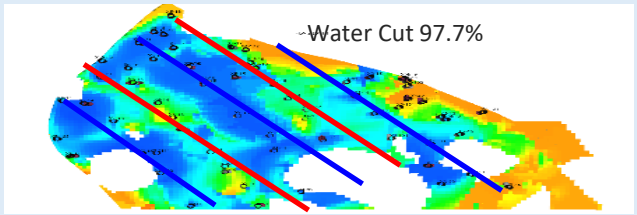
Implementation Effect

- 44% increase in daily oil production
- 25% reduction in operating cost per ton of oil
- 35% decrease in water consumption per ton of oil d

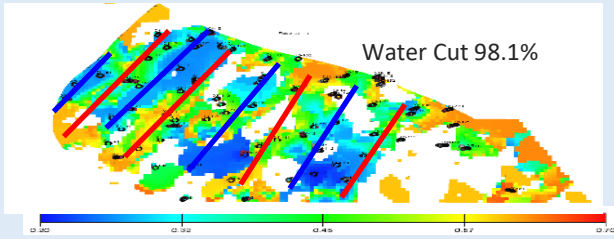
2.1% increase in recovery factor

Before

Planar remaining oil distribution map of upper strata

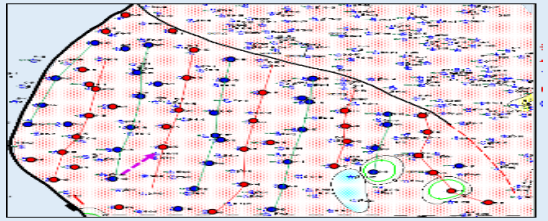


Planar remaining oil distribution map of lower strata

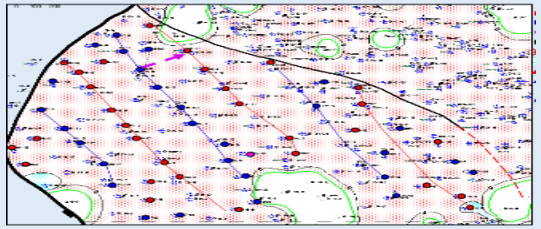


After

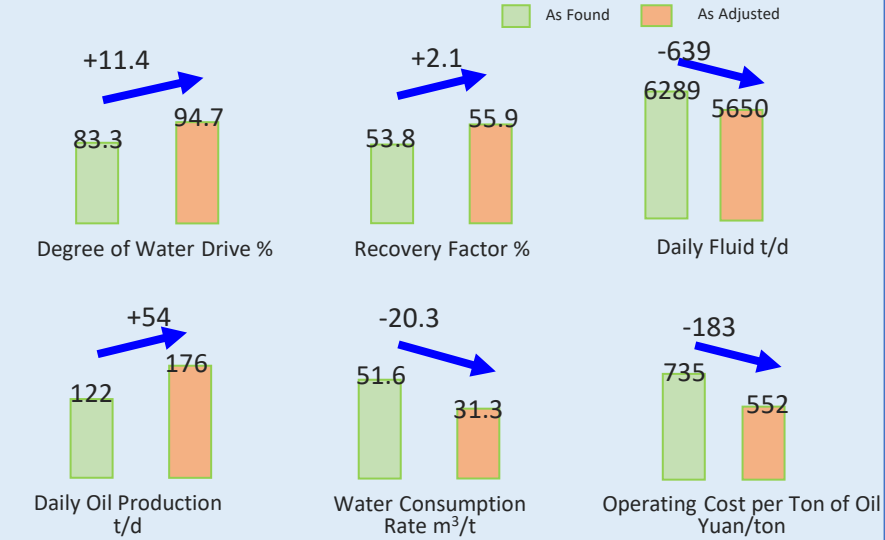
Well pattern diagram after adjustment of upper strata



Well pattern diagram after adjustment of lower strata

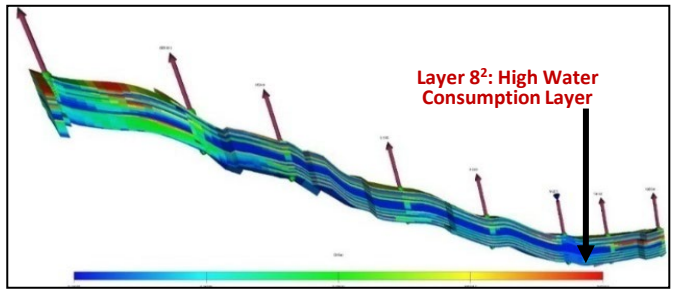


Effect and Benefit

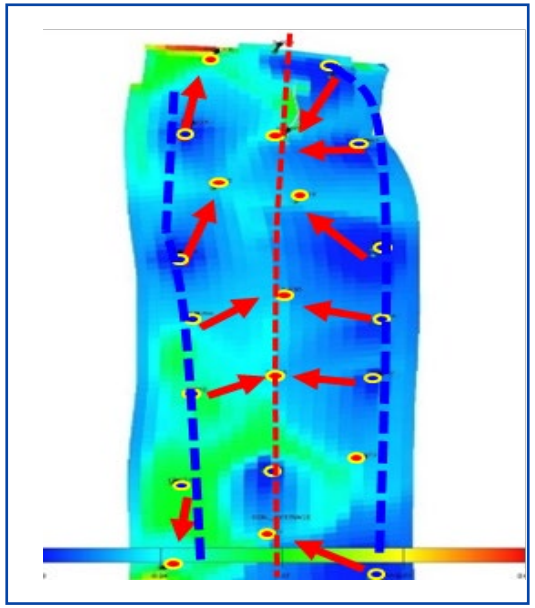


Case II: Fined Water Injection Technology for Strata Subdivision Flow Field Adjustment in T Block

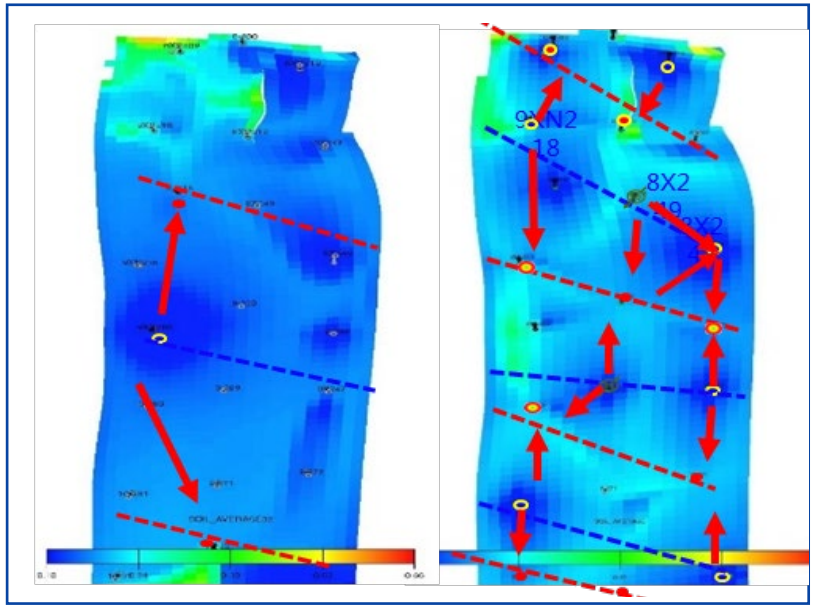
Before Adjustment
Longitudinal residual oil saturation distribution profile



Before Adjustment
Distribution diagram of overlapping residual oil of T blocks 8^1, 8^2 and 8^3



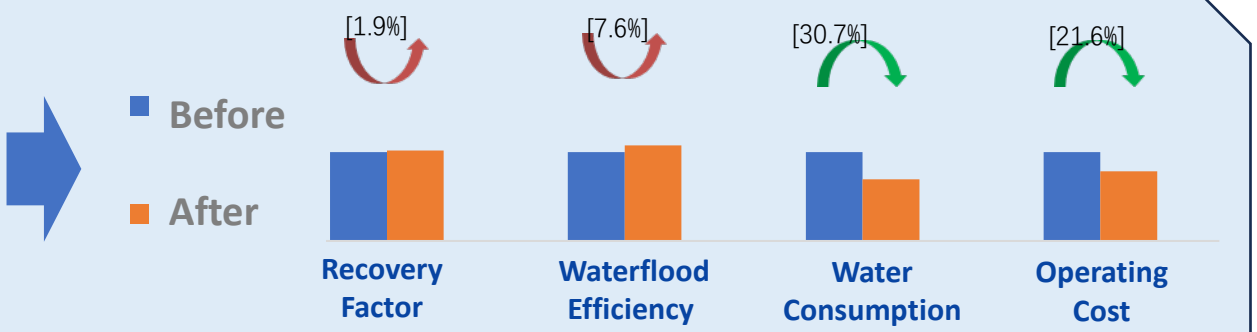
After Adjustment
Residual oil distribution map of strata subdivision development for 8^{1+3} and 8^2 of T block



SOLUTIONS

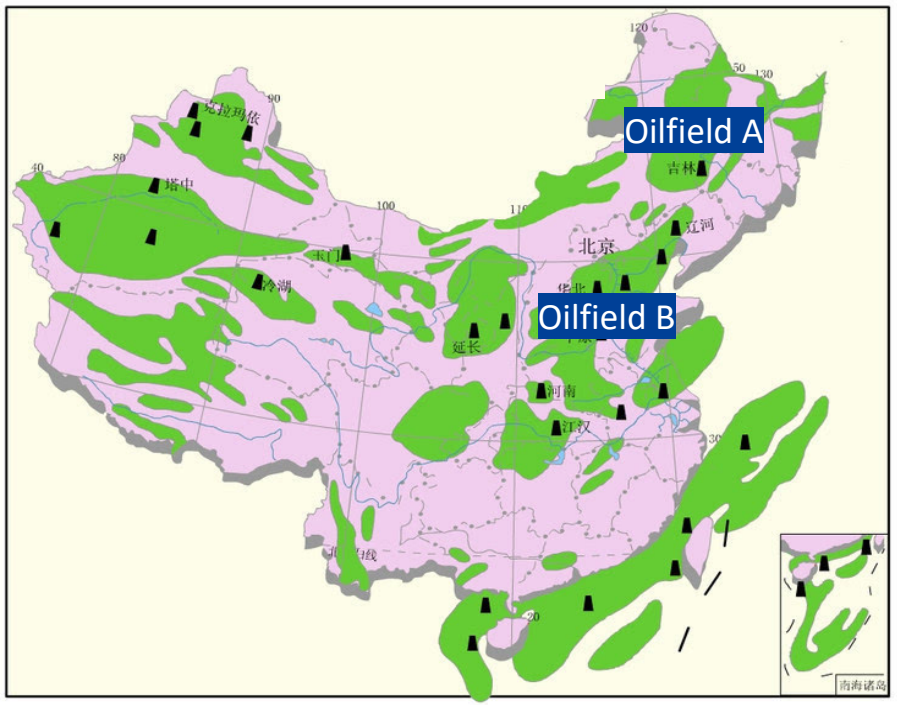
Technical Adjustment Scheme

- Vertical subdivision of two sets of development strata
- Horizontal well pattern transformation
- Subdivision water injection in rhythmic layers
- Completion of water injection adjustment



Case III: Chemical Flooding Development Technology

More than 730 polymer flooding projects have been implemented globally, mainly in **onshore sandstone reservoirs in the United States, Germany, India, and China**.



Oilfield A

- Temperature: <50°C; Salinity: <5,000 mg/L
- Good reservoir properties and low oil viscosity. Suitable for polymer flooding.
- **In 2023, oil and gas equivalent production was 35 million tonnes, including over 10 million tonnes from chemical flooding.**

Oilfield B

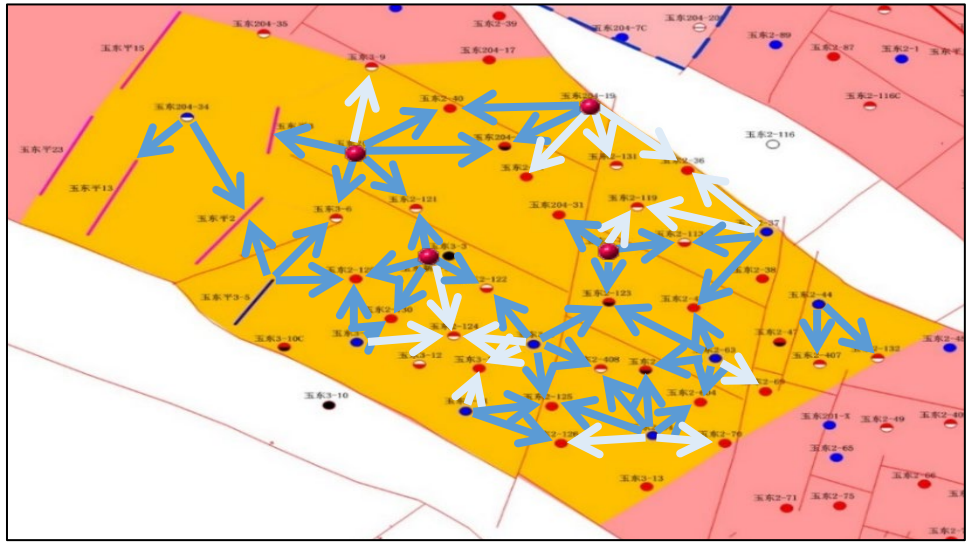
- Temperature: 50°C- 90°C; Salinity: < 30,000 mg/L
- Poor reservoir properties and high oil viscosity; polymer flooding is challenging.
- **In 2023, oil and gas equivalent production reached 24 million tonnes, with over 3 million tonnes from chemical flooding.**

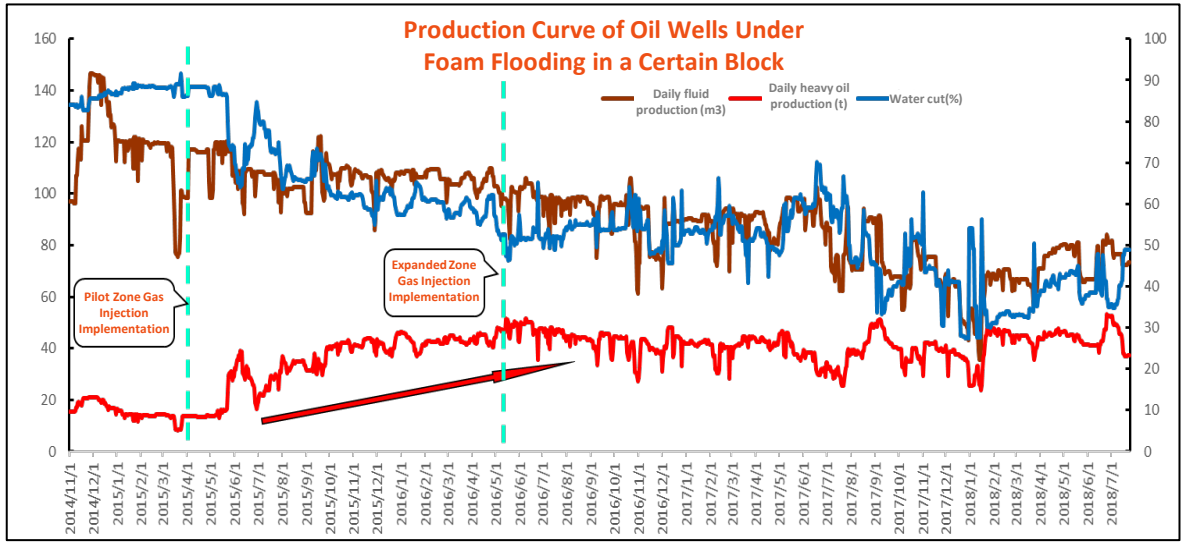
Case IV: Deep Heavy Oil Reservoir in Western China – Foam Flooding Pilot

Burial depth > 2,000 m Reservoir thickness > 40 m

Crude oil viscosity: **286 mPa·s** (heavy oil), small waterflood sweep volume, and the recovery degree **<5%**.

- Pilot trials started in September 2014, with industrial trials in June 2017.
- In a certain block, the **water cut** of 20 effective wells **decreased from 84.1% to 34.4%, and daily oil production increased from 47.6 tonnes to 191 tonnes.**
- A total of 38 well groups and 125 oil wells underwent nitrogen foam flooding, achieving **an incremental oil production of 150,000 tonnes.**





Case V: Compound Water Injection for Low-Permeability Reservoirs in Western China

2022 Stimulation Results - Target Block

- 5 horizontal wells treated with nitrogen + activated water (with imbibition drag-reducing agents)
- Cumulative oil increase: 2,490.8 tonnes; 3 wells with significant response **(averaging 830.3 tonnes/well)**
- Injection pressure 2–6 MPa lower than adjacent wells, achieving absorption enhancement and drag reduction

Effectiveness Statistics of Compound Water Injection Measures in a Certain Block

S/N	Well No.	Pre-Operation Production Status			Current Production Status After Operation			Production Days (Days)	Accumulated Oil Production (t)	Accumulated Oil Increment (t)
		Daily Fluid Production (m^3)	Daily Oil Production (t)	Water Cut (%)	Daily Fluid Production (m^3)	Daily Oil Production (t)	Water Cut (%)			
1	001	3.33	1.61	51.6	1.55	0.77	50.2	367	415.7	Minor Effect
2	002	0.8	0.64	19.5	6.64	3.86	41.9	370	1045.4	808.6
3	003	3.01	1.69	43.7	3.76	2.52	33	350	1539.5	948.7
4	004	2.16	1.74	19.5	1.33	0.91	31.7	350	508.3	Minor Effect
5	005	0.9	0.72	20.0	4.46	3.22	27.8	320	963.9	733.5
Total			**6.4**			**11.28**			**4472.8**	**2490.8**

Case VI: Fractured Carbonate Reservoir in Western China- Gas Injection Stimulation

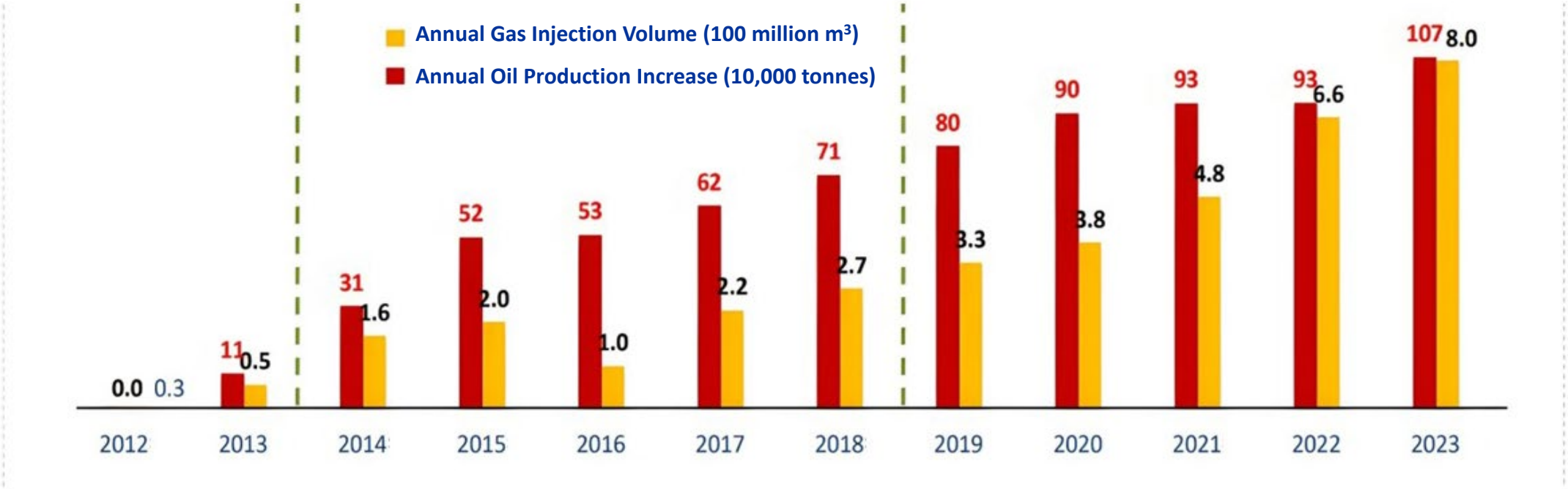
- **Test Stage**

  In 2012, a pilot nitrogen injection test was conducted with 8 cycles of nitrogen huff and puff, increasing oil production by 19,500 tonnes.

- **Expanded Application Stage**

  By the end of 2023, 992 gas injection wells operated with 3,028 well treatments, controlling 500 million tonnes of reserves, injecting 3.66 billion m^3 nitrogen, and increasing oil production by 7.43 million tonnes.

  In 2023, 800 million m^3 nitrogen injection alone led to an annual oil production increase of 1.07 million tonnes.

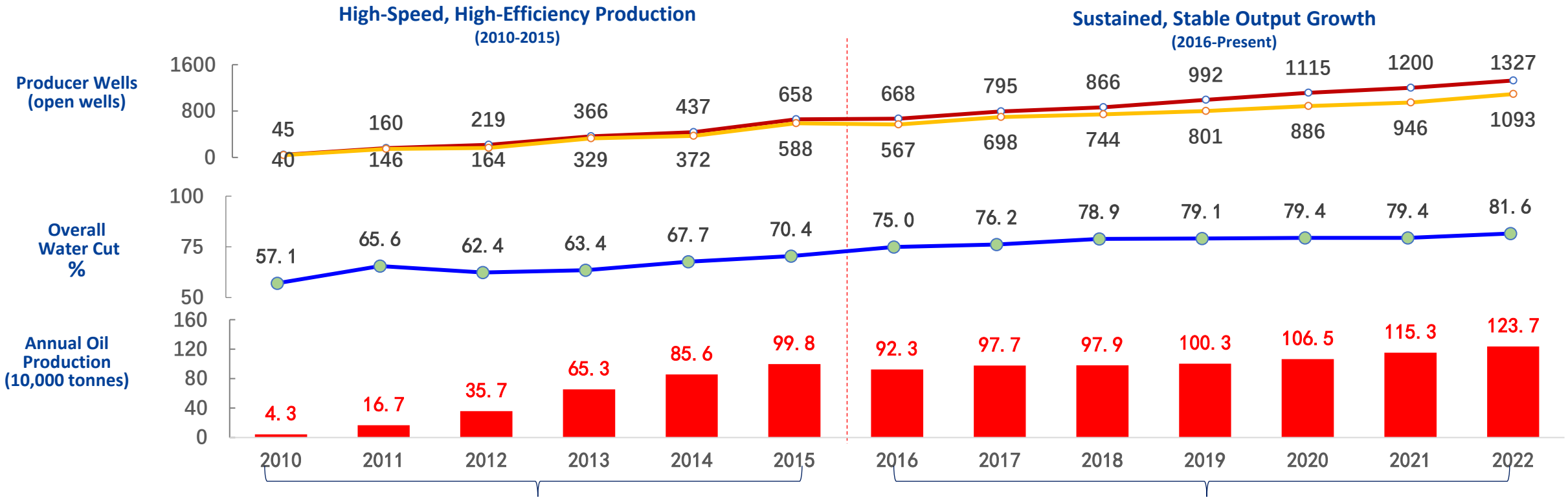


Case VII: Integrated Development Technology Case of Heavy Oil - A Shallow and Thin Heavy Oil Field in Eastern China

Shallow reservoir (150-750 m), thin pay zone (2-6 m), low temperature/pressure (18-35 °C, 2.0-6.1 MPa), and high-viscosity heavy oil (5-9 × 10^4 mPa·s).

Integrated development enabled stable production of over 1 million tonnes annually.

In 2022, 1,093 wells produced 1.237 million tonnes of oil, with 81.6% water cut.



KERUI PETROLEUM TECHNOLOGY

Customer Success, Co-Creation and Shared Growth

Shandong Kerui Petroleum Technology Co., Ltd.