More Efficient in Oil & Gas Extraction

Nitrogen Stimulation Technology
Content

Ⅰ. Brief Introduction of Kerui Group

Ⅱ. Nitrogen Stimulation and Injection-production Technology

Ⅲ. Application Cases
I. Brief Introduction of Kerui Group

Kerui Group is a very rapid development of comprehensive International enterprise group integrating high-end petroleum equipment research, integrated oilfield engineering technological service, and oilfield EPC turnkey contracting.

57  Global Branch Organization
16  R&D centers
  7  Technical Support Centers
  6  Research Laboratories
I. Brief Introduction of Kerui Group — High-end Petroleum Equipment Research

High-end industrial park covers oil and gas exploration and development, oil and gas gathering processing, marine equipment, petroleum equipment full industry chain, in an area of 2.4 million square meters.

Meeting customers demand for one-stop sourcing (Drilling and workover machines, production equipment, operating equipment, wellhead equipment, compressors, process equipment of oil and gas, LNG equipment, special equipment, oil pipeline, etc).
I. Brief Introduction of Kerui Group — Integrated Oilfield Engineering Technological Service

More Efficient in Oil & Gas Extraction

Oil & Gas Field Integrated Solution Provide
- Oil & Gas Field Block Evaluation
- Single Well Program Design
- Single Production Increasing Program Design
- Economic Evaluation

Drilling and Completion Integrated engineering technology service
- Drilling Engineering Service
- Drilling Fluid and Completion Fluid Technology Service
- Cementing Technology Service
- Directional Well Technology Service
- Mud Logging and Well Logging Technology Service
- Well Completion Engineering Technology Service

Workover Operation Engineering Technology Service
- Conventional Workover Technology Services
- Complicated Oil & Gas Well Fishing Service
- Horizontal Well Sidetracking Technology Service

Special Operation and Production Increasing Service
- Membrane Nitrogen Injection Engineering Technology Service
- Acidification and Fracturing Engineering Technology Service
- Coiled Tubing Engineering Technology Service
- Wet Steam Generator Technology Service

Unconventional Oil and Gas Development Integrated Engineering Technology Service
- Individualized Geological Research and Evaluation
- Factory Mode Design and Construction
- Large-scale Project Implementation and Organizational Management
- Digitization Development Whole Process Management Platform
I. Brief Introduction of Kerui Group — Oilfield EPC Turnkey Contracting

DESIGN CAPACITY

• Kerui Group has long-term strategic cooperation with Xinjiang branch, CPE Beijing branch and Xinan branch
  • 600 professional technicians
  • 173 senior engineers

PROCUREMENT CAPACITY

• Professional EPC procurement teams with more than 100 engineers
• Procurement localization
• Completed international procurement network platform and the excellent global transportation arrival capability

CONSTRUCTION CAPACITY

• More than 1,200 engineering and construction personnel
• With more than 10 years construction experience to realize the localization of construction resources
• Construction and testing equipments are nearly 480 sets
• Comprehensive manufacture equipments are more than 200 sets, including pressure vessel, large-scale lifting, forming, welding and machining facilities

Oil and gas gathering and processing, gas processing and comprehensive utilization, LNG, water treatment, oil refining project, etc.
I. Brief Introduction of Kerui Group

Integration
Powerful combination of multi-national enterprises with the best supplier integration capacity

Cost
All-in-one petroleum equipment manufacturer, reducing external procurement cost

Speed
Excellent capacity of global arrivals with the low transportation cost and high efficiency

Efficiency
Professional technical team, comprehensive integration of technical services, to ensure the project run efficiently

Fast and Efficient Ensure Global Customers Achieve Higher Revenue
Content

Ⅰ. Brief Introduction of Kerui Group

Ⅱ. Nitrogen Stimulation and Injection-production Technology

Ⅲ. Application Cases
II. Nitrogen Stimulation and Injection-production Technology

1. Why Choosing Nitrogen

Nitrogen property:
- bad thermal conductivity
- low surface tension
- low critical temperature
- high compacting factor
- density: 1.25 kg/m³

Nitrogen advantage:
- available water sensitive reservoir
- non-corrosive
- boost pressure
- high security
- low cost
- enrich air source
- low

A kind of clean, efficient and safe renewable resources
## II. Nitrogen Stimulation and Injection-production Technology

### 1. Why Choosing Nitrogen

Comprehensive cost performance comparison table of different injection media

<table>
<thead>
<tr>
<th>Comparative item</th>
<th>N₂</th>
<th>CH₄</th>
<th>CO₂</th>
<th>Flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>Cheap</td>
<td>Expensive</td>
<td>Expensive</td>
<td>Cheap</td>
</tr>
<tr>
<td>Material obtain</td>
<td>Easy</td>
<td>Easy</td>
<td>Not easy</td>
<td>Easy</td>
</tr>
<tr>
<td>Security</td>
<td>Well</td>
<td>Bad</td>
<td>Well</td>
<td>Well</td>
</tr>
<tr>
<td>Miscibility</td>
<td>Hard</td>
<td>Little hard</td>
<td>Easy</td>
<td>Hard</td>
</tr>
<tr>
<td>Cost performance</td>
<td>High</td>
<td>General</td>
<td>General</td>
<td>Higher</td>
</tr>
<tr>
<td>Ground construction investment</td>
<td>Small</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Displacement efficiency</td>
<td>Middle</td>
<td>High</td>
<td>Highest</td>
<td>Low</td>
</tr>
<tr>
<td>Maintenance workload</td>
<td>Light</td>
<td>Heavy</td>
<td>Lighter</td>
<td>Heaviest</td>
</tr>
<tr>
<td>Impact on environment</td>
<td>Nothing</td>
<td>Great</td>
<td>Nothing</td>
<td>Great</td>
</tr>
</tbody>
</table>
II. Nitrogen Stimulation and Injection-production Technology

1. Why Choosing Nitrogen

- Nitrogen foam

Foam system: N₂+foam agent+water;
Foam compound system: foam + polymer solution

Selective water plugging + SAA
- Adjustable density; good stability;
- Small affected by temperature and pressure;
- High viscosity, strong carrying capacity;
  Reduce the loss of adsorption;
- Strengthen plugging ability and selectivity.

Foam diversion experiment results in high and low permeability cores

Foam diversion experiment results in water and oil cores
II. Nitrogen Stimulation and Injection-production Technology

2. Nitrogen Service of Kerui Group

(1) “One-stop” All-around Service

Integrated Services and Solutions for End-to-end Oil Field Nitrogen Generation and Injection

- Equipment R & D and Manufacture;
- Analysis for Well Selection;
- Project Optimization

- Oilfield Construction and Adjustment
- Effect Tracking and Evaluation
- Follow-up Service

Raise Input-output Ratio, Maximize Customers Benefits
II. Nitrogen Stimulation and Injection-production Technology

2. Nitrogen Service of Kerui Group

(2) Membrane Nitrogen Generation Technology

- PRISM Composite Membrane;
- Dry-wet Spinning and waterproof;
- Design index of oil resistance is 20 ppm;
- Radius of membrane wire is 0.5 mm and dust permeability through the membrane is high;
- Working pressure: 1.8 ~ 2.4MPa;
- Working temperature: 5 ~ 65°C;
- Separation Efficiency: 48 ~ 53%;
- Attenuation ratio per year: ≤1.2%;
- The unit can work stably for ten years.

Applicable to high temperature, frigid, windy and dusty oilfield worksite.
II. Nitrogen Stimulation and Injection-production Technology

2. Nitrogen Service of Kerui Group

(2) Membrane Nitrogen Generation Technology

- Meet the demand of Nitrogen for all kinds of construction conditions
- Simplify working process, cost savings
- More convenience and economy

Nitrogen generation and nitrogen injection seamless docking

Skid-mounted membrane separation Nitrogen generation equipment

Vehicle-mounted membrane separation Nitrogen generation equipment
II. Nitrogen Stimulation and Injection-production Technology

2. Nitrogen Service of Kerui Group

(3) Manufactured the first offshore platform membrane nitrogen generation

- Researched and manufactured the first offshore platform membrane nitrogen generation.
- Production of "the water filling nitrogen low density foam fluid flushing system" review by CCS
- The first application of offshore platform of diesel driven membrane separation nitrogen generation device, and applied to the cnooc bohai sea oil field.

- $\text{N}_2$ flow capacity: 900Nm$^3$/h
- $\text{N}_2$ purity: 95%-99.99%
- Normal discharge pressure: 35MPa
- Diesel engine driven
II. Nitrogen Stimulation and Injection-production Technology

2. Nitrogen Service of Kerui Group

(4) High volume, super pressure nitrogen gas generation

- Flow capacity: 2000, 3600Nm³/h
- Normal discharge pressure:
  - 35MPa (5000psi)
  - 50MPa (7000psi)
  - 70MPa (10000psi)
- Adapt environment temperature: -60°C~65°C
II. Nitrogen Stimulation and Injection-production Technology

2. Nitrogen Service of Kerui Group

(5) High Purity Nitrogen

- **PSA Nitrogen making machine**
  - (Carbon molecular sieve pressure swing adsorption nitrogen making machine)
  - Electric power: 1650kW
  - Nitrogen flow rate: 2000Nm³/h
  - Output pressure: 50MPa
  - Purity: **99.99%**
## II. Nitrogen Stimulation and Injection-production Technology

### 2. Nitrogen Service of Kerui Group

#### (6) Motivation in a Variety of Forms

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Air Compressor/Booster</th>
<th>Pressure Rating (MPa)</th>
<th>Characteristic</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel driven</td>
<td>Diesel driven</td>
<td>35/70</td>
<td>Equipment performance is stable, suitable for remote scattered Wells</td>
<td>High cost</td>
</tr>
<tr>
<td>Electrical drive</td>
<td>Electrical drive</td>
<td>50</td>
<td>Low cost, easy to maintain and environmental protection</td>
<td>Use the wellsite power grid</td>
</tr>
<tr>
<td>Combination drive</td>
<td>Electrical drive</td>
<td>35/50</td>
<td>Power load small</td>
<td>Costs less</td>
</tr>
<tr>
<td>Driven by gas engine</td>
<td>Driven by gas engine</td>
<td>50</td>
<td>Nearby using natural gas, high performance-price ratio</td>
<td>Use gas source</td>
</tr>
</tbody>
</table>

Combination drive and Electrical drive can be exchanged, improve the complex environment adaptability and economy.
II. Nitrogen Stimulation and Injection-production Technology

3. 9 Nitrogen Stimulation Service Technologies

**Enhance Oil Recovery**
- Nitrogen Huff and Puff Technology
- Nitrogen Flooding/WAG Flooding Technology
- Nitrogen Foam Combination Flooding Technology
- Nitrogen Foam Profile Control (Water Coning Control) Technology
- Nitrogen Energization and viscosity reduction (heavy oil reservoir)

**Production Auxiliary**
- Nitrogen Unbalanced Drilling Technology
- Nitrogen Foam Sand-washing Technology
- Nitrogen(Foam)Flowing Back & Induced Flow Technology
- Nitrogen Displace...
II. Nitrogen Stimulation and Injection-production Technology

3. Nitrogen Stimulation Service Technologies

(1) Nitrogen Huff and Puff

To inject a certain amount of nitrogen into oil well in a short time and shut in for some time. When the nitrogen diffuses in the reservoir:

- Gravitational differentiation displacement
- Dilatation energy displacement
- Water coning control

are employed to displace the crude oil in the reservoir to enhance oil recovery.
II. Nitrogen Stimulation and Injection-production Technology

3. 9 Nitrogen Stimulation Service Technologies

(2) Nitrogen Flooding/ WAG Flooding

Utilize high injection/ low production well pattern and WAG injection mode to change strong/weak streamline distribution (After gas is injected to higher part of the reservoir, it gathers at II type of channel. With the pressure increase weak streamline will open). Thus residual oil between wells is driven out and oil recovery is enhanced.
II. Nitrogen Stimulation and Injection-production Technology

3. 9 Nitrogen Stimulation Service Technologies

(3) Nitrogen Foam Combination Flooding

- Foaming Flooding

- Foam Combination Flooding

Test model: double tube: 60 × 2.5cm
permeability: 2, 0.8μm²
temperature: 80°C
back pressure: 6.0MPa
oil viscosity: 81mPa·s
water salinity: 8379mg/L
II. Nitrogen Stimulation and Injection-production Technology

3. 9 Nitrogen Stimulation Service Technologies
   (4) Nitrogen Foam Water Coning Control Technology

Deficiency in traditional schemes

- It is not easy to control the pressure.
- Plugging rate reduced with the increase of water injection.
- Artificial interlayer and anti-water-coning application effect is not ideal.

Advantages of this technology

- Covering deficit of formation energy and slowing down bottom water coning
- Gravitational differentiation forms secondary gas top to increase elastic energy
- Nitrogen foam blocks bigger pores to shut off water
- Nitrogen foam has good stability in porous media

More Efficient in Oil & Gas Extraction
II. Nitrogen Stimulation and Injection-production Technology

3. 9 Nitrogen Stimulation Service Technologies

(5) Technology of energizing & viscosity reduction with Nitrogen (Heavy oil reservoir)

- Maintain reservoir pressure, increase the flexibility-energy
- Under high pressure, nitrogen partly soluble crude oil make volume expansion
- Immiscible displacement, the formation of emulsions, reduce oil viscosity
- Expand swept volume, reduce the interfacial tension
I. Brief Introduction for Kerui Group

II. Nitrogen Stimulation and Injection-production Technology

III. Application Cases
### III. Application Cases

#### 1. Nitrogen Huff and Puff (Carbonate Reservoir)

**Gas oil replacement ratio in the 1st cycle**

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Gas injection rate (10^4m³)</th>
<th>Water injection rate (m³)</th>
<th>Before gas injection</th>
<th>After gas injection</th>
<th>Compare</th>
<th>oil increment in the 2nd Cycle (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1#</td>
<td>826m³</td>
<td>200</td>
<td>35</td>
<td>0</td>
<td>100</td>
<td>53.0</td>
</tr>
<tr>
<td>2#</td>
<td>50</td>
<td>979</td>
<td>10</td>
<td>0.4</td>
<td>93</td>
<td>24.2</td>
</tr>
<tr>
<td>3#</td>
<td>50</td>
<td>1093</td>
<td>16</td>
<td>0.5</td>
<td>99</td>
<td>19.3</td>
</tr>
<tr>
<td>4#</td>
<td>60</td>
<td>1348</td>
<td>23</td>
<td>2</td>
<td>87</td>
<td>19.6</td>
</tr>
<tr>
<td>5#</td>
<td>50</td>
<td>1850</td>
<td>41</td>
<td>1.5</td>
<td>96</td>
<td>45.1</td>
</tr>
<tr>
<td>6#</td>
<td>50</td>
<td>793</td>
<td>54</td>
<td>2</td>
<td>93</td>
<td>28.3</td>
</tr>
<tr>
<td>7#</td>
<td>55</td>
<td>1379</td>
<td>17</td>
<td>0.1</td>
<td>92</td>
<td>57.0</td>
</tr>
<tr>
<td>Average</td>
<td>/</td>
<td>/</td>
<td>28</td>
<td>0.93</td>
<td>94.3</td>
<td>35.0</td>
</tr>
</tbody>
</table>
III. Application Cases

1. Nitrogen Stimulation (Tight Sand Reservoir) —— tight sandstone reservoir in Peru

<table>
<thead>
<tr>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Porosity 5%-25%</td>
</tr>
<tr>
<td>➢ Low permeability, between 0.01 ~ 2mD</td>
</tr>
<tr>
<td>➢ Low recovery with flexible develop</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Nitrogen energizing, lifting formation pollution, dredging oil flow passage</td>
</tr>
<tr>
<td>➢ Nitrogen form a &quot;gas cap&quot;, increase the driving pressure, increase crude oil production</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Customer value</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Operation results in 40 wells show that the single well production increment is 2,300 barrels</td>
</tr>
</tbody>
</table>
III. Application Cases

1. Nitrogen Stimulation (Tight Sand Reservoir)

Gas injection rate 48321 cube (1,546300 c.f.), gas injection time 49h, increase production > 3000bbl by the end of that year.
III. Application Cases

1. Nitrogen Stimulation (Tight Sand Reservoir)

Production curve for well groups (12 wells)

- **4# anti-water-coning & open the well**
- **5# & 6# are effected one after another**
- **Gas injection effect of 7#, 8# and 9# gets better**

WAG in the well group since March 10, 2014

- **80t**
- **72t**
- **70t**
- **25t**
- **95t**
- **80%**
- **61%**

More Efficient in Oil & Gas Extraction
III. Application Cases

3. Nitrogen Foam Combination Flooding

Reservoir Characteristics:

- $D=1125m$, $\phi=37\%$, $K=2304mD$
- $\rho=0.9743g/cm^3$, $\mu_o=1619mPa.s$
- $P_i=11.27MPa$, $T=60\degree C$

Implementation Situation:

- Utilize clear water to prepare mother solution and inject after dilution with waste water.
- Pre-slug: $0.03PV \times (1800mg/L \text{ Polymer} + 1.0\% \text{ Foaming agent})$, it is used for leading edge protection and sacrifice.
- Main slug: $0.3PV$, Nitrogen and $[1600mg/L \text{ Polymer} + 0.5\% \text{ Foaming agent}]$, alternate injection, alternate period is 4 days [Gas injection two days and liquid injection two days].
III. Application Cases

3. Nitrogen Foam Combination Flooding

Injection Curve for Central Well

Cumulative injection: nitrogen $103.6 \times 10^4 \text{ m}^3$, polymer 53.4 t, surfactant 259.6 t.
III. Application Cases

3. Nitrogen Foam Combination Flooding

Daily oil production of this well group significantly increased while water cut remaining decline.
III. Application Cases

4. Nitrogen Foam Water Coning Control

Low water cut, stable oil production, good coning control effect, with the oil increment in this stage 1413t.

Production curve for XX well during operation period

1.97↑4.9MPa

Gas injection

Water cut

Gas injection

14/10/5 14/10/19 14/11/2 14/11/16
Introduction for Kerui Nitrogen Stimulation Technology

4. Nitrogen Foam Water Coning Control

Challenge

- HS heavy oil reservoir: buried depth 504 m, low permeability, medium porosity, medium to strong acid sensitivity and medium to weak water sensitivity and salt sensitivity.
- Steam huff and puff: now in the high water cut development stage. With the continuous increasing of recoveries, the edge-bottom water intrusion is serious due to reservoir pressure drop and heterogeneity.

Solution

- To enhance oil recovery by the ways of injecting nitrogen foam, blocking high permeability zone, suppressing bottom water coning, and increasing the steam sweep efficiency.

Customer Value

- By the end of 2014, the success rate is over 80% in the overall project; water cut decreased by 22.0% after operation, monthly output in the peak increased by 86.0 m³ than before.
III. Application Cases

5. Energization and Viscosity Reduction for Heavy Oil

Challenge

- Heavy oil exploitation in alternating thin layers of Columbia is hard to enhance oil recovery influenced by interlayer heterogeneity and physical properties of crude oil.

Solution

- Profile control technology of thermal recovery system in alternating thin layers, supported with the casing insulation in injection process, Nitrogen and steam slug injection technologies, form the complete set of heavy oil development system in Colombia.

Customer Value

- Operation results in 556 wells show that the average single well production increment is 2600 barrels.
III. Application Cases

5. Energization and Viscosity Reduction for Heavy Oil

Oli Increment Statistics of XX Well in G Oilfield

Steam: 5500MMBTU, Nitrogen: 65500m³, Foaming agent: 5t; Oil increment in one cycle: 2666 bbl
Global Customers

We provide oilfield equipment, technical solutions and services for over 220 oil companies and over 350 engineering and service companies worldwide.
Customer Referral

Best and high efficiency serves - got customer high approval from the customers

More Efficient in Oil & Gas Extraction

Customer referrals from overseas (Columbia, Peru etc.) and domestic (Sinopec, CNPC, CNOOC) petroleum companies.
A Doer for Social Responsibilities

Kerui Charitable Foundation Establishment

Donating for Hope in Elementary School

Participating in Bogota Marathon

Donating for Yushu Earthquake Disaster Area

Participating in Dongying International Marathon

Donating for Kerui Charitable Foundation

More Efficient in Oil & Gas Extraction
MORE EFFICIENT IN OIL & GAS EXTRACTION

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