Technology Process of China’s CBM Exploration and Development

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China United Coalbed Methane Corporation., Ltd

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Outline

1. CBM Exploration & Development Progress from CUCBM

2. Current Status on China’s CBM Exploration & Development

3. Technology Trend of China’s CBM Exploration & Development

4. Question and Suggestion
1.1 The nature of the company

- China United Coalbed Methane Co., Ltd. (CUCBM) was established on March 30, 1996 upon the approval of the Chinese State Council. CUCBM is specialized in CBM exploration, development, production, transportation, sales and utilization, which was entitled the exclusive right to undertake exploitation, development and production in cooperation with foreign companies, in reference to management model of oil and natural gas.


- CUCBM currently has been the holding company by CNOOC after equity transfers and changes many times from Mar. 1999 to Dec. 2013.

- CUCBM obtained “A” Qualification of Gas Exploration and passed the system of ISO9001.
1.2 Progress on CBM Exploration & Development

- CUCBM has 29 exploration right licenses and 2 mining right licenses with the total area of 20000 km², which was located in Shanxi, Shaanxi, Anhui and other 10 provinces.

- CUCBM found the first CBM field in Qinshui Basin of China—Qinnan CBM field in 2001, and submitted the first CBM proven reserve report.

- CUCBM has successively conducted more than 50 CBM exploration & development projects, 30 foreign cooperation projects in 31 areas of 15 provinces since the founding of CUCBM, all sorts of 3500 CBM wells were drilled.

- Up to 2014, CUCBM has obtained CBM proved reserves of 170 billion m³, built production capacity of 2 billion m³ per year with annual gas output of 1 billion m³.
1.3 Science & Technology Led

- CUCBM did a series of basic work in CBM industry planning, policy making and the comprehensive utilization of the resources for the relevant departments.

- Developed over 30 rules and specifications for CBM exploration and development.

- Organized and involved in the compiling of the National CBM program the 11th and 12th Five-Year Plan.

- Director unit of “Strategic Alliance of Technological Innovation for CBM Industry”.

- Affiliated unit of CBM Professional Committee to China Coal Society.
1.4 Technology Integration and Demonstration Project

“Qinnan Hi-tech Industrial Demonstration Project” was completed in 2009

- Forming 8 technical series in high rank CBM development in Qinnan.
- 210 CBM wells were drilled in the first phase of demonstration project and had been produced for 5 years, the daily average production for single well reached 4000m³, the most of the country.
- The successful completion of the demonstration project is of milestone significance in the development of China’s CBM industry, marking the beginning of industrial production, which got the first prize of “National Energy Technology Progress”.
1.4 Technology Integration and Demonstration Project

Qinnan Hi-tech Project was granted by NDRC “the National Hi-tech Project for Industrial Demonstration the 12th China International Hi-tech Fair held on November 16, 2010.”
### 1.5 Actively exploring exploration & development technology in coal-bearing strata

The leading technology on CO₂ injection, replacement of CH₄ and enhancing recovery of CBM

<table>
<thead>
<tr>
<th>CO₂ -Enhanced CBM Pilot Test</th>
<th>2002-2006</th>
<th>China and Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology study on CO₂ injection and enhancing the recovery of CBM</td>
<td>2002-2003</td>
<td>MOST</td>
</tr>
<tr>
<td>Numerical simulation and economic evaluation of micro pilot test</td>
<td>2004-2005</td>
<td>MOST</td>
</tr>
<tr>
<td>Technology study on CO₂-injection/storage to enhance CBM production in deeper coal seam</td>
<td>2008-2010</td>
<td>China and Canada</td>
</tr>
<tr>
<td>Monitoring and verification of CO₂ storage and ECBM</td>
<td>2006-2008</td>
<td>China and Netherlands</td>
</tr>
<tr>
<td>Towards institutionalised collaboration on knowledge development for sustainable integrated exploitation of coal</td>
<td>2009-2010</td>
<td>China and Netherlands</td>
</tr>
<tr>
<td>China-UK Near zero emissions coal project (NZEC)</td>
<td>2007-2008</td>
<td>China and UK</td>
</tr>
<tr>
<td>Enhanced –CBM project research collaboration</td>
<td>2010-2012</td>
<td>China and Australia</td>
</tr>
<tr>
<td>Technology study on CO₂-injection in deeper coal seams</td>
<td>2010-2015</td>
<td>National Specific and Important Project</td>
</tr>
</tbody>
</table>
1.5 Actively exploring exploration & development technology in coal-bearing strata

Finishing shale gas evaluation in Qinshui Basin, raising favorable area and 3 wells were fractured and tested.

<table>
<thead>
<tr>
<th>Location</th>
<th>Shizhuang North</th>
<th>Shouyang</th>
<th>Qinyuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well type</td>
<td>Parameter + production well</td>
<td>Parameter + production well</td>
<td>Parameter + production well</td>
</tr>
<tr>
<td>Target Seam</td>
<td>Lower shihezi formation, Shanxi formation, Taiyuan Formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well depth</td>
<td>1207m</td>
<td>916 m</td>
<td>1977m</td>
</tr>
</tbody>
</table>
1.5 Actively exploring exploration & development technology in coal-bearing strata

Linxing-Shenfu favorable play with tight sands gas, where industrial gas flow was found in several wells. The steady daily production of LX-4 reached 200 thousand m³:

- Revealing high quality reservoir development mechanism of tight sands gas, raising the migration and accumulation model in Linxing-Shenfu Block.
- Forming technology series of sweet point recognition in gas-bearing of tight shale formation in sedimentary facies as core technology.
Outline

1. CBM Exploration & Development Progress from CUCBM
2. Current Status on China’s CBM Exploration & Development
3. Technology Trend of China’s CBM Exploration & Development
4. Question and suggestion
2.1 Current Status on China’s CBM Exploration & Development

41 basins, 114 gas plays, CBM area is 415 thousand km² shallow than 2000 m, prospective resource is 36.8 trillion m³, 14 basins with more than 0.5 trillion m³, which accounts for 93.4% of the total resources.

Characteristic of China’s CBM resources:
- Variety of coal forming conditions
- Multi-period of coal forming periods
- Stacking of metamorphism
- Multi-period and complexity of tectonic movement

Don’t copy American mature CBM technology
2.1 Current Status on China’s CBM Exploration & Development

- By the end of 2014, 15000 CBM wells has been drilled in China with the proved reserves of 600 billion m³.
- Forming 2 large gas fields (Eastern Ordos Basin and Southern Qinshui Basin) with hundreds billion m³.
- Implementation of coal mining project made production of coal mine more safe.
2.1 Current Status on China’s CBM Exploration & Development

- CBM transportation pipeline was completed and taken shape, transportation capacity increased greatly.
  - Completing five CBM pipelines with the annual transportation capacity 10 billion m³, the length of pipeline is about 2000 km.
  - Planning and constructing “three vertical and eleven horizontal pipelines” in Shanxi province, which will exceed 3000km.

- Wide application of CBM
  - City gas, fuel for car and industry.
2.1 Current Status on China’s CBM Exploration & Development

CBM Exploration from shallow area to the deeper area

- Deeper area designated: 800-1000m
- Characteristic of geologic reservoir in the deeper coal seams: stress is higher, permeability is greatly reduced, which led to fragile coal structure. The complicated drilling and fracturing and long-period production made CBM exploration in the deeper coal seams more challenging.

- Obtained good gas production for single well in some of deeper areas:
  - Qinshui Basin: coal seam depth is 900~1400 m, daily production reached 2500 m³
  - Ordos Basin: coal seam depth is 1500~2000 m, daily production reached 3600 m³
2.1 Current Status on China’s CBM Exploration & Development

Achievements in new areas, new fields, new series of strata

- In Southern Zhungeer Basin in northwest of China, daily production of horizontal well for pilot test reached 17 thousand m³.

- In Fuxin block in northeast of China, 26 wells were drilled, daily production was about 60 thousand m³; four wells in Hunchun, steady production for single well is 1500-2200 m³; six wells in Yilan, produced three years and steady production was 1000-1200 m³.

- Zhijin and Junlian area, in southwest of China, gas production for single well reached 1000 m³.
2.2 Technology Progress of China’s CBM Exploration & Development

A relatively mature CBM exploration and development technology has been formed which is suitable for high-rank coal in Southern Qinshui Basin, this technology provides strong technical support for China’s CBM development.

- Geology evaluation and site selection
- Casing completion
- Activated water and sand fracturing
- Stable control of fine production
- Multipoint access and flexible gathering

Drilling and well completion:
- Vertical well
- Directional well
- Multi-lateral and “U” horizontal well

Stimulation:
- Hydraulic fracturing
- Foam fracturing
- Clean frac fluid, foam fracturing, retarded acid fracturing fluid
- Horizontal well sectioned fracturing
### 2.2 Technology Progress of China’s CBM Exploration & Development

#### Summarizing production technology series suitable for China’s CBM

- **double control, regional depression gradually**
- “five stages, three pressures” production control
- Stable control of fine production

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<table>
<thead>
<tr>
<th>Status</th>
<th>Casing Pressure Before</th>
<th>Initial Gas</th>
<th>Gas Increasing</th>
<th>Steady Production</th>
<th>Gas Decreasing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Set fluid capacity, pressure funnel is gentle, expand pressure and drop area</td>
<td>Hold casing pressure, Control gas velocity, more powders stuck pump, keep formation energy</td>
<td>Production phase by phase, avoid gas and fluid increase rapidly, and then strata stress changes greatly. Keep steady gas supply through pressure and powder control</td>
<td>Sustainably steady gas production</td>
<td>Gas decreased gradually</td>
</tr>
<tr>
<td>II</td>
<td>Hold casing pressure, control gas velocity</td>
<td>Hold casing pressure</td>
<td>IV increasing stage</td>
<td>V steady gas stage</td>
<td>VI decreasing stage</td>
</tr>
<tr>
<td>III</td>
<td>Initial gas</td>
<td>Gas increasing</td>
<td>Gas decreased gradually</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Diagram:**
- **Water production**
- **Casing pressure**
- **Gas production**

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- To protect reservoir
- To furthest expand depression area
- To furthest release production capacity
2.2 Technology Progress of China’s CBM Exploration & Development

Forming gathering & transportation technical series of “multipoint access, flexible gathering” as core technology, suitable for complicated topographical condition of low production and more wells

“multipoint access, flexible gathering” realized technical breakthrough from three-staged arrangement traditionally to one-stage arrangement which greatly increases gathering radius, effectively reduces stages and then greatly reduces investment and easier to be managed.
2.2 Technology Progress of China’s CBM Exploration & Development

New technologies were tested successfully

Staged fracturing in “U” horizontal well

Well depth is 590 m, well thickness is 6.5 m, drilling footage is 617 m, fracture 7 sections

Daily steady gas production is 15000 m$^3$/d, casing pressure is still kept in 0.23MPa
2.2 Technology Progress of China’s CBM Exploration & Development

New technologies were tested successfully

Double-bench horizontal well was successfully for commingled production of thin seam and multi-seams

- First case in the world: multilateral horizontal well with inclined well connected to multi seams
- Design on production well of inclined to inclined and multi seams and equipment design
- Set up a new national record in gas production for single well in middle-rank coal

Daily gas production was kept in 15000m³ or so.
2.2 Technology Progress on China’s CBM Exploration & Development

New technologies were tested successfully

Latent acid (retarded acid) was applied in CBM fracturing, which improved matrix condition

A lot of calcites in coal fracture in Qinnan area, a few of calcites and plasters in pores

Extended fracture

Enlarge nanometer pore

矿物溶蚀前后扫描电镜对比

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2.2 Technology Progress on China’s CBM Exploration & Development

New Technologies were tested successfully.

CBM stimulation technology got breakthrough.

1. research and test on increasing flow area:
   - Optimizing Horizontal well completion and fracturing section by section
   - Horizontal well flushing with N₂
   - Redrilling, recycling and carrying out coal powder

2. extracting under-pressure: improving single well production through pressure increase or pipeline boost and then reduce flow pressure of well bottom.

Technology bottleneck still exists.
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3. Technology Trend of China’s CBM Exploration & Development

- **The key breakthrough:**
  Increasing gas production and reserves in Qinshui Basin and Ordos Basin

- **Multi-point blossom:**
  Extend and explore resources in new areas or new coal-bearing basins

- **Development concept:**
  - Combination of demonstration in different phases
  - Combination of surface development and extracting underground
  - both of main resources and replacement resources

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- Low rank CBM in Jurassic period in northwest of China
- CBM development in Mesozoic and Cenozoic in east of Inner Mongolia
- Different extracting type in coal mines
- Qinshui and Ordos Basin
  - Increasing production of old well and new well
  - Exploring CBM resources in middle and deeper areas
  - Comprehensive development of multi gas in coal bearing series
- Multi-seams, high stress in east of Yunnan and
3.1 Stimulation technology in Qinshui Basin and Ordos Basin

CBM industrialized bases of Qinshui basin and Ordos basin

- Big gap between the proved reserves and annual gas production
- Gas yield is different in different blocks
- More wells with poor production, slow production increasing
- Basic research is not further
- Development is more complicated with the deeper coal seam

Production well Dynamic characteristic study

<table>
<thead>
<tr>
<th>Sum up laws</th>
<th>geology</th>
<th>engineering</th>
</tr>
</thead>
</table>

Poor well Analyzing features

Optimizing technology

- Reservoir reconstruction
- Permeability increase
- Optimizing fracturing

Increase single well production and economic benefits
3.2 Comprehensive Exploration & Development Technology on Commingled production of CBM and Tight Sands Gas in Coal-bearing Series

- Abundant resources of CBM and Tight sands gas in coal-bearing series and huge potentiality.
- Longitudinal seam overlays with layers of tight sandstone and continuous accumulation, suitable for commingle.
- Technology core: promote CBM desorption through disturbing underground pressure system by high pressure to adjacent tight gas, reducing development difficulty and cost, extending time of steady production and improving benefits.

a) Reservoir composition type of CBM/TGS and fluid mechanism between layers
b) Destroying each other by engineering
c) Reservoir stimulation control and production technique.
3.2 Comprehensive Exploration & Development Technology on Commingled production of CBM and Tight Sands Gas in Coal-bearing Series

3 formations between 1000 and 2000 m in Powder River Basin of America, formation interval is 100 m, separately fracturing and commingled production on CBM layer and sandstone layer. Daily gas production for single well in 20 vertical wells reached tens of thousands m$^3$, the peak is more than 0.2 million m$^3$.

<table>
<thead>
<tr>
<th>Top hole depth (m)</th>
<th>Bottom hole depth (m)</th>
<th>Perforating density (hole/m)</th>
<th>Perforation diameter (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>879.04</td>
<td>879.95</td>
<td>3.28</td>
<td>0.96</td>
</tr>
<tr>
<td>884.83</td>
<td>885.14</td>
<td>3.28</td>
<td>0.96</td>
</tr>
<tr>
<td>890.01</td>
<td>890.32</td>
<td>3.28</td>
<td>0.96</td>
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<tr>
<td>903.12</td>
<td>903.42</td>
<td>3.28</td>
<td>0.96</td>
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<tr>
<td>934.21</td>
<td>937.87</td>
<td>3.28</td>
<td>0.96</td>
</tr>
<tr>
<td>939.69</td>
<td>940</td>
<td>3.28</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Commingled production on CBM and low permeability sandstone gas in White River Uplift of Piceance Basin. Target seam depth is 1560~2560 m, daily production of single well in 65 wells was steadily kept in 10890 m$^3$ or so, the peak is 14375 m$^3$, production formation is Cameo and sandstone layer.

26 CBM wells has been put into production in Fuxin coal mine of Liaoning since 2006, among of which 11 wells for commingled production. High production, stable production. Intermittent blow happened in some of wells.
3.3 CBM Reservoir Physical Property in the Deeper area and Key Development Technology

- Rich resources in the deeper area with huge potentiality
- In the recent two years, exploration and development is from shallow than 800 m to deeper than 1000 m

CBM reservoir physical property changes by index with the increase of buried depth, and then development is more difficult.
3.3 CBM Reservoir Physical Property in the Deeper area and Key Development Technology

The adaptive traditional technology

- The effectiveness of fracturing technology
- The effectiveness of displacement technology
- The effectiveness of depresssure technology
- The effectiveness of damage reduction on reservoir

Feasibility of new technology in the deeper area

- Permeability increase: fracture created, connection, block remover
- Desorption promotion: reaction of chemistry and physics (gas-water-organic matter-mineral)
- Depresssure technology: vertical stress
- Damage reduction on reservoir: formation fluid-coal-artificial fluid

CBM resource in China is 18.7 trillion m³ between 200 and 3000m? Sweet point?
3.3 CBM Reservoir Physical Property in the Deeper area and Key Development Technology

Advantages:
- Stress release in coal mines is helpful to desorption and migration of CBM, declining the difficulty of development
- Coal mining area is about 0.2 million km²

Disadvantages:
- Coordination of CBM development and coal exploitation

- Prediction technology on stress of depressure area
  - Pore-forming of horizontal well and reservoir protection
- Coal powder prevented
3.4 CBM Exploration & Development Technology Suitable for low-rank coal

- Gas production in America mainly from low-rank coal
- Low-rank coal in China has development potentiality from achievement of recent years
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**Question**

- China’s CBM development is still in the initial stage of scaled development, the complicated geologic condition decides the variety of CBM technology, which makes us not follow the American mature technology.
- The proven reserves rate of China is too low, 1.5%.
- CBM investment in the first stage is too great, long recovery period, which needs more support from Chinese government.

**Suggestion**

- Chinese government should increase exploration and provide more support for test, and to improve proved resources rate.
- Set up different demonstration projects for leading R&D of new technology and production and promote the rapid progress of CBM industry.
THANK YOU!