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Agenda

会议议程
Agenda
International Seminar on Shale Gas Technology and Standardization
November 5-6, 2019 | Chengdu, Sichuan Province
Workshop: November 5, 2019  9:00am – 12:20pm | November 6, 2019  9:00am – 12:40pm
Site visit: November 6, 2019 14:30pm – 18:00pm

Workshop Venue:  Chengdu Dading Century Hotel
No. 298 Tianren South Street, Gaoxin District, Chengdu

November 5, 2019
8:30am-9:00am  Guest Registration
9:00am-9:40am  Welcome Remarks
•  Li Luguang, Director General, China Shale Gas Standardization Technical Committee
•  Steven Winkates, Program Management Director for East Asia, U.S. Trade and Development Agency (USTDA)
•  Representative, State Administration for Market Regulation of China (TBD)
•  Francis Peters, Principal Commercial Officer, U.S. Consulate General in Chengdu
•  Ma Xinhua, General Manager, Petro China Southwest Oil and Gas Field Company

Moderator: Yue Hong, Deputy Secretary General of the China Shale Gas Standardization Technical Committee
Theme: Shale Gas Industry Trend and International Cooperation

9:40am-10:15am  Overview: Construction and Prospect of Technical Standards System of the Shale Gas Industry in China
Presenters: Chang Honggang—Deputy Director of China Shale Gas Standardization Technical Committee

10:15am -10:50am  U.S. Policy, Law, and Standards on Shale Gas Development  
*Presenter: Roland Goodman – Manager of Upstream Standards, American Petroleum Institute (API)*

10:50am-11:10am  Tea Break

11:10am-11:45am  U.S. Industry’s Role in the Development of Shale Gas Policies, Regulations and Standards and Compliance  
*Presenter: Mark Thurber – Partner of Hunton Andrews Kurth LLP*

11:45am-12:15pm  Overview of Solar Mobile Turbomachinery  
*Presenter: Chris Mellos – Market Development Manager, Solar Turbines (Caterpillar)*

12:20pm  Lunch

November 6, 2019

8:30am-9:00am  Guest Registration

**Moderator:** Xu Fang, Representative of the American National Standards Institute (ANSI) in China  
**Theme:** Case studies – Shale gas technology, practices, and standards

9:00am-9:35am  Current Situation of Global Shale Gas Development and the Future of International Cooperation on Standards Development  
*Presenter: Zhang Leifu – National Energy Administration Shale Gas Research Center*

9:35am-10:10am  Reserve Estimation of Shale Gas  
*Presenter: John Wheeler – President, Lee Keeling and Associates*

10:10am-10:45am  Trend of Shale Gas Drilling and Completion Technology  
*Presenter: Zhang Zheng – Senior Engineer, Petro China Southwest Oil and Gas Field Company*

10:45am-10:55am  Tea Break

10:55am-11:30am  Sinopec Shale Gas Exploration and Development and Fracturing Engineering Technology  
*Presenter: Niu Jun – Engineer, Sinopec*
11:30am-12:05pm  3D Integrated Drilling Solution in China  
*Presenter: Cai Yifan – Operation Manager of Drilling, Baker Hughes (GE)*

12:05pm-12:40pm  Research and Practice of Shale Oil and Gas Production Capacity Evaluation Technology  
*Presenter: Bai Yuhu – Senior Engineer, China National Offshore Oil Corporation*

12:40pm-14:30pm  Lunch

14:30pm-18:00pm  Site Visit  
*Petro China Southwest Oil and Gasfield Company*
页岩气技术及标准化国际研讨会
活动日程

时间：2019 年 11 月 5 日 - 6 日
研讨会日期：2019 年 11 月 5 日 上午 9:00 - 下午 12:20
2019 年 11 月 6 日 上午 9:00 - 下午 12:40
实地考察：2019 年 11 月 6 日 下午 14:30 - 18:00
研讨会地点：四川省成都市高新区天仁南街 298 号 成都大鼎世纪大酒店

2019 年 11 月 5 日
8:30 – 9:00 会议签到
9:00 – 9:40 欢迎致辞
- 李鹭光 中国能源行业页岩气标准化技术委员会 主任委员
- 溫凱 时 (Steven Winkates) 美国贸易发展署东亚区项目管理 主任
- 国家市场监督管理总局代表（待定）
- 范思杰 (Francis Peters) 美国驻成都总领事馆 商务领事
- 马新华 中国石油西南油气田分公司 总经理

主持：中国能源行业页岩气标准化技术委员会副秘书长 乐宏
上午研讨会主题：页岩气发展趋势及国际合作

9:40 – 10:15 中国页岩气标准化建设及未来概况
中国能源行业页岩气标准化技术委员会委员 常宏岗

10:15 – 10:50 有关页岩气发展的美国政策、法律和标准
美国石油学会上游标准委员会经理 Roland Goodman

10:50 – 11:10 茶歇
2019年11月6日

8:30 – 9:00  会议签到

主持：美国国家标准化机构中国代表 许方
下午研讨会主题：页岩气行业案例分享：科技、实践及标准

9:00 – 9:35  全球页岩气发展现状及标准制定国际合作
中国国家能源局页岩气研发（实验）中心 张磊夫

9:35 – 10:10  页岩气储量估算
Lee Keeling and Associates 主席 John Wheeler

10:10 – 10:45  页岩气钻井技术趋势
中国石油西南油气田分公司 张震

10:45 – 10:55  茶歇

10:55 – 11:30  中国石化页岩气勘探开发与压裂工程技术
中国石化 牛骏

11:30 – 12:05  3D钻井一体化提效模式在中国的应用
贝克休斯公司钻井部门作业经理 蔡一凡

12:05 – 12:40  页岩油气产能研究与实践评估技术
中国海油高级工程师 白玉湖

12:40 – 14:30  午餐

14:30 – 18:00  实地考察
中国石油西南油气田分公司
Hosts and Supporting Agencies Overview

主办单位介绍

(排序不分先后)
The U.S. Trade and Development Agency (USTDA) has the mutually beneficial mission of linking U.S. businesses to export opportunities by funding project preparation and partnership building activities that develop sustainable infrastructure and foster economic growth in partner countries.

USTDA promotes economic growth in emerging economies by facilitating the participation of U.S. businesses in the planning and execution of priority development projects in host countries. The Agency’s objectives are to help build the infrastructure for trade, match U.S. technological expertise with host country development needs, and help create lasting business partnerships between the United States and emerging economies.

**USTDA's Program Activities**

*Project Development*

Project identification and investment analysis generally involve technical assistance, feasibility studies and pilot projects which support large investments in infrastructure contributing to host country development. USTDA’s program in China includes the transportation, energy, agriculture, and healthcare sectors.

*Trade Capacity Building and Sector Development*

Trade capacity building and sector development assistance support the establishment of industry standards, rules and regulations, market liberalization and other policy reform. In China, USTDA has supported activities to enhance the protection of intellectual property rights, fair and transparent government procurement practices, science-based agricultural biotechnology regulations, and standards across a range of sectors.

*Cooperation Programs*

USTDA’s success in China is due in large part to the public-private cooperation programs that the Agency supports in-country. These programs provide a forum for government agencies and private companies from both countries to share technical, policy, and commercial knowledge to advance shared goals. USTDA has successfully established programs based on this model in the aviation, energy, healthcare, and agriculture and food sectors.

By adapting to the evolving needs of China’s market and closely coordinating with decision-makers in both countries, these public-private partnerships have achieved long-term success, providing continued trade opportunities.

*Reverse Trade Missions*

Through the Agency’s reverse trade missions (RTMs), USTDA has increased its support for programs designed to bring procurement officials to the United States to witness U.S. technologies, equipment, and ingenuity firsthand. These visits also facilitate new partnerships with U.S. companies needed to spur commercial cooperation. Related, USTDA also supports technology demonstrations, training, and specialized sector-specific workshops and conferences.
美国贸易发展署(USTDA) 致力于在新兴经济体推动经济发展和美国的商业利益。美国贸易发展署通过对项目前期，试点项目以及反向代表团赴美考察等形式的资金资助，达到在合作伙伴国家推动可持续性基础设施和经济增长的同时帮助美国企业寻找出口机会。

美国贸易发展署鼓励美国公司积极参与新兴经济体项目所在国重点发展领域里的项目规划和实施过程中的机会。目的是帮助美国有技术优势的公司配合项目所在国的发展寻求契机，并建立长期持久合作关系。

**美国贸易发展署的项目活动**

**项目开发**

美国贸易发展署支持的项目确认和投资分析通常为了支持项目所在国大型基础设施项目投资决策前以所需要的技术援助，可行性研究分析和试点项目等。在中国的项目集中在交通，能源和医疗卫生领域。

**能力建设和行业发展**

能力建设和行业发展是为了帮助推动建立行业标准，法规等相关政策需求的活动。在中国，美国贸易发展署支持过的项目内容涉及知识产权，公平透明政府采购，以科学为基础的农业生物技术规范，以及涉及其他更宽泛领域涉及行业标准的内容。

**国际商业伙伴关系项目**

通过国际商业伙伴关系项目，美国贸易发展署加大资金投入力度，组织更多灵活多样的赴美考察团，技术交流/研讨会和培训等，选择特定的一些行业，帮助中方人员了解美国技术，掌握第一手资料，加深对美国企业的了解并能推动潜在的商务合作。

**政府企业合作平台**

美国贸易发展署在中国取得成功的部分原因是与其他相关机构共同支持了政府企业合作项目的平台。在这个平台上，美国和中国的政府机构和私营企业均可以共享在特定领域的技术，政策和商业知识。美国贸易发展署已经成功地在航空、标准合格评定、能源和医疗保健等行业推动了该模式。

通过适应中国市场变化的需求，和中国决策者的密切配合，这些公私伙伴关系企业积累了一些长期合作的成功经验，提供持续的贸易机会，并推动中国支柱产业的发展。
U.S.-China
Standards and Conformity Assessment
Cooperation Program

Sponsored by the U.S. Trade Development Agency (USTDA) and coordinated by the American National Standards Institute (ANSI), the U.S.-China Standards and Conformity Assessment Cooperation Program (SCCP) provides a forum through which U.S. and Chinese industry and government representatives can:

- Cooperate on issues relating to standards, conformity assessment, and technical regulations;
- Foster the relationships necessary to facilitate U.S.-China technical exchange on standards, conformity assessment, and technical regulations; and
- Exchange up-to-date information on the latest issues and developments relating to standards, conformity assessment, and technical regulations.

In 2018, ANSI will coordinate 20 workshops over a 3-year period in China under Phase V of the SCCP. The workshops will cover a wide range of sectors, as proposed by interested U.S. private-sector organizations. Workshop topics will be chosen in coordination with relevant industry associations, ANSI, and USTDA.

To learn more about the U.S.-China SCCP or to express interest in sponsoring or participating in a workshop, please visit our website at:

www.standardsportal.org/us-chinasccp
中美标准与合格评定合作项目

由中国贸易发展署 (USTDA) 提供资助，美国国家标准化机构 (ANSI) 负责协调的中美标准与合格评定合作项目 (SCCP) 在以下几个方面为中国和美国的相关行业和政府代表提供了一个论坛：

- 标准、合格评定以及技术法规等领域的合作；
- 为促进中美在标准、合格评定以及技术法规等领域的技术交流建立必要的联系；
- 及时交流关于标准、合格评定以及技术法规等领域的最新议题和发展情况的相关信息。

未来三年，ANSI 将在中国协调举办 20 场研讨会。根据美国民间相关机构组织的倡议，研讨会内容将覆盖不同的行业和领域。研讨会的主题将由相关行业组织，ANSI 以及 USTDA 协调选定。欲了解该项目的更多信息或有意赞助或参与该项目，请访问下列网站：

www.standardsportal.org/us_chinasccp

欲了解其他信息，请联系

Mr. Henry Yuan
项目经理
美国国家标准化机构 (ANSI)
1899 L St. NW – Eleventh Floor
Washington, DC 20036
T: 202.331.3624
As the voice of the U.S. standards and conformity assessment system, the American National Standards Institute (ANSI) empowers its members and constituents to strengthen the U.S. marketplace position in the global economy while helping to assure the safety and health of consumers and the protection of the environment.

The Institute oversees the creation, promulgation and use of thousands of norms and guidelines that directly impact businesses in nearly every sector: from acoustical devices to construction equipment, from dairy and livestock production to energy distribution, and many more. ANSI is also actively engaged in accrediting programs that assess conformance to standards – including globally-recognized cross-sector programs such as the ISO 9000 (quality) and ISO 14000 (environmental) management systems.

ANSI has served in its capacity as administrator and coordinator of the United States private sector voluntary standardization system for the past hundred years. Founded in 1918 by five engineering societies and three government agencies, the Institute remains a private, nonprofit membership organization supported by a diverse constituency of private and public sector organizations.

Throughout its history, ANSI has maintained as its primary goal the enhancement of global competitiveness of U.S. business and the American quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems and promoting their integrity. The Institute represents the interests of more than 270,000 companies and organizations and 30 million professionals worldwide through its office in New York City, and its headquarters in Washington, D.C.
作为美国标准和合格评定体系的发言人，美国国家标准化机构授权其会员强化美国市场在全球经济中的地位，同时协助保障消费者的安全和健康以及环境保护事宜。

机构对数以千计的标准和指导方针的制定、颁布、实施进行监督，而这些标准和指导方针几乎直接影响商业的每个领域：从声呐设备到建筑设备，从乳制品及家禽产品到能源分配等等。美国国家标准化机构也积极参与评估合格到标准的委托项目——包括诸如ISO9000（质量）和ISO14000（环境的）管理系统等全球认可的跨领域项目。

在过去的一个世纪中，美国国家标准化机构担任美国私营部门自愿性标准化体系的管理者及协调者。自1918年由五家工程师协会和三个政府部门成立以来，本机构一直是一个民间、非营利性质的会员制组织，得到来自私营和公共部门的多元化支持。

纵观历史，美国国家标准化机构的首要目标一直是强化美国商业的全球竞争力，通过推进自愿性标准及合格评定体系并对它们进行完善从而提高美国人民的生活质量。机构总部设在华盛顿特区，并在纽约设有办公地点，代表全球超过27万家公司及组织和三千万专家的利益。
US-China Energy Cooperation Program (ECP)

Founded in September of 2009 by 24 US energy companies, US-China Energy Cooperation Program (ECP) was underscored by US President Barack Obama and China President Hu Jintao in the official joint statements during Obama’s visit to China in 2009. US government agencies including Department of Commerce, Department of Energy and US Trade and Development Agency together with Chinese government agencies including National Energy Administration and Ministry of Commerce signed bilateral Memorandums of Understanding to serve as official government advisors to support ECP.

US-China Energy Cooperation Program (ECP)’s mission is to create a bilateral business platform with US and Chinese companies to pursue private sector-based business opportunities, advance sustainable development in the energy industry and combat climate change. Members join ECP through working groups to form industry value chains. Within each working group, members establish a sector development road map according to the national strategies, local demand and potential local partners for both short and long terms. Through this process, each working group identifies annual business development objectives and concrete initiatives for implementation.

ECP currently has the following working groups:

- Oil and Gas,
- Coal,
- Nuclear Energy,
- Renewable Energy,
- Grid,
- Storage,
- Building,
- Industry,
- Transport,
- Urban Infrastructure,
- Resource Utilization

Learn more about the US-China Energy Cooperation Program by visiting: www.uschinaecp.org
中美能源合作项目（ECP）简介

中美能源合作项目（ECP）肩负着中美两国间清洁能源领域广泛合作的商业执行使命。作为由企业出资运营并管理的非盈利、非政府机构，ECP 于 2009 年 9 月由 24 家美国企业发起成立，致力于在中美两国推动清洁能源领域相关的产业开发、市场开拓、境外直接投资以及创造就业机会等相关工作。通过两国政府对 ECP 的正式承认和支持，ECP 作为一个政府和企业间的伙伴关系平台，为成员公司及商业伙伴提供动力。通过全方位解决方案产业联盟的组建和运行，推动必须经由集体性的和协调性的努力才能实现的商业发展成果的落实。成员公司通过参与有关工作组来组成不同的产业价值链。在每个工作组之下，各成员公司共同为工作组的相关产业设立短期、中期以及长期的产业开发路线图。在这一工作的过程中每个工作组就每年的相关工作，确立年度商业发展目标，并辅以切实的工作计划，推动实施。

经过六年多的工作，ECP 已经发展成为了包括中国企业在内的三十几家企业的共同平台。通过同各种各样的合作伙伴关系，致力于在以下诸多工作上有所建树：

- 推进新的行业以及市场的形成；
- 协助相关行业政策以及法规的制定；
- 为中美两国的政府间对话提供企业角度的支持；
- 搭建促进商业成果达成的管道。

中美能源合作项目（ECP）行业工作组

ECP 目前有以下行业工作组：
油气、煤炭、核能、可再生能源、电网、储能、建筑、工业、交通、城市基础设施、资源利用

ECP 项目：
为促进交流与合作，ECP 设计并提供相关培训，技术支持，研究及试点项目。ECP 成员公司有机会和中国能源界专家一起参与合作项目，这些项目都得到了国家级或省级的政府官员的认可。每年，ECP 在中国参与并支持诸多与清洁能源领域相关的重要议题、技术讨论及研讨会。
2013 年中美能源合作对话会议
ECP 使命：通过提高清洁能源解决方案的发展和部署，为中美政府和企业间的合作创建一个坚实的平台。

ECP 在中美两国的能源合作中发挥着重要作用，并通过努力推动以下方面的工作，促进和支持两国清洁能源产业的发展：
- 创造就业机会
- 知识产权保护
- 市场准入和行业发展
- 中美相互间的境外直接投资

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China Energy Industry Shale Gas Standardization Technical Committee (NEA/TC26)

On August 21, 2013, with the approval of the National Energy Administration, the Technical Committee for The Standardization of Shale Gas in China's Energy Industry (hereinafter referred to as the Shale Gas Standards Committee) was founded in Beijing.

The Shale Gas Standards Committee is a technical organization engaged in the standardization of shale gas, whose main responsibility is to manage shale gas standards in the energy industry, establish a standard system for the whole industry chain of shale gas, and carry out the relevant standardization work related to the research of shale gas general and basic standards. The secretariat of the Shale Gas Standard Committee is located at the Natural Gas Research Institute of China Petroleum Southwest Oil and Gas Field Corporation. The Natural Gas Research Institute has undertaken the work of the Secretariats for Upstream Sub-Committee of the ISO Natural Gas Technical Committee and the Secretariats of the National Technical Committee for Natural Gas Standardization. The Natural Gas Research Institute is responsible for shale gas exploration and development in China.

The current committee is composed of 59 members including China National Petroleum Corporation, China Petrochemical Corporation, China National Offshore Oil Group Co., Ltd., National Energy Shale Gas Research and Development (Experimental) Center, China Petroleum University, China Petroleum and Chemical Industry Federation, China Seismological Bureau and China Institute of Environmental Science.
Speaker Biographies

演讲人介绍
Francis Peters (范思杰)

Francis “Chip” Peters is the Principal Commercial Officer for the U.S. Commercial Service at the U.S. Consulate General in Chengdu. Prior to that, he spent a year at the Commercial Service office in Minneapolis; served for three years as the Commercial Attaché at the US Embassy in Bangkok assisting US exporters expand their markets in Thailand, Cambodia, and Laos; and served three years as a Commercial Officer in the U.S. Consulate in Shanghai, China where he led the office’s high-tech and chemical industry teams.

For 14 years, Chip worked in the private sector in the telecom and computer industry. He held positions in global marketing, international sales, and product management with Fortune 500 companies AT&T and Dell in the U.S. and Malaysia, as well as with high-tech startups in Austin, Texas and Thailand.

范思杰是美国驻成都总领事馆美的商务领事。在此之前，他在明尼阿波利斯的商业服务办公室工作了一年；在美国驻曼谷大使馆担任商务专员三年，协助美国出口商扩大在泰国，柬埔寨和老挝的市场；他还在美国驻中国上海领事馆担任商务官三年，领导该办事处的高科技和化学工业团队的工作。

范思杰在电信和计算机行业的企业工作了14年。他曾在美国和马来西亚的财富500强公司AT & T和Dell，以及在德克萨斯州奥斯汀和泰国的高科技初创公司担任全球营销、国际销售和产品管理的职位。
Steven Winkates is the Director of Program Management for the East Asia Region at USTDA, based at the U.S. Embassy in Beijing, China. He is responsible for managing USTDA’s activities in China and Mongolia, directing business development efforts, coordinating with relevant stakeholders in both the region and the United States, and marketing USTDA services to potential partners in both countries. Prior to this position, Mr. Winkates worked in Beijing for a consulting firm which specializes in developing transportation infrastructure projects. He also previously served as a Country Manager at USTDA, covering China and Southeast Asia during his tenure, and as a Policy Analyst at the U.S. Department of Commerce. Mr. Winkates holds a Master of Public Policy from Georgetown University and a Bachelor of Arts from Rhodes College.

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Roland Goodman

Roland is the Manager of Upstream standards for the American Petroleum Institute in Washington, D.C. Roland’s group is responsible for staffing 15 committees that develop and maintain approximately 370 equipment and operational standards covering onshore and offshore exploration, drilling, and production. These standards are used globally to enhance the safety of industry operations, assure quality, and help reduce costs. Roland has been with API for 25 years, with his first 11 years spent working on refining equipment standards. He has a Bachelor of Science degree in Industrial and Systems Engineering from the University of Southern California and is a member of the Society of Standards Professionals.

Roland 先生现任美国石油学会上游标准委员会经理，其领导的团队负责15个分委会370多项设备和操作标准的制修订工作，包括海上和陆上勘探、钻井、生产。这些标准被全球广泛使用，以加强行业操作的安全水平、确保操作质量并降低操作成本。Roland先生在API工作了25年。最初的11年中，他在炼油设备标准部门工作。他拥有南加州大学工业和系统工程学士学位，目前是标准专业人员协会的成员。
Mark Thurber

Mark is the Chief Representative for the Beijing office of Hunton Andrews Kurth, a major international law firm based in the United States with offices in Beijing, Bangkok, Brussels, Dubai and London.

Hunton’s Beijing office specializes in energy and infrastructure projects, and coordinates closely with its other international and domestic offices to deliver worldwide legal advice in a wide range of strategic projects and initiatives. Mark’s practice includes a wide range of upstream, midstream and downstream oil and gas projects, including LNG and power generation. He also has extensive experience in renewable and other alternative energy applications, such as waste to energy, distributed generation and smart energy.

Mark holds a Bachelor of Science degree and an MBA from Brigham Young University, and a J.D. degree from Columbia School of Law.

Mark’s职务是美国何威安卓律师事务所北京代表处的首席代表，何威安卓律所是一家大型国际律师事务所，在美国多地以及北京、曼谷、布鲁塞尔、迪拜和伦敦均设立了办公室。

何威安卓律所的北京代表处专长于能源和基础设施项目，并与其美国办公室及各国办公室紧密合作，为众多大型战略性项目和方案提供全球法律服务。

Mark的执业范围包括各种上游、中游和下游油气项目，包括LNG和发电项目。同时他还具有丰富的新能源和其他替代能源应用经验，例如废弃物能源回收、分布式发电和智慧能源。

Mark拥有杨百翰大学理学学士学位和MBA学位，并拥有哥伦比亚大学法学博士学位。
Mr. Wheeler is President of Lee Keeling & Associates (LKA), an international petroleum E&P consulting and reserve evaluation company founded in 1957. Before joining LKA, he worked in Amoco Research Center and then at Williams E&P. As a Certified Petroleum Geologist, Mr. Wheeler has 34+ years’ experience in geological and engineering investigations in oil and gas industry. He has conducted geologic and reservoir studies of both conventional and unconventional reservoirs in more than 30 countries and in every major U.S. petroleum province, highlighted with recently developed shale plays i.e. Permian, Eagle Ford, Haynesville, Marcellus, Bakken, Woodford and Niobrara. He has extensive experience in reserve evaluation for public and private oil companies, and financial institutes including hundreds of reserve report submitted and accepted by SEC. He also performs evaluation of oilfield properties for acquisition and divestiture as well as being a technical advisor to foreign and domestic companies looking to invest in U.S. oil and gas business. His other studies include pipeline feasibility assessment, gas storage evaluation and waterflood projects analysis. He also provides expert witness reports and testimony for legal cases.

**President, Lee Keeling & Associates, Inc.**

李基林资源评估公司
总裁

炜乐先生是成立于1957年的国际石油E&P咨询和储量评估公司--李基林资源评估公司（LKA）的总裁。在加入LKA之前，他曾先后在阿莫科研究中心和威廉姆斯E&P公司工作。作为认证石油地质学家, 炜乐先生在石油和天然气行业的地质和工程调查方面拥有超过34年的经验，在30多个国家和美国各大油气盆地对常规和非常规储油层进行了地质和储层研究，包括最近开发的页岩油气，如二叠纪、鹰滩、海恩斯维尔、马塞勒斯、巴肯、伍德福德和尼奥布拉拉。他拥有丰富的经验为上市和私营石油公司以及金融机构提供储量评估报告，其中包括数百份提交给美国证券交易委员会（SEC）的报告并得到认可。他还对油气田资产的收购和剥离提供评估，并为希望投资美国石油和天然气业务的国内和国外公司担任技术顾问。他的其他研究包括油气管道可行性、地下储气库和水驱项目的分析评估。他还为法律案件提供专家证人报告和证词。
Chris Mellos is a Market Development Manager for Solar Turbines Inc and is responsible for defining market requirements for new product development. Chris joined Solar in 1998 as a Mechanical Engineer responsible for package and systems designs. In 2012, Chris became Market Development Manager for Oil & Gas. Chris is focused on Electric Fracturing (E-Frac) technology and power solutions for Unconventional Resource Development (URD), having spent the last seven years working with producers and operators across the U.S. shale plays. Chris has a BS in Mechanical Engineering and an MBA from San Diego State University.

Chris Mellos 任职索拉透平公司市场开发经理，负责新产品开发的市场需求扩展。Chris Mellos 先生1998年加入索拉透平公司，任职成壳及系统设计的机械工程师职位。2012年成为油气业务市场发展经理，在过去七年与油气生产企业及操作企业一起在美国的页岩气田工作，为非传统资源开发提供E-Frac 技术及能源解决方案。

Chris 拥有圣地亚哥大学机械工程理学学士学位及MBA学位，
Cai Yifan, graduated from Shanghai Jiaotong University in 2010 with a master degree in engineering. He has worked in oil and gas industry for 9 years and started managing Baker Hughes shale gas operation in southwest China since 2014, currently working as operation manager in Chengdu. Previously he worked in Saudi Arabia and Kuwait, specializing in directional drilling, formation evaluation, etc.

CAI Yifan (蔡一凡)

贝克休斯公司
钻井部门作业经理

Operation Manager
of Drilling, Baker Hughes
Li Luguang worked in the Tarim Oilfield and held several positions in the past, including the General Manager of PetroChina Southwest Oil and Gas Field Company, the Director of the Sichuan Petroleum Administration Bureau, and the Head of the Coordinating Group of the oil companies in the Sichuan-Chongqing region of CNPC. In 2014, he was transferred to the headquarters of PetroChina as the assistant to the General Manager. In November 2016, he served as the General Manager of PetroChina Tarim Crystal Branch. In 2018, he served as General Manager of the exploration and production branch of Tarim Crystal Branch of China Petroleum Corporation and Deputy Secretary of the party committee. In June 2017, he served as Vice President of China National Petroleum Corporation. He has nearly 35 years of working experience in the Chinese petroleum industry.

Li Luguang (李鹭光)

页岩气标准化技术委员会主任委员

Director General, China Shale Gas Standardization Technical Committee
MA Xinhua (马新华)

中国石油西南油气田分公司总经理

General Manager,
Petro China
Southwest Oil and Gas Field Company
CHANG Honggang (常宏岗)

Chang Honggang graduated from Zhejiang University with a degree in Chemical Engineering. He is a professor-level senior engineer. Currently, he works as the president of the Research Institute of Natural Gas Technology, PetroChina Southwest Oil & Gas Fields Company, the Chairman of the ISO Natural Gas Upstream Subcommittee (ISO/TC193/SC3), the Deputy Director of the China National Natural Gas Standardization Technology Committee, member of the China National Oil and Gas Standardization Technology Committee and member of the China Shale Gas Standardization Technical Committee. He is mainly engaged in research, standardization, and management of oil and gas field development. His major responsibilities include research, standardization, and management in the field of oil and gas field development. He has won 8 national and provincial awards, published more than 40 papers, and formulated and amended more than 20 international and national standards.
ZHANG Leifu (张磊夫)

Zhang Leifu obtained Ph.D. in Geology from the University College Dublin and a Postdoctoral scholar from Peking University. He currently serves as Senior Engineer at CNPC Research Institute of Petroleum Exploration and Development and National Energy Shale Gas Research (Experiment) Center. He has been engaged in shale gas exploration and resources evaluation research. He published 10 peer-reviewed papers co-chaired many international conferences on shale oil and gas such as AAPG and EAGE.

张磊夫，都柏林大学地质学博士，北京大学博士后，现任中国石油勘探开发研究院、国家能源页岩气研发（实验）中心高级工程师，从事页岩气勘探、资源评价研究工作，发表SCI论文10篇，多次主持AAPG、EAGE等国际页岩油气会议。
ZHEN ZHANG obtained his Master’s degree in Engineering and he graduated from Australia Curtin University. He currently works for the Petrochina Southwest Oil & Gasfield company. He has participated in a number of national drilling and scientific research projects. He has rich experience in drilling field. At present, he mainly engaged in the research of optimal and fast drilling technology for horizontal wells and the related work of drilling standardization.

ZHANG Zheng (张震)

Senior Engineer, PetroChina Southwest Oil and Gas Field Company

张震，工学硕士，毕业于澳大利亚科廷大学，在中国石油集团公司西南油气田分公司工作，先后参与过多项国家级钻完井科研项目，并且有着较为丰富的钻井现场作业经验，目前主要从事水平井优快钻井技术研究以及钻完井标准化相关工作。
NIU Jun (牛骏)

Graduated with a concentration in fluid mechanics in Peking University, Niu Jun is a Senior Engineer and Deputy Director of the Oil Recovery Engineering Division of PEPRIS. He has been working in the integrated reservoir-wellbore numerical simulation and production optimization of shale oil and gas for many years. He was involved in publishing more than 10 SCI-related publications and owned 10 patents.

中国石化工程师

Engineer, Sinopec
Mr. Bai Yuhu is the Senior Engineer and Director of CNOOC Research Institute. He obtained the Ph.D. of fluid mechanics, and he had 17-years of experience in shale oil and gas, tight gas, natural gas hydrate research work. Currently, he is the Director of the Shale Gas Research Institute and Chief Reservoir Engineer at CNOOC Research Institute. He has won more than 10 scientific and technological progress awards and published over 100 papers and 6 books.

白玉湖 流体力学博士学位，中海油研究总院页岩气研究室主任，油气田开发首席工程师，具有17年的页岩油气、致密气、天然气水合物等非常规油气开发研究经历。获得省部级、局级科技进步奖10余项，发表论文100余篇，出版专著6部。

Senior Engineer, CNOOC
Presentations

演讲材料
Implementation and Prospect of China Shale Gas Technical Standard System

By: Chang Honggang

China Energy Technical Standardization Committee of Shale Gas

Nov. 5th, 2019
China highly focuses on the development of shale gas industry. Under the guidance of national industrial policies, the shale gas industry has been developed rapidly and stepped into the stage of large-scale exploitation. A technical standard system has been established, and adapts to the exploration and development of shale gas in China. The standard system regulates the exploration, development and utilization of shale gas. It meets the demands for the governmental supervision over shale gas development, and strongly supports the shale gas industry in China.
01 Overview of the Shale Gas Industry in China

02 Achievements of China Shale Gas Technical Standard System

03 Prospect of China Shale Gas Technical Standard System
There are three types of shale reservoir in China: marine, transitional and continental facies. The overall geography distribution is "marine in the south and continental in the north".

- **Marine shale**: 8 formations, current focus on Wufeng Formation and Longmaxi Formation.
- **Transitional and continental shale**: 7 formations, current focus on Shanxi Formation and Yanchang Formation.

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**Marine shale**

- Tieling Formation
- Hongshuizhuang Formation
- Xiamaling Formation
- Doushantuo Formation
- Wufeng Formation
- Niutitang Formation
- Longmaxi Formation
- Luofu Formation

**Transitional shale**

- Benxi Formation
- Shanxi Formation
- Longtan Formation
- Ziliujing Formation
- Shahejie Formation

**Continental shale**

- Liulin Formation
- Xujiahe Formation
- Luochuan Formation
- Mianfeng Formation
- Yinan Formation
- Yanchang Formation
- Shahejie Formation

---

**Resources Distribution of Shale Gas in China**
The exploration and development of shale gas was initiated in 2005, and developed rapidly in China. After years of continuous development, China is ranking top 2 of the shale gas production worldwide.

### Milestones and Stages of Shale Gas Development in China

**Preparation**
- **2005**: Screening of Shale Gas Areas in China
- **2006**: The first geological evaluation well for shale gas: Well Changxin 1

**Industrial Pilot Production**
- **2007**: Set-up of the exploitation right of the first shale gas
- **2010**: Discovery of Jiaoshiba Shale Gas Field
- **2012**: Discovery of Changning and Fushun-Yongchuan Shale Gas Fields
- **2013**: Shale gas "well factory" production test.
- **2014**: Reserve Ascertainment of Fuling Shale Gas Field
- **2015**: Proved reserves
- **2016**: Predicted production 78.8
- **2017**: Predicted production 108
- **2018**: Predicted production 90.2
- **2019**: Predicted production 44.7
- **2020**: Predicted production 108

**Large Scale Production**
- **2005**: Technical breakthrough in exploration and development over the depth of 3,500 meters

### Resources Distribution of Shale Gas in China

- **2005**: 2006
- **2007**: 2008
- **2009**: 2010
- **2011**: 2012
- **2013**: 2014
- **2015**: 2016
- **2017**: 2018
- **2019**: 2020

Shale gas production (10^8 m^3)
The marine shale gas has achieved effective production, in the depth less than 3,500 meters in the Sichuan Basin, and has achieved industrial breakthrough, in the depth over 3,500 meters.

- Submitted a proven reserves of nearly 2 trillion cubic meters
- Efficiently completed the establishment of Shale Gas Demonstration Areas

High-production shale gas wells were drilled in several plays, such as Lu 203, the testing production was 1.379 million m³/d.
- It is expected to establish the first batch of deep shale gas development demonstration areas in China by 2020.
The transitional and continental shale gas resources are in the evaluation stage, and some areas show a good indication.

**Ordos Basin:** 66 evaluation wells were drilled, and the highest testing production of single well is 53,000 m³/d.

**Sichuan Basin, Qaidam Basin and Southern North China Basin:** multiple wells prove the existence of the transitional and continental shale gas.
The shale gas reservoir in Sichuan Basin are quite different from those in North America

**Geological conditions**
- The storage conditions and gas content are generally poor, the key evaluation parameters of reservoir are poorer than those in North America

**Engineering conditions**
- Deep well, complicated structure, complex crustal stress, and more difficulties in drilling and fracturing

**Ground conditions**
- Steep mountains, dense population and limited environmental capacity

### Comparison of Geological and Ground Conditions between North America and Sichuan Basin

<table>
<thead>
<tr>
<th>System</th>
<th>Years ago (10^8 Years)</th>
<th>Depth (m)</th>
<th>Thickness (m)</th>
<th>Porosity (%)</th>
<th>Gas Content (m³/t)</th>
<th>Organic Carbon (%)</th>
<th>Area</th>
<th>Typical Gas Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>North America</td>
<td>Eagle Ford</td>
</tr>
<tr>
<td>Tertiary</td>
<td>0.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>North America</td>
<td>Haynesville</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>1.35</td>
<td>About 3,500</td>
<td>76</td>
<td>11</td>
<td>6.5</td>
<td>4.5</td>
<td>North America</td>
<td>Montney</td>
</tr>
<tr>
<td>Jurassic</td>
<td>2.05</td>
<td>3,200–4,200</td>
<td>75</td>
<td>12</td>
<td>6.1</td>
<td>3</td>
<td>North America</td>
<td>Montney</td>
</tr>
<tr>
<td>Triassic</td>
<td>2.50</td>
<td>2,500–4,400</td>
<td>150</td>
<td>7.8</td>
<td>5.8</td>
<td>3.6</td>
<td>North America</td>
<td>Montney</td>
</tr>
<tr>
<td>Permian</td>
<td>2.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sichuan</td>
<td>Changning-Weiyuan</td>
</tr>
<tr>
<td>Carboniferous</td>
<td>3.50</td>
<td>1,000–3,000</td>
<td>107</td>
<td>6</td>
<td>9.2</td>
<td>4.5</td>
<td>North America</td>
<td>Barnett</td>
</tr>
<tr>
<td>Devonian</td>
<td>4.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>North America</td>
<td>Marcellus</td>
</tr>
<tr>
<td>Silurian</td>
<td>4.40</td>
<td>2,000–4,500</td>
<td>42</td>
<td>4.0</td>
<td>4.1</td>
<td>3.2</td>
<td>Sichuan</td>
<td>Changning-Weiyuan</td>
</tr>
<tr>
<td>Ordovician</td>
<td>5.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sichuan</td>
<td>Changning-Weiyuan</td>
</tr>
<tr>
<td>Cambrian</td>
<td>6.00</td>
<td>3,000–5,500</td>
<td>125</td>
<td>1.7</td>
<td>1.9</td>
<td>2.9</td>
<td>Sichuan</td>
<td>Changning-Weiyuan</td>
</tr>
</tbody>
</table>
Based on the experience of North America, combined with the characteristics of shale gas reservoir in China, the theoretical and technical system for exploration and development has been innovated and established, including 6 technology series and 27 special technologies.

### Six Technologies for Shale Gas Exploration and Development in China

<table>
<thead>
<tr>
<th>Technology Series</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geological evaluation technology</strong></td>
</tr>
<tr>
<td>Reservoir analysis &amp; experimental technology</td>
</tr>
<tr>
<td>Seismic reservoir prediction technology</td>
</tr>
<tr>
<td>Horizontal well logging evaluation technology</td>
</tr>
<tr>
<td>Favorable area evaluation and optimization technology</td>
</tr>
<tr>
<td><strong>Shale Gas development optimization technology</strong></td>
</tr>
<tr>
<td>Modeling technology of geology-engineering integration</td>
</tr>
<tr>
<td>Development optimization &amp; deployment technology</td>
</tr>
<tr>
<td>Horizontal well optimal design technology</td>
</tr>
<tr>
<td>Dynamic tracking, quantitative analysis &amp; prediction technology</td>
</tr>
<tr>
<td><strong>Horizontal well optimized drilling technology</strong></td>
</tr>
<tr>
<td>Optimal drilling design technology of multi-well pad</td>
</tr>
<tr>
<td>Horizontal well fast drilling technology</td>
</tr>
<tr>
<td>Steering technology of geology-engineering integration</td>
</tr>
<tr>
<td>Cementing technology under oil-based drilling fluid conditions</td>
</tr>
<tr>
<td><strong>Horizontal well Volume-fracturing stimulation technology</strong></td>
</tr>
<tr>
<td>Fracturing design technology of geology-engineering integration</td>
</tr>
<tr>
<td>Low-viscosity slick water &amp; low-density proppant fracturing technology</td>
</tr>
<tr>
<td>Intensive stage &amp; high-intensity proppant injection technology</td>
</tr>
<tr>
<td>Fracturing real-time adjustment technology</td>
</tr>
<tr>
<td>Temporary plugging (multi-stage) fracturing technology</td>
</tr>
<tr>
<td><strong>Well factory operational technology</strong></td>
</tr>
<tr>
<td>Well factory layout technology</td>
</tr>
<tr>
<td>Well factory drilling technology</td>
</tr>
<tr>
<td>Well factory fracturing technology</td>
</tr>
<tr>
<td><strong>Clean and efficient exploitation technology</strong></td>
</tr>
<tr>
<td>Standardized design technology</td>
</tr>
<tr>
<td>Data acquisition and integration technology</td>
</tr>
<tr>
<td>Real-time monitoring and remote control technology</td>
</tr>
<tr>
<td>Flowback water reuse technology</td>
</tr>
<tr>
<td>Soil and water conservation technology</td>
</tr>
</tbody>
</table>
1 Geological evaluation technology

Obtained the distribution range and potential resource data, achieved the effective goal of all well targets in the production area.

Key Tech.
01. Reservoir analysis & experimental technology
02. Seismic reservoir prediction technology
03. Horizontal well logging evaluation technology
04. Favorable area evaluation and optimization technology

Technical level

Integrated logging & evaluation technology system significantly improved the accuracy.
Developed seismic processing and interpretation technologies for complex mountain area.

Accuracy rate of reservoir parameter prediction higher than 90%
III Six Technologies for Shale Gas Exploration and Development in China

2 Shale Gas development optimization technology

optimized recoverable shale resources and dynamic prediction of production, coincidence rate of geological modelling and dynamic prediction is more than 90%

Key Tech.

01 Modelling technology of geology-engineering integration
02 Development optimization & deployment technology
03 Horizontal well optimal design technology
04 Dynamic tracking, quantitative analysis & prediction technology

Technical Level

Overcome the complex ground environmental impact, and realized basically all Class I+II reservoirs exploitable.

Continuously optimized the high-production well operation procedure, and realized the production of Class I+II gas wells over 95% for 5 consecutive years

Special Pattern of Multi-well Pad

Spoon type
III Six Technologies for Shale Gas Exploration and Development in China

3 Horizontal well optimized drilling technology
Improved drilling rate, shortened the average drilling time of single well (< 5,000 m) within 70 days

Key Tech.

01 Optimal drilling design technology of multi-well pad
02 Horizontal well fast drilling technology
03 Steering technology of geology-engineering integration
04 Cementing technology under oil-based drilling fluid conditions

Drilling Parameters

<table>
<thead>
<tr>
<th>S/N</th>
<th>Parameter Type</th>
<th>Field Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Well bore configuration</td>
<td>Third spud-in &amp; third finishing drilling</td>
</tr>
<tr>
<td>2</td>
<td>Borehole track</td>
<td>Double two-dimensional well</td>
</tr>
<tr>
<td>3</td>
<td>Drilling parameters</td>
<td>High flow rate, high drilling pressure</td>
</tr>
<tr>
<td>4</td>
<td>Drilling equipment</td>
<td>52MPa pump and manifold</td>
</tr>
<tr>
<td>5</td>
<td>Steering tool</td>
<td>PDC+ rotary steering</td>
</tr>
<tr>
<td>6</td>
<td>Drilling fluid system</td>
<td>Oil base</td>
</tr>
</tbody>
</table>

The shortest single well drilling period is **20.83 days** (Wei 204H42-1)
The maximum length of the horizontal section is **2,820 m** (Changning H15-3)
The maximum footage of single drill trip is **2,540 m** (Ning 209H4-5)
The maximum TVD is **4371 m** (Zu 201-H1)
The average maximum drilling rate of the single well is **15.68 m/h** (Wei 202H10-9)
III Six Technologies for Shale Gas Exploration and Development in China

4 Horizontal well Volume-fracturing stimulation technology

Optimized fracturing parameters, reduced the cost of tools and fluid, realized the volume fracturing of shale reservoir with high differential stress

**Key Tech.**

01 Fracturing design technology of geology-engineering integration

02 Low-viscosity slick water & low-density proppant fracturing technology

03 Intensive stage & high-intensity proppant injection technology

04 Fracturing real-time adjustment technology

05 Temporary plugging (multi-stage) fracturing technology

**Key Tools & Fluid**

Developed multi-stage fracturing tools: with the self-developed tools, the cost was reduced by 30% to 50%

Developed new friction reducer: with the reduction down to 73% ~ 78% (TDS < 200,000 ppm), and the cost was reduced by 70%

**Mechanism of Friction Reducer**

**Technical Level**

<table>
<thead>
<tr>
<th>Indexes</th>
<th>Unit</th>
<th>Initial</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval length</td>
<td>m</td>
<td>80~100</td>
<td>45~55</td>
</tr>
<tr>
<td>Pumping Rate</td>
<td>m³/min</td>
<td>10~12</td>
<td>14~16</td>
</tr>
<tr>
<td>Sanding density</td>
<td>t/m</td>
<td>0.5~1.7</td>
<td>1.8~3.0, maximally 4.1</td>
</tr>
<tr>
<td>Fluid volume</td>
<td>M³/m²</td>
<td>26</td>
<td>35~40</td>
</tr>
<tr>
<td>SRV</td>
<td>10⁶m³</td>
<td>0.6</td>
<td>&gt;1.2</td>
</tr>
<tr>
<td>Well average test daily production</td>
<td>10⁶m³</td>
<td>9.8~16.7</td>
<td>19.7~22.9</td>
</tr>
</tbody>
</table>
5 Well factory operational technology

Improved the construction & operation efficiency, utilization rate of personnel & equipment, and realized the goals of "resource sharing, reutilization, efficiency improvement"

- Reduced equipment installation time by 70%, and increased drilling/fracturing efficiency by more than 50%, compared with single well operation.
- Increased the reuse rate of flowback water/oil base drilling fluid to more than 90% & 85% respectively.

Key Tech.

01 Well factory layout technology
02 Well factory drilling technology
03 Well factory fracturing technology

Technical Level
III Six Technologies for Shale Gas Exploration and Development in China

6 Clean and efficient exploitation technology

Improved the construction & operation efficiency and utilization rate of personnel & equipment, and realized the goals of "resource sharing, reutilization, efficiency improvement"

Key Technology

01 Data Acquisition & transportation and digital gas field Implementation technology

- Ground gathering and transportation system realized "standardized design, skid mounted equipment, modelling prefabrication and integrated equipment"
- Digital gas field realized "automated production, digital office and intelligent management"

Management and Analysis Center of Changning Shale Gas Field

02 Clean exploitation technology

- Drilling waste treatment technology realized "zero discharge of wastewater, non-hazardous treatment for solid waste"
- Flowback water treatment technology realized environmental friendly disposal

Drilling fluid treatment device
Fracturing flowback water treatment device

Before treatment
After treatment
Overview of the Shale Gas Industry in China

Achievements of China Shale Gas Technical Standard System

Prospect of China Shale Gas Technical Standard System
The government pays highly attention to the development of shale gas industry, and established **China Energy Technical Standardization Committee of Shale Gas** in July 2013 based on three standardization technical committees of natural gas, taking charge of the establishment and management of shale gas technical standards.

**Coordination function with three relevant standardization technical committees**

- China Petroleum Equipment Committee
- China Energy Technical Standardization Committee of Shale Gas
- China Natural Gas Standardization Technology Committee
- Technical Committee 355 on Petroleum & Natural Gas of Standardization Administration of China
**II Implementation and Effectiveness of China Shale Gas Technical Standard System**

**Principles**

<table>
<thead>
<tr>
<th>Demand-based</th>
<th>Coordinating and matching</th>
<th>Highlight features</th>
<th>Advanced and applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solve the existing issues in shale gas development and production</td>
<td>Directly adopt the applicable conventional natural gas standards, formulated by the 3 standardization technical committees of natural gas</td>
<td>Avoid overlapping, repetition and contradiction</td>
<td>Establishing standards with advanced and mature technology</td>
</tr>
<tr>
<td>Meet the needs of future exploration and development</td>
<td></td>
<td>Establish and implement the shale gas technical standards in line with China's national conditions</td>
<td>Lead the shale gas exploration and development in China</td>
</tr>
</tbody>
</table>
II Implementation and Effectiveness of China Shale Gas Technical Standard System

Cover the development of the shale gas industry chain, and adopt the structure of “1+6” according to professional characteristics.

Plan to establish **114 shale gas standards**, and adopt 1,599 existing conventional natural gas standards.

*Professional Framework of Shale Gas Technical Standard System*

- **Existing conventional oil & gas standards**
  - Geology Evaluation
  - Seismic & logging
- **General shale gas basic standards**
  - Gas reservoir exploration
  - Drilling & completion process
  - Reservoir stimulation
- **Safe and clean production**

General technical requirements for products, terms, etc. related to the whole industry in shale gas exploration, development, transportation and utilization.
1 Geological evaluation standards

- 10 standards were issued, including the geological analysis methods, resource evaluation guidelines, etc.
  - The Target Optimization Methods for Marine Shale Gas Exploration standardizes the key technical parameters for the field selection and the reservoir evaluation, providing important support for the optimization of favorable areas.

  ◆ Favorable shale areas in Sichuan Basin: Changning, Weiyuan, Zhaotong, Fushun-Yongchuan, Western Chongqing, and Fuling
  ◆ Key parameters: porosity, gas content, brittle mineral content, thermal maturity, etc.
II Implementation and Effectiveness of China Shale Gas Technical Standard System

2 Seismic and logging standards

- 2 standards were issued, including the technical specification for processing seismic exploration, and Monitoring Micro-seismic fracturing
  - The *Technical Specification for Processing, Interpretation and Prediction of Shale Gas Seismic Data* regulates the technical and quality requirements for the processing, interpretation and prediction of seismic data, and for the comprehensive evaluation of favorable areas.
  
  ◆ The seismic prediction error of buried depth is less than 1%
  ◆ Achieving the coincidence rate of comprehensive well interpretation of higher than 90%
3 Gas reservoir development standards

- 10 standards were issued, including the feasibility demonstration of exploration, recommended practice of reservoir exploration, etc.
  - The *Technical Specifications of Development Plan for Shale Gas* stipulates the content of parameters, quality control requirements, etc., provides scientific specifications for the development plans.

- Guided the Implementation of national shale gas demonstration areas

- Achieved accurate prediction of *life cycle productivity* and *EUR* of shale gas wells, with an coincidence rate of more than 90%
4 Drilling and completion technology standards

- 12 standards were issued, including the drilling design, drilling fluid, well control & HSE management, etc.
  - The Technical Requirements for Design of Shale Gas Horizontal Well standardizes the technical requirements for geological evaluation, well location site, etc., and greatly reduces the drilling time

- Reduced the average drilling time by 22.5% compared with that before implementation, and increased the penetration rate of Class I reservoir by 31.1%.
- The excellent cementing quality rate has increased by 11.6%.
5 Reservoir stimulation standards

- 13 standards were issued, including the fracturing design, chemicals, tools and equipment, etc.
  - The Shale Gas - Reservoir Stimulation - Part 1: Specification for Fracturing Design stipulated the fracturing design principle, operational parameters, etc., which is helpful to improve the efficiency and quality

- The fracturing efficiency was increased from 1.3 stages/day to 3.05 stages/day
- The annual average testing production was increased from 98,000 ~ 167,000 m$^3$/d to more than 200,000 m$^3$/d
II Implementation and Effectiveness of China Shale Gas Technical Standard System

6 Safety and clean production standards

- 2 standards were issued, including recommended practices for mitigating ground impact associated with fracturing and the specification for design of shale gas gathering & transportation system

  - The Specification for Design of Shale Gas Gathering and Transportation System supported the fast construction and production
    - The construction period of dehydrating station is shortened by 75 days

  - The Recommended Practices for Mitigating Ground Impact Associated with Hydraulic Fracturing regulates the selection and management of fracturing/flowback fluid, noise impact etc.
    - Occupied land reduce by about 2,300 mu Water saved by more than 3.80 million m³
The standard system supports the high-quality development of shale gas industry in China, and the largest domestic shale gas production base was constructed in South Sichuan.

The standard system promotes the technical progress of shale gas exploration and development technologies.

### Shale Gas Production in China from 2013 to 2018

<table>
<thead>
<tr>
<th>Year</th>
<th>CNPC</th>
<th>SINOPEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>10</td>
<td>33</td>
</tr>
<tr>
<td>2014</td>
<td>13</td>
<td>50</td>
</tr>
<tr>
<td>2015</td>
<td>28</td>
<td>62</td>
</tr>
<tr>
<td>2016</td>
<td>30</td>
<td>42</td>
</tr>
<tr>
<td>2017</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>66</td>
<td></td>
</tr>
</tbody>
</table>

### Key Technical Indicators for Shale Gas Development

<table>
<thead>
<tr>
<th>Class</th>
<th>Indexes</th>
<th>Unit</th>
<th>Current level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geophysical prospecting</td>
<td>Seismic data resolution</td>
<td>Hz</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Micro-seismic positioning error</td>
<td>m</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Logging</td>
<td>Excellence rate of storage logging data</td>
<td>%</td>
<td>&gt;80%</td>
</tr>
<tr>
<td></td>
<td>Coincidence rate of logging data interpretation</td>
<td>%</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>Development</td>
<td>Box range</td>
<td>m</td>
<td>3~5</td>
</tr>
<tr>
<td></td>
<td>Class I+II well ratio</td>
<td>%</td>
<td>&gt;88</td>
</tr>
<tr>
<td></td>
<td>EUR</td>
<td>$/mm³</td>
<td>1.0-1.2</td>
</tr>
<tr>
<td>Drilling</td>
<td>Drilling period</td>
<td>d</td>
<td>Average: 78, fastest: 27</td>
</tr>
<tr>
<td></td>
<td>Drilling rate</td>
<td>m/h</td>
<td>8.7-10.4</td>
</tr>
<tr>
<td></td>
<td>Penetration rate of Class I reservoir</td>
<td>%</td>
<td>&gt;96</td>
</tr>
<tr>
<td></td>
<td>Horizontal segment length</td>
<td>m</td>
<td>Average: 1,560, maximum: 2,820</td>
</tr>
<tr>
<td>Fracturing</td>
<td>Sanding density</td>
<td>t/m</td>
<td>Average: 1.8, highest: 3.2</td>
</tr>
<tr>
<td></td>
<td>Fluid Volume</td>
<td>m³/m</td>
<td>26-40</td>
</tr>
<tr>
<td></td>
<td>Cluster spacing</td>
<td>m</td>
<td>About 15</td>
</tr>
<tr>
<td></td>
<td>SRV</td>
<td>$/m³</td>
<td>Average: 1.46, highest: 3.23</td>
</tr>
<tr>
<td>Well Factory</td>
<td>Rig translation period</td>
<td>h</td>
<td>Average: 1.3, highest: 0.5</td>
</tr>
<tr>
<td></td>
<td>Translational return period</td>
<td>h</td>
<td>Average: 35, fastest: 31</td>
</tr>
<tr>
<td></td>
<td>Fracturing efficiency</td>
<td>stage/d</td>
<td>Average: 2.35, highest: 4</td>
</tr>
</tbody>
</table>
01 Overview of the Shale Gas Industry in China

02 Achievements of China Shale Gas Technical Standard System

03 Prospect of China Shale Gas Technical Standard System
Continuously promotes clean energy development in China, and the demand for natural gas is growing rapidly

- Natural gas accounts for a relatively low proportion in the energy structure in China, and there is still room for development compared with the world average
- The natural gas consumption has entered a period of rapid growth in China, with 161 billion m³ produced and 280.3 billion m³ consumed in 2018, and external dependence higher than 45%
Rich shale gas resources are the main contributor of rapid growth of natural gas

- The shale gas is rich in recoverable resources, and the increasement of future natural gas production mainly comes from shale gas in China. It is planned to achieve annual shale gas production of 80 to 100 billion m³ by 2030
- Accelerating the development and utilization of shale gas is of great significance for promoting economic and social development, and ensuring the energy security
II Future Development Direction of technology and standard

Innovation demonstration and standard leadership

Make great efforts to transform the achievements of application research & development of emerging technologies, and engineering demonstration into technical standards, and promote a virtuous cycle of technological innovation, standardization and industrial development.

International exchanges and cooperation

Actively participate in the international standardization organizations and undertake the establishment of relevant international standards.

Focusing Future

Focusing on the three technical aspects of shale gas exploration and development:
- Commercial development of shale gas formation (< 3,500m)
- Research the developing technology of deep shale gas formation (> 3500m)
- Optimize the clean exploitation technology of shale gas.
II Future Development Direction of technology and standard

**Improve the technology for commercial development of shale gas formation (<3,500m)**

- Continuously optimize the horizontal interval length and the fracturing parameters, comprehensively promote the geology-engineering integration, and strive to increase the average well EUR to more than 120 to 150 million m$^3$ by 2025
- Plan to establish international, national and industrial standards including technical specification of geology-engineering integration in shale gas industry, etc.

**Research the developing technology of deep shale gas formation (>3500m)**

- Improve the index system of deep shale gas field evaluation and selection, break through the crustal stress modelling technology of deep shale reservoir, optimize the deployment of three-dimensional development well pattern, and strive to increase the average well EUR to more than 200 million m$^3$ by 2025
- Plan to establish international, national and industrial standards including determination methods of methane isothermal absorption in shale part one: static volume determination, etc.

**Optimize the clean exploitation technology of shale gas**

- Optimize the treatment process and equipment for obtaining satisfactory flowback water, improve the non-hazardous treatment and resource utilization of oil-based cuttings, develop the technology to prevent and control noise in the process of drilling and fracturing
- Plan to establish international, national and industrial standards including underground water monitoring technical specifications in shale gas exploration, etc.
Plan for Standards Establishment from 2020 to 2025

<table>
<thead>
<tr>
<th>Specialties</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>General fundamentals</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geological evaluation</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Earthquake &amp; logging</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drilling &amp; completion process</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Reservoir stimulation</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Gas reservoir development</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Safe and clean production</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>3</td>
<td>19</td>
<td>1</td>
<td>6</td>
<td>14</td>
</tr>
</tbody>
</table>

II Future Development Direction of technology and standard

P32 /35
Conclusions

China is rich in shale gas reserves. Under the leadership of the Chinese Government, we will strengthen technical research, improve the standard system of the whole shale gas industry chain, promote the rapid and high-quality development of the industry, continue to optimize the energy structure, and satisfy the strong demand for clean energy from the rapid growth of the national economy.
THANKS

China Energy Technical Standardization Committee of Shale Gas
U.S. Policy, Law, and Standards on Shale Gas Development

The Shale Gas Technology and Standardization Seminar
Chengdu, Sichuan Province, China
November 5, 2019

Roland Goodman
Manager, Upstream Standards
American Petroleum Institute
goodmanr@api.org
Topics

- Hydraulic fracturing (HF) and shale gas overview
- Petroleum and natural gas production and consumption
- U.S. regulatory framework
- API standards program and HF-related documents
- Conclusions
Shale Gas Drilling Technologies

- **Hydraulic fracturing** is a well completion technology for the development of unconventional resources such as natural gas that is trapped in shale rock formations. It is used to create a fracture network through which oil and gas can migrate to the wellbore.

- **Horizontal drilling** is a technique where the well is drilled first vertically and then horizontal to surface.
Shale Resources – Lower 48 U.S. States

Current and prospective resources and basins in the continental US
U.S. Shale Gas Resources

- Prior to 2005, shale gas constituted 4% of U.S. gas production

- Shale production is projected to increase from 30% of total U.S. gas production in 2010 to 49% by 2035

- Current U.S. domestic production and reserves are now replacing gas and oil imports
U.S. Petroleum & Natural Gas Production

- The U.S. has been a net energy importer since 1953 (66 years)

- Current U.S. domestic production will lead to the U.S. being a net energy exporter in 2020

- In 2018, tight oil (shale) development accounted for 50% of U.S. crude oil production and 68% of U.S. natural gas production
U.S. Crude Oil Production

Source: U.S. Energy Information Administration

million barrels per day

2000 2010 2020 2030 2040 2050

2018

History

Projections

Shale oil

Alaska

Gulf of Mexico

Other
Global Shale Basins
Global Energy Demand

The world will require nearly 40% more energy in 2040, and more than half of it will be met by oil and natural gas.

Source: IEA, World Energy Balances 2018 and World Energy Outlook 2018
Global Natural Gas Consumption

Natural gas consumption grows most in non-OECD Asian countries

OECD natural gas consumption
quadrillion British thermal units

Non-OECD natural gas consumption
quadrillion British thermal units

Source: EIA International Energy Outlook 2019
Key state regulations include:

- Review and approval of permits
- Well design, location and spacing
- Drilling operations
- Stimulation
- Water management and disposal
- Air emissions
- Wildlife impacts
- Surface disturbance
- Worker health and safety
- Inspection and enforcement of day-to-day oil and gas operations
U.S. State Regulatory Permits

Types of permits required:

- Well drilling permit
- Water management plan
- Proposed alternate method of casing, plugging, venting or equipping a well
- Bond for oil and gas well(s) (individual or blanket, various bond types allowed)
- Waiver of distance requirements
- Variance from distance restriction from existing building or water supply (to put the well closer than 100 feet)
- Proposed alternate method or material for casing, plugging, venting or equipping a well
- Approval for alternative waste management practices
- Approval of a pit for control, handling or storage of production fluids
- Use of alternate pit liner
- Permit for discharges from stripper oil wells
- Water quality management permit for treatment facilities
- Alternative pit liners
- Inactive status
- Road spreading plan approval
- Transfer of well permit or registration
- Orphan well classification
- Off-site solids disposal
- Residual waste transfer stations and processing facilities
- Transportation of residual waste
- Road use permit – construction of access to state roadway
- Road use bond
- Surface use permit
- Permits for pipelines crossing streams
- Water obstruction – encroachment
- Dam permit for a centralized impoundment dam for Marcellus shale gas wells
- Permit for non-road engine air emissions
- Permit for natural gas compression facilities emissions
- Earth disturbance permit
- Erosion and sedimentation control permit
- Stormwater discharges from construction activities
- Water allocation
- Permit for bank rehabilitation, bank protection, and gravel bar removal
- Permit for intake and outfall structures
- Permit for utility line stream crossings
- Permit for minor road crossings
- Permit for temporary road crossings
- Permit for maintenance, testing, repair, rehabilitation or replacement of water obstructions and encroachments
Key federal regulations governing shale development include:

- Clean Water Act
- Clean Air Act
- Safe Drinking Water Act
- National Environmental Policy Act
- Resource Conservation and Recovery Act
- Emergency Planning and Community Right to Know Act
- Endangered Species Act
- Occupational Safety and Health Act
About API
About API

- API is an industry trade association representing all segments of the oil and natural gas industry
- Over 660 member companies involved in all aspects of the oil and natural gas industry
- Over 700 committees and task forces covering various advocacy and technical issues
- Staff of ~275 located in Washington, DC and in 34 states
- International offices in Brazil, China, Singapore, and the UAE
About API

- API is **accredited** by the American National Standards Institute (ANSI) and **must** comply with the following:
  - openness, balance, consensus, due process
  - standards undergo a review at least every 5 years
  - regular program audits (conducted by ANSI)
  - transparent process (anyone can comment on documents submitted for committee ballot)

- All comments **must** be considered regardless of their source

- API corporate membership is **not required**
Value of API Standards

- Improves safety and reliability
- Improves equipment interchangeability
- Reduces regulatory compliance costs
- Reduces procurement costs
- Foundation for company standards
Use of API Standards

- National Technology Transfer and Advancement Act (NTTAA):
  - NTTAA requires Federal Agencies to use voluntary consensus standards, encourages participation;
  - API standards are cited in regulations by U.S. regulatory agencies including BSEE, DOT, EPA, OSHA, SEC, and USCG;
  - 130 API standards are cited 460 times in U.S. Federal Regulations.

- API Standards also widely cited by States:
  - 216 API standards are cited 4035 times in U.S. State Regulations.
API RP 100-1

- **Scope** – contains recommended practices for onshore well construction and fracture stimulation design and execution as it relates to well integrity and fracture containment.

- The goals are to design a well plan that isolates and protects groundwater from drilling and fracturing operations and use well equipment that can meet the expected fracture load requirements.
Well integrity: the design and installation of well equipment to a standard that

- protects and isolates useable quality groundwater,
- delivers and executes a hydraulic fracture treatment, and
- contains and isolates the produced fluids.

Fracture containment: the design and execution of hydraulic fracturing treatments to contain the resulting fracture within a prescribed geologic interval covering

- existing formation parameters and their associated range of uncertainties,
- well barriers and integrity created during well construction, and
- controllable fracture design and execution parameters.
This document is **not** a detailed well construction or fracture design manual

While industry-wide practices concerning well construction are similar, there are considerable variations in the details of individual well design and construction due to varying geologic, environmental, regulatory, and operation requirements

Proven practices are the result of operators gaining localized and specific knowledge based on experience, along with the development and improvements associated with technology.
Protection of Groundwater

Each well contains multiple layers of casing and cementing to protect groundwater

Well design and construction has four main components.

1. **Conductor casing** (isolate shallow groundwater and surface sediments).
2. **Surface casing** (isolate groundwater aquifers).
3. **Intermediate casing** (isolate subsurface formations, protect from pressure).
4. **Production casing** (isolate production zone).
Understanding Fracturing Fluids

<table>
<thead>
<tr>
<th>Compound</th>
<th>Purpose</th>
<th>Common application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids</td>
<td>Helps dissolve minerals and initiate fissure in rock (pre-fracture)</td>
<td>Swimming pool cleaner</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>Allows a delayed breakdown of the gel polymer chains</td>
<td>Table salt</td>
</tr>
<tr>
<td>Polyacrylamide</td>
<td>Minimizes the friction between fluid and pipe</td>
<td>Water treatment, soil conditioner</td>
</tr>
<tr>
<td>Ethylene Glycol</td>
<td>Prevents scale deposits in the pipe</td>
<td>Automotive anti-freeze, deicing agent, household cleaners</td>
</tr>
<tr>
<td>Borate Salts</td>
<td>Maintains fluid viscosity as temperature increases</td>
<td>Laundry detergent, hand soap, cosmetics</td>
</tr>
<tr>
<td>Sodium/Potassium Carbonate</td>
<td>Maintains effectiveness of other components, such as crosslinkers</td>
<td>Washing soda, detergent, soap, water softener, glass, ceramics</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water</td>
<td>Disinfectant, sterilization of medical and dental equipment</td>
</tr>
<tr>
<td>Guar Gum</td>
<td>Thickens the water to suspend the sand</td>
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<td>Glass cleaner, antiperspirant, hair coloring</td>
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</tbody>
</table>
API RP 100-2

- **Scope** – provides proven practices applicable to the planning and operation of wells, and hydraulically fractured wells

- Topics covered include recommendations for managing environmental aspects during planning, site selection, logistics, mobilization, rig-up, and demobilization, and stimulation operation

- Includes guidance on managing environmental aspects during well construction
Provides recommendations on the following topics:

- baseline groundwater sampling
- source water management
- material selection
- transportation of materials and equipment
- storage and management of fluids and chemicals
- management of solid and liquid wastes
- air emissions
- site planning
- training
- noise and visual resources
API RP 100-2

- Puts hydraulic fracturing into perspective relative to drilling, completions, and production lifecycle
- Most aspects are independent of the well stimulation practice used to improve production
- Describe baseline practices
- Recommended practices are site-specific and can vary over the lifecycle of the well
Planning Water Use

Operator incentives to reduce water use and operate responsibly include:

- Cost and logistics of procuring and managing water
- Corporate citizenship
- Perceptions of regulators
- Community considerations
- Consequences of natural events
- Federal and state regulatory considerations
Produced Water Disposal

Underground injection control (UIC) wells safely return produced waters from oil and natural gas operations to geologic formations.
Water Treatment Technologies

- Water management and wastewater treatment presents major technical and economic challenge.
- The operator should evaluate the nature and character of the material(s) for potential reuse to determine if treatment of the material(s) is necessary.
- Treatment systems must be designed with a well’s specific water quality in mind.
- Treatment technologies include:
  - chemicals (oxidation)
  - membrane filtration
  - separation (distillation)
API Bulletin 100-3

- **Scope** – outlines what local communities and other key stakeholders can expect from operators.
- Designed to **acknowledge challenges and impacts** that occur during the industry’s presence in a given region.
- Provides **flexible and adaptable strategies**, recognizing application will vary from operator to operator and community to community.
- Guidelines are intended to support onshore oil and gas projects for **shale developments**; however, are adaptable to any oil and gas project.
API Bulletin 100-3

- Share as a guide for “good neighbor” policies to help maintain a license to operate.
- Manage expectations for all stakeholders.
- To be used by stakeholders and industry—operators, contractors, service companies, and local communities and officials.
- Assist the operator in developing an adaptable and evergreen engagement plan.
- Build long-lasting, successful relationships within the communities where the industry operates.
API Bulletin 100-3 Guiding Principles

- **Integrity** – “Companies operating with integrity strive to build positive and constructive relationships within the community and accumulate long-term sustainable relationships.”

- **Safety & Environmental Responsibility** – “Operate daily in a manner that protects the safety, environment and health of communities, employees and contractors during the complete lifecycle of the project.”

- **Communicating Effectively** – “Communication is a two-way process of giving and receiving information through a number of channels…. following basic communication principles to build credibility and improve dialogue and understanding.”
Timeline of a Well

EXPLORATION
3–5 years

PLANNING
12–18 months

SITE & WELL CONSTRUCTION
2–3 months

HYDRAULIC FRACTURING
3–5 days

PRODUCTON
30 + Years
Provides environmentally sound guidance for domestic onshore oil and gas operations.

Includes all production facilities and waste water handling facilities.

Coverage begins with design and construction of access roads and includes reclamation, abandonment and restoration operations.
API RP 51R

Key areas of coverage are

- roads;
- Production and injection/disposal wells;
- gathering and system lines;
- production and water handling facilities.

Includes guidance on

- Protection of the environment;
- personnel selection, training, and qualification;
- protection of public safety;
- respect for property owner rights.
Scope – contains practices for isolating potential flow zones, an integral element in maintaining well integrity.

The focus of this standard is the prevention of flow through or past barriers that are installed during well construction.
Describes industry recommended cementing and well construction techniques to help ensure proper cementing to include:
- planning;
- design;
- testing;
- execution;
- post-cement job analysis and process summary.

Defines different types of mechanical barriers, including cement as a barrier.

Addresses cementing practices and factors that lead to a successful cementing job.
Additional API Upstream Safety Standards

- Spec 14A – Subsurface Safety Valve Equipment
- RP 14B – Design, Installation, Operation, Test, and Redress of Subsurface Safety Valve Systems
- RP 14G – Fire Prevention and Control on Fixed Open-Type Offshore Production Platforms
- RP 14J – Design and Hazards Analysis for Offshore Production Facilities
- Spec 16A – Drill-through Equipment
- Std 16AR – Repair and Remanufacture of Drill-Through Equipment
- Spec 16C – Choke and Kill Equipment
- Spec 16D – Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment
Additional API Upstream Safety Standards

- **Std 18LCM** – *Product Life Cycle Management System Requirements for the Petroleum and Natural Gas Industries*
- **RP 49** – *Drilling and Well Servicing Operations Involving Hydrogen Sulfide*
- **Std 53** – *Blowout Prevention Equipment Systems for Drilling Wells*
- **RP 54** – *Occupational Safety for Oil and Gas Well Drilling and Servicing Operations*
- **RP 55** – *Oil and Gas Producing and Gas Processing Plant Operations Involving Hydrogen Sulfide*
- **RP 59** – *Well Control Operations*
- **RP 64** – *Diverter Equipment Systems*
- **RP 67** – *Oilfield Explosives Safety*
- **RP 74** – *Occupational Safety for Onshore Oil and Gas Production Operation*
- **RP 75** – *Development of a Safety and Environmental Management Program for Offshore Operations and Facilities*
Additional API Upstream Safety Standards

- Bull 75L – Development of a Safety and Environmental Management System for Onshore Oil and Natural Gas Production Operation and Associated Activities
- RP 76 – Contractor Safety Management for Oil and Gas Drilling and Production Operations
- RP 90 – Annular Casing Pressure Management for Offshore Wells
- RP 90-2 – Annular Casing Pressure Management for Onshore Wells
- RP 96 – Deepwater Well Design and Construction
- Bull 97 – Well Construction Interface Document Guidelines
- RP 98 – Personal Protective Equipment Selection for Oil Spill Responders
- RP 99, Flash Fire Risk Assessment for the Upstream Oil and Gas Industry
- Bull E2 – Management of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Production
Conclusions

- The shale gas revolution has significantly changed the U.S. energy outlook; U.S. crude oil and natural gas production continues to grow as a result of the further development of tight oil resources.

- The U.S. will become a net energy exporter in 2020 and will remain so through 2050 as a result of large increases in production of crude oil and natural gas, and increasing energy efficiency.

- API standards represent industry’s collective wisdom on operational practices, developed and refined over many years, and are an integral part of API’s hydraulic fracturing program.
Questions?

Roland Goodman
Manager, Upstream Standards
American Petroleum Institute
200 Massachusetts Ave., NW
Washington, DC  20001 USA
goodmanr@api.org

www.api.org/Standards
有关页岩气发展的美国政策、法律和标准

页岩气技术及标准化研讨会
四川成都
2019年11月5日

美国石油学会
上游标准委员会经理
Roland Goodman
goodmanr@api.org
发言内容

- 水力压裂法和页岩气概况
- 石油和天然气生产与消耗
- 美国监管体系
- API标准项目及水力压裂相关的标准
- 总结
页岩气钻井技术

水力压裂是一种用于开发非常规资源（如页岩岩层中的天然气）的完井技术，通过建立藏缝网将石油和天然气转移至井筒。

水平钻井是一种先垂直打钻，而后与地面保持水平方向打钻的钻井技术。
美国本土48个州的页岩气资源

美国大陆目前和未来的资源和盆地分布

堆叠资源
- 浅层
- 中间层
- 深层
美国的页岩气资源

- 截至2005年，页岩气生产占美国天然气生产总量的4%
- 页岩气生产预计从2010年美国天然气生产总量的30%增长到2035年的49%
- 目前，美国国内能源生产和储备取代了油气资源进口
美国石油和天然气生产

- 自1953年以来，美国已成为能源净进口国
- 目前美国的国内生产量将使美国到2020年成为能源净出口国
- 2018年，致密油（页岩）开发占美国原油生产的50%，美国天然气生产的68%
美国原油生产

百万桶/天

2018

历史纪录 预测

数据来源于美国能源信息署

页岩油

阿拉斯加

墨西哥湾

其他
美国原油生产
全球页岩盆地
全球能源需求

2040年，全球将需要增加近40%的能源，其中超过半数的需求量来自于石油与天然气

Source: IEA, World Energy Balances 2018 and World Energy Outlook 2018
全球天然气消费量
天然气消费增长量大多是亚洲非经合组织国家

经合组织天然气消费量
英国热量单位

非经合组织天然气消费量
英国热量单位

数据来源于美国能源信息署2019国际能源展望
监管体系：国家法规及许可

国家主要法规涉及：

- 审批许可证
- 井的设计、选址和间距
- 钻井作业
- 激励
- 水资源管理和处理
- 废弃排放
- 对野生动物的影响
- 地面扰动
- 人员健康与安全
- 日常油气作业检查与执行
所需的许可要求包括：

- 钻井许可
- 水资源管理计划
- 套管、封堵、排气或装备井的建议替代方法
- 油气井保证金
- 免除距离要求
- 与现有建筑或供水设施距离限制的差异
- 批准替代废物管理做法
- 批准用于控制、处理和存储生产液的坑
- 备用坑里衬的使用
- 低产油井排放许可
- 处理设施水质管理许可证
- 备用坑里衬
- 静止状态
- 道路扩展计划批准
- 油井许可证或注册的转让
- 孤井分类
- 场外固体处置
- 剩余废物转运站和处理设施
- 剩余废物的运输
- 道路使用许可证 – 国道通道施工
- 道路使用保证金
- 地面使用许可证
- 管道穿越河流许可证
- 水下障碍物–侵蚀
- 马塞勒斯页岩气井蓄水坝许可证
- 非道路用发动机空气排放许可
- 天然气压缩设施排放许可
- 土地干扰许可
- 侵蚀和沉积控制许可
- 施工活动产生的雨水排放
- 水量分配
- 堤岸修复、堤岸保护和碎石坝清除许可
- 建筑物进出口许可
- 公用事业管线穿越河流许可
- 穿越小型道路许可
- 穿越临时道路许可
- 水下障碍物维修、检测、修理和替换许可
页岩开发的主要联邦法规包括：

- 《水清洁法》
- 《空气清洁法》
- 《安全饮用水法案》
- 《国家环境政策法》
- 《资源保护和回收法》
- 《应急计划与社区知情权法案》
- 《灭绝物种法》
- 《职业安全与健康法》
关于API
关于API

❖ API 是一家行业协会，代表着石油与天然气行业各方面利益

❖ 超过660家会员公司，来自于行业内各领域

❖ 700多个委员会和工作组，涉及处理各种政策游说和技术问题

❖ 拥有275名雇员，分布于华盛顿总部和34个州办公室

❖ 在巴西、中国、新加坡和迪拜设有区域办公室
关于API

- API是一家由美国国家标准协会（ANSI）认可的标准开发组织并必须符合以下要求:
  - 公开、公平、意见统一、法定程序
  - 标准至少每五年进行一次审核
  - 常规项目审核（由ANSI完成）
  - 透明进程（任何人都可以对委员会进行投票的标准发表意见）

- 必须考虑所有意见，无论其来源如何
- 是否成为API会员并非必要条件
API标准的价值

- 提高安全和稳定性
- 提高设备可互换性
- 降低监管成本
- 降低采购成本
- 企业标准的基础
API标准的应用

- 美国技术转让与进步法案（NTTAA）
  - 该法案要求联邦机构使用共识标准，并鼓励参与标准开发过程
  - API标准被美国立法机构应用为法规，包括：BSEE，DOT，EPA，OSHA，SEC，and USCG
  - 130项API标准被美国联邦法典引用了460次

- API标准也被州政府广泛引用
  - 216项标准被美国各州法规引用了4035次
页岩气/水力压裂相关标准

Hydraulic Fracturing—Well Integrity and Fracture Containment

Managing Environmental Aspects Associated with Exploration and Production Operations including Hydraulic Fracturing

Community Engagement Guidelines

Isolating Potential Flow Zones During Well Construction

Environmental Protection for Onshore Oil and Gas Production Operations and Leases
API RP 100-1

- **范围**——包含陆上井建和与井身完整性及裂缝控制相关的压裂增产设计与实施推荐做法

- **目的是**为设计一份有效的实施计划，以便在钻井和压裂作业时隔离并保护地下水，并使用能满足预期断裂荷载要求的井筒装备
井身完整性：按标准设计与安装钻井设备
- 保护并隔离可利用优质地下水
- 提供并实施水力压裂处理
- 包含并分离产生的液体

裂缝控制：包含水力压裂的设计与实施，在规定的地质间隔内产生的裂缝
- 现有地层参数和与其相关的不稳定性
- 井建过程中的井障和油井完整性
- 可控裂缝设计和施工参数
该文件不是一份详细的井建或压裂设计手册

尽管全行业井建操作做法都很相似，但由于不同的地质、环境、监管和操作要求个别油井设计和建设细节有相当大的差异

被行业认可的有关做法是由作业公司根据与开发和提高现有技术相关的经验获得的本地化专业知识
为保护地下水，每口井都包含多层套管和固井水泥

油井设计和施工包括四种主要部件
1. 导管（隔离浅层地下水和地表沉积物）
2. 表层套管（隔离地下水含水层）
3. 中间套管（隔离地下地层，防止压力）
4. 油层套管（隔离生产区）
### 认识压裂液

<table>
<thead>
<tr>
<th>Compound</th>
<th>Purpose</th>
<th>Common application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids</td>
<td>Helps dissolve minerals and initiate fissure in rock (pre-fracture)</td>
<td>Swimming pool cleaner</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>Allows a delayed breakdown of the gel polymer chains</td>
<td>Table salt</td>
</tr>
<tr>
<td>Polyacrylamide</td>
<td>Minimizes the friction between fluid and pipe</td>
<td>Water treatment, soil conditioner</td>
</tr>
<tr>
<td>Ethylene Glycol</td>
<td>Prevents scale deposits in the pipe</td>
<td>Automotive anti-freeze, deicing agent, household cleaners</td>
</tr>
<tr>
<td>Borate Salts</td>
<td>Maintains fluid viscosity as temperature increases</td>
<td>Laundry detergent, hand soap, cosmetics</td>
</tr>
<tr>
<td>Sodium/Potassium Carbonate</td>
<td>Maintains effectiveness of other components, such as crosslinkers</td>
<td>Washing soda, detergent, soap, water softener, glass, ceramics</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water</td>
<td>Disinfectant, sterilization of medical and dental equipment</td>
</tr>
<tr>
<td>Guar Gum</td>
<td>Thickens the water to suspend the sand</td>
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API RP 100-2

❖ 范围——提供了适用于油井和水力压裂井策划和作业并被行业认可的操作做法

❖ 包括在策划、选址、运输、钻机搬迁、安装、迁返和增产时保护环境的做法

❖ 包括了井建过程中保护环境的指南
提供了以下推荐做法:

- 基线地下水采样
- 水源管理
- 原料选择
- 材料和设备运输
- 液体和化学品储存及管理
- 固体、液体废物管理
- 废气排放
- 场地规划
- 培训
- 噪音和视觉资源
API RP 100-2

- 将水力压裂与钻井、完井和生产作业生命周期相结合
- 大部分内容都与用于提高生产作业的油井增产做法无关
- 描述基线做法
- 推荐做法是针对特定地点的，在油井的整个生命周期内都会发生变化
用水规划

运营商减少用水和负责任运营的激励措施包括：

- 水资源采购与管理的成本与物流
- 企业公民
- 监管机构的看法
- 社区考虑因素
- 自然事件的后果
- 联邦和州监管考虑因素
地下注水井从油气作业中将采出水安全地回收到地质形成物中
水处理技术

水资源管理和废水处理是重大的经济技术挑战

运营商需要评估潜在再利用材料的性质和特性，而决定是否需要对材料进行处理

处理系统的设计必须考虑到井的具体水质

处理技术包括：
- 化学品（氧化）
- 膜过滤技术
- 分离（蒸馏）
范围——概述了当地社区和其他主要利益相关方对运营商的期望

旨在指出在行业发展期某个特定地区面临的挑战和影响

提供了灵活可取的方法，并对于不同的运营商和社区选取不同的方法进行使用

该指南主要为支持页岩开发的陆上油气项目；但也可用于任何其他油气项目
该标准作为一份“好邻居”政策指导文件，以便运营商维持作业许可证

管理对所有利益相关者的期望

被利益相关方和行业使用——运营商、承包商、服务公司、当地社区和有关政府人员

有利于运营商制定适用且长期有效的参与计划

在作业活动所在的社区建立长久、成功的合作关系
API Bulletin 100-3 指导原则

- **诚信**——“公司诚信经营是为了在社区内建立积极的、具有建设性的关系，以及积累长期可持续的相处关系”

- **安全与环保责任**——“每天在项目的整个生命周期里以保护社区、雇员和承包商的安全、环境和健康的方式进行运营”

- **有效沟通**——“沟通是通过多种渠道提供和接收信息的双向过程……遵循基本沟通原则，建立信誉，增进对话和理解”
油井作业周期

勘探 3-5年
策划 12-18个月
选址和井建 2-3个月
水力压裂 3-5天
开采 30多年
为国内陆上油气作业提供环境无害指导
包括所有生产设施和废水处理设施
覆盖范围从进场道路的设计和施工开始，包括填海、弃置和修复作业
覆盖的关键领域包括：

- 道路
- 生产和注水/处置井
- 集输管线和系统管线
- 生产和水处理设施

包括以下方面的指导：

- 环保
- 人员选择、培训和资格
- 公共安全保护
- 尊重产权
API Std 65-2

- 范围——包含保持井筒完整性不可缺少的要素——隔离潜在流体层的做法
- 本标准的重点是在井建时防止通过已安装的壁垒
该文件描述了行业推荐的固井和井建技术，以确保使用适当的固井方法，包括：

- 策划
- 设计
- 检测
- 实施
- 固井后的作业分析及工艺总结

明确了不同类型的机械壁垒，包括将水泥作为屏障

指出了固井做法以及成功固井的因素
其他API上游安全标准

- Spec 14A - 《水下安全阀》
- RP 14B - 《水下安全阀系统的设置、安装、操作、测试和维修》
- RP 14C - 《海上生产设施上安全系统的分析、设计、安装和测试》
- RP 14G - 《固定开放式海上生产平台的防火与控制》
- RP 14J - 《海上生产设施的设计和危险分析》
- Spec 16A - 《钻通设备》
- Std 16AR - 《钻通设备的维修和再生产》
- Spec 16C - 《节流压井设备》
- Spec 16D - 《钻井控制设备和系统上的分流器/控制系统》
其他API上游安全标准

- Std 18LCM – 《石油与天然气行业产品生命周期管理体系要求》
- RP 49 – 《含硫化氢的钻井和修井作业》
- Std 53 – 《钻井防喷设备系统》
- RP 54 – 《油气井钻井和修井作业职业安全》
- RP 55 – 《含硫化氢的油气生产和天然气处理装置作业》
- RP 59 – 《井控作业》
- RP 64 – 《分流器设备系统》
- RP 67 – 《油田爆破器材安全使用》
- RP 74 – 《陆上油气生产作业职业安全》
- RP 75 – 《海上作业和设施的安全环境管理体系》
其他API上游安全标准

- Bull 75L - 《陆上油气生产作业和相关活动安全环境管理体系》
- RP 76 - 《油气钻井和生产作业承包商安全管理》
- RP 90 - 《海上油井环空套管压力管理》
- RP 90-2 - 《陆上油井环空套管压力管理》
- RP 96 - 《深水井设计和建设》
- Bull 97 - 《钻井施工接口文件指南》
- RP 98 - 《溢油应急人员个人防护装备选择》
- RP 99 - 《油气行业上游领域闪火风险评估》
- Bull E2 - 《油气行业天然放射性物质的管理》
总结

- 页岩气革命极大地改变了美国的能源展望，致密油资源的进一步开发使得美国原油和天然气生产持续增长。

- 原油和天然气生产量的大幅增加以及能源效率的提高使得美国将在2020年成为能源净出口国，并将持续到2050年。

- 经过多年的发展和完善，API标准代表了行业在操作实践方面的集体智慧，成为API水力压裂项目的一部分。
问题？

美国石油学会
上游标准部经理
Roland Goodman
200 Massachusetts Ave., NW
Washington, DC  20001 USA

www.api.org/Standards
主旨演讲: 美国工业在页岩气政策、监管和标准以及合规发展中扮演的角色

Mark Thurber, Partner
马克·瑟伯 / 合伙人
Hunton Andrews Kurth LLC, Beijing Office
美国何威安卓律师事务所驻北京代表处

Privileged & Confidential

About Hunton Andrews Kurth LLP
美国何威安卓律师事务所简介

• Global law firm created by the 2018 merger of Hunton & Williams and Andrews Kurth Kenyon, creating a one-stop shop for the energy marketplace
2018年，美国何威安卓律师事务所由美国知名能源所Hunton & Williams和Andrews Kurth Kenyon合并而成，为能源市场创建了一站式服务
• More than 1000 lawyers in 19 offices worldwide
在全球拥有3000多名律师和19个办公室
• Full-service capabilities, organized around teams and practices
团队和执业范围可保证提供全方位的服务
• We have represented:
我们代表的客户：
• 90% of the Fortune 10
90%的客户来自世界财富10强公司

Shale Reserves in the United States
美国页岩储备

This complete geological map shows how vast and complicated the U.S. shale plays are.
这张完整的地质图显示了美国页岩油气的庞大规模和复杂程度。

Cover almost one-third of U.S. land mass.
几乎覆盖了美国国土面积的三分之一。

About half of the states in the U.S. have shale oil formations in them.
美国大约有一半的州拥有页岩油地层。
In terms of economic importance, these are the most important shale plays.

Of these, the most important in terms of gas are the Permian basin in West Texas and the Marcellus (Appalachian) formation in Pennsylvania and surrounding states.

Shale gas reserves are present on every continent and in a wide variety of countries, including many countries that import oil and gas.

China's situation is particularly interesting.

What Makes the U.S. Situation Unique?

There are several reasons why the development of shale oil and gas has taken off in the United States.

The United States is unique in that the owner of the land owns the hydrocarbon resources underneath the property—unlike elsewhere in the world where governments own subsurface mineral rights.

The oil and gas industry has access to capital and has abundant expertise with U.S. geology.

Finally, the U.S. benefits from having a large infrastructure network able to handle the expansion of the oil/gas sector.

How is U.S. Exploration and Production Regulated?

Regulation in the U.S. occurs at four levels:

- Private—Since oil and gas is owned privately, most of the "regulation" of the industry actually occurs through contracts among producers, contractors, and between producers and private landowners.
- Oil and gas leases
- Joint operating agreements
- Drilling contracts
- Division orders
- Contracts are standardized and are subject to arbitration.
How is U.S. Exploration and Production Regulated? (cont'd)
美国的勘探和生产是如何被监管的？（续）

- Judicial decisions
  司法裁决
  - Judicial decisions create the majority of oil and gas law, known as "case law". 司法裁决创造了大多数的石油和天然气法，被称为“判例法”
  - Over time, case by case, a body of legal precedent is created. 随着时间的推移，一个又一个案例，大量的法律先例被创造出来
  - Each state has its own body of oil and gas case law. 每个州都有自己的油气判例法体系

- But generally the case law of all states are similar in most important aspects. 但是一般而言，所有州的判例法在最重要的方面都是相似的
  - Texas, Oklahoma and Louisiana historically had the most oil and gas, so their case law constitutes the majority of oil and gas case law. 有史以来，德克萨斯州、俄克拉荷马州和路易斯安那州拥有最丰富的石油和天然气，因此他们的判例法构成了大部分的石油和天然气判例法。
  - Pennsylvania will become increasingly important because of the Marcellus formation. 由于马塞勒斯页岩地层的缘故，宾夕法尼亚州将变得越来越重要

- State-level regulations
  状态级监管
  - Originated with the Texas Railroad Commission in the 1930s. 起源于20世纪30年代的德克萨斯州铁路委员会
  - Objective was to prevent waste and to impose order. 其目的是防止浪费和建立秩序
  - Also wanted to support prices. 同样希望支持价格
  - Principally spacing and unitization. 主要是规范井间距离和形成单元化区块

- Federal-level regulations
  联邦级监管
  - Historically, not as important as private, judicial and state regulation. 从历史上看，不如私人、司法和州监管那么重要
  - Exception is interstate pipelines. 州际管道除外
  - In connection with the shale gas transformation, federal regulations have become more important. 在页岩气改革中，联邦监管变得更加重要

How is U.S. Exploration and Production Regulated? (cont'd)
美国的勘探和生产是如何被监管的？（续）

- The transformation occurred at a politically sensitive time. 转型发生在政治敏感时期
- Environmental concerns are at an all-time high. 对环境的关注度始终很高
- Many NGOs opposing shale formation development, using environmental regulation as a legal tool. 许多非政府组织用环境监管作为法律工具反对页岩地层开发

Federal Regulation of Shale Oil and Gas Industry
页岩油气业的联邦监管

- Federal regulation occurs principally through 9 different acts. 联邦监管主要通过9个不同的法案实施
  - All environmental in nature. 本质上全是环保问题
  - Production on federal lands (forest service, BLM, offshore, Indian lands) is covered by separate regulations. 在联邦土地（森林服务、土地管理局、海上、印第安土地）上生产会受不同的监管
Strictly Confidential

Federal Regulation of Shale Oil and Gas Industry (cont’d)
页岩油气业的联邦监管（续）

- **Clean Air Act**

- **CERCLA Comprehensive Environmental Response, Compensation, and Liability Act** (CERCLA), commonly known as Superfund, enacted by Congress on December 11, 1980.

  - EPA has the authority to take response actions, undergo investigations and monitoring, and gather information in certain circumstances.

  - EPA authority is triggered by the release of hazardous substances into the environment (ground or air).

  - Short-term response (for emergency situations)

  - Long-term response on national priorities list (superfund sites)

- **The Clean Water Act** regulates the discharge of pollutants to waters of the U.S.

- **The National Pollutant Discharge Elimination System (NPDES)** permit program under the Clean Water Act controls water pollution by regulating point sources that discharge pollutants into waters of the United States.

- Facilities that maintain extremely hazardous substances on-site in quantities greater than established threshold quantities must cooperate in emergency plan preparation.

- The **Emergency Planning and Community Right-to-Know Act (EPCRA)** of 1986 (EPCRA) was created to help communities protect public health, safety, and the environment from chemical hazards.

  - EPCRA is designed to help communities identify and respond to hazardous chemical incidents.

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Examples of application in the shale industry:

- During well development (drilling fluids), well stimulation (hydraulic fracturing fluids), well maintenance (scale removal fluids, corrosion inhibitors), and gas processing.

- Materials stored on site at a well pad may include motor oil, hydraulic oil, diesel fuel, drilling mud, and hydraulic fracturing fluid.

- Chemicals necessarily involved in the use of other equipment and processes, such as compressor engines, glycol dehydrators, condensate storage tanks, equipment components, and turbines.

- Biocides, a type of pesticide, are used to eliminate bacteria that produce corrosive by-products within well casings and to prevent bacteria from clogging fractures in rock formations.

- Herbicides may also be used along natural gas pipeline rights of way and/or to keep vegetation at bay on and around drill pads, compression stations, or gas plants.

- Pesticides may be included in the field processing impurities, including wastewater.

Federal Insecticide, Fungicide and Rodenticide Act

- Provides EPA with the authority to oversee the registration, distribution, sale, and use of pesticides.

- Some of the chemicals used in hydraulic fracturing are biocides.

Resource Conservation and Recovery Act

- Authorizes the EPA to regulate hazardous waste, including all stages of the waste’s life cycle: generation, transportation, treatment, storage, and disposal.
- Requires tracking of hazardous waste from generation to disposal, and permitting of hazardous waste management facilities.
-要求跟踪危险废物从产生到处置的全过程，并允许使用危险废物管理设施。

The Safe Drinking Water Act (SDWA) is the primary federal law that ensures the quality of Americans’ drinking water.

- Under SDWA, the EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers implementing those standards.
- May apply when hydraulic fracturing or other oil or natural gas production activities impact a public water system’s supply.
- 要求跟踪危险废物从产生到处置的全过程，并允许使用危险废物管理设施。
- May apply when hydraulic fracturing or other oil or natural gas production activities impact a public water system’s supply.
- 要求跟踪危险废物从产生到处置的全过程，并允许使用危险废物管理设施。
- Regulate the construction, operation, permitting, and closure of injection wells that place certain fluids underground.
Mark Thurber
Partner 合伙人
markthurber@huntonak.com

Questions?/欢迎提问
Thank You!/谢谢
索拉移动式发电车应用
Solar Mobile Turbomachinery

Solar Turbines
Market Development Manager
Chris Mellos

Powering the Future
1. 非常规石油天然气市场开发  SMT Market
   • Unconventional Resource Development (URD)

2. 液力压裂  Hydraulic Fracturing
   • 电气化与传统模式  E-Frac v. Conventional Frac
   • 经济性  E-Frac Economics
   • 索拉的业绩  Solar’s E-Frac Experience

3. 索拉电气压裂解决方案  Solar’s E-Frac Solutions
   • SMT60
   • SMT130
• 全球压裂需求 Global Frac capacity
  – To reach **31.4M** Hp in 2022.
  – An increase of **2.8M** Hp from 2017.
  – Attrition potential of **6.2M** Hp.
  – 5 year new equipment frac demand = **9M** Hp.
  – Frac Industry demand = **2M Hp /yr** (attrition + growth).
SMT市场是非常规石油天然气开采的发电应用

SMT Market is… Power Generation for URD

北美石油天然气大局发生变化：
The North American Energy Landscape has changed:

传统石油天然气已经受到非常规能源冲击：
Traditional Oil & Gas has been permanently disrupted by Shale Oil & Gas and URD has resulted from it:

- 石油天然气公司立足于降低单井成本 Oil & Gas companies are focused on reducing well costs.
  - 压裂作业作为新的页岩油气井的作业成本中最大的一部分 Hydraulic Frac makes up the largest cost category by a substantial margin for new shale wells
  - 柴油到井口气体的切换体现了燃料经济性 Economics for switching from diesel to field gas is key consideration

- 油气工业从往复机切换到电机已有相当长的时间 O&G industry has a long history of moving away from recips to electric motors:
  - 井口动力需要 Infield power provision i.e. lease power, artificial lift, drilling rigs
  - 充足的天然气供应及低廉的天然气价 Abundant gas supply and low natural gas prices is enabler

- 在Permian的微网为钻井、完井及页岩油气生产提供动力 Microgrid Power for Drilling/Completion & Shale Production in Permian
  - 临时动力方案 Temporary power solutions for: Power before the grid, flare to power, flare to LNG, gas processing, drilling
U.S. Wells Operates Two Fleets with 4 X T60 MPU’s for E-Frac
Each Fleet Powers 2500HP (600 V) Electric Motors

Taurus 60 MPU (5.7 MW) – Gen 1
Clean Fleet Operating in West Virginia
电气化多井井场
E-Frac Multi Well Pad

- T60 MPUs X 3
- 燃料处理装置 Fuel Treatment Skids X 3
- 电动泵 Motor driven pumps X12
- 变频器 VFDs X 7
- 变压器 Transformers
- 中控室 E-House
- 增压压缩机 Gas Boost Compressors X 3
- 砂搅拌机 Sand Mixers X 3
- 井口 Well Heads X 5
- 集气设备 Existing gas gathering equip
- 集气设备 Existing gas gathering equip
电动压裂技术
E-FRAC TECHNOLOGY

全电气化，可移动的井口电力系统
Fully Electric, Fully Mobile Well Stimulation System, Powered by Natural Gas

设备 Equipment
- 燃气轮机 Turbine
- 发电机 Generators
- 开关柜 Switchgear
- 变压器 Transformers
- 变频器及电机 VFD & Electric Motors

环境受益 Environmental Benefits
- 排放下降 Reduced Emissions
- 物流减少 Reduced Traffic
- 噪音降低 Reduced Noise
LOW EMISSIONS & NOISE

Emissions: NOx

- Tier 1
- Tier 2
- Tier 4 Interim
- Tier 4 Final
- Clean Fleet (Theoretical, Actual)

**Near Zero Emissions**

- Conventional Sound Pressure for Entire Site
- Clean Fleet Sound Pressure for Entire Site
- Up to 69% Reduction on Average Sound Pressure for Clean Fleet Site

平均声压69%的下降
压裂经济性
Fraconomics

全生命周期成本构成 Understanding Total Cost of Ownership (TCO):

- 资本投资 Owning Costs (CAPEX)
  - 初始购入成本 Initial Purchase Price
  - 安装和设计成本 Installation & Design Costs
  - 融资成本 Financing Costs
  - 再销售成本 Resale (+ Revenue)

- 运行成本 Operating Costs (OPEX)
  - 总燃料成本 TFC (Total Fuel Consumption = Diesel + Gas +
  - 滑油 Lube Oil (Consumption + Changes)
  - 预防性维护 PM (Preventative Maintenance)
  - 大修及修理 Overhaul & Repairs
  - 停产成本 Lost Productivity
    - 计划性 Planned
    - 非计划性 Unplanned

$ / HHP-hr
全生命周期成本分析
E-FRAC PRICE PER STAGE & TOTAL COST OWNERSHIP MODELS

假设 Assumptions:
• 井口气可用 High Availability Well Head gas
• 柴油 $2.75 / 加仑 Diesel fuel $2.75 / gallon
• 50%的维修成本下降 50% Maintenance labor reduction
  • 5000马力以上的电动压裂泵 E-frac enables use of 5000+ Hp pumps

Titan 130: $80 M (NPV) cost savings over conventional diesel frac
LESSONS LEARNED FROM 5+ YEARS EXPERIENCE

Ancillary connections
• Crane required
• Too many nuts and bolts
• Too many different sizes of nuts and bolts
• Feet off the ground

Low Speed Coupling
• Needs to stay in place when on the move
• Alignment takes too much time

Levelling
• All by hand
• Once is not enough as ground settles
• Make levelling legs a part of the trailer. They are too heavy.

Booster
• Weight, we are too heavy
• Too long
• Hard to connect and disconnect

HMI
• HMI troublesome on hot and cold days
• Doesn’t stand up to the travel over non DOT roads

Pneumatics
• Seize up a lot especially in cold weather
• Air compressor, big and heavy for operating a small system.
• Gives trouble.

Connections
• Too many connections especially to EER
**Customer Must Haves**

- **Set up time is crucial. Needs to be less than 4 hours.**
- **16m L x 4m H x 2.5m W envelope. 9000 kg per axle. No Trailer booster.**
- **No crane lifts. No feet off the ground.**
- **Low Speed Coupling needs to stay in place. Alignment takes too much time.**
- **Auto levelling system. Make levelling legs a part of the trailer. They are too heavy.**
- **You give me equipment I don’t need which drives the cost.**
WHAT ARE WE DOING?

- Complete redesign of trailer to incorporate the full package.
- Powertrain integrated directly onto the trailer with no frame.
- All Systems packaged directly onto the trailer.
- Lock the low speed coupling in place for transit. No alignments.
- Provide an auto levelling system.
- No crane lifts. No feet off the ground.
- 3 connections
  1. Black start
  2. Fuel
  3. Output power
- Park, plug and play
SMT60
主要部件
MAJOR ITEMS

1. EER (Electrical Equipment Room)
2. MV (Medium Voltage Connections, CT’s PT’s)
3. Generator Compartment
4. Oil Cooler (Left side)
5. Turbine Compartment
6. Turbine Air Inlet Filters (left side)
7. Enclosure Ventilation Fans (left side)
8. Turbine Exhaust
9. Detachable Gas Fuel System
10. Generator Ventilation Fans (Qty 2)
11. Auto Levelling System
Single trailer footprint

Approximate weight 125,000lbs (56,000kgs)
FRONT & BACK

Solar Turbines
A Caterpillar Company

Powering the Future
空气从两侧6个滤器排进入燃机进气总管，空气水平通过压气机进入燃机室与燃料混合燃烧，在机罩后部向上排气。

Air is drawn in through a bank of 6 filters (both sides) into the Turbine inlet duct. The air is drawn axially through the turbine where it mixes with fuel, combusted and exhausts at the rear of the enclosure in an upwards direction.
Solar Mobile Turbomachinery (SMT60)

Powered by the Taurus™ 60 engine from Solar, the SMT60 provides superior mobile technology:

- Widest well-head gas fuel flexibility in the industry
- World leader in dry low emissions
- Easy to relocate and DOT compliant
- Fully integrated modular power plant
- Robust, proven equipment with a global support network

SMT60 Specifications

- Dimensions: 56’2” × 8’6” w × 13’2” h
- 7700 HP (5.7 MWe) ISO
- 13.8KV / 4160V generator
- Reduced noise emissions
- Single trailer design
- Dry low emissions
- Dual fuel capable
- Runs on wide range of well-head gas fuels
- DOT compliant; no escorts required

1 | Electrical Equipment Compartment (EEC)
2 | Medium Voltage Compartment
3 | Generator Compartment
4 | Generator Ventilation Inlet Filter
5 | Turbine Compartment
6 | Integrated Air Inlet Duct and Filters
7 | Exhaust
8 | MV Connection Point
9 | SoLoNOx™ Gas Fuel System
10 | Auto-Leveling Jack
11 | Enclosure Ventilation Fans
Titan 130 Mobile Power Unit

- 15-20 Ton Crane for Ancillary Equipment
- Fork Lift (optional)
- Standard Hand Tools
- 5-Person Crew
- 3-5 day set-up

Solar Turbines
A Caterpillar Company

Powering the Future
索拉移动式燃机发电车 – 大力神130燃机
Solar Mobile Turbomachinery – Titan 130 Gas Turbine
SMT130-17 MW

Requirements

• 无需起重机
• NO Crane for Ancillary Equipment
• 叉车（可选）
• Fork Lift (optional)
• 标准手动工具
• Standard Hand Tools
• 2人操作队伍
• 2-Person Crew
• 12小时内搭建完成
• Set-up in 12 hours or less
• 无需重新对中
• No realignment between moves
• 双拖车
• 2-trailers

Summary of Current Concepts

Concept 1
Everything on one trailer except Air Inlet on secondary

Concept 2
Electrical compartment, Air Inlet and Ventilation fans on secondary

Concept 3
Split drivetrain
Trailer 1 – Turbine and Air Inlet
Trailer 2 – Generator and Electrical

Heaviest Weight ~105,000 kg
Longest Single Trailer ~20 m
Fastest Connections (Air Inlet duct only)

Weight ~90,000 kg
Trailer Length ~15.5 m
Smallest Footprint at site
Ducting and Electrical connections only

Lightest Weight ~63,000 kg
Shortest Trailers ~12.5 m
Longest Setup: Alignment required, plus Ducting, Electrical, Oil, and Forklift required to move Air Inlet

Disclaimer – All values are estimates
Backup
为何电动压裂 WHY E-FRAC?

占地
最小占地面积及最轻重量

现场测试过的燃机

Field Tested Gas Turbine Units:
• Scalable 4.5 MW (fully de-rated) power packs
• Allows Lime to utilize power more efficiently

Footprint
Smallest Footprint Lightest Package in the E-Frac Industry:
• 5000hp per trailer
• ~105-110K lbs. per trailer

降低的燃料成本
Decreased fuel cost

100%天然气，节省~70%的燃料成本
100% natural gas allows for ~70% decrease in fuel cost

维护工作量小
Less Maintenance

• 交流电机直接联接泵 - 无传动装置
• AC Motors directly connected to pumps – no transmission
• 意味着停产时间短，每天更多段的操作
• Allows for less downtime and more stages/day

现场人员需求小
Decreased Manpower

• 全自动化井场操作，降低管理成本
• Fully Automated well-site decreases overhead requirement
• 增加安全性
• Increases safety

效率更高
Increased Efficiency

• 更多地线性控制与功率输出
• More linear control and delivery of power
• 完全自动化及整合的井场操作
• Fully automated and integrated well-site

环境影响
Environmental

• 无需放气及放火炬，满足政府环保规定，降低排放和噪声
• Eliminates need to flare or vent • Complies with federal and state regulations • Lower emission and noise

Custom Automation
Control and Remote Monitor of Entire Well-Site (REAL-TIME):
• Fully automated and integrated well-site through a single software package
• Less downtime/maintenance - more stages per day
• Less manpower
• Safer well-site

用户自动化
控制及远程监测整个井场（实时）
• 全自动化，单一软件整合的井场操作
• 停产时间 / 维护少短 - 每天更多段的工作
• 人员需求小
• 安全性更高

Solar Turbines
A Caterpillar Company

Powering the Future
Air is drawn in through the coolers (both sides) into the Turbine enclosure. The air is drawn axially over the turbine and extracted by the ventilation fans and exhausted out the rear.
空气由发电机通风风扇送风，经从两侧进入发电机机罩，空气从驱动、被驱动两端轴向进入，从侧面排气。

Air is drawn in (both sides) into the Generator enclosure by the Generator vent fans. The air is drawn axially from both DE and NDE into the Generator and exhausted out through the sides.
感谢！有何问题？
Thank you, are there any...
Outline

1. Global shale gas E&P status
2. E&P technical development trend
3. Advice on standardization cooperation

4. Unconventional hydrocarbon production in 2 countries

- U.S. western hemisphere
  - Tight gas: 100 bcm
  - CBM: 28 bcm
  - Shale gas: 607.2 bcm
  - Tight oil: 0.31 billion ton
- China eastern hemisphere
  - Tight gas: 38 bcm
  - CBM: 5.4 bcm
  - Shale gas: 10.8 bcm
  - Tight oil: 1.5 million ton

EIA predicts 1.6 tcm shale gas in 2040

- According to EIA (2016), 1.6 tcm of shale gas can be expected in 2040, accounting for 24% of natural gas production, 60% of the natural gas increase.

4 countries have industrialized shale gas development

- In 2018, global shale gas total production 670.3 bcm:
  - U.S. 607.2 bcm, Canada 48 bcm, China 10.8 bcm, Argentina 4.3 bcm

Abundant shale gas resources in China

- Shale gas favorable area of 0.43 million km², recoverable resources 8.8—31.6 tcm
2018 China’s shale gas production exceeded 10 bcm

China’s shale gas production from 2013 to 2018

- PetroChina
- Sinopec

- 2013: 2 bcm
- 2014: 12 bcm
- 2015: 46 bcm
- 2016: 78 bcm
- 2017: 92 bcm
- 2018: 106 bcm

Shale gas development in China

- National demonstration area: Weiyuan, Changning (PetroChina Southwest Oil & Gas field company), National demonstration area in Zhaotong (Zhejiang Oilfield), Fushun-Yongchuan (CNPC-Shell, terminated)
- First vertical well: Wei 201 (2009)
- First horizontal well: Wei 201-H1 (2010)
- First commercial development well: Ning 201-H1 (2012)

National Continental Shale Gas Demonstration Zone: Yanchang, Ordos Basin

- As of 2018, 66 wells drilled, 53 vertical wells and 13 horizontal wells
- 62 wells fractured and tested, 52 vertical wells and 10 horizontal wells

Outline

1. Global shale gas E & P status
2. E & P technical development trend
3. Advice on standardization cooperation

Outline

China’s shale gas technological development trend

- Geological Theories
  - More intelligent forecasting the unconventional “sweet spot” under complex geological conditions

- Engineering Technology
  - Larger scale horizontal Wells SRV fracturing to increase the production of single well

- Development Policies
  - More efficient and more integrated development of multi-layer system

1. 10 years China’s shale gas development history

- 2008: First shale gas geological data well of Changxin 1 Well
- 2009: First evaluation well, first mining right of shale gas
- 2011: National Energy Shale Gas R&D Center, 973 Program
- 2012: NEA approved 4 shale gas demonstration zones
- 2017: 5 billion development plan of Changning and Weiyuan
- 2018: Shale gas production 10.8 bcm in 4 demonstration zones
2. Gaps exist compared to North America

<table>
<thead>
<tr>
<th>Field</th>
<th>Technical status (U.S.)</th>
<th>Technology in China and the gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource evaluation</td>
<td>Combination of static and dynamic methods</td>
<td>Volume method strictly established, recoverable resources evaluation method in use</td>
</tr>
<tr>
<td>Target area selection</td>
<td>Geological engineering comprehensive analysis method, comprehensive risk analysis method</td>
<td>Objective evaluation of geological factors, considering drilling and fracking</td>
</tr>
<tr>
<td>Drilling engineering</td>
<td>Horizontal well apparent drilling rate, drilling footage</td>
<td>Volume method initially established, recoverable resources evaluation method on the way</td>
</tr>
<tr>
<td></td>
<td>Drilling speed: 30-40kmh</td>
<td>Drilling in Sichuan Basin</td>
</tr>
<tr>
<td>Fracturing engineering</td>
<td>Cluster spacing: 6-15m</td>
<td>Cluster spacing: 6-15m, easy for well collapse and sticking</td>
</tr>
<tr>
<td>Development</td>
<td>EUR average: 0.3-0.4 bcm</td>
<td>EUR average: 0.1 bcm</td>
</tr>
</tbody>
</table>

Challenge 1. Geological theories
- Can the high-maturity marine shale in South China form large scale shale gas reservoirs?
- Can the non-marine shale in China form any large scale gas reservoirs?

Challenge 2. Technology for deep reservoirs
- Over 50% of CNPC's shale gas resources are buried deeper than 4000m
- High temperature—more than 150°C
- High stress—more than 100MPa
- High cost—more than 70 million RMB per well

Challenge 3: Costs control and environmental protection
- Complex cost: expensive water transporting, complex topography
- Strict environmental policies: water cycle system, toxic gas emissions

Standardization 1: Layer-division scheme for Longmaxi Formation

Standardization 2: Shale reservoir classification and evaluation
- Optimization of “Sweet Spot” geological and logging parameters, establishment of fine-scale evaluation standards
Standardization 3: Drawdown-strategy and target-rate management

- Thin-layered and soft shale reservoir structure implies highly sensitive stress.
- Effective stress changes can cause irreversible damage to the reservoir structure and greatly reduce the seepage capacity.

Outline

1. Global shale gas E&P status
2. E&P technical development trend
3. Advice on standardization cooperation

Construction of shale gas standard system

- In 2013, NEA issued 'Shale Gas Industry Policy' (no. 5, 2013, NEA), which proposed requirements from the perspective of industrial supervision to strengthen the supervision of shale gas development and production processes, and required that shale gas exploration, development and production activities must comply with the current technical standards and norms related.
- Shale Gas Standards Committee has closely focused on the needs and technical development of standards for the shale gas industry chain in China, and initially established a technical standard system from scratch.
- In addition to the general basic standards, shale gas characteristic technical standards include 6 professional majors.

China’s shale gas standard system: overview

- To date, a total of 1,693 national and industrial standards are planned, formulated and published in the Shale Gas Standard System, including 93 shale gas featured technical standards and 1,600 conventional oil and gas standards. 21 national standards and 68 industry standards were formulated by the Shale Gas Standards Committee.
- By March 2019, 69 shale gas standards had been formulated, including 6 by the National Standardization Administration (NSA), and 44 by the NEA, providing a standard guarantee for the scientific and orderly development of China’s shale gas industry (0.02 bcm in 2013 to 11 bcm in 2018).

China’s shale gas technical / standard demand

- 1. Incomplete technical system: At present, development technology for shale gas buried <3500m basically mature, but 65% of shale gas resources are buried >3500m, thus requires a breakthrough.
- 2. Poor recoverable resources: The payzone in southern China is deeply buried, with complex structural background and topography, which leads to high-cost and poor economic efficiency.
- 3. Lack of infrastructure: The low coverage rate of natural gas pipe network and the short main pipeline hinders the large-scale development of shale gas in China.

Prospects for international technology / standards cooperation

1. On standardization of deep-buried high-pressure shale gas E&P: To promote the comprehensive breakthrough of shale gas E&P.
2. On standardization of surface construction: To improve facilities, process and procedure standardization, to reduce cost and improve efficiency.
3. On standardization of shale rock testing (e.g. isothermal adsorption, shale gas content test, and geological evaluation): To improve the data comparability, and international cooperation.
Thank you!
Estimating Reserves in Unconventional Shale Wells

Outlines
- Factors affecting shale wells performance
- Fundamentals and theories
- Forecast methods and standards
- Type well profiles
- Regulatory concerns

Factors affecting performance

ROCK
- Permeability
- Thickness
- Pressure
- TOC
- Thermal maturity
- Brittleness

OPERATOR
- Well location
- Well spacing
- Lateral length
- Fracture stimulation
- Size
- Fluid type
- Completion technique
- Operational practices

U.S. Shale characteristics Comparison

Factors affecting performance

Flow Regimes
- Transient linear flow
- Transition flow
- Boundary-dominated flow
- Operator controlled

Fundamentals and theories

*Table showing U.S. Shale characteristics comparison with various parameters such as rock and operational characteristics.*
Fundamentals and theories

Flow Regimes

Complicating factors
- Early off-trend flow (fracture clean-up, choked flow)
- Multiphase (gas-oil) flow in reservoir (extends transition time)
- Interference between adjacent wells at late time

Forecast models
- Modified Arps
- Modified Fetkoivitch (Urtec 2019-39)
- Stretched exponential
- Sliding b-factor
- Variable Power Law (Urtec 2019-39)
- Rate Transient Analysis (RTA)
- Reservoir Simulation

Estimation methods
- Decline Curve Analysis (DCA)
- Rate Transient Analysis (RTA)
- Reservoir Simulation

Practical
- Given a collection of wells or a single well
- Find wells with similar characteristics
- Develop a type well profile and use this to evaluate the adjacent locations with similar characteristics

Factors affecting performance
- ROCK
  - Permeability
  - Thickness
  - Pressure
  - TOC
  - Thermal maturity
  - Brittleness
- OPERATOR
  - Well location
  - Well spacing
  - Lateral length
  - Fracture stimulation
  - Fracture size
  - Fluid type
  - Completion technique
  - Operational practices
Other considerations

- Parent-Child relationships
  - Dependent on offset parental depletion
  - Parent wells seem to benefit from child well stimulation
- Managing the relationship
  - Space wells sufficiently apart
  - Drill and complete child wells within a few months of the parent wells (time)

Arps’ hyperbolic decline model

Method used in most commercial software

<table>
<thead>
<tr>
<th>Years of History Match</th>
<th>Best Fit Arps b</th>
<th>Error in Remaining Reserves %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.04</td>
<td>145</td>
</tr>
<tr>
<td>5</td>
<td>1.91</td>
<td>104</td>
</tr>
<tr>
<td>10</td>
<td>1.91</td>
<td>30.6</td>
</tr>
<tr>
<td>25</td>
<td>1.20</td>
<td>7.8</td>
</tr>
<tr>
<td>50</td>
<td>1.14</td>
<td>0</td>
</tr>
</tbody>
</table>

Dealing with forecasts when b > 1

- After matching historical production and determining the hyperbolic exponent, some recommend that we define minimum Final Decline Rate, Dmin (exponential decline)
- Dmin should be used because hyperbolic curve extrapolation with b > 1 can seriously overestimate future production and life of well
- Just as a reservoir in a given geological environment has a typical “b” value, we should identify and use typical “Dmin” value
- Analogy is a best way to select “b” value and Dmin
  - Older horizontal wells
  - Vertical wells

Shale reserve/resource evaluation standards

- SEC (Securities and Exchange Commission)
  - Agency of US federal government
  - Latest version 2010
- PRMS (Petroleum Resources Management System)
  - SPE, AAPG, SE, WPC, AAPG, SPEE, SEG, SPWLA, EAGE
  - Latest version 2018

Map of US shale basins

(Source: EIA)
Barnett shale - gas
- well cost $2-3 MM
- 500 wells this plot
- EUR 3-4 Bcf

Eagle Ford - oil
- 200 wells this plot
- EUR: 65,000 bbl

Haynesville - gas
- 20 wells
- How to fit this curve?

Regulatory concerns
- Fresh water protection (surface/subsurface)
- Size/shape of drilling units (spacing)
- Land/property (noise, dust, roads, pipelines)
- Frac water (source, fluid chemistry)
- Produced water (re-use/disposal)
- Induced seismicity (monitoring/action reaction)
- Natural gas prod. (flare/market/allowables)
- Reserve/Resource classification

Water
- Air
- Land
- Others

Federal (EPA)
- Clean water act (CWA)
- Safe drinking water act
- Oil pollution act
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Emergency Planning and Community Right-to-Know Act
- Occupational Safety and Health Act
- Clean Air Act (CAA)
- Resource Conservation and Recovery Act (RCRA)
- Endangered Species Act

State
- State laws/bills
- Permitting
- Executing
- Enforcement

Local
- County/City
- Orders
- Roads
- Right of way

Thanks!
Large-scale beneficial development for the resources of Longmaxi Formation at 3,500m and shallower has been realized.

- Six shale strata widely distributed in Sichuan Basin:
  - Sichuan Basin is a large superimposed basin comprised of marine facies and continental facies formed through multiple stages of tectonic movement.
  - Six shale strata include marine facies, marine-continent transitional facies, and continental facies.
  - Qiongzhusi Formation and Wufeng Formation~Longmaxi Formation are comprised of marine facies, they are beneficial layers for exploration and development.

- Qiongzhusi Formation and Wufeng Formation~Longmaxi Formation have abundant shale gas resources:
  - Burial depth at 4,500m and shallower: area 11,000 km^2, resource quantity 3.2 trillion m^3
  - Distribution area: 144,000 km^2

- Burial depth of the bottom boundary:
  - Qiongzhusi Formation: 900m to 1,400m
  - Wufeng Formation~Longmaxi Formation: 4,500m to 6,500m

- Longmaxi Formation realization of the leap from a demonstration region to large-scale production. As of October 2019, the output has been reached 6.23 billion m^3, expected to reach 12 billion m^3 in 2020.

The development of shale gas in Sichuan Basin is expected to focus on the resources at 3,500m and shallower depth of Longmaxi Formation, it has realized the leap from a demonstration region to large-scale production. Currently, the China's largest production base of shale gas has been built with a daily output over 20 million m^3.
The drilling & completion has gone through three rounds of development to achieve great technological progress.

### 2. Wellbore trajectory optimization

- Complete the lateral displacement and kick-off to target in Longmaxi Formation, to make the wellbore trajectory smoother and the friction resistance lower.
- Select optimal kick-off point: employ high build rate every ensemble tools and move the kick-off point downward to shorten the distance before the target.

### 3. Drilling fluid

- Currently, the oil-based drilling fluid applicable to shale gas exploitation in South Sichuan has been independently developed, strongly promoting the drilling requirements at different stages.

<table>
<thead>
<tr>
<th>System</th>
<th>Density (g/cm³)</th>
<th>Alkalinity (kg/m³)</th>
<th>Plasticity (Pa)</th>
<th>Shear stress (mPa.s)</th>
<th>Water loss (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil base (H18-6)</td>
<td>1.88</td>
<td>67</td>
<td>80/20</td>
<td>2.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Bio-synthetic base (H19-4)</td>
<td>1.89</td>
<td>56</td>
<td>82/18</td>
<td>0.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>

### 4. Five-in-one geosteering technology

- The five-in-one while-drilling track control technology has been formed by using multi-source data and rebuild 3D geosteering model in real time throughout the whole drilling process, this improves the accuracy of wellbore trajectory control.

### 5. The factory drilling technology

- The factory drilling technology adopted to Sichuan mountainous topography was established, greatly improved operation efficiency.

- The data for drilling, adventure, supervision and operation optimization is normal.

- Drilling rig translation time decreases from the average 2.5h to 1.3h; and the construction consumption time decreases from the average with 45% (6.5 days) to 25% (4.5 days), solving the multiple problems such as low operation efficiency and long task cycle.
6. The technology of cleaner production

- Drilling wastewater treatment technology: Employ coagulation, flocculation, precipitation, and other technological means to control the treated water quality and make it meet the standards set out in the Inorganic Watershed Discharge Standards (GB8978-1996).
- Solid waste while-drilling collection and treatment technology: A specialized equipment is used to separate, store, or directly transport waste into designated areas.
- Drilling wastewater treatment equipment: The equipment is conditioned to prevent drilling fluid leakage.
- Meticulous fracturing design, implementation and post-evaluation techniques based on geological engineering integration

7. The technology of cleaner production

- The technology of cleaner production: Focus on process optimization, such as increasing water recycling.
- Solid waste while-drilling collection and treatment technology: The solid waste is transported to storage areas.
- Drilling wastewater treatment equipment: Specific equipment is used to separate and store solid waste.

8. New progress in research on mechanism of proppant migration

- Drilling wastewater treatment technology: Targeted efforts are made to improve drilling fluid properties.
- Solid waste while-drilling collection and treatment technology: Enhanced waste treatment methods are developed.
- Drilling wastewater treatment equipment: Advanced equipment is used to implement waste treatment.
- New processes and parameters

- Application of traditional technology to new large deep wells, with proven success.
- Drilling wastewater treatment: Focus on process optimization, such as increasing water recycling.
- Solid waste while-drilling collection and treatment technology: Enhanced waste treatment methods are developed.
- Drilling wastewater treatment equipment: Advanced equipment is used to implement waste treatment.

9. Hydraulically fracturing technology of deep horizontal well achieves a breakthrough

- Drilling wastewater treatment technology: Targeted efforts are made to improve drilling fluid properties.
- Solid waste while-drilling collection and treatment technology: Enhanced waste treatment methods are developed.
- Drilling wastewater treatment equipment: Advanced equipment is used to implement waste treatment.
- New processes and parameters

- Application of traditional technology to new large deep wells, with proven success.
- Drilling wastewater treatment: Focus on process optimization, such as increasing water recycling.
- Solid waste while-drilling collection and treatment technology: Enhanced waste treatment methods are developed.
- Drilling wastewater treatment equipment: Advanced equipment is used to implement waste treatment.
5. The technology of perforating, plug, fracturing fluid has been localized

- Plug developed fast drilling plug, large-diameter plug, soluble plug. Performance of which are superior to foreign tools.
- Pumping plug and perforation technology formed multi-cluster perforation visualization technology.
- Fracturing fluid, formed a slickwater system that meets the recycling of flow-back fluid with the degree of mineralization <10,000mg/L and hardness <3000mg/L. The friction reduction rate was 75%.
- Independent-research casing starting sliding
- Plug: developed fast drilling plug, large-diameter plug, soluble plug. Performance of tools are equivalent to the foreign tools.
- Pumping plug and perforation technology: formed multi-cluster perforation visualization technology.

6. Optimization of post-fracturing evaluation system

- The post-fracturing evaluation technology was formed based on construction pressure analysis, microseismic monitoring, gas production profile testing and tracer monitoring, which can effectively instruct the continuous optimization and improvement of fracturing schemes.

7. Improvement of high efficiency factory fracturing in mountainous area

- Form shale gas factory fracturing stock solution and fluid supply mode, water storage at the platform and water supply via centralized network, realized the regional water storage and supply network in Changning.
- Overlapping fluid tank
- Sand storage and supply equipment
- Well test
- Factory fracturing site

8. Electric fracturing system gradually popularized

- Large pump rate: electric fracturing pump can provide the pump rate of 2m³/min in normal working condition.
- Long working time: electric fracturing pump can work for 15 hours.
- Low working noise: the noise of electric fracturing pump is low in the process of operating and the site measured value is about 66 db.

(II) Technical Progress of Shale Gas Drilling & Completion and Hydraulic Fracturing in South Sichuan

(III) Standard Construction of Shale Gas Drilling & Completion and Hydraulic Fracturing

Chinese standard framework

- National standard: Refers to standard that has great significance for the economic and technological development in China and must be unified in China.
- Industry standard: Refers to unified standard in the industry in China.
- Enterprise standard: Refers to technical requirement, management requirement and working requirement that need to be coordinated and unified in enterprises.
1. Standards of Pre-drilling Engineering

- Chinese standard construction of shale gas is established based on the demand and technological development of shale gas scale production. Existing characteristics technical standard of shale gas, except general common oil and gas standards, is constructed according to its specialization.
- The published standards for drilling and completion technology and hydraulic fracturing are mainly industry standards and enterprise standards.

2. Standards of Pre-drilling Engineering

- Pre-drilling engineering standards have released pre-drilling civil construction standard and technical requirement for design of shale gas horizontal well, which effectively instruct the development of pre-drilling shale gas engineering, and supplement the existing basic standards for pre-drilling engineering.
- The released standards include the following categories:
  - Geosteering system:4 industry standards are issued and 1 industry standard is being made
  - Well completion engineering:3 industry standards are issued
  - Drilling engineering:7 industry standards are issued, 2 industry standards are approved and 3 industry standards are being made

3. Drilling Engineering Standard - Drilling Design

- Drilling engineering standards mainly involve drilling design, directional drilling, logging, drilling fluid, quality & safety and factory drilling technology, of which one standard is basic standard for drilling design.
- The released standards include the following categories:
  - Drilling engineering design of horizontal shale gas well:3 industry standards are issued and 1 industry standard is being made
  - Drilling engineering design of horizontal shale gas well:3 industry standards are issued and 1 industry standard is being made
  - Drilling engineering design of horizontal shale gas well:3 industry standards are issued and 1 industry standard is being made

4. Drilling Engineering Standard - Drilling Fluid

- Two industry standards have been issued for the drilling fluid, one is (The recommended method of drilling fluids for shale gas-Oil-based fluids) and another one is (Evaluating method of shale inhibition for drilling fluids).
- The released standards include the following categories:
  - The recommended method of drilling fluids for shale gas-Oil-based fluids:2 industry standards are issued
  - Evaluating method of shale inhibition for drilling fluids:2 industry standards are issued
### 5. Drilling Engineering Standard – Logging

- One industry standard has been issued for the logging, which mainly stipulates the logging items, logging technical requirements, logging evaluation process and logging evaluation content.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Category</th>
<th>Scope</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GXYT 71</td>
<td>Technical</td>
<td>Industrial standard</td>
<td>Official standard</td>
</tr>
</tbody>
</table>

- The standard stipulates the requirements for logging, evaluation process and logging evaluation content.

- The standard is applicable to the logging, logging evaluation process and logging evaluation content.

### 6. Drilling Engineering Standard – Well Completion

- This standard stipulates the requirements for drilling safety, well control safety management and borehole quality control and evaluation methods for shale gas cluster horizontal wells.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Category</th>
<th>Scope</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB/T 36470</td>
<td>Technical</td>
<td>Industrial standard</td>
<td>Official standard</td>
</tr>
</tbody>
</table>

- The standard is applicable to the well cementation quality evaluation for cementation of production casing of shale gas wells. This part is applicable to the cementation process and quality indicators, and guides the use of on-site well cementation tools, and promotes the smooth and orderly implementation of well cementation operations, improves the well cementation process, and unifies the corresponding evaluation methods.

### 7. Drilling Engineering Standard – Quality and Safety

- The quality and safety mainly stipulate the requirements of the drilling safety, well control safety management and borehole quality control and evaluation methods for shale gas cluster horizontal wells.

<table>
<thead>
<tr>
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<th>Scope</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB/T 36471</td>
<td>Technical</td>
<td>Industrial standard</td>
<td>Official standard</td>
</tr>
</tbody>
</table>

- The standard stipulates the terminology, requirement, and corresponding evaluation methods for the cement paste performance in well cementation, puts forward standardized and scientific requirements for cement paste design of shale gas well cementation, and provides the smooth and orderly implementation of well cementation operations.

### 8. Well Completion Engineering Standard

- This standard stipulates the technical requirements and evaluation methods for cement slurries.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Category</th>
<th>Scope</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB/T 36472</td>
<td>Technical</td>
<td>Industrial standard</td>
<td>Official standard</td>
</tr>
</tbody>
</table>

- The standard stipulates the technical requirements and evaluation methods for cement slurries design and construction.


- This standard stipulates the requirements for factory drilling, mainly stipulates the special requirements for factory drilling and factory operations, and has carried out standard requirements in various aspects of factory operations, effectively guiding the factory operation and management and borehole quality control and evaluation methods.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Category</th>
<th>Scope</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB/T 36473</td>
<td>Technical</td>
<td>Industrial standard</td>
<td>Official standard</td>
</tr>
</tbody>
</table>

- The standard stipulates the terms and definitions of shale gas factory drilling, drilling and factory operations, and has carried out standard requirements in various aspects of factory operations, effectively guiding the factory operation and management and borehole quality control and evaluation methods.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Category</th>
<th>Scope</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB/T 36474</td>
<td>Technical</td>
<td>Industrial standard</td>
<td>Official standard</td>
</tr>
</tbody>
</table>

- The standard stipulates the terms and definitions of shale gas factory construction, drilling and factory operations, and has carried out standard requirements in various aspects of factory operations, effectively guiding the factory operation and management and borehole quality control and evaluation methods.
1. Standards for Hydraulic Fracturing Design and Construction

- At present, 6 industry standards have been issued for the hydraulic fracturing design and construction, including:
  - Requirements for construction technology of clustering perforation in horizontal wells
  - Standard of Energy Industry of the People's Republic of China (III) Standard Construction of Shale Gas Drilling & Completion and Hydraulic Fracturing
  - Existing Enterprise Standard for Drilling & Completion and Hydraulic Fracturing
  - Recommended Practices for the Testing of Shale Gas - Determination and Evaluation Methods of Shale Fractures
  - Recommended Methods for the Determination of Water Sensitivity

2. Standards for Chemical Reagents for Fracturing

- Three industry standards have been issued for chemical reagents for fracturing, which respectively regulate the performance indexes and evaluation of the following types of fracturing fluid:
  - Shale gas continuously mixed water-based fracturing fluid
  - Polyacrylamide resistance reducing agent and shale gas continuously mixed water-based fracturing fluid
  - Shale gas continuously mixed water-based fracturing fluid

3. Standards for Fracturing Tools and Equipment

- One industry standard has been issued for fracturing tools, which respectively regulate the classification and types of components, bridge plugs, technical requirements, test methods, inspection rules, and marking, packaging, transportation, and storage. The testing and operating specifications for fracturing models bridge plugs are being formulated.
(III) Standard Construction of Shale Gas Drilling & Completion and Hydraulic Fracturing

Standard Application Effect
1. Promoting the progress of drilling and fracturing technology and greatly improve the engineering benefits
   - The drilling & completion technology and hydraulic fracturing standards have been promoted and applied, and the drilling and fracturing technology suitable for shale gas in southern Sichuan has been effectively improved, various core indicators of the shale gas engineering in southern Sichuan and laying a solid foundation for later production.

   - Sewage and cuttings collection pond is anti-seepage and anti-outflow, sewage through treatment can be reused
   - Sewage and clean water diversion at the well sites, partition anti-seepage and leakage prevention

   - The drilling & completion technology and hydraulic fracturing standards have promoted and applied the drilling and fracturing technology suitable for shale gas in southern Sichuan and laying a solid foundation for later production.

   - The recycling of fracturing flow-back fluid achieves more than 90% reuse, which greatly reduces the amount of fresh water used in fracturing construction.

   - The recycling of fracturing flow-back fluid achieves more than 90% reuse, which greatly reduces the amount of fresh water used in fracturing construction.

   - Treatment of residual fracturing flowback fluid after reuse, and the water quality after treatment reaches reuse, and the water quality after treatment reaches

   - Water pipelines dedicated for construction are set to gather and transport water to the recycling water treatment plant to avoid negative impacts on surrounding plants.

   - The recycling of fracturing flow-back fluid achieves more than 90% reuse, which greatly reduces the amount of fresh water used in fracturing construction.

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(III) Standard Construction of Shale Gas Drilling & Completion and Hydraulic Fracturing

5. Strict control of engineering operations and maximizing the protection of the ecological environment
   - Storage and clean water diversion at the well sites, partition anti-seepage and leakage prevention
   - Storage and cuttings collection pond is anti-seepage and anti-outflow, storage through treatment can be reused

   - By implementing the requirements for pre-drilling engineering operations of shale gas platform and making clear requirements for roads and well site items, the size of each fracturing construction platform can be greatly reduced by applying the "standardized" site design and gas acquisition area has been greatly reduced by adopting measures such as "cluster production platform and gas gathering and transportation station construction on the same platform".

   - After the implementation of the "factory" standards for shale gas drilling, the land utilization rate of each same platform has been greatly reduced and the level of "well factory" mode construction, "standardized" site design, and gas gathering and transportation station construction on the same platform has been greatly improved.

   - At present, the drilling & completion and hydraulic fracturing standards are industry standards and enterprise standards. Through the upgrading of standards, the popularity and recognition of the standards will be increased to provide strong technical support for the shale gas scale and green development of China.

(III) Standard Construction of Shale Gas Drilling & Completion and Hydraulic Fracturing

Part II Technical Progress of Shale Gas Drilling & Completion and Hydraulic Fracturing in South Sichuan

Part III Standard Construction of Shale Gas Drilling & Completion and Hydraulic Fracturing

Part IV Plan for Follow-up Work

1. To improve the existing standard system and make the engineering technology sector fully covered
   - There are many technologies involved in shale gas drilling & completion and hydraulic fracturing. Current standards have not been fully covered, such as drilling equipment, engineering management, electric fracturing pump skids, fracturing monitoring and evaluation, etc., all of which need scientific and standardized management via corresponding standards.

   - To upgrade existing technical standards and increase the popularity and recognition of the standards
   - As present, the drilling & completion and hydraulic fracturing standards are industry standards and enterprise standards. Through the upgrading of standards, the popularity and recognition of standards will be increased to provide strong technical support for the shale gas scale and green development of China.
SINOPEC Progress in Shale Gas Exploration and Development

Jun Niu
Petroleum Exploration & Production Research Institute of SINOPEC
2019.11.06

1. Introduction of SINOPEC Shale Gas
Shale gas E&P research in SINOPEC starts in 2006, three stages:

Stage 1: Basic Research and Area Evaluation (2006-2009)
2008-2009: Established professional institutions and teams to conduct evaluation of shale gasification areas in south China, and investigation on R&D in North America.

Stage 2: Exploration Breakthrough (2010-2012)
Breakthrough in Jiaoshiba District, 14 wells for geological evaluation and practices of engineering technologies, succeeded in JY1HF, initially over 200K m³/d.

Stage 3: Rapid Development (From 2013)
Accomplish two phases of three-dimensional seismic interpretation, from well group site experiments to productivity construction Phase 1-5 billion m³/year; Expand Fuling shale gas field, productivity construction Phase 2 another 5 billion m³/year.

For development evaluations of shale gas in Weiyuan-Rongxian, Rongchang-Yongchuan and Dingshan district in Sichuan Basin, we drilled series of exploration wells, industrial gas flow in several wells implies great potential.

Current Situation of SINOPEC Shale Gas Development

- 2D-seismic evaluation 12,000 km
- 3D-seismic evaluation 2,700 km²
- Exploration and development wells ~400
- Commercial shale gas field 1 (Fuling)

Favorable blocks

- Proved geological reserves 380.598 billion m³
- Technical recoverable reserves 95.150 billion m³
- Cumulative productivity 7 billion m³/year
- Fuling productivity 5.03 billion m³/year

Focus on marine shale gas in Sichuan Basin

Breakthrough in Jiaoshiba District, 14 wells for geological evaluation and practices of engineering technologies, succeeded in JY1HF, initially over 200K m³/d.
Contents

1. Introduction of SINOPEC Shale Gas
2. Shale Gas Development in Fuling
3. Shale Gas E&P Plan in 2020-2025

(1) History of the first marine shale gas field in China

- Breakthrough of Fuling marked by success in JY1HF in Jiaoshiba district
  - February 2012, Based on 2D-seismic interpretation, JY1 vertical well was drilled for evaluation of several layers;
  - June 2012, JY1 encountered Wufeng-Longmaxi shale layer, and found good gas shows. Thus we decided to drill a horizontal well, JY1HF well.

- In 2012, the first stage of Fuling test evaluation was completed.
  - JY1HF well: 269,800 m$^3$/d
  - JY3HF well: 115,000 m$^3$/d
  - JY4HF well: 209,000 m$^3$/d
  - 3 stages of horizontal well drilling and fracturing tests:
    - Horizontal well length (1000 m, 1500 m) and orientation tests;
    - Horizontal well spacing tests;
    - Optimization of well production rate.

(1) History of the first marine shale gas field in China

- In 2013, accelerate exploration evaluation in Jiaoshiba district
  - 3 vertical wells (JY2, 3, 4) drilled - Controlling of Jiaoshiba main district.
  - 594.5 km$^2$ 3D-seismic work carried out - Detailed interpretation of shale layer structure and distribution.
    - JY2HF well: 269,800 m$^3$/d
    - JY3HF well: 115,000 m$^3$/d
    - JY4HF well: 209,000 m$^3$/d
  - Deploy a development test well group (10 platforms, 26 wells) in 28.7 km$^2$ around JY1HF well, with productivity of 500 million m$^3$.
    - Horizontal well drilling and fracturing tests;
    - Horizontal well length (1000 m, 1500 m) and orientation tests;
    - Horizontal well spacing tests;
    - Optimization of well production rate.

(1) History of the first marine shale gas field in China

- In 2014-2015, 237 wells drilled with an average test output of 266,100 m$^3$/d, and the average unobstructed flow rate is 390,900 m$^3$/d.
  - Lead to increase of accumulative proven geological reserve up to 380.6 billion m$^3$,
    and technical recoverable reserve up to 95.15 billion m$^3$.

Productivity building Stage 1: 5 billion m$^3$/year
  - In 2014-2015, 237 wells drilled with an average test output of 266,100 m$^3$/d, and the average unobstructed flow rate is 390,900 m$^3$/d.
  - Lead to increase of accumulative proven geological reserve up to 380.6 billion m$^3$,
    and technical recoverable reserve up to 95.15 billion m$^3$.

Test production rate distribution

Test unobstructed flow rate distribution

30-50万方, 45.57%
10-30万方, 36.71%
<=10万方, 16.03%
>50万方, 1.69%
50-100万方, 28.27%
20-50万方, 40.51%
<=20万方, 27.85%
>100万方, 3.38%
Stage 2 block distribution

Finish building Stage 2: another 5 billion m³/year

3D seismic work: 552 km²;
Jiangdong and Pingqiao Blocks: integrate evaluation and production construction.
Establish productivity of 5 billion m³/year.
Baitao Area: Exploration evaluation.
Baima Area: Exploration evaluation.

History of the first marine shale gas field in China

We make Fulin the shale gas demonstration district certificated by the China National Energy Administration and the Ministry of Land and Resources.

Four series of shale gas E & P key technologies

Resource evaluation method: based on volume method, analog method, FORSPAN method and single well dynamic evaluation method
Reservoir development evaluation method: include more than 10 key parameters such as geology, engineering and economy

Key Tech1: Shale gas reservoir characterization and evaluation technology
- With integration of X-ray diffractometer, nano-CT, FIB, argon ion polishing-scanning electron microscopy, mercury intrusion-adsorption method, shale permeability tester and digital core, etc., we develop microscopic pore characterization and physical property analysis technology.
- Shale gas source-storage coupling mechanism and evaluation technology.
- Geological-engineering combining rock phase identification and evaluation technology.

Key Tech2: Geophysical fine description technology for shale gas reservoirs
- Develop mineral component and TOC logging evaluation method, "four-pore component" model and dry clay skeleton constraint physical logging interpretation techniques, and free gas saturation logging evaluation technique.
Develop unsteady productivity evaluation technique for shale gas fractured horizontal wells with multi-area and pore-fracture coupled flow; and an empirical decline analysis method for shale gas wells with variable working system;

Develop well testing technique for shut-in pressure recovery and well testing analysis technique with production data;

Develop three methods for evaluating dynamic shale gas reserves.

### Series 1: Shale gas resource and reservoir development evaluation technology

**Key Tech3: Shale gas well evaluation technology**

- Develop unsteady productivity evaluation technique for shale gas fractured horizontal wells with multi-area and pore-fracture coupled flow; and an empirical decline analysis method for shale gas wells with variable working system;
- Develop well testing technique for shut-in pressure recovery and well testing analysis technique with production data;
- Develop three methods for evaluating dynamic shale gas reserves.

### Series 2: shale gas drilling technology in complex geological and surface conditions

**Key Tech2: Low-cost, low oil-water ratio, low-viscosity, high-shear oil-based drilling fluid system**

- Applicable temperature: normal ~ 180 °C
- Cost: reduced by 20%-40%
- Oil to water ratio: 82/18 ~ 90/10 to 65/35 ~ 75/25
- Low viscosity: low cycle pressure consumption, good leak-proof effect
- High shear: good sand carrying performance

**Domestically manufactured and widely applied in Fuling gas field**

**Series 2: shale gas drilling technology in complex geological and surface conditions**

**Key Tech3: Long horizontal well cementing technology**

- Develop a resilient toughness cement slurry system. The elastic material improves the impact resistance of cement by more than 50%, and the tough material nearly doubles the fracture toughness of cement;
- Develop comprehensive horizontal well cementing technology for long horizontal sections, meeting the requirements of large-scale fracturing. The cementing quality pass rate is 100%, with the excellent rate 89%.

**Series 2: shale gas drilling technology in complex geological and surface conditions**

**Key Tech4: Mountain area “well factory” drilling mode**

- Fast moving drilling rigs and equipment
- Platform ground layout optimization and drilling plant operation design technology
- Optimization design technology of horizontal well structure and cluster horizontal well tracks
- Drilling fluid recycling technology

**Series 3: Long horizontal well staged fracturing technology**

- Dominated by pumped bridge plug and perforation, high-efficiency drag reduction water fracturing and coiled tubing plug drilling
- Drilled bridge plugs in order, and joint production of all stages

**Pumped bridge plug + perforation:**
- Unlimited stage, large pumping rate
- Drag reduction water fracturing:
- Construct complex fracture network for enlarging stimulation volume

**Coiled tubing plug drilling:**
- Fast drilling bridge plugs in order, and joint production of all stages
Series 3: Long horizontal well staged fracturing technology

Key Tech1: High-efficiency and low-cost shale gas fracturing materials
- Develop a new working fluid system, with excellent drag reduction performance, easy preparation, no residue, low reservoir damage and low cost.
- Select high-strength low-density coated sand, low-density ceramsite and coated ceramsite as preferred proppant series.

<table>
<thead>
<tr>
<th>Proppant type/sizes</th>
<th>Application conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>coated sand (40/70, 30/50)</td>
<td>depth &lt; 2800m, closure stress &lt; 69MPa</td>
</tr>
<tr>
<td>low-density ceramsite (40/70, 30/50)</td>
<td>depth &lt; 3500m, closure stress &lt; 86MPa</td>
</tr>
<tr>
<td>coated ceramsite (40/70, 30/50)</td>
<td>depth &gt; 3500m, closure stress &gt; 86MPa</td>
</tr>
</tbody>
</table>

50s dissolution rate > 90%
Drag reduction rate > 70%
Apparent viscosity 6.2-8.3mPa.s
Cost 60% lower than similar foreign products

Series 3: Long horizontal well staged fracturing technology
Key Tech2: Well factory fracturing parameter design and operation mode optimization technology
- Parameter design: segmentation, perforation location, construction scale staggered distribution, increasing stimulation volume.
- Operation mode: synchronized fracturing and bridge plug pumping, alternate operating among wells for improving operation efficiency.

Applied in more than 60 platform, operation period shortened by 30-40%, 6-8 stage fracturing/d.

Series 3: Long horizontal well staged fracturing technology
Key Tech3: Fracturing evaluation technology
- Five techniques combined:
  - Comprehensive fitting inversion
  - Tracer monitoring
  - Microseismic monitoring
  - Fluid production profile test
  - Mathematical statistics

Series 3: Long horizontal well staged fracturing technology
Key Tech4: Horizontal well fracturing equipments and tools
- Independently develop series of fracturing pump trucks, sand mixing trucks, instrument trucks, manifold trucks, coiled tubing working machines and snubbing equipments.
- Establish the system of development, testing and manufacturing of domestic high-power fracturing units and application specifications.
- Independently develop easy-drilling composite bridge plug, the performance close to the same type of foreign products, and the cost reduced by 50%.

Series 4: Shale gas clean production technology
Key Tech1: Shale gas clean drilling technology
- Promote the use of electric rigs to replace diesel-driven drilling rigs. In Fuling implemented 208 wells, saving more than 50 million yuan and reducing diesel consumption by 23,000 tons.
- Select platform avoiding caves and dark rivers, adopts four-layer casing structure with guiding eyes and three openings, use clear water and non-toxic drilling fluid, for realizing clean drilling process with zero pollution.

Series 4: Shale gas clean production technology
Key Tech2: Shale gas development waste liquid treatment technology
- Build a recycling process for waste liquid, and develop the first modular fracturing fluid return treatment device for shale gas development in China.
- The waste liquid during drilling, fracturing and gas production process treated and reused more than 200,000 square meters, of which 130,700 out of 132,700 square meters of fracturing fluids have been treated and utilized, and the treatment rate is 98.5%.
Series 4: Shale gas clean production technology

Key Tech3: Shale gas oil-based cuttings treatment technology
- Develop treating device for oil-based drilling cuttings
- Processed 50,727 tons, and the oil content of the drilling cuttings after processing is less than 2%, meeting the industry standard requirements.

Industrialization model for shale gas efficient development
- Establishing an oil company model with the core as “market-oriented operation and project management”, realize optimal allocation of resources around the world, the development cost keeps declining, and the investment for a single well reduced by 20%.

• Form well factory production organization model: drilling and fracturing period reduced by about 40%.
• Innovate standardized construction mode including standardized design, standardized procurement, modularized construction, and informatization improvement, has realized the prefabrication, modularization and digital management of ground gathering and transportation system.

Shale gas safety green development management
- Establish emergency protection system. Set up emergency rescue center, equipping with emergency rescue personnel and materials;
- Jointly establish “Shale gas development safety and security work committee” with Fuling Government, and cooperate with local public security, fire protection, health, environmental monitoring and other departments to establish joint management mechanism;
- Develop complete emergency plan

Shale gas safety green development management
- Design environmental monitoring program for the development of the Fuling shale gas field, set up 78 normalized monitoring points to monitor surface water, groundwater, atmosphere, noise, soil, etc. More than 10,000 monitoring data indicates no change in the Fuling environment.

Shale gas development management model
- Strictly follow the “Safe Production Law”, “Environmental Protection Law”, safety evaluation, environmental assessment, occupational health assessment, water body maintenance program, earthquake disaster safety and other related evaluations, and always operate after obtaining government approval.
- Develop strict “four in one” 3D supervision system. Establish a supervision mechanism combining enterprises, third parties, government and society, and implement full-process, all-round and all-weather supervision on key operational links and key critical processes such as drilling, logging, recording, fracturing and gas testing.
- Establish emergency protection system. Set up emergency rescue center, equipping with emergency rescue personnel and materials;
Shale gas safety green development management

- Implementation of cluster wells, standardized operation, intensive land use, save more than 30% area of single-well site, and strongly apply land reclamation for restoring ecological originality and protecting beautiful homes.

Contents

1. Introduction of SINOPEC Shale Gas
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(1) Five-Year development ideas and goals

Development ideas: Taking technological innovation as driving force, taking construction of national demonstration zones as guide, insisting on the integration of exploration and development, increasing exploration efforts, breaking through new fields (deep shale gas and normal pressure shale gas), practicing green development and benefit development concepts, grasping market opportunities and realizing long-term steady production; continue to strengthen basic research and technical research, achieve leapfrog development of shale gas, maintain shale gas industry as important benefit growth point of SINOPEC.

Development goal: Maintain 10 billion productivity, open up several new productivity building blocks, explore new areas of shale gas in the Sichuan Basin and the periphery and other areas, and build a new capacity of 10-15 billion. Increase the yield in 2020 to 10-13 billion.

(2) Strengthen basic research and technical research

Basic research

Shale gas enrichment rule and exploration evaluation method: focus on high-quality shale development characteristics, shale gas occurrence and preservation mechanism, main controlling factors of shale gas accumulation, and demonstrate shale gas enrichment rule; develop shale gas basin, zone, target evaluation system, give out shale gas resources potential and favorable targets in key exploration districts.

Shale gas generation and reservoir mechanism: focus on the hydrocarbon formation and storage mechanism of organic-rich shale, hydrocarbon-forming biological combination and hydrocarbon generation potential, and analyze the organic matter abundance, type, maturity, mineral composition and storage of shale and gas-bearing characteristics for comprehensive evaluation of shale gas quality; based on diagenesis analysis and pore formation evolution simulation experiments, study the microscopic pore characteristics of shale, reveal the formation and evolution of organic and inorganic pores and preservation mechanism, and establish an evaluation method.

Technical research

Strengthen geophysical technology

Focus on the target layer shale gas logging evaluation, high-precision seismic acquisition and processing, geological-engineering sweet point earthquake prediction, micro-seismic monitoring, and other key technologies to provide technical support for shale gas exploration and development.

Strength engineering technology research and support technology integration

Develop technology series for fast drilling, strong suppression drilling fluid, long horizontal well cementing and volume fracturing in various shale layers, especially deep shale gas, normal pressure shale gas, continental and transitional shale gas layers. Continue to strengthen the localization of various equipment, tools and materials.
Thanks!
**3D Integrated Drilling Solution in China**

**What is 3D?**

**Drilling Service:**
- **AutoTrak™ Curve**
- High-deviation steering system

**Drilling Completion Fluid:**
- **Carbo Drill™**
  - Oil-based drilling fluid

**Drill Bit:**
- **Dynam us™**
  - Jiao Long series drill bit

**Mile-A-Day Drilling in US**

**3D一体化模式源自北美提速增效**

**Achieved 4,000 ft per day**

- 1219 米/天

**Achieved 2,000 ft per day**

- 609 米/天

**16 WELLS**

**83 WELLS**

**24 WELLS**

**116 WELLS**

**First Utica 'Mile-a-Day' well**

**2019**

2018

2017

2016

2015

2014

2013

2012

**394 'Mile-a-Day' wells drilled**

**Achieved 7,000+ ft per day**

**First Marcellus 'Mile-a-Day' well**

**2019**

2018

2017

2016

2015

2014

2013

2012

**155 WELLS**

**Achieved 10,067 ft per day**

**2019**

2018

2017

2016

2015

2014

2013

2012

**Autotrak™ Curve**

- Continuous proportional steering, to fulfill best Inc.& Az. control in the industry
  - 尺寸矢量控制，以实现业界最精确的井斜和方位控制

- **Sealed hydraulic control system**, zero affect from the drilling fluid
  - 封闭的液压控制系统，不受泥浆清洁度影响

- **Integrated BHA design**, to save rig time on the rig floor
  - 一体化的工具设计，最大限度的减少在钻台上的组合时间

- **Motorized RSS**, to achieve both high DLS and ROP
  - 与马达组合，提高钻速与高造斜率兼得

- **No limitation on bit pressure drop**
  - 不受钻头压降的影响

- **Geo-Purpose Fulfill**, to maximize reservoir exposure
  - 实现地质目的，提高产层钻遇率

- **Drilling Efficiency Enhancem ent**, to minimize downhole problem
  - 提高钻井效率，减少复杂情况

- **Downhole Risk Avoidance**, to reduce stuck in hole
  - 保障施工安全，降低卡钻风险

- **Reduce NPT**, to maximize reservoir exposure
  - 降低非生产时间，提高产层钻遇率

- **Enhance ROP**, to save rig time on the rig floor
  - 提高机械钻速，最大限度的减少在钻台上的组合时间

- **Continuous proportional steering**, to fulfill best Inc.& Az. control in the industry
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- **Enhance ROP**, to save rig time on the rig floor
"Solo Run to TD" in Shale Gas
在国内页岩气实现“一趟钻完钻”

- AutoTrak™ Curve achieves solo run to total depth in 8.5" section
- 使用AutoTrak™旋转载向实现从造斜点到完钻点一趟钻完成8.5"井眼的钻井施工

截止今年10月已有7口井完成一趟钻完钻

- Achieve 7 wells of "Solo Run to TD"


共计已有11口井实现“一趟钻完钻”

- Total 11 "Solo Run to TD" wells drilled

7 WELLS

11 WELLS

Drill Bit Selection & Optimization
钻头选型和优化

- Beacon Remote Support Center
- 数据远程遥控中心

2019-12-18

Project Organization
项目组织结构

Beacon Remote Support Center
- 数据远程遥控中心

- Beacon Remote Support Center
- 数据远程遥控中心

- Beacon Remote Support Center
- 数据远程遥控中心

Problem Identification
分析问题

Understand Application
理解该应用环境

- Stability
- 稳定性

- Steerability
- 导向性

- Hydraulic optimization
- 水力学优化

- Materials Innovation
- 材料技术革新

- Drilling Bit Selection & Optimization
- 钻头选型和优化

- Drilling Fluid: Rheology & Hydraulics Optimization
- 钻井液：优化流变性与水力学表现

- Wellbore Cleaning and Suspension
- 井眼清潔与悬浮

- Lower Surge and Swab
- 更低启泵压力, 更低抽吸效应

- Low ECD
- 更低ECD

- Higher annulus velocity
- 更高环空返速

- WSOBM
- 贝克油基泥浆

- Other DCF
- 传统油基泥浆

- Beacon Remote Support Center
- 数据远程遥控中心

- Beacon Remote Support Center
- 数据远程遥控中心

- Beacon Remote Support Center
- 数据远程遥控中心

Beacon服务通过分析历史数据，同时实时跟踪钻进情况，打造综合提高钻井效率的解决方案。网络仪表盘整合并诠释隐藏在现有管理软件以及钻井报告系统中复杂的钻井参数，为客户随时随地可用于决策的信息。

- Beacon Remote Support Center
- 数据远程遥控中心

3D DS Case History in China
3D在国内的应用案例

- Beacon Remote Support Center
- 数据远程遥控中心

- Beacon Remote Support Center
- 数据远程遥控中心

- Beacon Remote Support Center
- 数据远程遥控中心
December 18, 2019

3D IDS Summary in Shale Gas


+45,000 m total footage
+8,000 ft 9th generation drill bit
+200 person-days

Record Performance for 3D IDS in Shale Gas

- 136° highest bottomhole temperature
- 25 m/hr average 3-day mechanical rate
- 2178 m single run record
- 1908 m horizontal section
- 276 m daily drilling period
- 9.33 days drilling period
- 1891 m single run record

Case History of Sichuan Shale Gas

Background

- Mini Fault & Micro Fracture
- T&D friction torque
- Mud loss & Pack off at the same time
- Pressure complex - leak, collapse, same layer
- Stuck or LIH Risk

Challenge

- Complex geological requirements
- Engineering safety

Baker Hughes 3D Integrated Drilling Service


- +45,000 m total footage
- +8,000 ft 9th generation drill bit
- +200 person-days

For the entire 8.5” section, the new record is 9.33 days drilling period.

The goal was to drill horizontally through 8.5” section, +45,000 m of total footage.

The challenges include complex geological conditions, engineering safety, etc.

The solution includes:

- ATK Curve & Motor combination for high GOR rate with extremely high reliability
- High shear release rate oil-based mud system
- Baker Hughes patent NANO SHIELD/BRIDGEFORM for页岩封堵 module, ensuring wellbore stability and clean wellbore
- T506SX drill bit with latest P121 cutters technology, stable and high efficiency in high silica rocks
- Rig crew and operational team precision operation, making the instrument and mud work stably and reliably in high temperature environment.
- 9.33 days drilling period, breaking the previous shortest drilling period record of the whole province.

Milestone - Shortest Drilling Period in the Area

- 2178 m single run record
- 136° highest bottomhole temperature
- 25 m/hr average 3-day mechanical rate
- 276 m daily drilling period
- 9.33 days drilling period
- 1908 m horizontal section

Baker Hughes 3D Integrated Drilling Service

1. Background

- CNOOC shale oil & gas, Eagle Ford and Niobrara
- Operator: Chesapeake
- Farmed in 2010
- CNOOC RI provided technology support since 2010.

Integrated technology system of exploration and development for shale oil and gas

Challenge of production forecast

Need scientific and objective technology and methods for the improvement of production forecast.

Differences between shale oil & gas and conventional:
- Nanopore, Nano Darcy, multi scale flow with more flow mechanisms.
- Multistage hydraulic frac, which cause reservoir more serious heterogeneous.
- Fast decline in the early stage, slow decline in the middle and late production stage.

Comparing operators by production and technology using public data

- Proportion of wells (Peak Boe=400-1600) increases year by year.
- Chesapeake is Large & Medium level by Peak production.
1. Background

- Comparison of production type curves by vintage
  - Peak of type curve increases by years.

2. Production forecast methods and application

2.1 Data mining method

- There are more than 3000 wells’ static and dynamic parameters available.
- And we are trying to find out how these parameters affect the production, and how to use these parameters to predict production.

Problems:
- There isn’t a significant relationship between static or dynamic parameters and production when doing single factor analysis (simple linear regression).

2.1 Data mining method

- Production factors: numerous, interactive.
- Hard to determine the key factors.

2.1 Data mining method

- Data mining method: factor interrelationship analysis and key factor determination.

- Subdivide areas by formation property
- Determine key factors by quantitative evaluation

Quantitative evaluation by weight of each factors
2.1 Data mining method

- Production forecast using ANN model

<table>
<thead>
<tr>
<th>Area</th>
<th>Model structure</th>
<th>Fitting accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-2</td>
<td>2 layers, Neuron 10/60</td>
<td>95.0%</td>
</tr>
<tr>
<td>5-3</td>
<td>2 layers, Neuron 40/8</td>
<td>98%</td>
</tr>
<tr>
<td>3-2</td>
<td>2 layers, Neuron 25/30</td>
<td>95%</td>
</tr>
</tbody>
</table>

- Set up forecast model separately for oil, volatile oil and wet gas.
- For single decline parameter, the prediction error < 10%.

<table>
<thead>
<tr>
<th>Area</th>
<th>Forecast parameter</th>
<th>Prediction error</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-2</td>
<td>Decline Rate (gas)</td>
<td>9.9%</td>
</tr>
<tr>
<td></td>
<td>Decline index (gas)</td>
<td>7.2%</td>
</tr>
<tr>
<td></td>
<td>Decline Rate (oil)</td>
<td>10.2%</td>
</tr>
<tr>
<td></td>
<td>Decline index (oil)</td>
<td>8.9%</td>
</tr>
<tr>
<td>5-3</td>
<td>Decline Rate (gas)</td>
<td>9.2%</td>
</tr>
<tr>
<td></td>
<td>Decline index (gas)</td>
<td>4.7%</td>
</tr>
<tr>
<td></td>
<td>Decline Rate (oil)</td>
<td>8.9%</td>
</tr>
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</tbody>
</table>

2.1 Data mining method

- Cum_production >3 years' prediction error < 10%

2.2 Type curve production forecast technology

- Problems: no universal method, different companies with different ways
  - How to determine type curve model and parameters, what is the standard process of type curve method.
  - Production rates are different among wells and blocks, which means that deterministic forecast method has potential risk.
  - Need different production forecast methods in different exploration and development stages.

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>Standard model for linear flow region</td>
</tr>
<tr>
<td>Hyperbolic</td>
<td>Designed to simulate the behavior of a well in a reservoir under linear flow condition</td>
</tr>
<tr>
<td>Modified Hyperbolic</td>
<td>Similar to Hyperbolic, modified to fit specific reservoir characteristics</td>
</tr>
<tr>
<td>Stretched Exponential</td>
<td>Modifies the hyperbolic model to better fit exponential decline</td>
</tr>
<tr>
<td>Power Law</td>
<td>Used in the early stage of production</td>
</tr>
</tbody>
</table>

- Determined the selection principle of type curve models and established the recommendation method of type curve production forecast.
  - Suggestions: in linear flow region, Doung's model or linear flow model is suggested. In later period, exponential model is suggested.
  - Established a three-segment model for shale gas.
  - Provided solutions on 6 key problems and recommended type curve forecast workflow:
    - Determination of initial production
    - Determination of the shortest production horizon
    - Production time efficiency effect on forecast
    - Consideration on fracture stages, etc.
2. Production forecast methods and application

2.1 Data mining method

2.2 Type curve production forecast technology

2.3 Analytical model production forecast technology

2.4 Numerical simulation production forecast technology
Controlled method for reducing multiple solutions in rate transient analysis

- Permeability and fracture parameters are key factors for oil and gas production, and important for production forecast with theoretical method.
- Hydraulic fracture length is an important factor for well distance.
- Formation and fracture difficulties: shale permeability is ultralow and fracture networks are complex when using multistage hydraulic fracturing which makes it hard to interpret formation permeability and fracture parameters, and to forecast production.

Experimental method is hard to get the low permeability.

Complex fracture network

Problems in field using:
1. Minus intercept
2. Variable rate-variable pressure
3. Multistage linear flow
4. Two phase flow
5. Determine the time of BDF

Production curve of type well (variable rate-variable pressure)

\[ \text{Material balance time:} \quad t_m = \frac{Q_{ogip} - Q_{wip}}{Q_{ogip}} \text{ time} \]

Production data analysis (PDA)

Establish linear flow analysis method for two-phase flow, variable rate-variable pressure, multistage linear flow and minus intercept problems.

Problems in field using:
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3. Multistage linear flow
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Rate-time log-log curve

Production curve of type well (variable rate-variable pressure)

Production data analysis (PDA)

Linear flow analysis method is based on the theory of long term transient linear flow. It is a theoretical method to interpret formation and fracturing parameters by analyzing production data (rate and pressure).

Carried out plenty of theoretical and practice works:
- Shale oil: dealing with linear superposition time is more close to the real value.
- Shale gas: when using pseudo time, linear superposition time is more accurate; when using real time, material balance time is more accurate.

Assumptions: half fracture length = 100m, permeability = 1000nD

Production data analysis (PDA)

• Two-phase flow mathematical model of condensate gas and volatile oil is established, and the analytical solution of two-phase flow production forecast is given.

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Analytical solution

- Established mathematical model for condensate gas and volatile oil.

Key points:
- hydraulic fracture
- inner reservoir, single medium
- outer reservoir, single medium
- two-phase flow, volatile oil, condensate gas

Theoretical analysis process:

1. Material balance time: \[ t_m = \frac{Q_{ogip} - Q_{wip}}{Q_{ogip}} \text{ time} \]
2. Linear superposition time: \[ t_s = \frac{Q_{ogip}}{Q_{ogip}} \text{ time} \]
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2. Production forecast methods and application

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2.3 Analytical model production forecast technology

2.4 Numerical simulation production forecast technology

2.3 Analytical model production forecast technology

- Production matching and prediction
  - Match and prediction data
  - Actual data

Match and prediction data

Forecast accuracy: 80%

2.4 Numerical simulation production forecast technology

- Numerical simulation proved the two-segment characteristics of production decline: the yield curve conforms to the “two-segment” typical curve.

- Sensitivity analysis indicated the directions of increasing production.

<table>
<thead>
<tr>
<th>Oil EUR (%)</th>
<th>Gas EUR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case: 553 MSTB</td>
<td>Base case: 2120 MMSCF</td>
</tr>
</tbody>
</table>

- Multi-scale flow characteristics: molecular scale, nano scale, micro scale, mesoscopic scale, macro scale.

- Seepage and diffusion characteristics: desorption, diffusion, non-Darcy flow, Darcy flow, stress sensitivity, start-up pressure gradient, micro-nano scale fluid phase states, etc.

The special flow mechanism of shale oil and gas

Multi-scale flow characteristics of shale oil and gas
Established a compositional model considering the particular mechanisms of shale oil and gas in multistage hydraulic fracturing.

Based on Eagle Ford geology and well completion parameters, the model is used to study the impact of stress sensitivity, start-up pressure gradient, adsorption and desorption, Knudsen diffusion, molecular diffusion, confined phase state and other mechanisms on productivity for shale gas, condensate gas, volatile oil and black oil.

2.4 Numerical simulation production forecast technology

Based on two-year data match, the yield prediction accuracy in 3-5 years is mostly 10%.

Establish a set of multi-method complementary production forecast methods.

Method comparison

Based on 3-year data fitting, the prediction accuracy can be 90% within 3-5 years. There is prediction difference in middle and late stages, and in different wells.

Conditions for method using:

- Big data, enough wells and parameters
- Type curve, decline trend, single phase flow
- Analytical model, uncertain predictions can be used
- Numerical modeling, need complete geological, engineering and fluid parameters.
- Method recommendation:

The four methods refer to each other, determine the EUR range, possible volume, or mean.

3. Conclusion

Shale reservoir particular characteristics, complex fluid flow in porous media, large scale hydraulic fracturing stimulation cause great challenge on shale oil & gas production forecast.

No universal production forecast methods, different researchers use with different methods. Even with the same method, different results will be obtained by the different researchers.

The methods based on the empirical and statistical analysis have some certain adaptability. However, the mechanism study is necessary to get scientific production forecast method.