页岩气技术及标准化国际研讨会

International Seminar on Shale Gas Technology and Standardization

中国能源行业页岩气标准化技术委员会(NEA/TC26)
ChinaEnergy Industry Shale Gas Standardization Technical Committee (NEA/TC26)

美国贸易发展署(USTDA)
U.S. Trade and Development Agency (USTDA)

中美能源合作项目(ECP)
U.S.-China Energy Cooperation Program (ECP)

美国国家标准化机构(ANSI)
American National Standards Institute (ANSI)

2019.11.5 四川·成都
November 5, 2019 Chengdu, Sichuan

Content / 目录

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**

	Presenter: 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

<u>2019 年 11 月 5 日</u>

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*
- ***温凯时（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**

11:10 – 11:45 **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**
美国何威安卓律师事务所合伙人 Mark Thurber

11:45 – 12:15 **索拉移动式发电车应用**
索拉透平公司市场发展部经理 Chris Mellos

12:20 **午餐**

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**)**

U. S. Trade and Development Agency (USTDA)

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.

U.S. TRADE AND DEVELOPMENT AGENCY

美国贸易发展署 (USTDA)

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

FOR MORE INFORMATION

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中美标准与合
格评定合作项目

由美国贸易发展署 (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。根据美国民间业界相关机构组织的建议，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情况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

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American National Standards Institute (ANSI)

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.

ANSI
American National Standards Institute

美国国家标准协化机构（ANSI）

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，为成员公司及其商业伙伴提供动力，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)CP 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

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)

美国驻成都总领事馆
商务领事

Principal Commercial Officer
U.S. Consulate General in Chengdu

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 (温凯时)

美国贸易发展署
东亚区项目管理主任

Director of Program Management, East Asia Region, U.S. Trade and Development Agency (USTDA)

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.

Steven Winkates是美国贸易发展署东亚地区项目管理主任，常设办公地在美国驻中国大使馆。他负责管理美国贸易发展署在中国和蒙古区域的项目，包括指导业务发展工作、协调该地区和美国利益相关方的关系、并向两国的潜在合作伙伴推广美国贸易发展署的活动及相关服务。在此之前，Winkates先生曾任职于一家专门从事交通基础设施项目开发的咨询公司。他曾担任美国贸易发展署中国和东南亚地区发展负责人和美国商务部政策分析师等相关职位。

Winkates先生先后获得罗德学院的文学学士学位和乔治城大学的公共政策硕士学位。

Roland Goodman

美国石油学会
上游标准委员会经理

Manager of Upstream Standards,
American Petroleum Institute (API)

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，目前是是标准专业人员协会的成员。

Mark Thurber

美国何威安卓律师事务所北京代表处的首席代表/合伙人

Chief Representative (Beijing Office) and the Partner, Hunton Andrews Kurth LLP

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的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际办公室紧密合作，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。

John Wheeler (张炜乐)

李基林资源评估公司
总裁

President,
Lee Keeling &
Associates, Inc.

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.

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

索拉透平公司
市场发展部经理

Market Development Manager, Solar Turbines (Caterpillar)

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 (蔡一凡)

贝克休斯公司
钻井部门作业经理

Operation Manager of Drilling, Baker Hughes

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.

蔡一凡，工学硕士，2010年毕业于上海交通大学。在石油和天然气行业从业9年，自2014年起开始负责贝克休斯中国西南地区的页岩气业务。目前在成都担任作业经理一职，此前工作于沙特阿拉伯和科威特等地，擅长定向钻井和地层评估等相关技术。

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

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.

李鹭光曾在塔里木油田工作，并担任过中石油西南油气田公司总经理、四川石油管理局局长、中石油川渝地区石油企业协调组组长等职务。2014年，调任中石油总部，任总经理助理。2016年11月，兼任中石油塔里木油田分公司总经理。2018年，任中石油塔里木油田分公司勘探与生产分公司总经理、党委副书记。2017年6月任中国石油天然气股份有限公司副总裁。在中国石油行业拥有近35年的工作经验。

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)

全国天然气标准化技术委员会副主任委员

Deputy Director of China Natural Gas Standardization Technical Committee

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.

常宏岗毕业于浙江大学化学工程专业，教授级高级工程师，现任中国石油西南油气田分公司天然气研究院院长，国际标准化组织天然气上游分技术委员会（ISO/TC193/SC3）主席，全国天然气标准化技术委员会副主任委员，全国石油天然气标准化技术委员会委员，能源行业页岩气标准化技术委员会委员。主要从事油气田开发领域的科研、标准化以及管理工作。获国家和省部级奖励8项，发表论文40余篇，制修订国际和国家标准20余项。

ZHANG Leifu (张磊夫)

中国国家能源局页岩气研发（实验）中心

National Energy Administration Shale Gas Research Center

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。

ZHANG Zheng (张震)

中国石油天然气股份有限公司西南油气田分公司高级工程师

Senior Engineer, PetroChina Southwest Oil and Gas Field Company

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.

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)

中国石化工程师

Engineer, Sinopec

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.

牛 骏 北京大学流体力学专业，中国石化石油勘探开发研究院采油工程研究所副所长，高级工程师。长期从事页岩油气储层-井筒一体化数值模拟及采油气工艺优化研究和现场支撑，发表英文SCI论文10余篇，获发明专利授权10项。

BAI Yuhu (白玉湖)

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。

中国海油高级工程师

Senior Engineer,
CNOOC

Presentations

演讲材料

Implementation and Prospect of China Shale Gas Technical Standard System

By:Chang Honggang

2019

China Energy Technical Standardization Committee of Shale Gas

Nov.5th.2019

Foreword

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

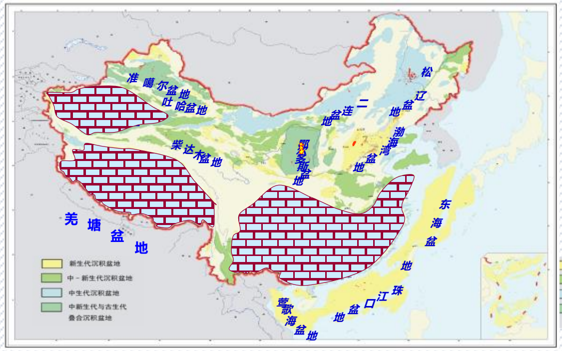
I Resources Distribution of Shal Gas in China

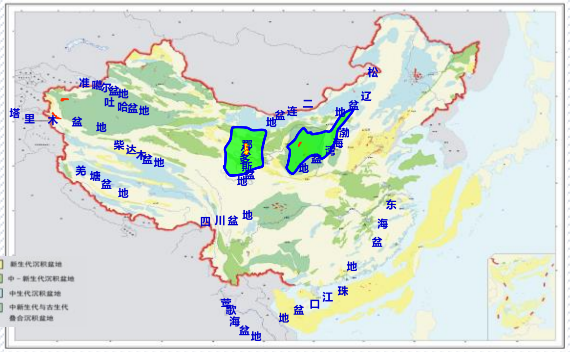
CSCSG
NEA/TC26

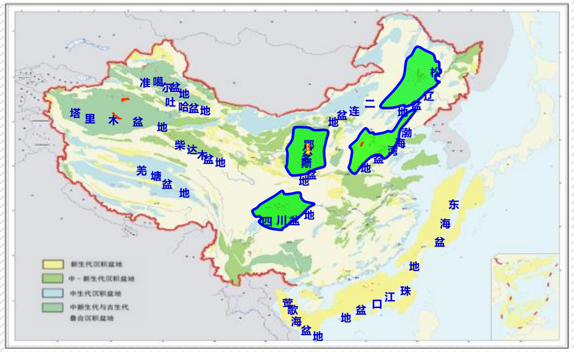
There are three types of shale reservoir in China: marine, transitional and continental facies, The overall geography distribution is "marine in the south and continental in the north"

- **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.


Schematic Diagram of Distribution of Organic-Rich Marine Shale

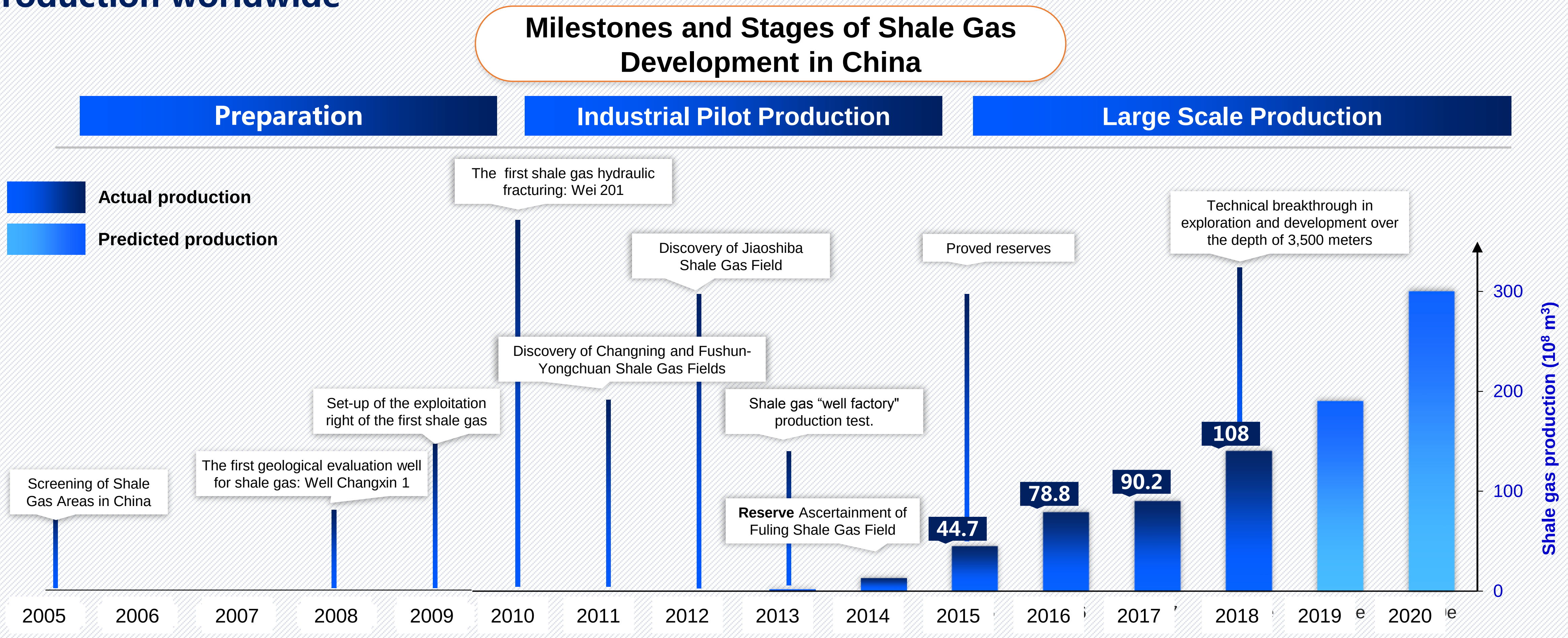

Schematic Diagram of Distribution of Organic-Rich Transitional Shale


Schematic Diagram of Distribution of Organic-Rich Continental Shale

Marine shale								Transitional shale			Continental shale			
Changcheng Period	Jixian County Period	Qingbaikou Period	Sinian Period	Cambrian Period	Ordovician Period	Silurian Period	Devonian Period	Carboniferous Period		Permian Period	Triassic Period		Jurassic Period	Paleogene Period
Tieling Formation	Hongshuizhuang Formation	Xiamaling Formation	Doushantuo Formation	Niutitang Formation	**Wufeng Formation**	**Longmaxi Formation**	Luofu Formation	Benxi Formation	**Shanxi Formation**	Longtan Formation	Xujiahe Formation	**Yanchang Formation**	Ziliujing Formation	Shahejie Formation

I 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



II History of Exploration and Development of Shale Gas in China

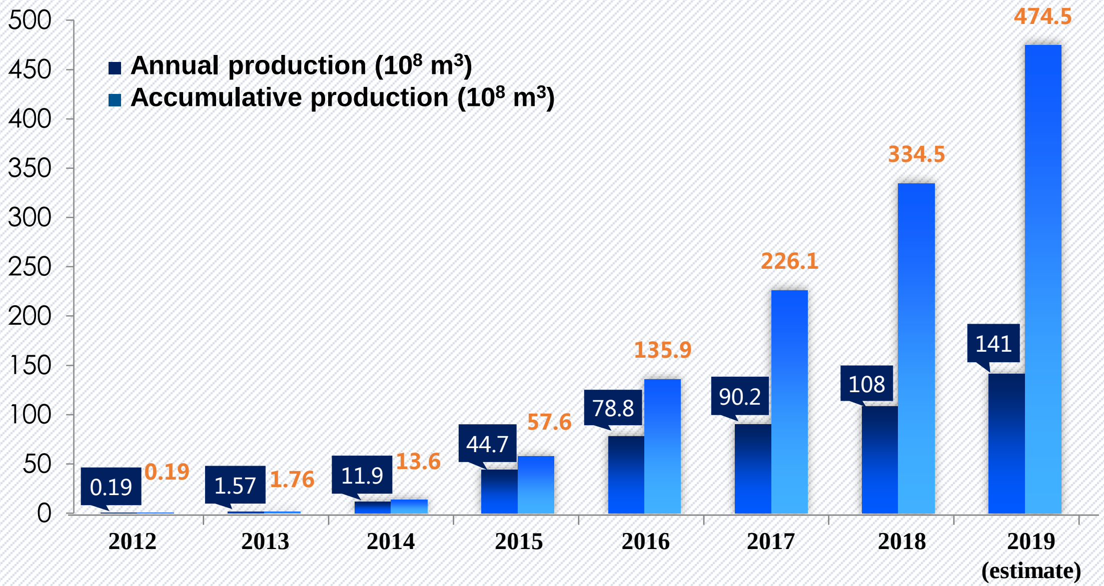
The marine shale gas has achieved effective production, in the depth less than 3,500 meters in the Sichuan Basin, and has achieved industrial breakthrough, in the depth over 3,500 meters

< 3,500m

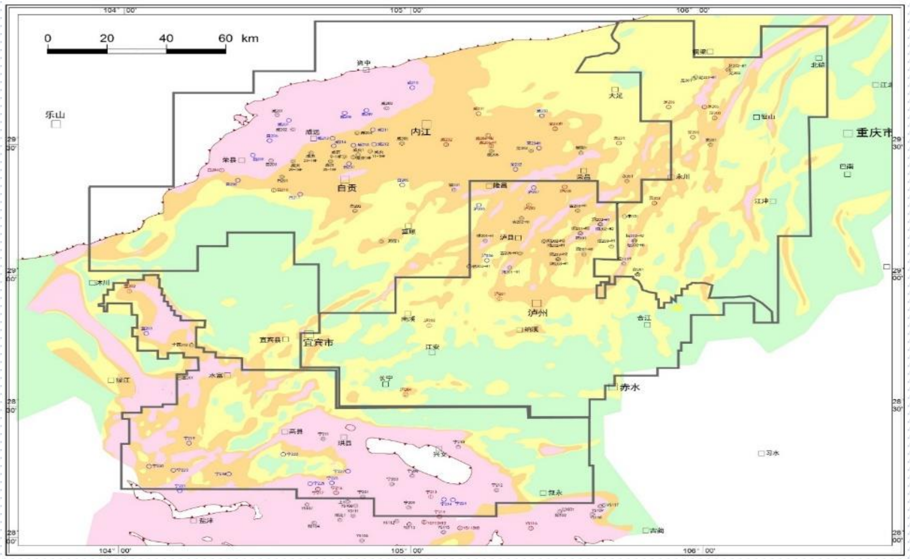
- Submitted a proven reserves of nearly 2 trillion cubic meters
- Efficiently completed the establishment of Shale Gas Demonstration Areas

> 3,500m

- High-production shale gas wells were drilled in several plays, such as Lu 203, the testing production was 1.379 million m^3/d.
- It is expected to establish the first batch of deep shale gas development demonstration areas in China by 2020.



Production of Marin Shale Gas in China

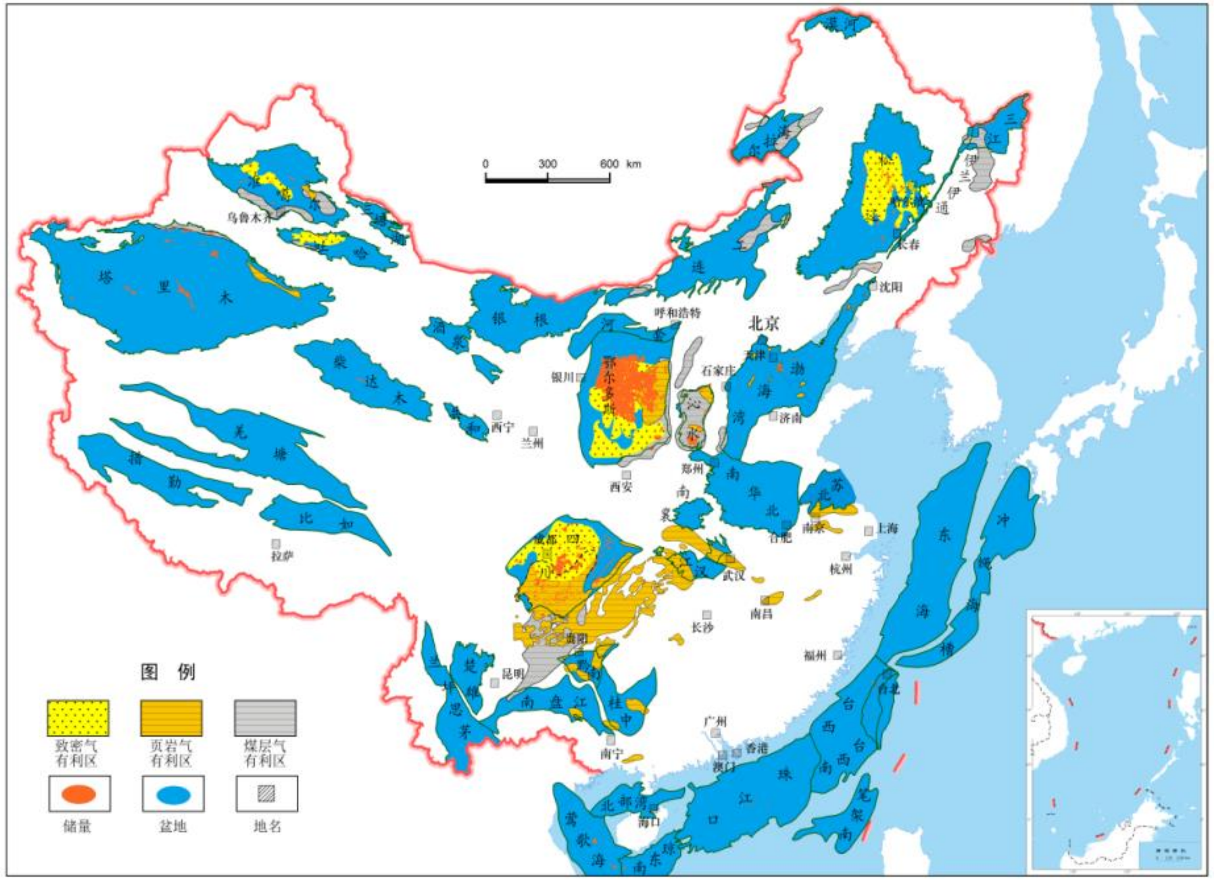


Deep Shale Gas Wells Planning

II History of Exploration and Development of Shale Gas in China

CSCSG NEA/TC26

The transitional and continental shale gas resources are in the evaluation stage, and some areas show a good indication



Main Gas Wells at Transitional and Continental Shale Formations

Ordos Basin: 66 evaluation wells were drilled , and the highest testing production of single well is 53,000 m^3/d.

Sichuan Basin, Qaidam Basin and Southern North China Basin: multiple wells prove the existence of the transitional and continental shale gas.

Continental Shale Gas Well Testing of Liuping 177

III Six Technologies for Shale Gas Exploration and Development in China

The shale gas reservoir in Sichuan Basin are quite different from those in North America

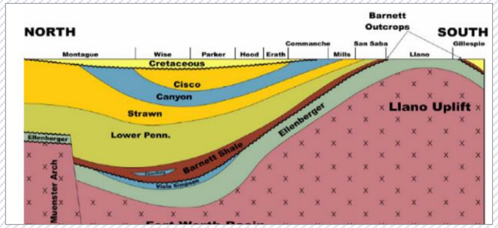
Geological conditions | The storage conditions and gas content are generally poor,the key evaluation parameters of reservoir are poorer than those in North America

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

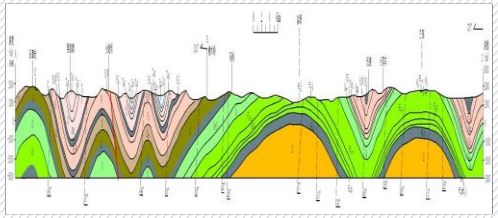
Comparison of Geological and Ground Conditions between North America and Sichuan Basin

System	Years ago (10^8 Years)	Depth (m)	Thickness (m)	Porosity (%)	Gas Content (m^3/t)	Organic Carbon (%)	Area	Typical Gas Field
Quaternary	0.02							
Tertiary	0.65							
Cretaceous	1.35	About 3,500	76	11	6.5	4.5		Eagle Ford
Jurassic	2.05	3200~4200	75	12	6.1	3	North America	Haynesville
Triassic	2.50	2500~4400	150	7.8	5.8	3.6		Montney
Permian	2.85							
Carboniferous	3.50	1000~3000	107	6	9.2	4.5	North America	Barnett
Devonian	4.05		94	7.8	5.5	7.1		Marcellus
Silurian	4.40	2000~4500	42	4.0	4.1	3.2	**Sichuan**	**Changning-Weiyuan**
Ordovician	5.00							
Cambrian	6.00	3000~5500	125	1.7	1.9	2.9	**Sichuan**	**Changning-Weiyuan**



Simple structure & gentle stratum in North America


Flat ground & less population in North America


Complex structure & fault development in Sichuan Basin


steep mountains & dense population in Sichuan Basin

III Six Technologies for Shale Gas Exploration and Development in China

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

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

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

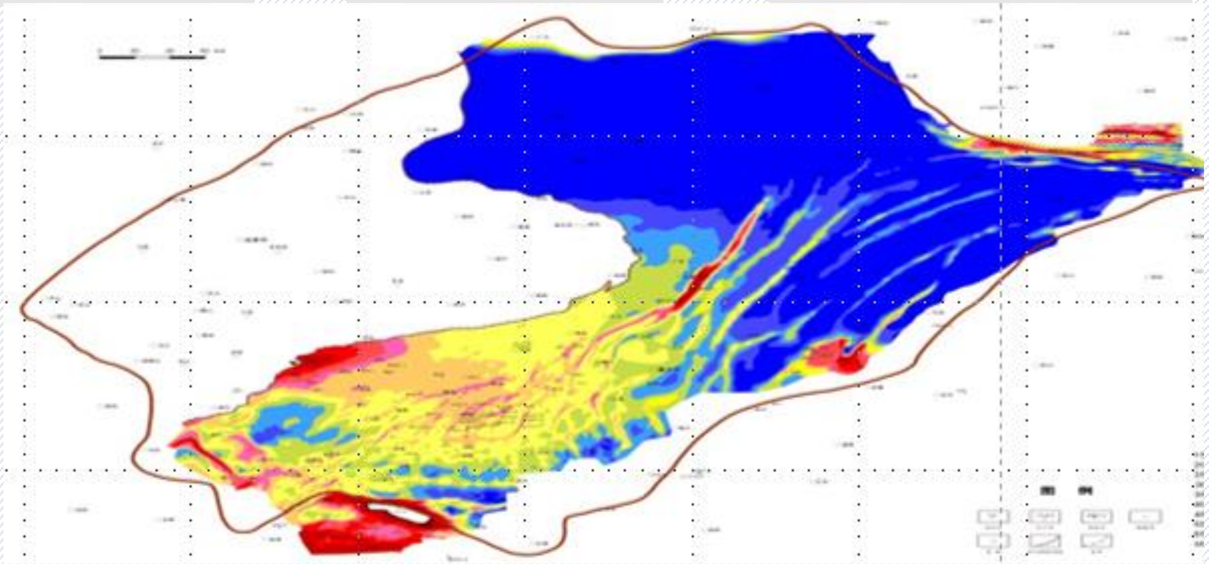
04 Favorable area evaluation and optimization technology

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%



Favorable Shale Gas Area between Wufeng Formation ~ Longmaxi Formation

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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.

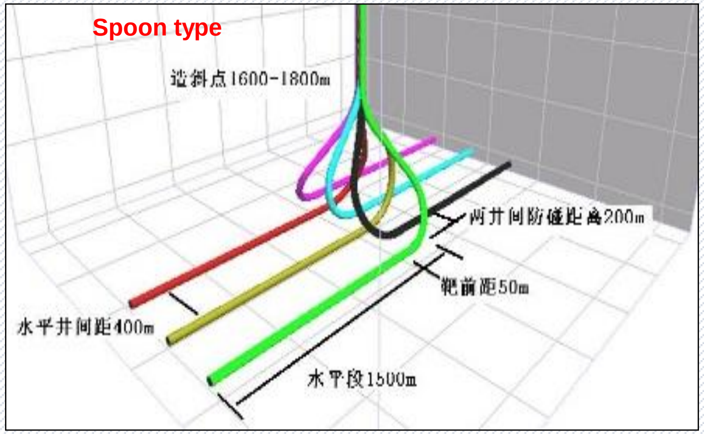
- **01** Modelling technology of geology-engineering integration
- **02** Development optimization & deployment technology
- **03** Horizontal well optimal design technology
- **04** Dynamic tracking, quantitative analysis & prediction technology

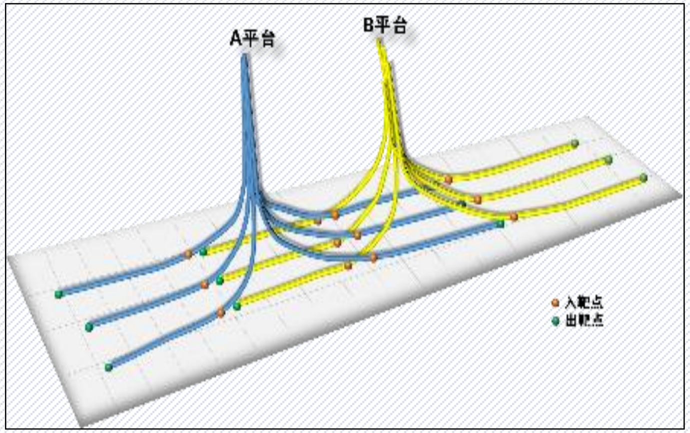
Technical Level

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





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.

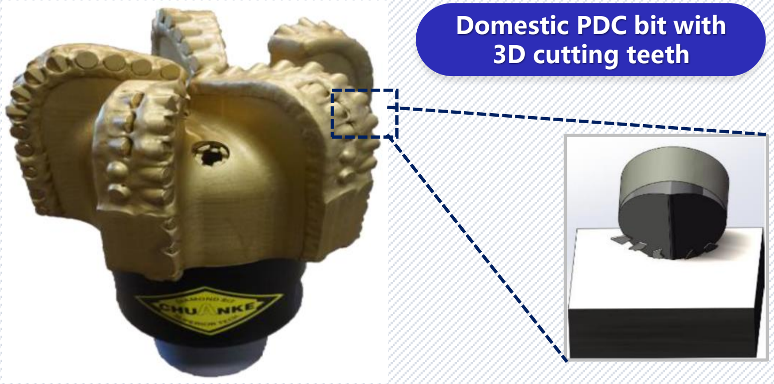
- **01** Optimal drilling design technology of multi-well pad
- **02** Horizontal well fast drilling technology
- **03** Steering technology of geology-engineering integration
- **04** Cementing technology under oil-based drilling fluid conditions

Drilling Parameters

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

Technical Level

- **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)



Domestic PDC bit with 3D cutting teeth

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

Technical level

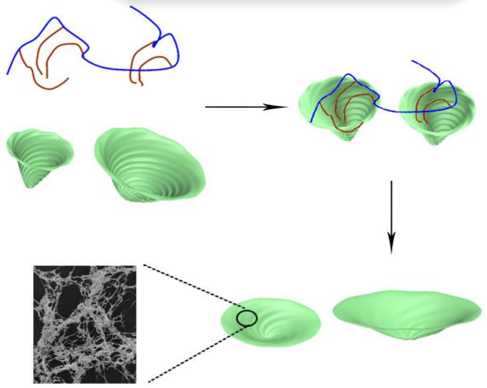
Indexes	Unit	Initial	Current
Interval length	m	80~100	45~55
Pumping Rate	m^3/min	10~12	14~16
Sanding density	t/m	0.5~1.7	1.8~3.0, maximally 4.1
Fluid volume	M^3/m	26	35~40
SRV	$10^8 m^3$	0.6	>1.2
Well average test daily production	$10^4 m^3$	9.8~16.7	19.7~22.9

Key Tools & Fluid

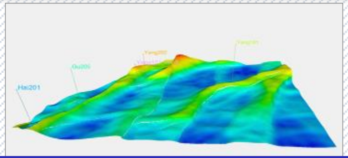
Developed multi-stage fracturing tools: with the self developed tools, the cost was reduced by 30% to 50%

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

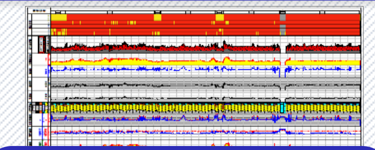
Mechanism of Friction Reducer



Integrated Fracturing Design and Implementation

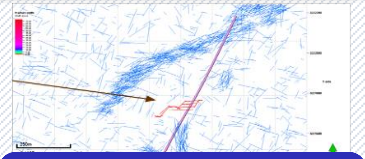


3D Geological Model of Well Site



Reservoir Evaluation of Horizontal Section

Overlay of Microseismic and 3D Crack Prediction



Fracture Prediction

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"

Key Tech.

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

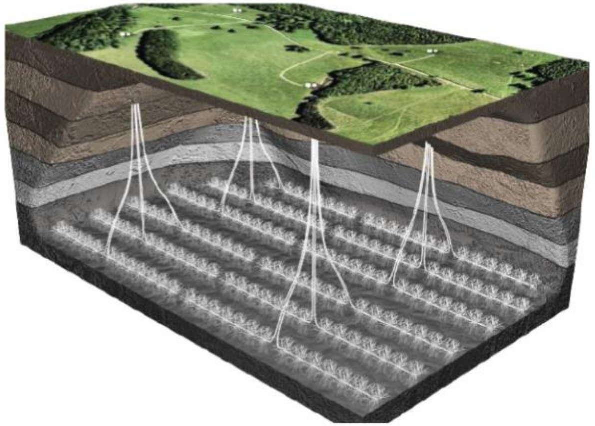
Technical Level

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

Well factory drilling

Well factory fracturing with two frac teams



Well factory layout

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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

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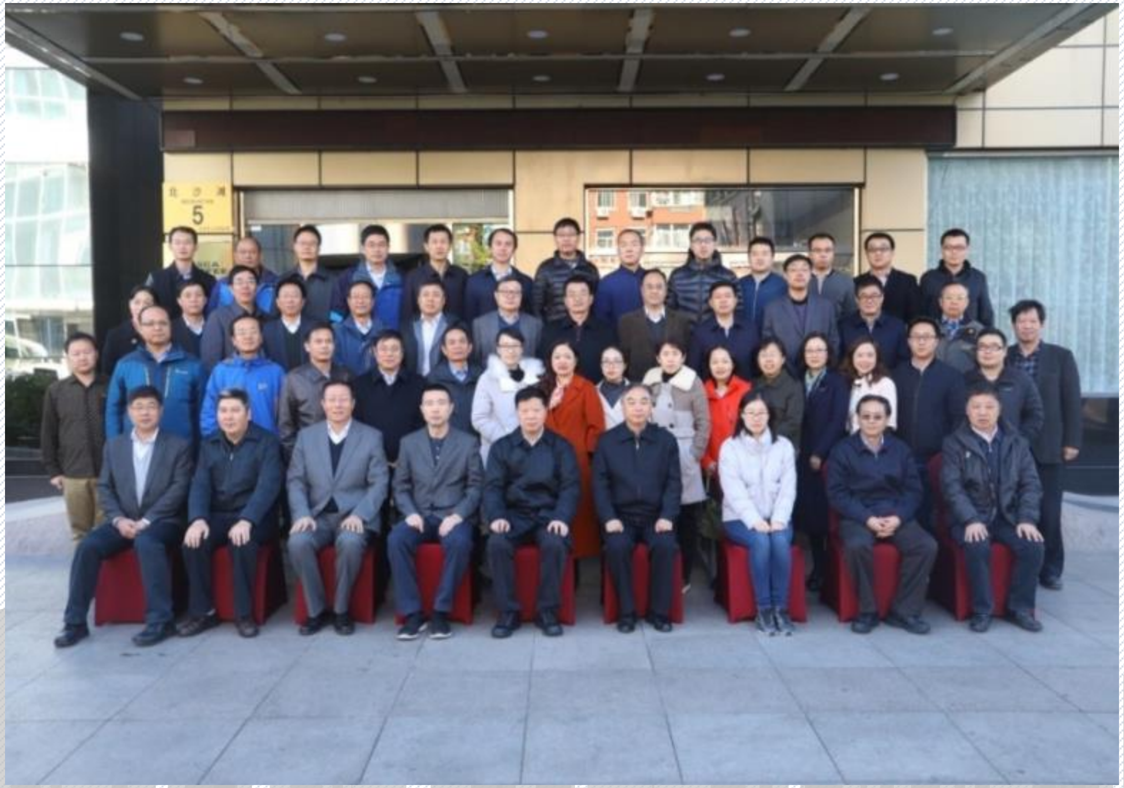
01 Overview of the Shale Gas Industry in China

02 Achievements of China Shale Gas Technical Standard System

03 Prospect of China Shale Gas Technical Standard System

I Shale Gas Standardization Organization

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

Principles

Demand-based	Coordinating and matching	Highlight features	Advanced and applicable
Solve the existing issues in shale gas development and production	Directly adopt the applicable conventional natural gas standards, formulated by the 3 standardization technical committees of natural gas	Avoid overlapping, repetition and contradiction	Establishing standards with advanced and mature technology
Meet the needs of future exploration and development		Establish and implement the shale gas technical standards in line with China's national conditions	Lead the shale gas exploration and development in China

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
- General shale gas basic standards
  - General technical requirements for products, terms, etc. related to the whole industry in shale gas exploration, development, transportation and utilization
- Geology Evaluation
- Seismic & logging
- Gas reservoir exploration
- Drilling & completion process
- Reservoir stimulation
- Safe and clean production

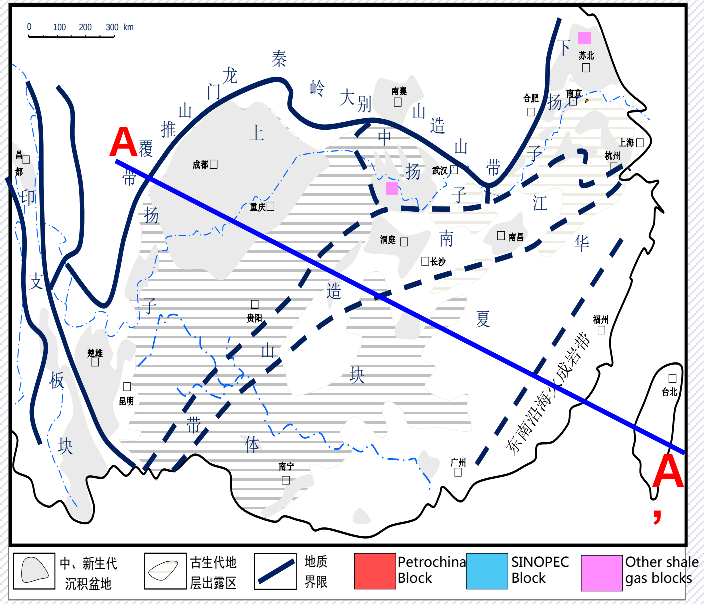
1 Geological evaluation standards

◻ 10 standards were issued, including the geological analysis methods, resource evaluation guidelines,etc.

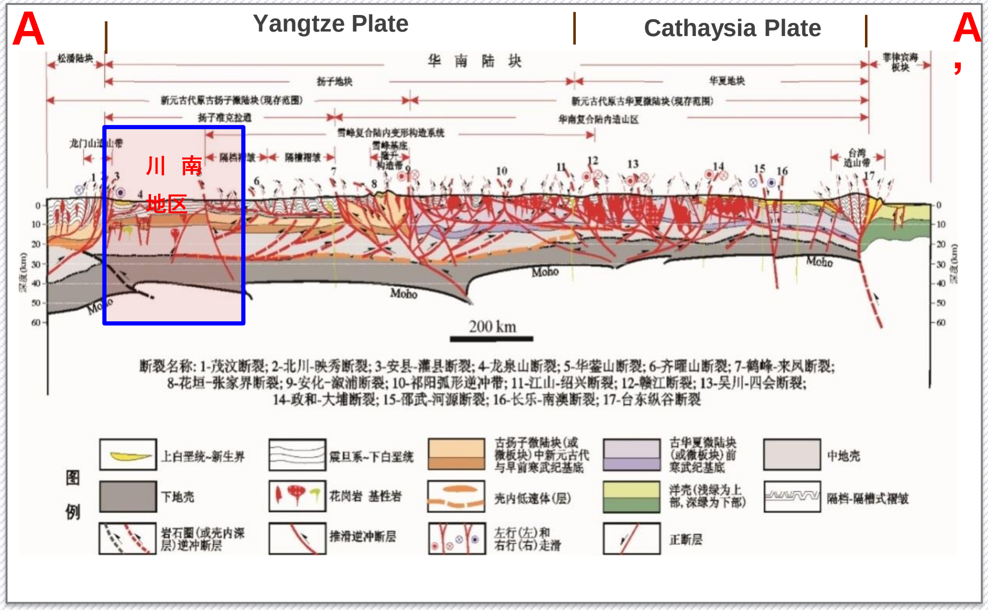
- The ***Target Optimization Methods for Marine Shale Gas Exploration*** **standardizes the key technical parameters for the field selection and the reservoir evaluation, providing important support for the optimization of favorable areas**

◆ **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.**



Shale Gas Regional Tectonic Position in South China



Profile of Yangtze Plate - Cathaysia Plate

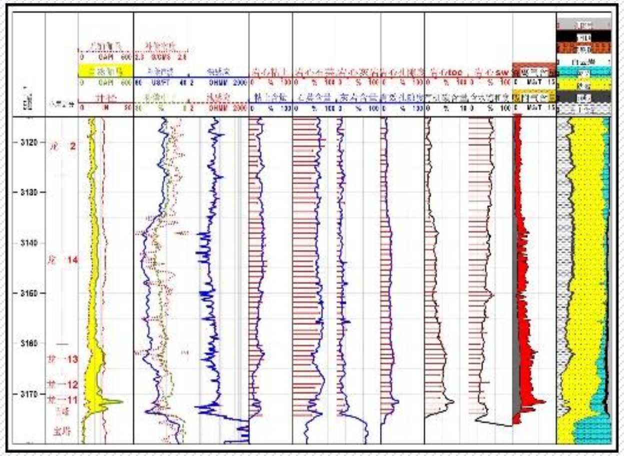
2 Seismic and logging standards

- **2 standards were issued, including the technical specification for processing seismic exploration, and Monitoring Micro-seismic fracturing**

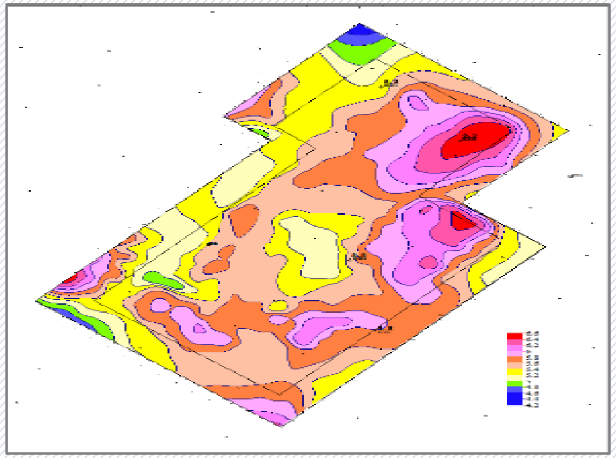
- **The *Technical Specification for Processing, Interpretation and Prediction of Shale Gas Seismic Data* regulates the technical and quality requirements for the processing, interpretation and prediction of seismic data, and for the comprehensive evaluation of favorable areas**

  - The seismic prediction error of buried depth is less than **1%**
  - Achieving the coincidence rate of comprehensive well interpretation of higher than **90%**

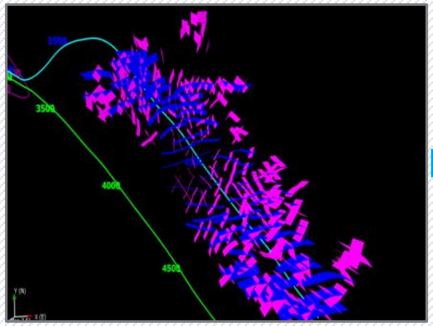
Statistical Chart of Calculation Error of Organic Carbon Content



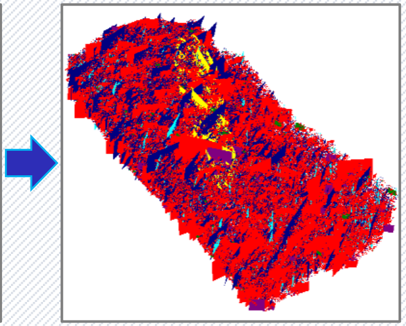
Marine Shale Reservoir Parameters & Fine Logging Evaluation Technology



Porosity Prediction Plan



Primary & Secondary Fracture DFN Model



3D Fracture Model

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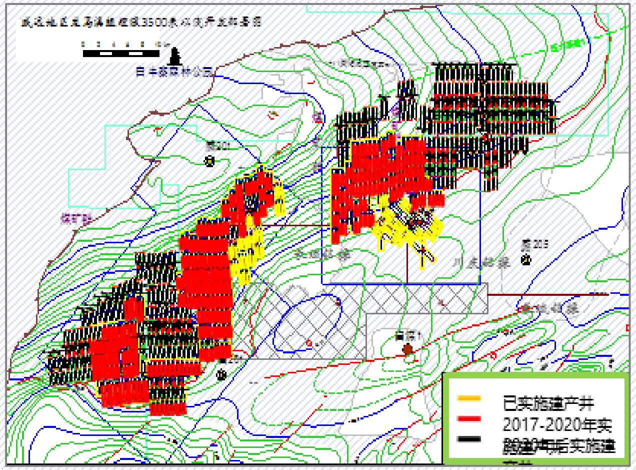
3 Gas reservoir development standards

- **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%**



Well Location Map of Weiyuan Development Plan

Establishment of national standards

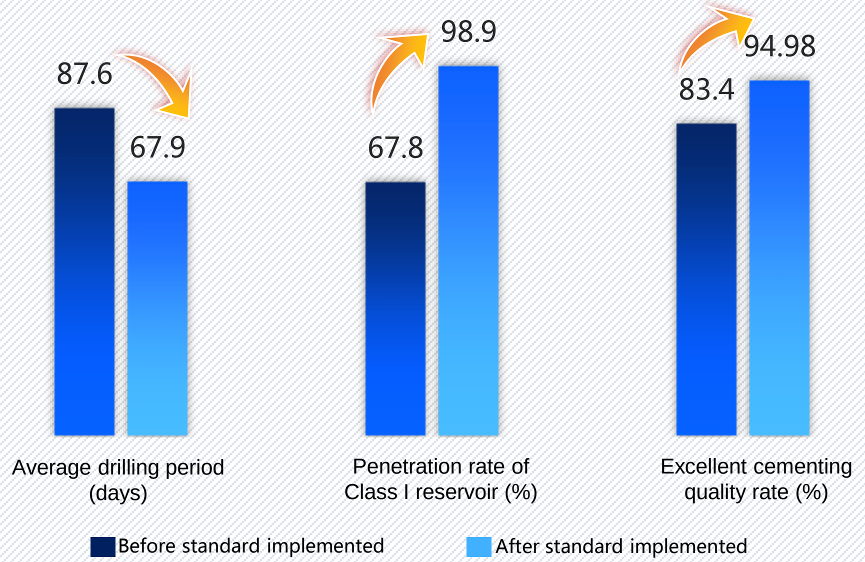
4 Drilling and completion technology standards

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%**

Drilling Site of Four Rigs in Wei 204H34



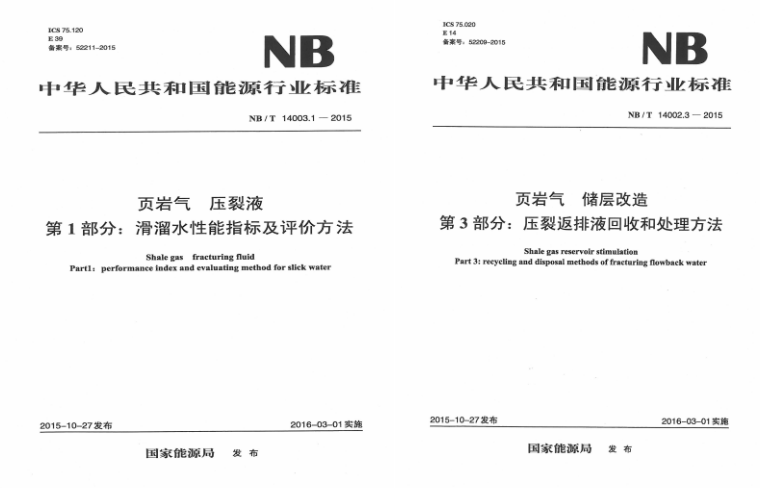
Drilling Technical Indicators

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** m³/d to more than **200,000** m³/d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中华人民共和国能源行业标准

NB / T 14003.1 — 2015

页岩气　压裂液
第 1 部分：滑溜水性能指标及评价方法

Shale gas　fracturing fluid
Part1：performance index and evaluating method for slick water

2015–10–27 发布　　2016–03–01 实施

国家能源局　发布

ICS 75.020
E 14
备案号：52209–2015

NB

中华人民共和国能源行业标准

NB / T 14002.3 — 2015

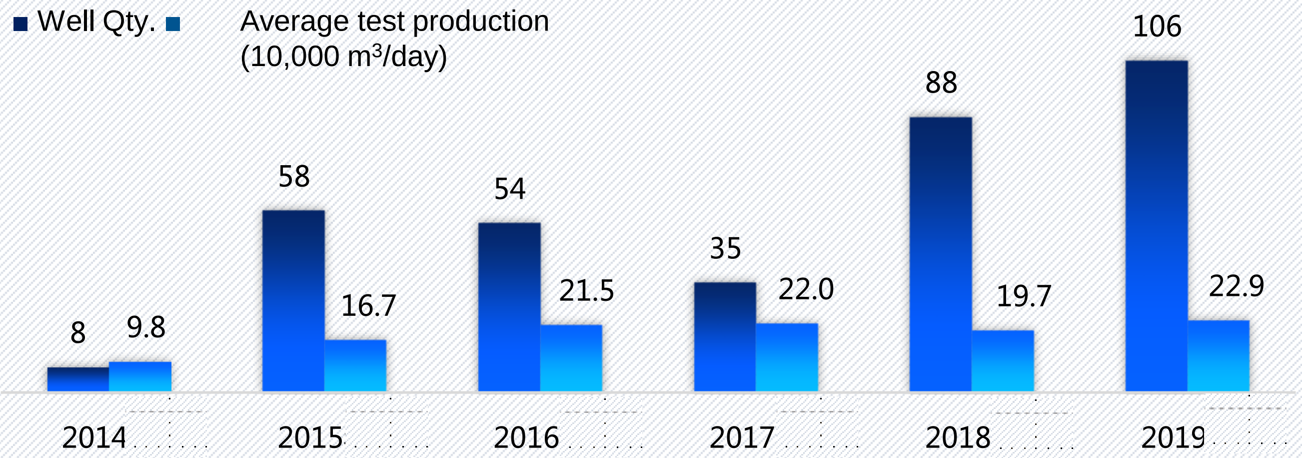
页岩气　储层改造
第 3 部分：压裂返排液回收和处理方法

Shale gas reservoir stimulation
Part 3: recycling and disposal methods of fracturing flowback water

2015–10–27 发布　　2016–03–01 实施

国家能源局　发布

Establishment of industry standards



Application Result of Reservoir Stimulation Standards

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** m^3

Gas Gathering Station Standard Design

Oil Based Mud(OBM) Recycling Facility

II Implementation and Effectiveness of China Shale Gas Technical Standard System

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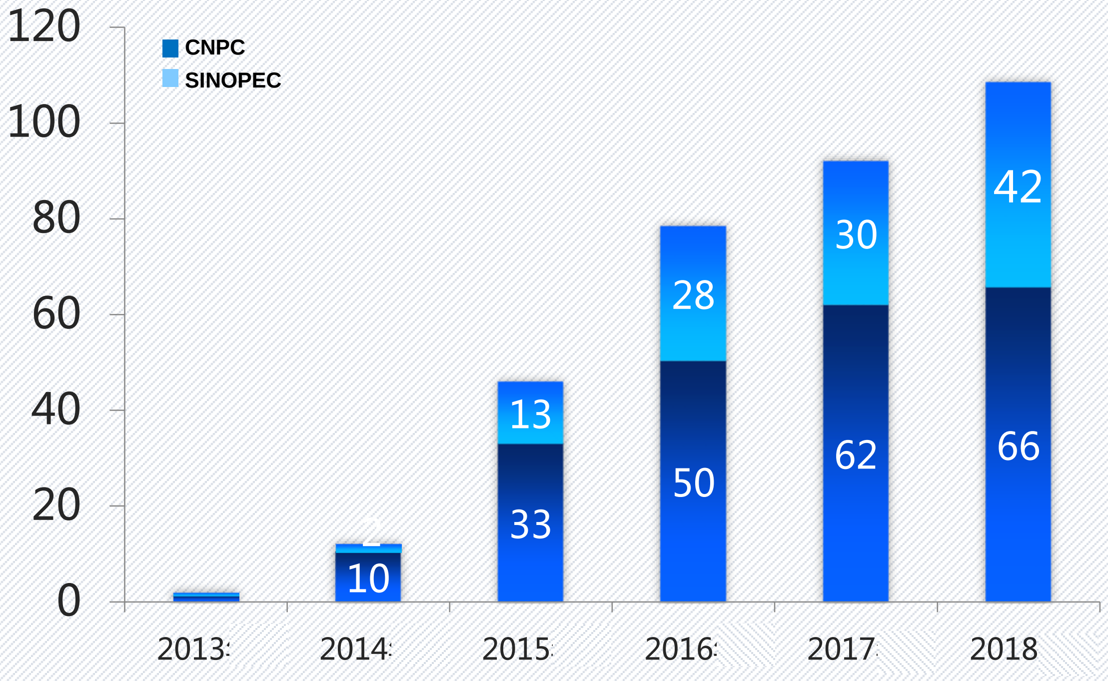
- The standard system supports the high-quality development of shale gas industry in China, and the **largest domestic shale gas production base was constructed in South Sichuan**.
- The standard system promotes the technical progress of shale gas exploration and development technologies

Shale Gas Production in China from 2013 to 2018



Key Technical Indicators for Shale Gas Development

Class	Indexes	Unit	Current level
Geophysical prospecting	Seismic data resolution	Hz	45
	Micro-seismic positioning error	m	<20
Logging	Excellence rate of storage logging data	%	>80%
	Coincidence rate of logging data interpretation	%	>90%
development	Box range	m	3~5
	Class I+II well ratio	%	>88
	EUR	10^8 m^3	**1.0-1.2**
Drilling	Drilling period	d	Average: 78, **fastest: 27**
	Drilling rate	m/h	8.7~10.4
	Penetration rate of Class I reservoir	%	>96
	Horizontal segment length	m	Average: 1,560, **maximum: 2,820**
Fracturing	Sanding density	t/m	Average: 1.8, **highest: 3.2**
	Fluid Volume	m^3/m	26~40
	Cluster spacing	m	About 15
	SRV	$10^8/m^3$	Average: 1.46, **highest: 3.23**
Well Factory	Rig translation period	h	Average: 1.3, highest: 0.5
	Translational return period	h	Average: 35, fastest: 31
	Fracturing efficiency	stage/d	Average: 2.35, highest: 4

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01 Overview of the Shale Gas Industry in China

02 Achievements of China Shale Gas Technical Standard System

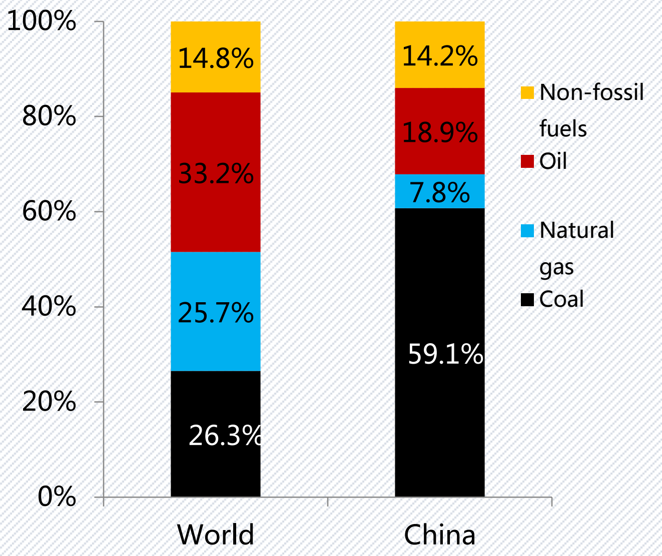
03 Prospect of China Shale Gas Technical Standard System

I Development Opportunities

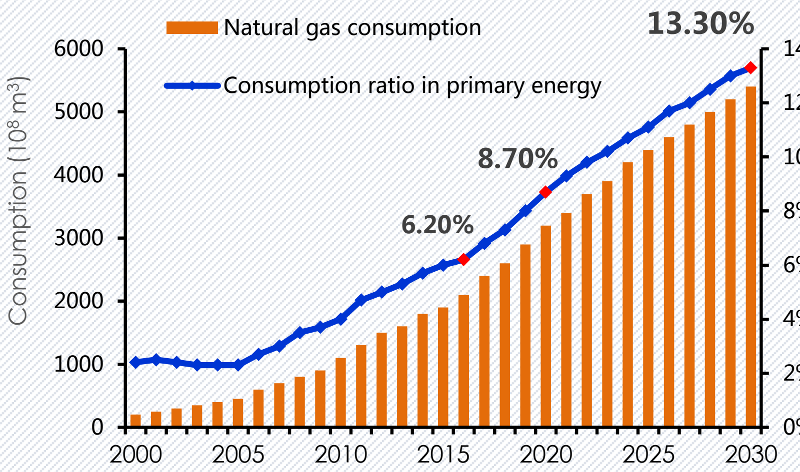
Continuously promotes clean energy development in China, and the demand for natural gas is growing rapidly

- 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%**

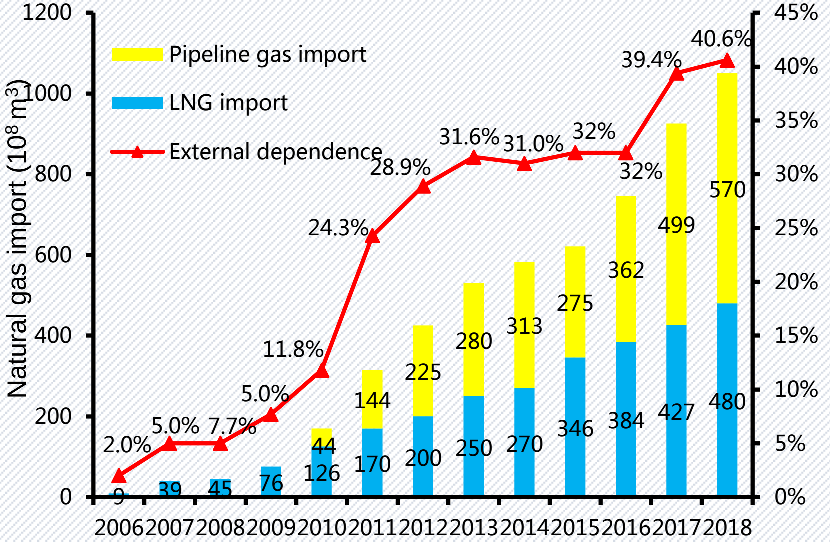
Comparison of China's Energy Consumption Structure with the World in 2018



Forecast of Growth Trend of Natural Gas Consumption & Its Proportion in Primary Energy in China



Import of Natural Gas in China from 2006 to 2018

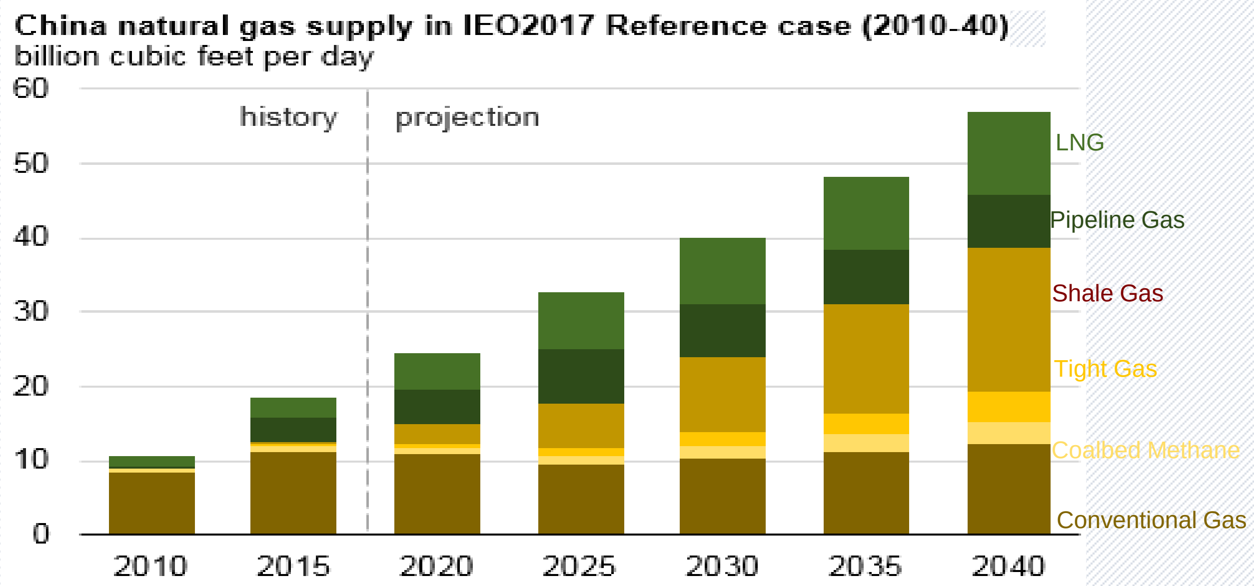


I Development Opportunities

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

Forecast of Future Natural Gas Supply Structure in China (EIA, 2017)



Several Opinions of the State Council on Promoting Coordinated and Sustainable Development of Natural Gas

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发文机关：	国务院	成文日期：	2018年08月30日
标 题：	国务院关于促进天然气协调稳定发展的若干意见		
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主 题 词：			

国务院关于促进天然气
协调稳定发展的若干意见
国发〔2018〕31号

各省、自治区、直辖市人民政府，国务院各部委、各直属机构：

天然气是优质高效、绿色清洁的低碳能源。加快天然气开发利用，促进协调稳定发展，是我国推进能源生产和消费革命，构建清洁低碳、安全高效的现代能源体系的重要路径。当前我国天然气产供储销体系还不完备，产业发展不平衡不充分问题较为突出，主要是国内产量增速低于消费增速，进口多元化有待加强，消费结构不尽合理，基础设施存在短板，储气能力严重不足，互联互通程度不够，市场化价格机制未充分形成，应急保障机制不完善，设施建设运营存在安全风险等。为有效解决上述问题，加快天然气产供储销体系建设，促进天然气协调稳定发展，现提出以下意见。

相关报道

- 国务院印发《关于促进天然气协调稳定发展的若干意见》

解读

- 全面部署“稳发展” 统筹协调“保供应”——国家能源局解读《关于促进天然气协调稳定发展的若干意见》
- 我国将着力破解天然气产业发展深层次矛盾——确保快速增

II Future Development Direction of technology and standard

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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

Specialties	2020			2021			2022			2023			2024			2025		
	International standards	National standards	Industrial standards	International standards	National standards	Industrial standards	International standards	National standards	Industrial standards	International standards	National standards	Industrial standards	International standards	National standards	Industrial standards	International standards	National standards	Industrial standards
General fundamentals	1																	
Geological evaluation			3		1	3		1	3			2			2			2
Earthquake & logging			1															
Drilling & completion process			3			3			3			3			3			3
Reservoir stimulation			4	1		4			2			2			2			2
Gas reservoir development		2	7		2	3			3			3			3			3
Safe and clean production		1	1		3	1		1	1			1			1			1
Total	1	3	19	1	6	14		2	12			11			11			11

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

2019

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

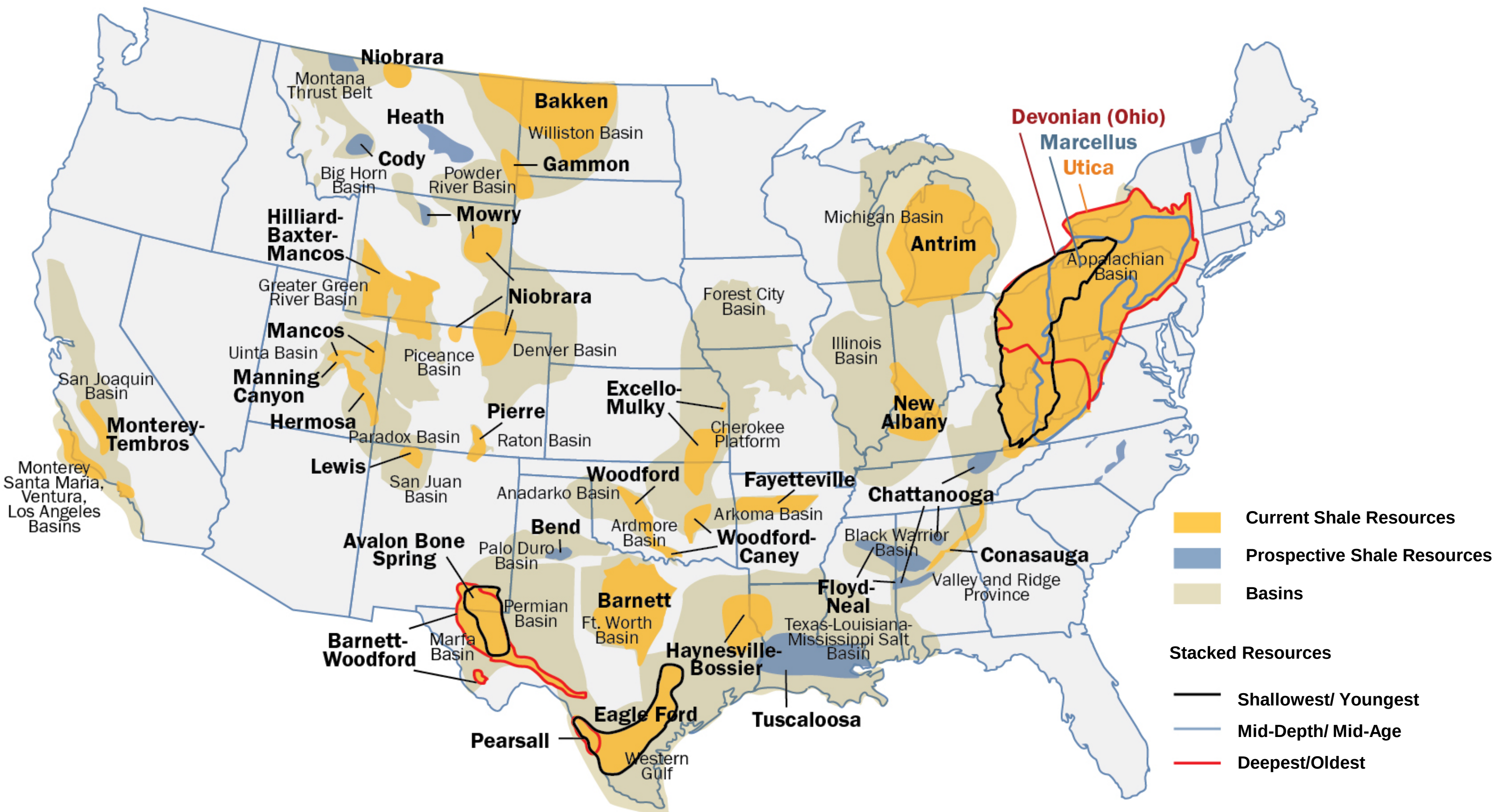
- Hydraulic fracturing (HF) and shale gas overview
- Petroleum and natural gas production and consumption
- U.S. regulatory framework
- API standards program and HF-related documents
- Conclusions

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

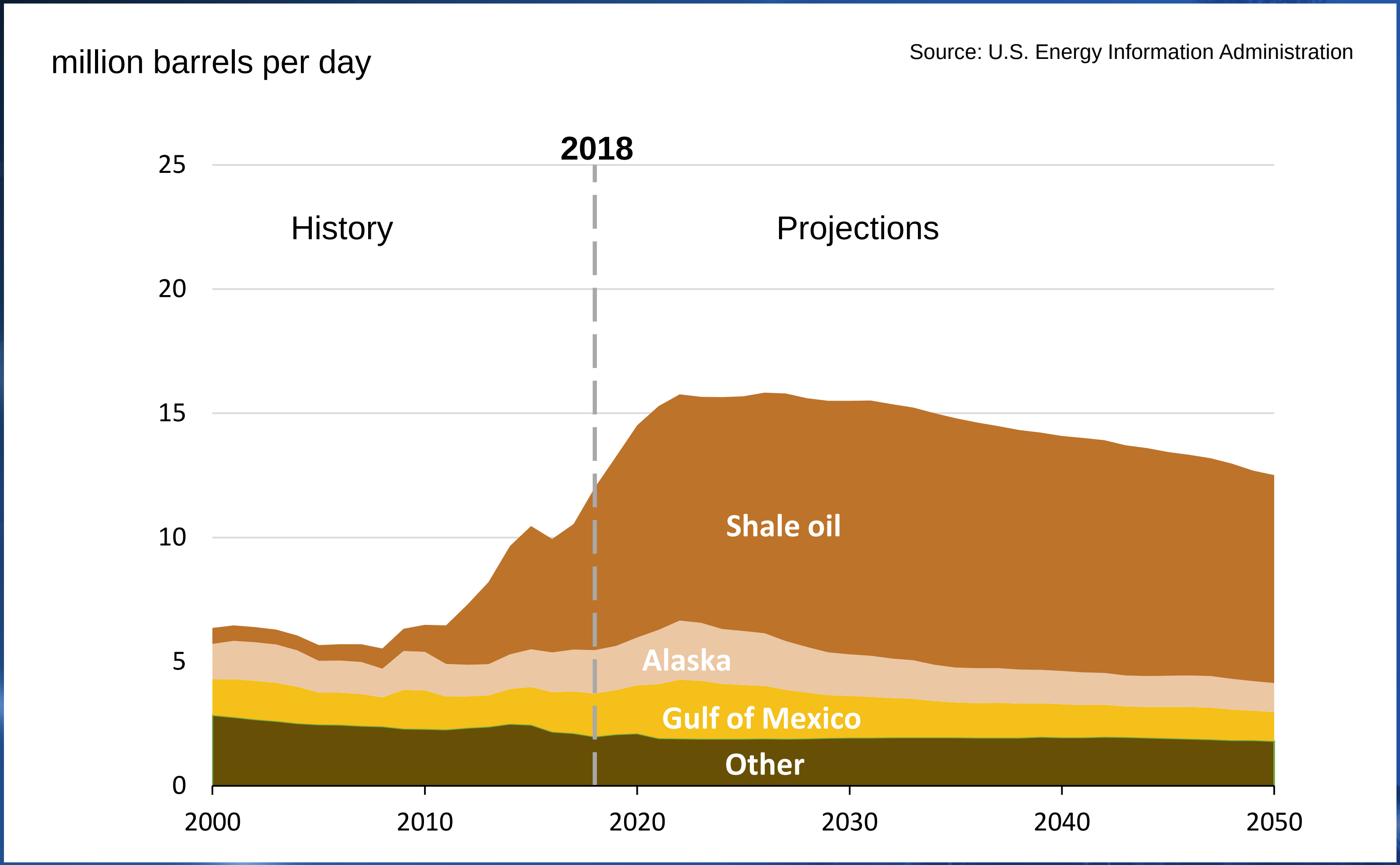
U.S. Shale Gas Resources

- **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**

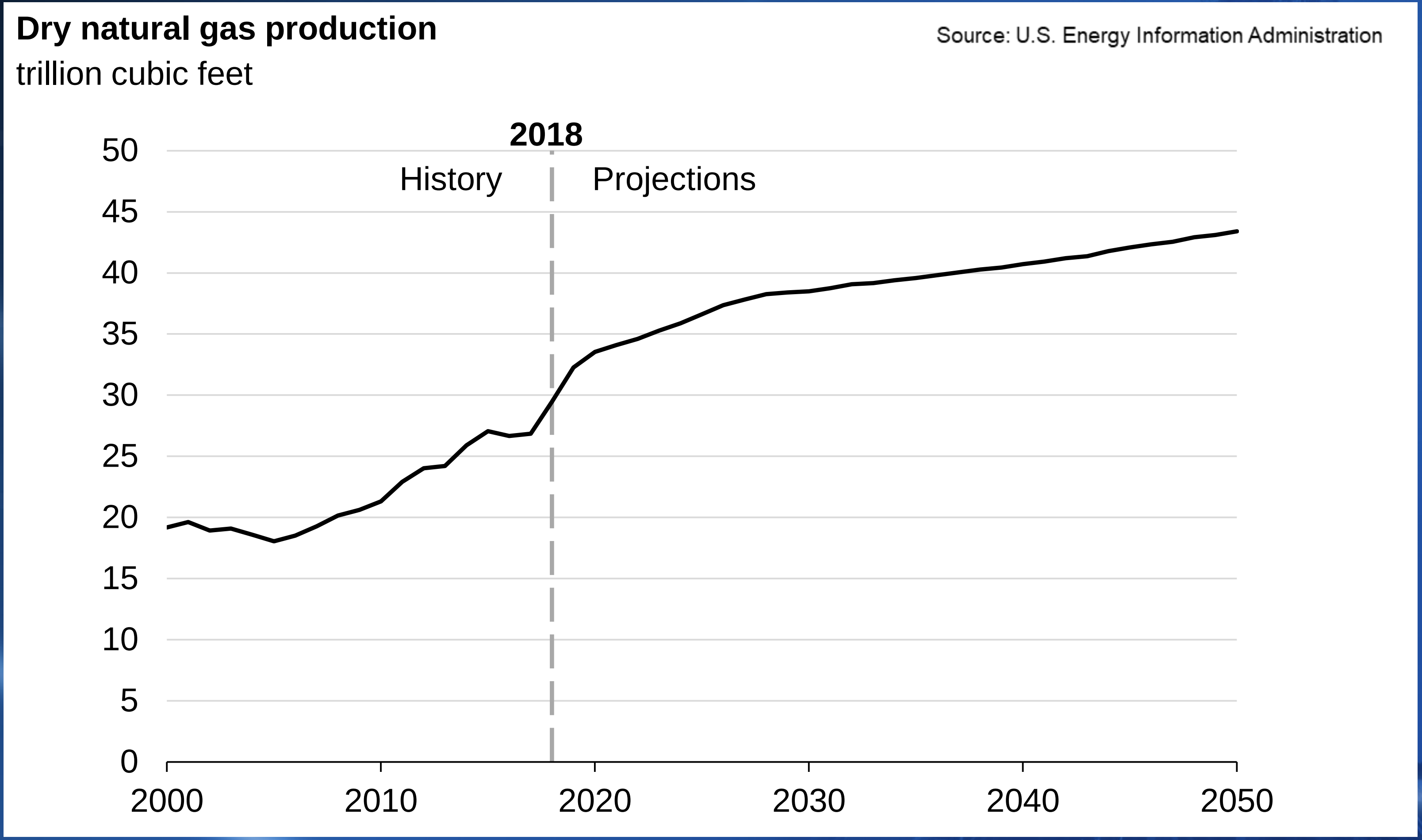
U.S. Petroleum & Natural Gas Production

- 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

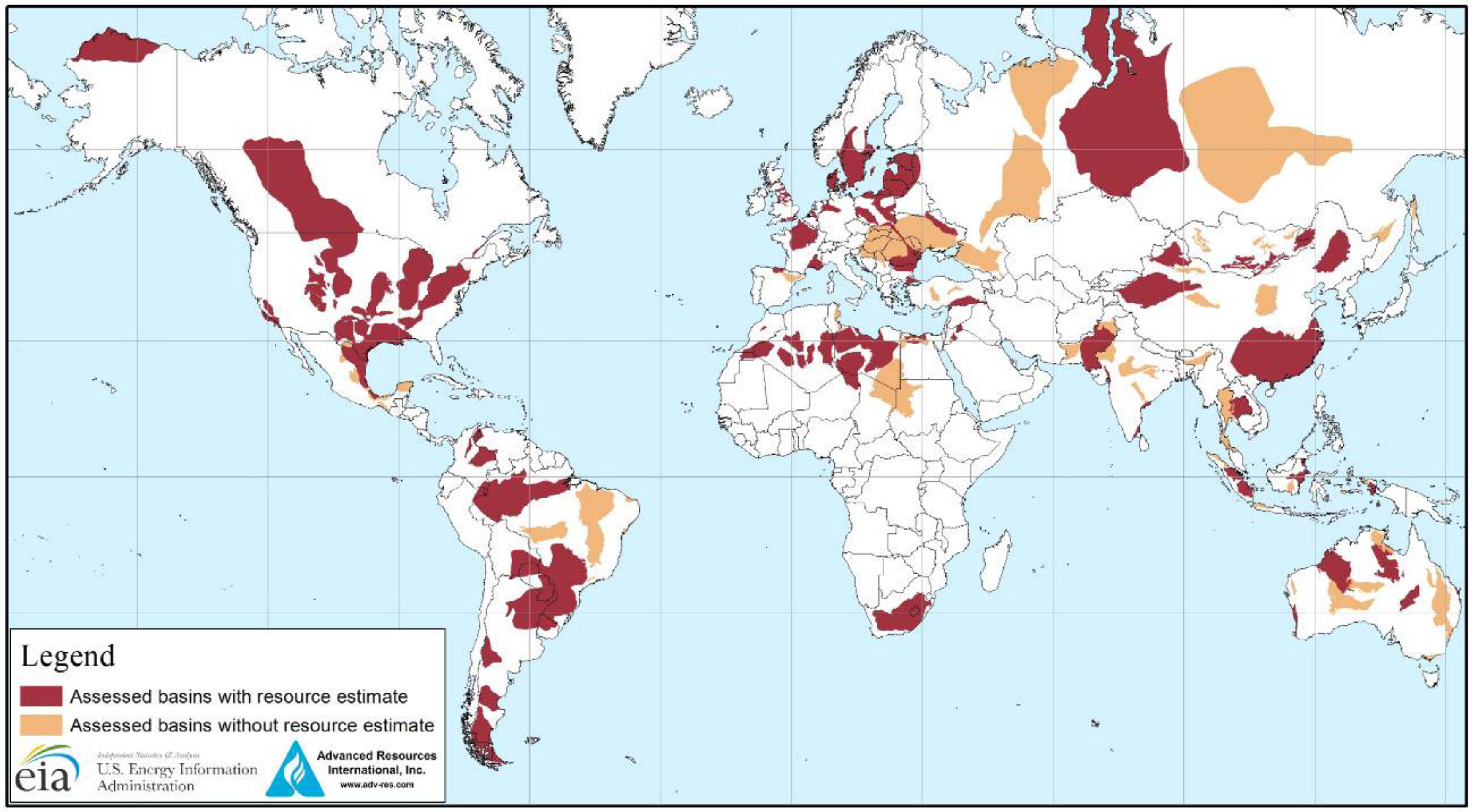
U.S. Crude Oil Production



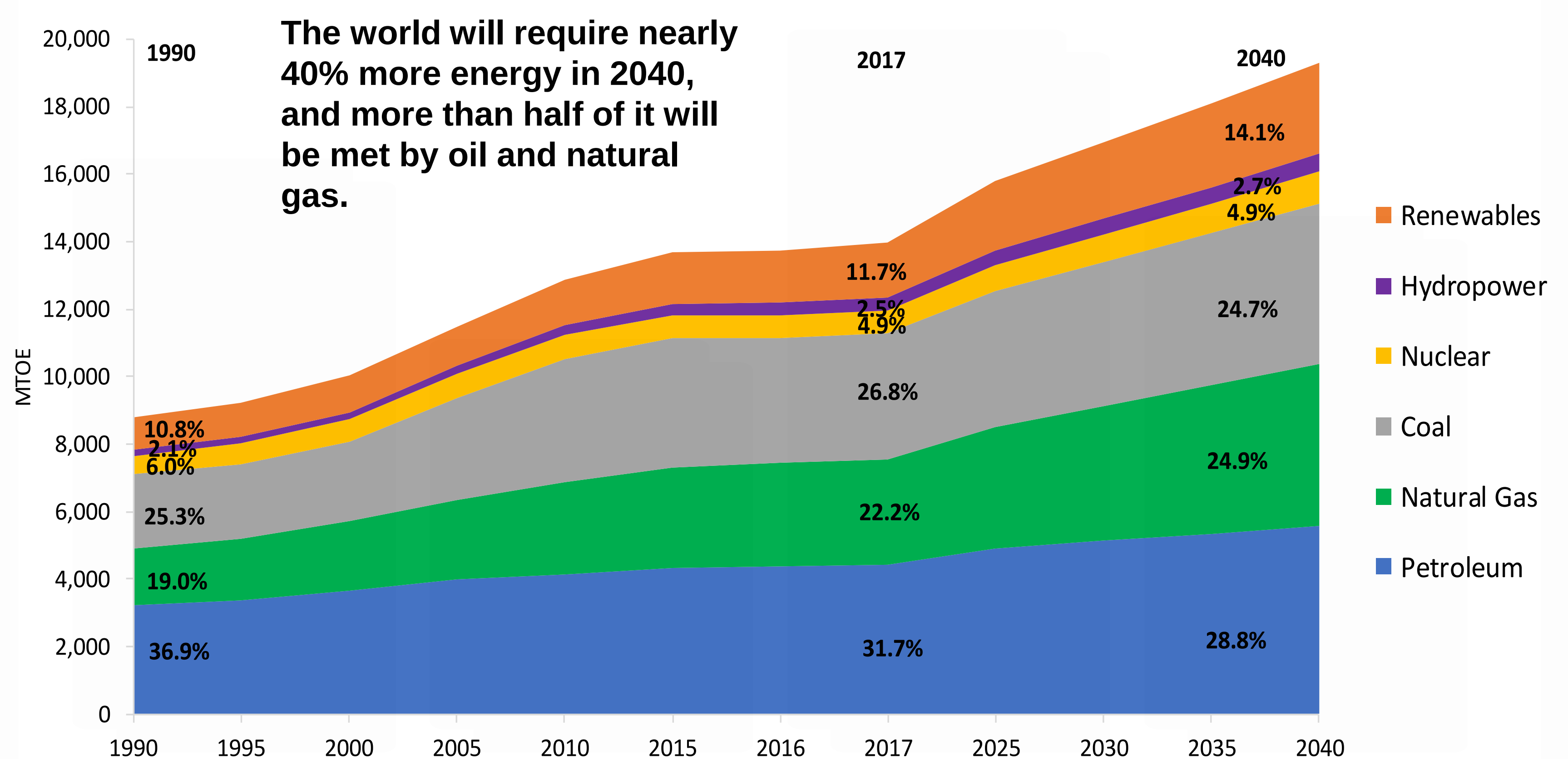
U.S. Natural Gas Production



Global Shale Basins



Global Energy Demand

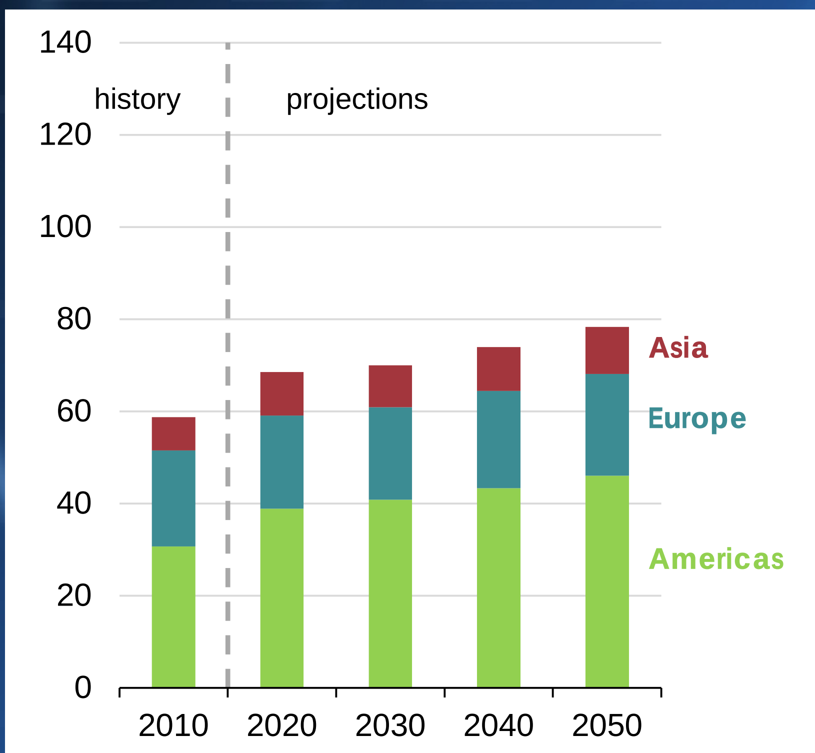


Source: IEA, *World Energy Balances 2018* and *World Energy Outlook 2018*

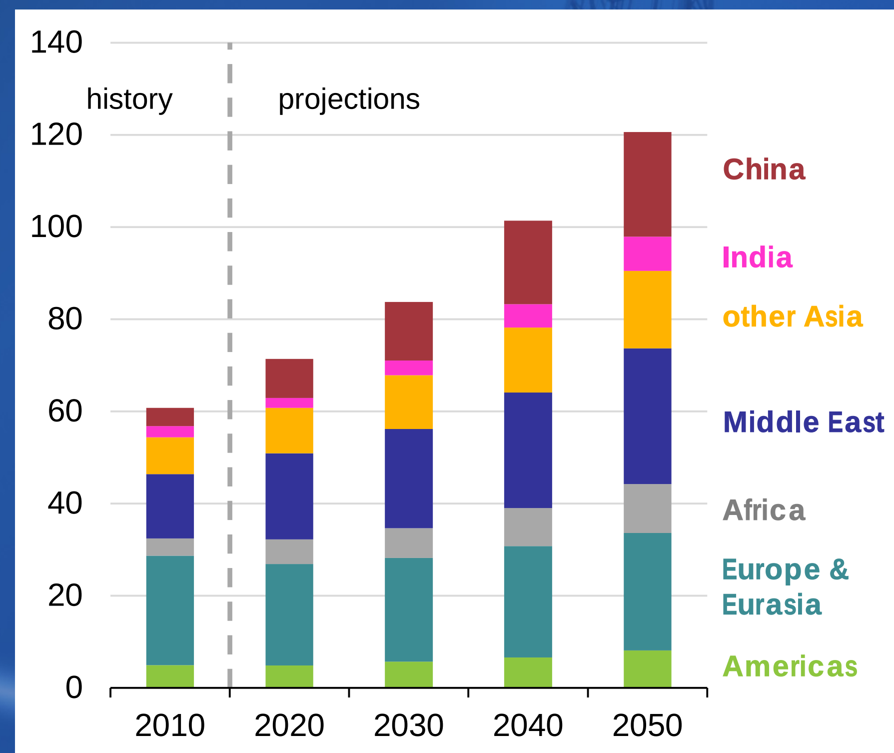
Global Natural Gas Consumption

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

Regulatory Framework: State Regulations and Permitting

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

energy API

Regulatory Framework: Federal Statutes and Regulations

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.

Shale Gas/HF-related Standard

Hydraulic Fracturing—Well Integrity and Fracture Containment

ANSI/API RECOMMENDED PRACTICE 100-1
FIRST EDITION, OCTOBER 2015

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

ANSI/API RECOMMENDED PRACTICE 100-2
FIRST EDITION, AUGUST 2015

AMERICAN PETROLEUM INSTITUTE

Community Engagement Guidelines

ANSI/API BULLETIN 100-3
FIRST EDITION, JULY 2014

AMERICAN PETROLEUM INSTITUTE

Isolating Potential Flow Zones During Well Construction

API STANDARD 65—PART 2
SECOND EDITION, DECEMBER 2010

REAFFIRMED, NOVEMBER 2016

AMERICAN PETROLEUM INSTITUTE

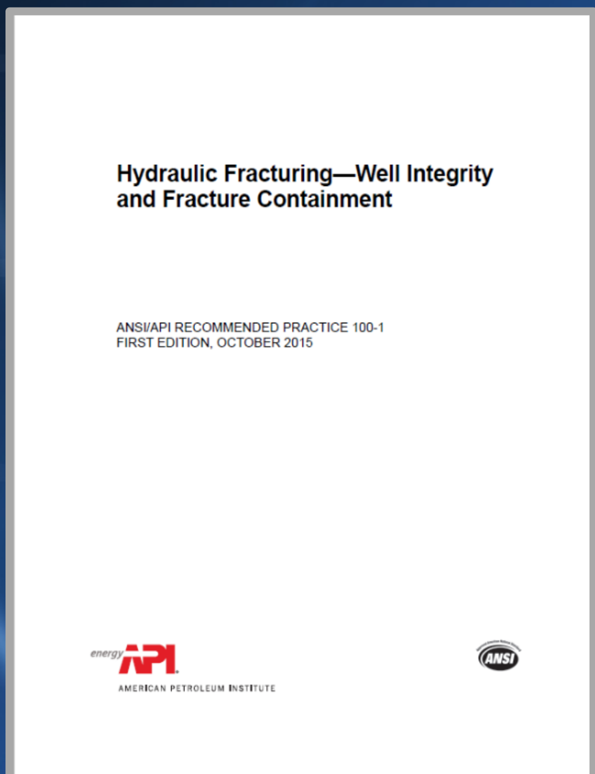
Environmental Protection for Onshore Oil and Gas Production Operations and Leases

API RECOMMENDED PRACTICE 51R
FIRST EDITION, JULY 2009

REAFFIRMED, DECEMBER 2015

AMERICAN PETROLEUM INSTITUTE

API RP 100-1



Hydraulic Fracturing—Well Integrity and Fracture Containment

ANSI/API RECOMMENDED PRACTICE 100-1
FIRST EDITION, OCTOBER 2015

- **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.

API RP 100-1

- **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.

API RP 100-1

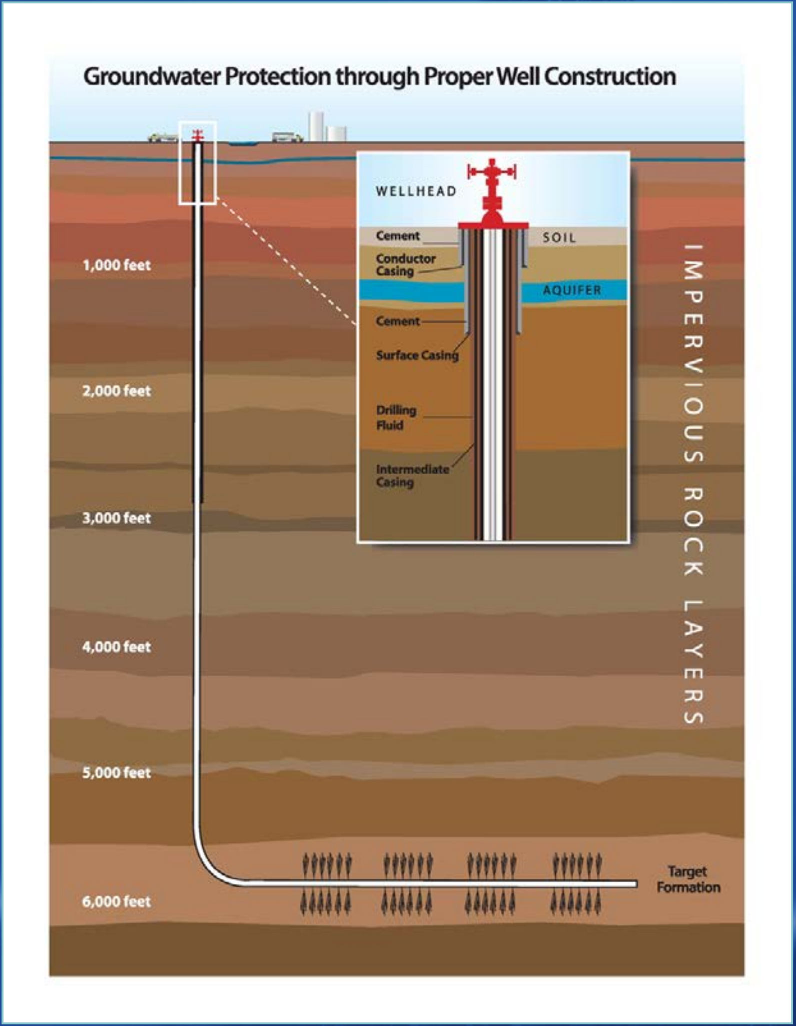
- This document is **not** a detailed well construction or fracture design manual
- While industry-wide practices concerning well construction are similar, there are considerable variations in the details of individual well design and construction due to varying geologic, environmental, regulatory, and 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

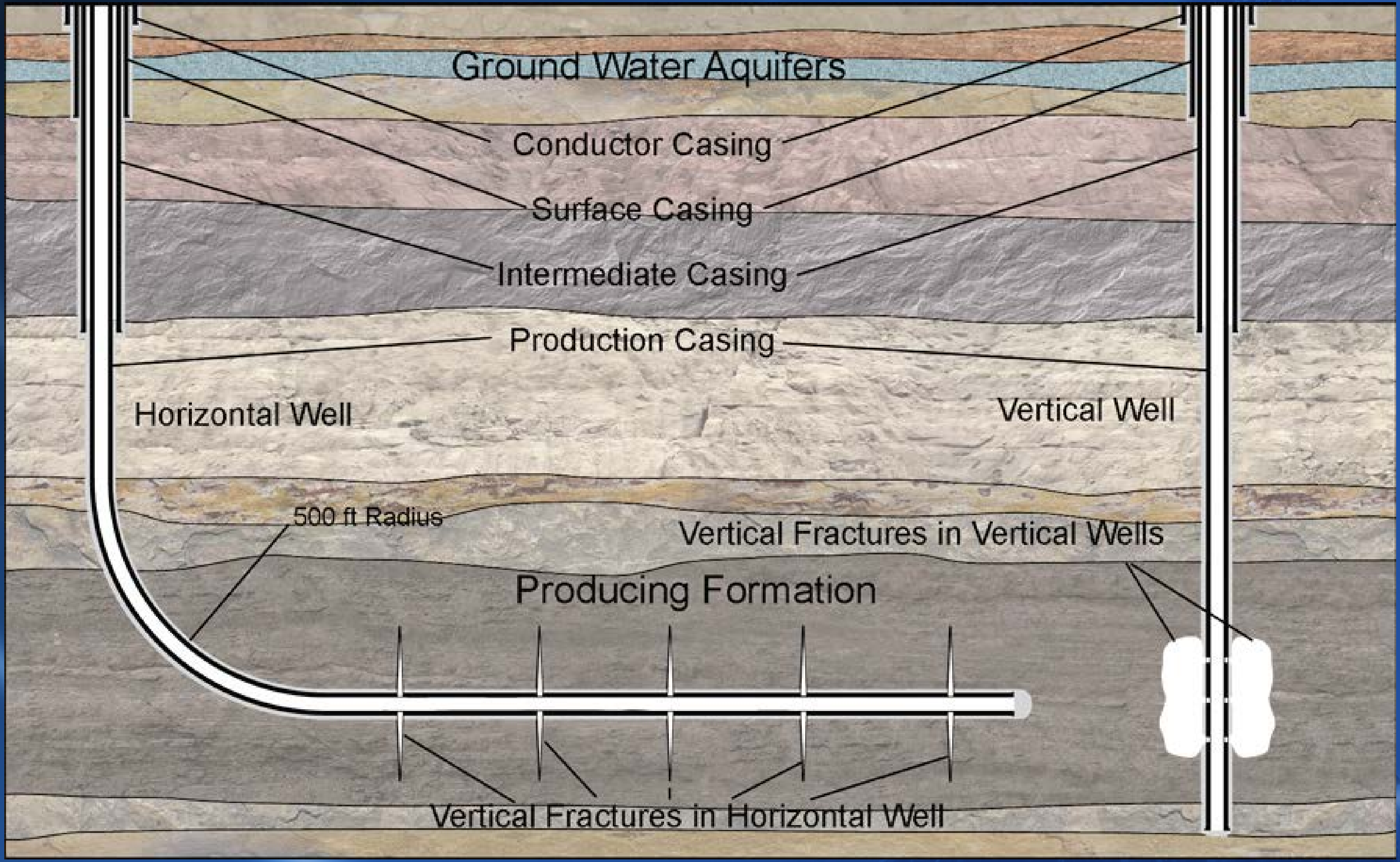
Each well contains multiple layers of casing and cementing to protect groundwater

Well design and construction has four main components.

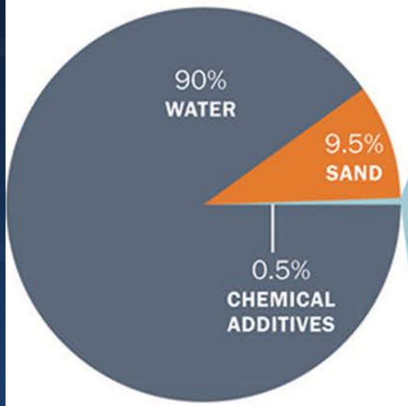
1. **Conductor casing (isolate shallow groundwater and surface sediments).**
2. **Surface casing (isolate groundwater aquifers).**
3. **Intermediate casing (isolate subsurface formations, protect from pressure).**
4. **Production casing (isolate production zone).**



Well Production Casing

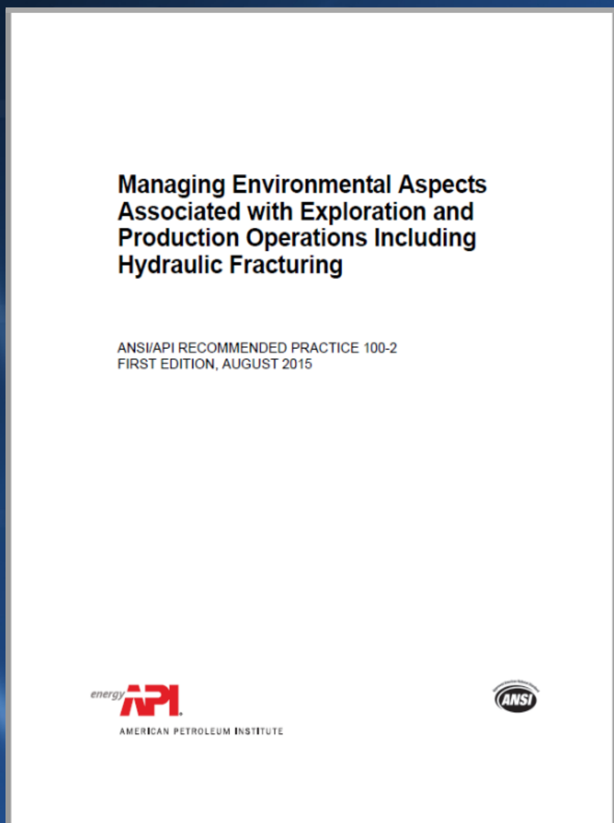


Understanding Fracturing Fluids



Compound	Purpose	Common application
Acids	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
Sodium Chloride	Allows a delayed breakdown of the gel polymer chains	Table salt
Polyacrylamide	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
Ethylene Glycol	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
Borate Salts	Maintains fluid viscosity as temperature increases	Laundry detergent, hand soap, cosmetics
Sodium/Potassium Carbonate	Maintains effectiveness of other components, such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
Glutaraldehyde	Eliminates bacteria in the water	Disinfectant, sterilization of medical and dental equipment
Guar Gum	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice
Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, hair coloring

API RP 100-2


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

ANSI/API RECOMMENDED PRACTICE 100-2
FIRST EDITION, AUGUST 2015

AMERICAN PETROLEUM INSTITUTE

- **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

API RP 100-2

- 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

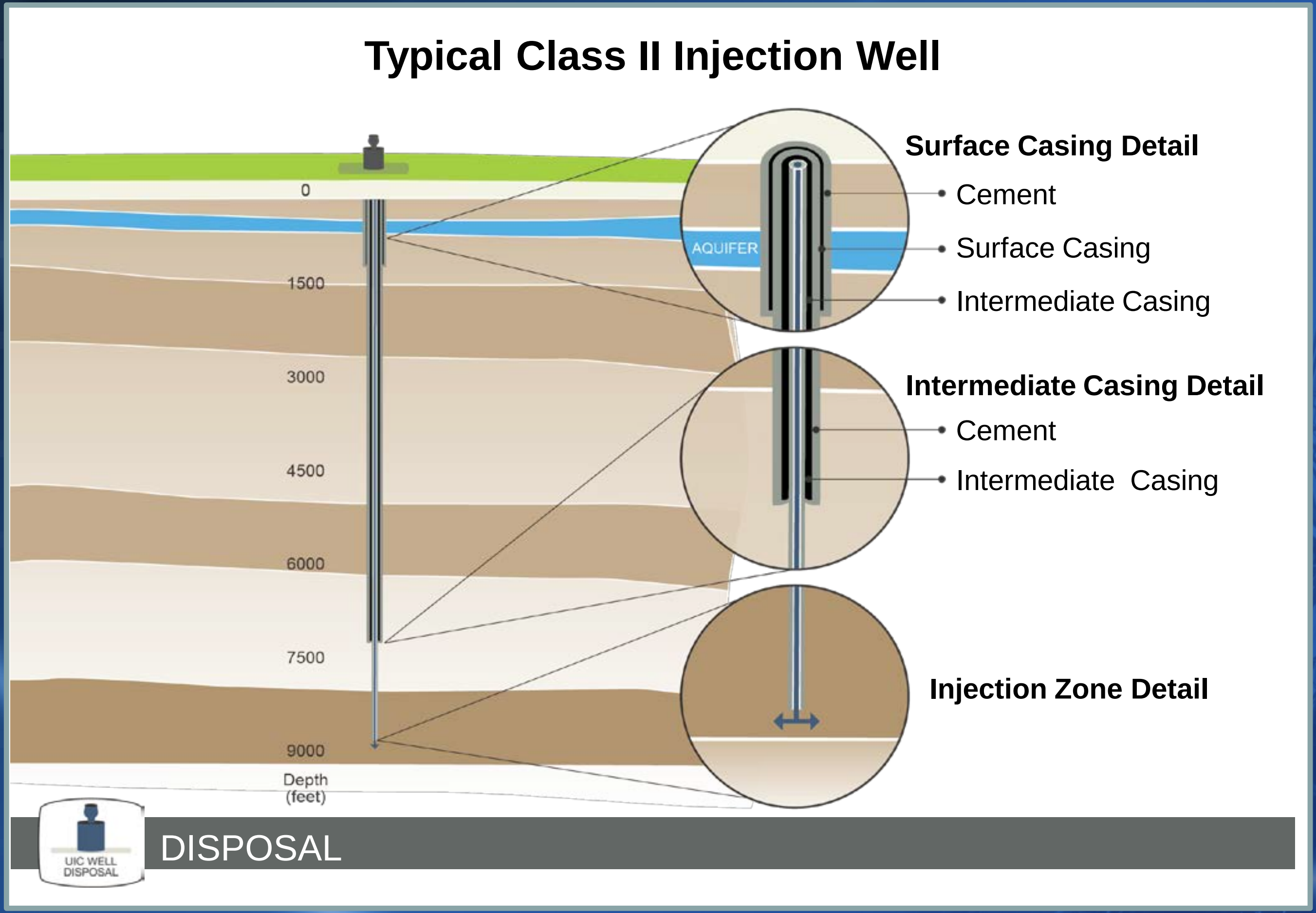
- Puts hydraulic fracturing into perspective relative to drilling, completions, and production lifecycle
- Most aspects are independent of the well stimulation practice used to improve production
- Describe baseline practices
- Recommended practices are site-specific and can vary over the lifecycle of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

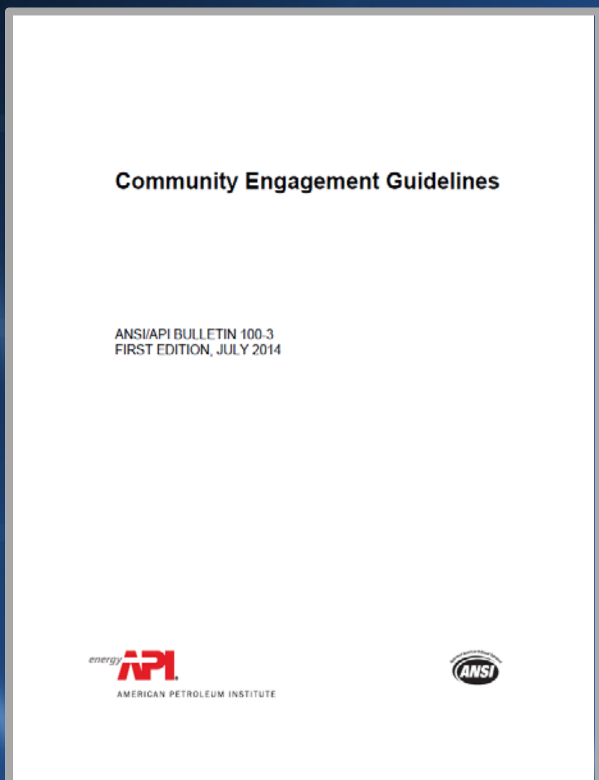


Underground injection control (UIC) wells safely return produced waters from oil and natural gas operations to geologic formations

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


Community Engagement Guidelines

ANSI/API BULLETIN 100-3
FIRST EDITION, JULY 2014

AMERICAN PETROLEUM INSTITUTE

- **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

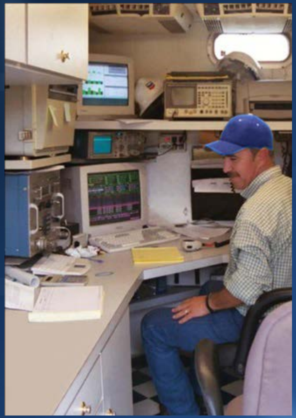
- **Integrity** – "Companies operating with integrity strive to build positive and constructive relationships within the community and accumulate long-term sustainable relationships."

- **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

EXPLORATI ON
3–5 years



PLANNING
12–18 months

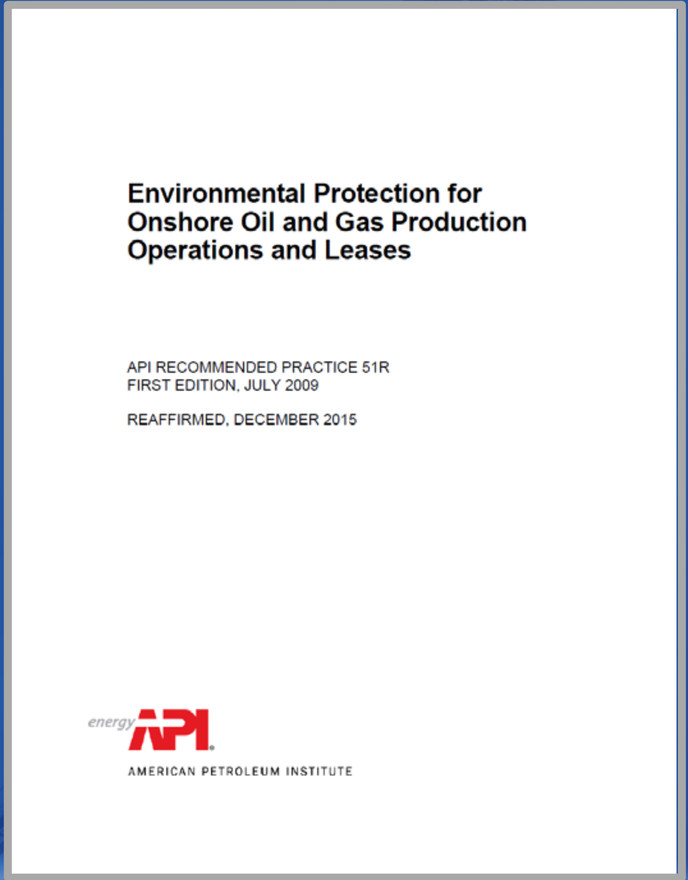
SITE & WELL CONSTRUCTION
2–3 months

HYDRAULIC FRACTURING
<u>3–5 days</u>

PRODUCTI ON
30 + Years

API RP 51R

- 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.


Environmental Protection for Onshore Oil and Gas Production Operations and Leases

API RECOMMENDED PRACTICE 51R
FIRST EDITION, JULY 2009

REAFFIRMED, DECEMBER 2015

AMERICAN PETROLEUM INSTITUTE

API RP 51R

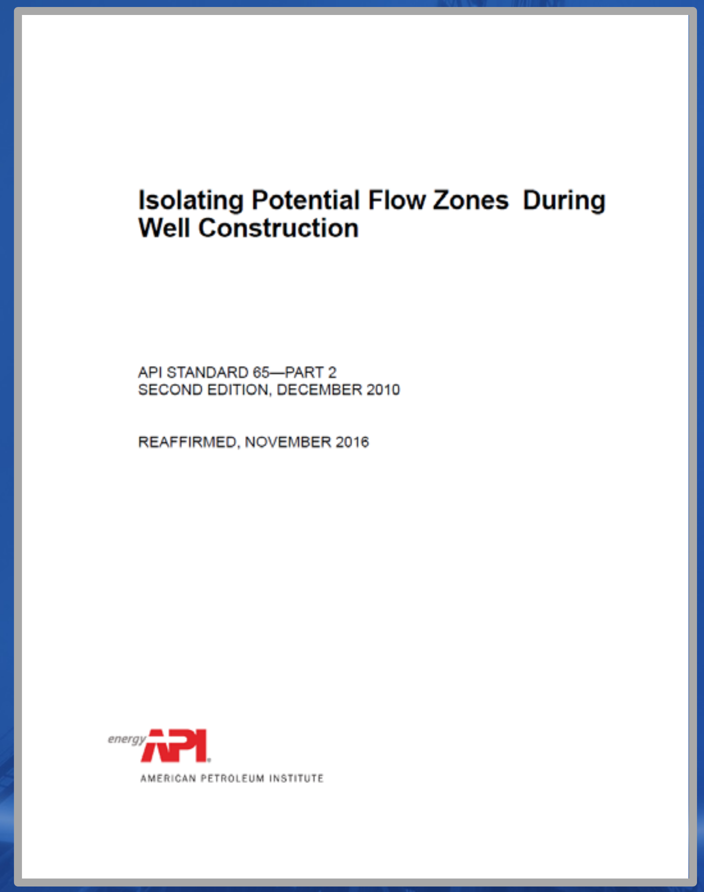
- Key areas of coverage are
  - roads;
  - Production and injection/disposal wells;
  - gathering and system lines;
  - production and water handling facilities.

- Includes guidance on
  - Protection of the environment;
  - personnel selection, training, and qualification;
  - protection of public safety;
  - respect for property owner rights.

API Std 65-2

- **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.**


Isolating Potential Flow Zones During Well Construction

API STANDARD 65—PART 2
SECOND EDITION, DECEMBER 2010

REAFFIRMED, NOVEMBER 2016

AMERICAN PETROLEUM INSTITUTE

API Std 65-2

- 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 14C –** ***Analysis, Design, Installation, and Testing of Safety Systems for Offshore Production Facilities***
- **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?

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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

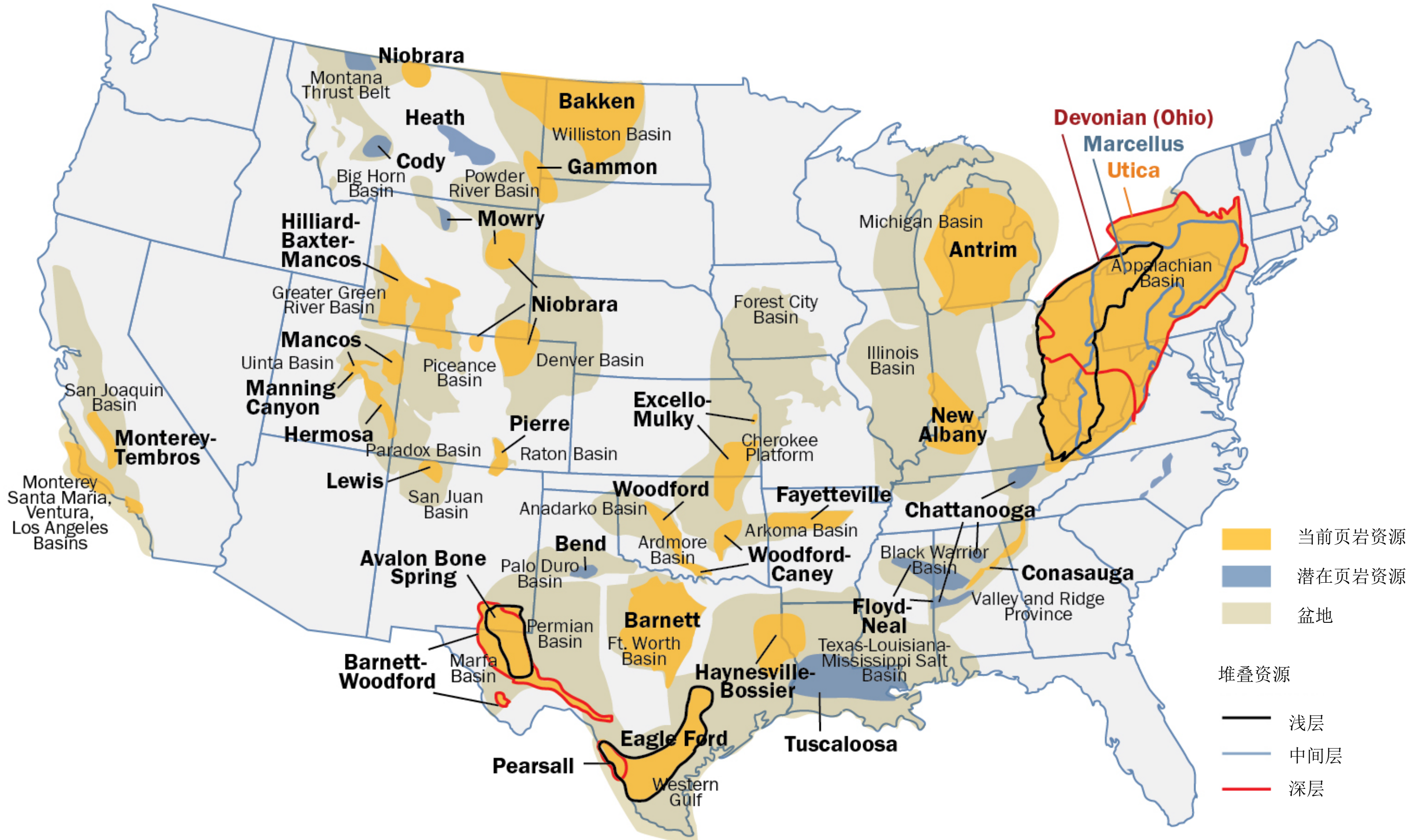
- 水力压裂法和页岩气概况
- 石油和天然气生产与消耗
- 美国监管体系
- API标准项目及水力压裂相关的标准
- 总结

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

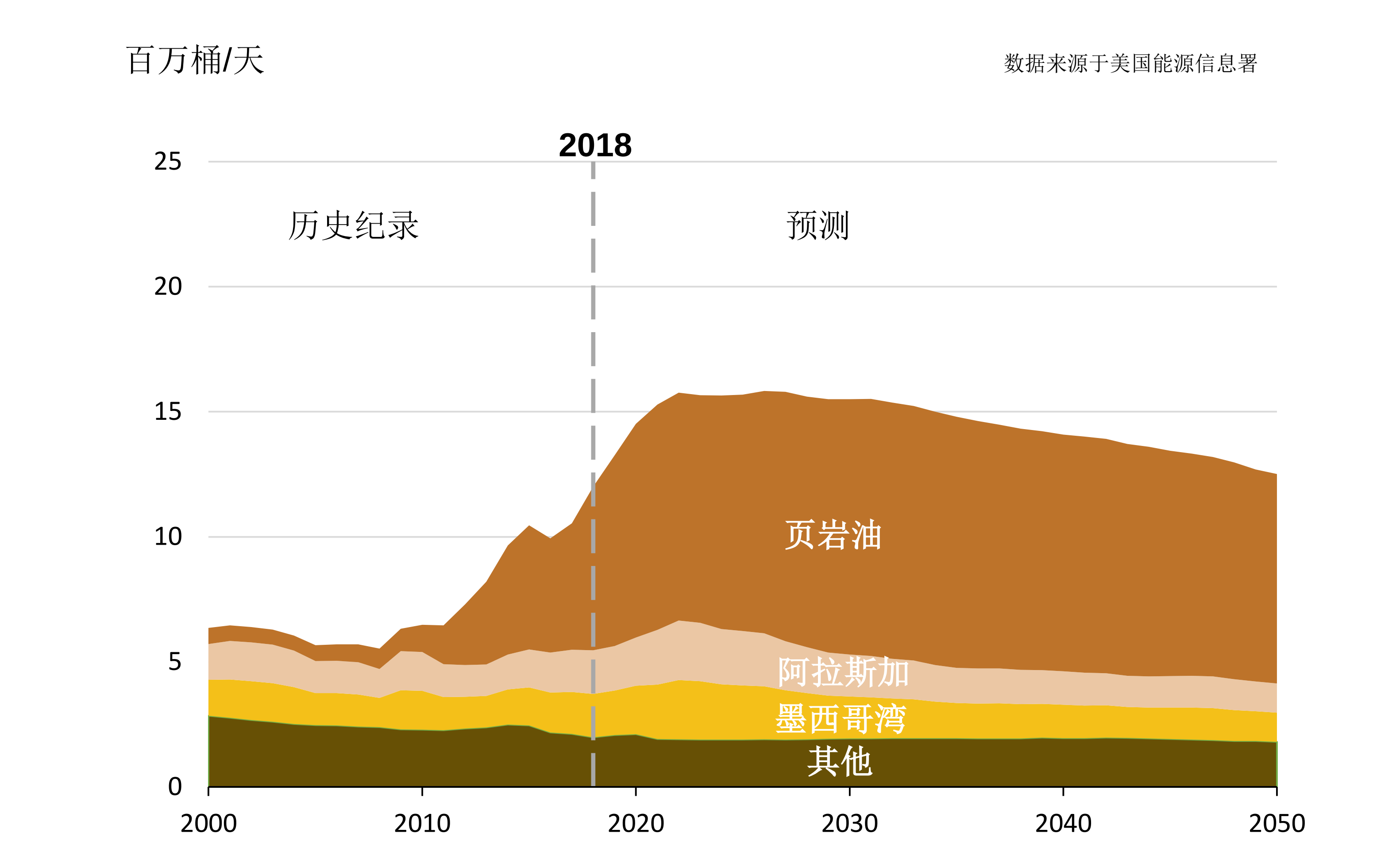
美国的页岩气资源

- 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

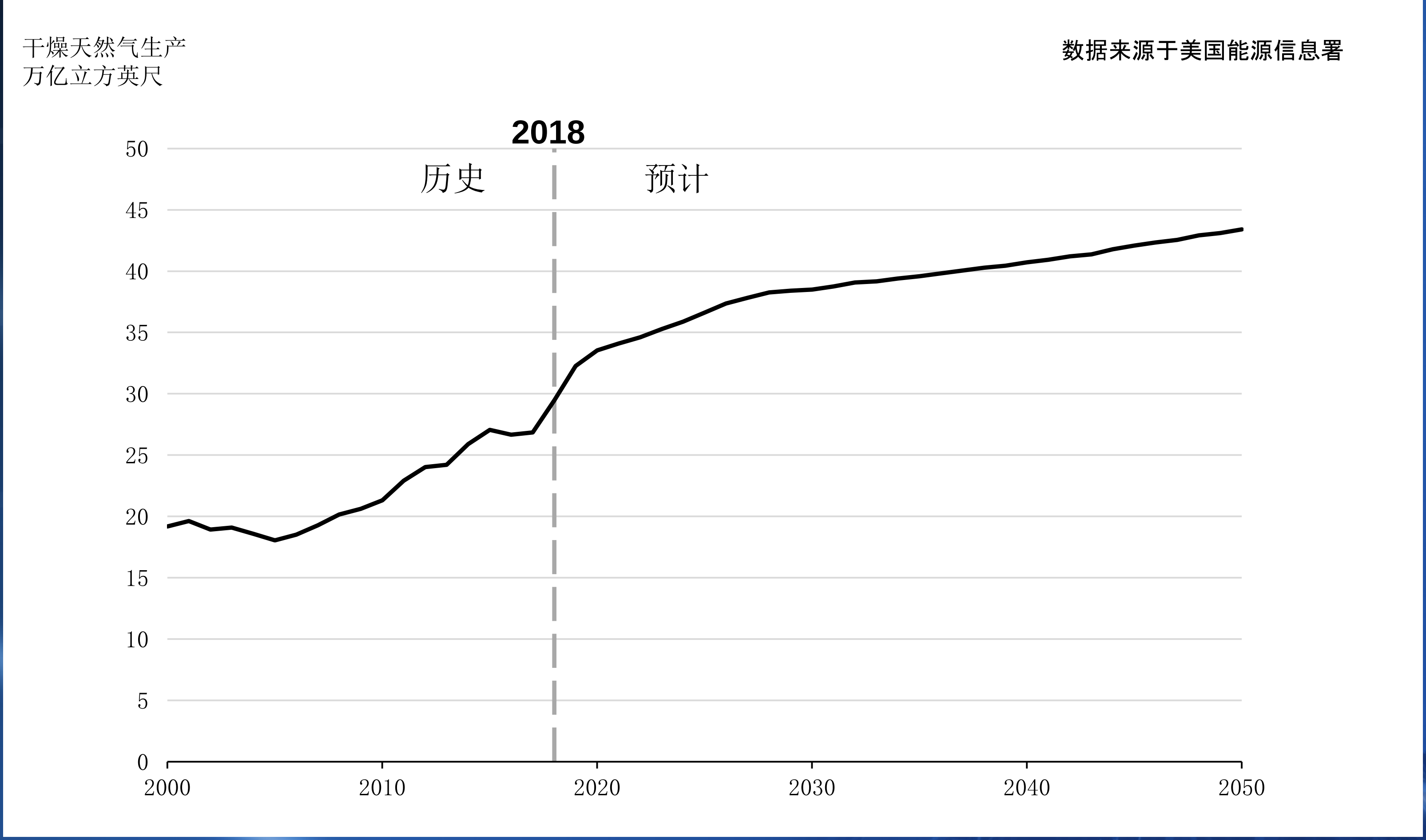
- 自1953年以来，美国已成为能源净进口国
- 目前美国的国内生产量将使美国到2020年成为能源净出口国
- 2018年，致密油（页岩）开发占美国原油生产的50%，美国天然气生产的68%

美国原油生产



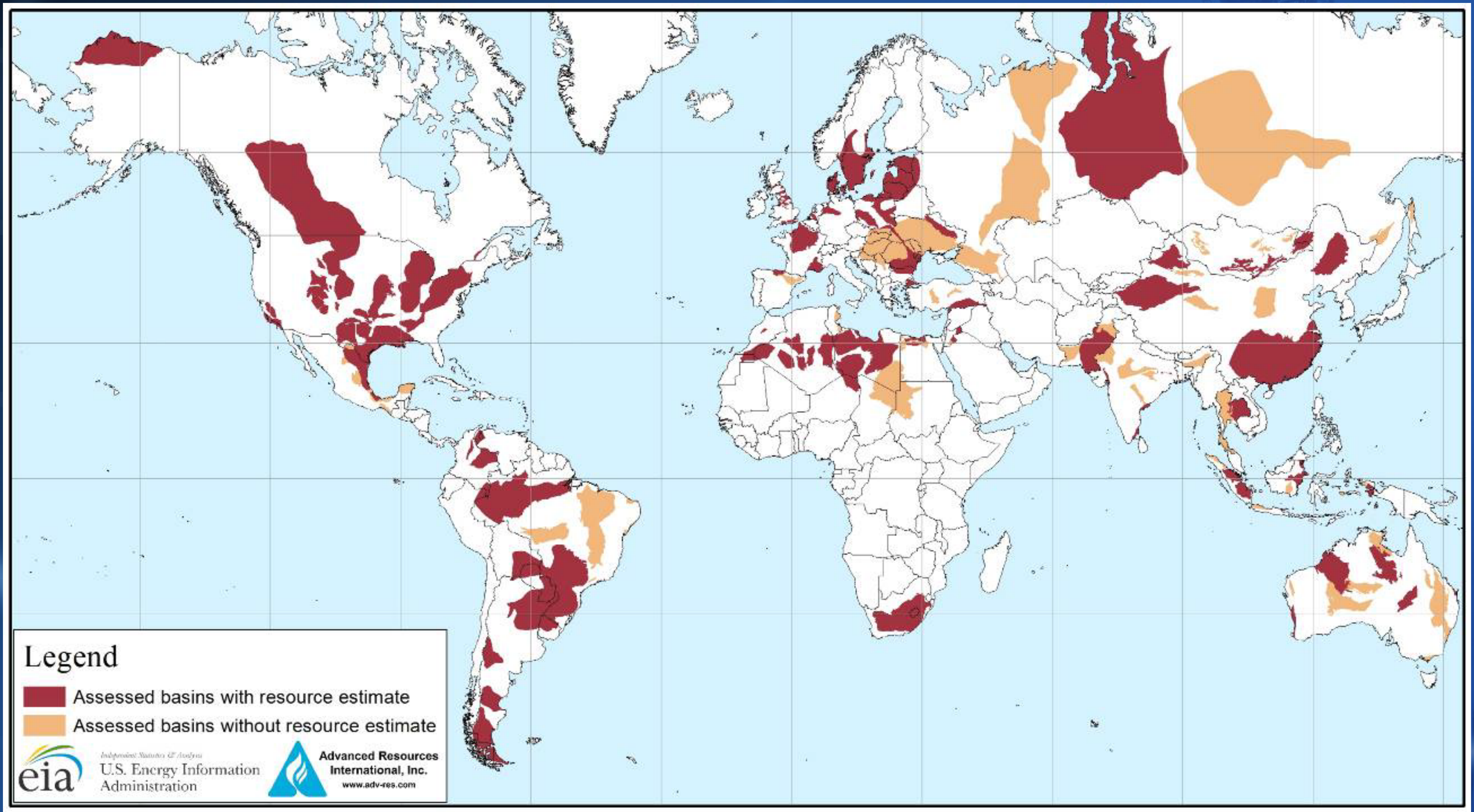
百万桶/天
数据来源于美国能源信息署
2018
历史纪录
预测
25
20
15
10
5
0
页岩油
阿拉斯加
墨西哥湾
其他
2000
2010
2020
2030
2040
2050

美国原油生产

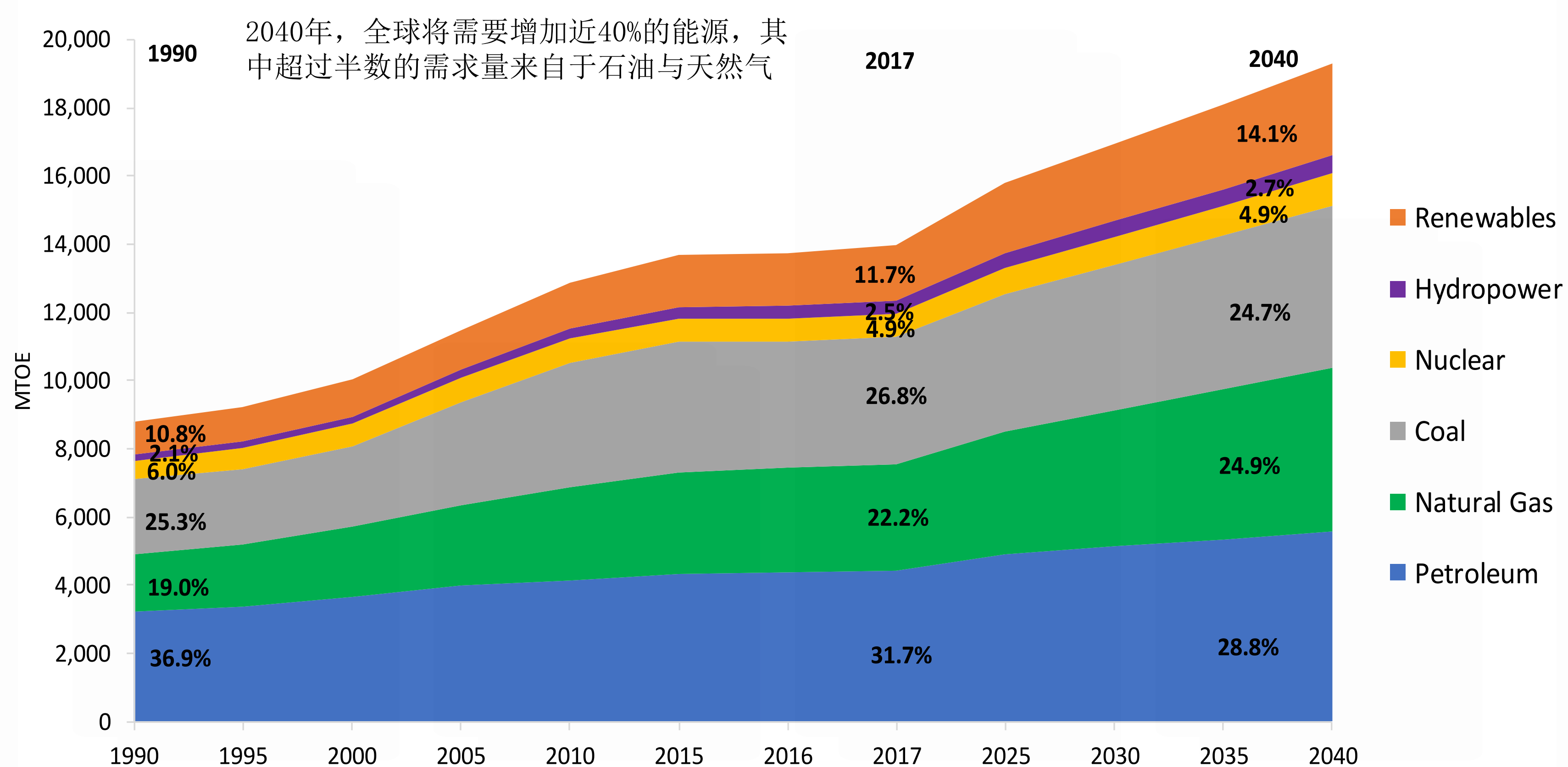


干燥天然气生产
万亿立方英尺
数据来源于美国能源信息署
2018
历史
预计
50
45
40
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050

全球页岩盆地


Legend
Assessed basins with resource estimate
Assessed basins without resource estimate
eia
U.S. Energy Information Administration
Advanced Resources International, Inc.
www.adv-res.com

全球能源需求

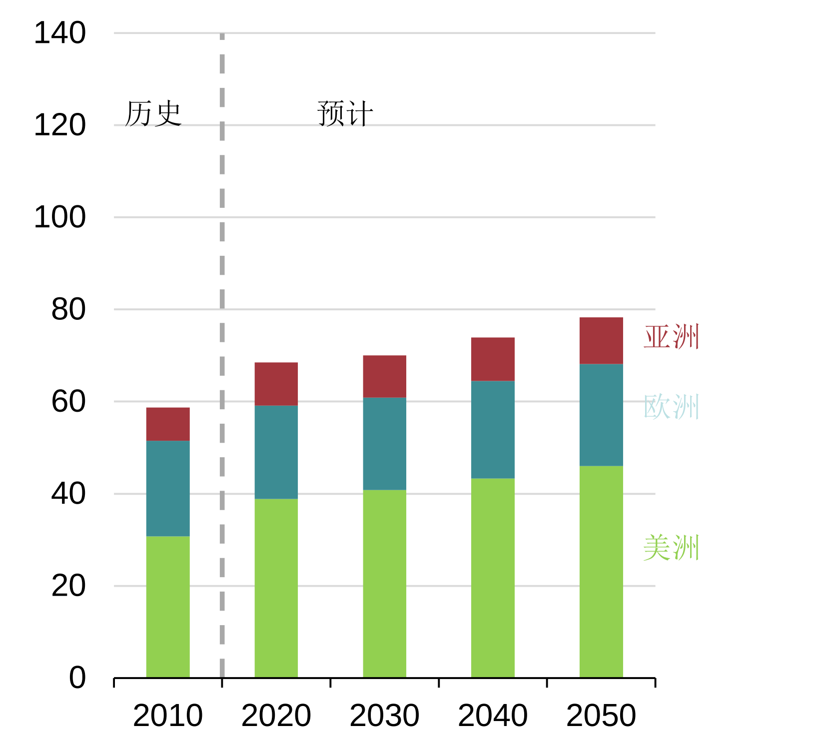


Source: IEA, *World Energy Balances 2018* and *World Energy Outlook 2018*

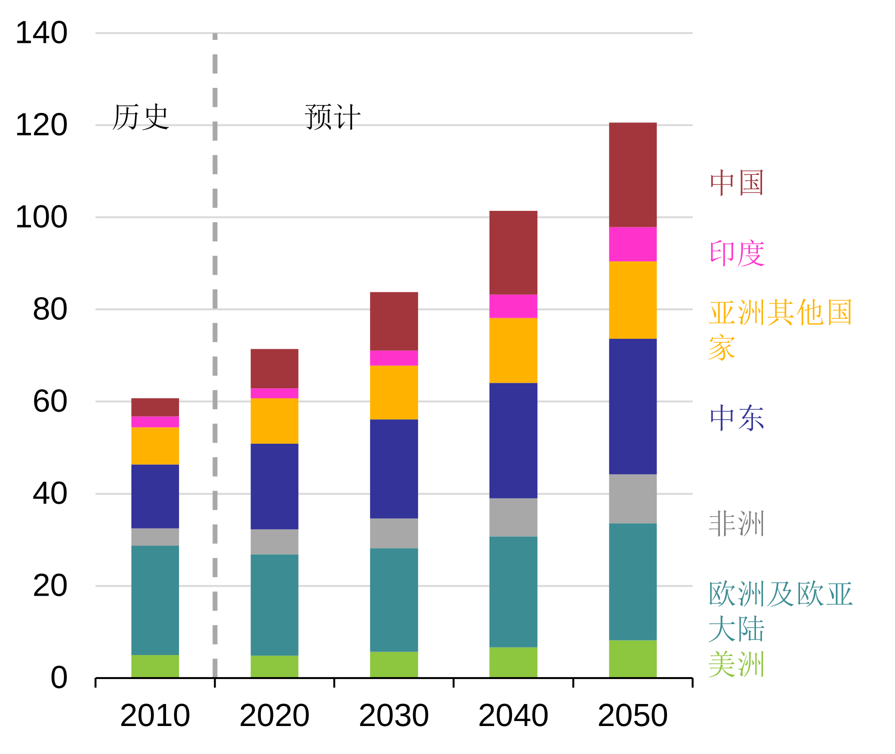
全球天然气消费量

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

美国州监管许可

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

energy API

国家监管体系：联邦法规

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

ANSI/API RECOMMENDED PRACTICE 100-1
FIRST EDITION, OCTOBER 2015

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

ANSI/API RECOMMENDED PRACTICE 100-2
FIRST EDITION, AUGUST 2015

Community Engagement Guidelines

ANSI/API BULLETIN 100-3
FIRST EDITION, JULY 2014

Isolating Potential Flow Zones During Well Construction

API STANDARD 65—PART 2
SECOND EDITION, DECEMBER 2010

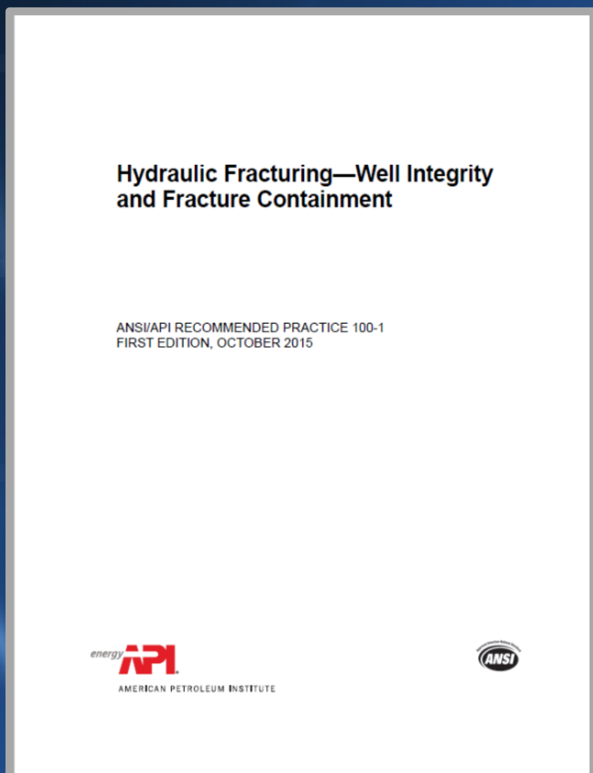
REAFFIRMED, NOVEMBER 2016

Environmental Protection for Onshore Oil and Gas Production Operations and Leases

API RECOMMENDED PRACTICE 51R
FIRST EDITION, JULY 2009

REAFFIRMED, DECEMBER 2015

API RP 100-1


Hydraulic Fracturing—Well Integrity and Fracture Containment

ANSI/API RECOMMENDED PRACTICE 100-1
FIRST EDITION, OCTOBER 2015

AMERICAN PETROLEUM INSTITUTE

- 范围——包含陆上井建和与井身完整性和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

API RP 100-1

- 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

API RP 100-1

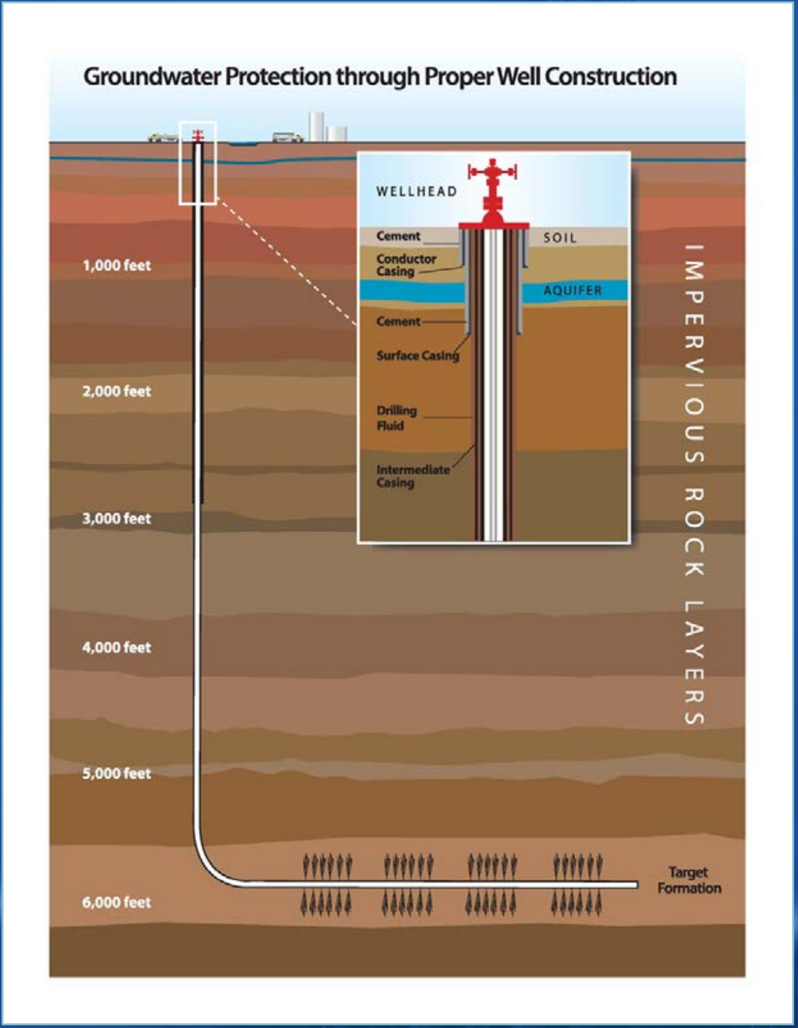
- 该文件不是一份详细的井建或压裂设计手册
- 尽管全行业井建操作做法都很相似，但由于不同的地质、环境、监管和操作要求个别油井设计和建设细节有相当大的差异
- 被行业认可的有关做法是由作业公司根据与开发和提高现有技术相关的经验获得的本地化专业知识

地下水的保护

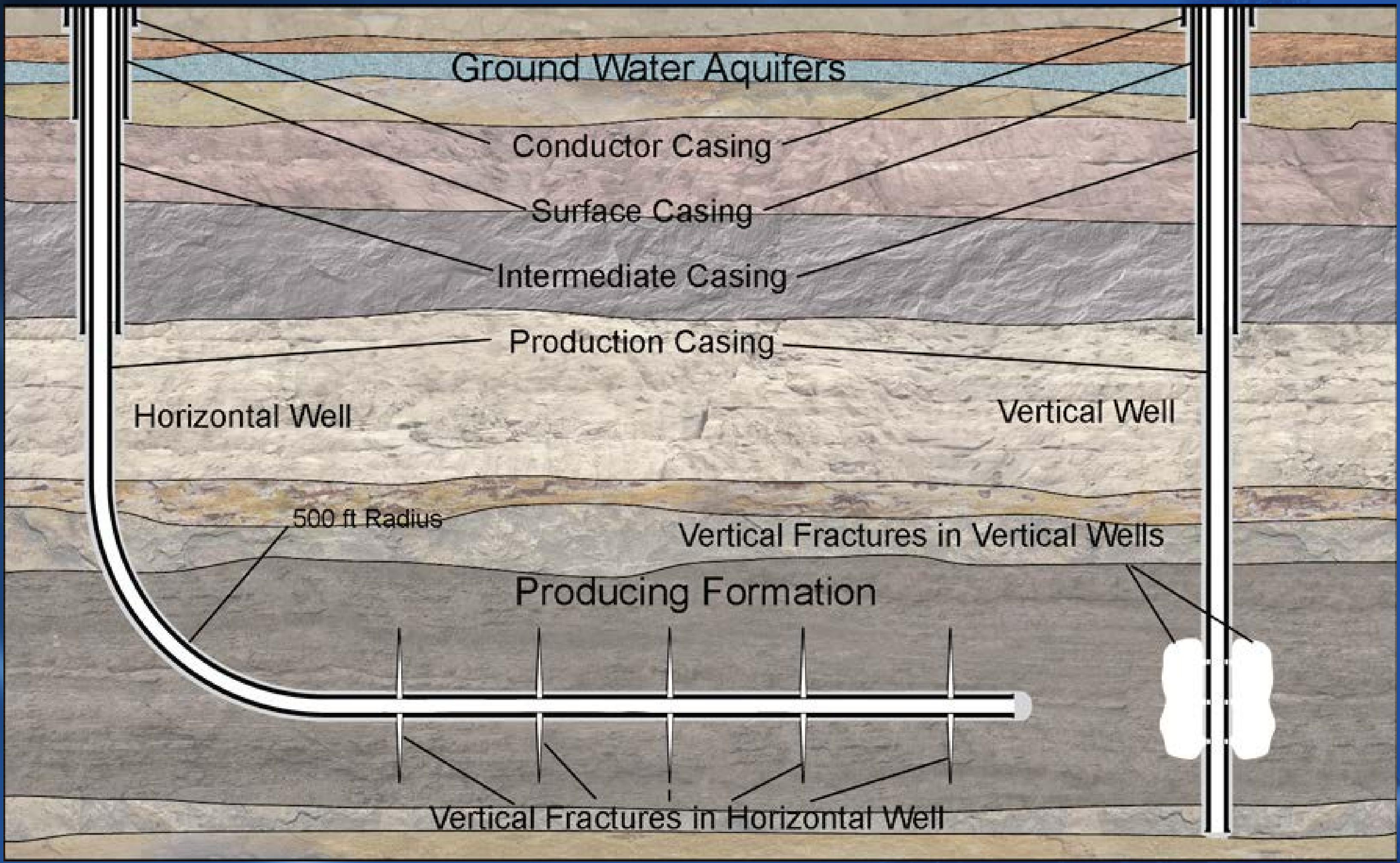
为保护地下水，每口井都包含多层套管和固井水泥

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 ）

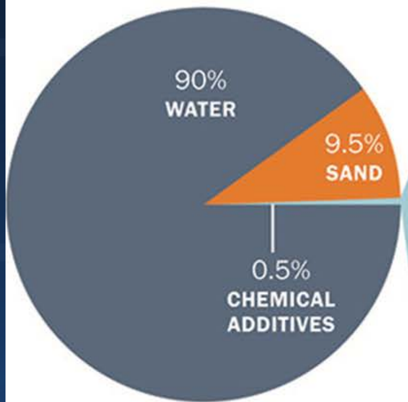


油井生产套管



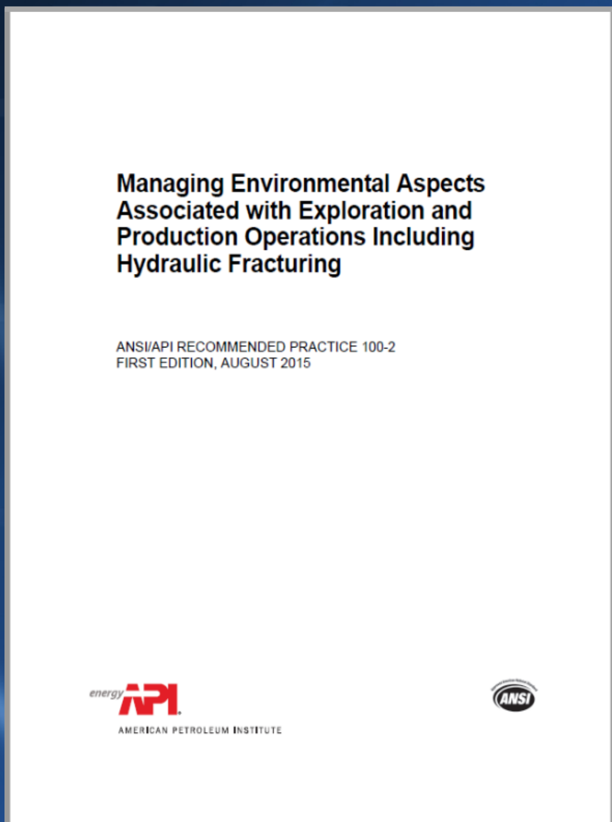
Ground Water Aquifers
Conductor Casing
Surface Casing
Intermediate Casing
Production Casing
Horizontal Well
Vertical Well
500 ft Radius
Vertical Fractures in Vertical Wells
Producing Formation
Vertical Fractures in Horizontal Well

认识压裂液



Compound	Purpose	Common application
Acids	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
Sodium Chloride	Allows a delayed breakdown of the gel polymer chains	Table salt
Polyacrylamide	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
Ethylene Glycol	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
Borate Salts	Maintains fluid viscosity as temperature increases	Laundry detergent, hand soap, cosmetics
Sodium/Potassium Carbonate	Maintains effectiveness of other components, such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
Glutaraldehyde	Eliminates bacteria in the water	Disinfectant, sterilization of medical and dental equipment
Guar Gum	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice
Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, hair coloring

API RP 100-2


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

ANSI/API RECOMMENDED PRACTICE 100-2
FIRST EDITION, AUGUST 2015

AMERICAN PETROLEUM INSTITUTE

- 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

API RP 100-2

❖ 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、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

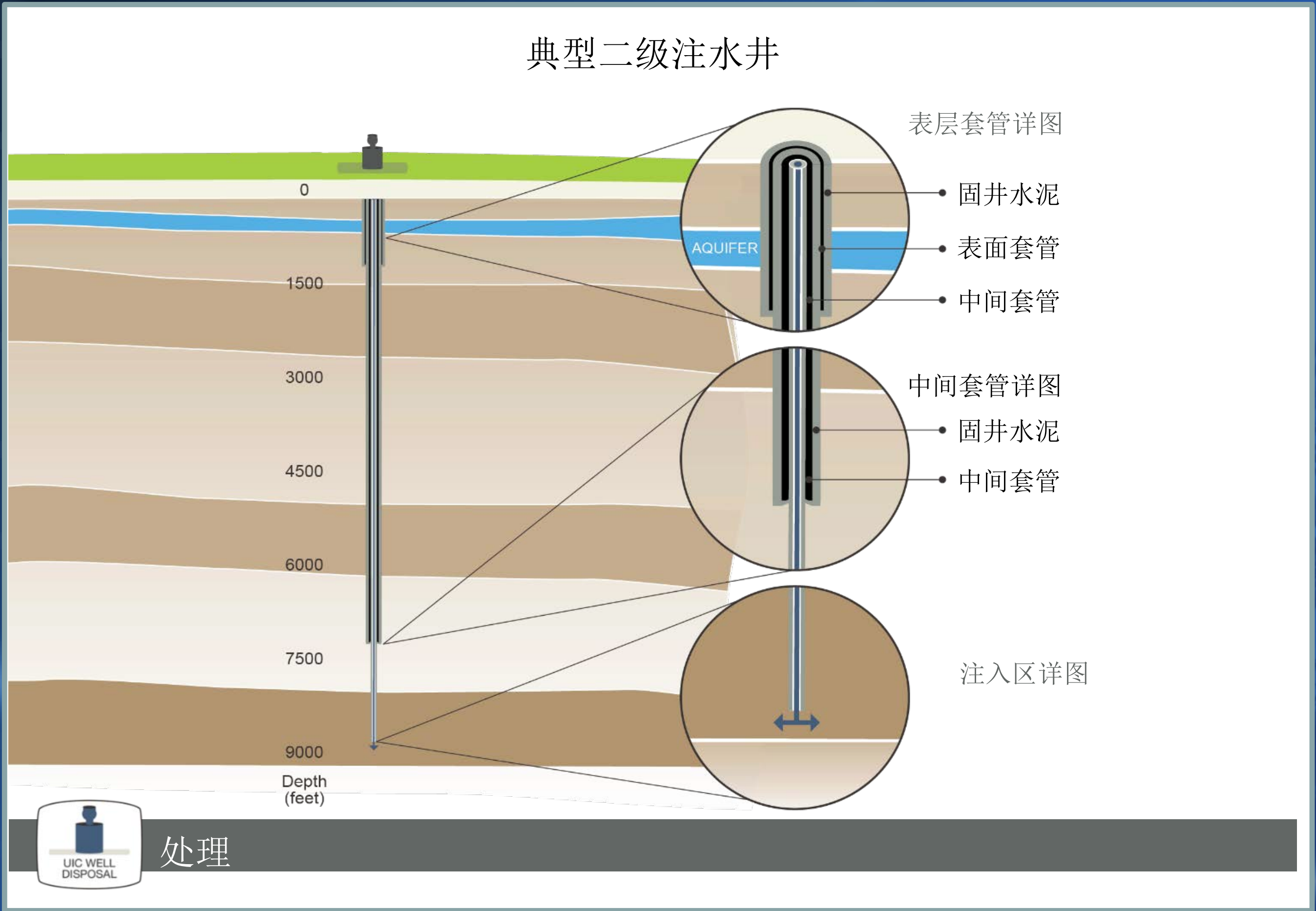
- 将水力压裂与钻井、完井和生产作业生命周期相结合
- 大部分内容都与用于提高生产作业的油井增产做法无关
- 描述基线做法
- 推荐做法是针对特定地点的，在油井的整个生命周期内都会发生变化

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

采出水处理

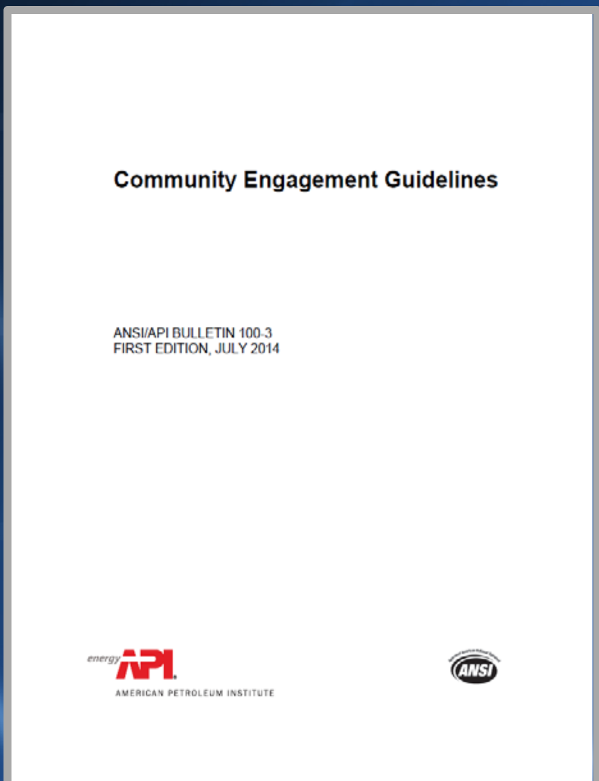


地下注水井从油气作业中将采出水安全地回收到地质形成物中

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）

API Bulletin 100-3


Community Engagement Guidelines

ANSI/API BULLETIN 100-3
FIRST EDITION, JULY 2014

AMERICAN PETROLEUM INSTITUTE

- 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

API Bulletin 100-3

- 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

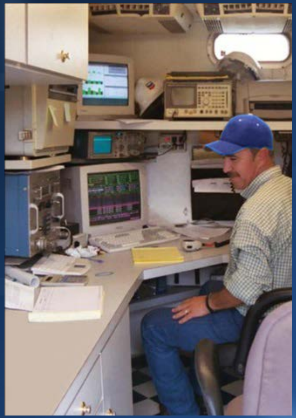
勘探
3－5年

策划
12－18个月

选址和井建
2－3个月

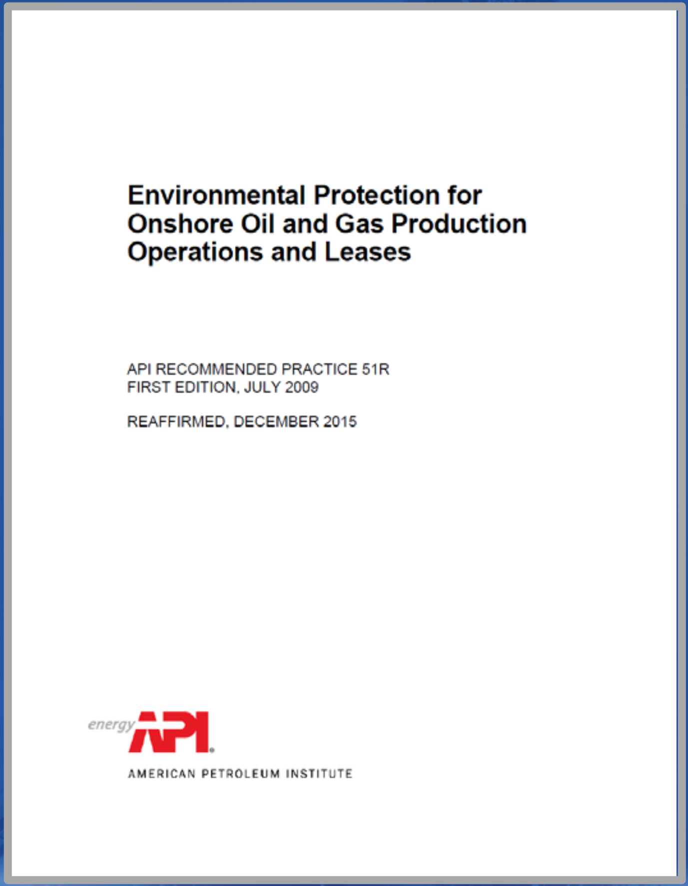
水力压裂
<u>3－5天</u>

开采
30多年



API RP 51R

- 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


Environmental Protection for Onshore Oil and Gas Production Operations and Leases

API RECOMMENDED PRACTICE 51R
FIRST EDITION, JULY 2009

REAFFIRMED, DECEMBER 2015

AMERICAN PETROLEUM INSTITUTE

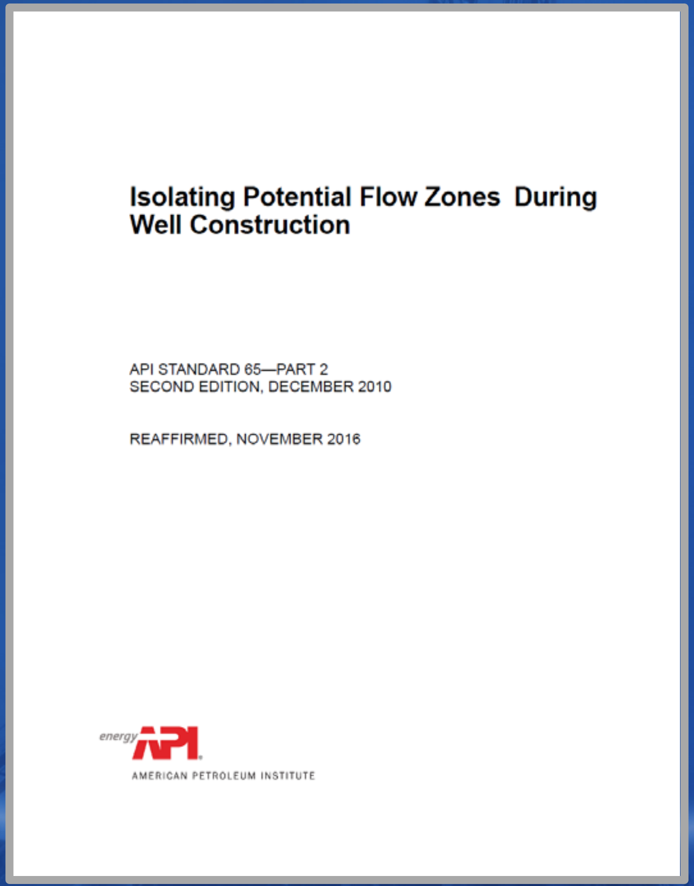
API RP 51R

- 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


Isolating Potential Flow Zones During Well Construction

API STANDARD 65—PART 2
SECOND EDITION, DECEMBER 2010

REAFFIRMED, NOVEMBER 2016

AMERICAN PETROLEUM INSTITUTE

API Std 65-2

- 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计、安装、运营、测试和修复》
- 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设备控制系统》

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?

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HUNTON
ANDREWS KURTH

Keynote Speech: U.S. Industry's Role in the Development of Shale Gas Policies, Regulations and Standards and Compliance
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

About Hunton Andrews Kurth LLP

美国何威安卓律师事务所简介

ABOUT OUR FIRM
关于本所

HUNTON
ANDREWS KURTH

- 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1000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

ABOUT OUR FIRM (cont'd)
关于本所（续）

HUNTON
ANDREWS KURTH

- 70% of the Fortune 50
  70%的客户来自世界财富50强
- 60% of the Fortune 100
  60%的客户来自世界财富100强
- Emphasis on client service and responsiveness
  注重客服服务和响应
  - BTI Client Service A-Team member for 16 straight years (annual survey of Fortune 1000 GCs)
    连续16年成为BTI客户服务A团队的成员（对财富1000强公司的总法律顾问进行的年度调查）
- Relationship-driven approach combined with industry expertise
  关系营销与行业专长相结合
- Preeminent M&A, energy, LNG, infrastructure and power practice and full-service strategic company experience
  拥有卓越的并购、能源、液化天然气、基础设施和电力业务以及提供全面服务的公司战略经验

ABOUT OUR FIRM (cont'd)
关于本所（续）

HUNTON
ANDREWS KURTH

19 offices worldwide.
全球19个办公室
100+ years of quality and service
100多年的高品质服务

Shale Reserves in the United States
美国页岩储量

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- This complete geological map shows how vast and complicated the U.S. shale plays are.
  这张完整的地理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。

Shale Reserves in the U.S. (simplified)
美国页岩储量（简化版）

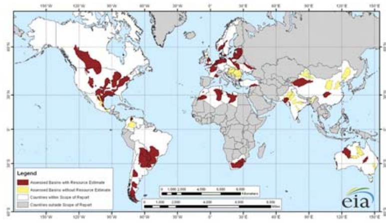
HUNTON ANDREWS KURTH

- In terms of economic importance, these are the most important shale plays.
  从经济重要性的角度讲，这些是最重要的页岩区块。
- 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
  其中，对于天然气而言，最重要的区块是德克萨斯州西部的二叠纪盆地和宾夕法尼亚州及其临州的马塞勒斯（阿巴拉契亚）地层。

Worldwide Shale Formations
全球页岩地层

HUNTON ANDREWS KURTH

- Shale gas reserves are present on every continent and in a wide variety of countries, including many countries that import oil and gas
  页岩气储量遍布各大洲和很多国家，包括许多进口石油和天然气的国家
- China's situation is particularly interesting
  中国的情况特别有意思



What Makes the U.S. Situation Unique?
是什么使美国的情况与众不同？

HUNTON ANDREWS KURTH

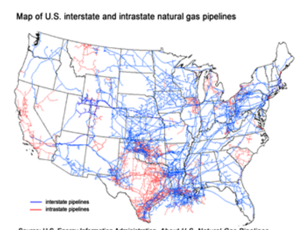
There are several reasons why the development of shale oil and gas has taken off in the United States.
在美国页岩油气开发兴起的几个原因。

- 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.
  美国的独特之处在于，土地所有者拥有地下烃类资源，这与世界上其他地方政府拥有地下矿权不同。
- The oil and gas industry has access to capital and has abundant expertise with U.S. geology.
  油气业拥有资金来源，并且在美国地质学领域拥有丰富的专业知识。

What Makes the U.S. Situation Unique? (cont'd)
是什么使美国的情况与众不同？（续）

HUNTON ANDREWS KURTH

- Regulations in the United States promote the development of oil and gas and provide a stable and predictable permitting process.
  美国的监管促进了石油和天然气的发展，并提供了稳定且可预测的许可程序。
- Finally, the U.S. benefits from having a large infrastructure network able to handle the expansion of the oil/gas sector.
  最后，美国得益于拥有一张能够应对石油/天然气行业扩张的大型基础设施网络。



Source: U.S. Energy Information Administration, *About U.S. Natural Gas Pipelines*

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

HUNTON ANDREWS KURTH

- Regulation in the U.S. occurs at four levels:
  美国的监管分为四个级别：
  - o <u>Private</u> – 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
  - o 私有层级 - 由于石油和天然气是私有的，因此该行业的大部分"监管"实际上是由生产商和承包商、生产商和私有土地所有者之间的合约实现。
    - ▪ Contracts are standardized
      合同标准化

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）

HUNTON ANDREWS KURTH

- Oil and gas leases
  石油和天然气租约
- Joint operating agreements
  联合经营协议
- Drilling contracts
  钻井合同
- Division orders
  分配协议

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）

HUNTON ANDREWS KURTH

- 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

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）

HUNTON ANDREWS KURTH

- 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

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）

HUNTON ANDREWS KURTH

- State-level regulations
  州级监管
  - 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

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）

HUNTON ANDREWS KURTH

- 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）

HUNTON ANDREWS KURTH

- 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

HUNTON ANDREWS KURTH

- 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

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

HUNTON ANDREWS KURTH

- Clean Air Act
  清洁空气法案

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

HUNTON ANDREWS KURTH

- Clean Air Act is the law that defines EPA's responsibilities for protecting and improving the nation's air quality and the stratospheric ozone layer
  《清洁空气法案》规定了美国环保署在保护和改善国家空气质量和平流层臭氧方面的责任
  - o Crude oil and natural gas facilities may release hazardous air pollutants during operations, for example, from equipment leaks, when materials are transferred from one location to another, or during discharge through emission stacks or vents
    原油和天然气设施在运行过程中有可能释放出有害的空气污染物，例如，当材料从一处转移到另一处时的设备泄漏，或者通过排放烟囱或通风口排放期间

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

HUNTON ANDREWS KURTH

- o Requires states to develop a general air quality plan to implement and enforce standards in all areas of the country
  要求各州制定总体空气质量规划以在全国所有地区实施和执行标准
- o Requires states to develop a specific plan to attain and maintain the standards for each area designated as a nonattainment area
  要求各州为标明的非达标区域的各地区制定具体规划，以达到并保持标准
- o Very complex
  非常复杂

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

HUNTON ANDREWS KURTH

- CERCLA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund,
  《综合环境响应、赔偿和责任法案》（CERCLA），俗称为超级基金法案
  - o enacted by Congress on December 11, 1980
    1980年12月11日由国会通过
  - o EPA has the authority to take response actions, undergo investigations and monitoring, and gather information in certain circumstances
    美国环保署有权采取应对措施、进行调查和监督并在特定情况下收集信息
  - o EPA authority is triggered by the release of hazardous substances into the environment (ground or air)
    美国环保署的权力来自向环境（地面或空气）释放有害物质
  - o Short-term response (for emergency situations)
    短期响应（在紧急情况下）
  - o Long-term response on national priorities list (superfund sites)
    国家优先事项清单的长期响应（超级基金站点）

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

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- The Clean Water Act regulates the discharge of pollutants to waters of the U.S.
  《清洁水法案》监管向美国水域排放污染物
- 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.
  《清洁水法案》中的国家污染物排放削减系统（NPDES）许可计划通过对美国水域排放污染物点源的监管来控制水污染。

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

HUNTON ANDREWS KURTH

- 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.
  1986年制定的《应急计划和社区知情权法案》（EPCRA）帮助社区保护公众健康、安全和环境免受化学危害。
- Facilities that maintain extremely hazardous substances on-site in quantities greater than established threshold quantities must cooperate in emergency plan preparation.
  实地维护超过规定阈值的极度危险物质的设施必须配合应急预案的编制。

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

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- Examples of application in the shale industry:
  页岩业应用实例：
  - During well development (drilling fluids), well stimulation (hydraulic fracturing fluids), well maintenance (scale removal fluids, corrosion inhibitors), and gas processing
    在油井开发（钻井液）、油井增产（液压压裂液）、油井维护（除垢液、缓蚀剂）和天然气处理期间
  - Materials stored on site at a well pad may include motor oil, hydraulic oil, diesel fuel, drilling mud and hydraulic fracturing fluid
    井场现场储存的材料可能包括机油、液压油、柴油、钻井泥浆和液压压裂液
  - Chemicals necessarily involved in the use of other equipment and processes, such as compressor engines, glycol dehydrators, condensate storage tanks, equipment components, and turbines
    使用其他设备和工艺所必需的化学品，如压缩发动机、乙二醇脱水机、冷凝液储罐、设备部件和涡轮机

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

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- Federal Insecticide, Fungicide and Rodenticide Act
  联邦杀虫剂、杀菌剂和灭鼠剂法案
- provides EPA with the authority to oversee the registration, distribution, sale and use of pesticides
  授权美国环保署监督杀虫剂的注册、分发、销售和使用
- Some of the chemicals used in hydraulic fracturing are biocides
  液压压裂中使用的一些化学物质是杀菌剂

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

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- 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
  杀菌剂是一种杀虫剂，用于祛除在井壁内产生腐蚀性副产物的细菌，并防止细菌堵塞岩层破裂
- 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
  除草剂可以在天然气管道沿线使用，和/或在钻台、压缩站或天然气站周围使用从而维护海湾的植被
- Pesticides may be included in the field processing impurities, including wastewater
  杀虫剂可被用于在实地处理杂质，包括废水

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

HUNTON ANDREWS KURTH

- Resource Conservation and Recovery Act
  资源保护回收法案
  - authorizes the EPA to regulate hazardous waste, including all stages of the waste's life cycle:
    授权美国环保署监管危险废物，包括废物生命周期的所有阶段：
    - generation, transportation, treatment, storage, and disposal
      生产、运输、处理、存储和处置
    - 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

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

HUNTON ANDREWS KURTH

- framework for the management of non-hazardous industrial solid wastes and municipal solid wastes
  无害工业固体废物和城市固体废物的管理框架
- certain exemptions available for oil and gas, but can be overridden by state-level regulation
  对特定石油和天然气进行免税，可以被州级法规推翻

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

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- The Safe Drinking Water Act (SDWA) is the primary federal law that ensures the quality of Americans' drinking water.
  《安全饮用水法案》（SDWA）是确保美国人饮用水质量的主要联邦法律。
  - Under SDWA, the EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers implementing those standards
    根据SDWA，美国环保署制定了饮用水质量标准，并监督州、地方和水供应商执行该类标准
  - may apply when hydraulic fracturing or other oil or natural gas production activities impact a public water system's supply
    可适用于当液压压裂或其他石油或天然气生产活动影响公共水体系的供应
  - regulate the construction, operation, permitting, and closure of injection wells that place certain fluids underground
    监管将特定液体导入地下的注入井的建设、运营、许可和关闭

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Thank You!/谢谢

Strictly Confidential 31

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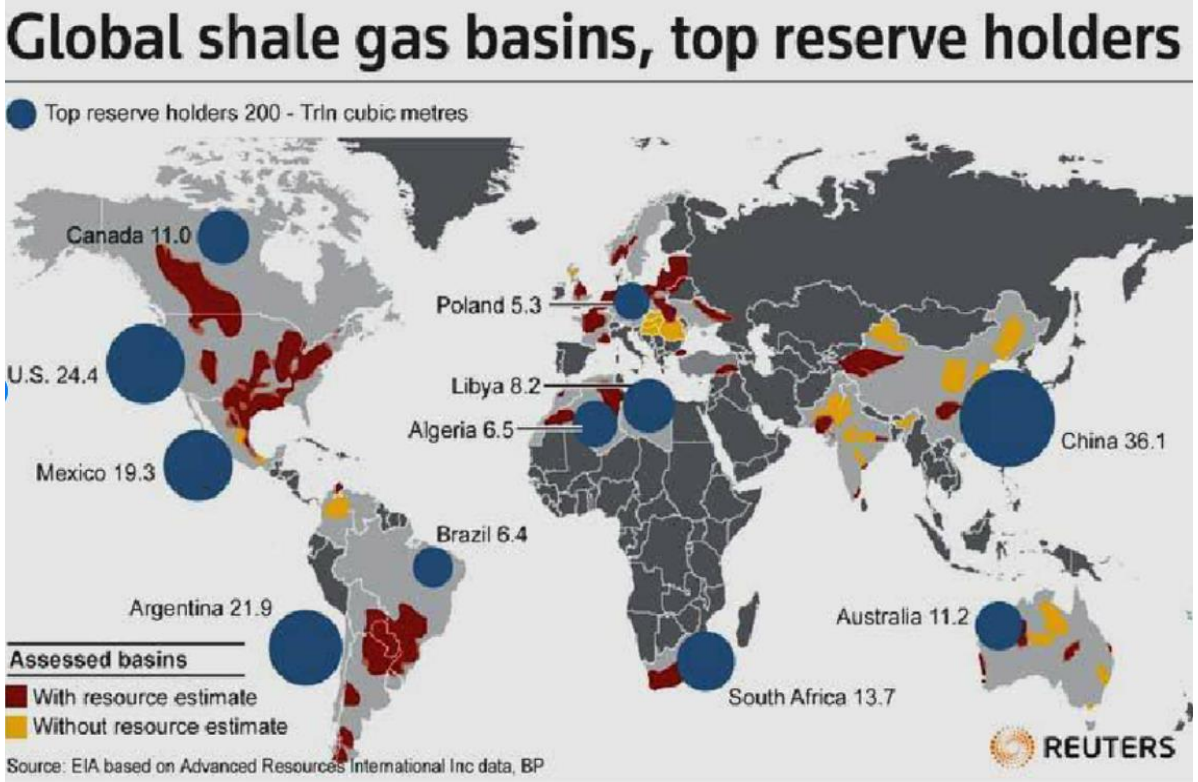
索拉移动式发电车应用
Solar Mobile Turbomachinery

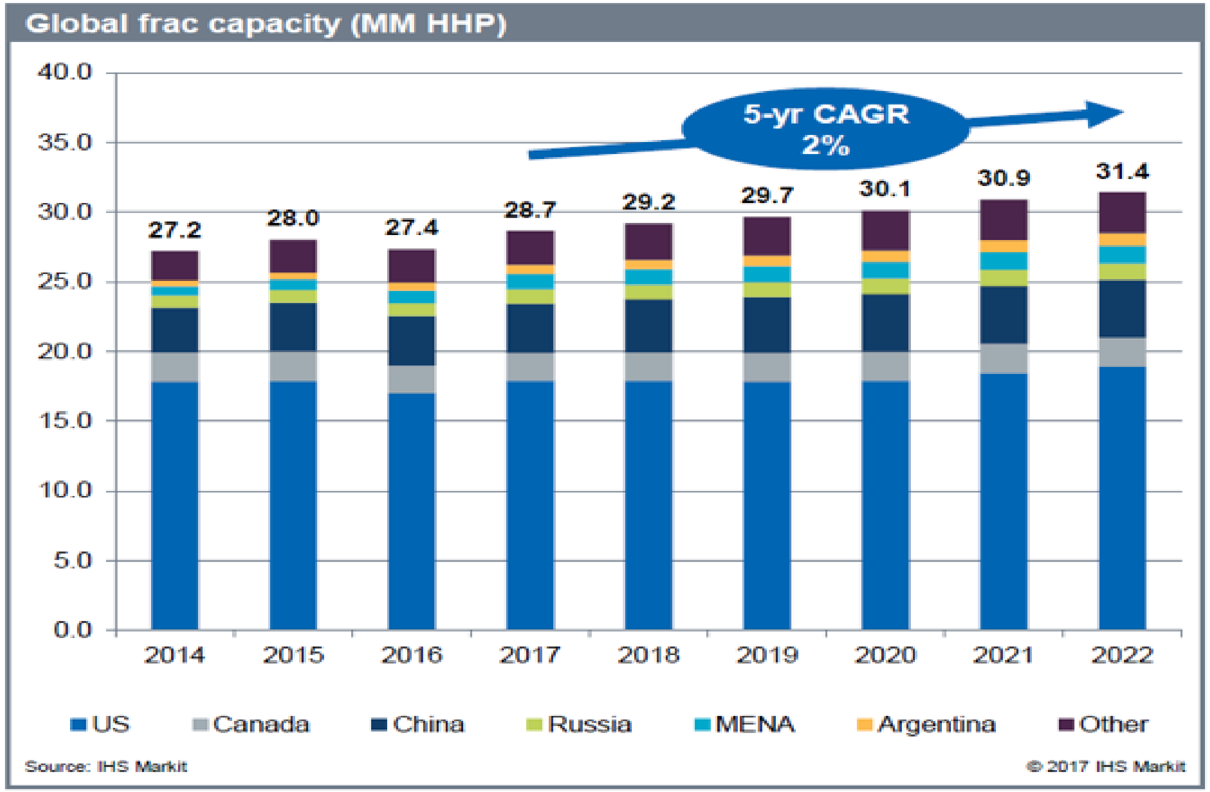
Solar Turbines
Market Development Manager
Chris Mellos

日程
AGENDA

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

全球压裂市场需求 GLOBAL FRAC CAPACITY & DEMAND





- 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:

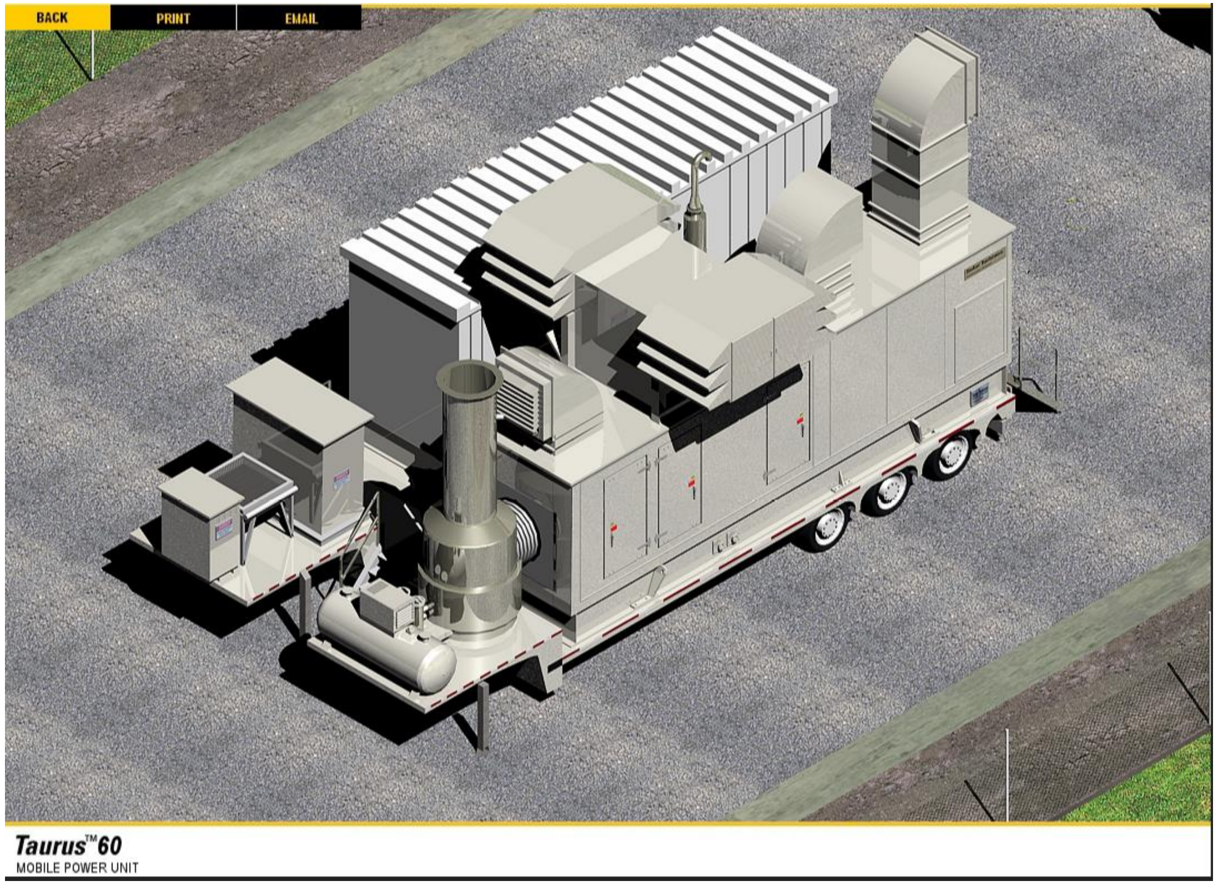
传统石油天然气已经受到非常规能源 – 页岩油气冲击：
Traditional Oil & Gas has been *permanently disrupted by Shale Oil & Gas and* ***URD*** *has resulted from it:*

Business Space	Unconventional Resources Development (URD)				
Activity	**Drilling**	**Hydraulic Fracturing & Completion**	**Production**	**Gathering**	**Processing**

- 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

金牛60移动式发电车
TAUROUS 60 MOBILE POWER UNIT FOR SHALE GAS DEVELOPMENT

- 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

电动压裂技术
E-FRAC TECHNOLOGY

<u>设备 Equipment</u>

- 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

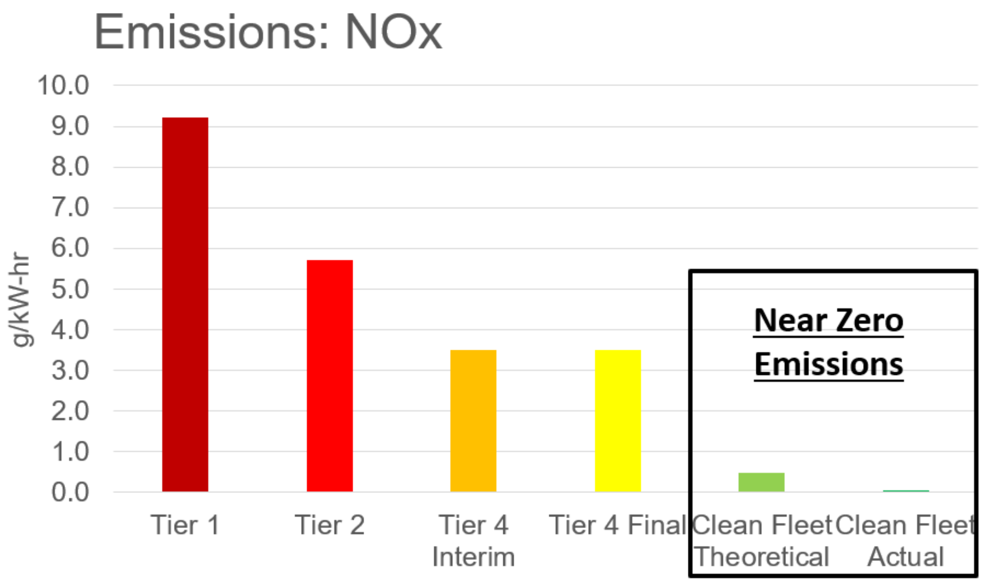
<u>环境受益 Environmental Benefits</u>

- 排放下降 Reduced Emissions
- 物流减少 Reduced Traffic
- 噪音降低 Reduced Noise

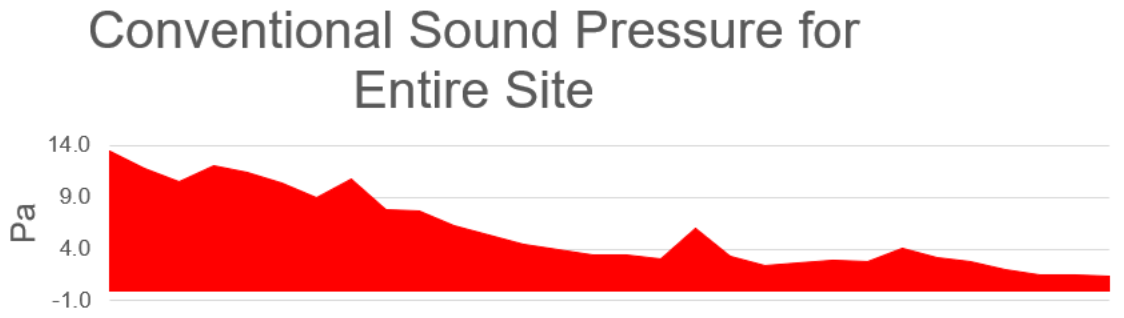
全电气化，可移动的井口电力系统

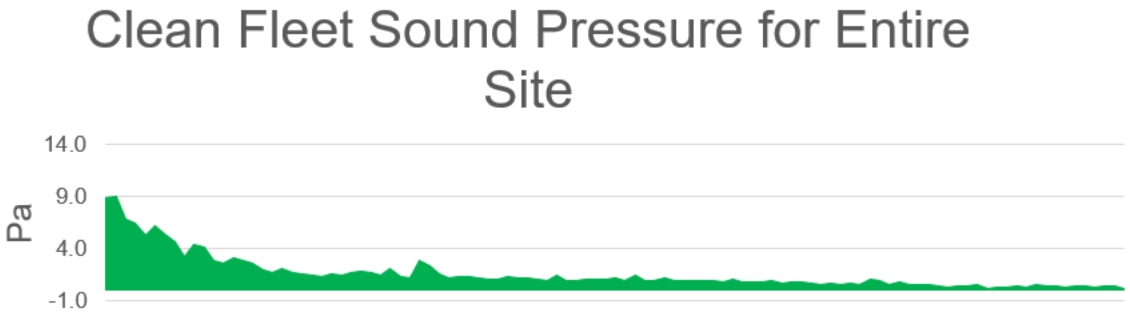
Fully *Electric*, Fully *Mobile* Well Stimulation System, Powered by *Natural Gas*

降低的排放及噪音
LOW EMISSIONS & NOISE



传统车队和清洁车队





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

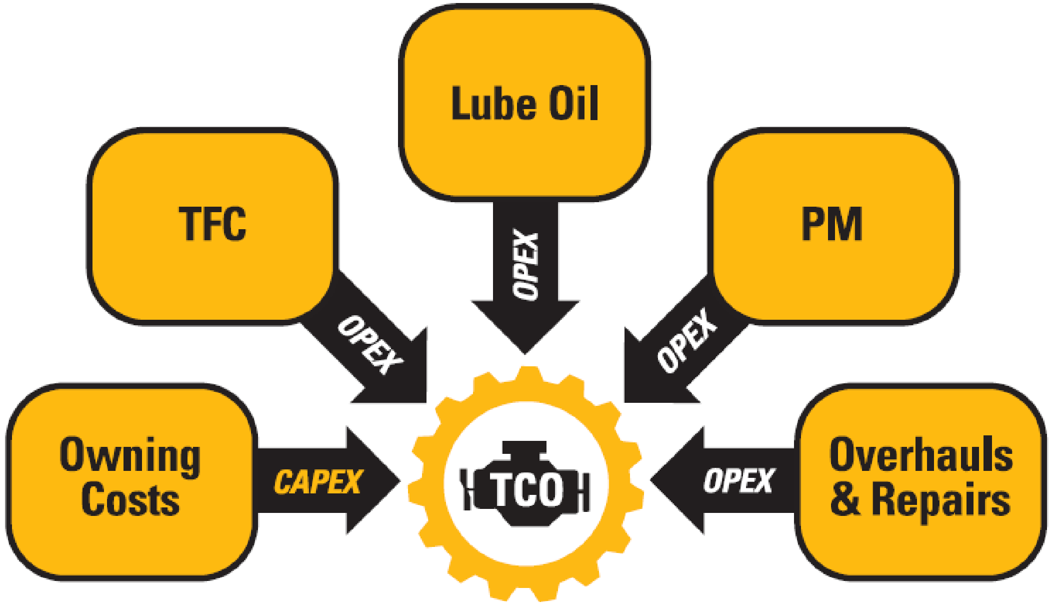
平均声压69%的下降

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)**
  - 初购成本 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

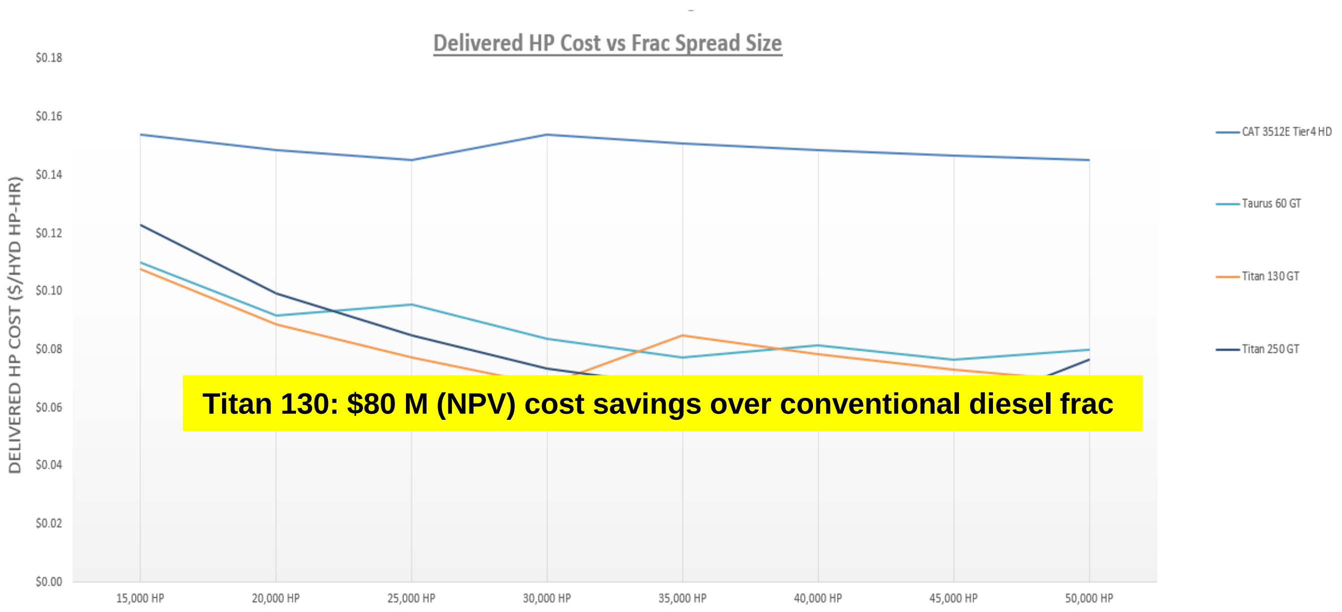


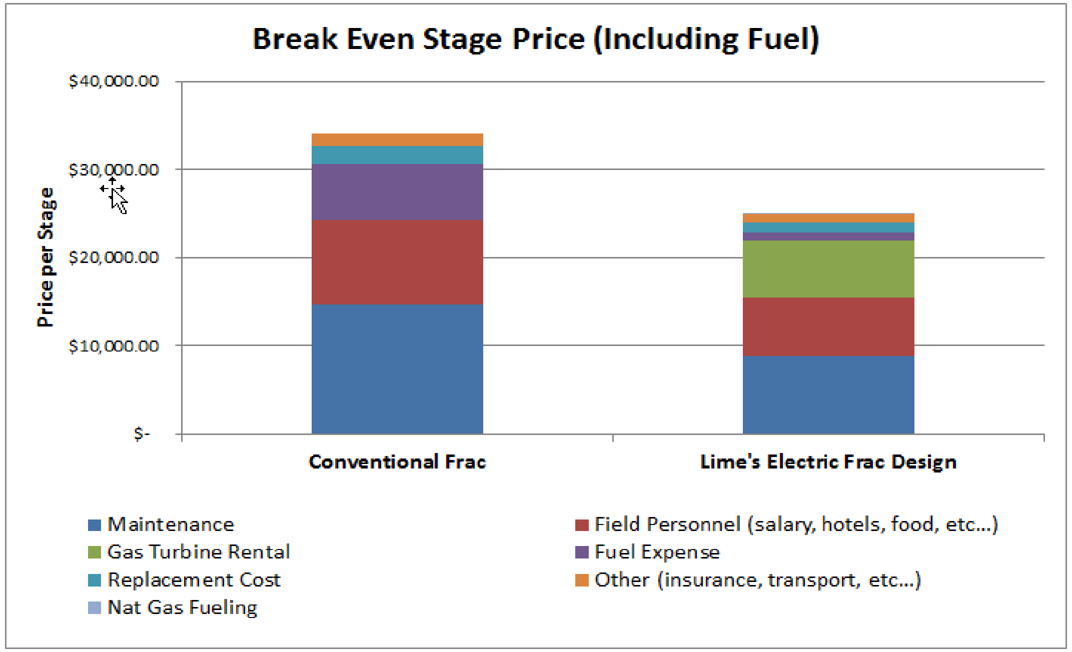
$ / HHP-hr

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





过去5年多的经验总结
LESSONS LEARNED FROM 5+ YEARS EXPERIENCE

辅助装置连接

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

低速联轴节

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

调平

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

助推器

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

人机界面

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

气动件

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

接口

Connections
- Too many connections especially to EER

客户的声音
Customer Must Haves

组建时间控制在4小时之内

Set up time is crucial. Needs to be less than 4 hours.

16米长x4米高x2. 5米宽=机位空间

无需拖车助推器

16m L x 4m H x 2.5m W envelope.

9000 kg per axle.

No Trailer booster.

无需起重机

No crane lifts.

无需额外支地点

No feet off the ground.

低过联轴节，须时时在位

Low Speed Coupling needs to stay in place.

对中花太多时间

Alignment takes too much time.

自动调平系统

Auto levelling system.

调平脚成为拖车的一部分，他们太重了

Make levelling legs a part of the trailer. They are too heavy.

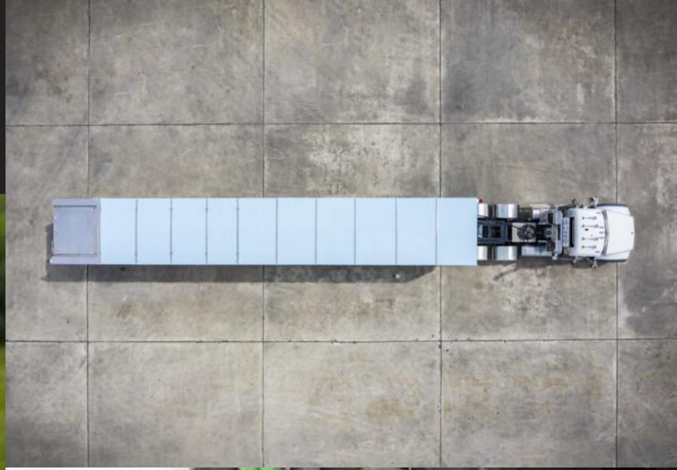
用户需要能快速应用的设备

You give me equipment I don’t need which drives the cost.

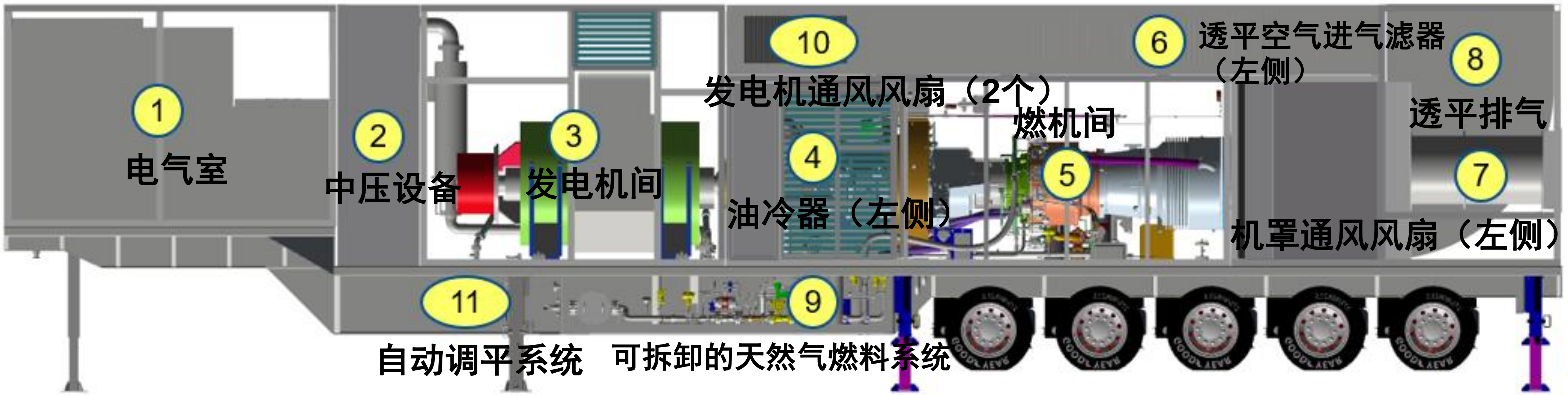
我们正在实施的改进…
WHAT ARE WE DOING?

- 对拖车的重新设计，　能包含完整的机组 Complete redesign of trailer to incorporate the full package.
- 直接安装在拖车上面，无需底座 Powertrain integrated directly onto the trailer with no frame.
- 所有系统直接在拖车上成橇 All Systems packaged directly onto the trailer.
- 在运送途中，锁定低速联轴节，无需对中　Lock the low speed coupling in place for transit. No alignments.
- 提供自动调平系统 Provide an auto levelling system
- 无需起重机，无额外支地点 No crane lifts. No feet off the ground
- 3个接口 3 connections
  1. 黑启动 Black start
  2. 燃料 Fuel
  3. 动力输出 Output power
- 停车、接线、运行 Park, plug and play

SMT60

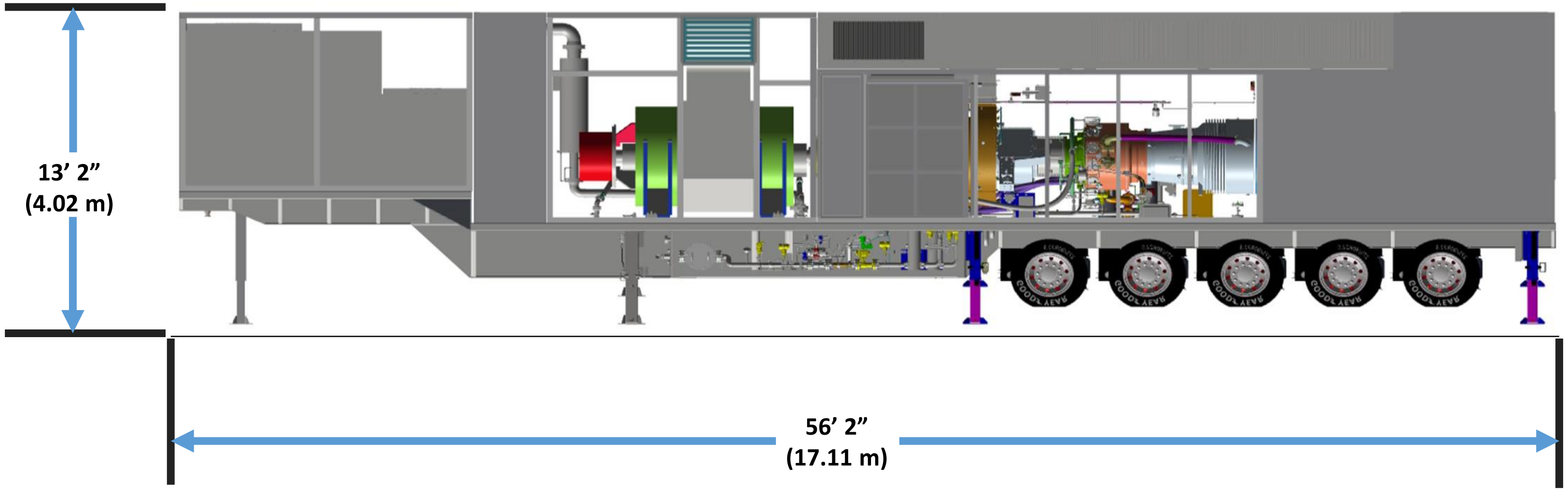


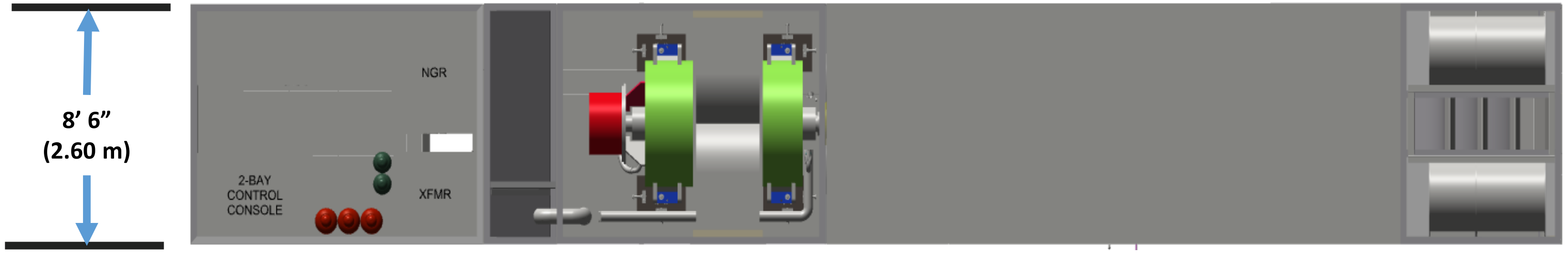
主要部件
MAJOR ITEMS



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

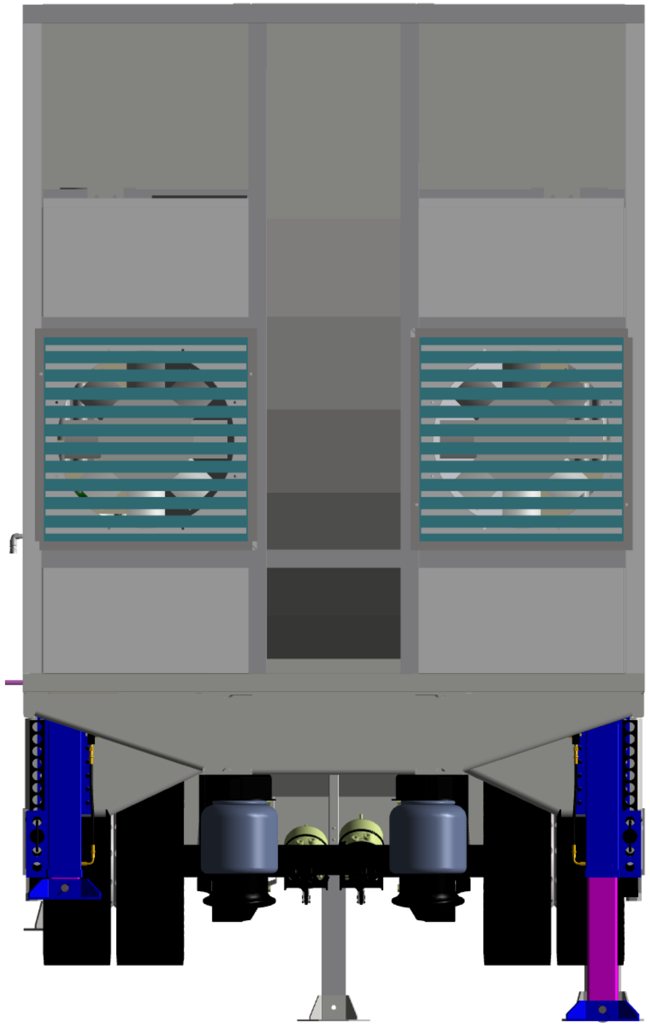
单拖车占地面积
Single trailer footprint



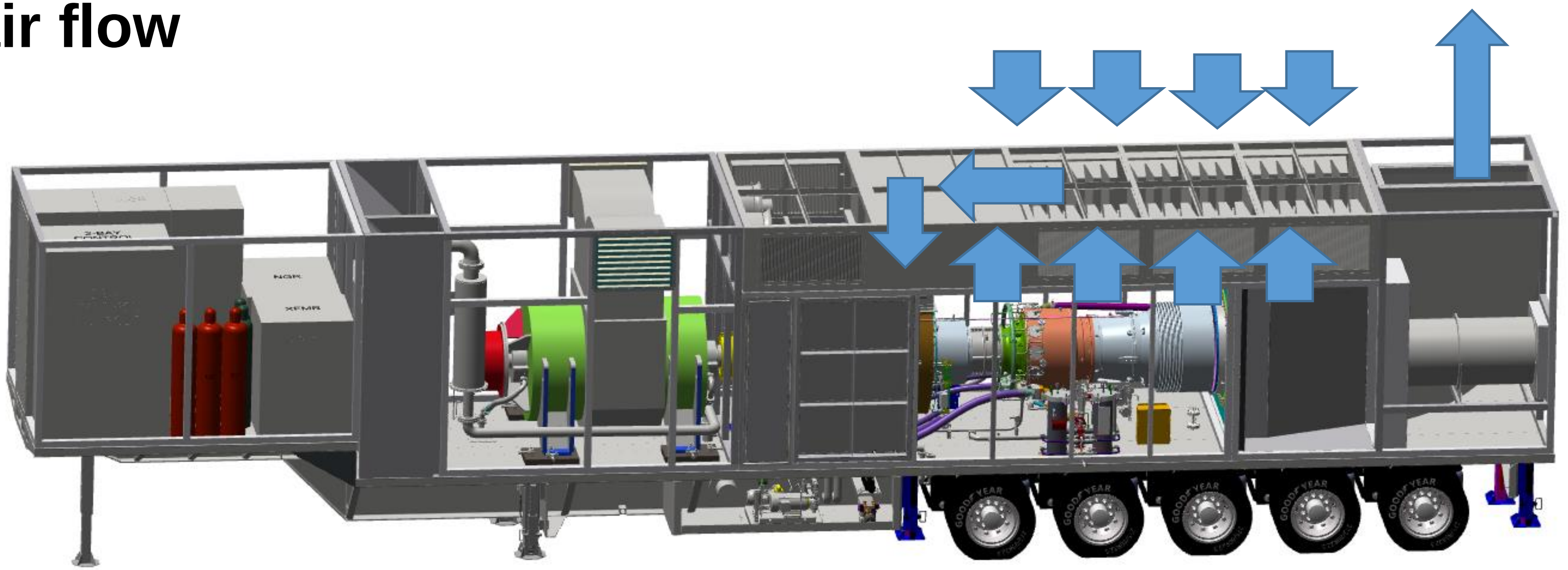


Approximate weight 125,000lbs (56,000kgs)

前后
FRONT & BACK



透平进排气
Turbine air flow



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.

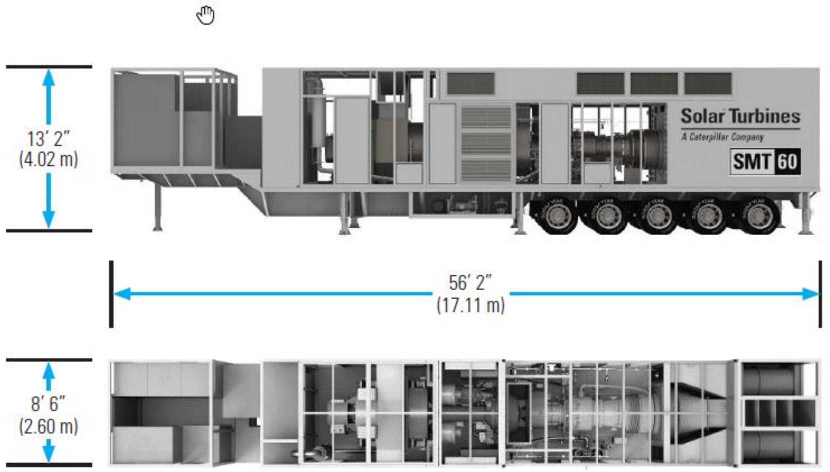
Solar Mobile Turbomachinery (SMT60)

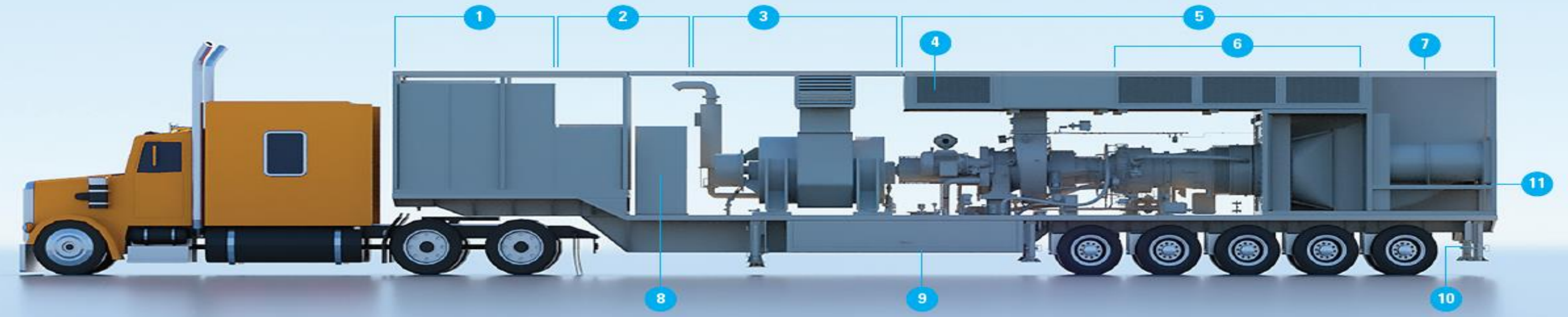
Powered by the Taurus™ 60 engine from Solar, the SMT60 provides superior mobile technology:

- 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

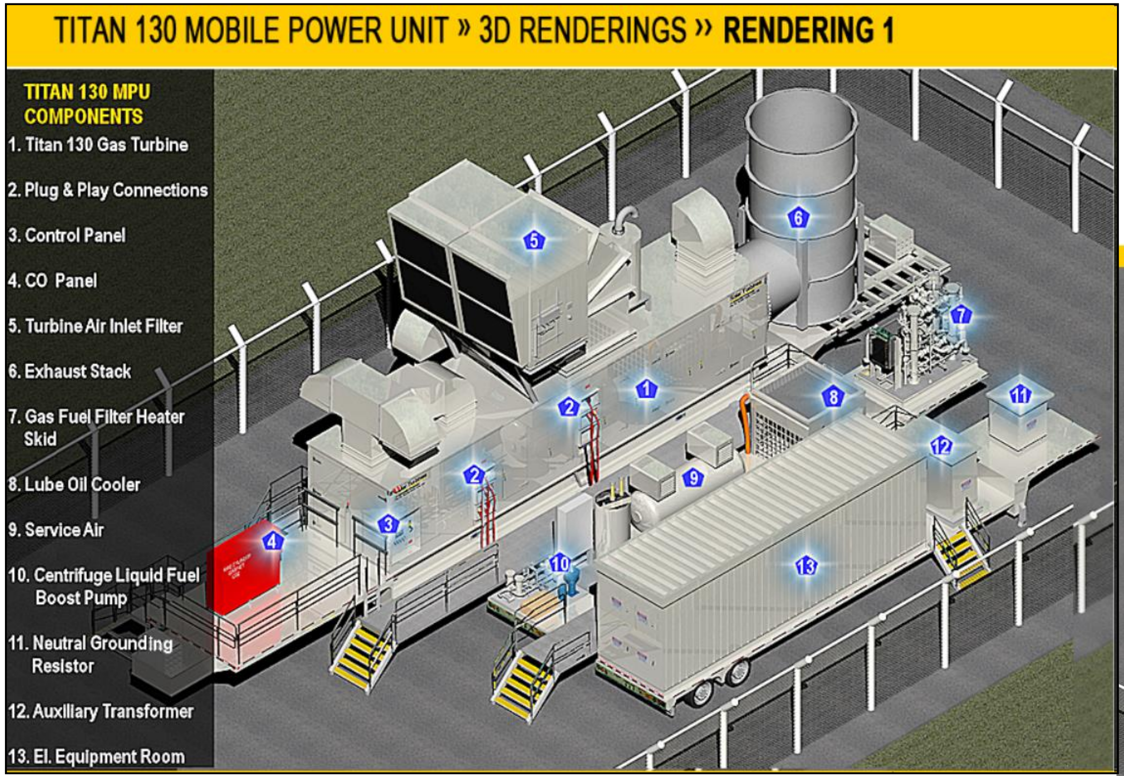
- Dimensions: 56'2" l x 8'6" w x 13'2" h
- 7700 HP (5.7 MWe) ISO
- 13.8KV / 4160V generator
- Reduced noise emissions
- Single trailer design
- Dry low emissions
- Dual fuel capable
- Runs on wide range of well-head gas fuels
- DOT compliant; no escorts required





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

大力神130移动发电单元
Titan 130 Mobile Power Unit



- 15–20吨的起重机用来起吊辅助装置
- 15-20 Ton Crane for Ancillary Equipment
- 叉车 （可选）
- Fork Lift (optional)
- 标准手动工具
- Standard Hand Tools
- 5人标准队伍
- 5-Person Crew
- 3–5天搭建完成
- 3-5 day set-up

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

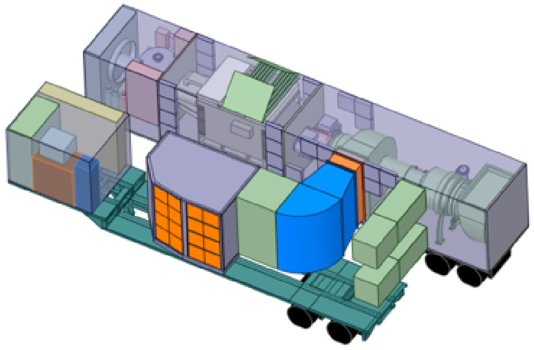
Requirements

- 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

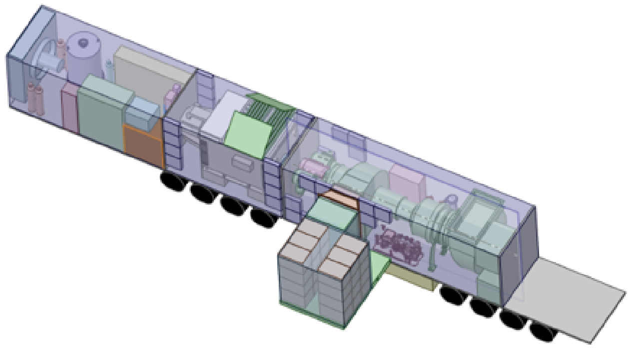
Concept 1
Everything on one trailer except Air Inlet on secondary

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



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

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



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

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

Footprint

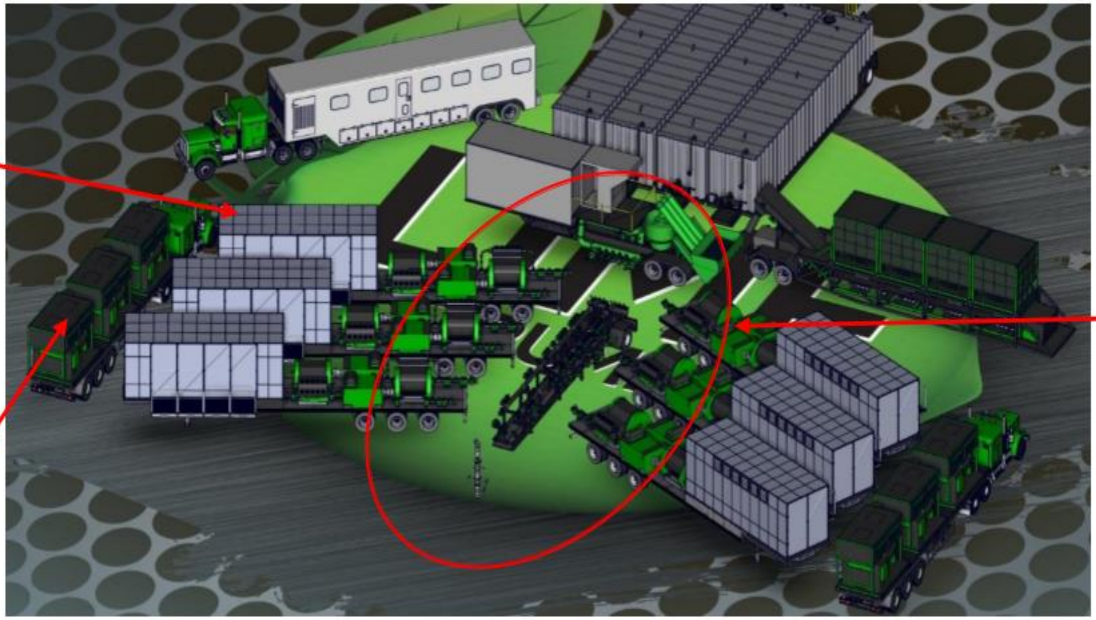
Smallest Footprint Lightest Package in the E-Frac Industry:

- 5000hp per trailer
- ~105-110K lbs. per trailer

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



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

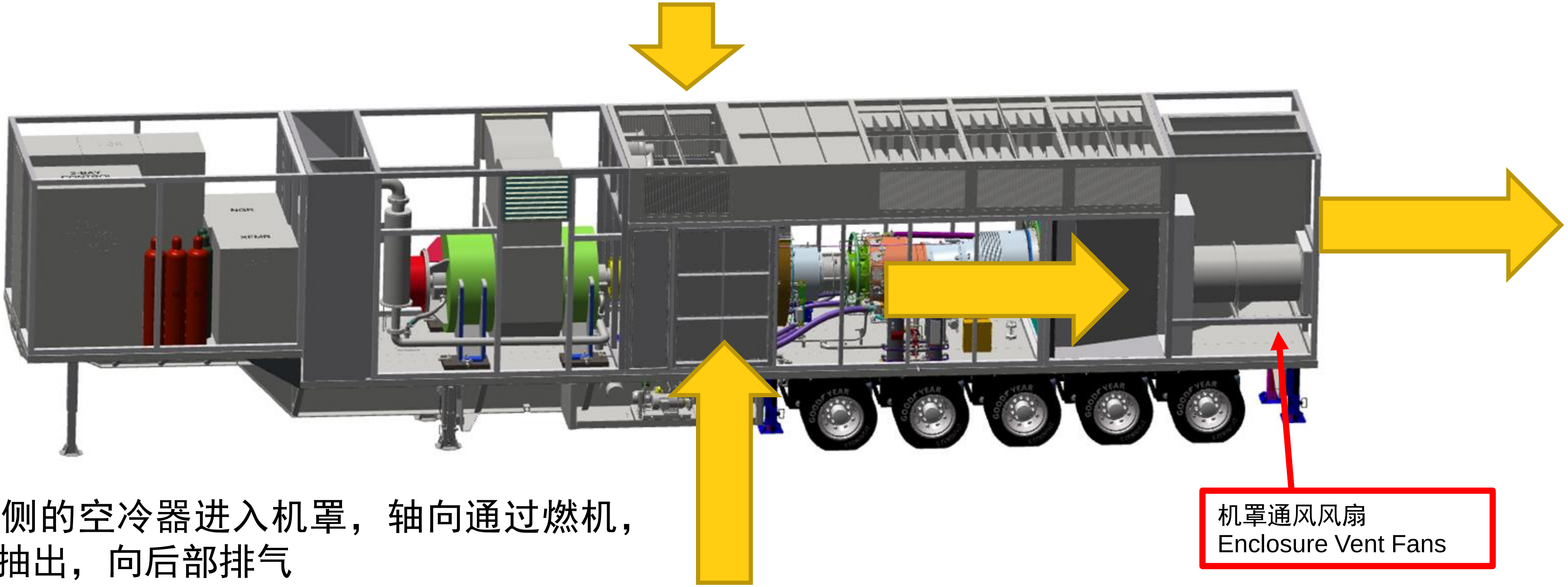
控制及远程监测整个井场（实时）

- 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

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

Caterpillar: Confidential Yellow

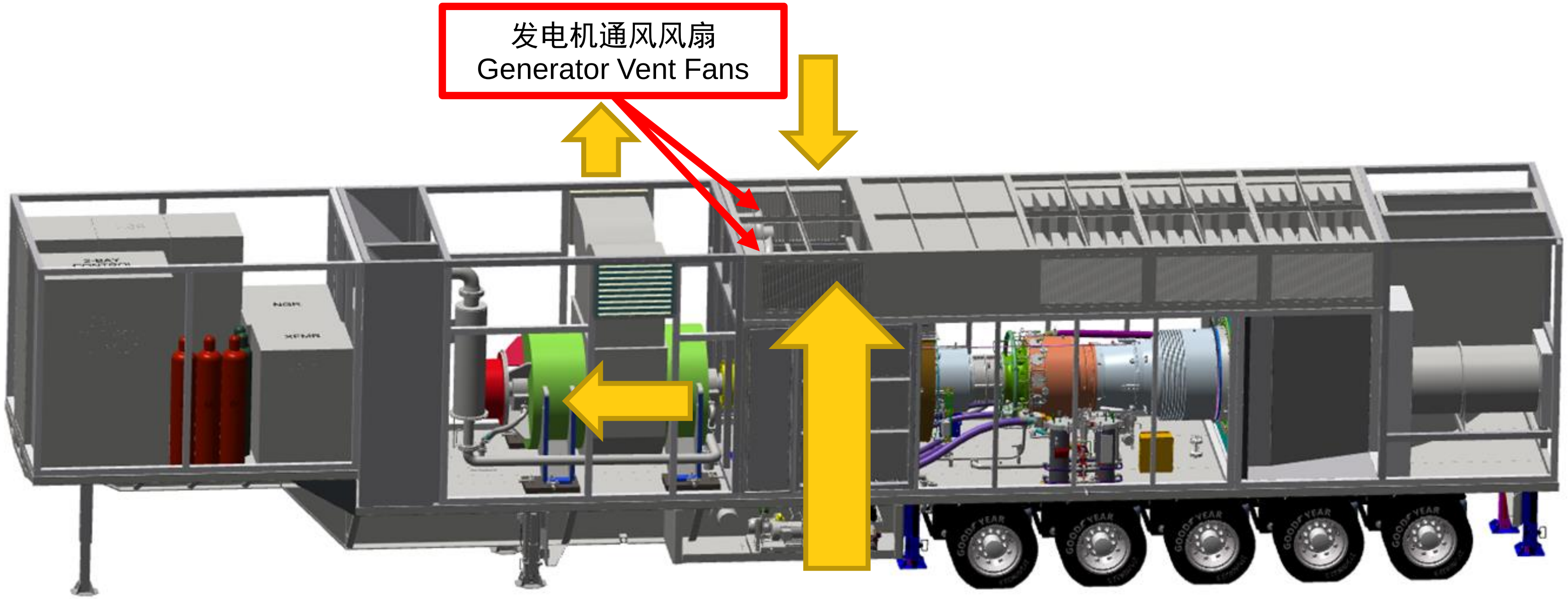
透平机罩通风
TURBINE ENCLOSURE VENTILATION FLOW



空气经过两侧的空冷器进入机罩，轴向通过燃机，由通风风扇抽出，向后部排气

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.

发电机机罩通风
GENERATOR ENCLOSURE VENTILATION FLOW



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…

Global Shale Gas Development Trend and Suggestions on International Cooperation on Standardization

中国石油

National Energy Shale Gas Research（Experiment）Center

2019.11

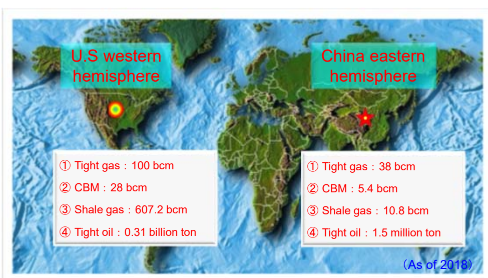
Outline

1 Global shale gas E & P status

2 E & P technical development trend

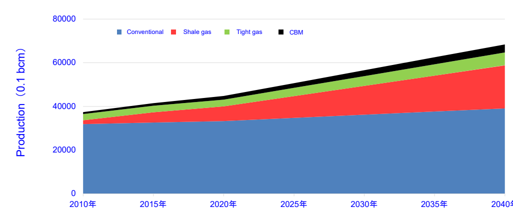
3 Advice on standardization cooperation

4 Unconventional hydrocarbon production in 2 countries



EIA predicts 1.6 tcm shale gas in 2040

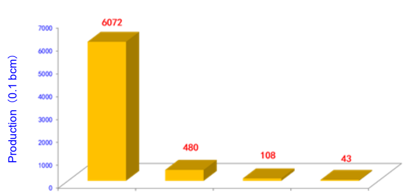
- According to EIA（2016）, 1.6 tcm of shale gas can be expected in 2040, accounting for 24% of natural gas production, 60% of the natural gas increase



2010-2040 natural gas production（EIA，2016）

4 countries have industrialized shale gas development

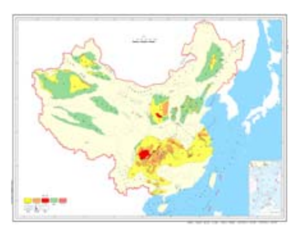
- In 2018, global shale gas total production 670.3 bcm：
U.S. 607.2 bcm, Canada 48 bcm, China 10.8 bcm, Argentina 4.3 bcm



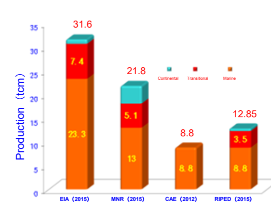
2018 Global shale gas production

Abundant shale gas resources in China

- Shale gas favorable area of 0.43 million km^2, recoverable resources 8.8～31.6 tcm



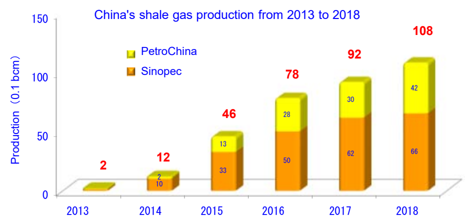
China shale gas favorable region prediction map



China shale gas resources evaluation

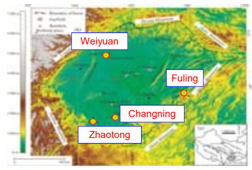
2018 shale gas production exceeded 10 bcm

2018 China's shale gas production 10.8 bcm: Sinopec 6.6 bcm, CNPC 4.2 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)



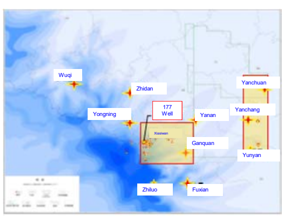

Wei201


Wei201-H1


Ning201-H1

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



Shale gas exploration area in Yanchang

On-site Shale gas wells in Yanchang

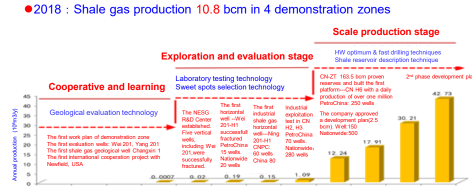
Outline

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

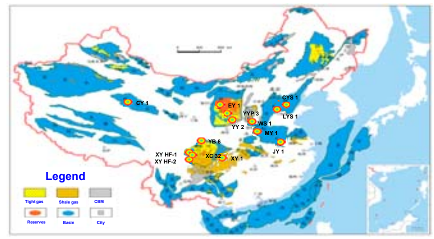


2. Gaps exist compared to North America

Field	Technical status（U.S）	Technology in China and the gap
Resource evaluation	● Combination of static and dynamic methods	● Volume method initially established ● Recoverable resources evaluation method on the way
Target area selection	● Geological-engineering comprehensive analysis method, comprehensive risk analysis method ● Applied in 12 strata in 22 basins	● Objective evaluation of geological factors considering geology and fracturing ● Only Longmaxi Formation in Sichuan Basin
Drilling engineering	● Horizontal well one-trip drilling, drilling footage 1500-2000m ● Drilling cycle 10-30d ● Drilling speed 30-80m/h	● One-trip drilling just started, drilling footage 500-1000m ● Drilling cycle 70-90d ● Drilling speed 6-8m/h, easy for well collapse and sticking
Fracturing engineering	● Cluster spacing 6-15m ● Interval spacing 35-60m	● Cluster spacing 20-30m ● Interval spacing 60-80m
Development	● EUR average 0.3-0.4 bcm ● Effective development for buried depth <4500m	● EUR average 0.1 bcm ● Effective development for buried depth <3500m

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 ?

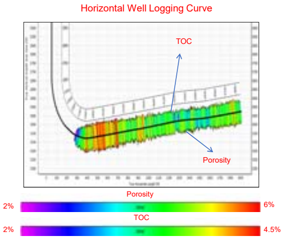


E & P map of unconventional gas (Zou et al. 2015)

Challenge 2. Technology for deep reservoirs

Over 50% of CNPC's shale gas resources are buried deeper than 4000m

Horizontal Well Logging Curve

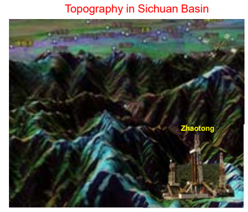


- High temperature---more than 150℃
- High stress---more than 100MPa
- High cost---more than 70 million RMB per well

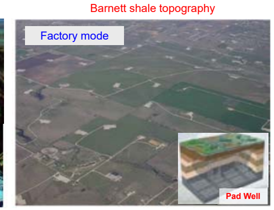
Challenge 3: Costs control and environmental protection

- Complex cost：expensive water transporting, complex topography
- Strict environmental policies：water cycle system, toxic gas emissions

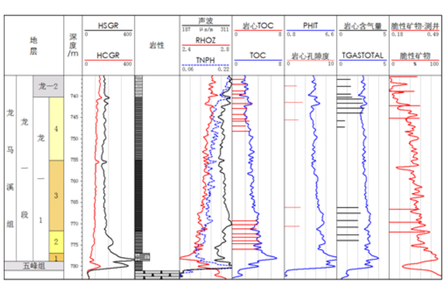
Topography in Sichuan Basin



Barnett shale topography



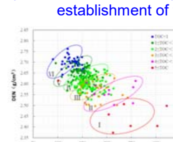
Standardization 1: Layer-division scheme for Longmaxi Formation



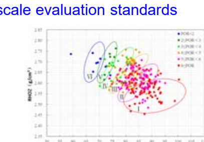
Layer-division scheme for Longmaxi Shale

Standardization 2: Shale reservoir classification and evaluation

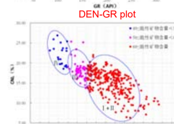
Optimization of "Sweet Spot" geological and logging parameters, establishment of fine-scale evaluation standards



DEN-GR plot



DEN-AC plot



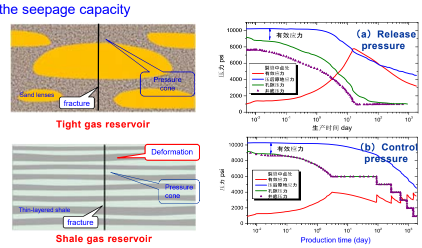
BR-CNL plot

Evaluation: geological and logging parameters

Reservoir		Geological parameters				Logging parameters			
		TOC (%)	Porosity (%)	BR (%)	Gas content (m^3/t)	GR (API)	DEN (g/cm^3)	AC (μs/m)	CNL (%)
Type	Ⅰ	>5	>6	≧60	>6	>200	<2.52	>82	<18
	Ⅱ	4~5	5~6	≧60	4.5~6	190~260	2.50~2.64	80~90	<18
	Ⅲ	3~4	4~5	50~60	3~4.5	150~200	2.55~2.65	76~85	15~20
	Ⅳ	2~3	3~4	40~50	2~3	140~180	2.58~2.67	73~82	>20
	Ⅴ	1~2	2~3	30~40	1~2	130~160	2.64~2.70	70~75	>20
Non Ⅵ		<1	<2	<30	<1	<140	>2.68	<70	>20

Standardization 3: Drawdown-strategy and target-rate management

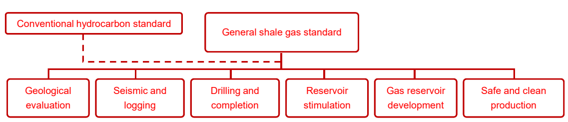
- Thin-layered and soft shale reservoir structure implies highly sensitive stress
- effective stress changes can cause irreversible damage to the reservoir structure and greatly reduce the seepage capacity



Outline

Construction of shale gas standard system

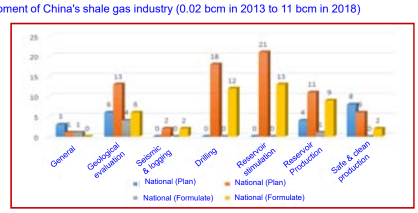
- In 2013, NEA issued "Shale Gas Industry Policy" (no. 5, 2013, NEA), which proposed requirements from the perspective of industrial supervision to strengthen the supervision of shale gas development and production process, and required that shale gas exploration, development and production activities 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



Shale gas technical standard system

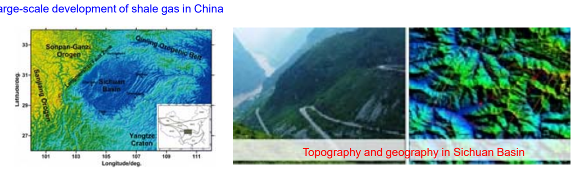
China's shale gas standard system: overview

- 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



Topography and geography in Sichuan Basin

To strengthen scientific and technological breakthroughs, to establish key technologies that can be replicated and popularized, to establish a comprehensive standard system are of great significance

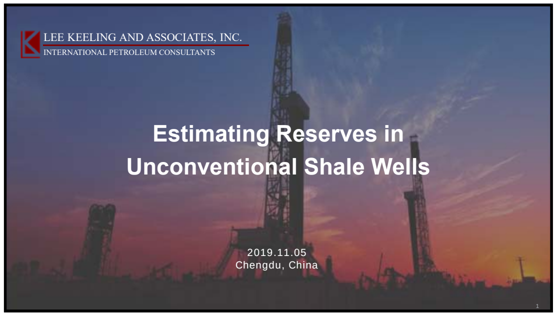
Prospects for international technology /standards cooperation

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!



LEE KEELING AND ASSOCIATES, INC.
INTERNATIONAL PETROLEUM CONSULTANTS

Estimating Reserves in Unconventional Shale Wells

2019.11.05
Chengdu, China

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

	Barnett	Fayetteville	Haynesville	Eagle Ford	Woodford	Bakken	Utica	Marcellus
Age	Mississippian	Mississippian	Jurassic	U. Cretaceous	Mississippian Devonian	Mississippian Devonian	Ordovician	Devonian Ordovician
Basin	Ft. Worth	Eastern Arkoma	East Texas/Gulf Coast	Maverick/Gulf Coast	Anadarko/Western Arkoma	Williston	Appalachian	Appalachian
Depth	6,500 – 8,500	1,500 – 8,500	11,000 – 13,000	4,000 – 10,000	6,000 – 14,000	4,000 – 11,000	4,000 – 14,000	4,000 – 12,000
Gross Thickness (ft)	200 - 300	50 - 325	200 - 350	100 - 300	100 - 220	10 - 60	50 - 500	50 - 250
Avg. Vclay (%)	23	40 - 60	27	7.5	30	10 - 20	15 - 30	10 - 20
TOC (%)	3.0 - 7.5	4.0 - 9.5	0.5 - 4.0	2.0 - 6.5	3.0 - 12.0	10.0 - 15.0	1.0 - 5.0	3.0 - 12.0
Thermal Maturity Vintrinite reflectance (%Ro)	1.0 - 1.74	1.5 - 4.0	1.85	1.0 - 1.27	1.1 - 3.0	0.45 - 0.60	1.2 - 3.0	0.6 - 3.0+
S2 (%) Rock – Eval Pyrolysis (mg/g)	-	-	-	-	40 - 47	-	-	-
Porosity (%)	3.0 - 9.6	4.0 - 5.0	8.0 - 15.0	3.0 - 15.0	-	3.0 - 12.0	3.2 - 6.45	1.5 - 12.0
Permeability mD	-	-	0.0001- 1.0	0.0001 - 1.1	0.05	0.05 - 10.0	0.041 - 0.73	0.0002 - 1
Oil in Place (mmbbl/sec)	-	-	-	10 – 50	-	5 - 15	-	-
Gas in Place (Bcf/sec)	100 - 150	25 - 60	160 - 240	40 - 223	-	-	93 - 100	93
Pressure Gradient (psi/ft)	0.43 – 0.45	0.38 – 0.45	0.7 – 0.9	0.43 – 0.54	-	0.5 – 0.58	0.20 – 0.60	0.4 – 0.7

Factors affecting performance

ROCK

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

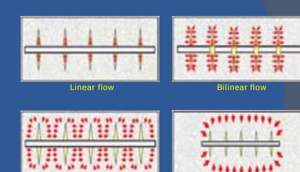
OPERATOR

- Well location
- Well spacing
- Lateral length
- Fracture stimulation
  - size
  - fluid type
- Completion technique
- Operational practices

Fundamentals and theories

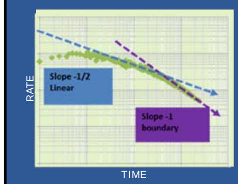
Flow Regimes

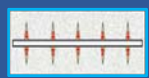
- Transient linear flow
- Transition flow
- Boundary-dominated flow
- Operator controlled



(SPE-188071-MS)

Fundamentals and theories




Linear flow


Bilinear flow


Fracture Interference


Boundary dominated flow

(SPE-188071-MS)

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

- Arps (Arps, J. J, 1944, "Analysis of Decline Curves", Trans. AIME (1945), vol 160, p. 228)
- Modified Arps
- Modified Fetkovitch (Urtec 2019-39)
- Stretched exponential
- Sliding b-factor
- Variable Power Law (Urtec 2019-39)
- Rate Transient Analysis (RTA)
- Reservoir Simulation

$$q(t) = \frac{q_i}{(1 + bD_i t)^{\frac{1}{b}}}$$

Estimation methods

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

Decline Curve Analysis (DCA)
Time
Production (oil, gas)

Rate Transient Analysis (RTA)
Time
Production (oil, gas)
Pressure
PVT properties
Static reservoir properties
Well length (heel to toe)
Distance between perforations
Number of fracture stages

Reservoir Simulation
Permeability
Porosity
Net-pay thickness
Elevation
Initial pressure
Initial fluid saturations
Formation volume factors
Viscosity
Solution gas-oil ratio
Fluid densities
Rock properties
Relative permeabilities
Capillary pressure
Pore-volume compressibilites
Well location
Producing interval
Production history of fluids present
Bottom-hole pressure and productivity index
Perforated lateral length
Stage spacing

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	OPERATOR
Permeability	Well location
Thickness	Well spacing
Pressure	Lateral length
TOC	Fracture stimulation • size • fluid type
Thermal maturity	Completion technique
Brittleness	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

$$q(t) = \frac{q_i}{(1 + bD_i t)^{\frac{1}{b}}}$$

Method used in most commercial software

Assumptions for constant b-factor:
- Boundary dominated flow
- No change to productivity index
- Constant drainage area

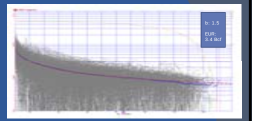
Limitations:
- forecasts only using early data is poor and overestimates reserves

(SPE 945228)

Empirical estimate		
Years of History Matched	Best Fit, Arps "b"	Error in Remaining Reserves %
2	2.66	145
5	1.91	104
10	1.51	30.6
25	1.20	7.9
50	1.14	0

Dealing with forecasts when b > 1

- After matching historical production and determining the hyperbolic exponent, b, 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 best way to select "b" value and Dmin
  - Older horizontal wells
  - Vertical wells

Dealing with forecasts when b > 1

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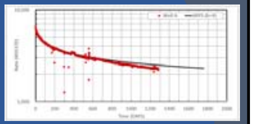

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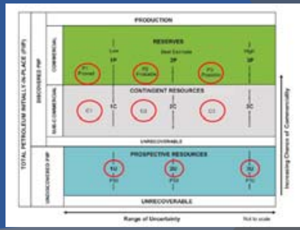
  - Vertical wells

Shale reserve/resource evaluation standards

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



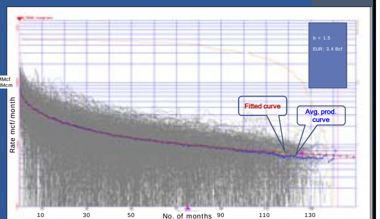
Map of US shale basins

(Source: EIA)

Type well profile - 1

Barnett shale - gas

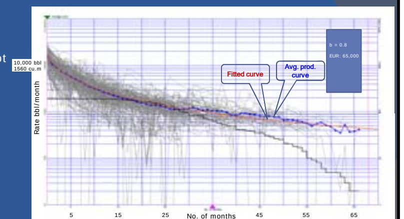
- well cost $2-3 MM
- 500 wells this plot
- b = 1.5
- EUR 3-4 Bcf



Type well profile - 2

Eagle Ford - oil

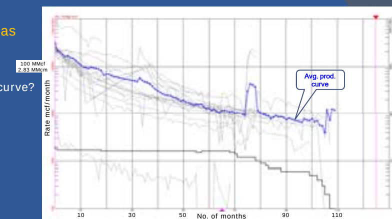
- 200 wells this plot
- b = 0.8
- EUR 65,000 bbl



Type well profile - 3

Haynesville - gas

- 20 wells
- How to fit this curve?

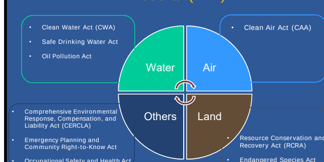


Regulatory concerns

- Fresh water protection (surface/subsurface)
- Size/shape of drilling units (spacing)
- Land/location (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

Regulatory concerns

Federal (EPA)



State

State bills
Permitting
Executing
Enforcement
……

Local

County/City
Orders
Roads
Right of way
……

Technical Progress and Standard Construction of Shale Gas Drilling & Completion and Hydraulic Fracturing

PetroChina Southwest Oil & Gasfield Company
November 2019

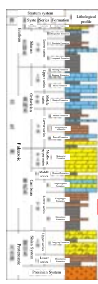
Six shale strata are widely distributed in Sichuan Basin

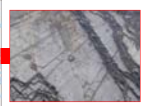
- Sichuan Basin is a large superimposed basin comprised of marine facies craton basin and continental facies foreland basin and that has gone through multiple stages of tectonic movement
- Six shale strata include marine facies、marine-continent transitional facies and continental facies
- Qiongzhusi Formation and Wufeng Formation~Longmaxi Formation are marine facies, they are beneficial layer for exploration and development

> Daanzhai Section of Ziliujing Formation of the Lower Jurassic
> Xujiahe Formation of the Upper Triassic
Continental facies

> Longtan Formation of the Upper Permian
Marine-continent transitional facies

> Wufeng Formation of the Upper Ordovician~Longmaxi Formation of the Lower Silurian
> Qiongzhusi Formation of the Lower Cambrian
> Doushantuo Formation of the Lower Sinian
Marine facies





Shale of Longmaxi Formation of the Silurian System

Shale of Qiongzhusi Formation of the Cambrian System

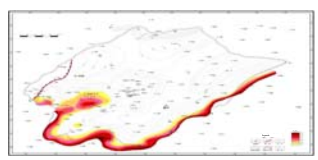
Qiongzhusi Formation and Wufeng Formation~Longmaxi Formation have abundant shale gas resources

Qiongzhusi Formation

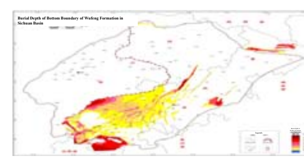
- Distribution area: 184,000km²
- Burial depth at 4,500m and shallower: area: 11,000km², resource quantity: 3.2 trillion m³

Wufeng Formation~Longmaxi Formation

- Distribution area: 144,000km²
- Burial depth at 4,500m and shallower: area: 49,000km², resource quantity: 18.5 trillion m³



Burial Depth of Bottom Boundary of Qiongzhusi Formation in Sichuan Basin



Burial Depth of Bottom Boundary of Wufeng Formation in Sichuan Basin

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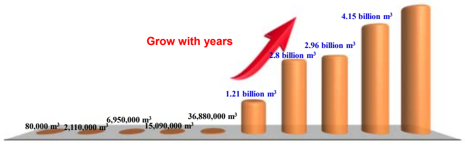
Large-scale beneficial development for the resources of Longmaxi Formation at 3,500m and shallower has been realized

- The development of shale gas in South Sichuan mainly focuses 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 m³ . As of October 2019, the output has been arrived at 6.23 billion m³, is expected to reach 12 billion m³ in 2020

Variation of Annual Output of Shale Gas in South Sichuan



Note: The output of 2019 is tallied up to October

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

The drilling & completion has gone through three rounds of development to achieve great technological progress

- Through locating key issues and independent innovation, the optimum & fast drilling technology has been basically formed for horizontal well under a multi-pressure system and complex stratum conditions after three rounds of continuous technical optimization, the effects are improved round by round

	First round	Second round	Third round
Locate Problem	• Serious wellbore collapse of shale well • Insufficient casing downward delivery • Low rate of penetration	• Low drill rate of quality reservoir • High casing deformation rate • Large friction torque	• Drilling capacity cannot be fully released due to limited equipment capacity • Low rate of penetration at deeper reservoir • Low directional drilling efficiency at kick-off section
Solution Approach	• Employ quality oil-based drilling fluid system • Improve well structure • Select quality drill bits and tools	• Test rotary steering + gamma logging • Upgrade the steel grade and wall thickness of casing • Improve 3D track into double-2D track	• Upgrade key equipment • Consolidate drilling parameter • Fully use rotary steering tools

Class I reservoirs drill catching rate constantly increases (%)

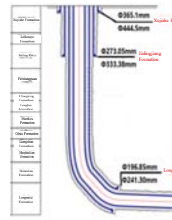
Wellbore integrity constantly increases (%)

Length of horizontal section constantly extends (m)

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

1. Well structure improvement

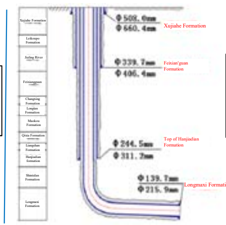
- The main producing area of shale gas in South Sichuan mainly employs the well structure of "3-spud", the technical casing moved upward for the purpose of increasing the drilling rate at lower well section
- Enlarge the dimension of production casing which contributes to the later fracturing operation



Design Limitation

- The technical casing is set at the Longmaxi formation
- The production casing is small and is not good for the later fracturing

Typical well structure (before improvement)



Design Advantages

- Lift the technical casing to the top of Hanjiadian Formation for reduce the depth of technical casing to increase drilling rate
- Enlarge the oil stratum casing to 215.9mm, to facilitate fracturing

Typical well structure (after improvement)

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

2. Wellbore trajectory optimization

- Change 3D wellbore trajectory to double-2D wellbore trajectory: the second spud start to torsion direction, and pre-deflection to complete the lateral displacement, and kick-off to target in Longmaxi Formation, to make the wellbore trajectory smoother and the friction resistance lower
- Select optimum kick-off point: employ high build rate-rotary steerable tools and move the kick-off point downward to shrink the distance before the target

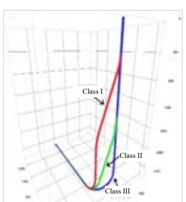
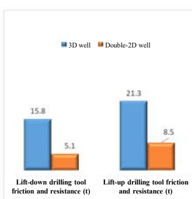
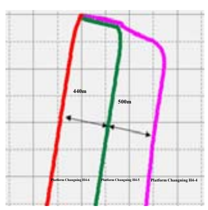


Diagram of Track Improvement



Friction-Resistance Comparison



Maximum offset of Platform Changning H4: 940m

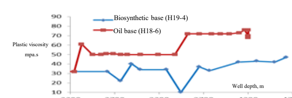
(II) Technical Progress of Shale Gas Drilling & Completion and Hydraulic Fracturing in South Sichuan

3. Drilling fluid

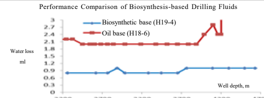
- Currently, the oil-based drilling fluid applicable to shale gas exploitation in South Sichuan has been independently developed, strongly guarantee the drilling requirements at current stage
- The new-type safe and environment-friendly biosynthesis-based drilling fluid has been test in several wells, laying a foundation for the green development of shale gas

System	Conventional properties							Rheological parameters			
	Density g/cm³	Funnel Viscosity S	Oil/ water	Mud cake mm	Sand content %	Alkalinity kg/m³	HTHP Water loss Ml 120°C	Static shear, Pa: Initial shear	Static shear, Pa: Final shear	Plasticity Viscosity mPa.s	Dynamic shear force Pa
Synthetic base	1.89	56	82/18	0.5	0.2	3.0	0.8	4.5	5	34	12
Oil base	1.88	67	80/20	2.0	0.2	2.0	2.4	2	4	56	6
Water base	1.89	73	/	2.0	0.8	/	5.2	3	9	48	15

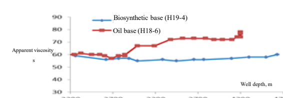
Performance Comparison of Biosynthesis-based Drilling Fluids



Comparison of Plastic Viscosity



Water Loss Contrast at High Temperature and High Pressure

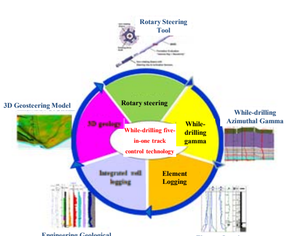


Contrast of Apparent Viscosity

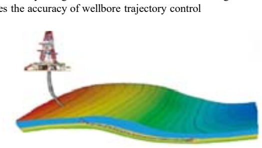
(II) Technical Progress of Shale Gas Drilling & Completion and Hydraulic Fracturing in South Sichuan

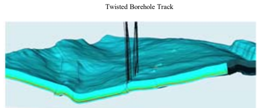
4. Five-in-one geosteering technology

- 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



Five-in-one While-drilling Track Control Technology


Twisted Borehole Track


3D Geological While-drilling Modeling

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

5. The factory drilling technology

- The factory drilling technology adapted to Sichuan mountainous topography was established, greatly improved operation efficiency
- Drilling rig translation time decreases from the average 2.2h to 1.3h and the construction resumption time decreases from the average 168h to 35h (5.5 days less), with a drilling fluid recovery rate over 77%, solving the multiple problems such as low operation efficiency and long task cycle

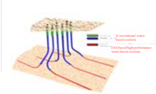
Drilling Machine Translation Equipment and Matching Technology

- **The time for drilling machine relocation & installation and operation preparation is reduced**
  - Large translation load (9,000kN) achieves the translation of drill floor with full display of drilling tools
  - The platform cross-borehole drilling machine movement takes 1.3h on average. The consumption time is 5.5 days less compared to that from the same period last year


Rail-type translation device

Batch Well Drilling and Resource Sharing

- **Drilling cycle is shortened and resource consumption decreases**
  - The number of personnel allocation is downsized from over 100 to over 70
  - The drilling fluid recovery rate is above 77%



Batch Drilling Procedures

Standardized Operation and Learning Curve Management

- **Management level and operation efficiency are raised**
  - Standard concurrent operation management shortens the completion time by 20%
  - Lean management of learning curve shortens the cycle and lowers the complexity


Standard Operation Management

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

6. The technology of cleaner production

- Drilling wastewater treatment technology: Employ coagulation, flocculation, oxidation, hyperfiltration, and other technological processes for drilling wastewater treatment, to ensure discharged water quality reach the standards for grade-I in *Integrated Wastewater Discharge Standard* (GB8978-1996)
- Solid waste while-drilling collection and treatment technology: The while-drilling collection and treatment technology is realized by the technological processes of collection, transfer and treatment of wastes, and enables resource utilization
- Skid-mounted oil-based cutting treatment technology: The thermal processing equipment is created with thermal analysis, extraction and other technologies, with a treatment capacity up to 2t/h

Drilling Wastewater Treatment Device

Solid Waste While-drilling Collection and Treatment Device

Appearance Comparison of Original Water and Discharged Water

Skid-mounted Oil-containing Cutting Treatment Device

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

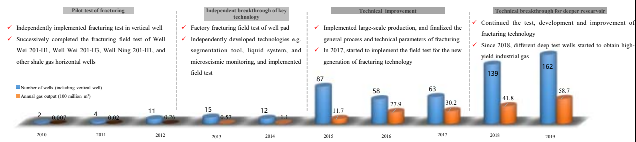
Through almost ten years of development, hydraulic fracturing technology has effectively supported the large-scale production of shale gas in South Sichuan

Multiple Domestic Top Honors

- ✓ In 2010, we independently completed the fracturing of the first domestic shale gas well - Well Wei 201
- ✓ In 2011, we completed the fracturing of the first domestic shale gas horizontal well - Well Wei 201-H1
- ✓ In 2012, we completed the fracturing of the first domestic shale gas horizontal well with commercial development value - Well Ning 201-H1
- ✓ In 2013, we completed the zipper-type fracturing test of the first domestic platform - Platform Changning H3
- ✓ In 2015, we builded the first domestic shale gas platform of million m^3 - Platform Changning H6
- ✓ In 2019, we builded the first domestic shale gas well with a daily output over 1 million m^3 - Well Lu 203

China's First Shale Gas Well

Simultaneous Fracturing of the ChangNing Shale



Development History of South Sichuan Shale Gas Fracturing Technology, and Annual Number & Output Variation of Fractured Wells

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

1. Continuous improvement of laboratory test and evaluation system for hydraulic fracturing

- Importing technology and independent development were both employed, and equipped with special test equipment dedicated for shale gas fracturing. The test device meets the overall needs for the rock mechanics test, liquid compatibility and fracturing process simulation of shale gas at the depth of 4,500m and shallower

Rock Mechanics Test Equipment

Multi-functional Rock Mechanics Instrument; Stress Test System; Paleomagnetism Tester; Rock Strength Scratch Meter

Liquid Compatibility Test Equipment

High-temperature High-pressure Shale Dilatometer; Capillary Suction Time Measure; Core Damage Evaluation Instrument; Scanning electron microscope

Fracturing Process Simulation Test Equipment

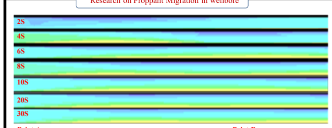
Proppant In-fracture Flow; Propped Fracture Flow Conductivity Instrument; Large Object Model Test Device; Complex Fracture Test Device

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

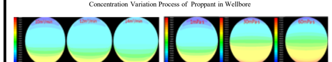
2. New progress in research on mechanism of proppant migration

- To build the solid-liquid two phase coupled flow model of horizontal wellbore for simulating the proppant migration in the wellbore under different viscosity, pump rate, sand concentration, and wellbore inclination
- The in-fracture sand transport model is established based on LBM and specifies the laws on how proppant migration is influenced by fracturing liquid viscosity, displacement, proppant particle size, and proppant density

Research on Proppant Migration in wellbore

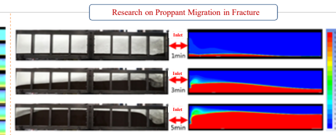


Concentration Variation Process of Proppant in Wellbore



Influence of Injection Displacement on Proppant Distribution　Influence of Liquid Viscosity on Outlet Proppant

Research on Proppant Migration in Fracture



Numerical Simulation Results of In-fracture Sand Transport and Physical Test Verification

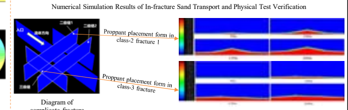
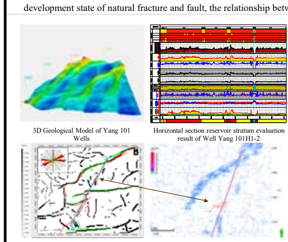


Diagram of complicate fracture

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

3. Meticulous fracturing design, implementation and post-evaluation techniques based on geological engineering integration are basically formed

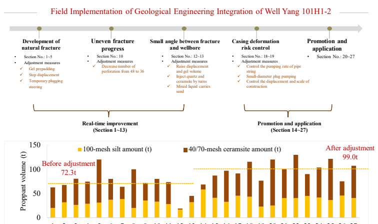
- With shale gas reservoir model as the basis, to formulate the elaborate and differentiated fracturing plan and parameters under the idea of geological engineering integration, the fracturing plan can be adjusted in real time at the construction site according to comprehensive evaluation of "RQ+CQ", the development state of natural fracture and fault, the relationship between wellbore trajectory and natural fracture



3D Geological Model of Yang 101 Wells　Horizontal section reservoir stratum evaluation result of Well Yang 101H1-2

Predicted Overlay of the Microseism of the 9th Section and 3D Fracture　The 9th section crack prediction of Well Yang 101H1-2

Field Implementation of Geological Engineering Integration of Well Yang 101H1-2



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

4. Hydraulic fracturing technology of deep horizontal well achieves a breakthrough

- Application of the technical strategy that uses large pump rate to deal with high stress、closely segmenting to deal with large stress difference, they effectively settle the difficult of deep well hydraulic fracturing

Geologic characteristic and engineering difficulties

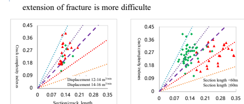
- High stress: the extension of hydraulic fracture is more difficult and the stimulated reservoir volume is finite
- Large stress difference: the complexity of hydraulic fracture is finite
- Stratification development: the leak-off increase; the vertical extension of fracture is more difficulte

Main process and parameters

- Main process: Slickwater + ceramsite
- Stage: Closely segment, the average stage length is about 50m
- Special process: Temporary plugging and division
- Pump rate: 14~16m³/min

Application effect

- Well Huang 202: test output 223,700 m³/day
- Well Zu 203: test output 213,000 m³/day
- Well Lu 203: test output 1.379 million m³/day



Relation among deep well section length, construction displacement and crack complexity in South Sichuan

Parameter List of Fracturing Construction of Deep Shale Gas Well in South Sichuan

Well No.	Vertical depth (m)	Section length (m)	Displacement (m³/min)	Liquid using strength (m³/m)	Sand adding strength (t/m)	Proportion of 40/70-mesh ceramsite (%)
Lu 203	3891.97	72.99	13.6~13.8	29.27	1.72	69.36
Well Lu 204	3854.96	46.50	13.4~13.8	35.30	2.00	74.08
Well Huang 202	3932.93	49.80	13.3~16	40.12	2.83	87.34
Well Zu 203	4169.66	55.22	15.9~16.5	41.86	1.76	70.89%

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

5. The technology of perforating, plug, fracturing fluid has been localized

- 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
- Fracturing fluid: formed a slickwater system that meets the recycling of flow-back fluid with the degree of mineralization <100,000mg/L and hardness <3000mg/L. The friction reduction rate >75%

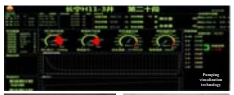
Self-developed fracturing plug tools


Independent-development fast drilling plug


Independent-research casing starting sliding sleeve

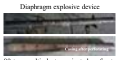

Self-developed large-diameter plug

Multi-cluster perforation technology




Diaphragm explosive device


time-delay explosive device

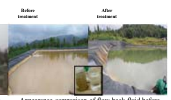


89-type multi-cluster oriented perforator with 15 holes/min

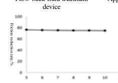
89-type multi-cluster oriented perforator

Recyclable slickwater system


Flow-back fluid treatment device



Appearance comparison of flow-back fluid before and after treatment



Saline and Hardness Tolerance Curve of Resistance Reducing Agent


Fracturing Curve

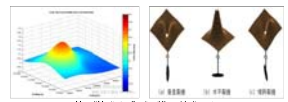
18/48

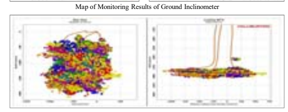
(II) Technical Progress of Shale Gas Drilling & Completion and Hydraulic Fracturing in South Sichuan

6. Optimization of post-fracturing evaluation system

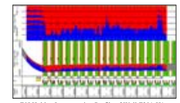
- The post-fracturing evaluation technology was formed based on construction pressure analysis, microseismic monitoring, gas production profile testing and tracer monitoring, which can effectively instruct the continuous optimization and improvement of fracturing schemes.

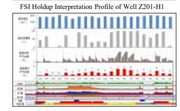
Fracture monitoring

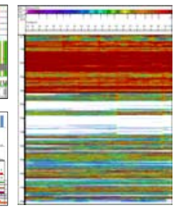

Map of Monitoring Results of Ground Inclinometer


Map of Microseismic Monitoring Results

Gas production profile testing


FSI Holdup Interpretation Profile of Well Z201-H1


Results of Gas Phase Tracer Monitoring of Well CNH11-2


Fiber Optic Monitoring DAS Signal of Well N09H12-1

19/48

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

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 unified transfer and distribution of regional water resources and proximal recycling of flow-back fluid
- Through upgrading the equipment, optimizing the platform layout and operation procedure to realize the fracturing and well test integration


Regional water storage and supply network in Changning


Overlapping fluid tank


Mixing device


Sand storage and supply equipment


Factory fracturing site


Well test

20/48

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

8. Electric fracturing system gradually popularized

- Large pump rate: electric fracturing pump can provide the pump rate of $2m^3/min$ in normal working condition
- 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
- Long working time: electric fracturing pump can work for 15 hours


Honghua 6000HP electric fracturing system


Electric fracturing system is on the shale gas fracturing site

21/48

22/48

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

Chinese standard framework

- Standard classification in China complies with *Standardization Law of the People's Republic of China* and is divided into national standard, industry standard, local standard and enterprise standard according to the application scope and approving authority of standards

National standard
- Refers to standard that has great significance for the economic and technological development in China and must be unified in China

Supplement ⇅ Preference

Industry standard
- Refers to unified standard in the industry in China

Supplement ⇅ Preference

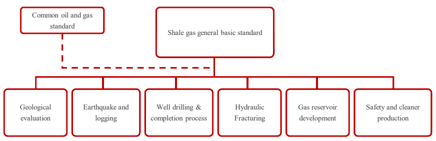
Enterprise standard
- Refers to technical requirement, management requirement and working requirement that need to be coordinated and unified in enterprises

23/48

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

Standard construction of shale gas

- Chinese standard construction of shale gas is established based on the demand and technological development of shale gas scale production. Existing characteristic technical standard of shale gas, except general common oil and gas standards, is constructed according to 6 specialties
- The published standards for drilling and completion technology and hydraulic fracturing are mainly industry standards and enterprise standards

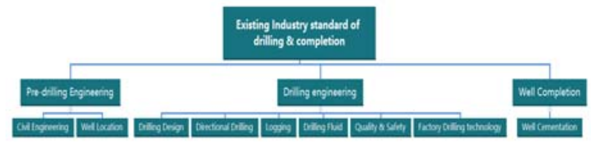


24/48

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

Industry standard of drilling & completion

- The industry standard of drilling and completion is divided into pre-drilling engineering, drilling engineering and completion engineering
- Pre-drilling engineering: 2 industry standards are issued
- Drilling engineering: 7 industry standards are issued, 2 industry standards are approved and 3 industry standards are being made
- Well completion engineering: 3 industry standards are issued and 1 industry standard is being made



25/48

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

1. Standards of Pre-drilling Engineering

- At present, 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

Code for the Pre-drilling Civil construction of Shale Gas Platform

Standard category Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope Stipulates the construction working requirements for road and well site engineering, foundation engineering of derrick and equipment, pools engineering, corrosion and leakage prevention, sewage diversion and partition engineering, blow-off pit engineering

Standard significance After the release and implementation of the standard, it can better guide the actual work of the civil engineering before drilling for the shale gas platform, further promote the scientific and standardized work of civil engineering before drilling, and lay a foundation for the later shale gas mining

Technical Requirements for design of shale gas horizontal well

Standard category Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope It stipulates the basic principles, technical requirements and design content and format of the well location design of shale gas horizontal wells, which is applicable to the shale gas evaluation and well location design of horizontal wells in shale gas development stage

Standard significance The implementation and formulation of the standard are more standard in the data preparation, geological demonstration, selection of shale gas horizontal wells and wellhead location, leading the scientific well location design of shale gas horizontal wells

26/48

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

2. Drilling Engineering Standard - Drilling Design

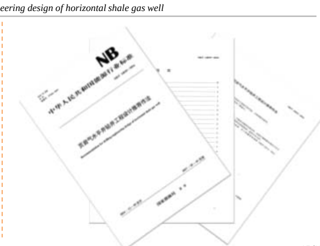
- Drilling engineering standards mainly involve drilling design, directional drilling, logging, drilling fluid, quality & safety and factory drilling technology, of which one standard has been issued for drilling design

Recommendation for drilling engineering design of horizontal shale gas well

Standard category Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope This standard stipulates the content, method and technical requirements for the drilling engineering design of onshore shale gas horizontal wells, which is applicable to the drilling engineering design of onshore shale gas horizontal wells

Standard significance The standard provides design reference basis for well bore mechanism design, borehole track design, drilling equipment selection, drilling tool combination design, drill bit selection and drilling parameter design, drilling fluid design, drilling fluid and weighting materials in storage, treating agent, oil and gas well pressure control as well as well cementation and well completion wellhead devices, which can effectively guide the drilling engineering design of horizontal wells



27/48

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

3. Drilling Engineering Standard - Directional Drilling

- Directional drilling standard mainly regulates geosteering technology, and puts forward scientific requirements for the trajectory tracking of the vertical stage and the kick-off stage, the target depth adjustment, the trajectory tracking and adjustment of the horizontal section

Technical requirements for geosteering of shale gas horizontal well

Standard category Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope This standard stipulates the data preparation and work requirements for geosteering of shale gas horizontal wells (including highly-deviated wells)

Standard significance The standard not only provides scientific and standardized requirements for track tracking and target depth adjustment of the vertical stage and the kick-off stage, but also puts forward relevant requirements for the track tracking and adjustment of horizontal sections, the updating of the icon, and the preparation of the single -geosteering report

28/48

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

4. Drilling Engineering Standard – Drilling fluid

- Two industry standards has 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 recommended method of drilling fluids for shale gas—Oil-based fluids

Standard category Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope This specification stipulates the basic requirements and recommended performance indexes of oil-based drilling fluid for shale gas horizontal wells, and regulates the preparation, in well conversion, maintenance, treatment, recycling and other processes of oil-based drilling fluid for shale gas horizontal wells.

Standard significance The release of this standard puts forward the safety and environmental protection requirements of oil-based drilling fluid for shale gas horizontal wells, and promotes the development of green environmental protection drilling fluid.

Evaluating method of shale inhibition for drilling fluids

Standard category Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope This specification stipulates methods such as inhibition dispersion rate test, debris recovery test, relative inhibition rate test, capillary absorption time CST value test, cohesion characterization test, immersion test, etc.

Standard significance The implementation of this standard specifies the requirements of drilling fluid for shale inhibition test.

29/48

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

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

Specification of shale gas surface logging techniques

Standard category

Application scope: industrial standard Application degree: recommended standard

Standard attribute: technical standard Maturity degree: official standard

Standard scope

This standard stipulates the logging items, logging technical requirements, logging evaluation process and logging evaluation content of shale gas wells, and the use of shale gas logging

Standard significance

This standard puts forward relevant technical requirements for various logging methods such as cutting logging, element logging and mineral logging, and puts forward standardized and scientific requirements for logging evaluation process and evaluation content

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

6. Drilling Engineering Standard - Factory Drilling

- At present, one industry standard has been issued for the factory operation, which mainly stipulates the special requirements for shale gas factory drilling engineering design, the drilling machine selection and matching, the special requirements for pre-drilling engineering technology, the special requirements for well site layout technology, the special requirements for equipment and wellhead device installation, the drilling machine mobile process, the drilling process and HSE requirements

Recommended practices for shale gas factory construction-Part 2: Drilling

Standard category

Application scope: industrial standard Application degree: recommended standard

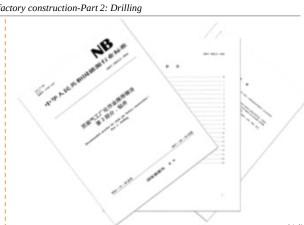
Standard attribute: technical standard Maturity degree: official standard

Standard scope

This section stipulates the terms and definitions of shale gas factory drilling, the special requirements for drilling engineering design, the drilling machine selection and matching, the special requirements for pre-drilling engineering technology, the special requirements for well site layout technology, the special requirements for equipment and wellhead device installation, the drilling machine mobile process, the drilling process and HSE requirements

Standard significance

Since its release, the standard has promoted the standardization of shale gas drilling and factory operations, and has carried out standard requirements in various aspects of factory operations, effectively guiding the factory operation of shale gas drilling



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

7. Drilling Engineering Standard - Quality and Safety

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

The recommended practices of safety drilling and hole quality control for shale gas cluster wells

Standard category

Application scope: industrial standard Application degree: recommended standard

Standard attribute: technical standard Maturity degree: official standard

Standard scope

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

Standard significance

The release of the standard mainly addresses the requirements of drilling safety operations and borehole quality control requirements and evaluation methods, and makes scientific regulations on drilling safety, well control safety, safety management, well bore quality requirements, borehole track control requirements and evaluation methods

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

8. Well Completion Engineering Standard

- Three industry standards have been issued for the well completion engineering, all of which are well cementation items, respectively covering technical specifications, cement paste technical requirements and evaluation methods, quality supervision and acceptance requirements and methods

Shale gas cementing engineering Part 1: Technical specifications

Standard category

Application scope: industrial standard Application degree: recommended standard

Standard attribute: technical standard Maturity degree: official standard

Standard scope

This specification stipulates the main technical contents and requirements for the design, construction preparation, operation procedures, and operation evaluation of shale gas well cementation. This standard is applicable to the well cementation operation for production casing of shale gas wells.

Standard significance

The release of the standard regulates the design related to well cementation operations, improves the well cementation process, guides the use of on-site well cementation tools, and promotes the smooth and orderly implementation of well cementation operations.

Shale gas well cementation engineering -Part 2: Performance requirements and evaluation methodologies for cement slurries

Standard category

Application scope: industrial standard Application degree: recommended standard

Standard attribute: technical standard Maturity degree: official standard

Standard scope

This specification stipulates the technical requirements and evaluation methods for cement paste performance in shale gas well cementation. This party is applicable to the cement paste design of shale gas well cementation

Standard significance

The implementation and formulation of the standard regulate the design of the cement paste performance in well cementation, put forward corresponding parameters for the cement paste of different casing procedures, and unify the corresponding evaluation methods

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

Shale gas well cementing engineering-Part 3: Requirements and methods for cementing quality evaluation and accepatance

Standard category

Application scope: industrial standard Application degree: recommended standard

Standard attribute: technical standard Maturity degree: official standard

Standard scope

This part stipulates the quality supervision requirements, quality inspection and assessment, and casing string pressure test for well cementation of production casing of shale gas wells. This part is applicable to the well cementation quality evaluation for production casing of shale gas wells.

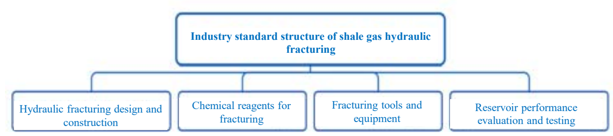
Standard significance

The release of the standard strengthens the supervision and acceptance of well cementation quality, standardizes the well cementation process and quality indicators, and guides the completion of on-site well cementation with high quality.

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

Industry standard structure of hydraulic fracturing

- Hydraulic fracturing design and construction: 6 industry standards have been issued and 1 industry standard is being developed
- Chemical reagents for fracturing: 3 industry standards have been issued
- Fracturing tools and equipment: 1 industry standard has been issued and 1 industry standard is being developed
- Reservoir performance evaluation and testing: 3 industry standards have been issued, 2 industry standards have been approved, and 1 industry standards are being developed



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

1. Standards for Hydraulic Fracturing Design and Construction

- At present, 6 industry standards have been issued for the hydraulic fracturing design and construction, covering fracturing design, factory fracturing operations, recovery and treatment methods of fracturing flow-back fluid, recommended practices for horizontal well pumping plug and clustering perforation technology, requirements for drilling and grinding plug and clustering perforation operations in horizontal wells

Shale gas hydraulic fracturing-Part 1: Specification for fracturing design

Standard category

Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope

This part stipulates the technical requirements of shale gas well fracturing design in terms of basic data, fracturing design principles, fracturing process, fractured interval selection, fracturing materials, construction parameters, pumping procedures, on-site construction preparation and equipment supporting requirements, fracturing construction and drainage, risk analysis and contingency plan, health, safety and environmental protection (HSE). It is applicable to the shale gas well fracturing design.

Shale gas hydraulic fracturing-Part 2: Technical specification for factory fracturing operations

Standard category

Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope

This part stipulates the well site roads, well site preparation, fracturing construction preparation, pumping bridge plug-perforation requirements, microseismic monitoring requirements, fracturing construction requirements and health, safety and environmental protection (HSE) requirements during the factory fracturing operation process of shale gas hydraulic fracturing. It is applicable to onshore shale gas factory fracturing operations, other factory fracturing operations may be implemented by reference.

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

Hydraulic Fracturing Design and Construction Standards

- At present, 6 industry standards have been issued for the hydraulic fracturing design and construction, covering fracturing design, factory fracturing operations, recovery and treatment methods of fracturing flow-back fluid, recommended practices for horizontal well pumping bridge plug and clustering perforation technology, requirements for drilling and grinding bridge plug and clustering perforation operations in horizontal wells

Shale gas hydraulic fracturing-Part 3: recycling and disposal methods of fracturing flowback water

Standard category

Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope

This part stipulates the design specifications for the ground recovery system of slickwater fracturing flow-back fluid in shale gas reservoirs, the recommended water treatment process for the reuse and drainage of slickwater fracturing flow-back fluid, the recommended water quality index requirements for reuse after treatment, and the methods for water quality index detection and analysis. This part is applicable to the recovery and treatment of slickwater fracturing flow-back fluid in shale gas reservoirs

Shale gas hydraulic fracturing-Part 4: Recommended practice for the technology of combined pumping fracturing plug and perforation in horizontal well

Standard category

Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope

This part stipulates the technical requirements for construction design, construction preparation, construction procedures, data acquisition and HSE of horizontal well pumping bridge plug and clustering perforation in shale gas reservoirs. This part is applicable to horizontal well pumping bridge plug and clustering perforation in shale gas reservoirs. Other types of horizontal well pumping bridge plug and clustering perforation in reservoirs can be implemented by reference

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

Hydraulic Fracturing Design and Construction Standards

- At present, 6 industry standards have been issued for the hydraulic fracturing design and construction, covering fracturing design, factory fracturing operations, recovery and treatment methods of fracturing flow-back fluid, recommended practices for horizontal well pumping bridge plug and clustering perforation technology, requirements for drilling and grinding bridge plug and clustering perforation operations in horizontal wells

Shale gas hydraulic fracturing-Part 5: Operation requirements for milling plug in Horizontal Wells

Standard category

Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

Standard scope

This part stipulates the construction design, construction preparation, construction operation, equipment disassembly, data processing, safety and environmental protection of the coiled tubing drilling and grinding the drillable bridge plug in horizontal wells. This part is applicable to the drilling and grinding of coiled tubing in shale gas horizontal wells.

Shale gas hydraulic fracturing-Part 6: Requirements for construction technology of clustering perforation in horizontal well

Standard category

Application scope: industrial standard Application degree: recommended standard
Standard attribute: technical standard Maturity degree: official standard

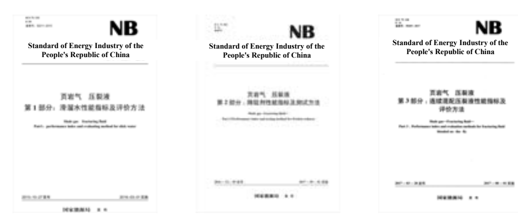
Standard scope

This part stipulates the technical requirements for the construction conditions, on-site construction operations, contingency plans and HSE of the clustering perforation construction process of cable transmission in shale gas horizontal wells. This part is applicable to the clustering perforation construction of cable transmission in shale gas horizontal wells.

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

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 and test methods of shale oil and gas, slickwater for tight oil and gas hydraulic fracturing, polyacrylamide resistance reducing agent and shale gas continuously mixed water-based fracturing fluid



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

3. Standards for Fracturing Tools and Equipment

- One industry standard has been issued for staged fracturing tools, which stipulates the classification and type of composite bridge plugs, technical requirements, test methods, inspection rules, and marking, packaging, transportation, and storage. The testing and operating specifications for fracturing soluble bridge plugs are being formulated

4. Standards for Reservoir Performance Evaluation and Testing

- Three industry standards have been issued for the evaluation of water sensitivity of core working fluid, the determination of long-term flow conductivity of shale proppant pack, and the determination of flow conductivity of shale gas self-supporting fractures

Standard No.	Standard name	Standard level	Status
NB/T 14022-2017	*Recommended Practices for the Evaluation of Shale Water Sensitivity*	NB/T	Released
NB/T 14023-2017	*Recommended Methods for the Determination of Long-term Flow Conductivity of Shale Proppant Pack*	NB/T	Released
NB/T 10120-2018	*Recommended Methods for the Determination of Flow Conductivity of Shale Gas Self-supporting Fractures*	NB/T	Released
-	*Determination and Evaluation Methods of Shale Brittleness Indexes*	NB/T	Approved
-	*Testing Technical Specifications for the Microinjection of Shale Gas Wells*	NB/T	Approved
-	*Specifications for Fracturing Construction Quality Control Technology and Acceptance of Shale Gas Wells*	NB/T	In formulation
-	*Recommended Practices for the Testing of Shale Gas Fracturing Flow-back Fluid Dynamic Scaling Trends*	NB/T	In formulation

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

Existing Enterprise Standard for Drilling & Completion and hydraulic fracturing

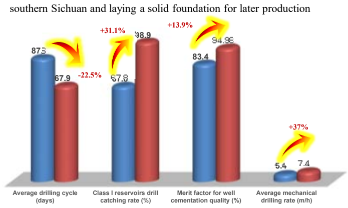
- Combined with the PetroChina regional construction characteristics, the enterprise standard for drilling & completion and hydraulic fracturing issued has formulated enterprise standards for pre-drilling engineering, drilling design, well logging, quality safety, drilling fluid, hydraulic fracturing design and construction, and chemical reagents for fracturing, and established the enterprise standard of drilling & completion and hydraulic fracturing of PetroChina, complementing the existing industry standard to further meet the on-site construction needs

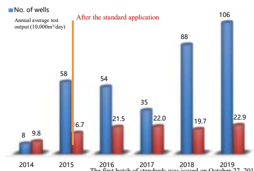
(III) Standard Construction of Shale Gas Drilling & Completion and Hydraulic Fracturing

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 promoted and applied the drilling and fracturing technology suitable for shale gas in southern Sichuan, effectively improving various core indicators of the shale gas engineering in southern Sichuan and laying a solid foundation for later production





The first batch of standards was issued on October 27, 2015, and implemented on March 1, 2016

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

2. Optimizing the use of land and water resources to reduce the consumption of environmental resources

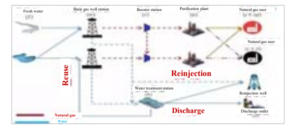
Land Occupation

- ✓ After the implementation of the "factory" standards for shale gas drilling, the land acquisition area has been greatly reduced by adopting measures such as "cluster well" design, "well factory" mode construction, "standardized" site design, and gas production platform and gas gathering and transportation station construction on the same platform
- ✓ By implementing the requirements for pre-drilling engineering operations of shale gas platform and making clear requirements for roads and well site items, the utilization rate of well sites is effectively improved, and the land occupation is reduced

Water Consumption

- ✓ Water pipelines dedicated for construction are set to gather and transport water to each fracturing construction platform to avoid negative impact on water consumption of surrounding residents
- ✓ The recycling of fracturing flow-back fluid achieves more than 90% reuse, which greatly reduces the amount of fresh water used in fracturing construction

Comparison of Well Sites before and after Reclamation



Integrated Water Resource Management and Shale Gas Supply Chain

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

3. Strict control of engineering operations and maximizing the protection of the ecological environment

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

Manufacture of Baking-free Brick Device

Drilling Fluid Recovery Site

Clean Production Operation Area of Drilling

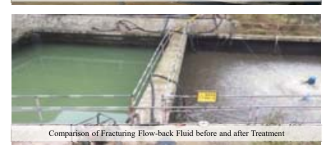
(III) Standard Construction of Shale Gas Drilling & Completion and Hydraulic Fracturing

- Waste management: the treatment and reuse of fracturing fluid reduce the consumption of water resources

Flow-back Fracturing Fluid

- ✓ Treatment of residual fracturing flowback fluid after reuse, and the water quality after treatment reaches the requirements for reuse water quality indexes in *Shale Gas Hydraulic Fracturing-Part 3: Fracturing Flow-back Fluid Recovery and Treatment Methods* (NB/T14002.3-2015)

Fracturing Flow-back Fluid Recovery and Treatment Device



Comparison of Fracturing Flow-back Fluid before and after Treatment

(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 standard 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

2. To upgrade existing technical standards and increase the popularity and recognition of the standards

- 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 standards will be increased to provide strong technical support for the shale gas scale and green development of China

Thank you !

SINOPEC Progress in Shale Gas Exploration and Development

Jun Niu
Petroleum Exploration & Production Research Institute of SINOPEC

中国石化 SINOPEC CORP.

2019.11.06

Contents

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)

2006-2007: Early Resource Potential Analysis on China' s Shale Gas-Evaluated favorable areas in south China and conducted a survey on North American shale gas.

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.

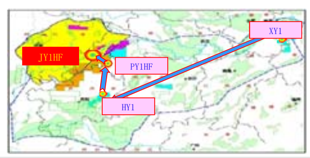
Research Project, 2007 | Research Issue, 2007 | Research Trends, 2009 | Area Evaluation, 2009

Stage 2: Exploration Breakthrough (2010-2012)

Combining the old well retest and new exploration well trials on continental and marine shale gas

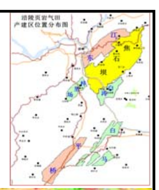
Delay continental shale gas exploration, complex geological condition and poor preservation conditions

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 m^3/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 m^3/year;
- Expand Fuling shale gas field, productivity construction Phase 2 another 5 billion m^3/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

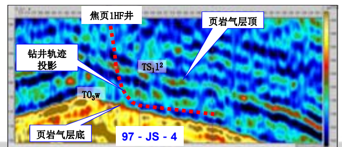
2D-seismic evaluation	12,000 km
3D-seismic evaluation	2,700 km^2
Exploration and development wells	~400
Commercial shale gas field	1 (Fuling)
Favorable blocks	5 (Rongchang-Yongchuan, Weiyuan-Rongxian, Dingshan, Jingyan-Qianwei, Pengshui).
Proved geological reserves	380.598 billion m^3
Technical recoverable reserves	95.150 billion m^3
Cumulative productivity	7 billion m^3/year
Fuling productivity	5.03 billion m^3/year

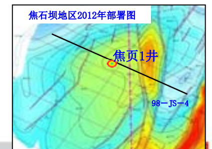
Contents

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

Breakthrough of Fuling marked by success in JY1HF in Jiaoshiba district

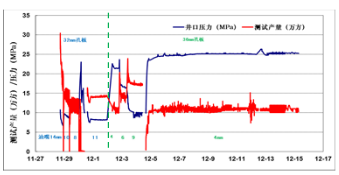
- February 2012, Based on 2D-seismic interpretation, JY1 vertical well was drilled for evaluation of several layers;
- June 2012, JY1 encountered Wufeng-Longmaxi shale layer, and found good gas shows. Thus we decided to drill a horizontal well, JY1HF well.





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

- 17 Oct to 14 Nov, 15-stage hydraulic fracturing conducted.
- 28 Nov, a high test production of 203,000m³/d indicated the discovery of Fuling shale gas field.



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

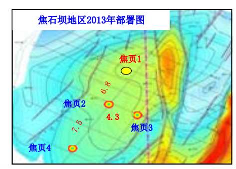
In 2013, accelerate exploration evaluation in Jiaoshiba district

- 3 vertical wells (JY2, 3, 4) drilled - Controlling of Jiaoshiba main district.
- 594.5km² 3D-seismic work carried out - Detailed interpretation of shale layer structure and distribution.

JY2HF well: 269,800 m³/d

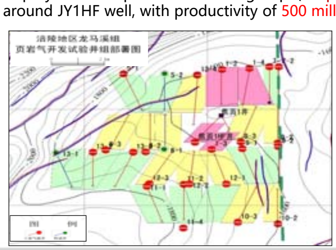
JY3HF well: 115,000 m³/d

JY4HF well: 209,000 m³/d



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

Deploy a development test well group (10 platforms, 26 wells) in 28.7km² around JY1HF well, with productivity of 500 million m³.



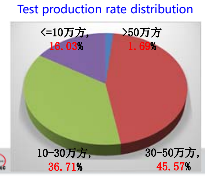
- Horizontal well drilling and fracturing tests;
- Horizontal well length (1000 m, 1500 m) and orientation tests;
- Horizontal well spacing tests;
- Optimization of well production rate.

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

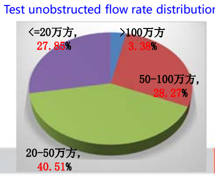
Productivity building Stage 1: 5 billion m³/year

- In 2014-2015, 237 wells drilled with an average test output of 266,100 m³/d, and the average unobstructed flow rate is 390,900 m³/d.
- Lead to increase of accumulative proven geological reserve up to 380.6 billion m³, and technical recoverable reserve up to 95.15 billion m³.

Test production rate distribution



Test unobstructed flow rate distribution



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

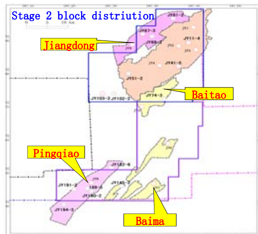
Finish building Stage 2: another 5 billion m³/ year

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.



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

National Energy Administration Expert Group: the high-level, high-speed, high-quality construction Chongqing Fuling National Shale Gas Demonstration District is a model for theoretical, technological and management innovation of shale gas exploration and development in China, which significantly enhances the confidence of shale gas commercial development, demonstrates the great prospect of shale gas in China.

(2) Four series of shale gas E & P key technologies

Series 1: Shale gas resource and reservoir development evaluation technology

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

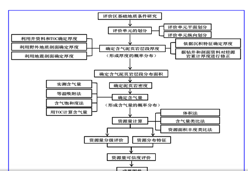
Series 3: Long horizontal well staged fracturing technology

Series 4: Shale gas clean production technology

Series 1: Shale gas resource and reservoir development evaluation technology

Resource evaluation method: based on volume method, analog method, FORSPAN method and single well dynamic evaluation method

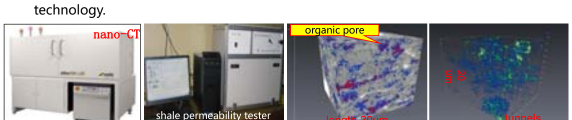
Reservoir development evaluation method: include more than 10 key parameters such as geology, engineering and economy



Series 1: Shale gas resource and reservoir development evaluation technology

Key Tech1: Shale gas reservoir characterization and evaluation technology

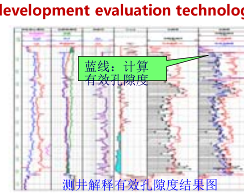
- With integration of X-ray diffractometer, nano-CT, FIB, argon ion polishing-scanning electron microscopy, mercury intrusion-adsorption method, shale permeability tester and digital core, etc., we develop microscopic pore characterization and physical property analysis technology;
- Shale gas source-storage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

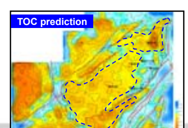


Series 1: Shale gas resource and reservoir development evaluation technology

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.



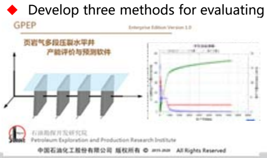


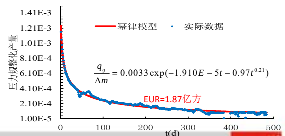
- Develop shale gas geological sweet point five-parameter prediction method based on seismic inversion, AFE, all-direction pre-stack anisotropy fracture prediction methods, as well as prediction techniques such as pressure and ground.

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 techique 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 Tech1: Shale gas horizontal well fast drilling technology

- Develop localized key drilling speed-up tool, realize 87% speed up with oriented special PDC drill, 130% increase of mechanical drilling speed of horizontal part in Wufeng layer, 68% increase of friction reducing tool drilling speed, and the life of the screw is almost doubled;
- Develop low-cost well path control technology based on conventional guidance;
- Achieve continuous increase of drilling speed of each opening.

oriented special PDC drill

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

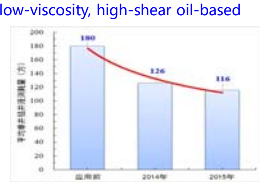
Applicable temperature: normal ~ 180 °C

Cost: reduced by 20%-40%

Oil to water ratio: 82/20 – 90/10 to 65/35 -75/35

Low viscosity: low cycle pressure consumption, good leak-proof effect

High shear: good sand carrying performance



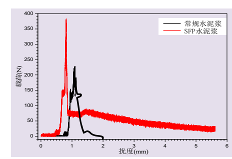
油基钻井液单井消耗量（水平段长1500m）

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%.

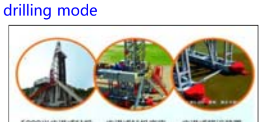


水泥石加载-变形试验对比

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

Key Tech4: Mountain area "well factory" drilling mode

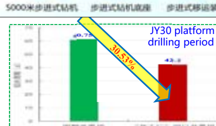
- Fast moving drilling rigs and equipment
- Platform ground layout optimization and drilling plant operation design technology
- Optimization design technology of horizontal well structure and cluster horizontal well tracks
- Drilling fluid recycling technology



Drilling cycle: 42.22 days, decrease of 30.53%

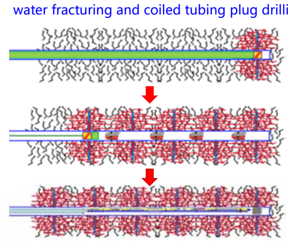
Well construction: 53.70 days, shortened by 34.35%

Drilling fluid amount saved by 41.46%



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



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

50s dissolution rate > 90%
Drag reduction rate > 70%
Apparent viscosity 6.2-9.3mPa.s
Cost 60% lower than similar foreign products

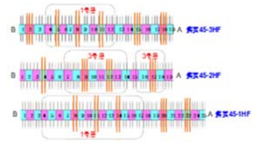
Proppant type/sizs	Application condition
coated sand (40/70、30/50)	depth<2800m, closure stress<69MPa
low-density ceramsite (40/70、30/50)	depth<3500m, closure stress<86MPa
coated ceramsite (40/70、30/50)	depth>3500m, closure stress>86MPa

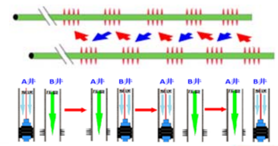
Series 3: Long horizontal well staged fracturing technology

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.

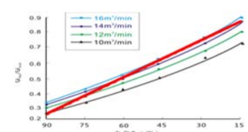


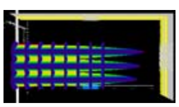


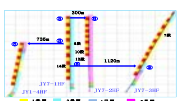
Series 3: Long horizontal well staged fracturing technology

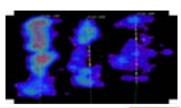
Key Tech3: fracturing evaluation technology

- **Five techniques combined:**
  - comprehensive fitting inversion
  - tracer monitoring
  - microseismic monitoring
  - fluid production profile test
  - mathematical statistics









Series 3: Long horizontal well staged fracturing technology

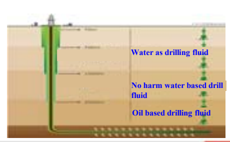
Key Tech4: horizontal well fracturing equipments and tools

- 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

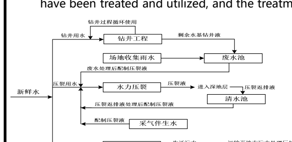
- Promote the use of electric rigs to replace diesel-driven drilling rigs. In Fuling implemented 208 wells, saving more than 50 million yuan and reducing diesel consumption by 23,000 tons
- Select platform avoiding caves and dark rivers, adopts four-layer casing structure with guiding eyes and three 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

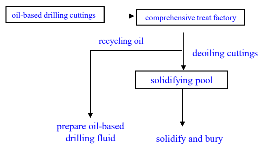
- Build a recycling process for waste liquid, and develop the first modular fracturing fluid return treatment device for shale gas development in China
- The waste liquid during drilling, fracturing and gas production process treated and reused more than 200,000 square meters, of which 130,700 out of 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.



(3) Shale gas development management model

Well factory organization and construction

- 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 informationized improvement, has realized the prefabrication, modularization and digital management of ground gathering and transportation system.

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%.

Shale gas safety green development management

- 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.

Shale gas safety green development management

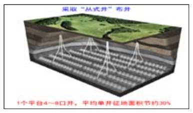
- Establish emergency protection system. Set up emergency rescue center, equipping with emergency rescue personnel and materials;
- Jointly establish "Shale gas development safety and security work committee" with Fuling Government, and cooperate with local public security, fire protection, health, environmental 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 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) 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 imoprtant 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

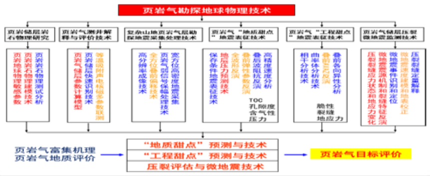
Shale gas enrichment rule and exploration evaluation method: focus on high-quality shale development characteristics, shale gas occurrence and preservation mechanism, main controlling factors of shale gas accumulation, and demonstrate shale gas enrichment rule; develop shale gas basin, zone, target evaluation 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 shale gas geophysical technology

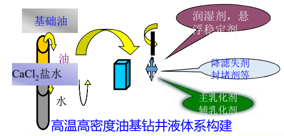
Focuse on the target layer shale gas logging evaluation, high-precision seismic acquisition and processing, geological-engineering sweet point earthquake prediction, micro-seismic monitoring and other key technologies to provide technical support for shale gas exploration and development.

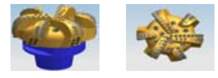


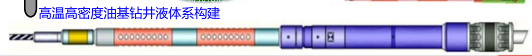
Technical research

strengthen 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！

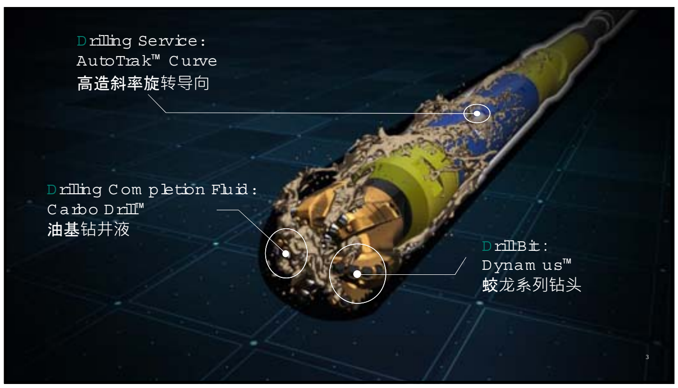
3D Integrated Drilling Solution in China

3D钻井一体化提效模式在中国的应用

Yifan Cai DS Operation Manager

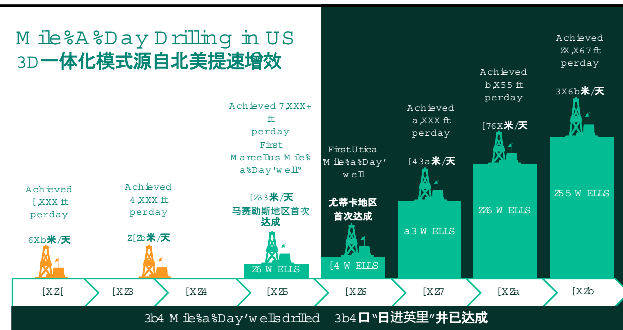
蔡一凡 钻井部门作业经理

Baker Hughes



M ile%A%Day Drilling in US

3D一体化模式源自北美提速增效



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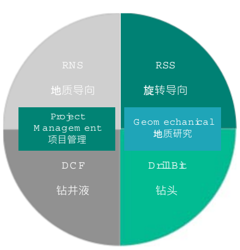
3D IDS in China

3D一体化模式在中国



Downhole Risk Avoidance
保障施工安全

- Reduce stuck in hole
- 降低卡钻风险
- Minimize downhole problem
- 减少复杂情况

Geo%Purpose Fulfill
实现地质目的

- Maximize reservoir exposure
- 提高产层钻遇率

Drilling Efficiency Enhancement
提高钻井效率

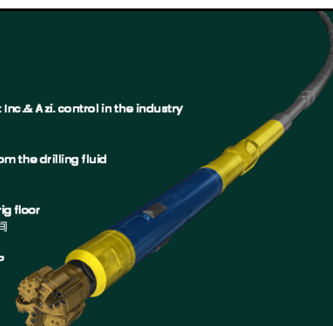
- Reduce NPT
- 降低非生产时间
- Enhance ROP
- 提高机械钻速

Baker Hughes

AutoTrak™ Curve

高造斜率旋转导向系统

- Continuous proportional steering, to fulfill best Inc.& Azi. control in the industry
  连续矢量控制，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



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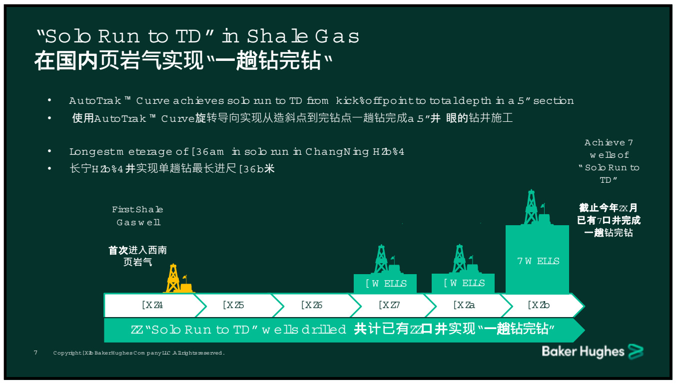
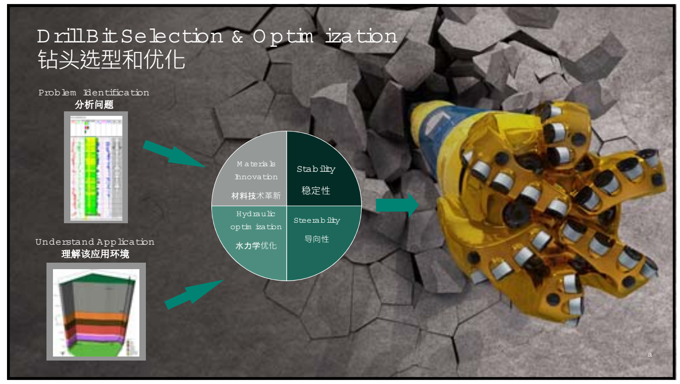
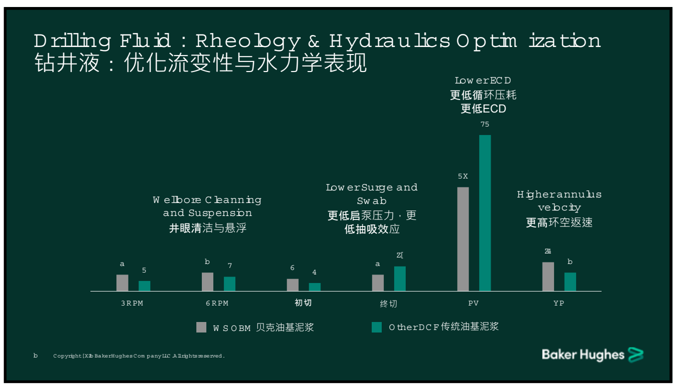
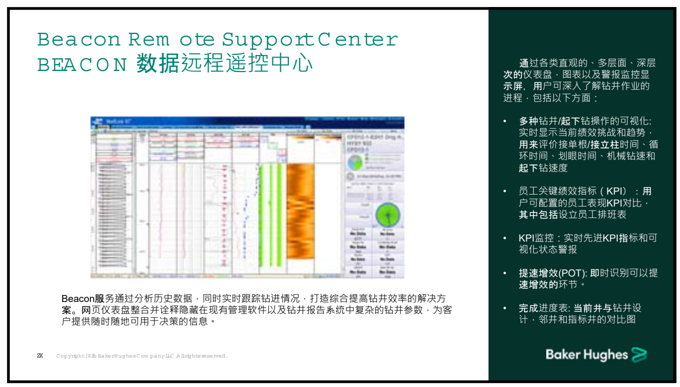
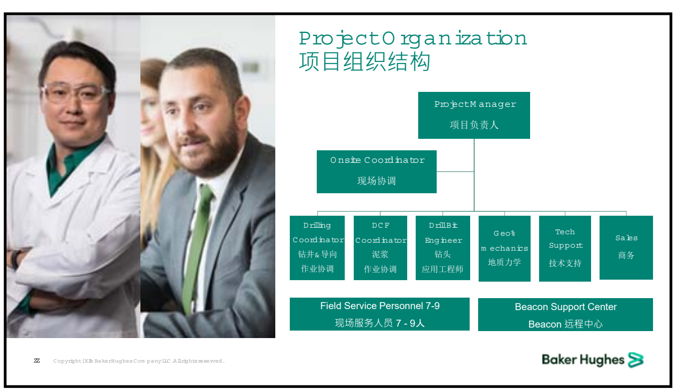

"Solo Run to TD" in Shale Gas
在国内页岩气实现"一趟钻完钻"
AutoTrak™ Curve achieves solo run to TD from kick-off point to total depth in a 5" section
使用AutoTrak™ Curve旋转导向实现从造斜点到完钻点一趟钻完成a 5"井 眼的钻井施工
长宁H2b%4井实现单趟钻最长进尺[36b米
First Shale Gas well
首次进入西南页岩气
Achieve 7 wells of "Solo Run to TD"
截止今年%月已有?口井完成一趟钻完钻
7 WELLS
Baker Hughes

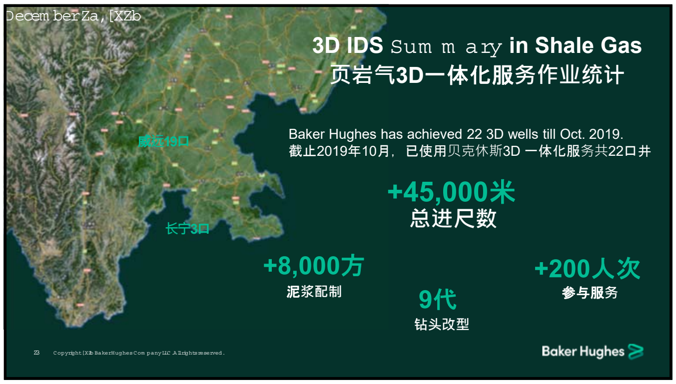

Drill Bit Selection & Optimization
钻头选型和优化
Problem Identification
分析问题
Understand Application
理解该应用环境
Materials Innovation
材料技术革新
Stability
稳定性
Hydraulic optimization
水力学优化
Steerability
导向性


Drilling Fluid : Rheology & Hydraulics Optimization
钻井液：优化流变性与水力学表现
Lower ECD
更低循环压耗
更低ECD
Wellbore Cleaning and Suspension
井眼清洁与悬浮
Lower Surge and Swab
更低启泵压力，更低抽吸效应
Higher annulus velocity
更高环空返速
初切
终切
PV
YP
贝克油基泥浆
传统油基泥浆
Baker Hughes


Beacon Remote Support Center
BEACON 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。网页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，为客户提供随时随地可用于决策的信息。
通过各类直观的、多层面、深层次的仪表盘，图表以及警报监控显示屏，用户可深入了解钻井作业的进程，包括以下方面：
多种钻井/起下钻操作的可视化：实时显示当前绩效挑战和趋势，用来评价接单根/接立柱时间、循环时间、划眼时间、机械钻速和起下钻速度
员工关键绩效指标（KPI）：用户可配置的员工表现KPI对比，其中包括设立员工排班表
KPI监控：实时先进KPI指标和可视化状态警报
提速增效(POT): 即时识别可以提速增效的环节。
完成进度表: 当前井与钻井设计、邻井和指标井的对比图
Baker Hughes


Project Organization
项目组织结构
Project Manager
项目负责人
Onsite Coordinator
现场协调
Drilling Coordinator
钻井&导向作业协调
DCF Coordinator
泥浆作业协调
Drill Bit Engineer
钻头应用工程师
Geomechanics
地质力学
Tech Support
技术支持
Sales
商务
Field Service Personnel 7-9
现场服务人员 7-9人
Beacon Support Center
Beacon 远程中心
Baker Hughes


3D IDS Case History in China
3D在国内的应用案例
Baker Hughes


Decem ber Za, [XZb
3D IDS Sum m ary in Shale Gas
页岩气3D一体化服务作业统计
威远19口
长宁3口
Baker Hughes has achieved 22 3D wells till Oct. 2019.
截止2019年10月，已使用贝克休斯3D 一体化服务共22口井
+45,000米
总进尺数
+8,000方
泥浆配制
9代
钻头改型
+200人次
参与服务
Baker Hughes


Case History of Sichuan Shale Gas
四川页岩气案例
Background 背景
Challenge 挑战
地质要求
工程安全
卡钻风险
最优靶窗厚度薄
地层易漏、易塌
微小断层发育
裂缝、层理发育
TVD 3ZXXm +
埋深3ZXX多米
Horizontal section Z5XXm – [XXXm
水平段长Z5XXm – [XXXm
Mini Faults Micro Facture
微裂缝、小断层发育
T&D
摩阻扭矩
Mud loss & Pack off at the same time
压力复杂——漏、垮同层
Stuck or LIH Risk
卡钻甚至工具落井风险
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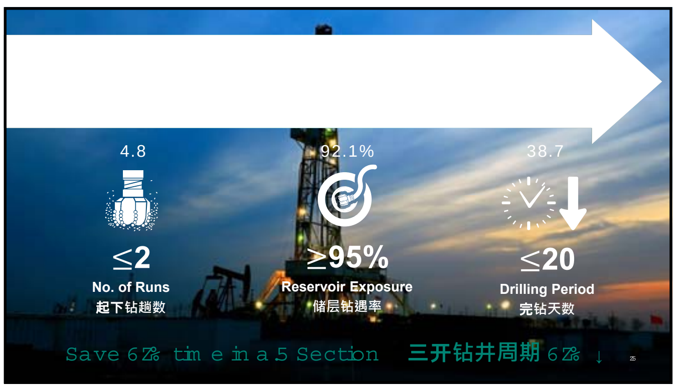
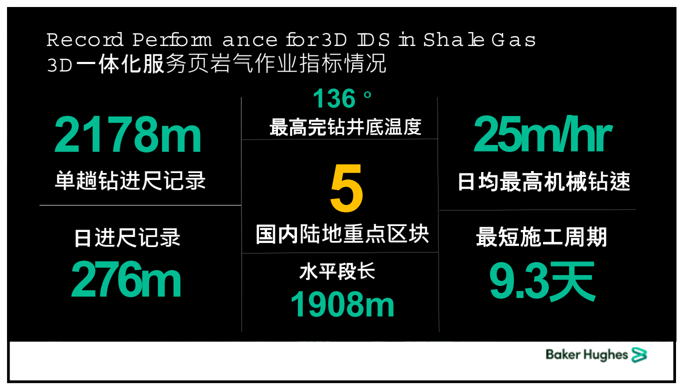
Baker Hughes


4.8
92.1%
38.7
≤2
No. of Runs
起下钻趟数
≥95%
Reservoir Exposure
储层钻遇率
≤20
Drilling Period
完钻天数
Save 62% time in a 5 Section
三开钻井周期 62% ↓


Record Performance for 3D IDS in Shale Gas
3D一体化服务页岩气作业指标情况
2178m
单趟钻进尺记录
136 °
最高完钻井底温度
25m/hr
日均最高机械钻速
5
国内陆地重点区块
日进尺记录
276m
水平段长
1908m
最短施工周期
9.3天
Baker Hughes


Milestone!– Shortest Drilling Period in the Area
里程碑！—— 区块最短钻井周期
Baker Hughes 3D 钻井一体化服务在页岩区块取得了9.33天完钻整个8.5”井段的新纪录
实现该区块页岩气井“个位数”天数完钻三开8.5”井段造斜+水平段的愿景
再一次打破由Baker Hughes保持的区块三开井周期最短纪录
钻具组合 AutoTrak Curve+Motor
开始时间 [XXX Z4/X3/[XZb
完钻时间 4XX [4/X3/[XZa
起始深度 (米) [aZa
停止深度 (米) 47Xb
总进尺 (米) ZabZ
钻进时间 Z[X.76
循环温度 (deg C) Z36
机械钻速 (米/小时) Z5.7
背景及挑战
2019年3月 四川, 中国
地层复杂多变，易出现垮塌风险
易产生震动、可钻性差的高硅质含量的地层
贝克休斯的3D钻井一体化服务解决方案及结果
ATK Curve与马达组合实现高造斜率的同时，工具表现出了极高可靠性
高剪切稀释率的油基泥浆体系配合Baker Hughes专利的NANOSHIELD / BRIDGEFORM页岩封堵模块，保证井壁稳定和井眼清洁
首次应用最新P121切削齿技术的T506SX钻头，稳健、高效的在高硅地层穿行、实现单只钻头完钻1891m，钻头出井依然状态完好
现场服务团队精细操作与配合，令仪器和泥浆在高温环境下表现稳定性和可靠性
9.33天完钻，此为Baker Hughes在2018年6月创造区块钻井周期最短纪录以来的又一个新纪录
Baker Hughes

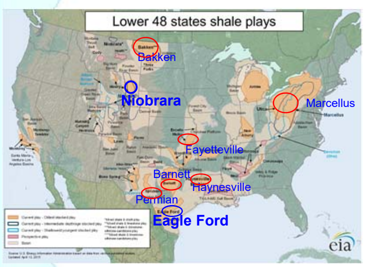

Baker Hughes

Shale Oil & Gas Production Forecast Methods of CNOOC RI
—— A Case Study on Eagle Ford

CNOOC Research Institute Co., Ltd.
2019.11

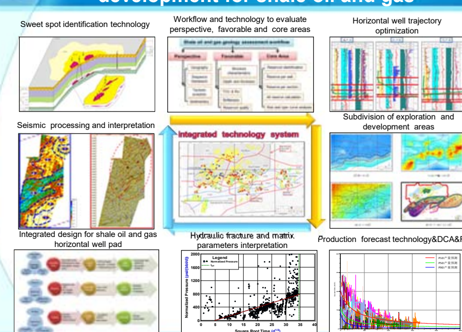
Content

1. Background



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

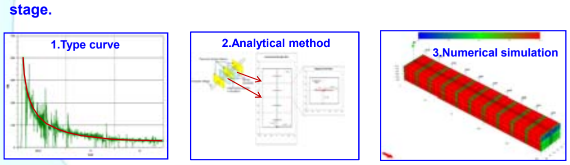
Integrated technology system of exploration and development for shale oil and gas



Challenge of production forecast

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

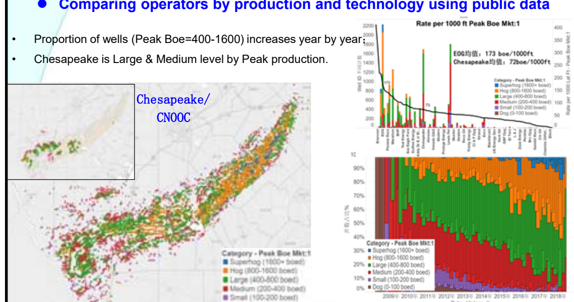
Differences between shale oil & gas and conventional:
- Nanopore, Nano Darcy, multi scale flow with more flow mechanisms.
- Multistage hydraulic frac, which cause reservoir more serious heterogeneous
- Fast decline in the early stage, slow decline in the middle and late production stage.



1. Background

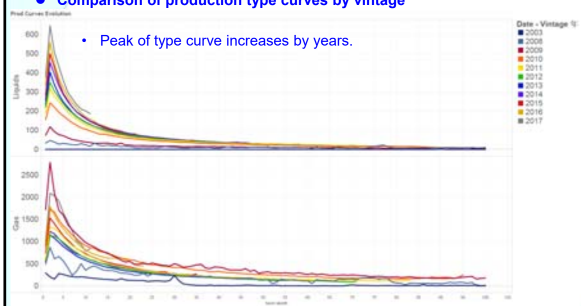
- Comparing operators by production and technology using public data

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



1. Background

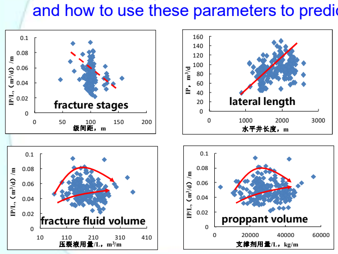
- Comparison of production type curves by vintage



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.

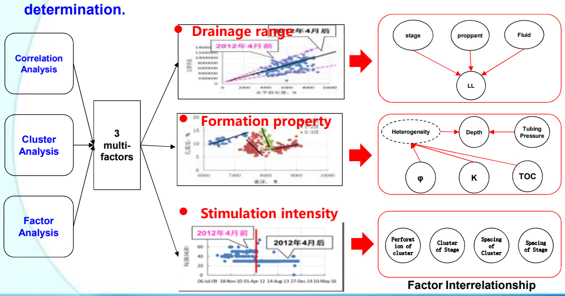
Factor
Oil
Gas
Water
TOC
Permeability
Porosity
Lateral Length
Depth
Fluid
Proppant
Tubing Pressure
Stages
Spacing of Stage
Spacing of Cluster
Perforation of cluster
Cluster of Stage

Information

- Production performance
- Seepage information
- Formation characters
- Resource potential
- Completion performance

2.1 Data mining method

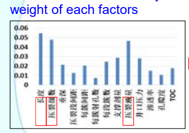
- Data mining method: factor interrelationship analysis and key factor determination.



2.1 Data mining method

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

Quantitative evaluation by weight of each factors

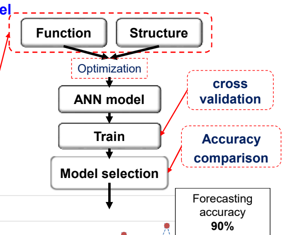


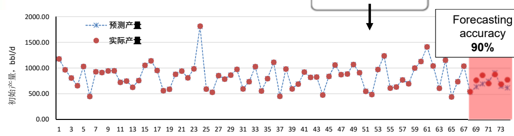
Area	Sub area	Key factor (Top 2)	Weight of multi-factor		
			Drainage range	Formation property	Stimulation strength
5-2	West	LL, Stage	53%	28%	19%
	East	K, TOC	40%	46%	14%
5-3	South	PHIE, TOC	30%	65%	5%
	North	K, PHIE	23%	73%	4%
3-2	Mid	Tubing P、Fluid	39%	53%	8%
	North	Stage, LL	74%	17%	9%

2.1 Data mining method

- Production forecast using ANN model

Area	Model structure	Fitting accuracy
5-2	2 layers，Neuron 10/50	98.0%-99.0%
5-3	2 layers，Neuron 40/8	99.9%
3-2	2 layers，Neuron 25/30	99%





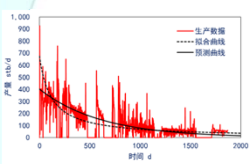
2.1 Data mining method

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

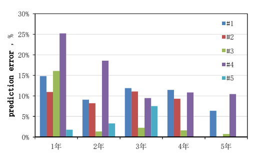
Area	Forecast parameter	Prediction error
5-2	Decline Rate（gas）	9.9%
	Decline index（gas）	7.2%
	Decline Rate（oil）	10.2%
	Decline index（oil）	8.9%
5-3	Decline Rate（gas）	9.2%
	Decline index（gas）	4.7%
	Decline Rate（oil）	8.9%
	Decline index（oil）	7.8%
3-2	Decline Rate（oil）	9.5%
	Decline index（oil）	9.2%

2.1 Data mining method

- Cum_production >3 years' prediction error < 10%



Production profile forecast



Error in comparison with actually prod

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

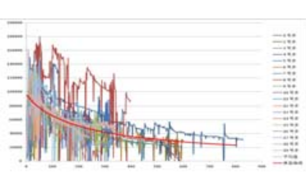
2.4 Numerical simulation production forecast technology

2.2 Type curve production forecast technology

➢Problems: no universal method, different companies with different ways

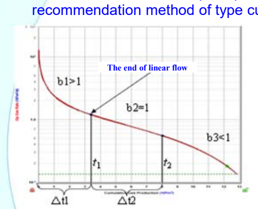
- How to determine type curve model and parameters, what is the standard process of type curve method.
- Production rates are different among wells and blocks, which means that deterministic forecast method has potential risk.
- Need different production forecast methods in different exploration and development stages .

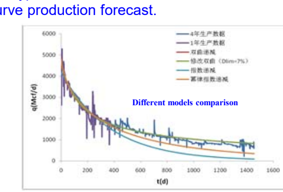
Model	Selection advice
Duong	Linear flow is obvious and linear flow period takes large portion in the whole forecast stage
Hyperbolic	Transient flow period takes large portion in the whole forecast stage
Modified hyperbolic	The transitional point can be determined from the BDF time in type curve analysis
Stretched exponential	BDF period takes large portion in the whole forecast stage
Power law	Used in the early stage of the production



2.2 Type curve production forecast technology

- 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 history
- Production time efficiency effect on forecast
- Consideration on fracture stages, etc.

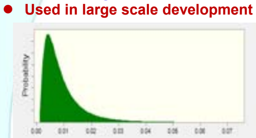
2.2 Type curve production forecast technology

- Proposed a series of probabilistic methods for type curve production forecast.

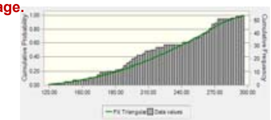
Probabilistic methods for type curve production forecast
- Probabilistic analysis method for single well
  - Probabilistic analysis method with production data available
    - Modified hyperbolic
    - Segmentation based on linear flow
  - Probabilistic analysis method without production data
    - Analytical probability method
- Probabilistic analysis method for blocks
  - Probabilistic analysis method with production data available
    - Monte Carlo method
    - Analytical model probability method with history match
  - Probabilistic analysis method without production data
    - Analytical probability method

2.2 Type curve production forecast technology

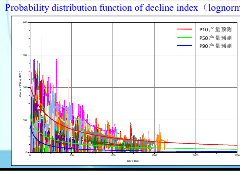
- Monte Carlo method :type curve probabilistic analysis method for blocks when enough production data available.
- Used in large scale development stage.



Probability distribution function of decline index（lognormal）



Cumulative probability analysis of initial production



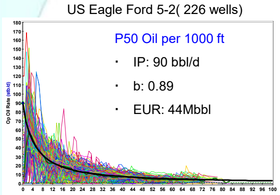
Shale gas	EUR（MMcf/100m）	d	n	Q(Mcf/100m)
p90	52.75	0.013358	1.076	124.95
p50	154.75	0.008153	1.402	169.86
p10	334.79	0.003944	1.130	303.63

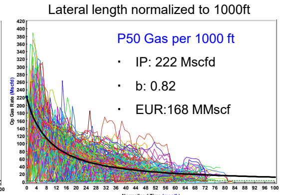
- Provided a possible variation range of type curve in a block.
- More scientific and objective for economic evaluation.

2.2 Type curve production forecast technology

A case: Eagle Ford type curve（P10/P50/P90）

US Eagle Ford 5-2(226 wells) Lateral length normalized to 1000ft





	IP,bbl/d	Decline Rate 1st year，%	b	EUR, Mbbl	5-year Cum,Mbbl	5-year Cum,%
Oil_P10	116	67	0.79	69	50	72
Oil_P50	90	74	0.89	44	32	73
Oil_P90	31	74	0.85	15	11	73

	IP, Mscfd	Decline Rate 1st year，%	b	EUR, MMscf	5-year Cum,MMscf	5-year Cum,%
Gas_P10	283	47	0.70	286	192	67
Gas_P50	222	59	0.82	168	116	69
Gas_P90	76	65	1.00	54	35	65

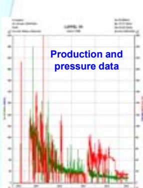
2. Production forecast methods and application

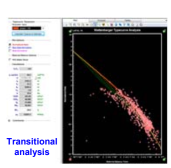
2.3 Analytical model production forecast technology

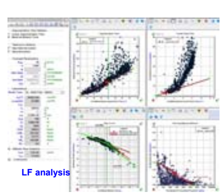
- Proposed workflow of production forecast with analytical method.

Production and pressure data → Transitional analysis, Fetkovich etc. → LF analysis, Xf, A, K, SRV → Type curve comparison → Match and forecast

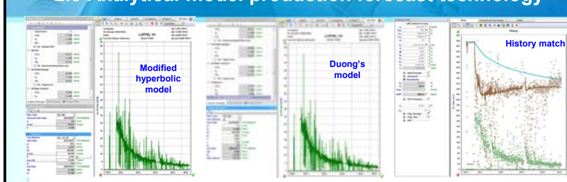
Taking LUFFEL 1H in Eagle Ford as an example





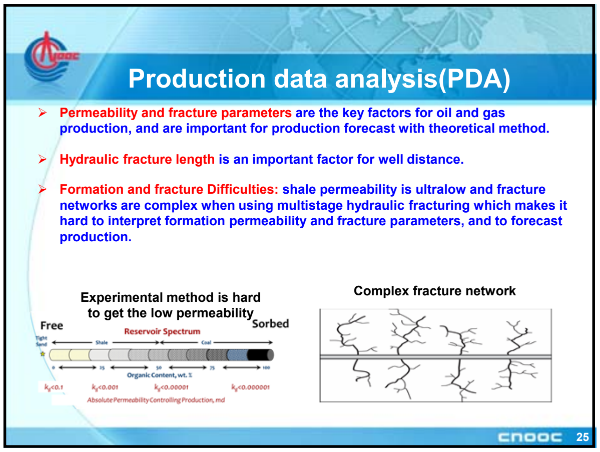


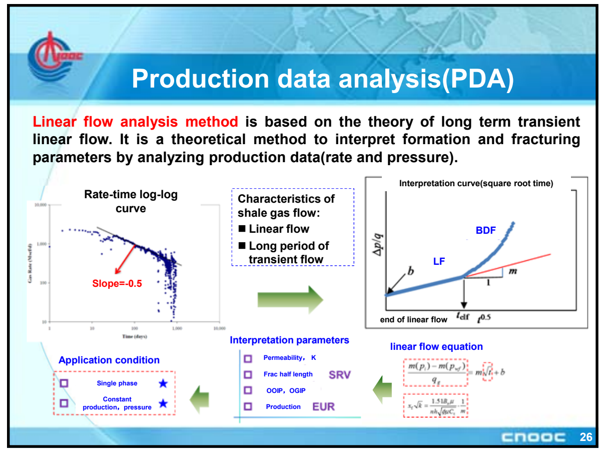
2.3 Analytical model production forecast technology

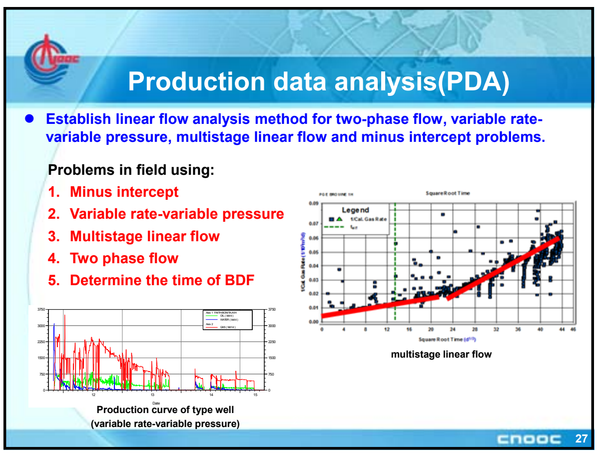


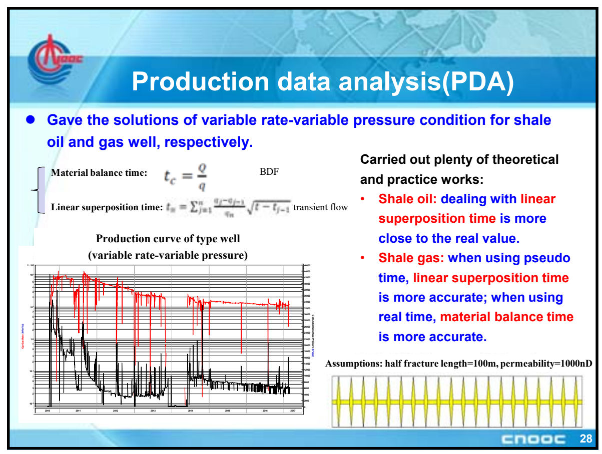
method	K ×10⁻⁴mD	Xf m	OOIP ×10³m³	EUR(30a) ×10³m³	Flow regime
LF	3.040	88.0	374.0	——	LF-BDF
Wattenbarger	——	——	——	——	LF-BDF
Arps	——	——	——	17.4	——
SEPD	——	——	——	14.8	——
Duong	——	——	——	42.0	——
Analytical method	3.02	101.1	429.3	18.7(@2000psi)	——

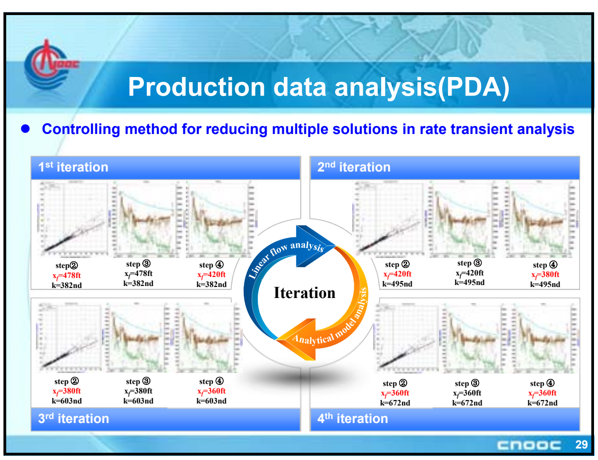
Analytical method:
- Interpretation of formation and fracture parameters
- Determine the reasonable well distance
- Analysis of reasonable working system
- Production forecast

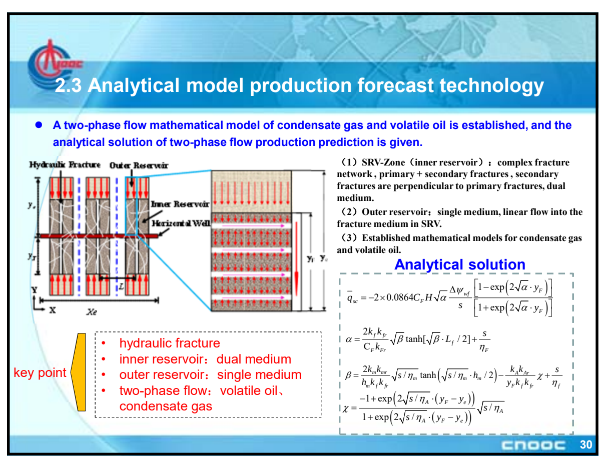

Production data analysis(PDA)
Permeability and fracture parameters are the key factors for oil and gas production, and are important for production forecast with theoretical method.
Hydraulic fracture length is an important factor for well distance.
Formation and fracture Difficulties: shale permeability 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
Free
Sorbed
Reservoir Spectrum
Organic Content, wt. %
Absolute Permeability Controlling Production, md
25


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).
Rate-time log-log curve
Slope=-0.5
Characteristics of shale gas flow:
Linear flow
Long period of transient flow
Interpretation curve(square root time)
BDF
LF
end of linear flow
Application condition
Single phase
Constant production, pressure
Interpretation parameters
Permeability, K
Frac half length
OOIP, OGIP
Production
SRV
EUR
linear flow equation
26


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:
1. Minus intercept
2. Variable rate-variable pressure
3. Multistage linear flow
4. Two phase flow
5. Determine the time of BDF
Square Root Time
Legend
multistage linear flow
Production curve of type well
(variable rate-variable pressure)
27


Production data analysis(PDA)
Gave the solutions of variable rate-variable pressure condition for shale oil and gas well, respectively.
Material balance time:
BDF
Linear superposition time:
transient flow
Production curve of type well
(variable rate-variable 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
28

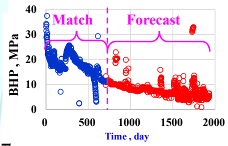

Production data analysis(PDA)
Controlling method for reducing multiple solutions in rate transient analysis
1st iteration
2nd iteration
3rd iteration
4th iteration
Iteration
Linear flow analysis
Analytical model analysis
29


2.3 Analytical model production forecast technology
A two-phase flow mathematical model of condensate gas and volatile oil is established, and the analytical solution of two-phase flow production prediction is given.
Hydraulic Fracture
Outer Reservoir
Inner Reservoir
Horizontal Well
(1) SRV-Zone (inner reservoir): complex fracture network, primary + secondary fractures, secondary fractures are perpendicular to primary fractures, dual medium.
(2) Outer reservoir: single medium, linear flow into the fracture medium in SRV.
(3) Established mathematical models for condensate gas and volatile oil.
Analytical solution
key point
hydraulic fracture
inner reservoir: dual medium
outer reservoir: single medium
two-phase flow: volatile oil、condensate gas
30

2.3 Analytical model production forecast technology

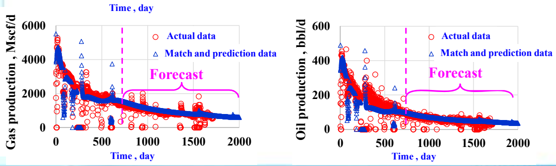
- Production matching and prediction validation（Typical Wells）

PGE BROWNE 1H



Match：Determine model parameters by HM of production data in the first 600 days.
Forecast：Forecast late production based on HM.

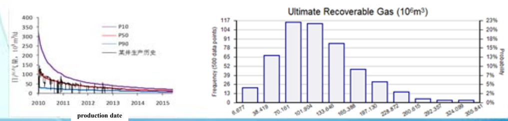
Forecast accuracy：80%



2.3 Analytical model production forecast technology

- **Analytic probability method：probability analysis method of type curve for blocks without production data. The probability distributions of geological, reservoir and fracture parameters are given.**

Parameters	value					distribution
	Min	Max	Mode	Average	Standard deviation	
K_2，mD	10^{-6}	10^{-5}	-	-	-	uniform
x_f，m	30	91	40	-	-	Triangular
n_F	18	90	19	-	-	Triangular
K_1，mD	5×10^{-6}	5×10^{-4}	5×10^{-5}	-	-	Triangular
h，m	46	125	101	-	-	Triangular
Φ，%	5	8	6	-	-	Triangular
P_i，Mpa^{-1}	31	41	-	35.9	3.8	Normal



2. Production forecast methods and application

2.1 Data mining method

2.2 Type curve production forecast technology

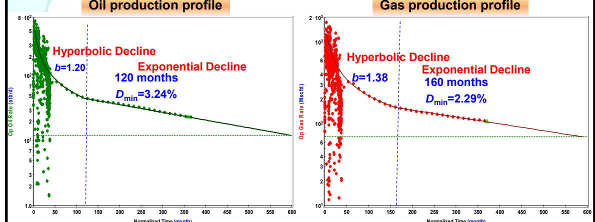
2.3 Analytical model production forecast technology

2.4 Numerical simulation production forecast technology

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.**

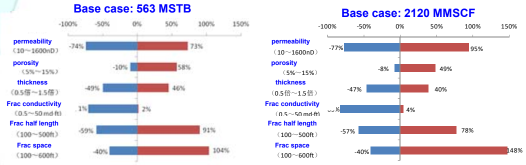
Oil production profile **Gas production profile**



For wells with oil-gas two-phase flow, the change of gas-oil ratio should be taken into account in the decline analysis.

2.4 Numerical simulation production forecast technology

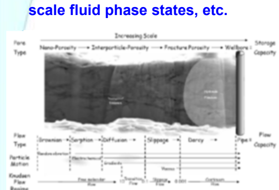
- Sensitivity analysis indicated the directions of increasing production.



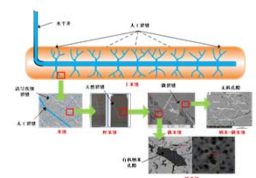
	Oil Rate, MSTB		Gas Rate, MMSCF	
	min	max	min	max
permeability（10～1600nD）	146	975	496	4126
porosity（5%～15%）	507	887	1952	3162
effective thickness（0.5～1.5times）	285	820	1133	2959
fracture conductivity（0.5～50 md·ft)	165	574	368	2214
fracture half-length（100～500ft）	231	1072	913	3774
fracture spacing（100～600ft）	338	1146	1267	5253

2.4 Numerical simulation production forecast technology

- **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.**



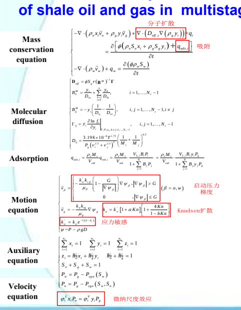
The special flow mechanism of shale oil and gas



Multi-scale flow characteristics of shale oil and gas

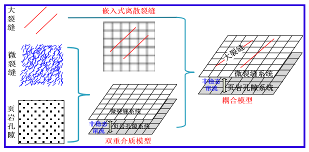
2.4 Numerical simulation production forecast technology

- **Established a compositional model considering the particular mechanisms of shale oil and gas in multistage hydraulic fracturing.**



Medium type： Shale pores, micro fractures, hyduralic fractures

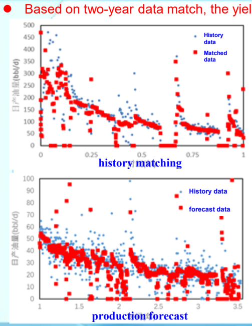
- ➢ Stimulated zone (shale pore + micro fracture) : dual medium model
- ➢ Unstimulated zone (shale pore) : single pore medium model
- ➢ Hydraulic fracture: discrete fracture model



Coupling simulation technical procedure of shale, micro-fracture and hydraulic fracture

2.4 Numerical simulation production forecast technology

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



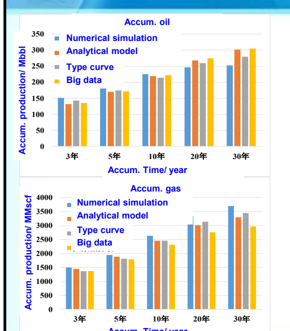
	well	compare	2 years	3 years	5 years
Black oil	Hatch DIM 1H	Actual/Mbbl	54.98	63.36	—
		Forecast/Mbbl	52.25	61.79	71.13
		Error	4.97%	2.48%	—
	Luffel 1H	Actual/Mbbl	56.35	66.14	77.62
		Forecast/Mbbl	57.89	68.32	81.31
		error	2.73%	3.30%	4.75%
Volatile oil	Faith Yana D 2H	Actual/Mbbl	135.1	168.66	200.43
		Forecast/Mbbl	147.71	188.87	227.33
		Error	9.33%	11.98%	13.42%
Condensate gas	PGE Browne 1H	Actual/MMscf	1422.75	1819.49	2349.51
		Forecast/MMscf	1449.65	1843.65	2385.47
		Error	1.89%	1.33%	1.53%
	PGE DOS 5H	Actual/MMscf	1102.92	1412.7	1850.18
		Forecast/MMscf	1141.22	1453.3	1891.5
		Error	3.47%	2.87%	2.23%

2.4 Numerical simulation production forecast technology

- **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.**

Type	mechanism	Action conditions and effect degree
Shale gas Condensate gas Volatile oil Black oil	Stress sensitivity	● All kinds of fluid phase states are affected; ● The stress is very important for all kinds of fractures; ● Matrix stress sensitivity is only observed when micro-fractures don't develop;
	Start-up pressure gradient	● Great influence on oil phase; ● Affect in the middle and late stages of production; ● The more develop the micro-fracture, the greater the influence;
	Adsorption	● Affect the gas phase; ● The influence is related to pressure level and adsorption curve;
	Knudsen diffusion	● Affect the shale gas; ● The pressure of gas reservoir is high (above 30MPa), and the influence of Knudsen diffusion is small;
	Molecular diffusion	● Little effect on all kinds of phase states;
	Confined phase state	● It has an effect on the oil phase and negligible effect on gas phase; ● Great influence in low pressure, low permeability and heavy component.

2.4 Numerical simulation production forecast technology



- **Establish a set of multi - method complementary production forecast methods.**
- **Method comparison**
- **Based on 2-year data fitting, the prediction accuracy can be 80% 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 values, 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.

Thanks

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