开采地层中的天然气水合物的数学模型 *

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喻西崇等. 开采地层中的天然气水合物的数学模型. 天然气工业 ,2004 ;24(1) :63～67

摘　要　目前从天然气水合物中开采天然气的方法 ,主要有热激发法、化学试剂法和减压法。文章通过适当简化 ,从理论上推导出减压法开采天然气的数值模型和水合物分解前缘边界曲面离井筒距离表达式 ,并对推导出的偏微分方程经过线性简化和自相似原理 ,推导出多孔介质水合物地层中压力和温度的分布方程和天然气产量方程。通过实例 ,研究了多孔介质水合物地层中压力和温度的分布规律 ,即离井筒越近 ,压力和温度越小。进行了影响水合物分解前缘边界曲面离井筒距离各影响因素的敏感性分析 ,得到了减小井筒压力和增大地层温度可以使离井筒越远地方的水合物层分解释放出天然气 ,天然气的产量随着开采时间的增大而逐渐减小但最终趋于一稳定值的结论。

主题词　天然气　水合物　开采　热力学　理论模型

目前 ,开采自然界中的天然气水合物的方法有热力分解法、减压法和注入化学剂等方法[1]。Yousif &Sloan (1991)、Handa &Stupin (1992) 和 T. Uchida &T. Ebinuma (1999) 等学者[1～3]作了大量研究 ,并取得了众多成果。笔者认为 ,减压法最大的特点是不需要昂贵的连续激发 ,因而可能成为今后大规模开采天然气水合物的有效方法之一。故重点对减压法开采进行了深入研究 ,这为水合物的开采提供了理论依据。

数 值 模 型

1. 天然气水合物的分解模型

CH_4 水合物的分解模型如下[4]:

$$(CH_4)_{气} + n(H_2O)_{水} \rightleftharpoons (CH_4 \cdot nH_2O)_{水合物}$$

当地层压力升高或温度降低时反应朝右进行(正反应) ,此时主要是地层多孔介质中的 CH_4 (客体

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(4) 可用于钻后分析和钻井模拟 ,促进钻井知识和经验的保留和传递。

(5) 将三维可视化技术与实时数据传输相结合 ,可以将办公室、井场和位于不同地点的有关专家联系起来 ,实现“纸上钻井”、远程钻井和钻井模拟等钻井协同分析和决策方式。

总之 ,基于三维可视化技术的钻井三维可视化软件为钻井工程师提供了一个强有力的工具 ,在钻井工程领域有着广泛的应用前景。

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(收稿日期　2003-06-18　编辑　钟水清)

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* 本文为国家 863 项目的一部分 :石油勘探开发分布式集成应用系统(863 - 306 - ZT04 - 03 - 3) 。

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分子)会结合在水分子(主体分子)中,其中水分子之间借助氢键形成主体结晶网络,客体分子和主体分子之间通过范德华力结合成固体形状的水合物。当地层压力降低或温度升高时反应朝左进行(逆反应),此时客体分子和主体分子之间通过范德华力减弱,固体形状的水合物结构会释放出大量的 CH_4 分子。因此从已形成天然气水合物地层中开采出天然气,实际上是就是天然气水合物形成的逆反应,即水合物的分解过程,前面提到的热激发法、抑制剂法和减压法等都是针对促进水合物分解的措施。

在地层中水合物分解和生成如图 1 表示。由水合物分解前缘边界曲面将地层分成两个区域,在分解前缘边界曲面左边靠近井筒区域为 1 区,此区域的压力低于水合物分解压力(p_D),水合物分解成天然气和水;在分解前缘边界曲面右边区域为 2 区,此区域的压力高于 p_D,水合物没有分解。由于地层图中只表示了直井开采水合物的示意图的 1/4,在井筒周围是对称分布的;对于水平井和大位移井的情况和直井类似,区别在于水合物分解前缘边界的不同。水合物分解前缘边界主要是由地层压力(p)和温度(T)等于水合物的分解温度(T_D)和分解压力(p_D)时各点组成的曲面,即 $p = p_D$、$T = T_D$,由于不同的地层、不同的钻井方式导致 p、T 的分布形式不同,同样 T_D 和 p_D 也有所不同,因此水合物分解前缘边界曲面的确定对水合物的开采非常重要。

2. 水合物分解前缘边界曲面的确定

(1) T_D、p_D 的确定

水合物分解前缘边界曲面的确定实际上就是确

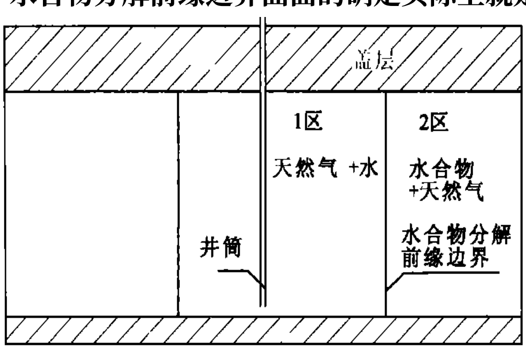


图 1　地层中水合物分解和生成的示意图

定 T_D、p_D。多孔介质中天然气水合物的形成条件与在管道、井筒中有明显的不同,在管道和井筒中可以忽略气体或液体与管壁面间的界面效应,而在多孔介质中,孔隙很小,流体与孔隙壁面间的界面存在吸附、润湿作用,必须要考虑界面对天然气水合物形成条件的影响[5],流体与孔隙壁面间的界面存在吸附、润湿作用可以通过毛管力来描述。流体在多孔介质中毛管力如图 2 所示。

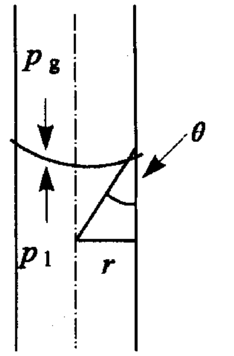


图 2　多孔介质中形成天然气水合物的毛管力示意图

根据多孔介质渗流力学的原理,在多孔介质中毛管力:

$$\Delta p = p_g - p_l = \frac{2\sigma}{r}\cos\theta \tag{1}$$

式中:p_g、p_l 分别为气相压力和液相压力,Pa;σ 为单位面积的界面自由能,J/m^2;r 为孔隙半径,m;θ 为润湿角,弧度。

在管道和井筒中,Δp 可以忽略不计,因此,Δp 为多孔介质中比管道和井筒增加的压力,其计算方法参见文献[5]。

因此在多孔介质中,如果已知单位面积的 σ、r 和 θ,就可以进行多孔介质中天然气水合物形成条件的预测,即能够给定 T_D 下,计算 p_D;或者能够给定 p_D 下,计算 T_D;因而水合物分解前缘边界曲面就可得出。

(2) 水合物分解前缘边界曲面位置的确定

1980 年 Verigin 等人利用水合物分解前缘边界的质量守恒得到如下表达式:

$$\rho_1 v_1 - \rho_2 v_2 = [\beta\varepsilon\rho_3 - (1-\alpha)\rho_1 + (1-\beta)\rho_2]\phi\frac{dl}{dt} \tag{2}$$

式中:ρ_1、ρ_2 分别为 1 区域和 2 区域天然气的密度,kg/m^3;v_1、v_2 分别为 1 区域和 2 区域天然气的速度,m/s;ε 为在甲烷天然气水合物中天然气的质量份额,无量纲;α、β 分别为多孔介质中水的含量和天然气水合物的饱和度,无量纲;dl/dt 为水合物分解前缘边界的运动速度,m/s。

1 区域和 2 区域天然气的密度 ρ_1、ρ_2 可由状态方程进行求解,即

$$\rho_1(l,t) = \rho_2(l,t) = \rho_0\frac{p_D T_0}{Z p_0 T_D} \tag{3}$$

式中:p_0、T_0、ρ_0 分别为标态下的常数,分别取 1.01 $\times 10^5$ Pa、273.15 K、0.706 kg/m^3;Z 为 p_D 和 T_D 下

的压缩因子。

将(3)代入(2)可得:

$$v_1(l,t) - v_2(l,t) = -\left[\beta\varepsilon\varphi p_3 \frac{Zp_0 T_D}{\rho_0 p_D T_0} - (\beta - \alpha)\right]\phi \frac{\mathrm{d}l}{\mathrm{d}t} \tag{4}$$

通过(4)可以确定水合物分解前缘边界曲面离井筒的距离。

3. 天然气水合物开采的数值模型

根据图 1 所示的地层中水合物分解和生成的示意图,2001 年 Chuang Ji 等人[6,7]根据经典的 Stefan 溶解模型,得到水合物地层中的一维压力分布(p_n)的数值模型:

$$\frac{\partial \phi_n \mu}{K_n}\frac{\partial p_n}{\partial t} = \frac{\partial^2 p_n^2}{\partial t^2} \tag{5}$$

在考虑多孔介质中的热传导和对流传递影响的条件下,可得一维温度分布(T_n)的数值模型:

$$a_n \frac{\partial^2 T_n}{\partial x^2} = \frac{\partial T_n}{\partial t} - \frac{C_V K_n}{C_n \mu}\frac{\partial p_n}{\partial x}\left(\frac{\partial T_n}{\partial x} - \delta\frac{\partial p_n}{\partial x}\right) - \eta\frac{\phi_n C_V}{C_n}\frac{\partial p_n}{\partial t} \tag{6}$$

式中:ϕ_n 为 1 区或 2 区的孔隙度,无量纲;K_n 为 1 区或 2 区的相渗透率,$10^{-3}\mu m^2$;μ 为天然气的动力粘度,Pa·s;t 为时间,s;p_n 为 1 区或 2 区的压力,Pa;T_n 为 1 区或 2 区的温度,K;a_n 为 1 区或 2 区的热扩散系数,m^2/s;C_n 为 1 区或 2 区的比热,J/(kg·K);C_V 为天然气的定容比热,J/(kg·K);η 为天然气的绝热系数,K/Pa;δ 为天然气的节流系数,K/Pa。

其中的 ϕ_n 计算如下:

$$\begin{cases} \phi_1 = (1-\alpha)\phi \\ \phi_2 + (1-\beta)\phi \end{cases} \tag{7}$$

式中:ϕ 为地层中多孔介质的孔隙度,无量纲。

4. 天然气水合物开采数值模型的求解

以井筒为 y 轴,垂直井筒的方向为 x 轴,坐标原点 o 在井筒的中心,取 1/4 来进行分析,水合物分解前缘边界曲面离井筒的距离为 $l(t)$,则 1 区为 $0 < x < l(t)$,2 区为 $l(t) < x < +\infty$(图 3)。

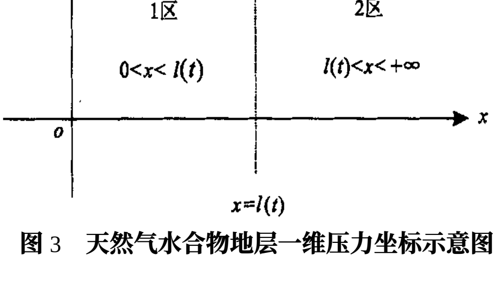


图 3　天然气水合物地层一维压力坐标示意图

边界条件和初始条件:

$$\begin{cases} p_1(0,t) = p_G \\ p_2(x,0) = p_2(\infty,t) = p_e \\ p_1(l(t),t) = p_2(l(t),t) = p_D(T_D) \\ T_1(l(t),t) = T_2(l(t),t) = T_D \\ T_2(x,0) = T_2(\infty,t) = T_e \end{cases} \tag{8}$$

式中:p_1、p_2 分别为 1 区和 2 区压力,MPa;T_1、T_2 分别为 1 区和 2 区的温度,K;T_e、p_e 分别为初始时刻($t=0$)地层或油藏温度和压力;p_G 为井筒压力,MPa;$l(t) = \sqrt{\gamma t}$,γ 是与水合物分解曲面前缘运动速度有关的定常数,m^2/s。

(1)压力微分方程的线性化和自相似解

作下面的近似分析:

$$\frac{\partial p_1^2}{\partial t} \approx 2p_G\frac{\partial p_1}{\partial t} \tag{9}$$

$$\frac{\partial p_2^2}{\partial t} \approx 2p_G\frac{\partial p_2}{\partial t} \tag{10}$$

则方程(5)可得:

$$\frac{\partial p_n^2}{\partial t} \approx x_n\frac{\partial p_n^2}{\partial x^2} \tag{11}$$

式中:$x_1 = \frac{K_1 p_G}{\phi(1-\alpha)\mu}$;$x_2 = \frac{K_2 p_e}{\phi(1-\beta)\mu}$。

根据边界条件和初始条件(8),得到方程(11)的线性和自相似解,即 1 区域和 2 区域的压力分布:

$$\begin{cases} p_1^2 = p_G^2 - (p_G^2 - p_D^2)\dfrac{\mathrm{erf}(\lambda_1)}{\mathrm{erf}(\alpha_1)} \\ p_2^2 = p_e^2 - (p_e^2 - p_D^2)\dfrac{\mathrm{erfc}(\lambda_2)}{\mathrm{erfc}(\alpha_2)} \end{cases} \tag{12}$$

式中:$\lambda_n = \frac{x}{2\sqrt{x_n t}}$,$\alpha_n = \sqrt{\frac{\gamma}{4x_n}}$;erf( )和 erfc( )分别为误差函数和补充的误差函数,$\mathrm{erf}(\xi) = \frac{2}{\sqrt{\pi}}\int_0^{\xi} e^{-\eta^2}d\eta$;$\mathrm{erfc}(\xi) = 1 - \mathrm{erf}(\xi)$。

(2)温度微分方程的线性化和自相似解

在忽略多孔介质中的热传导的影响,只考虑对流传递影响的条件下,方程(6)变成

$$\frac{\partial T_n}{\partial t} - \frac{C_V k_n}{C_n\mu}\frac{\partial p_n}{\partial x}\left(\frac{\partial T_n}{\partial x} - \delta\frac{\partial p_n}{\partial x}\right) - \eta\frac{\phi_n C_V}{C_n}\frac{\partial p_n}{\partial t} = 0 \tag{13}$$

根据边界条件和初始条件(5),得到方程(13)的线性和自相似解,即 1 区域和 2 区域的温度分布:

$$\begin{cases} T_1 = T_D + A_1\delta\left[\mathrm{erf}(\lambda_1) - \mathrm{erf}(\alpha_1) + \left(\frac{\eta}{\delta}B_1 - 1\right)(\psi_1(\lambda_1) - \psi_1(\alpha_1))\right] \\ T_2 = T_e - A_2\delta\left[\mathrm{erfc}(\lambda_2) + \left(\frac{\eta}{\delta}B_2 - 1\right)\psi_2(\lambda_2)\right] \end{cases} \tag{14}$$

式中：

$$\psi_1(\xi_1) = \frac{2}{\sqrt{\pi}}\int_0^{\xi_1}\frac{\eta e^{-\eta^2}}{\eta + W_1 e^{-\eta^2}}d\eta$$

$$\psi_2(\xi_2) = \frac{2}{\sqrt{\pi}}\int_{\xi_2}^{\infty}\frac{\eta e^{-\eta^2}}{\eta + W_2 e^{-\eta^2}}d\eta$$

$$A_1 = \frac{1}{2\mathrm{erf}(\alpha_1)}\frac{p_D^2 - p_G^2}{p_G}$$

$$A_2 = \frac{1}{2\mathrm{erfc}(\alpha_2)}\frac{p_e^2 - p_D^2}{p_e}$$

$$B_1 = \phi_1 C_V / C_1$$

$$B_2 = \phi_2 C_V / C_2$$

$$W_1 = \frac{(p_D^2 - p_G^2)C_V}{p_G C_1}\frac{K_1}{2\sqrt{\pi}\mathrm{erf}(\alpha_1)\mu\chi_1}$$

$$W_2 = \frac{(p_e^2 - p_D^2)C_V}{p_e C_2}\frac{K_2}{2\sqrt{\pi}\mathrm{erfc}(\alpha_2)\mu\chi_2}$$

这样，可得到天然气水合物多孔介质中的压力和温度场分布。

(3)减压法开采天然气水合物时开采得到的天然气产量公式

由上面推导的天然气水合物多孔介质中的压力和温度场分布，并根据井筒周围1区域的渗流规律可推导出减压法开采天然气水合物时开采得到的天然气产量公式：

$$Q = \frac{K_1}{\mu}\frac{\partial p_1(0,t)}{\partial x} = \frac{K_1}{\mu}\frac{(p_D^2 - p_G^2)}{p_G}\frac{1}{\mathrm{erf}(\alpha_1)}\frac{1}{2\sqrt{\pi\chi_1 t}} \quad (15)$$

由表达式(15)可以看出：①减压法开采天然气水合物时开采得到的天然气产量(Q)与时间(t)的平方根成反比，即随着天然气水合物的不断分解，开采得到的天然气产量逐渐减少；②天然气产量(Q)与井筒周围1区域的渗透率(K_1)成正比，与天然气的动力粘度(μ)成反比。

示例分析

已知某天然气水合物地层参数如下[9]：

初始时刻地层压力 $p_e = 15$ MPa、温度 $T_e = 280$ K，地层多孔介质的含水量 $\alpha = 0.15$，水合物饱和度 $\beta = 0.19$，天然气的压缩因子 $Z = 0.88$，天然气的节流系数 $\delta = 8\times10^{-7}$ K/Pa，天然气的绝热系数 $\eta = 3.2\times10^{-6}$ K/Pa，天然气的比热 $C_v = 3000$ J/(kg·K)，天然气的动力粘度 $\mu = 1.5\times10^{-5}$ Pa·s，1区和2区的比热 $C_1 = 2400.2$ J/(kg·K)、$C_2 = 1030.2$ J/(kg·K)，层中多孔介质的孔隙度 $\phi = 0.2$，1区或2区的相渗透率分别为 $K_1 = 12\times10^{-3}\mu m^2$、$K_2 = 10\times10^{-3}\mu m^2$。

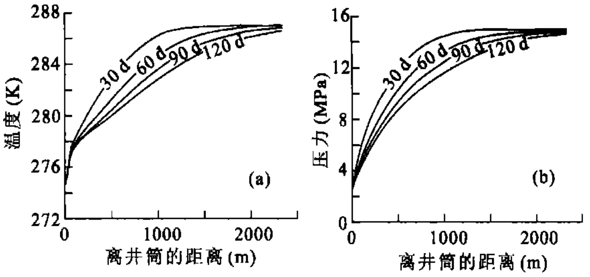
1.计算1区域和2区域的压力和温度分布

水合物分解压力(p_D)和温度(T_D)采用热力学关系表达式计算，计算结果如表1所示。

表1　p_D 和 T_D 计算结果

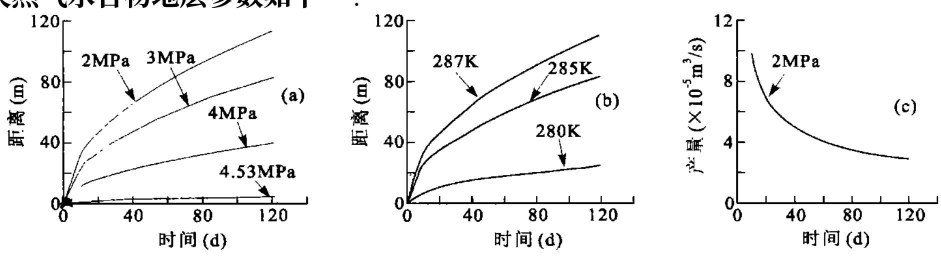
p_e(MPa)	T_e(K)	p_D(MPa)	T_D(K)
15	280	2.42	270.07
15	285	3.69	275.44
15	287	4.47	277.66
15	287	4.49	277.69
15	287	4.58	277.93
15	287	4.64	278.04

根据表达式(12)和(18)可以计算当井筒压力=2 MPa时，1区域和2区域的温度分布曲线(图4-a)、压力分布曲线(图4-b)。



$K_1=12\times10^{-3}\mu m^2, K_2=10\times10^{-3}\mu m^2$

图4　温度和压力随着离井筒的距离的变化曲线



$K_1=12\times10^{-3}\mu m^2, K_2=10\times10^{-3}\mu m^2$

图5　水合物分解前缘边界曲面离井筒的距离的敏感性分析

从图 4 可以看出：①距井筒越近，压力和温度值越小，并且减小的幅度越大；②距离井筒相同的位置，压力和温度值随着开采时间的增大而逐渐减小；③压力和温度的变化值随着开采时间 t 的变化是非线性的，相同时间 t 条件下，随着井筒距离 x 的变化也是非线性的。

2. 水合物分解前缘边界曲面离井筒的距离的敏感性分析

(1) 井筒压力的影响规律

其它条件不变的情况下，改变井筒压力 p_G，根据表达式(9)，计算 p_G 分别等于 2、3、4、4.53 MPa 下水合物分解前缘边界曲面离井筒的距离的变化规律(图 5-a)。

从图 5 可知：①在相同井筒压力下，水合物分解前缘边界曲面离井筒的距离随着时间 t 的平方根成正比关系，即随着开采时间的推移，水合物分解前缘边界曲面离井筒的距离越来越远。②在同一开采时间条件下，随着井筒压力的降低，水合物分解前缘边界曲面离井筒的距离越远，即可以开采离井筒越来的地方的水合物分解的天然气，因此要提高天然气的产量，须降低天然气的井筒压力。

(2) 地层温度(T_e)的影响

其它条件不变的情况下，改变 T_e，计算 T_e 分别等于 280、285、287 K 情况下天然气的产量(图 5-b)。

从图 5-b 可以看出，随着 T_e 的增大，水合物分解前缘边界曲面离井筒的距离增大，因此其它条件相同的情况下，可以通过提高地层的温度的方法来增大天然气的产量。热激发法正是基于此而提出的方法。

3. 天然气产量的变化趋势

根据表达式(18)，可以计算当井筒压力为 2 MPa 时天然气产量随着时间的变化曲线(图 5-c)。

从图 5-c 可以看出，给定井筒压力下天然气的产量随着开采时间的推移在开始的时候，减小幅度较大，但随后逐渐趋于缓和，最后趋于稳定在某一给定产量。

研究方向

今后还应对以下几方面进行深入研究：

(1) 地层压力和温度对天然气产量的影响程度；

(2) 利用类似油藏数值模拟的方法，提出更好的水合物开采的数值模型；

(3) 利用类似油气藏岩心试验原理，在实验室模拟水合物开采的实验模型；

(4) 加强在多孔介质中水合物生成条件(特别是加入抑制剂情况下)的理论和试验研究，加强水合物分解前缘边界曲面的运移与产量关系的理论研究。

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(收稿日期　2003-09-10　编辑　韩晓渝)

Sea area.

SUBJECT HEADINGS: Bohai Gulf, Horizontal extended reach wells, Completion technology, Completion fluids system, Reservoir protection, In-house study

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FORMATION COLLAPSED PRESSURE PREDICTING WITH LOGGING DATA [2)]

Liu Zhidi, Xia Hongquan (Southwest Petroleum Institute) and Zhang Yuanze (Sichuan Petroleum Administration). *NATUR. GAS IND.* v. 24, no. 1, pp. 57～59, 1/25/2004. (ISSN1000 - 0976; **In Chinese)**

ABSTRACT: It's very important to determine the formation collapsed pressure profile for bore-hole stabilization and safe drilling. The article focuses on studying how to accurately acquire rock mechanics parameters needed by the model from logging data after setting up the calculating model of formation collapsed pressure. The method is applied to the fine interpretation and processing of wells LJ 2 and others logging data in Luojiazhai structure. And the formation collapsed pressure and mud density that can keep bore stability are calculated for the different depths and sections of the wells. The results calculated by the method are used to practical drilling and make good practice, and provide the basis for scientific drilling on the mud density design of the area.

SUBJECT HEADINGS: Logging data, Formation collapsed pressure, Hole stabilization, Mud density

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APPLICATION OF 3-D VISUALIZATION TECHNIQUE IN PETROLEUM DRILLING [1)]

Guo Zhaoxue, Chen Ping and Zhou Kaiji (Southwest Petroleum Institute). *NATUR. GAS IND.* v. 24, no. 1, pp. 60～63, 1/25/2004. (ISSN 1000 - 0976; **In Chinese)**

ABSTRACT: Along with the increase in difficulty of oil and gas exploration and development, the degree of complication of petroleum drilling is relevantly increased. In order to raise drilling benefits, the interchange of these disciplines as drilling, geology and geophysics should be strengthened and the data related to these disciplines should be used as much as possible. The application of 3-D visualization technique in drilling engineering is described in the paper. Though combining the drilled data and pre-drilling design data with their related data on mechanics, geology and well log, the interrelations among them may be visually show up in a 3-D visualization environment. On the basis of this, the abilities of the drilling personnel in analyzing complicated data and extracting usable messages can be effectively enhanced in the processes of pre-drilling design, drilling monitoring, drilling trouble prediction and processing and post-drilling analysis, etc., thus accelerating their exchange and cooperation with the disciplines related and raising the drilling benefits.

SUBJECT HEADINGS: Drilling, Visualization, Design, Monitoring, Drilling problem, Comprehensive analysis

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MATHEMATICAL MODEL TO RECOVER GAS HYDRATE FROM FORMATIONS [2)]

Yu Xichong[1,2], Wu Yingxiang[1], An Weijie[2], Li Qingping[2] and Wu Yaling (1. Mechanics Institute of Chinese Sciences Academy; 2. Research Center of CNOOC; 3. Sichuan Petroleum Administration). *NATUR. GAS IND.* v. 24, no. 1, pp. 63～67, 1/25/2004. (ISSN1000 - 0976; **In Chinese)**

ABSTRACT: Now, the main methods to recover natural gas from gas hydrate are: increasing formation temperature, injecting inhibitors and depressurization. With proper simplification, the article theoretically derives the numeral model to recover gas by the depressurization method, and the represent of the distance of the hydrate decomposition front from the bore-hole. Also, with linearization approximation simplification and self-similar principle solution, the equation of temperature and pressure distribution in the hydrate reservoir, and the equation of gas production are derived. With real cases, the distribution law of pressure and temperature in hydrate reservoirs has been studied. It is found that the closer the distance from the bore-hole is, the lower the pressure and temperature is. At the same time, the sensibility analysis of various factors which influence the hydrate decomposition front from the bore-hole has been done. It is found that decreasing the hole pressure and increasing the formation temperature can make the hydrate that is far away from the hole releasing natural gas. The natural gas production will decrease as the time increases, but at last the production will become stable.

SUBJECT HEADINGS: Natural gas, Hydrate, Exploitation, Thermodynamics, Theoretical model

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STUDY ON RESERVOIR CHARACTERISTICS AND DEVELOPMENT TECHNOLOGY OF COAL-BED GAS IN CHINA [2)]

Liu Yijun and Lou Jianqing (China United Coal-bed Methane Corporation Ltd.). *NATUR. GAS IND.* v. 23, no. 1, pp. 68 ～ 71, 1/25/2003. (ISSN1000 - 0976; **In Chinese)**

ABSTRACT: Coal-bed gas reservoirs in China has special characteristics called "3 lows", i. e. low gas saturation, low permeability and low pressure, and has high original in-situ stress since strong tectonic/structural activities happened after coal forming. At present, coal-bed gas is exploited mainly aiming to the medium and high rank of coal that has strong heterogeneity. According to these characteristics, the article proposes to apply the conception of "steady within acting" to select and appraise exploitation areas of coal-bed gas. Also, the article studies the sealing and capping conditions of coal-bed reservoirs, mainly including the regional cap study and underground water kinetics study of coal-bed gas reservoirs. And reservoir protection of coal-bed gas is discussed in the article to prevent and minimize the reservoir damage caused by drilling and completion activities. The article suggests some measures to increase the production of coal-bed gas reservoirs, such as making effective in-situ stress releasing zones, conducting interference between wells which has got good results, increasing the conductivity and effective pressure difference of the reservoirs, speeding up the de-absorptive rate of coal-bed gas and improving the de-absorption quantity of coal-bed gas.

SUBJECT HEADINGS: China, Coal-formed gas, Reservoir characteristics, Development, Technology

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COUNTERMEASURES AGAINST THE PRODUCTION OF GAS WELLS IN T_3x_2 GAS RESERVOIRS IN WEST SICHUAN [1)]

Wu Yunlong (West Sichuan Production and Transferring Department of Southwest Branch of Star Petroleum Co., Sinopec). *NATUR. GAS IND.* v. 24, no. 1, pp. 72～74, 1/25/2004. (ISSN 1000 - 0976; **In Chinese)**

ABSTRACT: According to the features of T_3x_2 (i. e. the second member of Xujiahe formation, Upper Triassic) gas reservoir in west Sichuan gas fields, it is put forward in the paper that a single-string permanent completion method should be adoped; the metal-to-metal seal method was applied to the threaded connection; the materials of both H_2S corrosion-resistance and CO_2 corrosion-resistance should be used for the downhole packer, tubular goods and relevant corollary equipment; the corrosion inhibitor or an overall pipe string pre-filming was utilized in the process of well completion; and the corrosion control agents were periodically filled up during production. In water-free gas production period, with the aid of mathematical model, a series of optimal production rates were achieved, which can ensure the drilled strata against the occurrence of the quickly-sensitive effect the well bore against liquid accumulation and the tubing against being eroded, and the reasonable gas well working systems were relevantly made up, thus lasting the water free gas production period as far as possible. According to the mathematical models related, the critical liquid-carried flow rates were calculated under different pressures in water-carried gas production period, thus ensuring that the practical gas production will be larger than the critical liquid-carried flow rate, so as to utilize fully the formation energy to carry the liquids out. Because of the formation energy's reduction caused by the water accumulation in gas wells, the foam-draining and optimal pipe string were primarily chosen as the drainage gas recovery techniques for the water-producing gas wells in T_3x_2 reservoirs in order to maintain their normal production.

SUBJECT HEADINGS: T_3x_2 gas reservoir, Water-free gas