

文 23 气田整体压裂改造技术与效果评价

吴亚红* 林 涛 池圣平 李健萍
(石油大学·北京) (中原石油勘探局井下特种作业处)

吴亚红等. 文 23 气田整体压裂改造技术与效果评价. 天然气工业, 2001; 21(1): 69~72

摘 要 文 23 气田经过长达 3 年的压裂整体改造研究和现场实施, 取得了明显的地质效果和经济效益, 形成了适合中原油田块状气田压裂的配套技术; 文章针对文 23 气田的整体改造方案和开采现状, 开展了整体改造的配套技术研究, 成功地应用在整体压裂改造上, 并对压后的效果从工艺、地质和经济效益上进行评价, 并提出下步工作方向。

主题词 文 23 气田 整体压裂 酸化 技术改造 经济评价

文 23 气田位于东濮凹陷中央隆起带文留构造北部, 构造类型为被断层复杂化的不完整背斜, 受文东、文西两条大断裂系的控制, 内部三条次一级断层将其切割为四个断块区。气藏埋深 2 800~3 100 m, 层位为沙四段, 气层孔隙度 10%~15%, 空气渗透率 $0.27 \times 10^{-3} \sim 17.2 \times 10^{-3} \mu\text{m}^2$, 地层压力系数 1.2~1.3, 地层温度 90~110 °C, 属于低孔低渗高压块状干气藏。随着气田的开发, 地层压力已低于静水柱压力; 气井生产压差大, 最大达 20 MPa; 未压裂生产井表皮系数平均为 7.9, 气层污染较重; 边块出水量大, 造成井筒积液严重, 产量下降; 由于非均质的影响, 射孔层动用状况差, 不产层占射孔层 45.7%。针对上述地质特征及开采现状, 决定采用压裂来改善气田的生产状况和稳产基础, 提高边块储量动用程度。首批改造 6 口井, 其中主块 4 口, 东西块各 1 口。第二批改造 7 口井, 主块有 5 口井, 边块 2 口井。改造层位是沙四³⁻⁸。主块支撑缝长 80~150 m, 边块 60~90 m, 目的层压开程度达到 70%, 重点改造非产层和次产层, 增产倍数 3 倍左右。选择 4 口井压前压后均测产气剖面, 并进行裂缝方位监测及压降解释。

整体压裂改造配套技术研究

1. 选井选层技术

文 23 气田原始地层压力系数一般为 1.2~1.3,

经过十几年的开发, 压力系数已降到 0.9 左右, 在井层的确定上既要满足提高产量的要求, 也要考虑气井是否符合压裂的条件, 由于整体改造分 3 年实施, 所以在选井选层及先后安排上考虑关键因素是: 单井储量大, 目前产量低的井; 动用状况差的层, 即不产层和低产层; 生产压差大的井; 新射孔的井; 固井质量好, 套管无破损的井; 先压低产井, 压力系数较低的井, 含水相对较高的井。

2. 压裂方式的研究

考虑到文 23 气田为块状气藏, 单井射孔厚度大, 单层厚度大, 夹层薄, 压裂后自喷排液能力强, 同时一次压裂能够多压开一些射孔层, 压裂方式采用投球为主。为了控制缝高纵向延伸至夹层, 使缝高尽量在产层中产生, 压裂次数以二到三次为好, 以提高目的层的压开程度。

3. 压裂规模的研究

根据美国 Eikings 研究的不同低渗储气层有效渗透率为获得最大的净现值对支撑缝长的要求, 文 23 气田未压裂井有效渗透率在 $0.094 \times 10^{-3} \sim 0.3 \times 10^{-3} \mu\text{m}^2$, 其支撑缝长应为 152~305 m, 但考虑到断层及气水边界等地质问题, 主块压裂井支撑缝长 100~150 m, 边块 50~90 m, 把初步确定的支撑缝长用油藏模拟软件进行模拟计算, 从中选出最优的支撑缝长, 然后利用压裂设计软件优化泵注程序, 优化施工规模。

* 吴亚红, 高级工程师, 1966 年生; 1989 年毕业于江汉石油学院测井专业, 1998 年在西北大学获沉积学专业硕士学位, 现在石油大学(北京)攻读博士学位; 主要从事试油项目经营管理、压裂选井选层和井下综合地质研究工作。地址: (457061) 河南濮阳柳屯。电话: (0393) 4875313。

4. 管串设计

由于压裂改造的井均是生产的老井,考虑到气井压裂后自喷,压裂管柱又能代替生产管柱,管串设计原则:投球压裂使用 $\text{O}63.5 \text{ mmN}80$ 油管下带喇叭口;卡封压裂 $\text{O}76.2 \text{ mm}$ 油管带 RTTS 封隔器, $\text{O}63.5 \text{ mmN}80$ 新油管完井生产;边块产水的井,采用 $\text{O}63.5 \text{ mm}$ 油管下带喇叭口作为压裂及生产管串;除下封隔器压裂的井采用油管注入外,其余均采用油套合注方式。

5. 气层保护技术

为了减少压裂改造对气层造成的污染,在气层保护方面采取的措施为:采用低伤害压裂液;对基液进行精细过滤,滤掉 $2 \mu\text{m}$ 以上粒径杂质;备水前对大罐进行彻底清洗至干净;加砂后期加大水化剂浓度,缩短水化时间,尽量利用余压放喷返排,若一时不能自喷,则用液氮助排诱喷。

6. 入井材料研究

针对文 23 气田低孔低渗和地层存在污染的特点,选用携砂性能较好对气层伤害小的压裂液,稠化剂残渣比通常低 20%,表面张力比通常降低 15%,选用残渣 3.0%~4.0%、特级羟丙基胍胶 GRJ-11 作为稠化剂,有机硼交联,温度 110,剪切 120 min,粘度 96 mPa·s,24 h 后,粘度 1 mPa·s。为了防止压裂液滤失进入地层引起粘土膨胀或矿化度改变,引起的地层微粒的脱落和运移,在压裂液中选择氯化钾作为无机防膨剂,以平衡水基压裂液自身的矿化度,同时在前置液中使用有机聚合物 PTC-06B,增加压裂液的防膨效果。文 23 气田压裂井深一般在 3 000 m 左右,闭合压力在 30 MPa 左右,选用宜兴烧结陶粒作为支撑剂,密度 2.78 g/cm^3 ,破碎率 25 MPa 2.96%,40 MPa 5.6%,铺砂浓度 2.5 g/cm^3 ,30 MPa 闭合压力,裂缝导流能力 $40.5 \mu\text{m}^2 \cdot \text{cm}$ 。

7. 施工参数优选

由于文 23 块整体改造单井加砂量大,砂比高,综合考虑裂缝效率 80%左右,前置液量占总液量 35%为宜。为了尽可能压开射孔井段,裂缝高度要高,因此施工排量应在 $3.5 \text{ m}^3/\text{min}$ 以上。要提高裂缝导流能力,关键是提高施工砂比,而增产倍数要达到 3 倍以上,裂缝导流能力应达到 $100 \mu\text{m}^2 \cdot \text{cm}$,铺砂浓度应达到 5 kg/m^2 ,这就要求地面平均砂比必须高于 25%。顶替量按井筒容积等量顶替,以保证井筒附近裂缝导流能力;由于采用油管、套管合注,油管及环空横截面积不同,流速有差异,因此顶替量可按 5%附加。

8. 施工技术研究

现场施工严格按设计施工,顶替液采用活性水,以使井温仪器顺利入井,准确确定裂缝高度。施工液体在现场再次检测,各项指标合格后方可入井。施工设备使用两套哈里伯顿 1000 型和 1400 型车组,各有 6 台主压车,1 台混砂车,1 台仪表车,1 台管汇车,其性能完全满足文 23 气田压裂改造的要求。使用 RTTS 封隔器耐温 150,抗压差 80 MPa,能有效地保护套管,使施工顺利进行。

9. 监测技术研究

为了取全取准各项资料,正确评价压裂技术,确定了一套监测技术标准。采用压前压后测井温曲线,确定缝高;进行施工动态监测用来评价施工情况;施工过程进行裂缝方位监测,确定裂缝方位及长度,研究裂缝的有效性;施工停泵后测压降曲线,求取裂缝几何形态、液体效率及地层参数;压前压后测产气剖面,分析评价每层产出状况;压后选择部分井测压力恢复,求取渗透率、表皮系数、研究半径等参数,对压裂效果进行有效的技术评价。

整体压裂改造效果评价

经过 3 年的研究和具体实施,文 23 气田整体压裂改造 13 口井 28 次,其中测井温 6 口,测压降及动态监测 7 口,测裂缝方位 6 口井,测产气剖面 4 口井,测恢复 7 口井。

1. 工艺效果评价

文 23 气田整体改造从施工工艺技术上就是要最大限度地压开射孔层,降低对气层的污染,满足地质方案要求。

(1) 施工评价:3 年整体压裂改造施工,成功率为 100%,设计加砂 473 m^3 ,实际加入 472 m^3 ,加支撑剂符合率 99.8%,每井平均施工砂比均高于设计砂比,每井平均排量达到了设计要求。根据 6 口井的泵压变化数据整理绘制的裂缝几何形态的演变和注入期间压力变化双对数图得知:裂缝形成初期基本上按径向或椭圆形模式展开,而后受上、下隔层的阻挡,净压力上升,裂缝穿过隔层后,缝高增长较快,曲线斜率为 0,净压力值稳定。裂缝形成后期,曲线斜率小于 1/4,裂缝按类似的楔形模型。裂缝形成时,4 口井均受不同程度的高压隔层阻挡,形成缝高均穿过射孔井段的夹层,造缝高度较大。

(2) 压开程度评价:根据 6 口井压裂井温曲线的成果分析,平均压开程度 74.2%,超过经全国压裂专家评审通过的吐哈鄯善油田压裂整体改造方案中压

开剖面 70 % 的标准。从井温所测缝高与相应射孔厚度统计分析,有 40.6 % 的非气层被压开,单位排量压开缝高 15.9 m。

(3) 污染程度评价:根据压前压后测恢复的 5 口井的解释成果分析,有效渗透率均有提高,其倍数 4.6 ~ 9.0,表皮系数除文 23—3 井增加 0.11 外,其余 4 口井均降低,降低幅度 1.65 ~ 16.7。在压裂液返排方面,液体的返排率反映压裂液污染性能。返排率 76.8 % ~ 100 %,13 口井中有 10 口井自喷排液,有 3 口井利用液氮助排诱喷自喷。说明应用这种低伤害压裂液返排时间短,返排效率高,因而对气层污染较小。

(4) 裂缝几何尺寸及方位评价:在文 23 气田整体改造实施中,对 6 口井压后测了压力降落曲线,对 4 口井进行了压降解释。在文 23 气田压裂施工中,采用测微地震方法,监测裂缝延伸方位和长度 5 口井,主块的裂缝方位是东南至西北方向延伸,基本对称,东南在 109 度和 147 度之间,西北在 262 度和 292 度。

通过对解释成果的综合分析,计算的动态缝长和监测的动态缝长,相差较大,如文 23 井,压降解释动态缝长 113.2 m,监测动态缝长 166.8 m,主要是监测裂缝所测长度是压开各射孔层段中延伸最远的缝长,而压降曲线解释的动态缝长是压开射孔层段的平均缝长。

闭合压力反映压裂地层的整体性质,文 23 气田平均闭合压力为 32.5 MPa,4 口井闭合压力接近,说明性质稳定,属一个压力系统。根据闭合压力及砂比确定裂缝导流能力为 $128.2 \mu\text{m}^2 \cdot \text{cm}$,压降解释的支撑缝宽平均 3.2 mm,因而裂缝渗透率可达 $400 \mu\text{m}^2$,说明支撑剂完全适合文 23 气田压裂要求。文 23 气田压裂改造同用一种 GRA 胍胶压裂液,性能相同,但由于每口井储层性能不同,所求得的滤失系数也各不相同。综合滤失系数平均为 $6.88 \times 10^{-4} \text{ m} / \text{min}^{1/2}$,液体效率平均 43.1 %,渗滤到地层中的压裂液量最高只有 23 %,说明压裂液降滤性能好,污染影响小。

2. 地质效果评价

文 23 气田整体改造的 13 口井,平均单井日增气量 $34\,494 \text{ m}^3$,采气指数均增加,增产倍数平均 11.3 倍,有效率 100 %。由于文 23—1 地层出砂、井底沉砂和地面工程问题,井口气产量下降,其余井气产量均增加。

(1) 生产压差下降,采气指数提高:从 9 口井压

前压后测压资料分析,压前平均生产压差 8.02 MPa,其中主块 7 口井平均压差 5.23 MPa,边块 2 口井平均生产压差 17.76 MPa;压后 9 口井平均生产压差 2.15 MPa,下降 5.87 MPa,主块平均生产压差 2.15 MPa,下降 3.08 MPa,边块平均 2.16 MPa,下降 15.6 MPa。压前 9 口井平均采气指数 $11\,970 \text{ m}^3 / \text{d} \cdot \text{MPa}$,压后平均 $42\,080 \text{ m}^3 / \text{d} \cdot \text{MPa}$,提高 30 110 $\text{m}^3 / \text{d} \cdot \text{MPa}$,其中主块平均增产倍数 5.4 倍,边块平均 28.9 倍。压前主块压差小,污染小,压后增产倍数低,而边块生产压差大,污染重,增产倍数高。主块以改造气层为主,边块既改造了气层又解除了气层严重的污染。

(2) 产气剖面评价:通过对产气剖面资料的分析,压后主产层一定是压开层,而且厚度小,产气量高,如文 23 井,主产层 13.6 m 占总射开厚度 13.3 %,但承担了全井气量的 92.7 %,日产气 $94\,906 \text{ m}^3$;压前次产层压后可以高产,如文 23 井 29 号层采气强度最高可达 $12\,489 \text{ m}^3 / \text{d} \cdot \text{m}$,压前不产层压后不产或次产。但压前主产的层压后却出现次产甚至不产,这些层压前出力大,亏空严重,本次整体改造没有作为压裂对象,采用先投球暂堵,这些层基本都是微压开,返排能力差,气层容易污染,加之压开层压力较高,合采时层间干扰,由于压差不同,原主产层成为次产或不产层,随着生产状况改变,不产层会恢复到压前状态。

3. 经济效益评价

整体改造 13 口井共投入压裂、作业、监测费用 1 550 万元,截至 2000 年 2 月已增产气 $32\,118.252\,6 \times 10^4 \text{ m}^3$ 。气价按 0.7 元/ m^3 计算,增产的气量已实现产值 2.2 亿元,也就是说整体改造的资金投入不但已经全部回收,而且已经产生了显著的效益。

认识与建议

(1) 压力系数 0.67 以上的气井可以进行压裂改造,压力系数越高效果越好。

(2) 对于文 23 块这样的低渗高污染气藏,压裂既能解除污染又能提高地层的导流能力;压裂不但增加了单井气产量,也加快了采气速度,提高了采收率。

(3) 整体改造采用的低伤害改性胍胶有机硼冻胶压裂液水化彻底,返排率高,污染小;低密度中强度宜兴烧结陶粒保证了气井的大幅度增产和延长有效期对导流能力的需要。

(4) 井温测试、动态监测、裂缝方位监测、压降

欠平衡泡沫流体钻井工艺技术

方敏** 李家龙

(四川石油管理局川西南矿区)

何 纶

(四川石油管理局工程技术部)

方敏等. 欠平衡泡沫流体钻井工艺技术. 天然气工业, 2001; 21(1): 72~74

摘 要 欠平衡钻井由于有利于发现和保护油气层、提高钻速、降低成本, 减少井漏及压差卡钻等复杂情况, 而受到人们的高度重视。在已知的三种欠平衡钻井流体中, 泡沫流体由于比空气钻井更安全, 比雾化钻井液或纯气体钻井所需的设备功率更低, 净化井眼能力更强, 因而越来越广泛地应用于欠平衡钻井中。利用泡沫流体进行欠平衡钻井, 是一种较安全的钻井技术。文章介绍了泡沫流体的组成、性能、特点及作用, 分析了泡沫流体钻井中常见问题并提出了一些建议。

关键词 欠平衡 泡沫钻井 泡沫钻井液 钻井 技术

随着石油勘探技术的进步, 有限的油气资源不断被开发利用, 低压低渗透油气田的勘探开发越来越受到人们的高度重视, 而低压低渗透油气田的勘探开发对油气层的发现与保护提出了更高的要求; 同时随着开采程度的不断加深, 许多原本正常压力的油气田也变成低压油气田, 这些油气田的修井与继续开发同样变成新的难题。由此欠平衡钻井技术随之而不断地得以发展。

泡沫流体的组成与特点

1. 泡沫流体的分类与组成

(1) 硬胶泡沫: 它是气体、粘土、稳定剂和发泡剂配成的稳定性比较强的分散体系。其优点是防塌, 携砂能力特别强。特别适用于易塌、易漏地层。

(2) 稳定泡沫: 它是由气体、液体(纯溶液)、稳定剂和发泡剂配成的分散体系。

2. 泡沫流体的作用与特点

(1) 在低压地层中可以实现负压钻井, 有利于保

护油气层;

(2) 对岩心岩屑污染轻, 有利于分析地层;

(3) 机械钻速高, 钻头使用寿命长;

(4) 可在易漏地层钻进;

(5) 易于在缺水或高寒永冻地区钻井。

泡沫流体的性能

(1) 泡沫质量。它是泡沫流体重要的性能指标, 它决定着泡沫的稳定性与流变性。指在一定的温度、压力下, 单位体积泡沫中所含气体的体积。最佳泡沫质量为 0.98~0.75 或含液量 2%~25%。

(2) 泡沫的稳定性。它是指泡沫的弹性与持久性。常采用以下措施提高泡沫的稳定性: 降低表面张力; 达到平衡表面张力的适当速度; 增加泡沫膜表面活性剂浓度; 提高液相粘度; 泡沫液膜两边有电排力。前两种是提高泡沫的弹性, 即机械振动下泡沫的修复能力, 后两种是提高泡沫持久性。

(3) 泡沫流体的流变性。大量的研究表明, 当泡沫

测试、产气剖面测试等监测技术的应用, 为正确评价压裂效果和今后重复压裂提供了重要的依据。

(5) 对于地层压力较低的井压裂时应尽量提高施工砂比; 对于夹层、隔层较多、井段较长的井, 施工排量和压裂液粘度可适当降低, 尤其边块含水井压裂。

(6) 为了动用目前的次产和不产层, 下步应进行重复压裂改造, 同时, 可考虑部分调整井, 根据 RFT 资料选择高压层分层射孔, 逐层压裂投产。

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* 方敏, 女, 1972年生; 1995年毕业于西南石油学院油田化学专业, 一直从事钻井液工作。地址: (643000) 四川省自贡市毛家坝。电话: (0813) 4611384。

lithofacies database statistical mode, an automatic layer separation may be realized by use of extremum variance clustering procedure and the oolitic beach layers in a single well profile can be recognized by grey association analysis method. In addition, in combination with the reservoir petrophysical parameter interpretation, a model of logging identification on oolitic beach reservoirs was set up and relevant processing program was composed. Through applying it is shown that this method is of high resolution, by which the oolitic beach reservoirs with a thickness of over 0.5m in a single well profile can be recognized, thus raising the vertical and transversal prediction accuracies of the oolitic beach reservoirs.

SUBJECT HEADINGS: Sichuan Basin, East, Carbonate rock, Coide, Reservoir, Log interpretation

Xia Hongquan (lecturer), born in 1965, graduated from the Southwest Petroleum Institute and received his Doctor's degree in oil and gas development engineering in 1997. Now he is engaged in the teaching and scientific research on applied geophysics. Add: Nanchong, Sichuan (637001), China Tel: (0817) 2603433 - 3427 (2828)

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ANALYSIS OF SOME PROBLEMS IN CASING CALCULATION BY FINITE ELEMENT METHOD

Zhang Xiaoyu (Ching Petroleum Planning Institute). *NATURAL GAS IND.* v. 21, no. 1, pp. 62 ~ 65, 1/25/2001. (ISSN 1000 - 0976; **In Chinese**)

ABSTRACT: In this paper, some easy-to-be-ignored problems in casing calculation by finite element method, such as the influence of the factors of load-carrying step length, unit division and heterogeneity, etc., on the calculation results, are systematically discussed. The analysis results show that the load-carrying step length has an important influence on the calculation results, especially, after having entered into the plastic stage, the insufficiently precise step length will lead to wrong results; Because the casing form is relatively simple, the influence of the unit division on the calculation results is easy to be ignored. In fact, even for the stress calculation of the most simple plane problem, the unit quantity should not be too few, especially, for the casing deformation calculation, only one unit divided along the wall thickness direction is not enough and the influence of heterogeneous load on casing damage is very great, which are reflected in two aspects as follows: When the heterogeneity of load increases, the maximum load the casing bear will rapidly decrease and under the action of heterogeneous load and after a certain local yield appears on the casing, even the load does not increase any more, the casing deformation capacity will still continuously increase. These analyses and conclusions not only clarify some problems existed over a long period of time in the casing calculation by finite element method, but also make us have a new knowledge of the mechanism of casing deformation.

SUBJECT HEADINGS: Well cementing, Casing failure, Casing deformation, Finite element method, Load (force), Analysis

The author's introduction: See v. 19, no. 2, 1999. Add: No.

3, West Zhixin Road, Haidian District, Beijing (100083) Tel: (010) 62323366 - 2380

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A STUDY OF DOWNHOLE DEVICE FOR INCREASING FLOW OF ITSELF BY HYDRAULIC PRESSURE

Xiong Jiyou, Wang Xiyong, Yuan Qiji, Yang Hai and Sun Wentao (Southwest Petroleum Institute). *NATURAL GAS IND.* v. 21, no. 1, pp. 66 ~ 68, 1/25/2001. (ISSN 1000 - 0976; **In Chinese**)

ABSTRACT: In the operation of petroleum project, how to effectively convey the hydraulic energy into downhole and how to fully utilize the bottom hole energy is a subject the people have studied for a long time. In order to effectively utilize the hydraulic energy due to bottom hole fluid column pressure, a downhole device for increasing flow of itself by hydraulic pressure is specially designed and its resonant cavity structure parameters, the efflux parameters, the position and quantity of the self-increasing flow taps and the resonant conditions are analyzed and tested, which show that under the submerged experiment condition, the self-increasing flow of the device can reach to 30% and the position and quantity of the taps on the resonant cavity and the taps on the resonant cavity and the efflux energy are the key parameters. Two important characteristics of the device are as follows: The flow can increase of itself and an oscillating pulse efflux can form and the downhole hydraulic energy can be effectively utilized. The structure of the device is simple and it has no moving component and its principle can be applied to the research and development of other downhole tools.

SUBJECT HEADINGS: Petroleum Engineering, Downhole, Hydraulic energy, Utilization, Self-increasing flow, Device design, Resonant cavity, Experimental study

Xiong Jiyou (research fellow) was born in 1951, and he has been engaged in the scientific research work. Add: Nanchong, Sichuan (637001), China Tel: (0817) 2603433

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A STUDY OF OVERALL FRACTURING REFORMATION OF WEN-23 GAS FIELD AND ITS EFFECT EVALUATION

Wu Yahong (University of Petroleum (Beijing)), Lin Tao, Chi Shengping and Li Jianping (Special Downhole Operation Service of Chongyuan Petroleum Exploration Bureau). *NATURAL GAS IND.* v. 21, no. 1, pp. 69 ~ 72, 1/25/2001. (ISSN 1000 - 0976; **In Chinese**)

ABSTRACT: Through the research and application of overall fracturing reformation of Wen-23 gas field for three years, an obvious geological effect and economic benefits have been obtained, forming a complete technique suitable for fracturing the massive gas reservoirs of

Zhongyuan oil field. In the lights of the overall reformation plan for Wen-23 gas field and the present producing situation of the field ,the study of the technique necessary for overall reformation was carried out and the technique was successfully applied to the overall fracturing reformation. In this paper ,the effect after fracturing is evaluated from technology and geology to economic benefits and the direction of the work in the next stage is put forward.

SUBJECT HEADINGS: Wen-23 gas field ,Overall fracturing ,Acidizing ,Technical reformation ,Economic evaluation

Wu Yahong(*senior engineer*) , born in 1966 ,graduated in well logging from Jianhan Petroleum Institute in 1989. She received her Master s degree in sedimentology at Northwest University in 1998. Now she is studying for Doctor s degree at University of Petroleum(Beijing) ,being mainly engaged in the research on the management and administration of oil production test ,the selection of the wells and horizons to be fractured and downhole geology. Add :Liutun ,Puyang ,Henan(457061) ,China Tel : (0393)4875313

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TECHNIQUE AND TECHNOLOGY FOR UNDER BALANCE PRESSURE DRILLING WITH FOAM FLUID

Fang Min and Li Jialong (South Sichuan Mining District ,Sichuan Petroleum Administration) and Helun (Engineering and Technique Department of Sichuan Petroleum Administration). *NA TURAL GAS IND. v. 21 , no. 1 , pp. 72 ~ 74 , 1/25/2001. (ISSN 1000 - 0976 ; In Chinese)*

ABSTRACT:Under balance drilling is paid great attention to by people for it is favourable for discovering and protecting oil and gas reservoirs ,raising drilling speed ,reducing cost and lessening drilling lost circulation and differential pressure sticking. Among the known three kinds of under balance drilling fluids ,the foam fluid is more and more widely used for under balance drilling. Use of foam fluid for under balance drilling is a relatively safe drilling technique. In this paper ,the composition ,property ,characteristics and function of the foam fluid are presented ,the common problems in foam fluid drilling are analyzed and some proposals are put forward.

SUBJECT HEADINGS: Under balance , Foam drilling , Foam drilling fluid ,Drilling ,Technique

Fang Min (*female*) , born in 1972 ,graduated in oil field chemistry from Southwest Petroleum Institute in 1995. She has been engaged in the work on drilling fluid all along. Add :Maojiba ,Zigong ,Sichuan (643000) ,China Tel : (0813)4611384

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RESEARCH AND APPLICATION OF CEMENTING TECHNOLOGY FOR COAL BED GAS WELLS

Qi Fengzhong and Liu Aiping (Well Completion Department ,Langfang Branch of Research Institute

of Petroleum Exploration and Development). *NA TURAL GAS IND. v. 21 ,no. 1 ,pp. 75 ~ 78 ,1/25/2001. (ISSN 1000 - 0976 ; In Chinese)*

ABSTRACT:China is very rich in coal bed gas resource , but its development and utilization is still in the initial stage. As compared with the conventional oil- and gas-bearing beds ,coal bed has a shallow buried depth ,well-developed micropores and fractures and low mechanical strength and porosity ,so it is easy to collapse and easy to be polluted. In this paper ,based on the characteristics of coal bed gas well ,the difference between the cementing of common oil and gas wells and that of coal bed gas wells and the characteristics and difficulties of coal bed gas well cementing are presented ,the main problems existed in coal bed gas well cementing are summarized and the cementing technology and additives suitable to the characteristics of coal bed are proposed. Above-mentioned technology was adopted in the three wells in Jincheng area ,Shanxi Province ,obtaining an all-excellent cementing quality and solving the problem of poor cementing quality in this area on the main. The problems to be solved in the coal bed well cementing at present are discussed also in this paper.

SUBJECT HEADINGS: Coal bed , Coal-formed gas , Well cementing ,Light weight cement ,Cement additive

Qi Fengzhong(*engineer*) , born in 1971 ,graduated in applied chemistry from Southwest Petroleum Institute in 1994. Now he is engaged in the research ,application and development of well completion fluid. Add : P. O. BOX 44 , Wangzhuang , Hebei(065007) ,China Tel : (0316)6012801 - 3305

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A STUDY OF ACIDIZING AND FRACTURING TECHNOLOGY FOR HETIANHE GAS FIELD IN TALIMU BASIN

Wang Baofeng ,Jiang Weidong ,Hu En an ,Ding Yunhong and Zou Honglan (Fracturing and Acidizing Technical Service Center of Langfang Branch of Research Institute of Petroleum Exploration and Development) . *NA TURAL GAS IND. v. 21 ,no. 1 ,pp. 79 ~ 81 ,1/25/2001. (ISSN 1000 - 0976 ; In Chinese)*

ABSTRACT:On the basis of analyzing the capacity of fluids through porous media ,the damaged degree and the developed state of the natural fractures of Carboniferous and Ordovician carbonate reservoirs in Hetianhe gas field in Talimu basin and in view of the ability of existing acidizing technology and acidizing fluid system at home ,the depth acidizing technology suitable for this gas field is optimized and the conventional acid-etched conductivity test ,the test of the acid-etched conductivity in closed fractures ,the influence of closure on acid-etched conductivity ,the influence of flow rate on the effective acid-etching action radius and on the distribution of acid fluid concentration ,the optimal design for acidizing of sandstone ,the optimization of operating parameters and the prediction and analysis of the acidizing treatment effect in Hetianhe gas field ,etc. are studied.

SUBJECT HEADINGS: Talimu basin ,Hetianhe gas field ,