油气井筒相态分异特征识别及处理

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摘要 在油气田生产井测试时, 关井早期压力和温度曲线由于受井筒相态分异的影响, 出现所谓的“驼峰”效应。油井出现相态反映时,“驼峰”特征多反映在压力恢复曲线上; 气井出现相态反映时,“驼峰”效应特征多反映在温度曲线上。在实际试井解释工作中, 常因认识不清这两类相态分异的明显特征而影响解释结果。在分析油、气井相态分异不同特征的基础上, 归纳和总结出相应的识别方法。提出的合理测试施工解决方案, 可消除“驼峰”给测试解释带来的不利影响。

关键词 井筒相态 生产井测试 “驼峰”效应 相态分异

0 引 言

在油田生产测试时, 油井(以油为例) 多要经过一段时间的流动生产之后, 地面关井进行压力恢复测试。关井之后井筒中的混合流体伴随着流动生产过程中不断析出气体的膨胀而形成“驼峰” 效应, 随着关井恢复压力的升高, 井筒中析出的膨胀气体又逐渐被压缩转回到油流中, 成为单相流体。

国外某油田处于开发阶段的生产测试井较多, 常常见到关井早期出现“驼峰” 现象的试井资料, 采用一般的试井解释方法难以得出较为理想的模型拟合及参数结果。本文在分析油、气井相态分异不同特征的基础上, 归纳出相应的识别方法。对此类生产测试井提出相应的合理测试施工解决方案, 进而消除了“驼峰”给测试解释带来的不利影响。

1 油、气井筒相态分异特征及识别

一般油井或气井(干气) 测试(包括生产测试) 时, 经流动生产测试后某一时刻起; 无论采用地面或井下关井测试工艺, 一旦实施关井操作后, 一般压力恢复曲线呈上升趋势, 过渡“拐平” 直至可能达到目前测试地层的最大压力; 而温度曲线则呈下降趋势, 直至可能达到目前测试地层的最高地层静温。图 1 为一典型生产井流动和关井测试时, 具有“驼峰” 效应时的压力和温度曲线图。

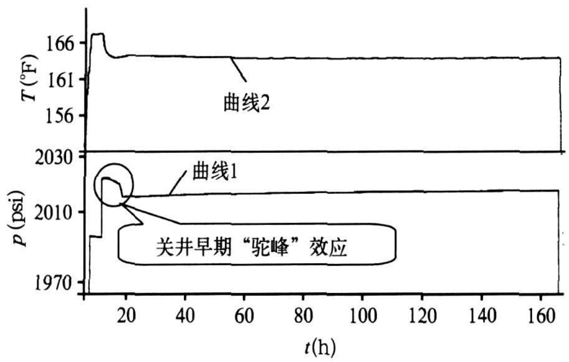

图1 X1井关井压力恢复和温度曲线图

1.1 油井井筒相态分异特征及识别

1.1.1 油井井筒相态分异特征

一般油井相态分异易发生在压力恢复曲线过渡阶段的早期。图 1 中曲线 1 表明,“驼峰” 效应已出现在压力恢复的早期阶段; 而温度曲线仍呈下降趋势, 如图 1 中的曲线 2 所示。

1.1.2 出现井筒相态分异时测试工艺条件

在生产测试井中的施工条件比较简单, 一般为地面井口控制开关井, 生产油管携带或不携带封隔器下至油层附近, 钢缆携存储式电子压力计和加重杆经井口防喷管、油管下至测试层附近。除以上施工条件外, 流动测试过程中, 大油嘴生产比较多见; 致使生产气油比短时间内剧增, 井筒和接近井底的流体中析出气体增多而呈多相流态, 反映在关井压力恢复早期阶段而出现“驼峰” 效应, 此时井底流动

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压力低于或与饱和压力比较接近。当地面关井后, 压力恢复早期阶段出现的“驼峰”效应会随着地面关井后井筒恢复压力的逐渐升高至某一时刻时“驼峰”消失; 即从井筒多相流体中膨胀析出的气体又被压缩而回到了单相流体油中(见图 1 中“驼峰”效应后的压力恢复曲线)。

1.1.3　油井井筒相态分异对试井解释影响

图2、图 3 为某油井受“驼峰”影响压力恢复曲线的双对数及其导数分析图和半对数分析图。尽管压力的双对数曲线能与理论模型曲线相拟合, 但由于“驼峰”段压力的急剧变化, 其实测点压力的导数计算值为零。故“驼峰”阶段理论的压力导数曲线与实测点无数据可拟合, 且理论的导数曲线至“驼峰”结束后而不再向前延伸。在半对数分析图上的“驼峰”效应影响更大, 除理论模型与实测曲线难以拟合外, 更难以确定的是径向流直线段的起始点位置(假定为一均质油藏模型), 故也不能采用半对数分析方法计算地层参数。显然, “驼峰”给油藏模型的拟合及其地层参数的计算等带来了许多不确定因素。

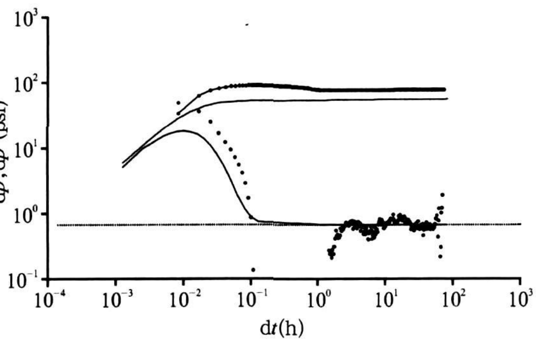

图2　X2井关井曲线的压力双对数及其导数分析图

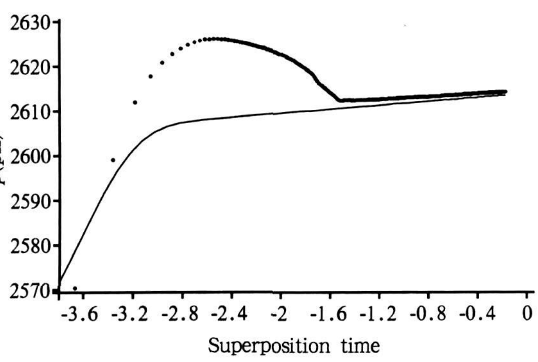

图3　X2井关井曲线的压力半对数分析图

1.2　气井井筒相态分异特征及识别

1.2.1　气井井筒相态分异特征

气井井筒相态分异特征一般在温度曲线上反映较为明显, 且与气体组份、温度和压力等密切相关, 多发生在地层产凝析气和湿气情形。气井井筒相态分异特征出现时, 在关井压力恢复的早期阶段, 压力恢复曲线呈正常的上升趋势; 而温度曲线则出现“驼峰”过后呈缓慢上升趋势(见图 4 中的曲线 1), 此时的井底流动压力与露点压力比较接近。除关井阶段温度曲线上出现“驼峰”外, 关井前流动末期温度曲线呈下降趋势(见图 5 中的曲线 1)。这两个阶段出现的温度变化, 恰好反映了气体吸、放热的复杂的物理变化过程。

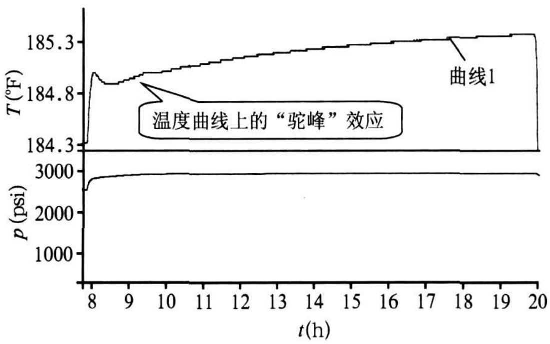

图4　X3井关井压力恢复和温度曲线图

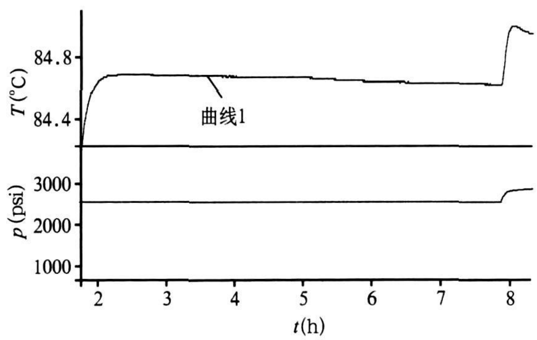

图5　X3井开井流动压力和温度曲线图

1.2.2　出现井筒相态分异时测试工艺条件

气井生产测试采用的工艺条件与油井差不多, 同样是地面井口控制开关井, 流动测试过程中, 生产气油比急剧变化, 使得井筒或接近井底的气体中析出的凝析液增多而呈多相流态, 由于凝析液析出过程中热能量交换的缘故, 温度曲线呈下降趋势。当地面关井后, 随着井筒恢复压力的逐渐升高和流体的流速降至零, 热能量交换速度也逐渐加剧, 便在温度曲线上出现“驼峰”效应, 当热能量交换速度降至某一时刻起, 温度曲线上的“驼峰”消失; 即气体中析出的凝析液(包括析出的少量水)又反转成为单相的凝析气。

1.2.3 气井井筒相态分异对试井解释影响

虽然气井的“驼峰”效应反映在温度曲线上，而在直观的关井压力恢复曲线上并无明显的特征反映，但凝析和反凝析的整个过程却隐含在关井恢复压力及其导数双对数曲线上(见图6)。

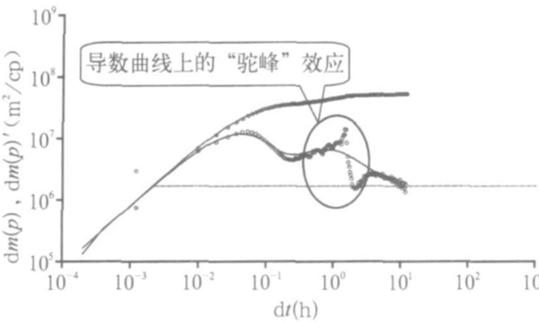

图6 X3井关井恢复压力及其导数双对数分析图

2 处理油气井井筒相态分异的方法

无论是油井和气井，若能改变测试工艺条件，即采用可控的井下开关井操作工具，注重流动生产测试过程，恰当的预选择合适的油嘴计量，控制生产气油比的快速增长，除凝析气或湿气井外，已能防止多数井筒相态分异的出现，消除其给试井解释带来的不利影响。考虑到实际生产测试阶段的测试成本，现场实际生产测试阶段已无提升操作井下开关井工具的钻机或修井机可用，即生产测试阶段均采用较为简单的地面井口控制开关井操作工艺，这就意味着井筒相态分异出现的可能性增大。

2.1 油井井筒相态分异的处理方法

针对实际生产情况，分析认为，一般井筒相态分异多发生在经过较长时间(一般十几个小时、几天或更长)的流动测试、地面关井之后压力恢复的1~2 h期间。若能考虑在流动测试期间，主关井压力恢复期之前，在液垫充分排尽和生产气油比较小的情况下，提前关井测2~3 h的压力恢复，用以替代主关井压力恢复期“驼峰”效应阶段的压力数据。因“驼峰”效应仅反映井筒内相态分异、流体再分布的变化，而受其干扰之后的压力恢复数据仍能真实的代表地层特性。基于此设想，建议现场调整生产测试施工方案，即在二次开井流动和主关井期的压力恢复测试前，预先进行一次2~3 h的初关井压力恢复测试。这一做法在实际试井解释工作中取得了满意的结果。

2.2 油井井筒相态分异解释实例

某油田生产测试的关井压力恢复和温度曲线如图7所示。

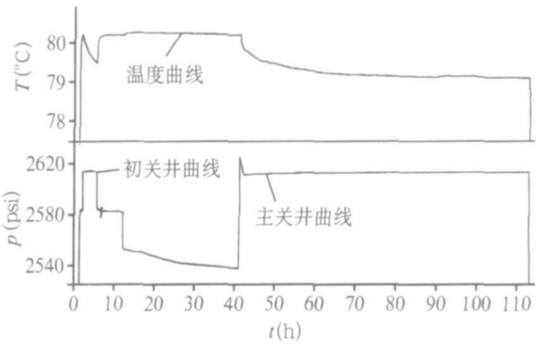

图7 X2井压力和温度曲线图

在开井流动测试过程中，生产井测试工具下至井底测取了一段时间的井底流压曲线后，先进行了3个多小时的初关井压力恢复测试，随后又进行了二次开井流动和主关井期(二次关井)的压力恢复测试。

若采用叠加分析方法处理主关井恢复期的压力数据，其拟合分析结果如图2和图3所示。“驼峰”效应对试井解释结果的影响非常严重。

用初关井早期压力恢复数据替代主关井恢复期“驼峰”效应段压力数据的具体做法是：首先应计算出从主关井压力恢复期的起始点至“驼峰”效应结束点的相应时间，再计算出初关井期相应阶段的时间步长(两个关井恢复段具有相同的采样点间隔)，要求每一点的时间步长尽可能均匀、准确。对压力数据除要求与时间步长一一对应外，不能有任意的更改和变动。然后，将其逐个点的时间—压力数据替代主关井压力恢复期“驼峰”效应段的压力数据，进行模型拟合，结果如图8、图9所示。

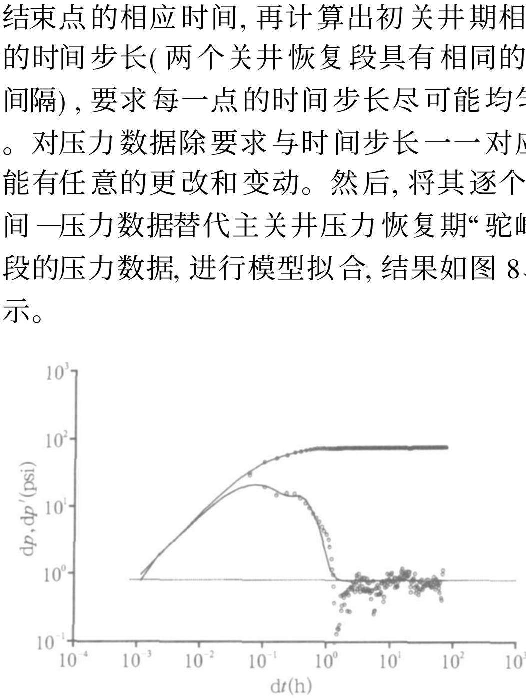

图8 X2井关井恢复压力及其导数双对数分析图

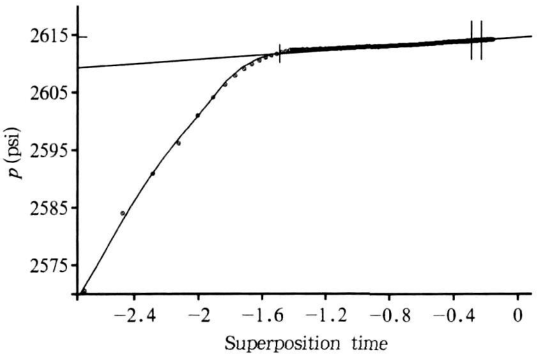

图9　X2井关井恢复压力半对数分析图

由上图不难看出, 用“替代”后的恢复压力数据所做出的压力及其导数双对数图和压力半对数分析图中, 除早期压力数据点的差异外,“驼峰”影响前后的压力数据点连续, 且“驼峰”影响后的压力导数曲线形态与“替代”前的特征完全一致。即用初关井压力数据替代主关井期“驼峰”效应段压力数据的方法能完全、真实的反映地层压力特性。采用此方法, 不仅消除了“驼峰”对压力及其导数双对数曲线和半对数曲线的拟合影响问题、地层参数的计算问题, 还可将初关井和主关井恢复期得到的目前地层压力进行比较, 用于检测地层压力特性的变化等。

2.3　气井井筒相态分异的处理方法

气井的流体性质相对于油井更为复杂一些(特别是凝析气和湿气)。一般若采用井下开关井操作工具, 即可阻止井筒相态分异的出现。

第一个实例是操作井下开关井工具测得的压力和温度曲线图(凝析气层), 以及关井恢复压力及其导数双对数分析图(见图 10、图 11)。图 10 温度曲线表明, 虽然流动测试过程中温度曲线呈下降趋势, 但关井后温度曲线近似于关井曲线般上升却无“驼峰”效应出现; 图 11 关井恢复压力及其导数双对数曲线上也未见“隐含” 的井筒相态分异特征反映。

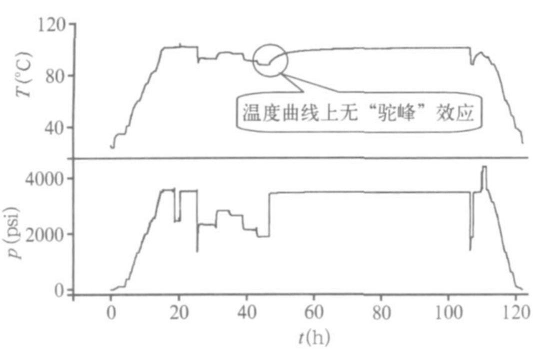

图10　X4井压力和温度曲线图

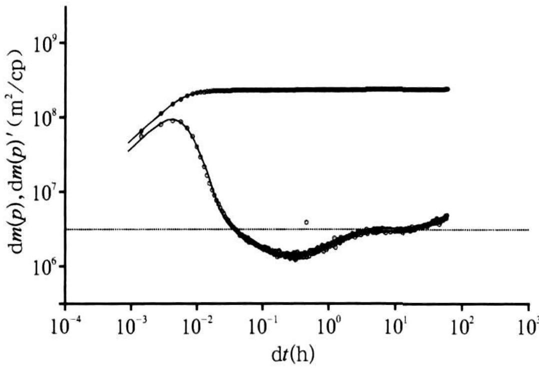

图11　X4井关井压力及其导数双对数分析图

第二个实例是地面开关井测得的压力和温度曲线图(凝析气层), 以及关井恢复压力及其导数双对数分析图(见图 12、图 13)。图 12 温度曲线表明, 流动测试过程中, 温度曲线总体呈下降趋势, 但关井后温度曲线上却有明显的“驼峰”效应出现。而在图 13 中关井恢复压力及其导数双对数曲线上也出现了所“隐含”的井筒相态分异特征反映。

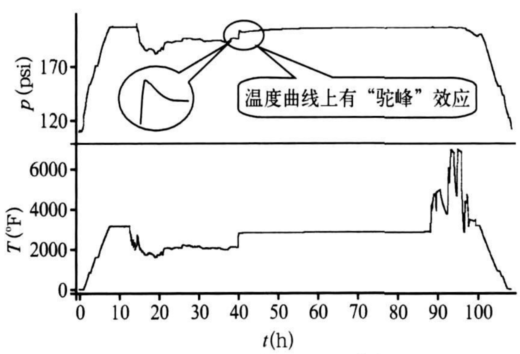

图12　X5井井底压力和温度曲线图

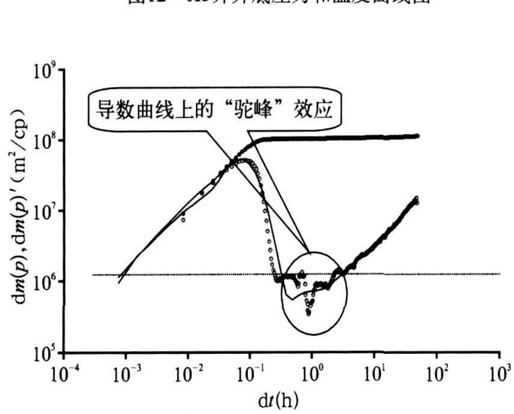

图13　X5井关井恢复压力及其导数双对数分析图

3　认识与结论

(1) 在生产测试井中, 为了克服油井相态分异带来的诸多解释问题, 可在二次开井流动和主关井期的压力恢复测试前, 预先进行一次 2~ 3 h 的初关井

压力恢复,即可用初关井早期压力数据替代主关井期"驼峰"效应段压力数据的方法。采用该方法得到的解释结果能完全、真实的反映地层压力特性,消除"驼峰"效应给试井解释带来的不利影响。

(2)一般气井井筒相态分异出现时,关井之前流温曲线呈下降趋势,关井后静温曲线早期出现所谓"驼峰"效应后呈上升趋势。

(3)气井出现井筒相态分异与油井有所不同,其"驼峰"效应除主要反映在温度曲线上外,多数则"隐含"在关井恢复压力及其导数双对数曲线上。应在前期生产的流动测试中加以控制,以及在后期的试井解释和识别当中认真分析。能否采用像油井那样的"压力数据替代"方法,还有待进一步加以实践。

(4)为防止出现井筒相态分异现象,尤其在生产测试时,若不能采用井下开关井工具,要求试油管柱尽可能携带封隔器入井,以减少井筒流体置换空间。压力计尽可能下至油层中部。在流动测试中应控制生产气油比的快速增加,以避免出现井筒相态分异和预防现场不安全隐患发生。

(5)一般对油井出现相态分异的特征较容易辨别,但现场测试工艺却不易控制,尤其是在无井下开关井工具可用时的生产测试井中。本文推荐的识别和处理方法,为改进生产测试工艺和处理试井解释难题开阔了新的思路。

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Literatures since the late 50 generations of 20th century about the string buckling of the oil and gas well are searched systematically. Based on analysis and study on these, string buckling area of the latest research result and application is introduced from the aspects of bending, buckling, post-buckling equilibrium, etc, and the focus of future development is directed.
Key words: string, buckling, normal contact force, look forward to

• Evaluation & Application •

Feature Identification for Phase Differentiation of Oil and Gas Wellbore and Its Treatment. 2011, 20(2): 20~24

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During well testing process for production well of oil and gas field, due to the effect of Phase Differentiation of wellbore on pressure and temperature curve at early shut-in time, a so-called "hump" effect is appeared. The "hump" feature is always reflected in the pressure recovery curve when oil well appears phase reflection, and it is reflected in the temperature curve when gas well appears phase reflection, In actual work of well testing interpretation, that of unclear this two obvious features of phase variation affects the interpretation results. By analyzing the oil, gas phase state of differentiation of characteristics, the corresponding identification method is induced and summarized, a reasonable test solution is proposed. The program can eliminate adverse effects of the "hump" on test interpretation.
Key words: wellbore phase, production well test, "hump" effect, differentiation phase

According to CBM Wells Fracturing Pressure Curve to Determine the Crack Distribution and Effects of Method of Gas Production. 2011, 20(2): 25~29

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According to statistics on operation curves from more than 200 fractured wells at Jincheng area, by sorting, classification, discrimination and combined with the results of ground test, the different types of curves corresponding to fracture the coal seam distribution case are worked out. Different artificial Crack extension of the standard curve of the typical distribution, which can distinguish fracturing effect, is developed. By using monitoring curve shape of fracturing and flowing and gas production situation after fracture, fracturing effect after fractured is analyzed and evaluated. The method is verified by more than 100 wells, and compliance rate is more than 70%.
Key words: fractured curve, coal bed methane well, crack distribution, gas production result, method, research

Characteristics of Safety Parameter Affecting the Down Hole Testing String and Study on Safety Evaluated Method. 2011, 20(2): 30~34

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The main factors to influence on safety of testing string and ground pipeline are axial deformation, axial force distribution and intensity and the main factors of affecting those deformation are inner and external fluid pressure, temperature, flowing resistance and formation pressure and an important factor of impacting strength of the testing stem and the ground pipe is corrosion. Complex mechanical analysis of Well testing string has been done that has an important sense for study of corrosion mechanism and the safety.
Key words: test string, security, parameter, evaluation, corrosion

Interpretation of the Pressure Monitor and Its Actual Example Analysis Case Study. 2011, 20(2): 35~37

Zhao Ming, Liu Li, Liu Wei, Cao Yuxin (Test Oil Testing Company, Jilin Oilfield)

According to monitoring data collected through swabbing by the hydraulic pump and pressure gauge in oil testing, by interpreting and analyzing from the monitoring pressure interpretation software (Topaze software), the relevant reservoir parameters, including the formation pressure and temperature, the flow coefficient of the reservoir, formation factor, effective Permeability, fracture half-length after fracturing and cracking of skin factor, are gained. Through analysis for field examples, the practical knowledge is illustrated and conclusions and recommendations related to the production are presented.
Key words: pressure monitoring, interpretation analysis, reservoir parameter

Research on Measuring and Adjusting Tech by up Pressure and Its Application. 2011, 20(2): 38~40

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To problems of pressure dropping at the first time and then rising when measuring and adjusting by down pressure to affect stability time, reduce transfer efficiency and shorten validity of data, the main factor influencing its effect is analyzed. By comparison of field test result between using pressure step-up method and step-down method, it shows that validity of applied data in the low permeability oilfield of measuring and adjusting tech by up pressure has been extended.
Key words: pressure step-up method, measuring and adjustment, influence factors, low permeability oilfield, applied result