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RESEARCH PAPER

Gas-water phase flow production stratified logging technology of coalbed methane wells

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Abstract: On the basis of the previous development of cumulative gas flow meter, a set of integrated coalbed methane (CBM) well production test instrument is developed and applied in field to solve the problem of gas-water phase flow production stratified logging test. This instrument uses a cumulative gas flow meter to test stratified gas production, which can be flexibly converted into a capacitive water holdup meter underground to obtain water holdup. Fluid flow rate can be measured by the converted capacitive water holdup meter combined with a gamma tracer flow meter, and hence stratified water production can be calculated. The instrument meets the gas and water production synchronous measurement and integrated miniaturization. A dynamic seal pressure balancing technology is applied to solve the unbalance between internal and external forces of pressure cylinder when down-hole piston is open in the well. The use of novel releasable guide cone to replace the squirrel cage guide cone effectively solved the difficult problem of the instrument entering the CBM well. With a diameter of only 22 mm, the instrument can be run in to the annulus through an eccentric wellhead. In field test the gas and water production of different layers can be obtained using declining method by placing the instrument at different coal seams, to evaluate gas and water production of different layers in commingle production CBM wells. Field application shows that the instrument has the advantages of small size, high measuring precision, short measuring time, and no disruption on well production, etc., and exhibits a broad application prospect in CBM development.

Key words: CBM wells; gas-water phase flow; production stratification logging; instrument miniaturization

Introduction

Because of the particularity of instrument size, measuring range and process, the CBM production stratified logging technology is only limited to indoor experiment[1–2] or used in a small number of CBM wells with 177.8 mm diameter casing[3]. Usually in CBM wells, tubing will be run in production casing to do drainage, making it difficult to test gas and water production by layer at the same time, and there is no mature CBM production test technique available at home and abroad[1–11]. As there is a water pump in the CBM well tubing, the test instrument can only be run through the annular. As most CBM well production casing outer diameter is 139.7 mm (inner diameter is 124.26 mm) and the tubing outer diameter is 73 mm, so the test instrument diameter is limited to less than 25 mm. In addition, often developed by multi-layer fracturing and commingled production, CBM wells feature long-term slow desorption, and low gas production[12–13] (less than 2 000 m^3/d), so the flow meter used in them must be high in precision. At present, the commonly used production profile testing techniques include turbine flow meter test[14–15], electromagnetic flow meter test[14], isotope tracer flow test[16] and ultrasonic flow meter test[17–18]. Packer type turbine flow meter cannot be used for perforation segments[14]. Non packer type turbine flow meter can't meet the accuracy requirements, if meeting the small size requirement. The electromagnetic flow meter is not suitable for the measurement of[14] liquid with large bubbles and single gas phase. The ultrasonic flow meter and isotope tracer flow method can only be used for the measurement of single phase water[14,16]. These methods are not suitable for gas water two-phase flow, therefore, the authors[2] have designed a volumetric gas flow meter and have used it to measure the gas production under the conditions of ambient temperature, atmospheric pressure and gas-water two-phase flow.

Based on the volumetric (cumulative) gas flow meter, a new type of dynamic seal pressure device is designed, so the gas meter can be converted into a capacitance water holdup meter downhole. The capacitance water holdup meter com-

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bined with a gamma ray tracer flow meter, allows water production stratified logging in mixed gas-water phase, which also considers the conversion of gas volume between the conditions of high pressure high temperature downhole and normal pressure normal temperature, and depth correction etc. In this study, the developed CBM gas-water phase flow production stratified logging instrument enables gas and water production test at different coal seams under the condition of multi-coal seam production and gas water two-phase flow. At present, it has been successfully used in many blocks and achieved good results.

1. Instrument integration and function

Only 22 mm in diameter, the CBM well production test combination instrument consists of a transmission joint, a magnetic locator, a pressure and temperature measuring instrument, a gamma tracer instrument, an electric centralizer, a cumulative gas flow meter/water holdup meter and a guide cone (Fig. 1): (1) The transmission joint is mainly used for downhole data acquisition and transmission. (2) The magnetic locator consisting of two polarity opposite coils and steel wires, is used for depth correction. (3) The main components of the pressure and temperature measuring instrument are pressure sensor and temperature sensor, which are used to measure the pressure and temperature at the bottom of the well, to convert the measured production underground to production at ground condition. (4) The gamma tracer composed of a tracer and a gamma instrument, is mainly used to measure the flow velocity of liquid[14]. When measuring, the instrument is placed on the perforation layer, the ground system supplies power to the tracer instrument through cable, to make isotope eject from the injection hole, as the distance between the injection hole and the gamma probe is given, the flow velocity of liquid can be calculated by using the time the isotope reaches the top of gamma probe, and then flow of liquid can be worked out. (5) The electric centralizer is used to improve the testing success rate. (6) The cumulative gas flow meter consisting of a circuit board, pressure cylinder, motor, push-pull rod, gas cylinder, piston and capacitor electrode[2], is used to test gas production. By using a new type of dynamic seal pressure device, the cumulative gas flow meter is converted into a capacitive water holdup meter to measure actual water production. (7) The guide cone located at the bottom of the instrument, is used to send the whole instrument down through annulus. In order to cope with narrow annulus space and complex well conditions in CBM wells, a releasable guide cone has been developed to replace the squirrel cage guide cone.

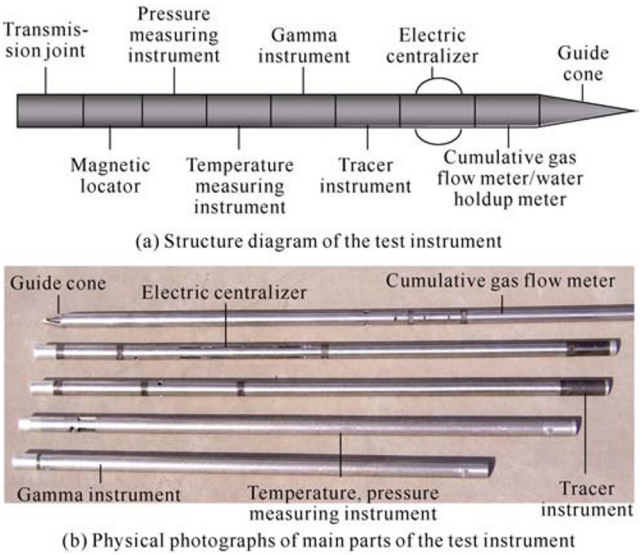

Fig. 1. Structure diagram of CBM well gas-water phase flow production stratified logging instrument.

2. Instrument key technology

2.1. Capacitive water holdup meter

The cumulative gas flow meter is used to test the stratified gas production (Fig. 2a). Gas and water flowing into the gas cylinder will show gravity differentiation because of their density difference, the capacitance sensor is used to detect the capacitance of gas cylinder medium to tell whether the cylinder is filled with gas, and then gas flow rate is calculated by using gas accumulation time and cumulative volume. The gas flow rate at different depths is recorded, and the stratified gas production is calculated by successive subtraction method.

Since the cumulative gas flow meter has a capacitor electrode, if the piston above the gas cylinder is set in the open state (Figs. 2b and 3), the fluid can pass through the gas cylinder freely. By using the existing capacitor electrode components, and based on the characteristic of the linear relationship between capacitive water holdup meter output frequency and the water holdup (the capacitance signal is collected by frequency), the cumulative gas flow meter can be converted into a capacitive water holdup meter. The water holdup is calculated by using the fluid capacitance signal (response frequency) at

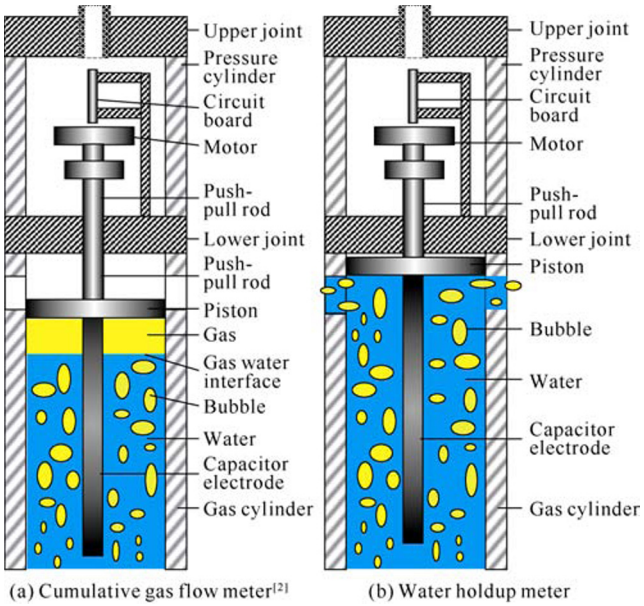

Fig. 2. Schematic diagram of the conversion of cumulative gas flow meter to water holdup meter.