COAL SEAM METHANE - EXPLORATION AND PRODUCTION

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Methane from coal seams is an abundant resource in many parts of the world. Determining how much gas is present, how to get it out and how it will subsequently produce is critical to the economic development of this resource. Once a market is proven to exist the real questions are:

- How much gas is in place?
- What do we do with the water that is also produced?
- What will it cost to produce at the required rate?

The first question may be relatively easily answered while the second one may be insoluble though it may be fairly easy to recognise the difficulties associated with the disposal of salty water. The final question requires a lot of information to be able to answer properly. This information is based upon knowledge of the reservoir properties and production technologies. Gaining adequate reservoir knowledge is critical, as this will decide whether to leave a reservoir alone or to proceed with its development. Reservoir knowledge will also affect the choice of production method.

Coal seams are some of the most complex reservoirs known and the determination of reservoir properties requires a significant amount of test work. Fortunately much of this can be undertaken as part of a properly devised exploration drilling programme. Drilling will in the first instance define the extent, thickness, and number of coal seams. The recovery of core is particularly beneficial in exploration especially where this is expedited by using wireline retrieval techniques.

CORE TESTING

The information that may be gained from the core is:

- Gas content
- Diffusion coefficient
- Strength
- Cleat (fine joints) spacing
- Joint infill material
- Shrinkage

Typically the gas content is obtained by placing the core into a vessel as soon as it comes to surface and by monitoring the gas release with time. Some gas is lost on retrieval of the core and methods exist to estimate this. Gas invariably remains in the core even after an extended test period because of the slowing process of diffusion. The diffusion process is usually expedited by crushing the core so as to release and measure the remaining gas. The diffusive behaviour of gas from the coal to the cleat is important. Two factors influence the rate of diffusion, the diffusion coefficient and the spacing between cleats. In some coals the rate of diffusion will control the gas production. The diffusion coefficient may be approximately calculated by measuring the rate of core desorption, while cleat spacing may be measured from core if the cleat spacing is reasonably close. Where the cleat is more widely spaced the estimation of its spacing becomes more difficult.

Coal shrinks with the desorption of gas. This is most important because shrinkage reduces the stress within the coal which is held at constant lateral dimension by the surrounding rocks. The permeability of softer coals is particularly sensitive to the effective stress (total stress - fluid pressure) - the higher the effective stress the lower the permeability. Shrinkage can be measured by adhering strain gauges to core that has been retrieved and is being used for desorption.

Coal strength may be assessed from core. The strength is important because it gives an indication of whether boreholes will remain open or will crush. Soft, weak coals are likely to show more change in permeability with effective stress increase. Problems may also exist in coals which have been stimulated by hydrofracture where the strength is low compared to the effective stress. In these the sand proppant may become embedded in the coal and the fracture lose its permeability. Laboratory tests may be conducted on fractured core to gain an indication of this behaviour.

DOWNHOLE TESTING

Downhole testing to determine the range of permeability and reservoir pressures is extremely valuable. A procedure by which fluid is produced from the seam and then fluid is injected is particularly useful. To this end Sigra undertake a fluid withdrawal (DST) test followed by an injection test. Fluid withdrawal is accomplished by opening a valve connecting the zone of coal to be tested to an empty drill string. Testing may be undertaken using straddle packer systems though these always have the risk of being trapped in hole should the seam collapse. A safer way is therefore to undertake the tests of the zone between the bottom of a packer and the hole base.

This type of testing can be accomplished by tools that can be run through a coring bit. Sigra's DST tools are designed to run with the Boart Longyear HQ wireline coring system. Before testing the core is pulled in the inner tube. The rods are then pulled back to above the seam and the DST tool is run through the rods so that the lower packer protrudes through the bit. The tools may be set and the fluid level in the rod string displaced into the annulus by the use of compressed air. This compressed air is released from the string and the tool is then ready to test with an empty drill string and seam pressure below the lower packer. The bottom valve is then opened and fluid flows through the tool into the drill string under seam pressure. The fluid may be water, gas or a mixture of the two. A pressure transducer measures the level of water rising inside the drill string while another transducer measures the bottom hole pressure below the lower packer. The compressed air or gas outflow is measured out of the top of the drill string. If this volume is greater than that of the water inflow then gas is known to be produced. After a period of inflow the valve at the bottom of the tool is closed preventing further inflow and the bottom hole pressure rises. The shape of the pressure rise curve is extremely important and may yield such useful information as reservoir pressure, sorption pressure (the pressure at which the first bubble of gas is released) and information on permeability.

The next test stage is to inject water into the coal seam at a known rate and to monitor the pressure rise before closing the bottom valve and once again monitoring pressure changes under conditions of zero flow.

Some coal seams effectively behave as simple aquifers provided the seam fluid pressure is adequately high to prevent gas from being released. Others show very much more complex characteristics. The stress related permeability affects can be extremely important. Sometimes injection tests show ten times the apparent near well bore permeability as fluid withdrawal tests.

Once gas is released from the coal the cleats begin to fill with gas to the exclusion of water. The coal then loses permeability to water and gains permeability to gas until after a period the coal has very low gas permeability. These permeability changes are called relative permeability effects.

The intrinsic permeability of the coal may also change due to variations in effective stress. If the coal's intrinsic permeability decreases with an increasing effective stress then a reduction in fluid pressure will bring about an increase in effective stress and a decrease in permeability. This effective stress increase may be countered by the effects of coal shrinkage that occurs as gas is released. Whether the permeability of a seam increases or decreases with production is extremely important to the economics of a coal seam methane operation.

A key to understanding coal seam reservoirs is to remember that the permeability varies and that any assessment of permeability is valid only at the time it is made.

WELL CONTROL - THE RISING BUBBLE

Drilling into any formation that may release gas is hazardous. If the pressure in the well drops locally below that at which gas is released then bubbles will be formed in the annulus between the drill rods and the borehole. These bubbles will expand as they rise and by occupying a larger volume of borehole they will displace liquid and hence reduce the overall density of the fluid in the hole. This reduced density will lead to a lowered pressure which will encourage the release of further gas. If the formation will supply adequate gas to sustain this process the well will blow and become out of control.

The normal method of well control is to drill with a fluid of sufficient density that the hydrostatic pressure in the wellbore prevents gas bubbles releasing. This has some distinct disadvantages in terms of drilling in coal because of the potential to damage the wellbore with an invasion of drilling fluid. Such damage may prevent the well from flowing freely later. A good alternative is to drill with water that would normally have sufficient density to prevent the release of gas into the well bore. Another alternative is to augment the hydrostatic pressure of the water with back pressure at surface. Sigra has a borehole pressurisation system for this purpose.

Where a release of gas starts it must be brought under control swiftly. The method to do this is to close in the annulus between the surface casing and the drill rods with a blow out preventer. This traps the fluid in the annulus. Fluid of increased density can be pumped in through the drill rods and the lighter fluid and the gas can be bled of out. The key to recognising a blowout is excess outflow over inflow from the well. There is no sensible reason why this should not be a totally automated flow measurement system which signals a warning.

Where wireline coring is being undertaken the greatest risk of a blowout occurs when the inner barrel is being pulled. To get reasonable core retrieval speed most drillers will lift the inner barrel at a sufficient speed that fluid is lifted out of the drill rods. This swabs the hole and lowers the pressure at the bottom of the hole so that gas ingress may occur. An expanding gas bubble within the core rods will drive the inner barrel upwards in an uncontrolled manner. As a consequence the inner barrel may be ejected from the rods at surface.

This problem may be fairly readily overcome by screwing a sub into the top of the drill rods. The wireline passes through a seal set in this sub. The inner barrel retrieval latch may be pumped down the rods through a fluid entry point in the sub. On lifting the inner barrel fluid overflow is prevented by the seal thus eliminating the problem of swabbing. Once the inner barrel has reached surface pressures can be examined and in normal circumstances the sub remove and the inner barrel removed with its core.

The full wireline well control system incorporates both the sealed sub and a blow out preventer such as the one shown in the photograph.

PRODUCTION

There is no single correct method for drilling and completing coal seam methane wells. The method used is dependent on the nature of the seam(s).

In very permeable seams the best method may be simply to drill and set casing and screens in the same manner as water wells. A pump can then be installed and the water head lowered until gas is released. Near well bore loss effects may affect production and there may be a need to develop the well conventionally. Methods to increase well bore diameter such as under reaming may assist production. Taken to its conclusion such techniques culminate in the use of cavity completion where compressed air is pumped into the seam for a period of some hours and then the well is suddenly depressurised causing fragmentation of the coal. The debris is then blown out of the hole and the process repeated. Such techniques have advantages where there is a need to access cleat systems to gain production. However, they may be counter productive in the case where the stress concentration around the hole causes the cleats to close and reduce permeability. In such cases the larger hole leads to a larger stressed zone with decreased permeability.

Another approach to getting more gas from a well is by hydrofracture. This usually involves having a well with a cemented casing that is perforated at the seam levels. High pressure fluid is then pumped through the perforations to fracture the coal. In most cases the fluid used will contain a proppant, which is carried into the fracture remains there at the end of fracturing. The fractures created by such a process may be quite large being of one or two centimetres width. They may extend over a hundred metres from the well.

The key to the success of hydrofracture is the stress situation in the coal. Ideally vertical fractures extend laterally in the coal seam. Many stress situations do not however permit this. A hydrofracture will propagate perpendicular to the direction of minimum stress. If this minimum stress is vertical then the fracture will be horizontal. If the not uncommon situation exists where there is a high ratio of maximum to minimum horizontal stress and a correspondingly high ratio of principal permeabilities then the use of hydrofracture may be unsuccessful. This failure arises because the hydrofracture extends in the direction of maximum permeability not across it. In some coals the ratio of maximum to minimum permeability may be very large and in such circumstances the use of hydrofracture well stimulation is unlikely to be successful unless the general level of permeability is high.

Hydrofracture is not controllable in terms of direction but drilling is. The use of directionally drilled in-seam holes is rapidly growing and has the advantage that the hole orientation may be controlled. The limitation of this system is the need to keep the hole open during drilling and following drilling so that a screen can be installed. Thus in-seam drilling is not suitable where the coals are weak or the stresses are high.

Current Australian practise is to drill a vertical well and to ream it locally in the area of the seam. A medium radius borehole is then directionally drilled from surface at one to two kilometres away from the vertical well. This in-seam borehole is steered toward the vertical well by conventional borehole survey systems. As it nears the vertical well drilling is halted and a magnet is lowered down the vertical well to distort the magnetic field. Magnetometers in the survey tool detect the distortion in the magnetic field and this distortion can be used to calculate the relative position of the in-seam hole and the vertical well. The in-seam hole may then be sidetracked to intersect the vertical well.

Several in-seam holes may be made to intersect the vertical well thus enhancing the productivity of the vertical many thousand-fold and simplifying the water removal and gas gathering systems.

The key to the success of such a system is a suitable seam and minimisation of dog legs and branches in the in-seam sections. The more tortuosity of well path the higher drag becomes reducing the ability to drill a distance. Indeed rod buckling occurs in the borehole when loads get to be too high. In such circumstances the rods form a helix in the hole and lock in. It is also possible to become trapped in hole as the rod withdrawal load can exceed that required to progress forward. To manage these problems a torque and drag simulation of the drilling process is invaluable. Branches in boreholes may be disastrous as they can lead to hole collapse or prevent screens being run successfully.

In all coal seam methane operations one of the key elements to success is the control of fines from the coal. A combination of successful screening and pumps that can lift fines are essential to making the process work.

Above all it is necessary to realise that methane is not oil and to make coal seam methane economically successful it is necessary to control costs rigorously. This can be substantially achieved by the use of appropriate technology.

Plates:

A Sigra in-situ stress measurement tool about to be lowered through an HQ drill string.

Set-up for testing coal shrinkage with desorption


A Sigra DST tool with a core drill.


A Sigra coring blow out preventer.