Putting a Stop to Gas Channeling

Ironically, intrusion of gas into the casing-wellbore annulus is sometimes facilitated by the presence of the cement put there to seal it. Understanding gas intrusion is an evolutionary process that has not yet run its full course. Meanwhile, practical efforts to stop the gas have advanced dozens of potential solutions.

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A key aim of cementing a well is to provide a durable isolation between different formations and the surface. Opposing this is the intrusion of gas into the cement-filled annulus. This can lead to development of a pathway for formation fluids within the cement sheath, either between zones or to the surface (above). Both are dangerous and potentially costly.

Of most concern are channels that allow gas to come to surface. This can occur either via casing strings cemented to surface or in liners where gas emerges at the liner hanger and is then circulated out of the well. The severity of annular gas flow ranges from hazardous to marginal: from a blowout to a few psi of residual gas at the wellhead. Interzonal communication is difficult to detect but can impair gas production or recharge an upper depleted zone, possibly affecting production and/or drilling conditions from adjacent wells.

In the extreme, the problem can lead to abandonment of the well. More frequently, remedial measures like squeeze cementing are attempted until gas intrusion is reduced to levels that comply with oil company and regulatory authority standards. Such squeezes are extremely difficult to perform and often unsuccessful. First, the gas channel must be detected and then cement has to be placed into it, often into very small gaps. Pressure exerted during the cement squeeze can break down cement-casing bonds creating new problems. Clearly, there is strong motivation for performing the job correctly in the first place.
Coming to Grips with the Problem

The chief difficulty in understanding gas intrusion is that the slurry evolves with time. A liquid immediately after placement, it progresses through a series of different states before hardening. This transition, when combined with the complex downhole conditions, makes laboratory simulation difficult (see “From Test Cell to Well,” page 38). Despite this, three separate routes by which gas comes to surface are recognized. All three may be present in the same annulus.1

The first route for gas is via columns of mud (stringers) left in the set cement as a result of poor mud removal (below). As the mud gels, dehydrates and shrinks, formation fluids can flow through the voids.

Second, gas can flow through microannuli along the cement’s interfaces with the casing and the formation (top, right). These microannuli develop because of volume reduction of cement as it sets and cures. Pressure and temperature variations during the life of the well can, at very least, exaggerate the problem, and some experts feel they are actually the main cause. The presence of thick, mushy filter cakes on the formation or mud clinging to the casing also increase any microannulus.

But it is the third mechanism of gas intrusion that has most exercised the theoreticians and experimentalists over the past 20 years or so. While the first two mechanisms effectively bypass the cement sheath, the third provides a route within the cement itself (above). In what is called matrix gas channeling, gas flows through the microstructure of the cement, or possibly creates tiny fractures in the setting cement (see “Commentary: Stu Keller,” next page).

At first, this seems impossible. If the well is killed by the drilling fluid prior to cementation and the slurry’s hydrostatic pressure exceeds the formation pressure, then gas should be kept at bay. However, after mud has been displaced and cement left static behind the casing, several processes begin that undermine this static state.

Fluid loss (dehydration of the liquid phase), sedimentation (settling and packing of the solid particles), gelation of the slurry and shrinkage are all occurring as cement sets. The relative importance of each depends on slurry composition and well conditions which may vary across the interval being cemented.

Shortly after placement, the still liquid slurry ceases to transmit its full hydrostatic pressure to the formation. This reduction in hydrostatic pressure has been measured by Exxon Production Research Co. Pressure and temperature sensors were placed on the outside of the casing in seven wells. Logging cable, also clamped to the casing, brought the data to surface (next page, left). Pressure generally decreased shortly after cement was pumped.2 Furthermore, pressure loss was greatest adjacent to permeable zones where fluid loss from the slurry was highest.

If there is a differential pressure between the slurry and a permeable layer, water can flow from the slurry into the formation. This leads to a volume reduction and, if this reduction is not compensated for, cement pore pressure declines. Compensation becomes harder as time passes, because the cement builds up gel strength as a structure...
is establishing its matrix. Static gel strength is the shear stress required to cause the cement to flow again, and its rate of development depends on slurry composition and downhole conditions. During gelation there is no significant hydration of the cement grains.

Eventually, when gel strength exceeds shear stress exerted by the weight of the cement and the mud above it, the cement supports itself. Once self-supporting, pore pressure within the cement structure is no longer controlled by the hydrostatic load transmitted through the cement. Rather it is controlled by the slurry permeability and shrinkage; this may lead to a substantial decrease in cement pore pressure. Hydration results in an absolute volume reduction of the cement matrix (shrinkage)—as much as 6 percent—because the volume of the crystalized phases is less than the sum of the volumes of the water and the dry cement particles.³

For all these reasons, cement pore pressure can ultimately drop below formation pressure (previous page, bottom) and there will be room for gas to enter the cement matrix. If gas invades the cement pore spaces, isolation of the formation is jeopardized and the success of the cement job is at risk.⁴

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Commentary: Stu Keller

There are generally three types of annular gas flow: channel, microannulus and matrix. Even if you have perfect displacement of mud by the cement, annular gas flow may still occur. By understanding the causes of the problem, it is possible to devise approaches that might be beneficial.

First, a low fluid loss slurry is almost universally accepted. This cuts the volume loss from the slurry since, by definition, a low fluid loss slurry yields a low permeability filter cake. Reducing the fluid loss helps maintain the cement pore pressure at a time when the cement column can no longer flow downward due to gel strength development.

A second approach is to use agents that block the cement matrix and lower the tendency of gas to flow through the cement even when there has been a reduction in cement pore pressure. While the gas flow through the cement matrix permeability may not be large, it may initiate formation of channels or fractures in gelled cement that are responsible for much higher volumes of gas flow.

A third alternative is to use a slurry that has delayed gel strength development with a right-angle set. Delayed gel strength development is advantageous because the fluid loss rate from the cement is a decreasing function of time. This means that when the cement does gel, the pressure reduction due to fluid loss will be less.

Right-angle set is likely to be beneficial because reducing the time the slurry spends in transition also cuts how long the slurry is most vulnerable to gas intrusion.

Beyond modifying the slurry, there are physical ways of opposing gas entry. Maintaining pressure on the annulus can help counteract gel strength development by making the column flow downward to compensate for any volume loss at the bottom of the column. The gel strength can generate resistance, so the effectiveness of this measure depends on the slurry design. Generally we are limited by the fear of exceeding the fracture pressure of the formation and can only exert a couple of hundred psi. Nevertheless, this is worth using in conjunction with other options, particularly where the cement column is relatively short.

This prompts another technique—limiting the height of the cement in areas where annular gas flow is expected. This is achieved through use of multistage cement jobs and by limiting the excess pumped. Theoretically, use of a larger annulus can also help cut the pressure reduction as the cement column begins to become self-supporting, though often this is not feasible because the casing and hole size are governed by other factors. Quite often with cementing, there are drawbacks with every potential action. You have to weigh all the factors before deciding what to do.

Chemical shrinkage during cement hydration has not been addressed by any of the above solutions, and I think it can, itself, cause a microannulus. It also contributes to initiation of gas flow by causing a significant reduction in cement pore pressure. A combination of an expansive cement with some of the other materials discussed might be a good approach.

Cement must provide a seal throughout the entire life of a well. But fluctuating temperature and pressure and drill pipe contact with the intermediate casing can also create a microannulus. Common sense is also needed. If there is 19-pound per gallon mud in the production casing while cement sets in the annulus, it is not a good idea from the point of view of annular isolation to then use diesel fuel as the packer fluid. You would probably want to use a heavier fluid to help avoid contraction of the casing that may cause a gap in the annulus.


There is no American Petroleum Institute (API) recommended procedure for testing cement's ability to withstand gas intrusion. Furthermore, the large number of variables require anyone interested in testing slurries to make simplifications. Reviewing every method that has been used to test the gas-blocking capabilities of cement slurries is beyond the scope of this article. Here are two examples:

Robert Beirute of Amoco Production Co. and others have developed a computer-controlled gas flow cell that applies a variable hydraulic pressure, allows fluid loss from the slurry and establishes a gas pressure differential across the slurry that mirrors formations of different pressures (right).<ref>1</ref>

At the heart of the apparatus is a modified high-temperature/high-pressure API fluid loss cell that contains the slurry. A hollow hydraulic piston with a 325-mesh screen is inserted into the cell through the top. Hydrostatic pressure is simulated by pressurizing the piston with mineral oil (which is itself pressurized by nitrogen). A pressure transducer monitors the piston pressure. The hollow piston shaft is connected by a flexible hose to the top backpressure regulator. Slurry filtrate from the top of the cell passes through the piston shaft and is collected and measured by an electronic balance.

Another 325-mesh screen is located at the bottom of the cell below which there is a nitrogen source connected to a differential pressure regulator which has its high-pressure side connected to the bottom screen. Between this regulator and the bottom screen is a second electronic mass flowmeter that measures the simulated formation gas flow rate into the cell. The low-pressure side of the differential pressure regulator is connected to the top backpressure regulator. And the pressure across the differential pressure regulator is monitored by a transducer control system.

Filtrate from the bottom of the cell is collected through the bottom backpressure regulator and measured using another electronic balance. The pore pressure of the cement slurry is measured using two pressure transducers 1 inch [26 mm] and 5 inches [130 mm] from the bottom screen. A thermocouple inserted through the side of the cell measures the cell temperature which is modified using a heating jacket. Movement of the piston shaft is monitored by a displacement transducer.

The test assumes a worst case of a gas zone with enough permeability to fully invade and charge a cemented annulus. After mixing, the test slurry is stirred for 20 minutes in an atmospheric consistometer at bottomhole circulating temperature (BHCT) while the test cell is also preheated to BHCT. At the same time, the nitrogen system is readied. With the formation gas valve closed, a simulated gas formation pressure is applied from gas valve to the top backpressure valve. The same pressure is also applied to the backpressure regulator. At this point the slurry is poured into the top of the cell, and the piston is inserted and used to apply the initial hydrostatic pressure.

The gas valve at the bottom of the cell is opened as is the bottom filtrate valve. This allows slurry fluid loss to occur. The top filtrate

**Measuring gas intrusion in the laboratory using complex apparatus. Computer control allows Amoco experimenters to automatically alter variables like cement hydrostatic and differential pressure.**
valve remains closed to avoid the formation of a filter cake which could inhibit later flow of filtrate and gas through the piston shaft. The cell is then heated from BHCT to bottomhole static temperature using a predetermined schedule that mirrors what really happens to a fluid once pumping stops. The hydraulic pressure of the piston above the slurry simulating the hydrostatic head is gradually reduced.

Cement pore pressure is continuously monitored as it falls, and once it approaches the constant simulated gas formation pressure, the piston hydraulic pressure is noted and kept constant for the rest of the test. At this point, the top filterate valve is opened, and differential pressure is applied across the cement slurry from the bottom of the cell to the top backpressure regulator. If gas flow occurs during the test, the flow rate is measured by the mass flowmeter.

Crucial to the relevance of the results are the hydrostatic pressure reduction program (which in the test determines the rate of fall in of the slurry pore pressure), the differential gas pressure applied across the slurry and how these values are scaled down to benchtop proportions.

The decline of cement slurry pore pressure with time is complex and not fully understood. It is a function of (among other things) gel strength development, fluid loss and shrinkage, in addition to downhole temperature and pressure. In this apparatus most of the fall in pore pressure is attributed to gel strength development. Using a separate apparatus, the slurry gel strength development versus time is measured under downhole temperature and pressure. From these results, a program for reducing the hydrostatic pressure transmission that occurs as the slurry becomes self-supporting is calculated and translated into pressures applied by the piston during the test.

Deciding what pressure differential to apply across the slurry is not as straightforward as it may first appear. It is not enough to apply a pressure gradient calculated by subtracting the pressure of a weak zone in the well from that of the high pressure zone and dividing it by the distance between the two zones; gas compressibility has to be considered. For instance, while in a well, a gas zone at 7,000 psi may be flowing toward a zone at 6,500 psi. The laboratory simulation will have a gas source at 400 psi flowing towards a lower discharge pressure. To calculate this discharge pressure, Beirute applies Darcy’s Law for linear flow and assumes that the slurry bulk permeability and gas viscosities are the same for the well and the cell. In this way, flow rate per unit area in the well is calculated and then used to produce the discharge pressure for the cell.

Koninklijke/Shell E&P Laboratorium has opted to use U-tube gas suction apparatus (below). The U-tube is filled with cement slurry and gas pressure applied to the top of one of the tube legs. The cement is allowed to set and the gas pressure monitored continuously. Cement permeability to the gas can then be measured by increasing the pressure differential across the U-tube by up to 3,000 psi and measuring the resultant flow rates.

To separate the effect of flow through a microannulus (due to shrinkage of the cement) and flow through cement, the U-tubes are rapidly cooled after a leakage rate has been established. In this way, the microannulus is believed to be sealed by the shrinkage of the U-tube, and the subsequent gas flow rates can be wholly attributed to matrix gas channeling.

This apparatus measures the pressure differential across the U-tube. In this way, it can monitor the pressure-transferring capacity of a slurry during gelation and during setting. If the pressure differential across set cement is less than the pressure imposed originally, the cement has leaked, and Shell can then calculate its permeability.

The experiments start with the same pressure on both sides of the U-tube because the cement is liquid and able to transmit pressure. But, once it starts to set, a differential is established. If the slurry is able to maintain this differential, Shell believes that the cement will be able to stop, or at least delay, gas migration.

The selection of apparatus to test a slurry effectively selects simplifications which in turn help determine the choice of additives and job procedures. The complete simulation of a well with gas intrusion capability remains a dream.

U-tube gas suction apparatus for measuring cement permeability to gas. Shell measures permeability by applying a differential pressure across the tube.
Putting Theory into Practice

Current solutions to stop gas intrusion fall into three categories: optimization of conventional good cementing practices, adding new properties to cement slurries and hardware/procedural modifications.

Of all cementing practices, effective mud removal is one of the most important and has a major bearing on preventing gas intrusion. Field experience shows that however good a particular slurry is at resisting gas invasion, reliable zonal isolation is possible only when coupled with effective mud removal practices. Prevention of mud stringers depends on completely displacing drilling fluid during cement placement (see “Mud Removal: Research Improves Traditional Cementing Guidelines,” page 44).5

Another aim in conventional slurry design, particularly for cementations requiring maximum integrity (like liners), is control of fluid loss from cement into the formation. Since reduction in cement pore pressure is proportional to the reduction in slurry volume, fluid loss control is even more important when gas intrusion is anticipated. In the laboratory, increasing the concentration of the fluid loss control agent and ensuring a low fluid loss test has been shown to lead to less gas invasion and lower cement permeability.6

In high-angle wells, microannulus development has been attributed to settling of the slurry and release of free water. This is because, in some circumstances, the free water can form a continuous communication between a gas zone and the surface (above, right). Slurry stability, a goal for all cement designs, becomes even more important when gas intrusion threatens.7

However, such improved practices alone are often inadequate to fight gas intrusion. Isolation can then be achieved only by special modifications to the cement slurry (see “Commentary: Hal Grant,” left). Special systems reflect the diversity of approach within the industry. Gas bubbles, rapid setting and modified gel strength development have all been used. More recently, impermeable cements, those containing surfactants and slurries with viscosified mix fluid, have been added to the list of options. These additives all aim to prevent channeling through the slurry matrix. Expansive cements have been used to combat microannulus development.

Entrained Gas

Normal cement slurries have low compressibilities, so small volume losses create significant pressure reduction in the annulus. Slurries containing entrained gas are designed to be more compressible. As cement hydrates and shrinks, entrained gas bubbles expand to compensate for the volume reduction and so maintain a positive pore pressure across the formation. These slurries are produced either on surface as foamed cement by the introduction of an inert gas (usually nitrogen) or in situ through use of additives (usually fine aluminum or magnesium powder) that react with the cement downhole to produce hydrogen, which creates a sort of foam.

Deliberate introduction of a gas into the slurry seems to be a perverse way of opposing unwelcome gas entry. However, the gas in foam is not mobile because it forms small bubbles that do not coalesce. But foamed cement’s low density and high compressibility can lead to difficulties achieving sufficient hydrostatic pressure to place the cement in deep high-pressure wells without collapsing the foam.

Some success has been reported with the in-situ development of hydrogen.8 Because hydrogen is explosive, questions have been raised over the safety of operations using hydrogen-producing additives, both during slurry placement and when the set cement is drilled out. Further difficulties can arise if the generated gas breaks out and migrates upwards, enhancing the chance of gas inflow rather than its restraint.9
Right-Angle Setting

Right-angle setting cements, named for the shape of their consistometer readings in the laboratory, show no progressive gelation and set very rapidly (below). These properties allow transmission of the full hydrostatic load of the cement column to gas-bearing zones until shortly before the cement sets. Reducing the slurry's transition period cuts the time available for gas intrusion.\(^1\)

Delaying development of gel strength has the advantage that hydrostatic pressure is maintained while any reduction in slurry volume due to fluid loss is occurring—an ungelled column can more easily compensate for the volume loss.

However, right-angle setting slurries tend to exhibit high volumetric shrinkage. Furthermore, if the bottomhole circulating temperature is less than 121°C (250°F), it is hard to design right-angle set slurries because hydration kinetics of cement are significantly slower. Below 27°C (80°F) plaster can be added to cement to give right-angle set properties.

![Compressive strength vs. time](image)

**Right-angle setting cement.** By moving rapidly from liquid to solid, right-angle setting cement spends the minimum time possible in the vulnerable transition state, in this case less than 10 minutes.

**Consistency and compressive strength development tests were carried out at 16°C (60°F) and atmospheric pressure.**

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**Commentary: Gerard Bol**

Problems that arise with cement jobs do not necessarily need new technology. We may not be applying current technology correctly. The challenge is to make people in the field understand what is important and appreciate the need for quality control during cement jobs.

There is a whole list of points to which you must adhere and if you do so I am confident it is possible to succeed in 90 percent or more cases. This requires an understanding of the mechanisms at play, a cementing program that is ‘fit for purpose’ and good quality control.

For many years we have stressed an integrated approach. Using special additives is fine, but if your displacement is poor, you are not going to get anywhere. We believe that this generally means using a thin scavenger slurry ahead of a main slurry with low fluid loss, displaced at as high a pump rate as possible.

Gas zone cementation requires the same rules but employs extra additives. There is a potential for gas to migrate through the cement—in addition to traveling through a microannulus or a channel—and we realize that in certain cases we are required to stop it.

On the microscale, gelled cement can be considered a matrix into which gas can enter. In experiments, cement placed inside a steel pipe coated internally with rubber to avoid creation of a microannulus and exposed to differential pressure has definitely exhibited flow through the matrix—not large volumes, but in a well enough to create significant pressure at the top of the annulus.

Supporting this is the observation that all the successful gas migration additives—latex cements, additives with a foaming capacity or microsilica—plug gelled cement's relatively coarse porous matrix. This suggests not only that the matrix is strong enough to hold the plugging agents but that gas migration occurs through the matrix and not just by macromized blobs of gas.

Higher volumes of gas flow indicate mud channels or microannuli. To prevent the formation of a microannulus after the cement has set, we have looked closely at seal rings placed on the outside of the casing. Full evaluation in the field is difficult because we can never be sure whether the seal ring has performed or whether there was no microannulus anyway. In laboratory experiments using seal rings, we found that there is an enormous improvement.

The mechanism is clear: if you have a casing under pressure and if at any time during the life of the well the pressure is let off, a microannulus may develop. So any well that you expect to artificially lift or one that will show clear reservoir pressure drops may need seal rings. However, with the exception of the Gemoco seals, there are no purpose-designed seals available to shut off gas flow. We started to develop a seal, but it has yet to come to fruition. We intend to review this to see if any further action is required.

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**Modified Gel Strength**

Diametrically opposing the above philosophy are thixotropic cements that rapidly develop gel strength which can be broken down by shearing. In this case, the gel strength is designed to prevent the flow of gas bubbles before the cement sets. This gelation can be achieved through creation of a microcrystalline structure or microgelatinous network of mineral hydrates throughout the cement slurry. Alternatively, polymers dissolved in the interstitial water can be chemically treated to yield a self-supporting viscous gel.

Such systems are reported effective in combating entry of gas bubbles.\(^5\) However, it is debatable whether they resist gas molecules that are smaller than the cement pore size and can enter the cement matrix once it has become a two-phase system (see "Commentary: Gerard Bol," above).
Permeability Blocking

As cement makes the transition from liquid to solid, it becomes a two-phase permeable system. One way of preventing gas migration, therefore, is to reduce matrix permeability. Several materials used for this include microsilica and latex.

Microsilica comprises 85 to 98 percent amorphous silicon dioxide (SiO₂) in the form of small spherical particles 0.02 to 0.50 microns (μm) in diameter—around 100 times finer than cement particles. The tiny particles are thought to plug spaces between cement particles and reduce matrix permeability. Another explanation holds that microsilica’s very high surface area—15 to 25 square meters per gram (m²/g) compared with about 0.3 m²/g for cement—means that it has high pozzolanic activity and reacts with the calcium hydroxide in the cement, further reducing permeability.

Development of the microsilica additive centered on cement systems lighter than 14 pounds per gallon (lbm/gal) to control shallow gas pockets encountered in the Gullfaks field in the Norwegian North Sea. Now densities range from 11 to 16.2 lbm/gal. The low densities also use glass beads as a lightweight extender.

Large volumes of the additive are needed—more than 20 percent by weight of cement is often recommended. This can present bulk handling headaches and has also raised doubts about how such large volumes of additive affect cement strength. This is particularly true at high temperatures at which silica fume has to replace the larger silica flour which is traditionally used to oppose strength retrogression. Using both additives would leave too little cement in the slurry.

Another permeability blocker is latex. Solid latex polymer particles are dispersed in water and stabilized by anionic surfactants and protective colloids. The polymer particles are discrete and remain dispersed within the slurry until setting starts. They are small enough (0.2 to 0.5 μm) to occupy the cement’s pore spaces. During setting, the pore water reacts with the cement and the latex particles coalesce to form a coherent, low-permeability plastic film that blocks further gas migration through the cement.

Although many latexes are commercially available, only a few can withstand the drastic requirements of storing, mixing and pumping, and then the downhole temperature, pressure and chemical environment which can cause flocculation and loss of film-forming ability. Because of these sensitivities, stabilizers are also employed.

Surfactants and Viscosifiers

A technique in between entrained gas and permeability blocking uses the foaming capacity of some cement additives. Some standard additives like dispersants offer limited foaming, but for greater foaming capability, surfactants are added to the cement slurry. When gas enters the matrix, the surfactants react, forming a stable foam at downhole conditions. These stabilized bubbles can then oppose matrix influx in the same way as foamed cement. This mechanism has been confirmed in studies by Koninklijke/Shell Exploratie en Produktie Laboratorium, Rijswijk, The Netherlands.

Viscosification of the interstitial water is yet another technique. This seeks to create a gummy, viscoelastic film within the cement pores (below), limiting the mobility of the cement filtrate and reducing gas mobility (see “Commentary: Franco Marcassa,” next page). Viscosifying polymers have also been used along with a blend of cement and slag (containing primarily oxides of calcium, silicon, aluminum and magnesium) which, among other attributes, helps reduce slurry porosity, further impeding gas intrusion. Another idea related to viscosification involves reducing cement matrix pore throats using bridging and polymeric agents, which swell to further immobilize fluids within the cement pore spaces.

Expansive Cements

Expansive cements aim to prevent the formation of microannuli by opposing shrinkage with cement expansion. Cement systems that incorporate gas bubbles mentioned above are often quoted as offering expansivity. However, once the cement has set, entrained gas can no longer expand and so does not offer much benefit (above).

The other principal method for achieving expansion is through crystal growth. Ettringite—a highly hydrated form of calcium sulfoaluminate—may be formed by the reaction of calcium sulfate with the aluminate phases. Such reactions give a linear expansion of 0.2 to 0.5 percent but are limited to bottomhole static temperatures of 85°C (185°F). Expansivity can also be attained through addition of high quantities of sodium chloride, sodium sulfate, or both.

Addition of calcined magnesium oxide at a concentration of 0.25 to 1 percent by weight of cement also provides an expansive force within the cement due to hydration to magnesium hydroxide. Expansion increases with increasing temperature but proves insufficient at less than 60°C (140°F). However, it can lead to low strength in set cement and, when greater than 1 percent, expansion can leave cracks and fractures. Oil companies are researching ways of combining gas-blocking properties with expansivity.
Hardware and Procedures

While slurry modification techniques have become an important element in the fight against gas intrusion, earlier efforts concentrated on use of special hardware and modifying operational procedures. Physical means to reduce gas migration include using external casing packers and stage cementing to cut the height of the cement column and effectively reduce the amount of hydrostatic pressure that can be lost during setting.

In the past, much emphasis was given to increasing mud density in the well prior to cementing; today, this is less popular, although some operators recommend pressuring up on the annulus during cementing. Mechanical seal rings have also been employed to help seal the casing-cement interface and guard against the consequences of casing contraction. Furthermore, scratchers mounted on the outside of the casing have been used successfully to remove mudcake on the formation and improve mud removal.

A novel way of preventing the buildup of gel strength and therefore avoiding the downhole pressure drop involves vibration of the casing. This has been tested in both the laboratory and in a test well. Favorable results are reported with the additional benefit of seemingly improving the hydraulic seal at the cementation interface.—CF

Commentary: Franco Marcassa

For us, gas channeling is an old story. In 1976-77, offshore Borneo, Indonesia, we experienced gas at surface and lost one or two wells. At that time, there were no commercially available additives to combat gas intrusion, so we in research were asked to find some way to control the gas.

One of the main driving forces of gas channeling is the pressure loss that comes from the self-support of the cement column which reduces the hydrostatic pressure exerted on the formation. But don’t forget that setting cement contains a network of small holes. This led to the development of a catonic polymer that increases the mix fluid viscosity as the cement sets, creating a viscous material inside the porous matrix of the cement to oppose gas migration. This resistance does not depend on pH or any other additive, only on the water concentration, which is controlled by setting. There is an optimum polymer concentration to make a cement gas-proof. This catonic polymer has been used on more than 100 wells with 95 to 98 percent success.

The key to the viscosity increase is the loss of water into the formation. This loss occurs during hydration and increases the relative polymer concentration and hence the fluid’s viscosity. The mix water viscosity of about 30 centipoise (cp) will rise to as much as 5,000 cp during setting. One aspect of the polymer is that it tends to make the slurry viscous. This can limit slurry flow rate during displacement in certain cement jobs.

In the field, when you add a product to stop gas, people tend to think that it will stop gas whatever you do. This is wrong. All products for stopping gas migration are designed to do so inside the cement. Gas channeling may be the result of an operational problem arising from bad casing cleaning, a permeable zone or bad operation sequence.

Franco Marcassa, senior drilling fluid and cement engineer, Total Compagnie Francaise des Pétroles, Centre Scientifique et Technique.

Because we are dealing with a lot of money in the field, people want to save time, and so when the cement job is finished they want to start nipping up and testing the blowout preventers and pressure testing the casing. If carried out too soon, these operations may induce gas channeling.

And you have to get the job right the first time. I do not believe too much in remedial cementing, especially when there is gas channeling. The space to be squeezed is too small even for extra-line cements. This is because you do not know where the squeeze cement will go. When you have channeling problems, you perforate the casing and generally squeeze most of the cement into the formation, not the channel that needs it. The chances of significant quantities of cement going into the channel are virtually nil.

With gas, as soon as you have a small leak it is forever. It is not like liquid. You can see this in the lab, once you have a small leak in gas equipment it is virtually impossible to repair. Gas is very mobile.


