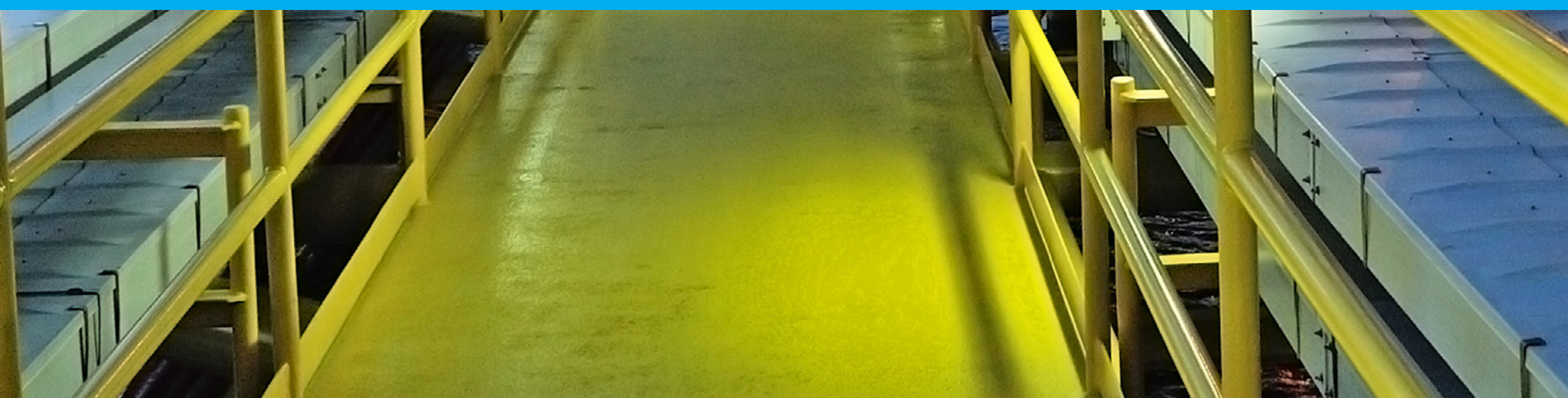
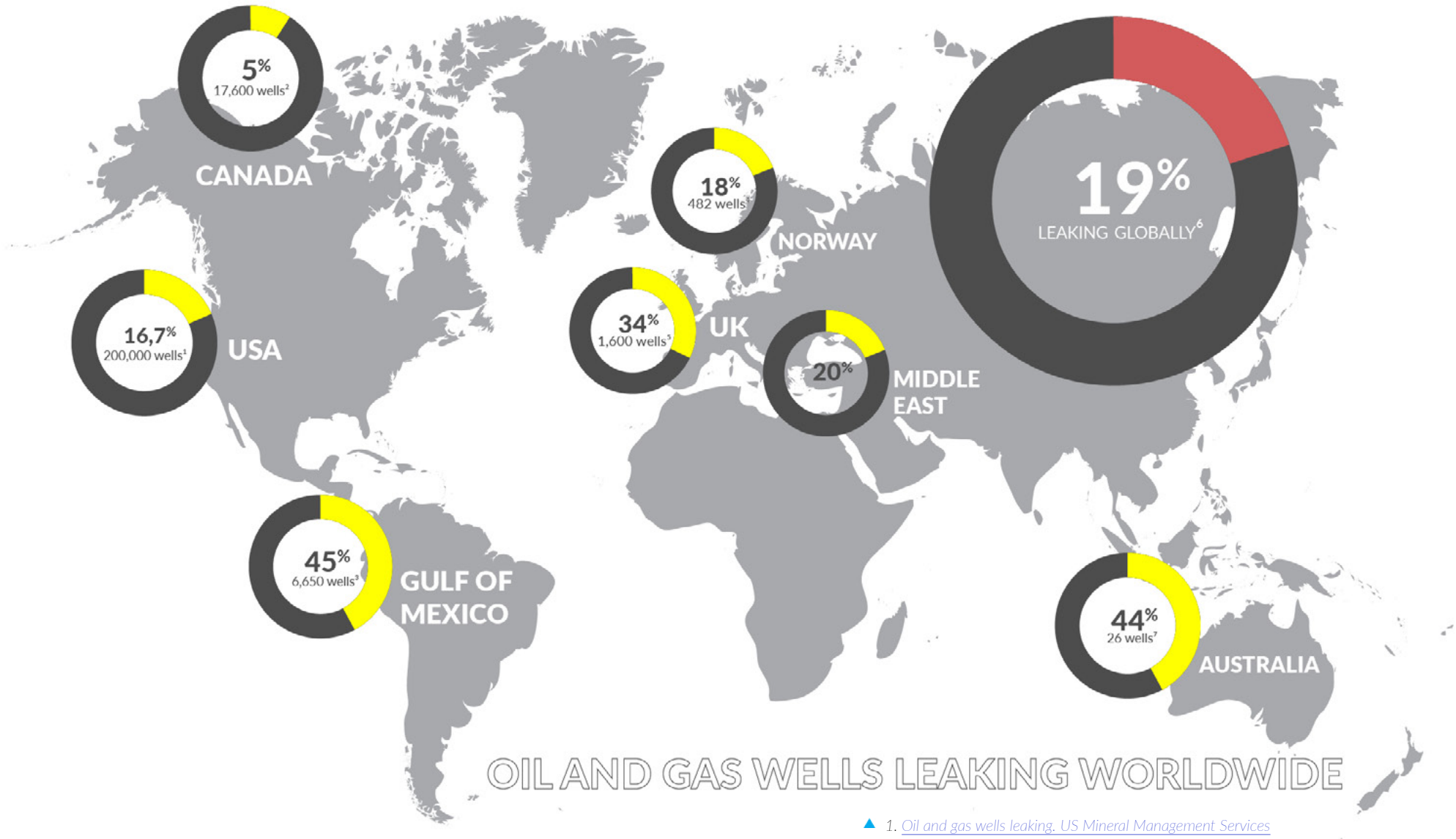
Author Svein Normann

The most common causes for leaks in oil wells and 8 questions to consider before you select solution





1. Oil and gas wells leaking. US Mineral Management Services
2. Oil and gas wells leaking. US Mineral Management Services
3. Offshore gas wells leaking. US Mineral Management Services
4. Offshore gas wells leaking. Norwegian Petroleum Safety Authority
5. MMS Gulf og Mexico wells had SAP. US Mineral Management Services
6. Gas wells leaking. Archer
7. Coal seam gas wells leaking. Quensland Mines Department

Introduction

Leaking wells have been a persistent and chronic problem for the oil and gas industry causing loss of production, safety issues, and environmental threats for decades. Part of this is just basic physics; most fluids in a well are light and tend to want to move upwards due to gravity, pressures in a well is normally higher the deeper you get. These forces tend to drive any well fluid upwards. When we drill a well, we create a potential vertical path for it, which is really the purpose of drilling a well, but we only want certain fluids up to the surface under controlled conditions and only for a certain time.

Leaks have obvious well safety and environmental aspects, but also aspects related to production, reputation and asset value are important. Like fixed installations and other petroleum industry facilities, wells need to be maintained and monitored to prevent faults and incidents. Oil and gas wells are far more than a simple hole in the ground.

A Sintef-study (SPE no.112335) from the North Sea in 2006 found 18% of the wells surveyed leaking, almost half of these 18% had the wells shut in due to integrity issues. Now that is costly! A simple estimate on yearly losses only due to loss in production, was calculated to 5.3 billion dollars (assuming USD 50/barrel) and this was only for the Norwegian Continental Shelf.

Well Integrity (which you have if you do not have any leaks) is defined in Norsok D-010 as: “application of technical, operational and organizational solutions to reduce the risk of uncontrolled release of formation fluids throughout the lifecycle of a well.”

When selecting technical solutions, it is important to define the requirements for the well barrier to ensure the well integrity is maintained throughout the well life and choose the right equipment specifications accordingly. Most will count the producing years as life

of a well, but really we have made a vertical pathway that will be there for hundreds if not thousands of years. That should be considered both when constructing a well and when abandoning it.

In this guide, we will point out some of the most common causes for well leakage problems. Also we list 8 questions or issues you must consider before you select a solution to your problem.

Leaks in oil and gas wells are very common. The huge number of leaking wells is a structural rather than regulatory problem. That's because the industry is unable to build wells that don't leak. In almost every area of the oil and gas industry, you find one thing is constant – leaks.

Type of Leaks

The majority of well-leakage is due to time-independent mechanical factors controlled during well drilling, construction or abandonment, mainly cementing. The uncemented or poorly cemented casing is a main factor in sustained casing pressure, gas migration, or casing failure occurrence. Good quality cementing will likely protect wells against cement degradation and casing corrosion. Very often surface casing gives problems because we do not pay so much attention to these jobs when it comes to cement slurry or placement designs.

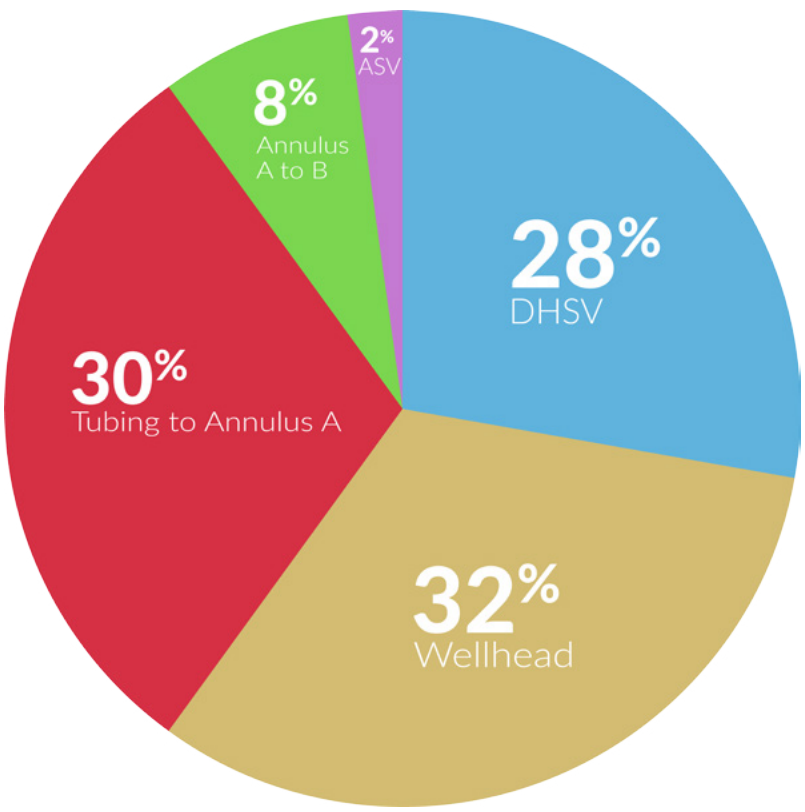
Of course, you can have leaks through casing or liner due to other factors also, parted casing or collapsed pipe for one or another reason.

Other leaks can be packers not sealing; this can be liner packers, external casing packers in various places, swell packers for production, production packer, etc.

Then we have leaks at the very end of a well's life, P&A plugs that do not seal properly, either they are mechanical or cement. Control lines that leak or have parted.

Some of the leaks described above are not visible at the surface, or maybe only visible after a long time.

Note: In some parts of the world there are some very old wells. Wells that were abandoned many years ago and today for various reason may not even have an owner, and certainly nobody is keeping an eye on the conditions of the well. When gas or oil then are finally seen at surface or in groundwater, not only is it very difficult to remedy, but it can be very difficult to find out who is responsible to fix the problem.



Type of leaks seen in a study of 217 wells in the North Sea from 2007 (Sintef study)

For more current wells, what we typically do see at the surface are:

- A-annulus pressure build-up or leak
- B-annulus pressure build up or leak
- Leaking safety valve
- Low LOT or FIT after drilling out the shoe
- Leaking cement plug
- One can also see a leak path from a CBL (cement bond log).
- Pressure test of liner hanger packer, production packer fails
- Production of undesirable fluid
- Fluids going where they should not

Searching for solutions

“The survey of well integrity on the Norwegian shelf revealed a number of defects and shows that both the industry and the authorities must reinforce their efforts in this area. We see a substantial potential for improvement, both with regards to safety and improved recovery/ value creation,” *say Birgit Vignes and Jan Andreassen*.

The Petroleum Safety Authority (PSA) colleagues were responsible for a study which as resulted in a report back in 2006. This was the first such comprehensive study of well conditions on the Norwegian shelf.

Since then the industry has done much to improve well integrity and is now working together for safety and productivity.

”The industry sees real opportunities for mutual benefits by joining forces to find joint solutions in certain areas. The industry must find a standardization solution that contributes to better documentation and overview of the conditions in the wells," say Vignes and Andreassen, and add that the challenges linked to safe wells also require cooperation and standardization efforts across shelf borders.

Now, not all leaks are equally serious and some you can live with, at least for a while. It is not unusual to see pressure build-up in for example annulus of older wells. If the build-up is slow and steady, it may just be monitored and bled off at regular intervals. Eventually though, even these leaks need to be dealt with.

Underlying reason for leaks

There are many different types and severity of leaks. Often the reason for the leak is due to equipment in the well that are not designed for the conditions, or the conditions have changed, or the well is used differently from its original intended use (injector instead of producer, for example). Further on, many reasons for leaks are due to operational errors during the construction or the completion of the well. These reasons have very much to do with proper planning, training and execution per plan.

Many reasons are related to cement! Either directly, or indirectly and either due to things happening (or not happening) in the planning and execution phase, like;

- Lack of cement or top of cement too low
- Poorly placed cement
- Bad mud removal
- Poorly executed cement jobs – too low rate
- Losses during cementing
- Bad centralization of casing or liner
- Cement slurry with the wrong design properties, or several other issues,

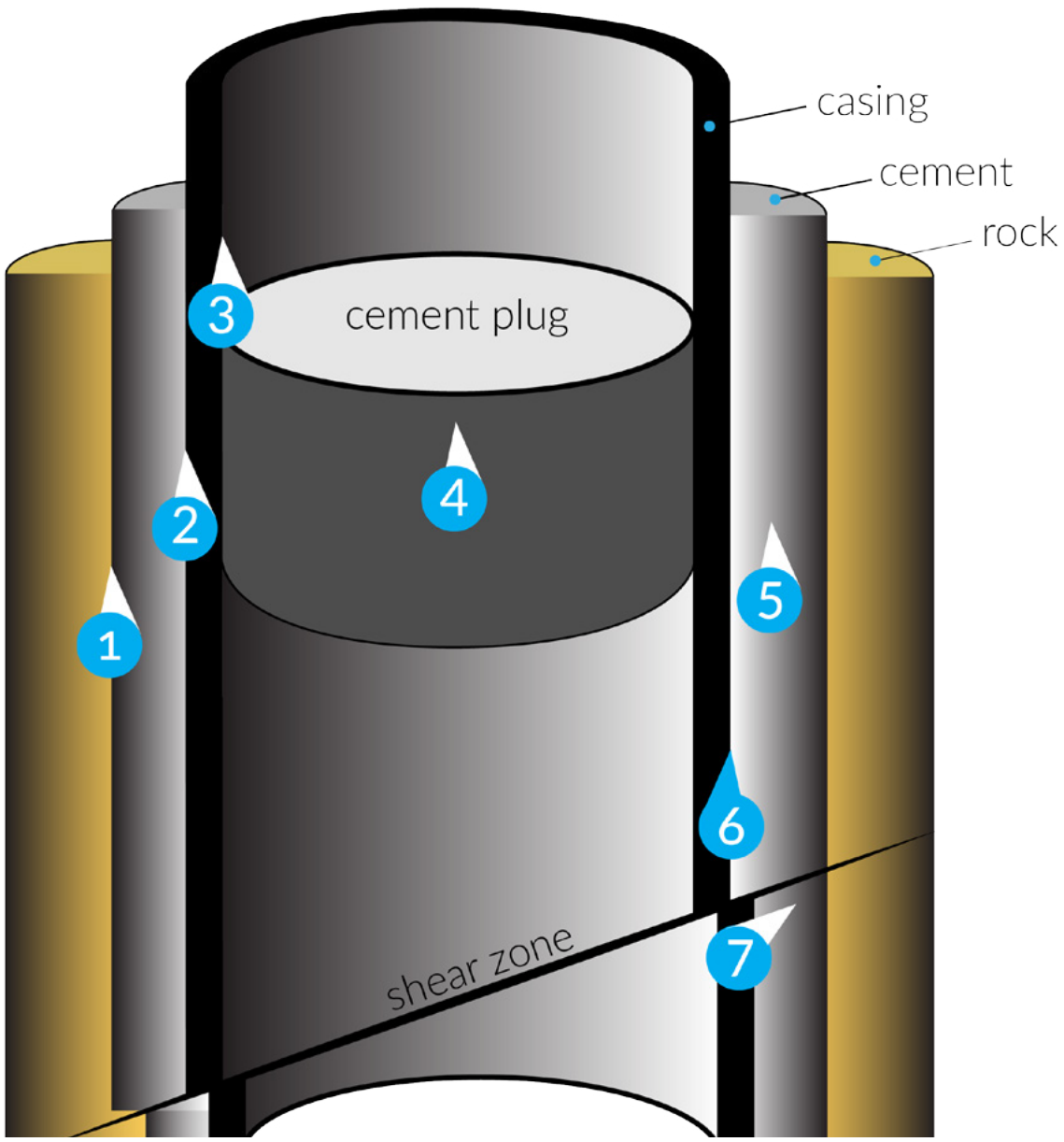
or it is due to what happens in the post job phase leading to cracked or de-bonded cement, indirectly due to the inherent brittleness of cement.

If the cement is exposed to stress, especially cyclic stress over time, it is likely to crack or at least de-bond from the casing/liner or possibly from the formation. This will

then open migration paths for fluids and in many cases, eventually lead to a leak that is recognized at the surface. These stresses could be due to pressure cycles, temperature cycles or mechanical stress from drilling or tools or strings run in a hole or out of a hole

Microannulus in cement sheet can be inherent from bad placement of the cement, but can also be induced after placement by for example increase and reduction in pipe pressure before the cement has cured fully. That cement tends to crack and open leak-paths over time, this is well known and even indirectly recognized by one of the leading service companies that now provides a cement that self-heal when cracks occur.

Some of the above may not lead to a leak directly but could lead to water or gas getting in contact with the pipe and then corrosion of casing or liner and leaks that way. Contributing factors here would be the choice of steel grade for the pipe. If you expect for example CO2 (or even worse, H2S) as a possible source that could corrode your pipe, you should choose a steel grade that is resistant to CO2 corrosion. If you do have CO2, but not casing hardware that is CO2 resistant, the steel grade could be one of the root causes of the leak.



Routes for fluid leak in a cemented wellbore.

1 *between cement and surrounding rock formations,*

2 *between casing and surrounding cement,*

3 *between cement plug and casing or production tubing,*

4 *through cement plug,*

5 *through the cement between casing and rock formation,*

6 *across the cement outside the casing and then between this cement and the casing,*

7 *along a sheared wellbore. After Celia et al. (2005) and this paper.*

What to do

Leakage is very likely to occur sooner or later in a well. What do you need to think about when you observe a leak? Well, some things are obvious, some, not so much;

1. Very few leaks start out dramatically, so you normally have time. Priority is how to secure the well, so your secondary barriers must be checked and verified.

2. Leaks do not go away by themselves, if they do, it is because of Murphy's 2nd law; meaning that it doesn't fail right now so that it can fail much worse at a later stage, or as bad but at a much worse time.

3. If the leak is in a valve or seal that can be replaced, then replace it. But do double-check that type, size, temperature etc. is the correct for the intended use. Very often the leak is due to installation issues, but it could have other reasons.

4. Use the time to establish FACTS about the type of leak and where the leak is coming from. Do not assume things! Fixing it at the source is normally the best choice, but not always possible. The obvious reason for a leak is often the problem, BUT not always. Note also that when you establish the root cause of the leak, this could be very valuable for other wells in the area. Often the root cause can be traced back to the construction phase of the well, if other wells in the area are still being constructed, you may still be able to do something to prevent them from leaking for the same reason. Either it be changing casing material or raise the TOC, using a better quality type of cement, better centralization etc. Again, it is normally a lot easier to prevent a leak in the first place than repairing it later.

5. Leaking cement plug. Repairing cement with more cement is not always the best solution. Although the cement (or lack of it) may be the reason for the leak, repairing this with more cement is not always the best choice. It may however be the quick and easy choice, especially if you are still in the phase of the well where there is cementing equipment and an operator on the rig. Most problems with cement plugs are not the cement itself, but the problems in placing the cement intact and effectively where you want it. So before you pump another cement plug, consult carefully a best practice guide for cement plugs.

6. A small blip in your cement bond log doesn't mean you have communication that is determinantal to your well, and it certainly doesn't mean that you will fix it by perforating and try to squeeze cement in. Most likely you will make it worse. Squeeze cement jobs rarely works, really! Unless you have a serious lack of cement behind the casing and you manage to do a proper circulation

6 squeeze. I remember working on a rig where any small blip in the CBL led to a squeeze cement job. I put a balance plug down across perforations in the casing and squeezed cement till pressure came up. As long as an increase in pressure was observed, the squeeze was determined to be successful, no new CBL was ever run, seemingly they did not give “reliable” results after a squeeze job. Often I pumped less than 10 bbl of cement slurry with water ahead and behind. I feel I was lucky even getting a pressure build-up. Regardless, the most you can hope for is that the cement goes into the perforations enough to at least seal them off. Attempting to squeeze cement into cracks smaller than 300-500 µm simply isn’t possible and even specially formulated micro cement do not enter cracks smaller than 150 µm. If you have cracks in cement or deal with a microannulus, the openings are likely to be well under 150 µm.

7 If you have hole in the casing, a patch or straddle packer could fix your leak, tie-back liner as well, but it is worthwhile to investigate a bit on the reason for the hole. All the listed options are large and expensive ones requiring a rig in most cases. If you suspect it is due to external corrosion in the casing, you may also have only “patched” the problem and the root cause, possibly corrosive gas or fluids contacting the casing, will continue and later make more holes. It could in these cases be a very good idea to squeeze a sealing fluid into the hole that can move through the tiniest communication channels and seal them up, preventing corrosive fluids from migrating to the casing and continue the corrosion.

8 In retrospect, it is easy to see that to spend time planning and executing the construction of the well and particularly the primary cement job in an optimum way rather than fixing it later, is the preferred way of doing things. Constructing a well is complicated and expensive business, it is often tempting to take some short-cuts at some stage that seems OK and insignificant, but can lead to big problems later in the life of the well. Another very important, but often forgotten aspect of planning is that although the plan maybe good and well executed, if somebody (normally for good reasons) at a later stage suddenly wants to use the well in a different way (injector instead of producer for example), all the good planning and execution can then be wasted.

Wellcem AS

Orstadveien 108
N-4353 Klepp stasjon
+47 52 98 65 00
post_no@wellcem.no
www.wellcem.no

About the author

Svein Normann has a MSc from the Norwegian University of Science and Technology and 27 years' experience in the oilfield. 10 years in field operations as cement operator, design engineer and operations manager. Further on 16 years in oilfield equipment engineering and development. He is today working as senior project engineer at Wellcem AS.