BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LX No. 4A/2008	101 - 108	Seria Tehnică

Compliance of "Sandaband" with the Barrier Concept in Well Abandonment

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Abstract

The scope of this paperwork is to review the compliance of "Sandaband" with the barrier concept from the rules and regulations for well abandonment and suspension in Romania and UK, when using Sandaband material as a well barrier element in suspension and abandonment operations. A comparison has been made with Norwegian NORSOK standards because UK rules have been developed following closely this standard. In Romania the ANRM instructions are mentioning only how to deploy the cement plugs for such activities and no further references to non-conventional materials have been made[1] .

Key words: *well, suspension, abandonment, Sandaband ,barrier*

Introduction

Sandaband is a Bingham plastic fluid and is a relatively new and patented product in the market to improve the efficiency in abandonment of wells. The product is based on special blend sand slurry, which through its low permeability and high specific gravity works as a plugging material. The product is protected by an international Patent, [4]. Sandaband Well Plugging AS from Norway is holding a licence to use this product.

Sandaband consists of about 70-80% by volume of solids, together with about 20-30% of water and other fluidising additives. Its rheology can be characterised as Bingham plastic. Sandaband mixture is a solid inside a liquidized annulus of itself when it is in motion, otherwise it's a deformable solid. Fig. 1 shows Sandaband volumetric particle distribution.

The *Sandaband* technique for abandoning wells has previously been marketed as a temporary means of plugging the well, due to the fact that a *Sandaband* plug also is easy to remove when the temporary suspension period is over. However, as opposed to most other materials used in the plugging of wells, the plug formed through *Sandaband* has an effect where the properties to function as a barrier element do not deteriorate over time. It consists exclusively of material, which is not biologically degradable over time. Hence, it could be used for permanent plugging and abandonment of wells.

Other applications have also previously been marketed, like *Sandaband* used instead of primary cement behind casing, etc. The full description of the technique and material that is used can be found in [4].

In Romania well suspension and abandonment is carried out following regulations from Agenţia Naţională pentru Resurse Minerale and the instructions to follow are grouped under "Instrucţiuni tehnice privind avizarea abandonării/ridicarea abandonării sondelor de petrol şi progamul de de asigurare a sondelor propuse spre abandonare şi abandonate"[1].

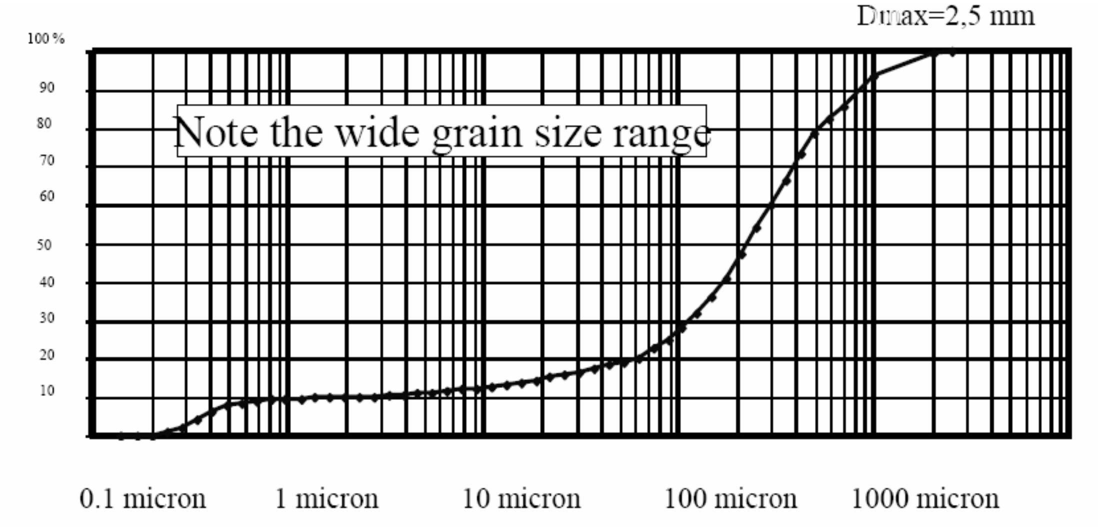

Fig. 1 Sandaband volumetric particle distribution

In UK well suspension and abandonment operations follows a set of guiding documents grouped under UK Offshore Installations and Wells (Design and Construction etc) Regulations 1996, commonly known as DCR [2]. Abandonment of wells in the UK is carried out under Oil and Gas UK, (formerly known as UKOOA – United Kingdom Offshore Operators Association) Guidelines for the Suspension and Abandonment of Wells, which were generated to help operators to comply with the requirements specified within DCR.

Experimental Details and Results

Gas Migration Test

The purpose of this test is to demonstrate that even if the Sandaband does not have the property to bond to the casing it can provide the required gas tightness.

A Sandaband slurry has been tested for gas tightness by Intertek West Lab on behalf of SWP at bottom hole temperatures of 19°C, 40°C, 80°C, 120°C, 160°C at an angle of 45° and 75°. The Sandaband slurry had a density of 2200kg/m^3 and 2050 kg/m^3 when it was mixed with 6% by weight of Starglide (lubricant). The next table is summarising the tests results:

Table 1. Gas migration tests results (pure Sandaband slurry)

Test Condition		Differential Pressure - bar (Pressure gradient – bar/m)		
Temperature - °C	Inclination - °	Original Sandaband	Hydrostatic contribution – bar/m	Yield contribution – bar/m
19 (ambient)	0	0,47 (0,35)	0,21	0,14
40	0	0,47 (0,35)	0,21	0,14
80	0	0,47 (0,35)	0,21	0,14
120	0	0,48 (0,36)	0,21	0,15
160	0	0,51 (0,38)	0,21	0,17
160	45	0,39 (0,29)	0,15	0,14
160	75	0,26 (0,19)	0,06	0,13

Table 2. Gas migration tests results (Sandaband slurry + lubricant)

Test Condition		Differential Pressure – bar (Pressure gradient – bar/m)		
Temperature - °C	Inclination - °	Sandaband added 6 % Starglide	Hydrostatic contribution – bar/m	Yield contribution – bar/m
19 (ambient)	0	0,35 (0,26)	0,20	0,06
78	0	0,35 (0,26)	0,20	0,06
160	0	0.35 (0,26)	0,20	0,06

Friction Reduction Test

Friction reduction testing has been performed by Intertek West Lab on samples of Sandaband slurry without lubrication and Sandaband slurry with 6% by weight of Starglide (lubricant). The temperature had increased during testing from ambient to 78°C and the pressure had increased up to 320bar in the same time. The friction coefficient for Sandaband without Starglide – 0.105027 was reduced two times for Sandaband with Starglide – 0.052513. Some lubricant has been observed floating after the test has been finished so, it can be recommended, to reduce the Starglide content to 5% by weight. The pertinent conclusion of the test is that Starglide is working well as a lubricant in Sandaband slurry.

Onshore Pumping Test

SWP has been contracted by StatoilHydro to test the Sandaband Product containing 5% weight of Starglide. All tests have been related to Statfjord B well 33/12-B-42AT2 and have been done as a preparation before pumping Sandaband into the B annulus (9-5/8"X11-3/4"). The decision to add Starglide has been made to reduce the risk of premature plugging in the B annulus by Sandaband due to its high yield point and high plastic viscosity.

The 3 main objectives for the test were:

- Determine Sandaband's plastic viscosity and yield point
- Pump through an annulus with same dimensions as the tightest spot in the well
- Simulate pumping through the wellhead, and check for wear, tear and erosion of casing hanger

A total of 4 pumping tests have been performed and all the objectives of the test have been accomplished.

In the first test, Sandaband slurry was pumped through an 80m coiled flexible hose staging the flow rate from 203LPM to 650LPM. A total of 8.75m3 of slurry was pumped; the temperature of the slurry increased noticeably during the test and a decision was made to stop the test and repeated it again but with the hose uncoiled. This operation has been performed in test four. Pertinent rheology data has been calculated from the Pressure-Pump rate diagram raised after the test:

- Plastic Viscosity (PV) = 776cP
- Yield Point (YP) = 71.4 lbf/100sq.ft.

The second test had the purpose to demonstrate that Sandaband can be pumped through an annulus with the same dimensions as the tightest spot in the well. Between the 9-5/8" and 10-3/4" casing strings there is only a 9mm gap if they are perfectly cantered. A device which copied the real situation was manufactured; a volume of 106.4m3 was pumped at an average rate of 601LPM during a 3 hours period and the average pressure dropped by more than 10bar. The temperature in the slurry was very hot towards the end of the pumping session. The manufactured annulus element was opened and the inner pipe recovered. There was no evident wear or tear on the pipe. This apparent lack of erosion has been seen on all previous performed pumping tests and operations.

The third test had been engineered to simulate the erosion tendency on the casing hanger. More than 110m3 of slurry were pumped at a rate greater than 600LPM. Erosion had taken place and had made a gentle and circular groove approximately 3mm depth in the plate. The central part of the plate showed little if any erosion.

Long Term Gas Migration Test

The test was performed by Intertek West Lab on behalf of StatoilHydro who wanted to determine if Sandaband is a suitable solution for the development of one of their fields. The scope of the test has been to determine the followings:

- The maximum gas gradient that Sandaband can hold back
- If the test gas (nitrogen) migrates into Sandaband over time
- Establish failure modus when maximum gas gradient is exceeded: column movement / break through
- Establish whether Sandaband maintains its gas tightness upon relative movement of the pipe, included by subsidence
- Establish whether Sandaband maintains gas tightness during simulated production induced vibrations
- Establish that Sandaband self repairs and becomes gas tight after the break through test

The tests have been performed on Sandaband slurry under various outdoor temperatures and under atmospheric pressure and under 37 bar of pressure. A test (February) where the Sandaband slurry contained antifreeze and another test (March) done in sub-freezing temperature has failed. The tests have been rescheduled in April and have been shown good results.

The Sandaband slurry was tested for bonding after has been kept under approximately 37 bar and the pull force was 10 ton. This indicated good bonding.

The slurry was under test for 4 hours, with a vibrating device located in the test column, and Sandaband maintained its ability to hold back the gas pressure.

The tests have been repeated in May 2008. The break-through pressure was 3.28bar (a gradient of 0,27bar/m). The slurry was left under approximately 2bar (0,16bar/m) of pressure for a week and no gas migration was observed. The pressure was increased again and the break through limit was 3.13bar (0). This proved that Sandaband has the ability to self repair after a break through.

A reversed pressure test has been also performed on Sandaband. In 3 days time a total of 5 litres of fluid had been collected from the outlet at the bottom of the Sandaband column. Approximately 1.5bar (21.76 psi) of differential pressure has been held above the Sandaband column.

Conclusion: the Sandaband slurry is, despite the amount of free fluid, gas tight under the conditions it was tested.

Barrier Concept Compliance

The following, table 3, is a comparison of the compliance of a Sandaband plug vs. the requirements for acceptable permanent barriers in Oil and Gas UK Guidelines and in NORSOK D-010, Section 9.3 – Well Barrier Acceptance Criteria. The table shows Sandaband compliance with the UKOOA Guidelines for Suspension and Abandonment of wells.

Table 3. Comparison Table Regulatory Agencies – Sandaband

Acceptable Permanent Barriers In UKOOA (Oil&Gas UK) Guidelines	Well Barrier requirement in NORSOK	Sandaband Compliance	Condition	Comment
Function and type		-		Referenced req's related to barrier framework only
Positioning	Positioning	Like for cement, the verification of its position may be a challenge.	Relies on other measures to place in correct position.	Sandaband is positioned in a fluidized state.
Materials	Materials	OK	Continuous mechanical disturbance/penetration of plug will prevent it from setting out	The long term integrity is in order as material plug consists of non-degradable material.
Leak testing and verification	Leak testing and verification	OK	Pre-job testing of new Sandaband blends is required to verify its design under the planned installation conditions.	Insufficient empirical data from positioning of Sandaband plugs is at time of writing available to make job performance data a reliable means of documenting proper installation.
	Sidetracking	-		

	Suspension	-		
	Temporary abandonment	-		
Permanent Well Barrier				
Very low permeable to prevent flow of hydrocarbons or overpressured fluid through barrier	Impermeable	OK	Sandaband plug must be designed with a minimum length to account for differential pressures and hole angle.	Gas tightness has been verified during test, and is subject to proper composition of the Sandaband blend, as well as minimum plug length.
Long term integrity	Long term integrity	See "Materials" above	UKOOA: long lasting isolation characteristic of the material, not deteriorating over time.	
Non – shrinking	Non – shrinking	OK	UKOOA: to prevent flow between the barrier plug/casing annulus	The Sandaband slurry settles and forms final shape within few minutes.
Ductile, non-brittle material	Ductile	OK	UKOOA: to accommodate mechanical loads and changes in the pressure and temperature regime	The ability to withstand movements is good as it is non-curing. I.E. it can return to a fluidized form, reshape and settle again.
Resistance to downhole fluids and gases (CO_2, H_2S, HCs, etc.)	Resistance to chemicals, etc.	OK		The additives used for improving the ability to place the Sandaband slurry are not designed to last over time.

Able to bond to the casing or formation in which is placed	Wetting/bonding	It has similar wetting properties as sand.	Requires permanent "floor" which supports its placement and position.	Does not bond to steel. Gravity force, however, keeps it in place. (S.G. is around 2.3 in fluidized form.

In analysing the findings in the above table (Table 3), two issues are highlighted. One is that Sandaband is not bonding to the casing or formation, but the gas migration tests performed by Intertek West Lab on SWP request shows that the product can withstand big pressure gradient (The vertical hydrostatic component of a Sandaband fluid is 0.22 bar/m (TVD), whereas the pressure required to shear a plug amounts to 0.14 bar/m "along hole" in a 4" hole, total of 0,35bar/m), In addition the full scale test performed by Intertek Westlab showed a very good bonding when lifting the inner pipe in the test rig. This evidence furthermore proves the ability of Sandaband to provide a viable permanent barrier between the reservoir and the seabed.

Another issue is that Sandaband plug must be designed with a minimum length to account for differential pressures and hole angle. This issue can be easily overcome at the design stage: Sandaband plugs with the other fluids (brine, mud, etc.) present in the well should have a greater hydrostatic pressure than virgin reservoir pressure.

Conclusions

There appears to be no formal requirement that prohibits the use of *Sandaband* as a method to plugging wells in the UK and Romania. Although the requirements that specifically apply in Oil and Gas UK Guidelines for the Suspension and Abandonment of Wells**,** currently refer to Cement Plugs as the only recognised permanent barrier element, it also opens up the options for use of other materials. The condition is that "Alternative materials should generally conform to the requirements" that are listed in Section 5.1, Barrier (Plugging Material) Requirements: "The long-term integrity of materials should be documented. Once placed, there should be a means by which the barriers can be verified." [3]

Regarding the ANRM instructions, nothing is mentioned about the use of other non traditional materials. The only materials specified are sand to plug the perforations and cement to do the required cement plugs [1].

The following items need to be taken into account during the planning of well abandonments or well suspensions:

- A suitable Risk Assessment for the use of a "non-traditional" material such as a *Sandaband* (a Bingham plastic type material).
- Documentation, standardisation and structure for a *Sandaband* application.
- An observation process.

References

1. *** - A.N.R.M - *Instrucțiuni tehnice privind avizarea abandonării/ridicarea abandonării sondelor de petrol şi progamul de de asigurare a sondelor propuse spre abandonare şi abandonate.*
2. *** - Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996 (Statutory Instrument 1996 No. 913)

3. *** - Oil and Gas UK *Guidelines for the suspension and Abandonment of Wells*, Issue 2 July 2005.
4. S v i n d l a n d , A . - *Method and plugging material for reducing formation fluid migration in wells*, Patent No. 6,715,543.

Conformitatea produsului “Sandaband” cu conceptul de barieră în abandonarea sondelor

Rezumat

Scopul lucrării este de a verifica dacă produsul “Sandaband” îndeplineşte cerințele conceptului “barieră” în cazul abandonării sondelor, cerințe provenite din instrucțiunile de abandonare a sondelor dinRomânia şi Marea Britanie. Articolul face o comparație între standardul norvegian NORSOK si cu cel din Marea Britanie pentru că cel din urmă este dezvoltat după primul. În România, instrucțiunile ANRM meționează locul unde trebuie instalate dopurile de ciment, dar nu precizează nimic despre materialele neconvenționale care ar putea înlocui cimentul în abandonarea sondelor.