Beyond API: How to Evaluate Industry Standards for Practical Applications Improving Cementing Fluid Designs and Testing Accuracy

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Abstract /

A standard can represent the foundational instruction for performing any task consistently and enabling repeatable results. Laboratories, as well as personnel, can apply the practices and techniques documented in standards without the knowledge of the intent — how it relates to managing the risk at the well site and achieve the execution success. Within standards there can be instructions, which have resulted from field experience, helping to improve the representative test conditions in the laboratory to overcome risks previously identified.

As well operations evolve, cement placement and the resulting laboratory testing evolve, aligning with standard organizations using a reaffirmation process for documents over time. As standards tend to omit acceptance or evaluation criteria due to differences of opinion across the industry or potential misinterpretation by regulatory agencies, this article serves as a complimentary document helping to identify risks during well site execution and a means to optimize designs with suggested evaluation criteria as well as test method modifications when applicable.

Introduction

The term cementing standards can represent a series of documents with the domain accounting for differences in the scope as well as the instruction. The intent of this article focuses on cementing laboratory testing standards, which are classified as a recommended practice as opposed to document nomenclature, which details specification or standard.

Most operators enforce cement laboratory testing standards, as the portfolio of wells can vary across regions and continents, which require the use of multiple laboratories from different service companies. The standards attempt to bring efficiency in the form of consistency and repeatability in the laboratory testing results. The industry standard that receives the greatest usage and reference for cement laboratory testing is the API RP 10B-2[1], which used to align with a previously co-branded document, ISO-10426-2[2]. The document in reference is the intent of the guidance presented within this article.

Application and Evaluation

The recommended practice details testing instruction to provide a comprehensive evaluation of cement and spacer for use in well operations. The practices provide the who, what, and where, and limited guidance on the why, and can avoid the how — how can the laboratory data help evaluate the well site execution risks?

The following information reflects the author's view of the most applicable practices, which additional guidance could improve the process of cement design optimization, testing accuracy for representative field conditions, and minimize risk to the well site execution success.

Mixing Time

During the preparation of a cement slurry, there are two periods that compose the total mixing time process; target shear rates of 4,000 revolutions per minute (rpm) and 12,000 rpm. The focus centers on the lower shear rate period, representing the ability of a cement to properly wet solids upon the addition to the mix fluid and create a resulting vortex. As cement designs today vary with the increasing placement requirements, it is not uncommon to exceed 15 seconds to achieve the required wetting.

The results provide insight on the ease in which mixing the cement in the field may observe, specifically risks for continuous mixing (on-the-fly) during pumping over static mixing (batch) before pumping. Table 1 provides guidance and evaluation criteria to determine the degree of field mixing risks the cement design may present.

It is important to understand the likely cause of a mix time, such as a high solids content, the particle sizes of the solids used, the additive chemistries, and the behavior during the order of addition when added to the mix fluid or similar considerations. There are previous work efforts that discuss other considerations of the mixing energy as well as the mix time on the cement properties[3].

Table 1 *Laboratory mixing risk analysis for cement.*

Risk	Mixing Time	Criteria	Field Mixing Method
None	15 s or less	Acceptance	On-the-fly
Low	16 to 30 s	Identify likely cause for acceptance	On-the-fly with caution
Medium	31 to 45 s	Redesign depending on cause	Batch
High	46 s or more	Avoid the use if redesign is not possible	Batch

Compatibility

Having compatible fluids during cement placement is important to minimize the risks of excess viscosity, flocculation, settling, separation, or similar incompatible behavior, which can affect the isolation requirements, or in the worst case, lead to premature job abortion. In the recommended practice, admixtures using varying contamination ratios between the cement, spacer, and mud help identify each admixture behavior over a series of possible tests to evaluate the degree of compatibility.

The focus is on the rheological behavior of the admixtures to primarily determine whether the spacer design is sufficient to act as a compatible medium between the cement and the mud. Though some methodologies for compatibility emphasize a fixed shear rate or a series of calculations to arrive at a representative shear rate in the annulus, it limits a comprehensive view of the system compatibility, which can increase the risk to the job success.

Table 2 provides guidance and evaluation criteria to determine whether the design of the spacer is suitable across the complete range of admixtures, which can help overcome the risks of incompatible behavior. Although, Table 2 does not account for three-way admixtures.

Table 3 shows an example of admixture data used to identify compatibility risks using a similar methodology discussed in Table 2.

Engineering judgement should help provide clarity for circumstances that may not fit with the guidance in Table 2, such as the effects of high solids content fluids compromising an admixture. For these cases, alternative methods should determine compatibility.

Wettability

Spacers use surfactants and other cleaning solutions (surfactant package) to achieve favorable bonding surfaces in the annulus when muds contain nonaqueous fluids. When a spacer design creates a water-wet surface in the annulus, it can help mitigate the risk of improper bonding due to oil-wet surfaces. Recommended practices discuss up to 75% by volume of spacer to demonstrate a water-wet conductivity value of the mud spacer admixture before considering a redesign. The chemistries of the oils used today to improve drilling performance can present challenges to achieve water-wetting as the industry works to find new chemical solutions to improve the cleaning efficiency.

Considering these challenges, it is important to minimize the risks associated with oil-wet surfaces affecting the degree of isolation that could be achieved. Table 4 provides guidance and evaluation criteria to determine the wetting efficiency of a spacer design.

Having a water-wet surface under laboratory conditions may not equate to downhole performance, as it can be a function of spacer volume, displacement rate, displacement volume, annular configuration, contamination, as well as temperature. A spacer design, for a given application, should account for contributing factors, which could prevent achievement of the isolation requirements. There are alternative methods in use to evaluate wettability, though these are not part of the recommend practice[4].

Sedimentation Test

The sedimentation test helps to demonstrate the stability or risk of instability for a cured cement design at the anticipated downhole conditions. The recommended practice discusses making comparisons of the cured density to the mixed density across the sample to investigate the stability risks. The mixed density at the surface of the unset cement can vary from the cured or set density due to the in situ fluid consumption during the curing process. As a result, the density comparison of the cured cement segments between each other can help evaluate the settlement risk.

Table 5 provides guidance and evaluation criteria to determine the risk of instability for a given cement design after curing at

Table 2 *Compatibility risk analysis (rheology).*

Risk	Criteria	Redesign
None	No admixture greater or less than each corresponding ad-mixture	No
Low	No admixture exceeds 100% of the baseline fluid	No
Medium	An admixture exceeds ± 25% of the 100% baseline fluid	Recommended
High	An admixture exceeds ± 50% of the 100% baseline fluid	Yes

Table 3 *An example of a method to identify compatibility risks using admixture rheological data.*

	Mud 100%	**Mixture Ratio (Average Reading)**					**Spacer 100%**
RPM		**95%:5%**	**75%:25%**	**50%:50%**	**25%:75%**	**5%:95%**	
300	76	79	80	71	64	62	60
200	56	59	65	55	53	56	51
100	36	38	47	39	42	45	38
60	26	28	38	32	36	39	32
30	19	20	29	24	31	33	26
6	12	12	17	16	21	22	17
3	10	10	15	14	19	19	15
10 min Gel Set	18	—	—	—	—	—	18
Ty	12	17	28	24	32	35	19
Compatibility Results		OK	Attention	OK	Redesign	Redesign	

	Spacer 100%	**Mixture Ratio (Average Reading)**					**Spacer 100%**
RPM		**95%:5%**	**75%:25%**	**50%:50%**	**25%:75%**	**5%:95%**	
300	60	64	84	125	170	185	186
200	51	56	72	98	132	141	139
100	38	47	55	69	84	86	84
60	32	41	46	54	60	61	57
30	26	34	37	39	36	38	34
6	17	23	23	20	20	13	13
3	15	19	19	15	12	10	12
10 min Gel Set	18	—	—	—	—	—	24
Ty	19	36	37	33	29	24	15
Compatibility Results		Redesign	Redesign	OK	OK	OK	

Table 4 *The wettability risk analysis of a spacer design.*

Risk	**Criteria**	**Redesign**
None	< 30%, no significant viscosity increase, no change in rpm	No
Low	< 40%, no significant viscosity increase, change in rpm ± 25%	No
Medium	< 50%, no significant viscosity increase, change in rpm ± 25%	Recommended
High	< 60%, slight viscosity increase, change in rpm ± 50%	Yes
Extreme	> 60%, significant viscosity increase, change in rpm > 50%	Yes

Table 5 *The risk analysis for instability of a given cement design.*

Risk	Density Difference between Any Segment	Redesign
None	No more than or equal to 0.25 ppg	No
Low	No more than or equal to 0.50 ppg	No
Medium	No more than or equal to 0.75 ppg	Recommended
High	More than 0.75 ppg	Yes

the anticipate downhole conditions. Understanding the cement design composition in comparison to the results should help when using Table 5 to evaluate risks.

Thickening Time Test

The cement thickening time can represent the available placement time before the gel strength development prevents further movement under dynamic test conditions. Some tests incorporate a custom schedule to vary the motor speed for well operations, i.e., static or planned shutdown periods, allowing additional monitoring of the gel strength development upon resumption of dynamic conditions to ensure there is an appropriate safety margin to achieve the placement objectives.

The more notable static periods, i.e., a motor off period, account for downhole equipment operations where the cement could develop premature gel strength. The recommended practice allows accountability for the static periods, but the completion of the testing uses the dynamic test conditions to evaluate the Bearden units of consistency (Bc) evolution over time, or the set profile of the cement.

For most conventional cement designs, the recommended practice of using the dynamic conditions until the test completion satisfies the concern or risk of an adequate safety margin to ensure the placement objectives can be met. Extended and thixotropic cement designs, for example, may not be exposed to sufficient temperature or pressure, may contain a low cement to water ratio, or the design struggles to represent the performance ability to satisfy the placement objectives under the dynamic test conditions. The industry considers the designs to have a gel set or extended set, where Bc reporting could be misleading, such as a time to 70 Bc or 100 Bc, representing hours of additional placement time not available.

Conversely, it is important to recognize when a cement design has built sufficient gel strength to proceed with subsequent operations such as wait-on-cement time, pressure testing, or wellhead management. Figure 1 is an example of an extended cement, under similar conditions previously discussed, having a thickening time behavior representing a gel set. The placement time required is 110 minutes although the testing shows over 12 hours of thickening time under dynamic conditions.

A modification to the recommended practice test schedule allows a more accurate approach to evaluating the risks associated with a gel set thickening time behavior. The modification represents well site operations, which after placement, the cement undergoes static test conditions despite the traditional thickening time testing proceeding under dynamic test conditions. The modification differs from a hesitation schedule, which is a continuous motor on-off schedule.

Introducing an additional static testing period, i.e., a motor off period, to represent the behavior of the cement after placement — for a given time frame — helps validate the cement designs' ability to achieve sufficient gel strength to prevent further movement. A common practice of the method uses a final static test period containing 60 minutes after an additional 60 minutes of safety margin for the placement time under the dynamic test conditions.

The evaluation criteria for determining if the cement achieves similar gel strength performance to being tested under dynamic test conditions without the performance limitations is a spike or rapid increase, exceeding 70 Bc, when attempting to resume dynamic test conditions, i.e., resuming the motor to the on position. It is common for the test modification to result in the locking pin failing, or the spike could be missed on the chart depending on the time interval set for data recording. The technician normally confirms the setting by inspection of the cup upon disassembling.

Other supporting metrics include the use of the internal and external temperature measurements of the cell, which can indicate the heat during hydration. Figure 2 demonstrates the thickening time test modification to Fig. 1, by evaluating the set performance on an extended cement, which struggles to perform under the dynamic test conditions accurately.

Figure 2 represents 110 minutes of placement time with an additional 60 minutes of safety and 60 minutes of shutdown. After the motor went to the on position, the cement exhibits the spike representing the gel strength required to prevent further movement. Similarly, the modification adds value for thixotropic cement designs allowing a more accurate representation after placement of the ability to gel or remain fluid.

More commonly, the schedule can use a 30 minute shutdown period, as an example, for checking gel behavior for set. Optimization of the design using the shutdown schedule supports a better chance of placement success and downhole performance for the anticipated conditions.

Spacer Stability

Compatibility behavior and wettability performance are important to mitigate the risks associated with inadequate spacer design affecting the isolation requirements. Another property with equal importance is the spacer stability under the anticipated downhole conditions. During placement, the spacer experiences static and dynamic periods. The static period is commonly after placement where it contributes to the hydrostatic pressure applied to the cement as it goes through the transition period.

If the spacer is unstable while static, it could affect the cement's performance. An unstable spacer design could demonstrate

Fig. 1 *An example of a thickening time chart with a gel set profile.*

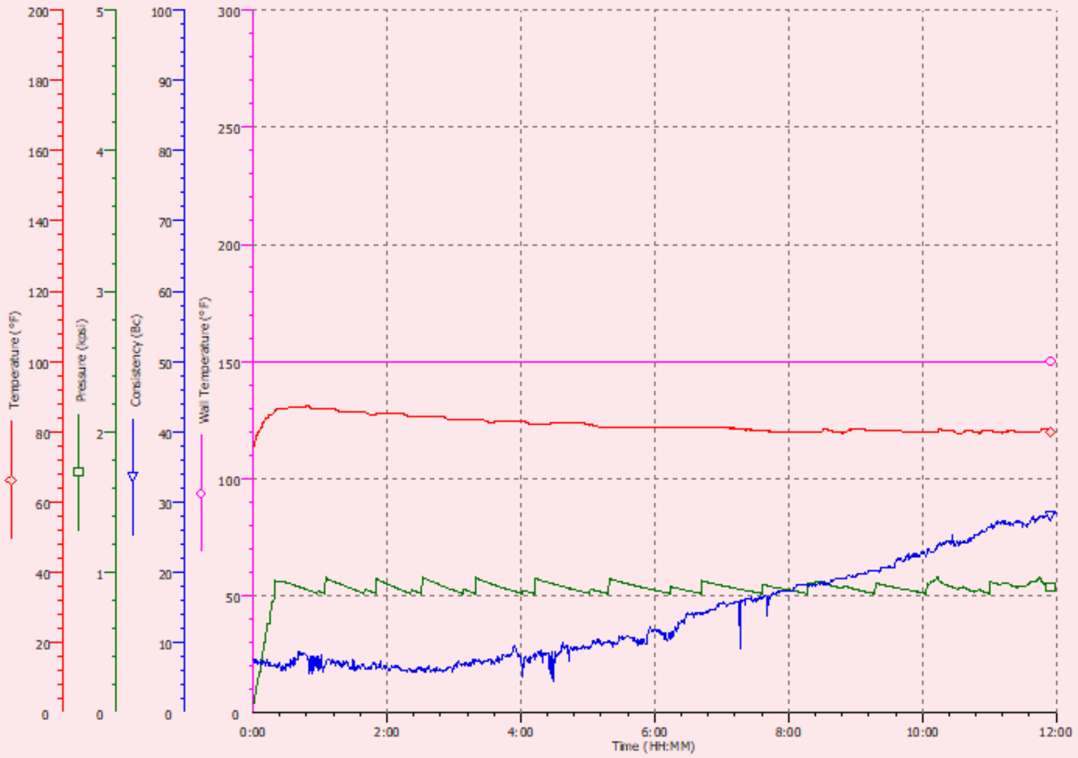
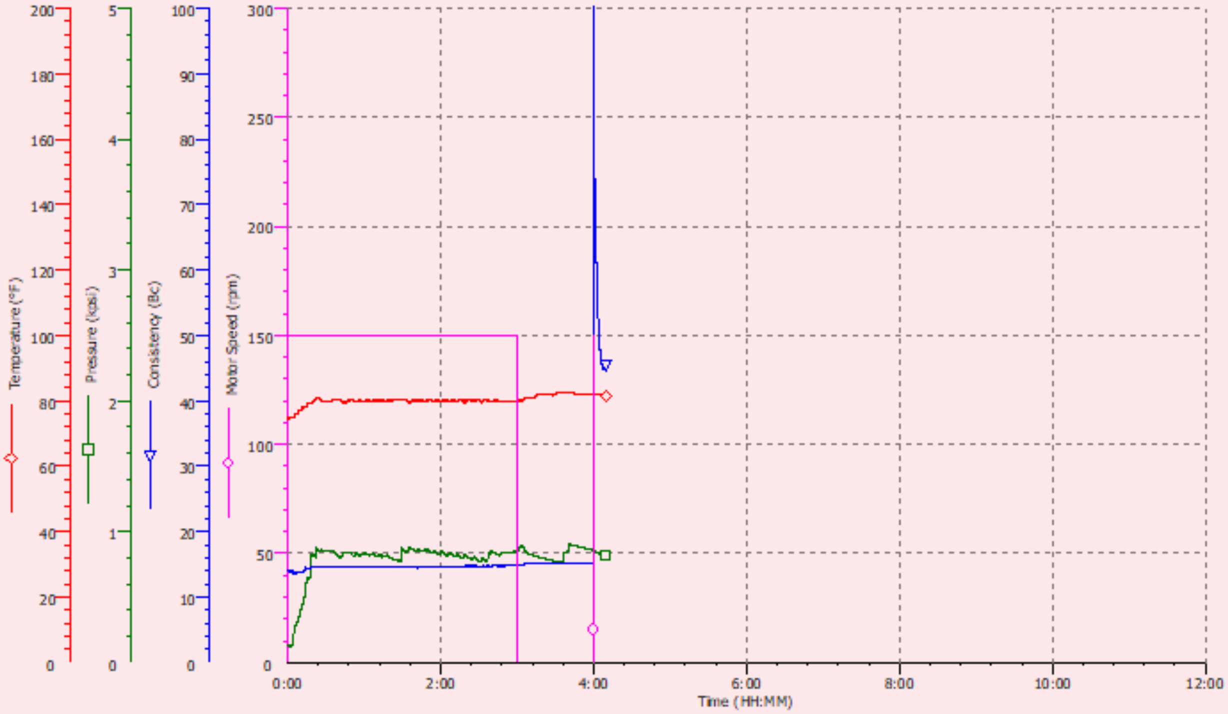


Fig. 2 *An example of a thickening time chart using a shutdown schedule to confirm the set performance on an extended cement.*



settling, separation, unplanned viscosities, or thinning. A sequence of testing modifications to the recommended practice helps evaluate the dynamic and static spacer stability.

Preparation: The preparation of the weighted spacer uses a laboratory bench top paddle mixer with a variable speed controller to simulate field mixing (shear) conditions using an appropriately sized container. The density confirmation uses a calibrated pressurized fluid balance.

Dynamic Test: Similar to the pressurized consistometer used for thickening time, the spacer replaces the cement in the consistometer cup. The spacer testing follows the same schedule as the cement experienced during the placement. For liner applications, the schedule incorporates the static period for downhole equipment operations before circulating out.

The first part of the evaluation is the spacers' ability to demonstrate consistency over time with no indication of unstable behavior seen with cements such as fluctuations of consistency, spikes or significant drops of consistency, approaching 0 Bc during placement, and monitoring the temperature stability as well as other applicable measured trends.

Figure 3 provides an example of an unstable spacer undergoing the dynamic stability test in the consistometer.

Figure 4 is an example of a stable spacer after undergoing the dynamic stability test.

The second part of the evaluation continues after completion of the dynamic testing with visual inspections or observations of the spacer from the consistometer cup to confirm the dynamic test results. The inspections follow a practice of pulling the slurry cup from the machine while keeping it upright, thereby preventing movement of the paddle shaft.

After removing the top cap and pulling the paddle out slowly, there should not be indications of settling or gelling on the assembly. The inside of the cup and bottom cap should have similar inspections performed.

Figure 5 is an example of a stable spacer after undergoing the dynamic stability test visual observations.

Static Test: Similar to the free fluid testing procedure in API 10B-2[1], the spacer from the dynamic testing pours into the graduated cylinder to evaluate the static stability over a two-hour period. If the application has deviation, use similar laboratory practices for angling the free fluid cylinder as part of the evaluation. The first part of the static stability evaluation is free fluid percentage and visual observations. There should be no observations of channeling, settling, or separation. A stable spacer would result in a free fluid value of no more than 2%. If the free fluid exceeds this threshold, evaluate the spacer for risk of use for the application.

The second part of the static stability evaluation is a direct density measurement from the cylinder. A syringe with tubing syphons approximately the top 83 milliliters or the top one-third of the spacer, the middle one-third, and the bottom or final one-third of the spacer. An analytical balance helps determine the density of each part of the spacer. Similar to the slurry stability evaluation criteria, a stable spacer results with no density difference greater the 0.5 ppg across any one-third sample. If the density difference exceeds this threshold, redesign the spacer for improved stability.

Blend Management

Cement blend consistency is important for the outcome of the well site execution and resulting downhole performance of the cement. A homogeneous blend provides a means of laboratory testing accuracy between the field and pilot blends. A non-homogeneous blend increases the risk of the field results, deviating from the pilot testing efforts. There are several aspects of the bulk blending process, which contributes to the accuracy as well as consistency between the field and pilot blends. The recommended practice does not discuss blending practices or a means to evaluate a blend accurately.

Most blending facilities use pneumatic methods, i.e., pressurized or vacuum, to create cement blends. The facility setup or configuration, equipment, and blending techniques influence the blend results. More emphasis should focus on the accuracy of the field blend specific gravity (SG) compared to the pilot blend SG to minimize the risks of inadequate performance during the well site execution and improve the accuracy of the test results.

Facilities using two batch blenders, i.e. scaling tanks, to create a given cement blend provides a greater level of accuracy compared to using a single batch blender. The pneumatic blending technique should use equal part additions for building a blend in the scaling tank with a given order, based upon the bulk quantity requirements, additive SGs, and particle sizes. It is common practice to have the first and last additions represent the largest bulk quantity the blend composes; normally neat cement. A sandwich technique is a common name for using the equal parts addition approach. Table 6 lists examples of using the equal parts blending technique.

Before blending, verification of the additives and the neat cement SGs' minimizes the risks of improper blend SG measurements. Use the information to update the blend component's SG in the given platform, which creates the blend calculations. The resulting blend sheet provides the true or theoretical blend SG; the target for evaluating the blend accuracy.

Blend homogenization is an essential part of the blend's consistency as well as the actual blended SG accuracy in comparison to the theoretical SG. After building the blend in the scaling tank, the preference is to transfer in between another scaling tank providing multiple transfers to intermix and homogenize the blend. It is common to transfer a blend either three or four iterations, depending on the particle sizes and number of blend components, before deeming it suitable for field use. After the third iteration, a sample could be taken to check the SG of the blend to determine if a fourth iteration is required or the fourth iteration allows capturing a composite sample for evaluation.

A pycnometer measures the blend's actual SG, which provides the comparison to the theoretical. To evaluate the actual blend risks to the well site execution, use a tolerance of no more than or no less than 1% from the theoretical blend SG. The tolerance provides an equivalent density variance close to 0.2 ppg for most designs. The industry generally accepts a 0.2-ppg density tolerance for field applications as it should not affect the resulting performance properties at the surface or downhole. If the blend falls out of tolerance, it should have further transfers to homogenize and achieve a value within the 1% tolerance.

Tables 7 to 10 shows designs using freshwater, a cement SG of 3.14 and a silica SG of 2.63. Table 7 is an example of the 1% SG tolerance on equivalent density for a Class G blend with by weight of cement (BWOC) silica.

Fig. 3 *An example of an unstable spacer undergoing the dynamic stability test in the consistometer.*

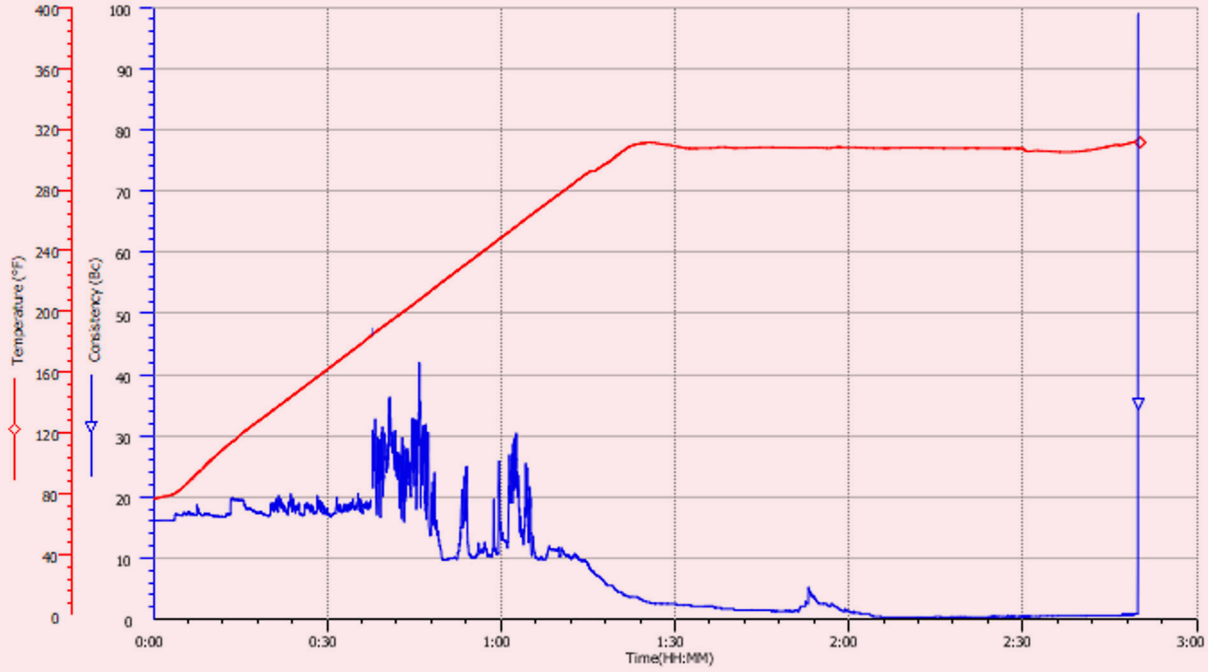


Fig. 4 *An example of a stable spacer after undergoing the dynamic stability test.*

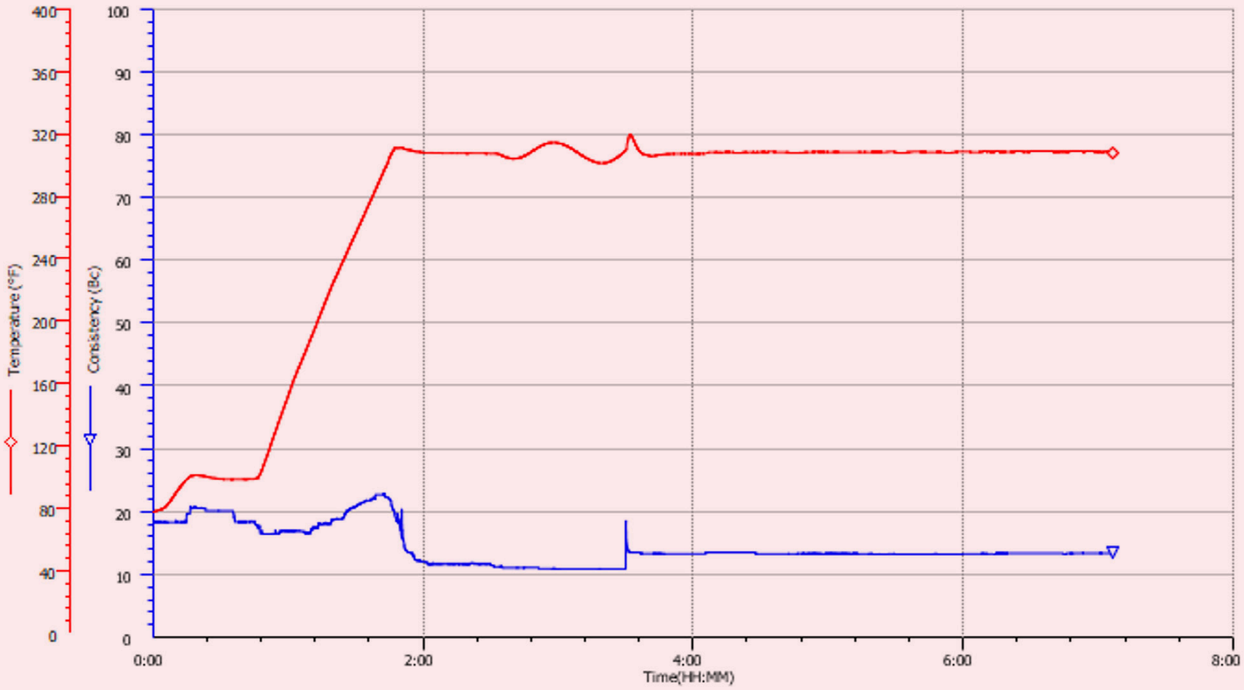


Fig. 5 *Visual observations of the: (a) paddle, (b) inside of the cup, and (c) bottom cap.*

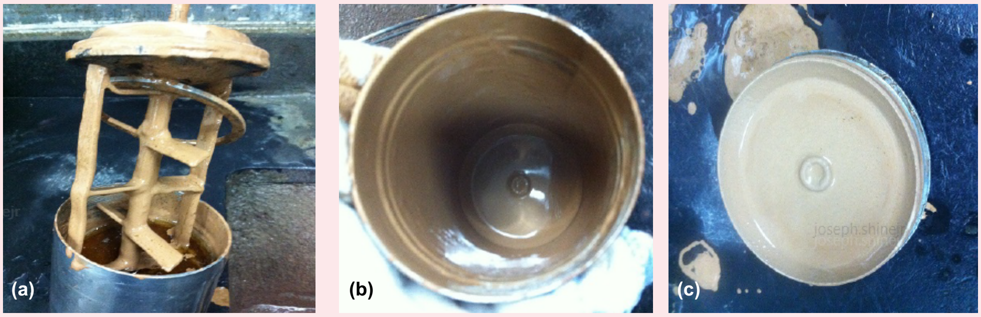


Table 6 *An example of using the equal parts blending.*

Order of Addition	Blend Method 1	Blend Method 2
1	50% Neat Cement	33.3% Neat Cement
2	50% Additive 1	50% Additive 1
3	100% Additive 2	50% Additive 2
4	50% Additive 1	33.3% Neat Cement
5	50% Neat Cement	50% Additive 2
6	—	50% Additive 1
7	—	33.3% Neat Cement

Table 7 also shows that when the measured SG varies by 1% in either direction from the target, what the equivalent solids' percentage the silica represents mixed at the target density of 15.8 ppg. The equivalent percentage of water represents the mixed density to achieve the equivalent percentage of water as the target given the 1% tolerance in either direction for the resulting blend variance. The same methodology applies to the subsequent tables.

Table 8 is an example for a Class H blend and the 1% tolerance effects on mixed density.

Table 9 is an example of a heavyweight blend using Class H and the 1% tolerance effects on mixed density.

Table 10 is an example of a lightweight blend using Class G and the 1% tolerance effects on mixed density.

Liu (2021)[5] has more detailed information on blend management

Table 7 *An example of using a 1% SG tolerance on a Class G blend. (*Gallons per sack of cement. **Ft^3 per sack of cement.)*

Design	Water (gps*)	Water (%)	Yield (cfs**)	Blend SG	Tolerance	Equivalent % Water (ppg)
25% Silica	5.979	53.0	1.432	3.04	1%	15.6
35% Silica	6.331	56.2	1.536	3.01	—	—
45% Silica	6.860	60.9	1.696	2.98	-1%	16.0
15.8 ppg Class G with 35% BWOC silica.						

Table 8 *An example of using a 1% SG tolerance on a Class H blend. (*Gallons per sack of cement. **Ft^3 per sack of cement.)*

Design	Water (gps*)	Water (%)	Yield (cfs**)	Blend SG	Tolerance	Equivalent % Water (ppg)
25% Silica	5.181	46.0	1.325	3.04	1%	16.2
35% Silica	5.476	48.6	1.422	3.01	—	—
45% Silica	5.770	51.2	1.519	2.98	-1%	16.6
16.4 ppg Class H with 35% BWOC silica.						

Table 9 An example of using a 1% SG tolerance on a Class H heavyweight blend. (*Gallons per sack of cement. **Ft^3 per sack of cement.)

Design	Water (gps*)	Water (%)	Yield (cfs**)	Blend SG	Tolerance	Equivalent % Water (ppg)
55% Hematite	6.117	54.3	1.673	3.58	1%	18.3
50% Hematite	5.859	52.0	1.623	3.54	—	—
45% Hematite	5.601	49.7	1.574	3.51	-1%	18.7

18.5 ppg Class H with 35% BWOC silica, 50% BWOC hematite, and 5.0 SG hematite.

Table 10 An example of using a 1% SG tolerance on a Class H lightweight blend.

Design	Water (gps*)	Water (%)	Yield (cfs**)	Blend SG	Tolerance	Equivalent % Water (ppg)
17% Spheres	4.670	49.8	1.71	2.71	1%	11.7
18% Spheres	3.936	42.9	1.65	2.68	—	—
19% Spheres	3.203	36.0	1.59	2.65	-1%	11.3

11.5 ppg 85:15 Class G: Microfine with 18% BWOC spheres, 1.5 gal/sks microsilica, 2.85 SG microfine, and 0.38 SG spheres.
*(*Gallons per sack of cement. **Ft^3 per sack of cement.)*

as well as transferring, sampling, and storage best practices.

Gas Migration

An important aspect of well construction is the cement design for applications where there is a known fluid inflow or gas migration risk during or after placement. There are varying opinions on what constitutes a cement design that demonstrates performance properties helping to mitigate the gas inflow risk through the cement. A common misconception of gas migration control cement is an API fluid loss value of less than 50 cm^3 per 30 minutes, which deems a design gas tight. In addition, some consider a transition time or critical static gel strength period as low as possible or minimized to the extent possible to prevent gas inflow.

API STD 65-2[6] does not discuss a relationship between transition time and the ability to prevent gas migration, but does discuss a value of 45 minutes or less when the flow potential is severe. The flowing fluid is undefined. API RP 10B-6[7] does not discuss or relate the performance testing to the constitution of a design to prevent gas migration either. The recommended practice for the critical gel strength determination provides testing instruction to achieve the transition time results' consistency within the industry and have the end users determine the suitability of a design for the application. A fluid loss of less than 50 cm^3 per 30 minutes and a transition time — as low as possible — may not be sufficient for a cement design to minimize the risk of gas inflow[8].

A direct measurement of the cement designs' ability to pass a gas inflow test helps minimize the risk of gas migration in comparison to using a fluid loss with transition time criteria. There are different equipment configurations across the industry, which can test a cement designs' ability to minimize the risk of gas inflow[9]. Most equipment configurations allow programming to vary the different control parameters such as the confining pressure, gas inlet pressure, as well as the time during the test, to initiate gas inflow. The key criteria to evaluate during these tests is the cement designs' pore pressure vs. time. The pore pressure of the cement should stabilize over the test duration without demonstrating any signs of inflow.

There are two common scenarios to configure the gas inflow test; the test initiates with gas inflow or delays the gas inflow until a specific time, which can relate to a cement pore pressure value. To determine the confining pressure and gas inlet pressure, some considerations include the overbalance between the wellbore fluid and the flow zone, the total pressure reduction during the transition period, and the pressure in which the formation pore pressure equates to the pore pressure of the cement during transition. This improves the accuracy of the results using the most representative or anticipated conditions.

To evaluate a given cement designs' risk of gas inflow, the pore pressure of the cement should achieve a stable value of 100 psi or less for no less than 24 hours. During the hold period, the cement pore pressure should not indicate signs of instability such as gas or flow breakthrough, which would represent a greater risk of gas inflow. It is recommended to continue the test duration for 72 hours to monitor any post-setting affects, which could also demonstrate a risk of gas inflow. Figure 6 is an example of a test result that represents a greater risk of gas inflow.

Figure 7 is an example of a test result that minimizes the risk of gas inflow and would pass the evaluation criteria using a stable value of 100 psi. The cement design in Fig. 7 is the redesign of Fig. 6.

Conclusions

The manuscript serves as a complimentary document to industry standards helping to identify as well as mitigate risks, which may occur during the well site execution process that

Fig. 6 *An example of a gas inflow test result, which does not pass the evaluation criteria.*

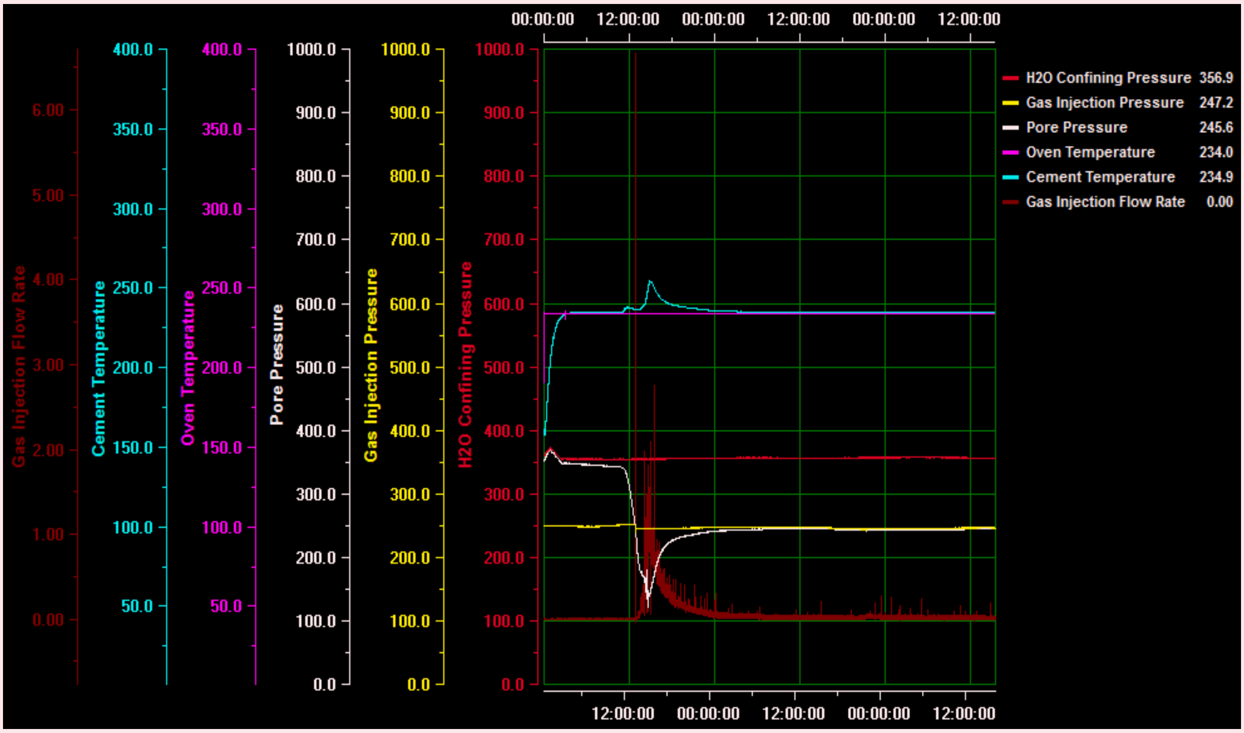
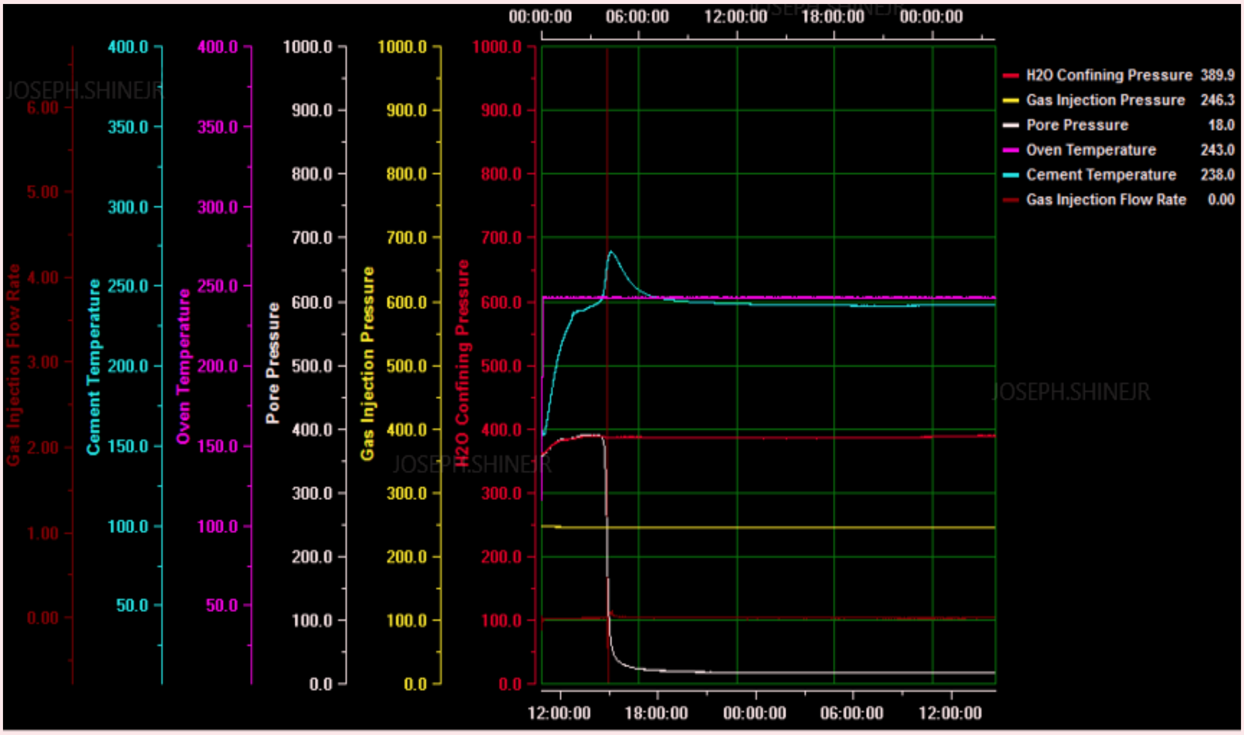


Fig. 7 *An example of a gas inflow test result, which passes the evaluation criteria.*



could affect the isolation requirements. Providing evaluation criteria to several aspects of the cementing laboratory testing standards should improve cementing fluid designs and testing accuracy across the industry.

The article shows how various testing methods, when using specific evaluation criteria for a known set of risks, can be strengthened to help users decide whether a design is suitable for an application or to present risks. Test modifications shown to routine test methods help provide insight on the cement performance to better quantify safety margins to avoid premature gel strength development.

Last, there are topics not covered in the referenced standards that allow for optimization of the well site execution success by minimizing the risks of gas inflow using evaluation criteria for nonstandard testing equipment as well as field blend inaccuracies by applying quality assurance measures at the bulk blending facility.

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