Annex C
(informative)
API Composite Well Cements

C.1 Preface

Composite well cement consists of Portland cement and additional constituent(s) such as silica, fly ash (coal ash), expanded shale or clay and/or other natural, processed or manmade materials that are either blended* or interground. Such composite well cements have been manufactured by cement manufacturers and others and have a long and successful history of use for cementing oil and gas wells. Such composite well cements are appropriate for use for cementing oil or gas wells when used by themselves or when further blended with other materials to enhance their properties to meet the well conditions and all appropriate design and regulatory requirements for mixing, placement and performance in the well.

This annex defines specifications for certain composite well cements that are manufactured by facilities cement manufacturers having a fully implemented recognized quality management system in place that is tailored to cement production but doesn’t preclude the use of other composite well cements as described above for use in wells when such composite well cements meet the requirements of the well.

The physical and chemical specification for API Composite Well Cements of this Annex may be used for reference testing of field blended composite cements before tailoring them to the specific well cement conditions.

Footnote:
* blending — a process in which two or more ingredients are combined into an intimate and uniform product of finely divided dry material, as by special blending equipment. In contrast to this, intergrinding in a (cement) mill additionally involves a comminution respectively grinding process grinding Portland cement clinker with suitable other components to produce the finely divided dry material.

C.2 Specification, chemical and physical requirements

C.2.1 Classes and Grades

C.2.1.1 General

Composite well cements according to this Annex shall be referred to as API Composite Well Cement-s and specified using classes K and L, the first being available in different grades: ordinary (O), moderate sulfate-resistant (MSR) and high-sulfate resistant (HSR).
API Composite Well Cement-s by this Annex shall be manufactured at facilities cement plants having a fully implemented recognized quality management system in place that is tailored to cement production.

API Composite Well Cement-s are obtained by intergrinding Portland cement clinker and one or more forms of calcium sulfate with composite constituents as specified in Clause C.2.2, or by subsequent blending of separately produced Portland cement with separately processed composite constituents as specified in Clause C.2.2.

An API Composite Well Cement- that has been manufactured and supplied in accordance with this Annex may be mixed and placed in the field using water ratios or additives at the user's discretion. It is not intended that manufacturing compliance with this part of API Specification 10A be based on such field conditions.

Processing additives, set modifying agents or chemical additives used to reduce chromium (VI) shall not prevent an API Composite Well Cements- from performing its intended functions shall not be used in producing the API composite well cement.

C.2.1.2 Class K (working title “silica composite”) [TG4]

This product Class K composite well cement is obtained by intergrinding Portland cement clinker and one or more forms of calcium sulfate with silica as specified in Clause C.2.2.1, or by subsequent blending of separately produced Portland cement with separately ground silica flour as specified in Clause C.2.2.1. To the manufacturers discretion another constituent (additive) as specified in any of the Clauses under C.2.2 can be interground or interblended. When added, such other constituents must be reported to the final user by content and type.

This product is intended for use as a basic well cement and is available in O, MSR and HSR grades, depending on the C3A content of the Portland cement clinker being interground or Portland cement being blended to produce the product. For calculation of percentage mass fraction of C3A of clinker the formulas of API Specification 10A, Table 1 apply.

C.2.1.3 Class L (working title “fly ash composite”) [TG6]

This product is obtained by intergrinding Portland cement clinker and one or more forms of calcium sulfate with fly ash as specified in Clause C.2.2.3, or with other pozzolanic material as specified in clause C.2.2.2, or by subsequent blending of separately produced Portland cement with separately processed fly ash as specified in Clause C.2.2.3, or with other pozzolanic material as specified in clause C.2.2.2. To the manufacturer’s discretion Free Fluid may be adjusted by use of Bentonite-bentonite or other water absorbent materials that provide suitable particle suspending properties which when added must be reported to the final user by content and type.
This product is intended for use under conditions when require a lower slurry-density cement slurry will meet the performance requirements.

C.2.2 Composite constituents (other than cement or clinker)

C.2.2.1 Silica

Silica is synonymous with silicon dioxide (SiO2). Silica exists in different forms that can be crystalline (most commonly as quartz) as well as non-crystalline (amorphous)*.

The term silica in the context of this specification refers to crystalline silica only with a silicon dioxide content of at least 90 %. Silica flour or processed silica refers to crystalline sand being ground to a fineness that makes it suitable as a composite constituent for composite cement Class K according to this Annex.

In well cementing under conditions where strength retrogression may occur, finely ground crystalline silica flour, when blended to Portland cement, chemically reacts with the cement during hydration. This helps to preventing compressive strength retrogression and stabilizes permeability of hardened cement.

Footnote:
* A special form of amorphous silica is silica fume specified e.g. in EN 197-1:2011-11 (Clause 5.2.7). This form of amorphous silica is not considered in the context of this specification.

C.2.2.2 Pozzolanic constituents

C.2.2.2.1 General

Pozzolanic constituents are siliceous or siliceous and aluminous materials or a combination thereof, which possess little or no cementitious value but which will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. These compounds are similar to those that are formed in the hardening of hydraulic materials.

Pozzolanic constituents consist essentially of reactive silicon dioxide (SiO2) and aluminum oxide (Al2O3). The remainder contains iron oxide (Fe2O3) and other oxides. The proportion of reactive calcium oxide for hardening is negligible. The reactive silicon dioxide content shall be not less than 25.0 % by mass.

Before using for manufacturing of API composite cements according to this Annex, pozzolanic materials shall be correctly prepared, i.e. selected, homogenized, dried, or heat-treated and comminuted, depending on their state of production or delivery.
Although some fly ashes have pozzolanic properties, they are specified in separate sub-clauses (see C.2.2.3).

C.2.2.2.2 Natural pozzolanic constituents

Natural pozzolanic constituents are materials of volcanic origin or sedimentary rocks with suitable chemical and mineralogical composition and shall conform to C.2.2.2.1.

C.2.2.2.3 Natural calcined pozzolanic constituents

Natural calcined pozzolanic constituents are materials of volcanic origin, clays, shales or sedimentary rocks, which are thermally treated in order to improve or activate their pozzolanic reactivity. They shall conform to C.2.2.2.1.

C.2.2.3 Fly ashes

Fly ash is the non-combustible residue of combustion of pulverized coal and is obtained by electrostatic or mechanical precipitation-separation of fine particles from the flue gases from furnaces.

C.2.3 Chemical requirements

API Composite Well Cements shall conform to the respective chemical requirements as stipulated in the following. Although API composite well cement must meet the requirements as specified here, application conditions must be considered and the cement modified to meet the performance requirements according to those field conditions. It is not intended that this manufacturing compliance be applicable to field conditions. This part of API Specification 10A is not applicable to the use of cements that do not conform to the chemical requirements of classes and grades as set forth in the following.

C.2.3.1 Class K

The manufacturer of Class K is required to calculate and make available to the end user the CaO to SiO2 mole ratio of the finished product. This is to be done for determining the capability of the product to prevent or lessen strength retrogression at elevated well temperatures. Usually such capability is given at a ratio lower than 1,05.

API Composite Well Cement Class K is further specified by sulfate-resistance grades ordinary (O), moderate sulfate-resistant (MSR) and high-sulfate resistant (HSR). The sulfate resistance grade of the finished Class K composite well cement depends on the percentage mass fraction of C3A of the Portland cement clinker or the Portland cement. The first in case the API Composite Well Cement is manufactured by intergrinding the composite constituents, the latter in case the API Composite Well Cement is manufactured by blending
Portland cement with the composite constituents. For calculation of percentage mass fraction of C3A of clinker and cement the formulas of API Specification 10A, Table 1 apply.*

Footnote:
* Generally the formulas of API Specification 10A, Table 1 apply only to the finished cement as an interground blend of Portland cement clinker and gypsum. When applying them to clinker only, the error due to missing the absence of gypsum can be considered as marginal (negligible) for the here concerned purpose of this annex.

C.2.3.2 Class L

The manufacturer of Class L is required to calculate and make available to the end user the CaO to SiO2 mole ratio of the finished product. This is to be done for determining the capability of the product to prevent or lessen strength retrogression at elevated well temperatures. Usually such capability is given at a ratio lower than 1.05.

No further chemical requirements are set for API Composite Well Cement -Class L.

C.2.4 Physical and performance requirements

API Composite Well Cements by this Annex shall conform to the respective physical and performance requirements specified in Table C.1 and in Clauses 7 to 10 of API Specification 10A. When reporting results of specification testing the manufacturer shall always state them in conjunction with the applied mix water percentage at which the conformity (specification?) tests were performed. The composite cement may be used at different mix water percentages and with other modifying additives to meet the performance requirements for the well in which it is applied.
Table C.1 – Summary of physical and performance requirements for API Composite Well Cements

<table>
<thead>
<tr>
<th>Well cement class</th>
<th>K¹</th>
<th>L²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix water, % mass fraction of cement (Table 5)</td>
<td>NR²</td>
<td>NR*</td>
</tr>
<tr>
<td>Free fluid content, maximum, percent (Clause 8)</td>
<td>5.9</td>
<td>5.9**</td>
</tr>
<tr>
<td>Compressive strength test</td>
<td>Schedule Final curing Curing Minimum compressive</td>
<td></td>
</tr>
<tr>
<td>number</td>
<td>temperature</td>
<td>pressure</td>
</tr>
<tr>
<td>(8 h curing time)</td>
<td>(Table 6)</td>
<td>°C (°F)</td>
</tr>
<tr>
<td>(Clause 9)</td>
<td>NA</td>
<td>60 (140)</td>
</tr>
<tr>
<td>Compressive strength test</td>
<td>Schedule Final curing Curing Minimum compressive</td>
<td></td>
</tr>
<tr>
<td>number</td>
<td>temperature</td>
<td>pressure</td>
</tr>
<tr>
<td>(24 h curing time)</td>
<td>(Table 6)</td>
<td>°C (°F)</td>
</tr>
<tr>
<td>(Clause 9)</td>
<td>38 (100)</td>
<td>atm</td>
</tr>
<tr>
<td>Thickening time test</td>
<td>Specification Test Maximum Consistency Thickening Time</td>
<td></td>
</tr>
<tr>
<td>schedule number</td>
<td>Test</td>
<td>(15 to 30 minutes stirring period)</td>
</tr>
<tr>
<td>(Clause 10)</td>
<td>4 (Table 9)</td>
<td>30</td>
</tr>
<tr>
<td>(Clause 10)</td>
<td>5 (Table 10)</td>
<td>30</td>
</tr>
<tr>
<td>(Clause 10)</td>
<td>5 (Table 10)</td>
<td>30</td>
</tr>
</tbody>
</table>

a NR indicates "no requirement".
b NA indicates "not applicable".
c Bearden units of consistency, Bc, obtained on a pressurized consistometer as defined in Clause 10 and calibrated in accordance with the same clause.
d Minimum thickening time.
e Maximum thickening time.
* Mix Water determined by slurry density desired
** Free Water may be adjusted by use of Bentonite or other water adsorbing materials.
¹ Class K is intended for use as a basic well cement commonly associated with Silica. To the manufacturers discretion another constituent (additive) as specified in Clause C.2.2 can be interground or interblended.
² Class L is intended for use when conditions require a lower slurry density.

Footnote 1 – change wording to “... basic well cement requiring silica.”

Footnote 2 – change wording to “... where a lower density cement slurry will meet the performance requirements.”

For clarity, the “minimum” and “maximum” should be put at the heads of the two columns.
NR – I think we need something here, perhaps a note stating that the water requirement for manufacturing and specification testing shall be defined by the manufacturer. The water requirement has to be defined somewhere, otherwise these requirements are meaningless.

Curing Pressure – omit Mpa (psi) as the requirement is “atm”

Delete the “Schedule Number” column for strengths.

I’m struggling with the columns for thickening time Min/Max requirement. Do the columns refer separately to the Min and Max or to the two classes? See footnotes “d” and “e”