



COMPATIBILITIES AND INTERACTIONS

SECTION B9

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B9.1 Compatibility with glass

Concentrated formate brines, like other high-concentration alkaline solutions, dissolve glass, and should therefore never be prepared or stored in commonly used borosilicate glass containers. The extent of dissolution depends on the temperature and exposure time. After exposure to a glass, a white hazy layer of dissolved silicate appears on the bottom of the container. During fluid compatibility testing in heated glass bottles, this can often be mistaken for other precipitate, and the fluids may erroneously be deemed incompatible. Even after short exposure time, invisible chemicals can be released, which may affect laboratory measurements of, for example, corrosion, formation damage, and crystallization temperature. **To avoid creating misleading laboratory artifacts, it is recommended that laboratory glass equipment is not used with formate brines.**

B9.2 Compatibility with tank lining

Coflexip Stena Offshore Limited has tested the compatibility between cesium formate brine and its Coflon series of tank-lining material (Coflexip Stena Offshore Ltd., 2001). Coflon tank-lining materials are compatible with formate brine, and can be used without limits other than the normal supplier-recommended application limitations.

International Marine Coatings has tested compatibility of high-density formate brines with some of its tank-lining products (International Marine Coatings, 1996). The brines tested were concentrated potassium formate brine, concentrated cesium formate brine, and a 50:50 (w:w) cesium / potassium formate brine blend. The following four tank-lining products and schemes were tested:

- Interline 704 at 2 x 125µm dft
- Interline 904 at 3 x 90µm dft
- Interline 925 at 1 x 300µm dft
- Interline 994 at 3 x 100µm dft (ambient cure)

The above were applied by airless spray and cured at 23°C / 73.4°F. Panels were immersed in the test brines for 84 days followed by one day venting and 15 days immersion in seawater.

No failures were observed in any of the tests. Based on these results, Interline 704, 904, 925, and 994 are suitable for carriage of formate brines.

B9.3 Compatibility with subsea control fluids

The subsea control fluid, Oceanic HW740R, has been tested for compatibility with a 2.20 g/cm³ cesium formate brine (MacDermid Offshore Solutions 2004). Oceanic HW740R was tested with cesium formate in the proportions 10:90, 25:75, 50:50, 75:25, and 90:10 for seven months at room temperature. No incompatibilities were found between the HW740R control fluid and the cesium formate brine.

B9.4 Compatibility with thread compounds

Four thread compounds have been tested for compatibility with a 1.92 g/cm³ / 16.0 lb/gal cesium / potassium formate brine (Westport Technology Center International, 1999). The thread compounds tested are shown in Table 1.

Based on API Recommended Practice 5A3 on Thread Compounds for Casing, Tubing, and Line Pipe, two modified test methods were employed:

- TEST A (application / adhesion test)
- TEST B (formate leaching test)

Based on test results, the following conclusions can be drawn:

- The formate brine did not exhibit any noticeable change in appearance when contacted by the thread compounds.
- Formate brine did not leach out any significant levels of chemical species from the thread compounds.
- Results of TEST A indicate that the formate treatment did not significantly affect brushability of the thread compounds.

Table 1 Thread compounds tested for compatibility with cesium formate.

Manufacturer	Product	Features
Bestolife	2010 NM	Low-temperature grade, metal-free
	2000	Cu-containing alternative to API Modified
Oil Center Research	Lube-Seal	API Modified thread compound (1.85 g/cm ³)
	Eco-Seal OCR-325-AG	Bio-degradable, non-metallic petroleum, hydrocarbon and PTFE free (1.18 g/cm ³)

B9.5 Compatibility with flowline gate sealant

A simple procedure was conducted to test a silicon sealant for compatibility with formate brine. The actual sealant tested was VALLANCE – Premium All-Purpose Sealant, which is routinely used to seal off gates in pit rooms prior to using cesium formate brines.

The test involved sealing two metal surfaces together and allowing them to contact the formate brine for a period of three weeks. No penetration or deterioration of the silicon sealant was observed during this time.

It is believed that any general purpose silicon sealants would perform just as well in this application.

B9.6 Compatibility with subsea cables

Total Norge has carried out compatibility testing between Metrol subsea cables and a cesium / potassium formate brine blend (Total, 2010). As it was planned to have this brine present in the marine riser during a DST operation, compatibility between fluid and cables had to be confirmed. Testing was conducted with a Hydrobond (Hytrel-sheathed) and a TEC cable system to verify their compatibility.

Testing was carried out on two cables in accordance with test procedure JN1171-018B. These cables were:

1. Hydrobond Yellow (Hytrel) cable, temperature rating unknown.
2. TEC complete with encapsulation, rated to 150°C.

Each cable system was tested in the formate brine for two and five days at 110°C / 230°F and for eight days at ambient temperature.

B9.6.1 Hydrobond Yellow (Hytrel) cable

The manufacturer had previously advised that the test temperature (110°C / 230°F) was too high for a five-day exposure of the Hytrel cable and connector assembly. Testing in cesium / potassium formate brine for two and five days confirmed this. Failure occurred at the polyurethane molding / connector interface within 48 hours. No failures were detected during the eight-day exposure at ambient temperature. Hydrobond has not given an exact temperature limit for the Hytrel cable, so anyone using this product with formate brines should always test the cable for integrity maintenance at the predicted operational temperature.

B9.6.2 TEC complete with encapsulation

This cable, rated to 150°C / 302°F, is composed of an Incoloy 825 control line with polypropylene encapsulation. The complete TEC cable with encapsulation was tested

for two and five days at 110°C / 230°F and for eight days at ambient temperature. The TEC encapsulation showed no signs of failure or breakdown in any of the three tests. There was also no apparent degradation of the Incoloy 825 in the TEC control line.

B9.7 Compatibility with Carbolite NRT proppant

Compatibility between Carbolite NRT proppant from CARBO Ceramics Inc. and a 1.80 g/cm³ / 15.0 lb/gal cesium / potassium formate brine blend was tested by Cabot Operations & Technical Support Laboratory in Aberdeen, UK (Cabot, 2017). The brine was buffered with 14.3 kg/m³ / 5 lb/bbl potassium carbonate / potassium bicarbonate to a pH of around 10.

A 0.12 mg/mL CARBO Carbolite 30 / 50 mesh proppant was added to the buffered formate brine and a water sample. The samples were hot rolled at 90°C / 194°F for four hours and then kept in a static oven at 138°C / 280°F for 16 hours. A control sample of buffered brine without any added proppant was given the same treatment.

After thermal ageing, the brine was filtered through 0.45-micron filter paper for cation analysis by ICP-OES to check the gadolinium concentration. The proppant was then washed, dried, and sent to Carbo for ICP composition analysis (Carbo, 2017).

Results show that the formate brine has not undergone any obvious change in critical properties, such as density, pH, or buffer concentrations during thermal ageing, with or without Carbolite proppant. The density of the water sample containing Carbolite increased from 0.999 to 1.0146 g/cm³ / 8.337 to 8.467 lb/gal, which might be caused by some Carbolite powder in the water (see Figure 1). No such density increase was seen in the formate brine. ICP-OES analyses show that gadolinium did not leach out into the brine.

ICP analyses by CARBO Ceramics Inc. confirm that the gadolinium concentration in the proppant was not affected by heat ageing in formate brine.



Figure 1 Samples after filtration through a 300-micron sieve – water to the left, brine to the right.



Figure 2 From left: glass-fiber tube, flare ring, and seal ring.

B9.8 Compatibility with pipe-liner materials

The compatibility of cesium formate brine with three common pipe-liners – thermoset-glass-fiber tube, flare ring, and seal ring – was tested by MERL. These pipe-liner samples were exposed to cesium formate brine for four weeks at 140°C / 284°F (MERL, 2012). Exact details of the materials tested are unknown, but the sample pipe liners are shown in Figure 2.

To determine any effect of exposure to cesium formate brine, several pre- and post-exposure tests were carried out. These included procedures to measure possible changes in mass and volume, a modified version of ASTM D790M to test flexural strength, an ASTM D2344 interlaminar shear test, and an ASTM D2583 test for Barcol hardness. Readings were taken after one, two, and four weeks of exposure.

B9.8.1 Thermoset-glass-fiber-material results

The thermoset-glass-fiber material lightened uniformly in color during the four-week exposure to cesium formate brine. Mass and volume increased with exposure, but only by 1% overall. The interlaminar shear strength and flexure strength tests both show decreases of about 15%, whilst the Barcol hardness data show a slight increase of three units. See results in Table 2.

Table 2 Exposure test results for thermoset-glass-fiber material.

Exposure period [days]	Mass change [%]	Volume change [%]	Young's Modulus [GPa]	ILS [MPa]	Barcol hardness
0	–	–	11.14	29.8	67
6	1.0	1.1	10.79	27.7	–
14	0.9	0.4	10.93	26.3	–
28	0.5	0.8	9.42	25.5	70

B9.8.2 Flare-ring results

The flare ring didn't show any signs of ageing during the four-week exposure to cesium formate brine – there were no changes in mass and volume, appearance, or maximum stress values. However, stiffness increased by up to 42%.

Table 3 Exposure test results for flare ring.

Exposure period [days]	Mass change [%]	Volume change [%]	Max. stress [MPa]	Stiffness [N/mm]
0	–	–	73.0	210.8
6	0.3	0.3	65.3	226.5
14	0.3	0.1	93.3	255.4
28	0.2	-0.2	85.4	299.4

B9.8.3 Seal-ring results

The seal ring showed no significant signs of ageing during the four-week exposure to cesium formate brine. There was no evidence of degradation or change in color, and only very small changes in mass and volume were measured. The flexural properties show a slight increase in maximum stress and stiffness (2% and 20% respectively).

Table 4 Exposure test results for seal ring.

Exposure period [days]	Mass change [%]	Volume change [%]	Max. stress [MPa]	Stiffness [N/mm]
0	–	–	25.5	274.9
6	1.3	1.2	26.3	309.3
14	1.5	0.8	25.2	244.3
28	1.8	0.9	26.0	329.6

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