This Sealant Assessment Table can be used to assess and compare different sealants when developing or selecting sealants for a well exposed to CO_2 during CO_2-injection and (geological) storage. Testing conditions, and the selection of relevant tests should be based on expected conditions and research needs for each application separately.
The Key abilities and Critical Properties included in this sheet are based on research performed as part of the ACT-CEMENTEGRITY project (2021-2024). The included properties were selected based on existing regulatory documents as well as own research performed as part of the project. For more information regarding the selection of these properties, see the below reports and papers.

Note that the CEMENTEGRITY project focused on the properties of the cured sealant materials, and did not take into account fluid state properties such as setting time or viscosity. As the fluid state properties are of great importance for sealant emplacement, for any new sealant material or specific application it should be ensured that these properties are also suitable.

References:

Van Noort, R. (2024) Overview of current standards and common other testing methods used in wellbore sealant assessment. CEMENTEGRITY Deliverable 7.1, 2024-01-26.

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Van Noort, R. (2025) Critical properties and testing methods for sealants in CCS applications. CEMENTEGRITY Deliverable 7.2, 2025-03-27.

NOGEPA (2021) Industry Standard 45: Decommissioning of wells. NOGEPA.
NORSOK (2021) D-010: Well integrity in drilling and well operations. NORSOK.
UK OG (2015) Guidelines on Qualification of Materials for the Abandonment of Wells (GQMAW). Oil & Gas UK.
UK OE (2022) Guidelines on Well Decommissioning for CO_2 Storage – Issue 1. Offshore Energies UK.

Sealant for CCS - key abilities assessment

1) Ability to form and maintain a seal	Assessment methods	Methods notes	Results (description)	Impact of exposure (if done)	References
	Bond strength/shear tests	44 mm ø sealant cylinder pushed out of 50 mm long mild steel casing (wall thickness 3.2 mm) - USA patent US11054353B2. Curing: 80°C, 30 MPa for 3 days; raised to 150 °C in 7 days, held 21 days. Conditioned at 80 °C before measurement.	No reliable measurements obtained.	N.D.	
	Bulk conductivity/electrical tests	44 mm ø sealant cylinder pushed out of 50 mm long mild steel casing (wall thickness 3.2 mm) - USA patent US11054353B2. Curing: 80°C, 30 MPa for 3 days; raised to 150 °C in 7 days, held 21 days. Measurement at 20 °C.	Average bulk conductivity 0.0974 S/m. Average bulk conductivity 0.0384 S/m. Note that the electrodes were in the form of 2 strainless-steel rods, 2.4 mm diameter, 15 mm separation.	N.D.	
	Bond strength/shear tests	6 mm ø stainless-steel tube (wall thickness 1 mm) pushed out of 70 mm long, 30 mm ø sealant sheath	Average peak shear stress 3.0 MPa.	See below for thermal exposure.	
	Annular leakage/hydraulic sealability	N2-flow rate measured along annular contact by applying 0.3 Mpa pressure to one end of cylinder; other end open to atmosphere.	Leakage rates of 5.8-6.5 ml/min. Note that these measurements were performed on an annular contact of sealant around stainless steel with a contact diameter of 6 mm.	See below for thermal exposure.	

2) Ability to resist CO2-containing fluids	Exposure method	Conditions and fluid used	Results (description)	Impact of compound exposure (if done)	References
	Batch	12 mm ø, 30 mm long cylinder; wet supercritical CO2, 80 °C, 10 MPa.	Full penetration of CO2 within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 960 µm, with degradation in outer 20 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; CO2-saturated water, 80 °C, 10 MPa.	Full penetration of CO2 within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 2260 µm, with degradation in outer 200 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; wet supercritical CO2 with 1.6 mol% H2S, 80 °C, 10 MPa.	Full penetration of CO2 within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 1400 µm, with degradation in outer 100 µm. S contents somewhat elevated, especially in the outer ~200 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; CO2-saturated water, 1.6 mol% H2S in CO2-phase, 80 °C, 10 MPa.	Full penetration of CO2 within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 2180 µm, with degradation in outer 400 µm. S contents somewhat elevated in the outer ~200 µm, and inwards from ~1000 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; supercritical CO2 equilibrated with concentrated H2SO4, 80 °C, 10 MPa.	Full penetration of CO2 within 4 weeks. At 16 weeks, further chemical and microstructural alteration in outer 1300 µm, with some degradation in outer 100 µm. S contents somewhat elevated, especially in the outer ~250 µm.	N.D.	
	Flow-through	38 mm ø, 80 mm long cylinder; wet supercritical CO2, 80 °C, 13.8 MPa Pconf, 11.7 MPa Pup; 8.3 MPa Pdown.	Continuously decreasing flow during full duration. Increased hardness in carbonated matrix; depth to unaffected >80 mm at 180 days.	N.D.	
	Flow-through	38 mm ø, 80 mm long cylinder; CO2-saturated water, 80 °C, 13.8 MPa Pconf, 6.2 MPa Pup; 1.4 MPa Pdown.	Initial rapid flow decreasing over intial ~500 hrs to constant flow rate for remaining duration. Increased hardness in carbonated matrix; depth to unaffected 70 mm at 90 days; >80 mm at 180 days. Some mechanical degradation at injection surface; to 2 mm depth at 180 days.	N.D.	

3) Ability to withstand thermal shocks and cycles	Exposure method	Exposure conditions	Results (description)	Impact of compound exposure (if done)	References
	Unconfined, solid sealant cylinder	Sample length 70 mm, ø 30 mm. 120 °C sample shocked in 20 °C water bath, 8 cycles	N.D. due to time constraints	N.D.	
	Unconfined, solid sealant cylinder with channel drilled along axis	Sample length 70 mm, ø 30 mm, drilled hole diameter 4 mm. 120 °C sample flushed with 20 °C water, 8 cycles	N.D. due to time constraints	N.D.	
	Confined, solid sealant cylinder with channel drilled along axis	Sample length 70 mm, ø 30 mm, drilled hole diameter 4 mm. 120 °C sample confined at 1.5 or 10 MPa, flushed with 20 °C water, 8 cycles	N.D. due to time constraints	N.D.	
	Unconfined, solid sealant cylinder	Sample length 80 mm, ø 38 mm. 200 °C sample shocked in 5 °C water bath, 16 cycles	1.4% increase in sample mass. 4.7% decrease in porosity as measured using He-pycnometry. UCS reduced by 26%.	N.D.	
	Unconfined, solid sealant cylinder	Sample length 80 mm, ø 38 mm. 200 °C sample shocked in 5 °C brine bath (15 wt.% NaCl), 16 cycles	9.3% increase in sample mass. 27.3% decrease in porosity as measured using He-pycnometry. UCS reduced by ~9%.	N.D.	
	Unconfined, sealant cylinder cast around stainless-steel tube	Sample length 70 mm, ø 30 mm, tube diameter 6 mm. 60 °C sample flushed with 5 °C water through tube, 16 cycles	No crack formation seen in CT-scans. Leakage rates increase by ~2.2x. Shear stress needed to separate tube from annular seal decreased by ~12 %.	N.D.	
	Confined, sealant cylinder cast around stainless-steel tube	Sample length 70 mm, ø 30 mm, tube diameter 6 mm. 60 °C sample confined at 1.5 MPa, flushed with 5 °C water through tube, 8 cycles	No crack formation seen in CT-scans. Leakage rates decreased to 56 % of initial value. Leakage rates decreased to 71 % after confinement only. Shear stress needed to separate tube from annular seal increased by ~19 %.	N.D.	

Sealant for CCS - critical properties assessment

Property		Relevance (Req; KII; FSM; CO2; TSC)	Reference sample	CO2-exposed	Exposed to thermal shocks/cycling
Permeability		Req; KII; CO2			
	Water, constant flow		0.52-0.44 x 10-18 m2 (after curing) 0.23 x 10-18 m2 (180 days reference)	0.25 x 10-18 m2 (180 days CO2-sat H2O); 0.21 x 10-18 m2 (180 days sc. CO2)	N.D.
Mechanical properties					
	Compressive strength	Req; KII; FMS; TSC	48-50 MPa	42 MPa (90 days CO2-sat H2O and 180 days CO2-sat H2O)	N.D. due to time constraints
	Tensile strength	Req; KII; FMS; TSC	5.6-6.2 MPa	4.4 MPa (90 days CO2-sat H2O) to 6.4 MPa (180 days CO2-sat H2O)	N.D.
	E-modulus	Req; KII; TSC	12.7-13.1 GPa	11.4 GPa (90 days CO2-sat H2O) to 12.5 GPa (180 days CO2-sat H2O)	N.D.
	Poisson ratio	Req; KII; FMS; TSC	0.25-0.27	0.29 (90 days CO2-sat H2O) to 0.28 (180 days CO2-sat H2O)	N.D.
	E/C-ratio	Req; KII; TSC	255-275	271 (90 days CO2-sat H2O) to 297 (180 days CO2-sat H2O)	N.D.
Volumetric behaviour					
	During curing	Req; FMS	N.D.	-	-
	Over time	Req; FMS	N.D.	N.D.	N.D.
Thermal properties					
	Thermal diffusivity	TSC	0.75 (mm2/s)	N.D.	N.D.
	Expansion coefficient	TSC	8.15 (10-6/K)	N.D.	N.D.
Mass/density					
		KII; CO2	1.90-1.94 g/ml (water-saturated, measured on ~1.2 cm diameter, 3 cm long cylinders) 1.49 g/ml (dried)	Exposed to wet sc. CO2, 4-8-16 weeks: gradual decrease from 1.96-1.92 g/ml. Exposed to CO2-saturated water 4-8-16 weeks: gradual decrease from 1.94 to 1.88 g/ml. Exposed to wet sc. CO2 with H2S, 4 weeks: 1.94 g/ml; 16 weeks: 1.89 g/ml. Exposed to CO2-saturated water with H2S, 4 weeks: 1.92 g/ml; 16 weeks: 1.89 g/ml. Exposed to sc. CO2 with H2SO4, 4-8-16 weeks: gradual decrease from 1.79 to 1.68 g/ml.	N.D.
Composition		Req; CO2			
	Chemical, Mineralogical, Microstructure		Particles of precursor materials, some larger than 100 µm, held in a gel matrix with inhomogeneity in density and hardness.	Batch exposure to wet supercritical CO2 caused some degradation in the outer ~20 µm, with densification due to carbonate precipitation inwards of that to ~500 µm, and further minor alteration to ~960 µm. Minor variations in Ca/Si-ratios associated with carbonate precipitation. Little to no leaching or other chemical change otherwise. Extrapolation of carbonation depths not possible. Exposure to CO2-saturated water caused leaching (removal of Ca and Mg), with alterations at the exposure surface up to ~2.3 mm after 16 weeks (batch). Some degradation in the outer ~200 µm (16 weeks batch). Alt. 2 mm degradation depth after 180 days flow-through. Speculative extrapolated carbonation depth after 1000 years 3.8 m.	N.D. due to time constraints

Req: Required property (Norsok D010, GQMAW, and/or Nogepa45)
KII: Key integrity indicator (Norsok D010, and/or GQMAW)
FMS: Ability to Form and Maintain a Seal
CO2: Ability to resist exposure to CO2-containing fluids
TSC: Ability to withstand Thermal Shocks or Cycling