This Sealant Assessment Table can be used to assess and compare different sealants when developing or selecting sealants for a well exposed to CO2 during CO2-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 CO2 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.	Average peak shear stress (apparent bond strength) 0.54 MPa. Bond strength may have been negatively affected by rapid setting. Repeated measurement with set retarder (composition otherwise identical) resulted in 5.57 MPa (little corrosion was observed on mild steel casings).	N.D.	
	Bond strength/shear tests	44 mm ø sealant cylinder pushed out of 50 mm long stainless 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.	Steel type had no significant impact on bond strength.	N.D.	
	Bulk conductivity/electrical tests	44 mm ø sealant cylinder encased in 50 mm long mild steel casing (wall thickness 3.2 mm). Samples cured initially at 80°C for 3 days and 30 MPa before being raised to 150 °C over 7 days and held constant at 150°C for a further 21 days. Measurements taken at 20 °C.	Average bulk conductivity 0.0702 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 1.1 MPa.	See below for thermal exposure.	
	Annular leakage/hydraulic sealability	N_2-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 2.2-3.4 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 CO_2, 80 °C, 10 MPa.	Full penetration of CO_2 within 4 weeks. At 16 weeks, further chemical and microstructural alteration without significant degradation in outer 350 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; CO_2-saturated water, 80 °C, 10 MPa.	Full penetration of CO_2 within 4 weeks. At 16 weeks, minor degradation in outer 80 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; wet supercritical CO_2 with 1.6 mol% H_2S, 80 °C, 10 MPa.	Full penetration of CO_2 within 4 weeks. At 16 weeks, further chemical and microstructural alteration without significant degradation in outer 700 µm. S content somewhat enriched, especially in the outer ~1000 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; CO_2-saturated water, 1.6 mol% H_2S in CO_2-phase, 80 °C, 10 MPa.	Full penetration of CO_2 within 4 weeks. At 16 weeks, no significant other alterations or degradation observed. S content somewhat enriched, especially in the outer ~700 µm.	N.D.	
	Batch	12 mm ø, 30 mm long cylinder; supercritical CO_2 equilibrated with concentrated H_2SO_4, 80 °C, 10 MPa.	Full penetration of CO_2 within 4 weeks. At 16 weeks, further chemical and microstructural alteration without significant degradation in outer 900 µm. S contents somewhat enrichred in the outer ~900-1000 µm (at 16 weeks).	N.D.	
	Flow-through	38 mm ø, 80 mm long cylinder; wet supercritical CO_2, 80 °C, 13.8 MPa Pconf, 11.0 MPa Pup; 8.3 MPa Pdown.	Initial rapid flow with strong decrease in first days. Then, near-constant flow-rate over full duration. Increased hardness in carbonated matrix; depth to unaffected >80 mm at 90 days.	N.D.	
	Flow-through	38 mm ø, 80 mm long cylinder; CO_2-saturated water, 80 °C, 13.8 MPa Pconf, 3.5 MPa Pup; 1.4 MPa Pdown.	Initial rapid flow with strong decrease in first days. Then, near-constant flow-rate over full duration. Increased hardness in carbonated matrix; depth to unaffected >80 mm at 90 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	CT-scanning shows significant crack formation due to thermal shock. UCS reduced by ~67 %	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	CT-scanning shows significant crack formation due to thermal shock. UCS reduced by ~41 %	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	No crack formation seen in CT-scans. ~3.0 % decrease (at 1.5 MPa) to 3.0 % increase (at 10 MPa) in UCS after confinement and thermal shocking.	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 ~1.5x. Shear stress needed to separate tube from annular seal decreased by ~25 %.	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 44 % of initial value. Leakage rates decreased to 69 % after confinement only. Shear stress needed to separate tube from annular seal increased by ~2.2 %.	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		0.90-1.0 x 10-18 m2 (after curing) 2.1 x 10-18 m2 (180 days reference)	0.55 x 10-18 m2 (180 days CO2-sat H2O); 0.37 x 10-18 m2 (180 days sc. CO2)	N.D.
Mechanical properties					
	Compressive strength	Req; KII; FMS; TSC	21-23 MPa	34 MPa (90 days CO2-sat H2O and 180 days CO2-sat H2O)	35 MPa for unexposed reference sample. 9.1-14 MPa (after 8 unconfined quenches) to 21 MPa (after 8 unconfined flushes). 33-35 MPa (after 8 confined flushes at 1.5-10 MPa confining pressure).
	Tensile strength	Req; KII; FMS; TSC	4.2-4.4 MPa	6.1 MPa (90 days CO2-sat H2O and 180 days CO2-sat H2O)	N.D.
	E-modulus	Req; KII; TSC	7.0-7.4 GPa	9.0 GPa (90 days CO2-sat H2O) to 9.4 GPa (180 days CO2-sat H2O)	N.D.
	Poisson ratio	Req; KII; FMS; TSC	0.21-0.25	0.21 (90 days CO2-sat H2O) to 0.20 (180 days CO2-sat H2O)	N.D.
	E/C-ratio	Req; KII; TSC	313-336	266 (90 days CO2-sat H2O) to 274 (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	0.51 (mm2/s)	N.D.	N.D.
	Expansion coefficient	TSC	12.32 (10-6/K)	N.D.	N.D.
Mass/density					
		KII; CO2	1.90-1.92 g/ml (water-saturated, measured on ~1.2 cm diameter, 3 cm long cylinders) 1.51 g/ml (dried)	Exposed to wet sc. CO2, 4 weeks; 1.73 g/ml; 8-16 weeks: 1.87-1.89 g/ml. Exposed to CO2-saturated water 4-8-16 weeks: gradual decrease from 1.906 to 1.85 g/ml. Exposed to wet sc. CO2 with H2S, 4-16 weeks: 1.91 g/ml. Exposed to CO2-saturated water with H2S, 4-16 weeks: 1.90-1.91 g/ml. Exposed to sc. CO2 with H2SO4, 4-8-16 weeks: 1.56-1.59 g/ml.	N.D.
Composition		Req; CO2			
	Chemical, Mineralogical, Microstructure		Globular particles in the micron to 10s of micron range, bound together by a mostly homogeneous matrix.	Exposure to wet supercritical CO2 did not cause any significant microstructural or chemical/mineralogical changes, except some minor densification in the outer ~100 µm, and minor chemical alteration in the outer ~350 µm (batch). No degradation observed. Extrapolation of carbonation depth not possible. Exposure to CO2-saturated water did not cause any significant microstructural or chemical/mineralogical changes, except some minor degradation in the outer ~80 µm (batch). No degradation observed after up to 180 days flow-through exposure. Little to no leaching or chemical alteration observed. Alteration depth >80 mm after 90 days flow-through exposure. Extrapolation of carbonation depth not possible.	CT-scanning (32 µm/voxel resolution) showed increase in voids from 0% to 2.3% (after 8 unconfined quenches) or 1.1% (after 8 unconfined flushes). No change observed after confined flushing.

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