Statement on the state of European standardization concerning the required composition of impure CO_2 in transport infrastructure – Extension of drafting period

To whom it may concern,

Since its inception in 2024, CEN/TC 474 has conducted standardization work in the areas of Carbon Capture, transportation, Utilisation and Storage (CCUS). Among other topics, it has been tasked with the standardization of the composition of CO_2 streams to be transported in a prospective intermodal European infrastructure. It has since become apparent that data on this matter are scarce and, in many cases, not available to the CEN experts. CEN/TC 474 thus calls upon owners to make it available.

Work on CO_2 quality standardization has so far mainly focused on transport in pipelines due to the more advanced state of development. However, the lack of relevant data and pre-normative research demands an extension of the drafting period of the standard until July 2026. Work on tank transport will commence at a later stage.

There is consensus among the experts in the Working Group responsible that a European harmonization of CO_2 composition should not unduly impede the development of CCUS projects. It should thus be parsimonious in its requirements and focus on issues that

1. *have the potential to hamper interoperability between operators of transport infrastructure,*
2. *are independent of existing and prospective national legislation upon which a carbon economy is to be built (e.g. permitting criteria), or*
3. *cannot adequately or only less efficiently be addressed by other means.*

The most important issue meeting these criteria is corrosion due to acid formation and precipitation. It has been known for some years that for carbon steel assets in a CO_2 environment this can lead to local corrosion rates in excess of 10 mm/yr. These phenomena cannot be addressed through established means of integrity management, such as adding corrosion allowances to pipe walls or inline inspection at regular intervals.

Asset integrity is potentially compromised through acid corrosion by a complex interaction of chemical, thermodynamic and flow effects:

1. ***Acid formation**: The presence of hydrogen sulphide (H_2S), sulphur oxides (SO_x), nitrogen oxides (NO_x), oxygen (O_2) and water (H_2O) can result in chemical reactions producing sulphuric and nitric acid (H_2SO_4 and HNO_3, respectively). If the CO_2 has been produced under reducing conditions (like CO_2 from natural sources, where chemical reactions are limited by the available amount of oxygen), of these compounds only H_2S and H_2O will be present. This is the case in the majority of the CO_2 pipelines that have been operated since decades, mainly in North America. No strong acids will form under these conditions.*
   If the CO_2 is derived from a combustion-based process (oxidizing conditions, characterized by a surplus of oxygen), the other compounds, as well as H_2O, will be present in some amounts.

Many CO_2 emissions that are considered unavoidable or hard-to-abate, such as from cement, lime and steel production, waste incineration, and the production of some chemicals, are combustion-based. In the resulting impure CO_2, sulphuric and nitric acid can be formed. If impure CO_2 from reducing and oxidizing environments is then blended in an open-access transport infrastructure, the presence of H_2S will enhance and accelerate the formation of acids. The amount, pathways and rates of acid formation will depend on temperatures, pressures and of course the amounts of individual impurities present. The amount to which a given impurity must be reduced to avoid the formation of acid depends on the amount of the other impurities.

2. ***Acid precipitation**: H_2SO_4 can only be dissolved in CO_2 to a small degree. If a given concentration threshold is exceeded, it will form a phase separate from the dense or gaseous CO_2. This threshold depends on the physical state, pressure and especially temperature of the bulk CO_2. Even if deposited on a surface susceptible to it, pure H_2SO_4 will not cause corrosion. As a strong hygroscopic drying agent, it will however absorb H_2O from the bulk CO_2, even though the solubility of H_2O in pure CO_2 is higher by several orders of magnitude than the solubility of H_2SO_4. As a polar molecule, HNO_3 will be absorbed by H_2SO_4 as well. Even though pure H_2SO_4 is solid below a temperature of 11 °C, this does not fundamentally change its behaviour. The resulting aqueous phase consisting mainly of H_2O, H_2SO_4 and HNO_3 will be highly corrosive. No aqueous phase will be formed without strong acids present unless the water content is very high.*

3. ***Acid accumulation**: The acidic aqueous phase will have a much higher density than the CO_2. That opens up the possibility of accumulation of the acid-rich phase, even if the precipitation first takes place by forming small suspended droplets. Depending on the flow regime and the geometry of the vessel, the aqueous phase may subsequently form films on surfaces and larger volumes of liquid in e.g. branches or at the bottom of tanks. Even though the fraction of acids in the CO_2 is in the single-digit ppm range, this can quickly lead to a loss of containment since the absolute amounts of aqueous liquid will be sufficient for corrosion if collected in an area with low flow velocities.*

This reflects the current understanding of acid corrosion in impure CO_2. This understanding is incomplete, with respect to all three steps. Yet the approach of avoiding corrosion through the definition of an allowable CO_2 composition, i.e. avoiding the dropout of acids by staying below the solubility limit, cannot be foregone. Alternative approaches also suffer from drawbacks that suggest they will not be applicable in all relevant cases:

- *In both pipelines and tanks, temperatures and flow conditions cannot be sufficiently controlled to rule out corrosion.*
- *Pipes made of composite material systems suffer from limitations with respect to maximum diameter and lifetime.*
- *The use of Corrosion-Resistant Alloys (CRA) has not been fully investigated, and no alloy is known whose integrity will reliably be maintained when exposed to the aqueous phase described above.*
- *When a suitable CRA has been found, its use as pipe material or cladding must be proven to enable design of dense-phase pipelines against Running Ductile Fracture (RDF). Such a methodology exists but currently does not extend beyond carbon steels of a certain grade.*

Because of this limited understanding, current specifications published by projects or other stakeholders should be seen as work in progress and rather than a basis for standardization. The number of experimental facilities with the equipment and experience necessary to dose and measure the required low levels of several impurities in a CO_2 matrix is low and their capacity limited. Because of the limited availability of experimental data giving insight into the fundamental mechanisms at work, numerical models are not yet sufficiently validated to help derive allowable specifications.

As mentioned before, the solubility of acids strongly depends on the temperature and physical state of the CO_2*. In pipelines* CO_2 *is transported as a single phase whose temperature will depend on initial conditions and the ground temperature, but will need to be above 0 °C. Tank transport always takes place in two phases, with a small portion of the tank volume filled by gas. In the so-called medium pressure range as it is long established for food-grade* CO_2 *on trucks, railcars, barges and ships, pressures vary between 15 and 20* bar_g*, and consequently, temperatures between about -30 and -20 °C. That means that in tanks the solubility limits for acids, and thus the required limits for acid-forming impurities, are lower than in pipelines. This will be reflected through separate specifications for pipeline and tank transport.*

The issues and conditions to be considered when deriving a harmonized European CO_2 *stream specification are not limited to acid corrosion:*

- *The specification under development is intended to enable blending of impure* CO_2 *from reducing and oxidizing environments in open-access infrastructures. No such infrastructures exist yet. In infrastructures where no blending takes place, it does not need to be applied to avoid corrosion.*
- *The specification should contribute to, or at least not to hinder, a cost optimization not just of* CO_2 *transport, but of the whole CCUS value chain as well. That means e.g. that higher transport and storage costs caused by lower* CO_2 *quality will be justified if they are more than compensated by savings in* CO_2 *capture or treatment.*
- *The removal of different impurities is associated with different costs. When faced with clearly defined alternatives, the approach leading to lower costs should be preferred.*
- *The specification needs to create a level playing field between different capture techniques, including nascent ones.*
- *In keeping with existing regulation principles for the transport of natural gas and hydrogen, the final specification will not be a Whitelist. Impurities not listed are in principle admissible, as long as they do not cause damage to the asset or compromise its integrity.*
- *Additional limits and quality-related restrictions may apply, subject to national regulation or contractual agreements with the infrastructure operator.*
- *Contrary to the history of limits on emitted impurities, it is expected that specifications of* CO_2 *destined for storage and usage can be relaxed as knowledge on acid corrosion and other issues improves. This may provide opportunities for optimization in* CO_2 *capture and treatment.*
- *In the case of tank transport, the issue of vapour return merits special consideration. This is due to the accumulation of some acid-forming impurities in the vapour phase as the number of return trips increases, and new constraints with respect to venting.*

CEN/TC 474 requests parties who raise and own data that can improve the current state of knowledge to share said data and plans for further investigations, and contribute to the ramp-up of CCUS.

Sincerely,

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