DYNAMIC BEHAVIOR - COOL DOWN AND HEAT UP EFFECTS

Next to corrosion aspects prevention of brittle fracture is another important aspect for the applied materials of construction, concerning the temperatures during transport and storage of CO_2. All equipment in the logistics chain is designed for a certain operation pressure and temperature. This is the steady operation condition, but during shutdowns, start-ups or transient operation the conditions may differ. The influence of this on material and the required mitigation measures will be discussed in this paragraph.

Brittle fracture could occur when liquid CO_2 is stored as compressed gas since the temperatures will be very low. Normally the minimum design temperature of a vessel filled with liquefied gas is equal to the atmospheric boiling point. CO_2 has no atmospheric boiling point, but an atmospheric sublimation point (−78.5 °C). In consultation with the authorities the correct minimum design temperature of the liquid CO_2 storage vessels has to be determined. Prevention of brittle fracture has been assessed by MCC [9] using Annex B of EN-13445-2. Fine-grain steels show better impact behavior compared to normal steels. Generally, such fine-grain steels are Al-killed steels and/or micro-alloyed and subject to a special heat treatment.

Down to about −60 °C fine-grain steels can be used. Steels for application below −50 °C are often alloyed with a small amount of nickel. For CO_2 at a temperature of −78.5 °C, 3.5 %Ni steel is mentioned as a suitable material of construction.

Further is it important to consider the temperatures that could be attained during depressurizing, release or leakage of CO_2. If depressurization of a CO_2 pipeline to atmospheric pressure takes place very fast, temperatures up to −78 °C could be reached, depending on the initial pressure. The material should be selected to withstand these kind of temperatures. In addition, solid CO_2 formation and possibly blockage of the valve should be taken into account when designing the relief valves.

Excessive thermal stresses, which could lead to pipe rupture, should be prevented. Therefore the cooling down rate of equipment (e.g. the storage tanks on ship and at the hub) must be limited. A typical rate that is believed to be admissible is 10 °C/hour [11]. Thermal stresses could also occur due to expansion or contraction of equipment, piping and pipelines as a result of being subjected to high temperature differences. During the design the possible contraction and expansion has to be taken into account to prevent any damage.

The storage tanks are likely to be subjected to high expansion or contraction rates, since they are large and in use they will operate at a temperature of −50 °C, while during downtime they could be reach temperatures up to 30 °C. The expansion or contraction can be supported by applying one fixed saddle and further applying sliding saddles. Piping and pipelines, which could be subjected to very low temperatures, can be protected for expansion and contraction by adding expansion joints. Stress calculations have to be made in order to prepare a safe design.

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