

# DYNAMIC BEHAVIOR - CONCLUSIONS

Based on the results of the QRA it can be concluded that all of the CO<sub>2</sub> activities could pose an effect on the direct vicinity when an unintentional release occurs.

However, the corresponding risk levels appear to be below the Dutch risk criteria.

Therefore, in DNV's opinion the safety risks associated with the LLSC are acceptable for all of the considered activities.

The overall chain reliability is also an important factor for safety, health and environment. A low reliability increases the frequency of maintenance and repairs.

Any maintenance or repair operation will require the shutdown of (part of) the logistics chain. Consequently venting of CO<sub>2</sub> to the surrounding will be necessary.

The release of CO<sub>2</sub> reduces the efficiency of the chain, but also poses a risk to the health of persons present in the proximity of the release and to the environment. If

possible pipelines and piping should be sectionalized by means of valves. When maintenance or repair of the pipeline/piping has to be performed, it will not be

required to vent the whole pipeline/piping system but only the particular segment.

Parts of seagoing ships which are exposed to seawater required more maintenance than parts of the ship that has no contact with seawater. More maintenance has

obviously a negative effect on the reliability.

By minimizing the exposure of equipment and piping to the environment the maintenance requirement could be minimized.

Some aspects should be taken into account during the design phase to avoid damage caused by corrosion, brittle fracture, heat up and cool down effects and waterhammer. The possible solutions for prevention or mitigation of the above-mentioned phenomena's are summarized below.

- The most relevant corrosion degradation mechanisms are wet CO<sub>2</sub> erosion-corrosion, soil corrosion, seawater corrosion and corrosion under insulation (CUI). Appropriate materials should be selected, which will highly depend on the conditions of the CO<sub>2</sub> (temperature, pressure, water content).
- Brittle fracture of the applied materials of construction should be prevented by applying the proper material. Down to about -60 °C fine-grain steels can be used. For CO<sub>2</sub> at a temperature of -78.5 °C, 3.5 %Ni steel is mentioned as a suitable material of construction.
- It is Important to consider the temperatures that may occur during depressurizing, release or leakage of CO<sub>2</sub>. The pipeline material should be selected to withstand the lowest temperatures occurring.
- To prevent rupture as a consequence of thermal stresses, the cooling down rate of equipment and piping must be limited.

- As a result of being subjected to high temperature differences, the equipment, piping and pipelines can expand or contract. During the design the possible contraction and expansion have to be taken into account.
- Waterhammer can take place in any system containing a fluid that is subjected to a rapid flow velocity change. The velocity change initiates a pressure surge inside the system, which could lead to pipeline rupture or collapse. The pipeline system has to be designed to withstand the maximum pressure that could be reached during the pressure surge. The severity of the surges can be reduced by using appropriate flow velocities and valve open/closure times. If surge pressures are still higher than design pressures, measures have to be taken to mitigate the consequences of pressure surges e.g. safety valves, expansion vessel.

For prevention of cargo sloshing some measures can be taken. The filling level of the cargo tanks have a high influence. Very low filling levels or very high filling levels are not expected to be able to cause damage, most problems arise for intermediate filling levels (thus during unloading). The shape and size of the tanks and the motional behavior of the vessel itself are of influence and pending further engineering and sloshing simulations, sloshing bulkheads might be applied.

Source: <http://hub.globalccsinstitute.com/publications/co2-liquid-logistics-shipping-concept-llsc-safety-health-and-environment-she-report/6>