MODELING PIPELINE LOC SCENARIOS

The pipeline rupture scenarios have been modeled with the “long pipeline” model in Safeti-NL which means that the 2-sided outflow during a pipeline rupture is considered in the calculations. During normal operation the pressure in the pipeline decreases due too internal friction. As a result the discharge upon a rupture will vary depending on where the pipeline ruptures. To take this into account, the pipeline rupture scenario is modeled with 5 consecutive pipeline segments, each having their own (decreasing) pressure setting resulting in a different discharge.

The underground pipeline scenarios have been modeled with a release height of 0 meter and a vertical release direction. It is expected that a crater will be formed during the release and that there is no loss of momentum of the CO_2 jet. The aboveground scenarios have been modeled with a release height of 1 meter and a horizontal release direction. These assumptions are all according to MBRA.

The pipeline crossings under the Yangtze harbor and the Maasgeul will be done via HDD and are located at a depth of more than 30 meters. A LOC of a pipeline at such depth will lose momentum and which should be taken into account.

The Dutch guidelines are not specific on how to model LOC scenarios of pipelines located under waterways.

In case of a gas release underwater a bubble plume will form. This bubble plume will decrease the release velocity and prevent jet dispersion. This risk analyses assumes a surface diameter of the bubble plume of 30% of the pipeline depth, based on the guideline for risk analysis from the international Association of Oil and Gas Producers (OGP) [Ref 22] and the research done by the Petroleumtilsynet for Norpipe [Ref 23].

The OGP guideline calculates a surface diameter of the bubble plume of 20% of the pipeline depth. However, because for a CO_2 release a low release velocity will result in larger effects the conservative diameter of 30% was used, based on the analyses done by the Petroleumtilsynet.

The CO_2 velocity at the surface was determined with the release rate and surface area of the plume. The CO_2 temperature, to calculate the density, was assumed equal as the water temperature due to the intense mixing with the water during the release.

The dissolving of CO_2 in the water is not considered in the calculations, which is a conservative assumption.

All the effect distances of the scenarios have been calculated with a weather type F1.5 (steady atmosphere, low wind speeds), which is the most conservative for toxic scenarios, and D5 (normal atmosphere, higher wind speeds).

The situation after a rupture pipeline leak will give a near zone (bubble zone) above the leak point and a CO_2 cloud outside the near zone. There have been raised some concerns about the potential loss of buoyancy if vessels sail into, or are in the bubble zone at the time of release.

In earlier risk assessments performed for offshore hydrocarbon pipelines, the potential hazard of sinking ship/vessels due to loss of buoyancy has been considered negligible. This is partly based on conclusions from a study performed in 1987, Marintek called “Risk Assessment of Buoyancy Loss – RABL/PP2”. The report focuses mainly on the effect on semi-submersible platforms subjects to a subsea gas blowout, but addresses some effects on vessels sailing away from the gas release as well. The main conclusion from this study is that the effects of buoyancy loss do not represent any risk to vessels sailing away from the near zone. The conclusion of the tests was that the effect of the upward velocity more than counteracts the one of buoyancy loss. The tests indicate no risk for capsizing as long as the compartments are closed. However the motions are severe.

However, the evaluation of this potential hazard was based on the assumption that a scenario with CO_2 in principle will be the same as a heavy hydrocarbon gas release.

10.3.1 Modeling of a LOC scenario of dense phase CO_2

The rupture and leak scenarios have been modeled with the maximum outlet pressure of 130 bara and a maximum operating temperature of 80 ”C. Under these conditions the CO_2 is in dense phase and solid (ice) formation could take place when a LOC occurs (see also paragraph 2.1.4.2). Dry ice sublimates at atmospheric pressure directly into vapor. Safeti-NL does not accurately take this effect into account. Therefore, an extra model in the consequence and risk calculations for the vertical releases is used to make sure that solid formation is considered.

Horizontal release

During a horizontal release the dry ice will “rain” out from the CO_2 jet and then slowly sublimates from the ground. This sublimation will cause a higher CO_2 concentration at the release location. However, the influence of the sublimating CO_2 is negligible compared to the direct effect of the gaseous CO_2release.

Therefore, the sublimation effect is not considered for horizontal releases and it is assumed that all the CO_2 will be released as vapor. This is a conservative assumption as the calculated effect will be larger than in reality.

Vertical release

A vertical CO_2 release will most of the times not cause dangerous CO_2 concentrations at ground level. However, when solid formation occurs, the sublimation of dry ice may cause a dangerous CO_2concentration at the release location. Therefore, solid formation will be considered for vertical releases to prevent underestimation of the consequences and risks.

The amount of dry ice formed during a release is determined with the Mollierdiagram of CO_2. A fully isentropic process is assumed for the CO_2 release is. The dry ice is modeled in Safeti-NL as a “user defined source” at which the CO_2 vapor is released vertically with a low velocity and a low temperature. The flow is set equal to the solid formation, which is a conservative assumption.

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