19. Risk assessment for abnormal CO_2 venting emissions
a) Identify all the discrete emission points venting CO_2 and provide their location (either coordinates or a map).
b) Describe all the scenarios under which venting of CO_2 might happen, for example during other than normal operating conditions, such as start-up, shut-down, emergency depressurisation, etc.
c) Provide an environmental risk assessment for these emission points following the methodology set out in Environment Agency guidance https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit. Where applicable, the risk assessment should be informed by an appropriate dispersion model for all the applicable CO_2 venting points, following the guidance set out in Environmental permitting: air dispersion modelling reports – GOV.UK (www.gov.uk) and taking into account the higher density of concentrated CO_2 emissions (dense gas modelling).

Notes: Table 7-4 of the Application Supporting Document refers to a CO_2 compressor vent. Item 1.3 of the Accident Risk Assessment provided in Appendix A.4.0 of the Application Supporting Document states that CO_2 discharge to atmosphere is planned during plant start-up and shutdown. However, you have not risk assessed these emission points.

A risk assessment, following the methodology set out in Environment Agency guidance, has been completed for abnormal CO_2 emissions from the proposed hydrogen production plant (HPP).

19 possible release scenarios were included in the risk assessment. Details of these scenarios are included in the CO_2 Vent summary document attached as Appendix 1 to this response.

The CO_2 Vent summary document details the CO_2 vents with information on:

- Location
- Stack Height and vent size
- Description & case reference
- Classification as normal or 'other than normal operating'
- Expected frequency of venting and duration of venting
- Inlet and outlet conditions and venting rates (inc. peak or average)
- Vent composition

The cases highlighted in red have not been modelled as:

- PSV-002_1 and PSV-0025 are 'less worse' sub-sets of other cases with the same reference
- 10-FAB-U-102_1 is a low emission continuous vent which is not classified as concentrated CO_2; note that even though this is a low emission rate vent, the potential for its capture will be investigated during detailed design.
- CCU_4 is a nitrogen purge case

As highlighted in previous schedule 5 response 19b, there are also additional scenarios whereby venting will be required due to the CO_2 Transport and Storage Network (T&S) becoming unavailable. These scenarios are initiated outside the HPP plant and have not been modelled. However, in these scenarios, the exit route for the CO_2 will essentially be isolated and hence they are aligned with the existing CO_2 compressor package 'blocked outlet' scenario whereby the full flow is vented.

With respect to frequency and duration, note that the HyNet Basis Of Design requires availability of the CO_2 network to be ≥99%. For planned shutdowns Liverpool Bay CCS (LBCCS) will co-ordinate with HPP to ideally align major shutdowns to avoid CO_2 venting. If this is not possible, if the planned duration is short, HPP could be turned down to minimise venting; else for longer durations an additional HPP outage could be taken outside the normal turnaround windows. This will be developed further during detailed design to determine the best strategy for reducing total emissions.

The remaining 15 scenarios were assessed in detail in the attached dispersion modelling assessment (Report FM1383/R3/22 'Environmental risk assessment for abnormal emissions of carbon dioxide, Essar Stanlow Refinery'). The locations of the vents and sensitive off-site receptors are shown in the report.

The dispersion modelling was carried out using ADMS 5, which was determined to be the most appropriate method for the dispersion modelling assessment. The proposed modelling methodology and the choice of model are discussed further in the CERC proposal 'P2595: Dispersion modelling of abnormal emissions of CO_2', attached as Appendix 3.

Emissions rates have been based on vendor data and internal calculations. Vent exit temperatures were developed using this data (pressures/flows/starting temperatures), based on atmospheric release conditions. This was done using hysys software. The change in temperature associated with the depressurisation was based on an adiabatic setup.
Apart from the low emission continuous vent 10-FAB-U-102_1 (which has not been modelled), peak flowrates have been used to provide the most conservative results. It is conservatively assumed that these peak flowrates are maintained for the duration of the venting scenario.

The EA's guidance on air emissions risk assessments for environmental permits requires the comparison of the impact of emissions to air against the following Environmental Standards:

- Air Quality Standards Regulations 2010 Limit Values and Target Values;
- UK Air Quality Strategy Objectives;
- Environmental Assessment Levels.

There are no values available for CO_2 for any of these standards and the Workplace Exposure Limit Values (WELs) are not directly relevant for occasional public exposure, as they relate to routine workplace exposure. As there are no values for direct use, and no suitable data for the derivation of EALs, the short term threshold level has been derived based on two documents provided by the Environment Agency for the purposes of deriving a threshold level for the purpose of this risk assessment. The two documents are:

- 'Assessment of the major hazard potential of carbon dioxide' published by the HSE
- 'Compendium of Chemical Hazards: Carbon Dioxide' published by PHE (now UKHSA)

As the Environment Agency summarise in their email dated 3rd August 2022 (F. Di Stefano to K. Rothwell): "The HSE document reports a concentration of 3% CO_2 for 1 hour exposure as the concentration responsible for headaches and defines higher specified levels of toxicity (SLOT) associated with different exposure times for land use planning.

The PHE document indicates a 2-5% CO_2 concentration as the indicative reported effect level associated with symptoms such as headaches, dizziness, sweating, shortness of breath for inhalation

of CO_2. Your assessment should demonstrate that public exposure levels in the case of venting of CO_2 during other than normal conditions are well below the levels at which the onset of symptoms and effects are reported."

The most stringent (lowest) of these reported effect levels, 2% (20,000 ppm) was therefore used as the acute threshold value for the purposes of this assessment. A maximum (100^{th} percentile) of hourly averages was chosen to represent the acute exposure effects.

The modelling was carried out to predict the resulting concentrations of CO_2 in the surrounding area, for comparison against the above acute exposure threshold. The modelling was carried out using hourly sequential meteorological data for the five years 2016 to 2020 inclusive.

The maximum (100^{th} percentile) of hourly average carbon dioxide concentrations were generated on an output grid with a resolution of 5 m, and at the sensitive receptor locations described in Section 4.2 of the attached report.

The significance of the released emissions was assessed by comparing the Process Contribution (PC) to the derived threshold. For assessment of short-term objectives, the Environment Agency considers the release to be insignificant if the PC is less than 10% of the air quality standard. Where a release is insignificant, the pollutant is screened out and no further assessment of levels of that pollutant undertaken.

The hazards associated with carbon dioxide are concerned with its oxygen displacement qualities, respiratory suppression and asphyxia at high concentrations. As these impacts are acute, the scenarios were only screened out against the criteria for short term PC. In addition, scenarios that were modelled are expected to occur only on a short-term basis. Consequently, screening against the criteria for long term PC is not considered appropriate or necessary for this risk assessment.

Results

- Maximum offsite concentrations:

Based on the derived threshold of 20,000 ppm (2%), the maximum predicted short-term offsite concentrations are screened out for all the modelled scenarios, except the BDV-0001_2, CCU_1 and Blocked Outlet- Package scenarios.

For the BDV-0001_2 scenario, the maximum 1-hour average offsite carbon dioxide PC is 2,418 ppm, 12% of the threshold, calculated using meteorological data for the year 2018. Including the background concentration of 420 ppm, the maximum predicted offsite PEC is 14% of the threshold.

For the CCU_1 scenario, the maximum 1-hour average offsite carbon dioxide PC is 2,275 ppm, 11% of the threshold, calculated using meteorological data for the year 2017. Including the background concentration, the maximum predicted offsite PEC is 14% of the threshold.

For the Blocked Outlet-Package scenario, the maximum 1-hour average offsite carbon dioxide PC is 4,368 ppm, 22% of the threshold, calculated using meteorological data for the year 2020. Including the background concentration, the maximum predicted offsite PEC is 24% of the threshold.

- Concentrations at sensitive receptors:

The maximum predicted 100th percentile of 24-hour average PC to concentrations of carbon dioxide are screened out at all of the sensitive receptors, as the PC is less than 10% of the 20,000 threshold value at all locations.

Conclusion

Results of the dispersion modelling for the scenarios for venting CO_2 have shown that for all the identified scenarios, the process contributions at sensitive receptors are below the levels defined as insignificant.
The results of the dispersion modelling have also shown that the maximum predicted short-term offsite concentrations are screened out on the basis of the level defined for insignificance for all but three of the modelled scenarios.

For the three modelled scenarios that are above the levels defined for insignificance, the Predicted Environmental Concentrations (PEC) are significantly below the determined threshold value and are not in a location of a sensitive receptor.

Based on these modelling results, Essar Oil UK does not consider that the proposed design would cause any significant harm to persons off-site from the emissions of CO_2, therefore no design changes are proposed to alter the dispersion characteristics.

Assessment Uncertainties

As the modelling assessment has been undertaken using design data, there will be a level of uncertainty in relation to the inputs for the modelling. The Hydrogen plant design is Johnson Matthey technology who are leaders in this field. Additionally, standard BASF amine technology is used to capture and remove CO_2. This limits the levels of uncertainty regarding the plant scenarios and assessment data.

Originally developed for regulatory authorities in the UK, ADMS is an advanced, world leading, dispersion model software used for modelling industrial air pollution, and is used in many countries worldwide by a variety of users, including industry, consultants and environmental regulators. ADMS 5 is a new generation Gaussian plume air dispersion model. The suitability of using ADMS 5 for this assessment is discussed in further detail in the CERC proposal 'P2595: Dispersion modelling of abnormal emissions of CO_2', attached as Appendix 3.

A maximum (100th percentile) of hourly averages was chosen to represent the acute exposure effects and, for the purposes of the dispersion modelling, all sources were assumed to be emitting continuously for all hours of the year. This provides a conservative assessment.
In addition, the proposed short term threshold level was derived from the most stringent of the reported effect levels in the documents provided by the Environment Agency for the purposes of deriving a threshold level for this risk assessment.

The majority of the scenarios were screened out as insignificant, with only three scenarios being above the 10% screening threshold. For the three modelled scenarios that are above the levels defined for insignificance, the Predicted Environmental Concentrations (PEC) are significantly below the

determined threshold value and are not in a location of a sensitive receptor, which allows for head room for any uncertainties in this assessment process.
The maximum predicted 100th percentile of 24-hour average PC to concentrations of carbon dioxide are screened out at all of the sensitive receptors.

Assumptions made during the dispersion modelling are further described in the attached dispersion modelling assessment (see Appendix 2).

Appendices

Appendix 1: CO2 Vent summary

Appendix 2: 'Environmental risk assessment for abnormal emissions of carbon dioxide, Essar Stanlow Refinery' FM1383/R3/22

Appendix 3: P2595: Dispersion modelling of abnormal emissions of CO_2