PROJECT DRAGON

LANZATECH

PORT TALBOT, WALES

HSE DESIGN PHILOSOPHY

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HSE DESIGN PHILOSOPHY

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1. INTRODUCTION

LanzaTech UK (part of the LanzaTech Group) is exploring the installation of a 30M gal/year (ca. 115million litres/year) Alcohol-to-Jet (ATJ) plant in Port Talbot, Wales. The ATJ plant is to consist of two technologies, an Ethanol to Ethylene (ETE) and an Ethylene to Jet Fuel (ETJ) technology. A project feasibility study was completed in 2018.

As part of this work LanzaTech (LT) awarded a FEED project for the ISBL element of the project in September 2021 which has been completed in April 2022 with the permitting and OSBL identification/basic engineering work completed by others.

Following the completion of the ISBL FEED project, LanzaTech have requested Technip Energies (T.EN) to develop a proposal for the Front-End Engineering Design (FEED) for a Consolidated FEED package for the full facility including both ISBL and OSBL elements of the ATJ unit.

The FEED package will include the engineering and process design scope to deliver a +/ 10% cost estimate which will aim to support a Final Investment Decision by Q1 2024.

The main purpose of the FEED package is to combine the previously separate Process Area (Legacy ISBL) FEED and Utilities and offsites area (Legacy OSBL) Pre-FEED packages (developed by others) into a single consolidated FEED definition package which is “Execution Ready” and includes the necessary elements for the project to move efficiently to the next phase. This will include development of the Utilities and offsites, optimisation of the Process and Utilities area interfaces and updates required as a result of the recent optimisation studies.

A further aspect of the project will be the support of the planning and permitting process which is seen as a key success factor for the project. T.EN shall provide inputs to this process to support the third-party subcontractors which have been employed by LanzaTech for the project.

2. SCOPE OF DOCUMENT

This document defines the design philosophy for Health, Safety and Environment (HSE) applied on Project Dragon. The objectives of the HSE Philosophy are to:

- Ensure potential hazards to people (internal and external) and environment are identified.
- Risks identified are reduced to ALARP
- Facilities are developed consistent with inherently safer design (ISD) and best available techniques (BAT).

The philosophy shall place emphasises on developing an engineering design that fully considers the inherent potential risks associated with the facility. All appropriate safety features as identified shall be incorporated in the design to minimise potential for hazardous events and provide operators with means to mitigate those events occurring in the facility.

3. REFERENCE DOCUMENTS

3.1 STANDARDS

The standards and codes used are the latest revisions at time of writing, refer to the project document listing the relevant codes and standards for Project Dragon

Number	Title of Document
202947C-000-PP-00110-A	List of Codes and Standards

3.2 PROJECT DOCUMENT

Number	Title of Document
202947C-000-PP-00205	HAZOP Procedure
202947C-000-PP-00205	SIL Procedure
202947C-000-PP-00216	HAZID/ENVID Procedure
202947C-000-RT-1900-00001	HAZOP Report
202947C-000-RT-1900-00002	SIL Assessment Report
202947C-000-RT-6200-00001	HAZID/ENVID Report
202947C-000-JSD-1900-00004	Escape, Evacuation and Rescue Analysis
202947C-000-RT-1990-00001	Fire and Explosion Risk Assessment

Number	Title of Document
202947C-000-RT-1990-00002	QRA Study Report
202947C-000-RT-6201-00001	Gas Dispersion Analysis Report
202947C-000-JSD-1900-00002	Hazardous Area Classification Schedule
202947C-000-JSD-1300-00001	Piping Basis of Design
202947C-000-CN-0008-00001	Overpressure Protection and ESD Philosophy
202947C-000-CN-0008-00003	Isolation Philosophy
202947C-000-CN-0008-00005	Drainage and Venting Philosophy
202947C-000-JSD-6200-00001	Environmental Basis of Design
202947C-000-DW-1940-00001	Fire Zone Layout
202947C-000-DW-1960-00001	Safety Equipment and Escape Route Layout
202947C-000-CN-1901-00001	Firewater Demand Summary
202947C-000-CN-0007-00002	Process Design Basis
202947C-000-CN-0007-00003	Basis of System Design

4. DEFINITIONS AND ABBREVIATIONS

Abbreviations	Definitions
AFP	Active Fire Protection
AIT	Auto Ignition Temperature
ALARP	As Low As Reasonably Practicable
ANSI	American National Standard Institute
ATEX	Atmosphere Explosibles
ATJ	Alcohol-to-Jet
BAT	Best Available Techniques
BATc	BAT conclusions
BLEVE	Boiling Liquid Expanding Vapour Explosion
BREF	BAT Reference Documents

Abbreviations	Definitions
BS	British Standard
CCTV	Closed Circuit Television
CCPS	Centre for Chemical Process Safety
COMAH	Control of Major Accident Hazards
Company / Client	LanzaTech UK
DfT	Department for Transport
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
EC	European Council
EEC	European Commission
ETE	Ethanol-to-Ethylene
ETJ	Ethylene-to-Jet
EER	Escape, Evacuation and Rescue
EERA	Escape, Evacuation and Rescue Analysis
EI	Energy Institute
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EN	European Standard
ENVID	Environmental Identification
EPC	Engineering Procurement & Construction
ESD	Emergency Shutdown
FAC	Fire Alarm Call
FEED	Front End Engineering Design
FERA	Fire and Explosion Risk Analysis
FGS	Fire and Gas System
FPE	Fireproofing Envelope
FSA	Functional Safety Assessment

Abbreviations	**Definitions**
GHS	Globally Harmonised System of Classification and Labelling of Chemicals
HAZID	Hazard Identification
HAZOP	Hazard Operability
HC	Hydrocarbon
HP	High Pressure
HSE	Health, Safety and Environment
HSE Critical Equipment	Equipment item is HSE critical if (i) its failure can cause or contribute substantially to a major accident or environmental release, or (ii) its purpose is to prevent or limit the effect of a major accident or environmental release
HSEIA	Health Safety and Environmental Impact Assessment
HVAC	Heating, Ventilation, and Air Conditioning
IEC	International Electrotechnical Commission
IOGP	International Oil and Gas Producers
IR	Infra-Red
ISBL	Inside Battery Limit
ISD	Inherently Safer Design
LOC	Loss of Containment
LOPA	Layers of Protection Analysis
LNG	Liquefied Natural Gas
LP	Low Pressure
LPG	Liquefied Petroleum Gas
MAC	Manual Alarm Call
MAH	Major Accident Hazards
MATTE	Major Accident to the Environment
MOC	Management of Change
MP	Medium Pressure

Abbreviations	Definitions
NRW	Natural Resources Wales
OSBL	Outside Battery Limit
PFP	Passive Fire Protection
PPE	Personnel Protective Equipment
QRA	Quantitative Risk Assessment
RADD	Risk Assessment Data Directory
SCBA	Self-Contained Breathing Apparatus
SIF	Safety Instrumented Function
SIL	Safety Instrumented Level
SIS	Safety Instrumented System
T.EN	Technip Energies
UNECE	United Nations Economic Commission for Europe
UV	Ultra Violet
VCE	Vapour Cloud Explosion
VESDA	Very Early Smoke Detection Apparatus

5. SAFETY IN DESIGN

5.1 PROCESS SAFETY PRINCIPLES

5.1.1 Inherently Safer Design (ISD)

The principle of inherently safer design is a concept that shall be applied by the designers and engineers throughout the FEED phase of the project.

Inherently Safer Design principles considered by the project include:

- Minimization/ Intensification - minimizing hazardous inventory
- Substitution - replacing a hazardous material with a less hazardous one

- Moderation/Attenuation - utilise hazardous materials in their least hazardous form, design equipment to avoid requirement for protective equipment, layout plant to avoid escalation of incidents.
- Simplification - reduce equipment that can fail, reduce ways in which errors can occur and minimize consequence of human errors.

Inherently Safer Design shall be reviewed as part of the HAZID study.

5.1.2 Hierarchy of Control Measures

The project shall consider the hierarchy of controls in determining feasible and effective control solutions to reduce exposure to occupational hazards. The hierarchy of controls from most effective to least effective strategy is:

1. Elimination - Physically remove the hazard
2. Substitution - Replace the hazard
3. Engineering Controls - Isolate People from the Hazard
4. Administrative Controls - Change the way people work
5. PPE - Protect the worker with personal protective equipment.

The application of hierarchy of control measures contributes to maintaining a safe workplace and the demonstration of Hazard management to the relevant regulatory authorities.

5.1.3 Operability

The facility is to be designed such that its human and machine or equipment interface points are suitable for the task and ISD principle of simplification has been considered. Operators are to be provided with clear and concise information to allow actions that could be easily implemented. Hardware that requires manoeuvring, such as valves, should be positioned ergonomically and take into account factors such as frequency of use and the force required. The plant design should also take into consideration of personnel access and egress for normal operation and emergency situations.

5.1.4 Maintainability

The plant is to be designed to take into account accessibility of maintenance equipment, safe isolation of equipment as well as personnel access and egress during maintenance activities.

5.1.5 ALARP Demonstration

The project will demonstrate that all identified risks have been reduced to As Low As Reasonably Practicable (ALARP). This involves demonstrating that the sacrifice to implement a further risk reduction measure is grossly disproportionate to the level of risk reduction achieved. Deciding a risk is ALARP will be by good practice if risk is broadly acceptable and by first principles if risk is tolerable if ALARP.

5.1.6 Major Accident Hazards (MAH) / MATTE

The COMAH Regulations guidelines defines a Major Accident Hazard (MAH) as the potential for a major accident, which in itself is an occurrence such as a major emission, fire or explosion resulting from uncontrolled developments in the course of the operation of any establishment to which the COMAH Regulations apply, and leading to serious danger to human health or the environment (whether immediate or delayed) inside or outside the establishment, and involving one or more dangerous substances.

A MATTE is a Major Accident to the Environment, such as a release of flammable or toxic liquid, gas or vapour onto land, water or the atmosphere.

The potential for the following MAHs /MATTEs shall be considered during this project:

- Unignited release of flammable liquids or gas
- Ignited release of pressurised flammable liquids or gas resulting in a jet fire
- Ignited release of accumulated flammable liquid or gas resulting in a pool fire or flash fire
- Ignited confined accumulation of flammable liquid or gas resulting in pool fire or vapour cloud explosion (VCE)
- Ignited vessel of flammable liquid resulting in a boiling liquid expanding vapour explosion (BLEVE)

5.2 HAZARD IDENTIFICATION AND SAFETY REVIEWS

The project shall complete the following hazard identification and safety reviews:

- HAZID/ENVID reviews shall consider the design, as depicted on the process flow diagrams, with particular emphasis being placed on major accident hazards (MAHs) and major accidents to the environment (MATTE) and any unusual hazards affecting the safety of employees, public and environment. Additionally, the reviews will highlight key concerns that may need to be subjected to further risk assessment and consider application of ISD. A project specific procedure will be written for the FEED phase HAZID/ENVID reviews.
- Hazard and Operability (HAZOP) study is a structured and systematic technique used for identifying potential hazards and examining operability problems in a system, with the objective of providing a basis for risk management. A Preliminary HAZOP review shall take place during FEED phase of the project, and will follow the guidance provided in international standards such IEC 61882, as well as any Client specifications. A project specific HAZOP Procedure will be written for the consolidated FEED phase.

  Gaps identified during the HAZOP will be assessed using Layers of Protection Analysis (LOPA) to support that identified mitigations have reduced risk to ALARP. All changes to P&IDs and C&Es post final project HAZOP will be subjected to Management of Change to ensure hazard identification and risk mitigation.
- Safety Integrity Level (SIL) assessment shall be conducted in accordance to IEC 61508/61511 to classify and assign respective safety integrity levels to safety instrumented systems (SIS). The output from the preliminary HAZOP will serve as the input for the SIL assessment. A project specific procedure will be written for the consolidated FEED SIL Assessment.
- A Plot Plan review shall be conducted to determine if all HSE design related requirements have been incorporated into the layout of the facilities and equipment.
- A 3D Model review shall be carried out with detailed reviews about the operation and maintenance of the plant in order to provide visual checks on safety, operability and maintainability design issues. The 3D model shall show vertical and horizontal dimensions of passageways, escape routes and reserved volumes for operation and maintenance activities.
- An Occupied Building Risk Assessment (OBRA) shall be completed to CIA guidance and this will assess the exposure of personnel in buildings on the plant

site to major accident hazards and identify hazard management safety measures that can be implemented to ensure risk is reduced to ALARP.

- A Quantitative Risk Assessment shall be carried out to establish the risk profile and quantify the risks to personnel, the environment, assets and reputation.

5.3 HAZARDOUS AREA CLASSIFICATION

The project shall complete Hazardous Area Classification consistent with requirements of the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002. Area classification is a method of analysing and classifying the environment where flammable, explosive and toxic fluids or gas atmospheres may occur.

The main purpose is to facilitate the proper selection and installation of apparatus to be used safely in that environment, taking into account the properties of the flammable materials that will be present. DSEAR specifically extends the original scope of this analysis, to take into account non-electrical sources of ignition, and mobile equipment that creates an ignition risk and also covers toxicity from dangerous substances.

Electrical apparatus are to be certified for use in one of the hazardous areas listed below:

- Zone 0, that part of a hazardous area in which flammable atmosphere is continuously present or present for long periods
- Zone 1, that part of a hazardous area in which flammable atmosphere is likely to occur in normal operation
- Zone 2, that part of a hazardous area in which flammable atmosphere is not likely to occur in normal operation and, if it occurs, will exist only for a short time.

The classification of hazardous areas for the project shall to be in accordance with Energy Institute “Model Code of Safe Practice Part 15 Area Classification for Installations Handling Flammable Fluids” (EI 15). Where separation cannot be maintained, appropriate mitigation shall be provided.

In addition, the project will consider area classification for potential explosive dust atmosphere in plant areas where flammable dust will be considered to exist e.g. from the use and handling of catalyst or other flammable dust activities.

All Process area electrical equipment shall be classified for Zone 2, Gas IIB and Temperature Class T4 as a minimum requirement.

The hazardous area classification of equipment installed by the project will be summarized in the Hazardous Area Classification Schedule.

5.4 QUANTIFIED RISK ASSESSMENT

The overall risk of the project facilities shall be quantified based on the frequency and consequence assessments. The risk assessment will identify the main contributors to Project Dragon risk profile and include a breakdown of risk by hazard category, leak sizes and release source. Individual personnel risk and personnel group risk will be calculated. Risk contributions will also be determined according to accident type and work areas.

The identification of the main risk contributors will provide the basis for identifying potential remedial actions. The identified hazardous scenarios that may impact on personnel are mainly outcomes from accidental releases of flammable material such as fires, explosions and flammable and toxic gas dispersion. In general, the major accident hazard and major accidents to the environment hazard scenarios that will be assessed will include the following but not limited to;

- Jet fires
- Pool fires
- Flash fires
- Flammable gas dispersion
- Toxic gas dispersion
- Vapour cloud explosion
- Boiling liquid expanding vapour explosion (BLEVE)

The risk quantification and analysis for Project Dragon will include the risk assessment techniques listed below and with the aim of achieving their corresponding underlining objectives:

- Fire and Explosion Risk Assessment
  - Identifying potential fire and explosion hazards in the facilities
  - Identifying the impact of fires and explosions on plant equipment and facilities
  - Defining the required protection measures which control or mitigate the effects of fires and explosions
  - Assessing opportunities to reduce risks further from possible fire and explosion hazards, and
  - Providing recommendations to minimize the severity of fires and explosions

- Quantitative Risk Assessment
  - Quantifying the overall risk to personnel associated with the facilities within the scope of the plant
  - Where required, identifying the main contributors to the overall risk
  - Identifying measures to reduce the overall risk and analysing their effectiveness
  - Where a number of alternative options are available, determining the relative safety and effectiveness of the alternatives, and
  - Demonstrating compliance with the risk tolerability criteria and assisting in the demonstration of ALARP
- Gas Dispersion Analysis

6. PLANT LAYOUT

The plant layout of Project Dragon will be designed with an emphasis on inherently safer design and reducing identified risks to ALARP. The layout design will follow the requirements to be outlined in the Piping Basis of Design to be issued on the project.

A number of principles will be considered for laying out the facility to ensure its safety as well as ease of operability, which may include but is not limited to:

- Separation of high-risk equipment items, to control the loss of containment hazards and minimize escalation.
- Separation of plant and buildings by distance, to control or minimise effects of hazards.
- Provision of an open arrangement of plant to minimise potential for gas or vapour leak accumulation.
- Minimisation of hazardous inventories, by reducing pipe runs.
- Accessibility for normal and emergency operations.
- The layout shall meet safety requirements for personnel and vehicular traffic, security and access for maintenance and operation.
- Adequate and safe access will be considered and provisions made for emergency evacuation and firefighting.

- Adequate separation between flammable hydrocarbons and potential ignition sources.
- Adequate separation between hydrocarbon handling areas and emergency services, life-safety equipment, escape routes and muster points.
- Location of emergency muster points shall be identified.
- Operator shelters shall be located in a non-hazardous area.
- The safety requirements for hazardous area classification and the selection of electrical equipment shall be duly implemented. Where buildings exists such as sub-stations and control buildings, they shall be located as far as practicable in areas that are classified as non-hazardous. In any event, HVAC intake for such buildings shall be located in non-hazardous area and away from possible hydrocarbon leak sources.
- Electrical facilities shall be preferentially located so that they are largely unaffected by incident heat radiation or explosion overpressures resulting from credible accidents.
- Design of facilities to ensure structural integrity can be maintained during a hazard condition to avoid escalation, and provide sufficient time to enable orderly evacuation to be achieved.
- Design the plant such that the detrimental effects of natural forces are minimal.
- Provision of suitable and sufficient drainage and spill control.
- Orientation of plant such that the prevailing wind directs any accidentally released flammable and/or toxic gases away from potential sources of ignition, safe areas or inhabited property outside the boundary fence.
- Containment of large quantities of flammable fluids shall be located such that prevailing winds will direct any vapour from an accidental spill away from the units and plant.
- Vehicle access and the constraints of plant restricted area classification.
- Vents and flares shall be located to reduce minimum interference or hazard to personnel, plant and general public.
- Limit or prevent escalation of a fire by providing spacing that adequately separates the process unit, large structures and process drainage systems.

- Avoid loss of life and serious injuries by providing adequate means of escape for personnel to evacuate safely, access for emergency responders to a fire and safe access for personnel to isolate plant and equipment.
- Contain and prevent the spread of fire by having early detection and warning devices and systems that enable emergency isolation, shut down of process equipment to limit the volume of material released in the event of fire.
- Protect steel structures by providing passive and active fire protection systems in hazardous areas.
- The design of the plant layout will ensure emergency services such as fire and ambulance services have a clear approach to the facility.

Application of these principles is intended to limit the consequences of hazardous incidents (such as a leakage or fire) to the area of occurrence.

The plant layout and design shall also incorporate agreed recommendations from the Fire and Explosion Risk Assessment (FERA) and Quantitative Risk Assessment (QRA) studies.

6.1.1 Escape Routes

An Escape, Evacuation and Rescue Analysis (EERA) study shall be completed as part of this project.

Adequate means of escape shall be provided from all plant areas, regardless of frequency of occupancy. Escape routes shall take the most direct route away from a hazardous area to a safe haven, that is lead to an area of lesser hazard for any reasonable emergency event. There shall be at least a minimum of two escape routes from all commonly used areas on the plant, but excluding infrequently accessed elevated platforms or modules.

Emergency escape routes shall be readily accessible, unobstructed and they shall be clearly marked. Escape route direction signs shall be strategically positioned along escape routes, to guide personnel to the muster areas.

6.1.2 Minimize Leak Sources

Leak sources are to be minimised without compromising maintainability and constructability wherever practicable. Small bore connections shall be adequately supported and protected against mechanical damage.

Design shall include a closed drain system as described in Drainage and Venting Philosophy. Where practical sample and analyser connections shall return flushing material to the process..

Materials of construction shall to be selected to be appropriate for the process conditions, in order to control the effects of temperature, corrosion, embrittlement etc and, hence, avoid loss of containment. Gaskets selected shall be consistent with EN 13555 standard described in BATs with bleeds and vents to atmosphere provided with positive isolation (cap, plug or blind flange).

6.1.3 Muster Points

Muster points for the assembly of personnel in an emergency shall be clearly designated for Project Dragon facility. These areas shall be located such that they are in a safe and protected area.

Muster points shall be provided in sufficient areas to account for difference in weather conditions and incident locations. They shall be clearly identified by a large sign and a sheltered standard telephone for means of communication with the emergency response team provided adjacent to it.

6.1.4 Fire Zone Segregation

This is covered in the Fire Protection Philosophy (202947C-000-JSD-1900-00005).

7. FIRE SAFETY AND EQUIPMENT PROTECTION

The aim of fire safety protection policy is to minimise loss of life and serious injury or damage to asset and environment by containing and preventing the escalation and spread of fire.

The ability to detect fire early and initiate warning signals enables facilities to proactively attend to and actively protect against fires which will minimise potential damage and financial loss that can result from such an incident.

In order to be able to assign the right fire mitigation measures within any plant, a few factor may be considered which may include the following:

- Locations where fire can occur (fire areas)
- Type of fire (jet or pool) and its duration

- Likelihood of the fire scenario
- Fire size i.e. the possible area exposed to the fire
- Heat load onto impinged and neighbouring equipment or objects

7.1 EMERGENCY SHUTDOWN (ESD) AND DEPRESSURISATION SYSTEM

This is covered in the Overpressure Protection and Emergency Shutdown (ESD) Philosophy document (202947C-000-CN-0008-00001).

7.2 RELIEF AND VENTING

This is covered in the Overpressure Protection and Emergency Shutdown (ESD) Philosophy (202947C-000-CN-0008-00001).

7.3 FIRE AND GAS DETECTION AND ALARM SYSTEMS

This is covered in the Fire and Gas Detection Philosophy (202947C-000-JSD-1900-00001)

7.4 FIRE PROTECTION SYSTEM

This is covered in the Fire Protection Philosophy (202947C-000-JSD-1900-00005).

8. PLANT PERSONNEL SAFETY AND HEALTH

8.1 GENERAL

To ensure the safety and health of plant operators/personnel that would be required to work in Project Dragon plant, there are various facilities and equipment that are expected to be provided.

8.2 SAFETY EQUIPMENT

8.2.1 Safety Signage

Safety signs shall be provided throughout the plant to provide warning or information, or to identify locations of safety, firefighting and survival equipment, etc. Safety signage shall include painted lines where additional PPE is required (e.g. hearing protection, personal gas monitor, googles, gauntlet gloves).

Safety and environmentally critical equipment tags shall be differentiated from other equipment tags (e.g. white text on red background instead of black text on white background). They shall combine the geometrical shape, colour and pictorial symbol to give specific health and safety or emergency information, instruction, prohibition and/or advice on safety matters. All signs containing script shall be English language and shall follow the HSE guidance L64 Safety Signs and Signals, ISO 3864, BS EN ISO 7010:2020 and BS 5499 to meet the Health and Safety Regulations 1996.

8.2.2 Safety Showers and Eyewash Baths

Safety showers and eye wash units shall be located at strategic locations of the process or utility plot where hazardous substances are stored or used. The shower units shall operate with a potable and clean water supply source, they are to be self-draining after use and be provided with a water flow alarm reporting to the main control room. Safety showers shall be located, as a minimum, close to chemical and catalyst handling areas, battery rooms, laboratories and general vicinity of locations where exposure to chemicals which upon contact with the skin or eyes can causes skin/eye irritation, injury or burns.

Caustic solution shall arrive in shipments and shall be stored on site. The site shall have safety showers and eye wash stations by all chemical handling areas and in general vicinity for any chemical exposures. General distance shall depend upon the time permissible before injury can occur. Anything that is considered hazardous to personnel (via adsorption, surface irritant, eye/mucus membrane, respiratory) will need to be washed off.

Safety shower and eyewash units shall be provided within modules and throughout the site, at loading/unloading facilities, water treatment (CT, BFW, WW, etc.). These shall be provided with sunshades where installed in the open. The units shall be capable of delivering controlled flow of tepid water between 16 - 38°C, achieved by the use of temperature controller and valve in the heater circuit to maintain the required temperature as outlined in ANSI Z358.1 for both cold and hot days. The shower shall be automatically operated by stepping on a treadle and the eyebath either by a treadle or elbow lever.

Lighting, including emergency lighting, shall be provided at the safety shower locations. Safety shower and eyewash station locations shall be identified as part of this project and shown within the Safety Equipment and Escape Route Layout Drawing (202947C-000-DW-1960-00001).

8.2.3 Manual/Fire Alarm Call Points

This is covered in the Fire and Gas Detection Philosophy (202947C-000-JSD-1900-00001).

8.2.4 Mobile And Portable Fire Extinguishers

This is covered in the Fire Protection Philosophy (202947C-000-JSD-1900-00005).

8.2.5 Fire Blankets

This is covered in the Fire Protection Philosophy (202947C-000-JSD-1900-00005).

8.2.6 Medical / First Aid Facilities

Life-saving kits suitable for electrical shock injuries, defibrillators and first aid boxes shall be provided at strategic locations within the plant complex.

8.2.7 Self-Contained Breathing Apparatus

Self-contained breathing apparatus (SCBA) is an important piece of equipment first responders will take into a fire, and it is also useful where there is a potential for plant personnel to be exposed to dangerous concentrations of hazardous substances or in cases of oxygen depletion resulting from smoke generation, fire emergencies or release of toxic (e.g. Sox) or inert gases (e.g. Nitrogen)

SCBA shall be provided in building and designated plant areas, and they shall be housed in protective containers. The containers shall be suitably painted and provided with signs to advise personnel of their contents. The SCBA sets shall be regularly checked and maintained and facilities shall be available on site, or at a local depot, to recharge the air bottles at short notice.

The quantity of breathing apparatus to be provided for Project Dragon shall be greater than the expected number of the firefighting and emergency response team and personnel working in the process area of the plant when fully manned. In addition, the site will hold extra SCBA sets in store to accommodate for periodic maintenance, recharge and refill of the SCBA cylinders.

8.2.8 Windsocks

Windsocks shall be located at strategic elevated locations around the process plant.

At least one windsock should be visible from any location within the plant area. This assists personnel in determining a safe direction of travel when evacuating the unit in the event of an emergency. The direction of travel will be arranged such that personnel can travel in a cross-wind and upwind fashion to the prevailing wind direction.

The windsocks shall be provided with adequate nearby light to ensure visibility at night times.

8.3 STAIRS AND LADDERS

Stairs and ladders shall be provided at specified intervals within the facility.

Secondary or alternative means of escape shall be provided from top of platforms in open frame structures such as open modules (external plant) containing process plants.

8.4 GUARD RAILING

Platforms, walkways, ramps and floors with open sides above grade are to be provided with guard railings.

8.5 EMERGENCY LIGHTING

Emergency lighting units with integral battery backup are to be provided for the light fittings inside buildings, modules and plant structures to light up escape routes, means of escapes such as stairways etc.

8.6 PROTECTION FROM HOT AND COLD SURFACES

Hot or cold surfaces that could result in injury to personnel in normally accessed areas shall be provided with personnel protection mesh .

8.7 MACHINERY GUARDING

All exposed moving parts on all machinery shall be suitably guarded to protect personnel from injury. Guards and safety devices provided shall be well maintained and kept in position whilst machinery is running.

8.8 PROTECTION FROM TOXIC SUBSTANCES

The criteria for the classification of the Toxicity for the Gas/Vapor streams, are necessary for:

- the assignment of welding classes for the piping
- isolation philosophy and requirements for positive isolation

To the aim of toxicity classification, the criteria described herein are based on:

- Globally Harmonized System of Classification and Labelling of Chemicals (GHS), 3rd Edition, United Nations Economic Commission for Europe (UNECE)
- Regulation (EC) No. 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No. 1907/2006

The classification criteria of toxic fluids provided by GHS and European Regulation is resumed in the following table, where the hazard categories considered in this Criteria and the general criteria to assign toxic substances/mixtures to each hazard category are specified. A common class for carcinogenicity (Category 1) is considered, which includes categories 1A and 1B stated in European Regulation.

TABLE A-1: Classification Criteria of Toxic Fluids According to GHS and EC Regulations

HAZARD CLASS	HAZARD CATEGORY	ASSIGNMENT CRITERIA
Toxicity	Acute Toxicity: Acute Toxicity category 1 (AT-1)	Inhalation concentration thresholds (LC50): LC50 ≤ 100 ppm (gas) ≤ 0.5 mg/l (vap.)

HAZARD CLASS	HAZARD CATEGORY	ASSIGNMENT CRITERIA
	Acute Toxicity category 2 (AT-2) Acute Toxicity category 3 (AT-3)	100 ppm < LC50 ≤ 500 ppm ≤ 2 mg/l (vap.) 500 ppm < LC50 ≤ 2500 ppm ≤ 10 mg/l (vap.)
	Carcinogenicity:	Carcinogens by inhalation
	Carcinogenicity category 1	Carcinogenicity category 1, Known / presumed to have carcinogenic potential for humans, classification is largely based on human evidence
	Carcinogenicity category 2	Carcinogenicity category 2, Possibly / suspected carcinogenic to humans

General Notes:

1. European Regulation foresees other hazard categories in addition to those specified in Table A1. Some hazard categories are excluded from these Criteria since either they are characterized by a minor hazard severity or they include substances leading to long term effects on repeated or prolonged contact, such that more stringent engineering measures to reduce the potential releases are not justified from a costs/benefits point of view. Examples of excluded hazard categories are:
   - Acute Toxicity category 4 (AT-4) including substances defined as harmful for human health but not toxic;
2. These criteria consider toxic fluids causing acute/chronic effects for inhalation only. Oral and dermal exposure routes are excluded, so refinery products (like naphtha, kerosene, gasoline, etc.) that are classified “carcinogenicity category 1B” due to their content of polycyclic HC, are neglected in the context of this document, since they exert their action by repeated skin contact; such substances are therefore not considered toxic.

A graded definition of hazardous characteristics of process fluids according to the three categories "Toxic", "Very Toxic" and "Extremely Toxic", has been identified. The correspondence between these categories and the European Regulation classification is given in the following Table A-2.

TABLE A-2: Correspondence between project Categories and International Classification of Toxic Substances

EXTREMELY TOXIC	VERY TOXIC	TOXIC
Acute Toxicity Cat. 1 (AT-1)	Acute Toxicity Cat. 1A (AT-1) Carcinogenicity Category 1	Acute Toxicity Cat. 1B / 2 (AT-3) Carcinogenicity Category 2

Examples of pure substances characterization related to the project are listed in Table A-3 below, with the relevant classification and Hazard Statements according to European Regulation 1272/2008/CE.

TABLE A-3: Examples of GHS Categorization for Pure Substances

Substances	CAS No.	LC_{50} (4h)	GHS Category	
			Acute Toxicity	Carcinogenicity
Ethanol	64-27-5	117 mg/l	N/A	-
Diethyl Ether	60-29-7	97.5 mg/l	N/A	-
Methanol	67-56-1	3.1 mg/l	AT-3	-
Acetaldehyde	75-07-0	13300 ppm	N/A	Carc-1B / 2

TABLE A-4 reports criteria for the classification of hazardous mixtures based on concentration of substances contained in the mixture.

TABLE A-4: Classification of Toxic Mixtures versus Substances Concentration

EXTREMELY TOXIC	VERY TOXIC	TOXIC
AT-1 ≥ 0.2% AT-2 ≥ 1% - -	0.02% ≤ AT-1 < 0.2% Canc-1 ≥ 5% 0.1% ≤ AT-2 < 1% AT-3 ≥ 10%	0.005% ≤ AT-1 < 0.02% 0.1% ≤ Canc-1 < 5% 0.01% ≤ AT-2 < 0.1% 0.5% ≤ AT-3 < 10 % Canc-2 ≥ 1%

General Notes:

1. Concentrations indicated in Table A-4 are:
   - percentage by volume if the substance is gaseous at operating conditions of pressure and temperature;
   - percentage by weight if the substance is liquid at operating conditions of pressure and temperature.
2. Concentration thresholds are additive for substances belonging to the same toxicity/carcinogenicity class and to the same phase (evaluated at operating conditions of pressure and temperature).
3. Criteria given in Table A-4 are alternative: satisfaction of one of them is sufficient to attribute to the mixture the most conservative class of toxicity.

By the application of the above criteria, the toxic classification for gas/vapor stream mixture containing the hazardous substances reported in Table A-3 is as follow in Table A-5:

TABLE A-5: Examples of GHS Categorization for Substances in Mixtures

EXTREMELY TOXIC	VERY TOXIC	TOXIC
	Methanol ≥ 10%	0.5% ≤ Methanol < 10% Acetaldehyde > 1%

9. ENVIRONMENTAL REQUIREMENTS

Guidance on the environmental criteria to be followed during the design of the Project Dragon facilities will be provided by the Environmental Basis of Design (202947C-000-JSD-6200-00001). This design basis will set out the required air and aqueous release (emission and discharge) limits, hazardous waste control measures, noise emission limits, and other considerations that shall be applied to the Project design.

The Environmental design basis shall take into account the legislative requirements of Natural Resources Wales (NRW), LanzaTech guidelines and codes of practice, and any other permitting requirements applicable to FEED design.