INSTITUTION OF GAS ENGINEERS AND MANAGERS
IGEM/TSP/24/259

IGEM/UP/22
Communication TBC

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Whole Lifecycle Management of Vacuum Insulated Tanks for Liquefied Natural Gas

DRAFT FOR COMMENT

1 This draft Standard IGEM/UP/22 has been prepared by a Panel chaired by Jason Smalley

2 This Draft for Comment is presented to Industry for comments which are required by 29 January 2025, and in accordance with the attached Reply Form.

3 This is a draft document and should not be regarded or used as a fully approved and published Standard. It is anticipated that amendments will be made prior to publication.

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Andrew Richardson
IGEM
IGEM House
26-28 High Street
Kegworth
Derbyshire, DE74 2DA
Tel: 01509 678150
Email: andrew@igem.org.uk

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IGEM/TSP/24/259

Attached is the Draft for Comment of IGEM/UP/22 – "Whole Lifecycle Management of Vacuum Insulated Tanks for Liquefied Natural Gas" and the associated comment form.

We wish to make it as easy as possible for those of you representing industry bodies to issue the draft to your Members. You can either forward this email with attachment complete or forward it without the attachment and invite them to visit our website via https://www.igem.org.uk/resource-library-search.html?information_type=out-for-comment where the Draft and Comment Form are posted.

Organisations to which this Draft has been circulated:

Organisation	Representative
BSI/GSE/30	SOPHIE SHERWOOD
BPEC	MALLY BUTTERS
BRITISH GAS	BRETT JOHNSON
CADENT	HILARY BUXTON
CIBSE	ANASTASIA MYLONA
CIPHE	TONI-LOUISE MATTHEWS
CMAP	JOHN HEYBURN
DNO COLLAB FORUM	HILARY BUXTON
EI	MARK SCANLON
ENA	James Earl
EUA	STEVE SUTTON
EUSKILLS	RICHARD HARPER
GSR	JONATHAN PALMER
GISG	BOB MURRY
HHIC	STEVEN SUTTON
HSE	DIANE KERR
HSE	PAUL NEWTON
HSENI	SEAN KEOGH
B&ES (was HVCA)	JACK VERBER
ICOM	STEVE McCONNELL
*Large Business Forum	TREVOR SMALLPEICE

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RETAIL ENERGY CODE (REC)	ERIC FOWLER
NGN	IAIN FOSTER
OFGEM	VIC TUFFEN
SGN	DOMINIC CUMMINGS
LIQUID GAS UK	RICHARD HAKEEM
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MEMB C	CLAIRE McHUGH
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TCC	CHRIS GORMAN
GMC + ACTIVE PANELS	DAVID HARPER
GUC + ACTIVE PANELS	GRAHAM McKAY
HYDROGEN C	KEITH OWEN
LNGC	MARK JOHNSON
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Whole Lifecycle Management of Vacuum Insulated Tanks for Liquefied Natural Gas

DRAFT FOR COMMENT

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IGEM House
26 & 28 High Street
Kegworth
Derbyshire, DE74 2DA
Tel: 0844 375 4436
Email general@igem.org.uk

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SECTION 1 : INTRODUCTION

1.1 The requirement for this Standard has been agreed between the IGEM Technical Co-ordinating, Gas Transmission and Distribution, Gas Utilisation, Hydrogen, Liquid Natural Gas (LNG) and Gas Measurement Committees, who are responsible for the publication of IGEM Standards.

1.2 This Standard has been created to ensure a consistent approach is taken in producing IGEM Standards. It therefore provides a framework for the content, style, layout and publication which need to be taken into consideration when writing or revising IGEM Standards.

1.3 IGEM/UP/22 is for those organisations involved in the design and operation of Vacuum Insulated Tanks (VIT) for Liquefied Natural Gas Service

1.4 This Standard summarises best practice for the design, installation, operation, inspection, maintenance and decommissioning of VITs for LNG service. It combines well established practices with new advice on aspects of design and construction of such installations. The Standard consolidates best practice and guidance from Legislation, and existing gas industry standards and procedures, with the aim of helping to achieve safe designs, installations and continuing safe operation for installed VITs throughout the lifetime of the asset.

1.5 This Standard is intended primarily for an informed and experienced audience such as Gas Engineering professionals, Architects, Mechanical and Electrical Engineering Consultants, Building Facilities and Maintenance Managers and the Responsible Person associated with LNG VITs. It is assumed that readers of this standard are familiar with and understand the roles specified in the Construction (Design and Management) Regulations (CDM).

1.6 Compliance with this Standard cannot confer immunity from statutory legal obligations.

1.7 This Standard makes use of the terms "must", "shall" and "should", when prescribing particular requirements:

- the term "must" identifies a requirement by law in Great Britain (GB) at the time of publication
- the term "shall" prescribes a requirement which, it is intended, will be complied with in full and without deviation
- the term "should" prescribes a requirement which, it is intended, will be complied with unless, after prior consideration, deviation is considered to be acceptable.

Note: The phrase "prior consideration" means that a suitable and sufficient risk assessment will be completed and documented to show that the alternative method delivers the same, or better level of protection

Such terms may have different meanings when used in Legislation, or Health and Safety Executive (HSE) Approved Codes of Practice (ACoPs) or Guidance, and reference needs to be made to such statutory Legislation or official Guidance for information on legal obligations.

1.8 The primary responsibility for compliance with legal duties relating to health and safety at work rests with the employer. The fact that certain employees, for example "responsible engineers", are allowed to exercise their professional judgement does not allow employers to abrogate their primary responsibilities. Employers must:

- have done everything to ensure, so far as is reasonably practicable, that there are no better protective measures that can be taken other than relying on the exercise of professional judgement by "responsible engineers".
- have done everything to ensure, so far as is reasonably practicable, that "responsible engineers" have the skills, training, experience and personal qualities necessary for the proper exercise of professional judgement.
- have systems and procedures in place to ensure that the exercise of professional judgement by "responsible engineers" is subject to appropriate monitoring and review.
- not require "responsible engineers" to undertake tasks which would necessitate the exercise of professional judgement that is beyond their competence. There should be written procedures defining the extent to which "responsible engineers" can exercise their professional judgement. When "responsible engineers" are asked to undertake tasks that deviate from this, they should refer the matter for higher review.

1.9 It is now widely accepted that the majority of accidents in industry generally are in some measure attributable to human as well as technical factors. People who initiated actions that caused or contributed to accidents might have acted in a more appropriate manner to prevent them.

To assist in the control of risk and proper management of these human factors, due regard is to be taken of HSG48 and HSG65.

1.10 Notwithstanding Sub-Section 1.7, this Standard does not attempt to make the use of any method or specification obligatory against the judgement of the responsible engineer. Where new and better techniques are developed and proved, they are to be adopted without waiting for the modification of this Standard. Amendments to this Standard will be issued when necessary and their publication will be announced in the Journal of IGEM and other publications as appropriate."

1.11 Requests for interpretation of this Standard in relation to matters within their scope, but not precisely covered by the current text, to be either:

- addressed to Technical Services, IGEM, IGEM House, 26 & 28 High Street, Kegworth, Derbyshire, DE74 2DA; or
- emailed to technical@igem.org.uk.

These will be submitted to the relevant Committee for consideration and advice, but in the context that the final responsibility is that of the engineer concerned. If any advice is given by or on behalf of IGEM, this does not imply acceptance of liability for the consequences and does not relieve the responsible engineer of any of their obligations.

1.12 This Standard was published in (date TBC) 2025.

SECTION 2 : SCOPE

2.1 This Standard shall be applied to the design and operations of LNG VITs for vessels in excess of 200 Tonnes for vessels operating above 500mBar. The standard shall be applicable for all new installations.

Note: BS 13645 is applicable to a range of 5 – 200 tonnes with larger vessels to EN1473

2.2 The equipment system boundary shall encompass the vessel, its supporting structure, spillage retention bunds and valving, and include any other valves and fittings required for its own operation such as vessels, gauges, pipework systems, and fill valves.

2.3 Out of scope: The following items of plant are considered to be outside of the main VIT equipment system boundary and are therefore outside of the scope of this standard:

- LNG transfer pumps
- Vaporisers
- atmospheric storage tanks (including tanks below 3.5 barg)
- design of compressors
- conventionally insulated bulk storage, e.g., single wall tanks with polyurethane insulation
- buried storage
- associated LIN tank and LIN system
- product quality and custody transfer measurement
- foam suppression and other arrangements for active fire protection

2.4 This Standard also provides guidance and mandatory requirements to be applied for each stage of the lifecycle of the asset:

- Conceptual and Detailed Design
- Testing
- Commissioning
- Operation
- Maintenance and Inspection
- Decommissioning and disposal

Note: MAH/COMAH and planning consideration for multiple vessels are covered in sections 4.

SECTION 3 : LNG VIT MANAGEMENT SYSTEMS

3.1 OVERALL PRINCIPLES

3.1.1 Any form of management system applied to LNG VIT assets should follow the basic principles of the Plan, Do, Check and Act management cycle outlined in HSG65.

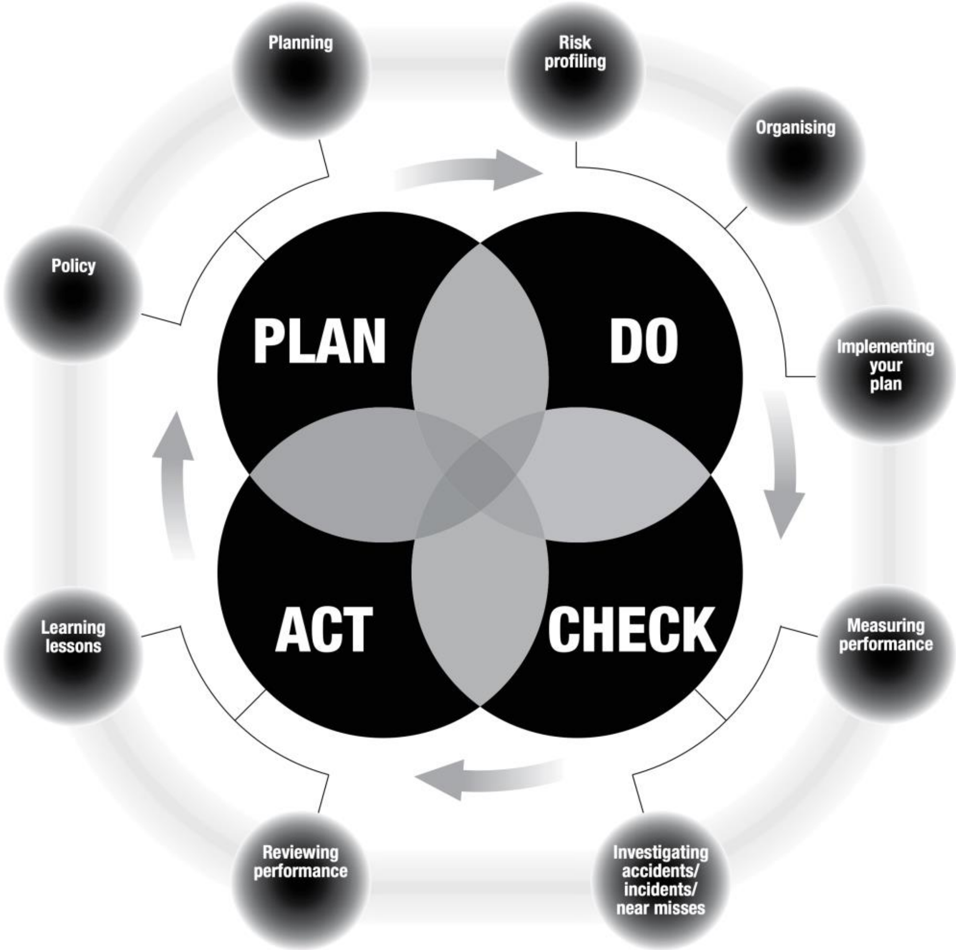

FIGURE 1: THE HSG65 PLAN, DO, CHECK, ACT CYCLE

The HG65 principles ensure that policies and plans for implementation are in place and that all probable risks have been identified and assessed.

Appropriate control measures should be set, implemented and managed throughout the lifecycle of the plant.

Performance (monitor before events, investigate after events) should be measured and reviewed on a routine basis.

Learning should be taken from measurements and findings of investigations and appropriate actions and amendments to control measures should be applied.

3.2 PERSONNEL TRAINING AND COMPETENCY

3.2.1 Any person engaged in the design, construction, commissioning, inspection, operation, maintenance, or alteration of LNG VITs shall be competent to carry out such work.

This may be achieved by an appropriate combination of education, training, and practical experience.

3.2.2 Only persons trained for the specific task shall be allowed to install, put into service, fill, handle, operate or maintain the vessel and its equipment.

The training programme shall include

- normal operating procedures
- product and hazard identification
- safe operating limits
- emergency procedures
- physical and chemical properties of the vessel's contents and their effects on the human body
- personnel protective equipment (e.g. safety boots, goggles, gloves).

Training shall be repeated as necessary to ensure that personnel remain competent. A training record shall be maintained which details the information personnel have received.

3.3 QUALITY ASSURANCE AND QUALITY CONTROL

3.3.1 All materials and equipment shall be selected to ensure safety and suitability for the conditions of use, in accordance with relevant legislation, standards, technical specifications and this Standard.

Note 1: All materials and components are to be obtained from suppliers operating a quality system in accordance with an appropriate standard such as BS EN ISO 9001 to ensure that products achieve consistently the required levels of quality.

Note 2: Material certification are to be critically reviewed to avoid procurement of counterfeit components. Guidance is provided in EEMUA Publication 224, A guide to risk-based procurement.

3.3.2 Effective arrangements shall be made to ensure that materials and workmanship are in accordance with the design requirements and construction specification. All material certificates, test certificates, weld records and insulation records shall be retained throughout the life of the plant as part of the permanent construction records.

3.3.3 The results of any in-service inspections shall be retained as an ongoing and permanent record of the VIT installation.

3.2.4 A quality plan and associated work procedures shall be developed, to provide control and monitoring of all activities from design through to operation. A suitable audit plan should be formed to check adherence to procedures.

3.2.5 A post construction site inspection audit may be used to establish that the as-built construction satisfies the design and construction requirements.

3.3 SAFETY MANAGEMENT

3.3.1 The initial integrity of any vessel is established through proper design, material selection, sound construction practices and testing procedures.

3.3.2 The design stage provides an important opportunity for reducing risks to people and property as a result of appropriate consideration of health and safety factors. The design stage, which covers concept selection through to detailed design specification (drawings, calculations, specifications, etc), provides the maximum potential for reducing risks, by application of the principles of inherently safer design.

Note 1: Detailed guidance on risk management is provided in the HSE Guidance note: Risk management: Expert guidance - Policy and guidance on reducing risks as low as reasonably practicable (hse.gov.uk)

It is particularly important to assure initial build integrity for LNG VIT's, as it is not normally practicable to apply periodic thorough internal inspection once they are in service. The design stage offers a unique opportunity to ensure that careful and robust design considerations are applied which should ensure safe operation throughout its lifecycle.

3.3.3 After commissioning and during operation, a programme of condition monitoring, periodic inspection and maintenance shall be undertaken to ensure integrity is maintained.

3.3.4 In order to ensure that any installed LNG VIT operates at the levels of safety envisaged in Section 4, all of the requirements shall be considered and implemented as necessary. The criteria from any section of this Standard are not intended to be used in isolation. If changes are made to any criteria, the possible impact on other sections of the Standard should be considered.

Note 1: The integrity of a LNG VIT installation is dependent upon many inter-relating activities. Figure 2 shows the main links between the major activities. It does not attempt to show all the items necessary to ensure integrity, nor does it show the complex links within a major activity, but it does provide a flow chart/checklist to ensure that all aspects of integrity are being addressed.

Note 2: Regulatory authorities require LNG operators to provide positive demonstration that integrity is properly established, monitored and maintained.

All workers involved in work associated with the construction, installation, testing and maintenance of LNG VITs shall have the necessary qualifications, skills and experience for the work, and for the inspection and maintenance of the equipment they need to use.

Detailed requirements and standards for weld procedures / welder qualification, NDT personnel, Notified Body requirements, etc. are provided within sections 6 and 9 covering Construction and In-service Operation.

All workers must be familiar with the workplace risks and the control measures in place.

Workplace health and safety Regulations (see Section 4), and associated HSE ACoPs, outline what employers are required to do to manage health and safety at work, including the provision of clear information to both employees and contractors engaged on site.

Clear and effective communication shall be established and maintained with all parties throughout the VIT lifecycle for all construction, operating and maintenance operations. Consideration shall be given to language barriers where workers' first languages are not the same. Hand signals can vary between countries so any non-verbal communication shall be well understood in advance of any operation.

3.3.5 After commissioning, continued integrity shall be ensured by implementing an appropriate safety management system (see also Sub-Section 3.4 and Figure 2).

Note: The safety management system would normally follow these principles in line with HSG65:

- *_policy – the operator would have clearly defined policies which set out what is trying to be achieved in terms of safe management of the pipeline/installation.*

- *_organisation – there would be appropriate organisational structures in place to effectively deliver the policy requirements: These would include clearly defined roles and responsibilities within the organisational structure.*
- *_planning and implementation – there would be appropriate management controls in place to ensure that pipeline and/or installation operations are carried out safely and in line with the defined policies. These controls would include ensuring that individuals responsible for carrying out safety related activities have the appropriate training and competencies.*
- *_measure – the pipeline/installation performance would be measured against agreed standards to reveal when and where improvement is needed.*
- *_audit – there would be appropriate audit processes in place to ensure that policy requirements are being adequately delivered.*
- *_review – the overall management process would be under continuous review to ensure that it is delivering the required levels of performance. Normally, this would involve the monitoring of fault, accident and near miss data.*

The safety management system must be documented in the operator's Major Accident Prevention Document (MAPD).

Note: Further guidance on safety management is given in PD 8010 Pt.4, and BS EN 17649:2021.

3.4 ENVIRONMENTAL MANAGEMENT

3.4.1 Environmental management of any LNG VIT installation shall be carried out in accordance with relevant statutory requirements and good engineering practice. Relevant statutory requirements include the environmental impact assessment (EIA), management of reinstatement materials, noise, management of radioactive, materials and testing, disposal of waste (including water used for hydrostatic testing) and air emissions.

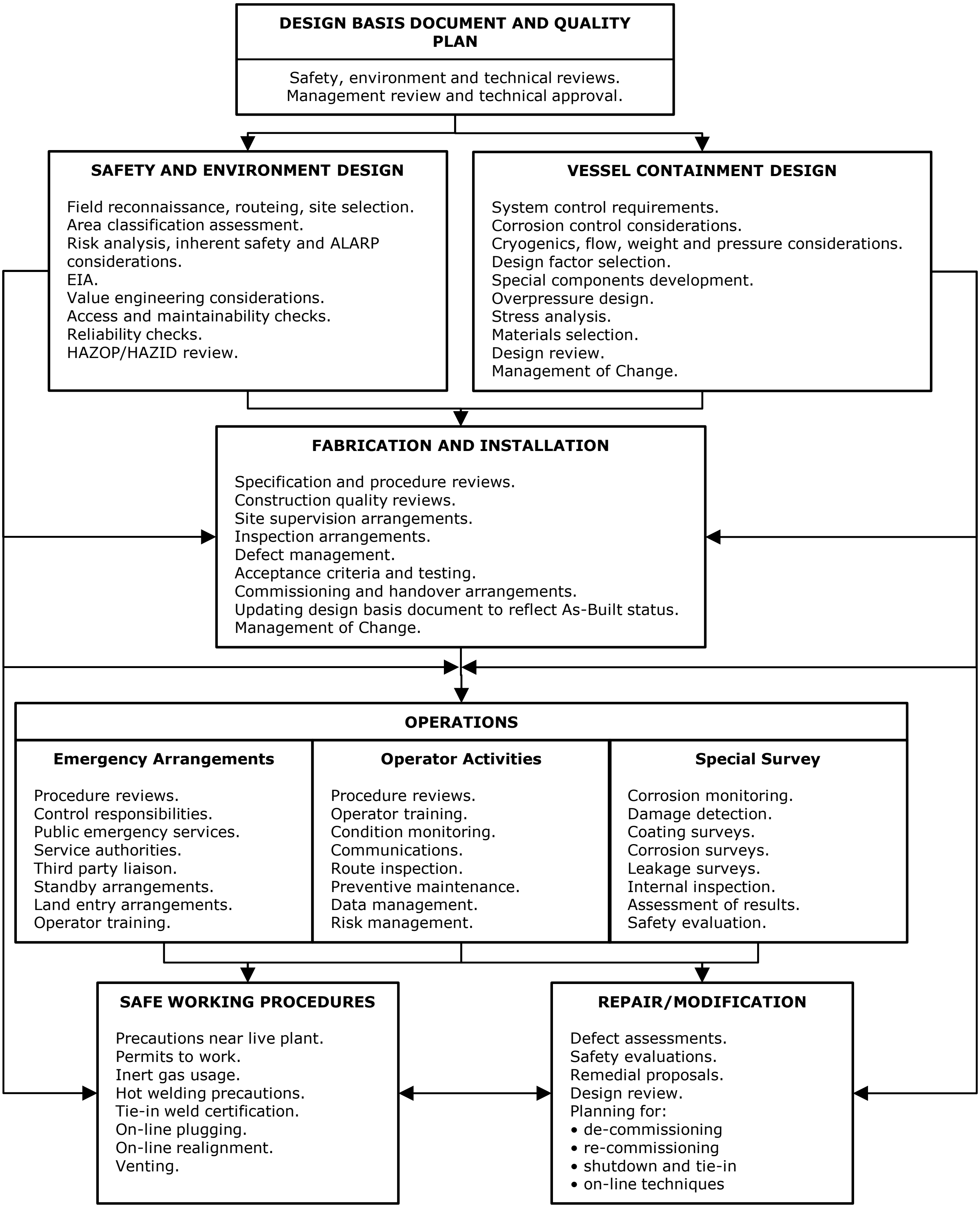

FIGURE 2: SAFETY AND ENVIRONMENT MANAGEMENT SYSTEMS

3.5 INTEGRITY MANAGEMENT

Integrity is defined as the strength, quality and condition which provides resistance to applied loads and tolerance to damage such that the product is contained at an adequate level of safety. Comprehensive requirements for ensuring the integrity of a LNG VIT shall be assessed and defined during the design stage and implemented as part of the commissioning, testing and operational lifecycle phases.

3.5.1 Integrity Management Process

3.5.1.1 Vessel integrity shall be managed and controlled at all stages of the asset life cycle (see Figure 3). The primary requirement of the vessel integrity management process is the identification of potential threats, evaluation of risks associated with each threat, and the implementation of specific risk control measures.

3.5.1.2 Potential threats to vessel integrity may include:

- material and construction defects
- ground movement
- external interference
- corrosion (external and internal corrosion, stress corrosion cracking (SCC), corrosion induced by AC/DC, etc.)
- fatigue
- overpressure.

Specific threats posed by these potential risks will depend on the location of the LNG VIT installation, and this should be taken into account in the evaluation of risks and identification of risk control measures.

The requirements for LNG VIT management at each stage of the asset life cycle, required by this Standard, are summarised in Table 1.

3.5.2 Integrity Management System

3.5.2.1 An LNG VIT integrity management system, which facilitates the integration and relation of integrity data on the vessel and all auxiliary equipment, pipework and fittings located within the equipment system boundary, should be used to ensure that integrity data is accurately related to the condition of the vessel protection, coating and pipework throughout the lifecycle of the VIT installation.

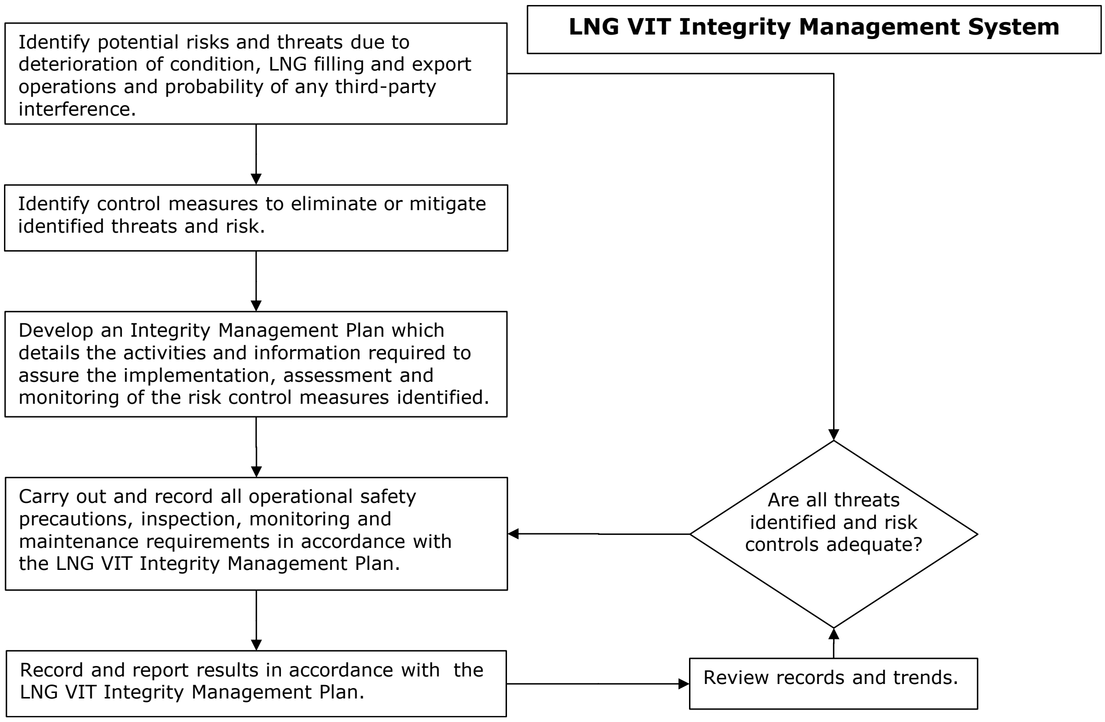

FIGURE 3 – LNG VIT INTEGRITY MANAGEMENT SYSTEM

3.5.2.2 The complexity of the system required should be determined by the operator taking into account the size, capacity, orientation and age of the VIT, the operational arrangements and the competence of available operations and maintenance personnel.

STAGE OF VIT LNG LIFE CYCLE	**INTEGRITY MANAGEMENT REQUIREMENT**
Design	Identify and assess the location and risk profile of the installation accordance with Sections 3 and 4. Select materials in accordance with Section 5. Design for area type, operational and additional loads and specific locations in accordance with Section 5.
Construction and Testing	Construct vessel in accordance with Section 6 and apply corrosion protection in accordance with Section 6.7 to ensure that the installed vessel can support the required level of integrity and original design specification. Test and commission the installation in accordance with sections 7 and 8
Operation	Manage operational activities in accordance with safe operating procedures given in Sub-Sections 9.1, 9.2. Operate within the specified design limits in accordance with Section 4 to ensure an adequate safety margin is maintained.
Inspection, Maintenance and Repair	Inspect, maintain and repair in accordance with Sections 9. Ensure that adequate records as specified in section 9.7 are kept of all inspection and maintenance activities. Maintenance and inspection history shall be reviewed periodically by a competent person who should assess and advise changes to the integrity risk control and Written Schemes of Examination, as required.
Decommissioning and Disposal	Discharge and dispose of residual LNG and vapours economically and safely in accordance with Section 10. Purge and test the vessel and pipework ensuring that the internal atmosphere is safe for opening and entry. Either prepare the vessel for re-use or dismantle and dispose in accordance with local waste and hazardous material requirements

TABLE 1 – LNG VIT INTEGRITY MANAGEMENT REQUIREMENTS

SECTION 4 : PLANNING AND LEGAL CONSIDERATIONS

4.1 PLANNING

4.1.1 General

4.1.1.1 The effect a vessel and the risks of the hazardous substance it contains has on the environment and human population depends largely on the location of the vessel and shall be taken into account during design and construction.

4.1.1.2 The planning process shall accommodate the acquisition and application of the required hazardous substance consents.

Note: The HSE provides detailed guidance on hazardous substance consent in the guidance note on land use planning: HSE: Land use planning - Hazardous substances consent

4.1.1.3 The environmental impact of the vessel location shall be assessed at an early stage. All areas requiring special consideration for environmental controls shall be identified and allowance made, thus minimising the possibility of changes in design or more expensive remedial measures on completion of the project.

4.1.2 Location

4.1.2.1 The planning process should incorporate a conceptual design stage which should be used to examine, develop and refine the proposed solutions and options to ascertain if the equipment function can be realistically achieved whilst sustaining all requirements for safety and environmental factors.

The conceptual ideas and working principles for the vessel should be assessed in order to define the essential elements and options available, reducing them to a single solution to applied to the detailed design.

(a) Initially, the various constraints, and all potential planning problems likely to have an adverse effect on the vessel location should be identified and recorded. Such constraints may be divided into, but are not limited to, the following categories:

- nature conservation
- ecology
- archaeology
- water resources
- land use
- landscape features
- planning policies
- agriculture
- socio-economic factors
- geology
- heritage features
- transport infrastructure.

Note: Some of these features may cover considerable areas requiring the boundary of the sites to be established.

(b) The scope of consultation should be expanded to include, but not be limited to:

- Landowners
- Health and Safety Executive

- Environmental Agency
- Relevant local authorities
- Conservation groups
- other utilities, etc.

(c) Any nature conservation site within the boundaries of the site should be identified and recorded.

(d) Any statutorily-protected site or other known site of archaeological or heritage importance within, or in proximity to, the site, should be identified and recorded.

(e) Any major water resource feature within the site should be identified and recorded and information obtained on aquifer protection zones and major water abstraction sites.

(f) Any major geological feature should be recorded, and its engineering implications considered.

(g) Any areas or type of existing land use that could affect the site and/or the design of the vessel should be recorded.

(h) Any existing, planned or disused extraction zone should be identified and avoided where possible.

(i) Any area within the site that is zoned for future development (domestic, industrial, commercial or mineral) or other developmental controls, should be identified and recorded. Discussions with relevant planning authorities, to establish recent changes in policies or departures from approved plans, should be considered.

(j) Any major landscape and topographical features within the site should be identified and recorded, to avoid unnecessary difficulties or disturbance.

(k) Any areas of high-grade agricultural land within the site should be identified and recorded.

(l) With all relevant information available from the above surveys, a reference location should be selected and suitably scaled plans prepared (typically, 1:2500 or 1:10000).

4.1.3 Multiple Vessels

4.1.3.1 Special requirements must be applied where multiple vessels are required at a single location and appropriate planning measures applied.

4.1.3.2 Where more than one vessel is used, consideration should be given to escalation in the event of an incident, an assessment should be undertaken to determine the risk, additional recommendations and demonstration of ALARP, (as detailed in section 4.2.3 of this document).

4.1.4 Construction Plans

Following the detailed examination/environmental assessment of the location, the construction maps and drawings should be prepared.

The information on the map should include:

- the proposed position and orientation of the vessel (for consideration of missile generation) easement details and special conditions
- details of additional and restricted working areas
- location of other services and apparatus
- local government and other relevant boundaries
- reference to any borehole or other geological information obtained
- any access routes negotiated
- area classification details
- quantitative risk assessment

4.2 UK LEGAL CONSIDERATIONS

4.2.1 General

This Standard is set out against a background of Legislation in force in GB at the time of publication (see Appendix 2). The devolution of power to the Scottish, Welsh and Northern Ireland Assemblies means that there may be variations to the Legislation described below for each of them and consideration of their particular requirements is to be made. Similar considerations are likely to apply in other countries and reference to appropriate national Legislation will be necessary.

All relevant Legislation is required to be complied with and relevant Approved Codes of Practice (ACoPs), official Guidance Notes and referenced codes, Standards, etc. are to be taken into account.

Care is to be taken to ensure that the latest editions of the relevant documents are used.

Requirements within IGEM Standards assist competent engineers in complying with legal requirements and provide instruction and guidance on the requirements to ensure efficient, safe and environmentally sustainable LNG assets.

4.2.2 Health and Safety at Work etc. Act (HSWA)

HSWA applies to all persons involved with work activities, including employers, the self-employed, employees, designers, manufacturers, suppliers, etc. as well as the owners of premises. It places general duties on such people to ensure, so far as is reasonably practicable, the health, safety and welfare of employees and the health and safety of members of the public who may be affected by the work activity.

4.2.3 Control of Major Accident Hazard Regulations (COMAH) & Reducing Risk to ALARP

These Regulations aim to prevent major accidents involving significant quantities of flammable, environmentally hazardous or toxic substances and if they happen, require Asset Owners to limit the effects on people and the environment.

Formal HSE notifications need to be submitted at the start of construction and prior to the hazardous substance being introduced.

An establishment is subject to the *Control of Major Accident Hazards (COMAH) Regulations 2015* if it produces, uses, handles, or stores any dangerous substance which is present at or above the qualifying quantity specified in Schedule 1 of the Regulations.

There are two 'COMAH thresholds', known as lower tier and upper tier. A site with an LNG inventory of 200 tonnes would qualify as an upper tier COMAH establishment, with additional requirements applying. For example, COMAH Regulation 8 requires that: *Every operator of an upper tier establishment must prepare a safety report for the purposes of –*

(a) demonstrating that a major accident prevention policy and a safety management system for implementing it have been put into effect in accordance with the information set out in Schedule 3.

(b) demonstrating that the major accident hazards and possible major accident scenarios in relation to the establishment have been identified and that the necessary measures have been taken to prevent such accidents and to limit their consequences for human health and the environment.

(c) demonstrating that adequate safety and reliability have been taken into account in the design, construction, operation and maintenance of any installation, storage facility, equipment and infrastructure connected with the establishment's operation which are linked to major accident hazards inside the establishment.

(d) demonstrating that an internal emergency plan has been prepared in accordance with regulation 12, which includes sufficient information to enable an external emergency plan to be prepared.

(e) providing sufficient information to the competent authority to enable decisions to be made regarding the siting of new activities or developments around establishments..

Newly constructed establishments are required to submit a pre-construction safety report in a reasonable time before construction begins. What constitutes a 'reasonable period of time' before construction varies, but it is normally between three to six months. The scale and complexity of the proposed plant, the extent to which new or unusual technology is employed and the scale of the hazard will be relevant considerations.

The pre-construction submission should focus on conceptual design. The competent authority should have the opportunity to review as much information as possible at the pre-construction stage, to assess whether the inherent features of the design are sufficient to prevent, control and mitigate major accidents. At this pre-construction stage the competent authority will examine, as far as it can, whether the purposes of the safety report in regulation 8 have been fulfilled.

New build establishments are subsequently required to submit a pre-operation safety report. The timing of submissions before operation should be influenced by the same factors as for those before construction. A 'reasonable period' before operation for submission is normally between three to six months.

Start of operation is taken to be the first time that dangerous substances are introduced into the establishment and will include commissioning if dangerous substances, in any quantity, are used at that stage.

The pre-operation report should build upon and update the earlier pre-construction report and describe how any previously outstanding issues have been resolved. Elements which were not available at the pre-construction stage are likely to include operational systems of prevention, control, and mitigation, together with management systems.

Operators may choose to integrate the pre-construction and pre-operation parts and submit this as a complete safety report before operation. Taken together, the two parts should allow the competent authority to see the whole basis on which the measures necessary to prevent and mitigate a major accident have been taken.

Risk Management and ALARP

COMAH Regulation 5 requires that "*Every operator must take all measures necessary to prevent major accidents and to limit their consequences for human health and the environment*". This is interpreted as the equivalent of reducing risks to 'as low as reasonably practicable' (ALARP).

For top tier COMAH sites, an ALARP demonstration should form part of the safety report submitted to the Competent Authority under COMAH Regulations 8 and 9. In essence, making sure a risk has been reduced to 'as low as reasonably practicable' (ALARP) is about weighing the risk against the sacrifice needed to further reduce it. To avoid having to make this sacrifice, the duty-holder must be able to show that it would be grossly disproportionate to the benefits of risk reduction that would be achieved.

During the design stage of a project, which covers concept selection through to detailed design specification (drawings, calculations, specifications, etc), there is the maximum potential for reducing risks, by application of the principles of inherently safer design. The HSE attaches particular importance to reducing risks to people through appropriate consideration of health and safety in plant design.

In most situations, deciding whether the risks are demonstrated to be ALARP involves a comparison between the control measures a duty-holder has in place or is proposing, and the measures HSE would normally expect to see in such circumstances i.e., relevant good practice. The table below illustrates this process, at different project stages:

Project stage	**Elements in demonstrating that risks are ALARP**
Choosing between options or [design] concepts	• Risk assessment and management according to good design principles. • Demonstration that duty-holder's design safety principles meet legal requirements. • Demonstration that chosen option is the lowest risk or justification if not. • Comparison of option with best practice, and confirmation that residual risks are no greater than the best of existing installations for comparable functions. • Risk considered over life of facility and all affected groups considered. • Societal concerns met, if required to consider.
Detailed design	• Risk assessment and management according to good design principles. • Risk considered over life of facility and all affected groups considered. • Use of appropriate standards, codes, good practice etc. and any deviations justified. • Identification of practicable risk reduction measures and their implementation unless demonstrated not reasonably practicable.

Note 1: Guidance on the Control of Major Accident Hazards (COMAH) Regulations 2015, and on reducing risks to ALARP, is available on the HSE website:

Risk management: Expert guidance - Policy and guidance on reducing risks as low as reasonably practicable (hse.gov.uk)

Note 2: Guidance on the Control of Major Accident Hazards (COMAH) Regulations 2015, and on reducing risks to ALARP, is available on the HSE website. Further links to the relevant HSE guidance informing the draft text above:
L111 COMAH 2015   Guidance on Regulations.pdf
Control Of Major Accident Hazards Regulations 2015 (COMAH) (hse.gov.uk)
understanding-comah-new-entrants.pdf (hse.gov.uk)
COMAH - The Competent Authority (hse.gov.uk)
Guidance on ALARP Decisions in COMAH - SPC/Permissioning/37 (hse.gov.uk)
Risk management: Expert guidance - ALARP at a glance (hse.gov.uk)

4.2.4 Planning (Hazardous Substances) Regulations 1992

All establishments wishing to hold stocks of certain hazardous substances above a threshold quantity must apply to the Hazardous Substances Authority (HSA) - usually the local planning authority - for a hazardous substances consent under the Planning (Hazardous Substances) Regulations 1992. For LNG the threshold is 15 tonnes. HSE is one of eleven organizations that the HSA must consult as to the advisability or otherwise of locating a major hazard establishment in the location designated.

4.2.5 Management of Health and Safety at Work Regulations (MHSWR)

MHSWR imposes a duty on employers and the self-employed to make assessments of risks to the health and safety of employees, and non-employees affected by their work. They also require effective planning and review of protective measures.

4.2.6 Pressure Systems Safety Regulations (PSSR)

The aim of PSSR is to prevent serious injury from the hazards of stored energy as a result of failure of a pressure system or one of its component parts. With the exception of steam, PSSR do not consider the hazardous properties of the contents released following system failure. PSSR do not apply to the installations within main buildings covered by this Standard but may apply to such gas infrastructure as network pipelines and PRIs external to the building.

Note: L122 is an ACoP on PSSR.

4.2.7 Pressure Equipment Safety Regulations (PESR)

The regulations apply to design, manufacture and conformity assessment of pressure equipment and assemblies of pressure equipment with a maximum allowable pressure above 0.5 bar, although there are several exclusions, which are set out in regulation 4 and Schedule 1 to the Regulations. "Pressure equipment" means vessels, piping, safety accessories and pressure accessories. "Assembly" means several pieces of pressure equipment assembled to form an integrated, functional whole.

Note: HSE provide detailed guidance on the conformity assessment of pressure equipment in the guidance note on equipment and machinery accreditation: HSE conformity assessment guidance.

4.2.8 Dangerous Substances and Explosive Atmospheres Regulations (DSEAR)

4.2.8.1 DSEAR are concerned with protection against risks from fire, explosion and similar events arising from dangerous substances used or present in the workplace.

DSEAR require that risks from dangerous substances are assessed, eliminated or reduced. They contain specific requirements to be applied where an explosive atmosphere may be present and require the provision of arrangements to deal with accidents, emergencies, etc. and provision of information, training and use of dangerous substances. DSEAR also require the identification of pipelines and containers containing hazardous substances.

4.2.8.2 DSEAR require an employer to classify gas installations into hazardous and non-hazardous areas. In particular:

- where a dangerous substance is or is liable to be present at the workplace, the employer is required to make a suitable and sufficient assessment of the risks to their employees which may arise from that substance
- where an explosive atmosphere may occur at the workplace sufficient information is required to be given to show:
- those places which have been classified into zones (Regulation 7)
- equipment which is required for, or helps to ensure, the safe operation of equipment located in places classified as hazardous
- that any required verification of overall explosion safety has been carried out
- the aim of any required coordination (Regulation 11) and the measures and procedures for implementing it.

Note 1: L138 is an ACoP and provides guidance on DSEAR. It recommends that overall explosion safety is independently verified by a Competent Person.

SECTION 5 : VESSEL DESIGN AND MATERIALS

5.1 GENERAL DESIGN

5.1.1 The general design of the installation shall follow a "hierarchy of control" approach, whereby the complexity of design and major accident hazard mitigation shall be proportional to the potential risk that the installation may pose.

5.1.2 The LNG tank shall safely withstand the mechanical and thermal loads, and the chemical effects encountered during pressure test and normal operation. These requirements are deemed to be satisfied if sections 6 t 8 are fulfilled. The vessel shall be tested in accordance with section 7 and marked in accordance with sections 5.4.1 and 5.4.2

5.1.3 Detailed guidance on design and materials including theoretical criteria and formulae for establishing mechanical loading, pressure limitations, chemical loading and thermal effects is provided in ISO 21009 pt 1. Sections 5-11

5.1.4 Static cryogenic vessels shall be equipped with valves, pressure relief devices, and instrumentation and configured and installed in such a way that the VIT can be operated safely. The number of openings in the inner vessel for this equipment shall be kept to a minimum.

5.1.5 The static cryogenic vessel shall be clean for the intended service in accordance with ISO 23208.

5.1.6 The manufacturer shall retain the documentation, and all supporting documents (including those from subcontractors, if any), taking legal compliance into consideration (e.g. product liability). In addition, the manufacturer shall retain all supporting and background documents (including those from subcontractors, if any) which establish that the vessel conforms to this document. This information must be transferred to the asset owner as part of the commissioning and handover process.

5.1.7 The 'base' design shall consist of double walled vacuum insulated storage tank with supplementary insulation in the annular space. The inner storage tank is constructed of stainless steel while the outer jacket may be constructed of carbon steel, or stainless steel according to the location and risk profile of the site.

5.1.8 Where additional protection is sought, the outer jacket may be constructed of stainless steel, however, the outer jacket is not generally registered or certified as a pressure vessel. Even with stainless steel outer jacket, the installation cannot be described as a "full containment" tank due to the positioning of the ESD valve external to the outer jacket and the installation of vacuum lift plates.

5.1.9 Design considerations should address the issues associated with brittle failure of a carbon steel outer skin on the vessel (e.g., due to vessel location, nearby population, potential missile trajectory, adjacent plant, etc.), and also the risks related to potential economiser pipework failure (where relevant), and also the risks. Factors and Risks to consider for cryogenic fluids and containment are:

- Cryogenic liquid storage tanks have been run safely in the UK for many years with few significant incidents reported.
- Cryogenic liquid storage tanks with economiser piping assemblies can, under some operating configurations, be subject to repeated and substantial differential thermal expansions within piping systems. This can significantly increase the risk of a hidden failure.
- Impingement of cryogenic fluids onto the carbon steel outer jacket of a cryogenic storage tank could lead to brittle fracture and the ejection of

fragmented steel. Such ejected fragments could result in serious injuries or fatalities to individuals in the vicinity of the tan. They could also compromise nearby safety critical plant or containment systems such as pipes, tanks or other vessels.

5.1.10 Where a secondary containment is required, this shall be provided via an impounding basin located a safe distance from the tank itself. The method and arrangements for impoundment shall be designed to safely direct LNG spills to a safe location, and to prevent LNG spills from entering water drains, sewers, waterways, or any closed-top channels.

Detailed requirements and guidelines for the design and construction of impounding basins for LNG spillage containment are provided in EN 1473: 2021 (Installation and equipment for liquefied natural gas - Design of onshore installations) and NFPA 59a (Standard for the Production, Storage, and Handling of Liquefied Natural Gas, 2006).

5.2 SELECTION OF MATERIALS

5.2.1 Materials which are or might be in contact with the cryogenic LNG fluid shall be selected to be compatible with ISO 21010.

5.2.2 The toughness requirements of metallic materials used at cryogenic temperatures shall follow the requirements of the relevant ISO 21028-1 and ISO 21028-2; any non-metallic materials used shall be suitable for operating temperatures and the liquefied gas.

5.2.3 For suitable material specification see prEN 13458-2. For other materials a "European approval of pressure equipment material" (according to Article 11 of the Directive 97/23/EC) or a particular material appraisal shall be available.

5.2.4 An inspection certificate substantiating that materials have been selected to the required standards shall be certified by an inspection certificate 3.1 B in accordance with EN 10204.

5.2.5 ISO 21009, Annex K, provides a list of the base materials that may be employed in the manufacture of the cryogenic vessels conforming to this document.9.3 Inspection certificate. *[Provide a copy of the Annex K as a appendices to this document for easy reference]*

5.2.6 The head and shell material shall be declared by an "inspection certificate 3.1", in accordance with ISO 10474:2013, 5.1, or "inspection certificate 3.2", in accordance with ISO 10474:2013, 5.2, if a specific manufacture qualification is not available.

5.2.7 The material manufactured to a recognized document shall be declared by an "inspection certificate 3.1", in accordance with ISO 10474:2013, 5.1, or "inspection certificate 3.2", in accordance with ISO 10474:2013, 5.2, if a specific manufacture qualification is not available.

5.2.8 Materials for the outer jackets and service equipment, not subjected to cryogenic temperature, shall be manufactured from material suitable for the intended service.

5.3 CIVIL STRUCTURE

5.3.1 The LNG storage area shall be paved and inclined such that any significant spill or leakage of LNG from a tank or equipment is directed a safe distance away from equipment and storm drainage. This should allow the cryogenic liquid to safely evaporate in a suitably designed impounding basin or open area as per local regulations.

5.3.2 Above ground equipment and piping shall be protected against accidents involving vehicles.

5.4 STORAGE TANK

5.4.1 LNG storage tanks shall be double walled vacuum insulated with supplementary insulation in annular space being perlite/powder or multi-layer insulation.

5.4.2 Expansion and contraction of inner and outer shell shall be accounted for in the design calculations of the vessels, including internal supports for the inner vessel and external saddle supports for the outer vessel.

5.4.3 The vessels shall be adequately supported on carbon steel legs or other associated supporting structures. Fireproofing requirements for supports are provided in section 5.5.1

5.4.4 Typical annual configurations according to required integrity levels are shown in figure 4.

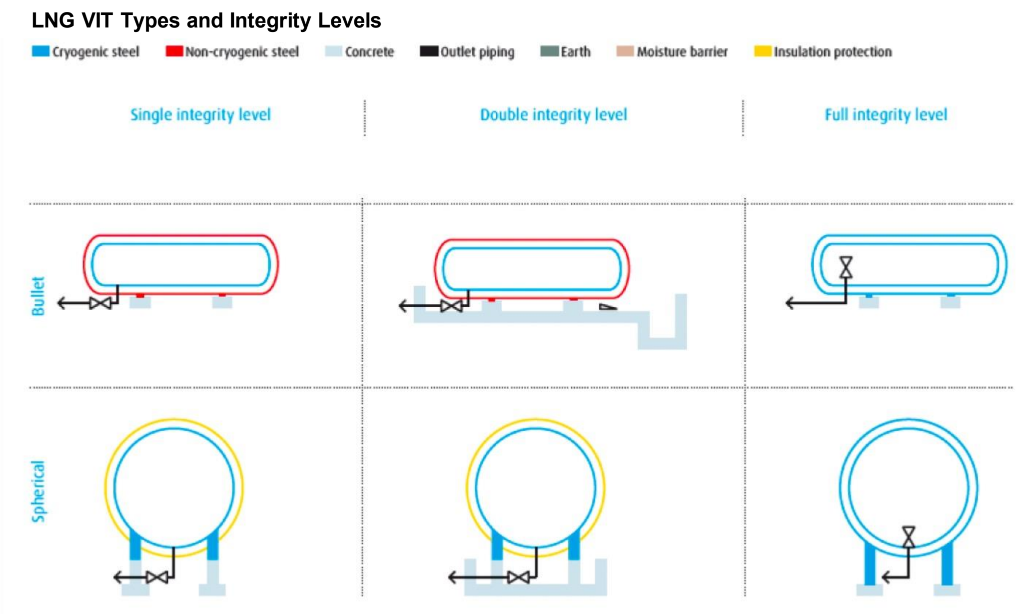

FIGURE 4: LNG VIT INTEGRITY LEVELS

5.4.1 Inner Tank

5.4.1.1. Minimum Design Metal Temperature (MDMT) for the inner vessel shall be -196 °C (-320 °F) and constructed of material Type 304/316 SS.

5.4.1.2 LNG pressure vessels shall be designed, fabricated and tested in accordance with The Pressure Equipment (Safety) Regulations 2016, which regulate the design, manufacture and conformity assessment of pressure equipment and assemblies with a maximum allowable pressure PS greater than 0.5 bar.

Note: The PE(S)R implemented Directive 2014/68/EU on pressure equipment and assemblies (The PED). The EU Withdrawal Act 2018 preserved the PE(S)R and enabled them to be amended so as to continue to function effectively once the UK left the EU. Accordingly, the Product Safety and Metrology etc. (Amendment etc.) (EU Exit) Regulations 2019 see footnote 2 fixed *any deficiencies that arose from the UK leaving the EU (such as references to EU institutions) and made specific provision for the GB market.*

There is therefore one set of UK PE(S)R, but some of the provisions apply differently in Northern Ireland under the terms of the Windsor Framework. References to the PE(S)R in this guidance are references to those Regulations as they apply in Great Britain.

General design criteria for unfired pressure vessels shall be applied in accordance with BS EN 13445. Specific requirements for Cryogenic service shall comply with BS EN 13458/ ISO 21009

Note: At the time of writing this Standard, BS EN ISO 21009 has superseded EN 13458 part 3 and covers installation and operation of cryogenic storage vessels. EN 13458 Parts 1 and 2 is still current and applicable for fundamental requirements, design, fabrication, inspection and testing. Part 1 of ISO 21009 is currently still in development and is assumed to fully supersede EN 13548 in due course.

5.4.1.3 The maximum operating pressure of the storage vessel shall allow for normal operational pressure increases due to pressure fluctuations without the need for boil off gas management or venting.

5.4.1.4 The static cryogenic vessel shall bear the following markings in clearly legible and durable characters on the inner vessel:

- name and address, or other means of identification of the manufacturer of the inner vessel
- serial number of the inner vessel
- mark confirming successful final acceptance tests of the inner vessel

5.4.2 Outer Jacket

5.4.2.1 Vacuum lift plates shall be provided on the outer jacket, oriented such that the insulating material shall not flow out if activated.

5.4.2.2 The outer vessel shall bear:

- Reference to design standard applied to vessel, to demonstrate that the static cryogenic vessel is in conformity with the design codes and standards applied. This may be EN ISO 21009 or other appropriate UK or international standard
- name and address, or other means of identification of the manufacturer of the static cryogenic vessel
- serial number of the static cryogenic vessel
- maximum allowable working pressure (PS in bar) of the static cryogenic vessel
- test pressure (PT in bar) of the static cryogenic vessel
- volume of the inner vessel (in litres)
- year of manufacture
- date (year followed by the month) of the final test
- the identification of those cryogenic fluids for which the static cryogenic vessel is approved (Chemical symbols may be used)

The information marked on the inner vessel shall be repeated on the data plate mounted or permanently attached to the outer jacket:

The marking and labelling referred to above shall be permanently affixed, e.g. stamped, either on a reinforced part of the static cryogenic vessel, or on a data plate.

The technique employed for marking and attaching shall not adversely affect the integrity of the static cryogenic vessel.

Additional markings such safety or filling criteria are permitted, provided that they do not obscure or create confusion with specified markings called for in this standard.

5.4.3 Annular Space & Internal Pipework

5.4.3.1 Piping in the annular space shall not contain expansion bellows. All connections and welded joints shall be butt welded with full penetration welds.

5.4.3.2 The insulation system shall be designed to limit the boil off rate to less than 0.25% volume/day at 50% LNG liquid filled volume at atmospheric saturated pressure.

5.4.4 Valves

5.4.4.1. Valves in cryogenic service shall be constructed of grade 316/316L, 304/304L, 321 or 347 austenitic stainless stee, or alternative materials as may be specified in applicable standards such as BS EN 12567:2000 Isolating Valves for LNG - suitability and verification tests (4.10) or BS EN 1473: 2021

5.4.4.2 An ESD valve shall be installed as close as possible to the storage tank and be of fire safe design.

5.4.5 Pressure Relief Devices

5.4.5.1 The LNG storage tank shall be provided with installed spare relief devices such that each pressure relief device can be isolated for maintenance while keeping the storage tank in service.

All pressure relief devices shall be sized and selected according to ISO 23251:2019

5.5 PROCESS SAFEGUARDING

5.5.1 Overfill Protection

5.5.1.1 Relief protection (combination of relief valves and/or rupture disks) on the vessel shall be sized for overfill scenarios to prevent possible tank rupture. Sizing should allow for pressure accumulation up to the hydrotest pressure.

5.5.1.2 To mitigate against overfill and overpressure the vessel shall be equipped with level indicators, high level alarms and independent high-high level alarms. Set levels shall be established based upon response time (manual or automated).

5.5.1.3 ISO 16924 recommends that the maximum LNG pressure achievable at the LNG storage tank filling nozzle during filling should be lower than the set pressure of the relief valve of the LNG storage tank.

Where it is not possible to meet this requirement, two independent high-level trips shall be provided for the LNG storage tank and the detection of high level shall automatically stop the transfer pump and close the loading line valve(s).

NOTE: For this purpose, the two independent systems of liquid level measurement can be used, or additional liquid level systems may be added. Typically, this would comprise 2 independent level transmitters with fully automated system to stop the transfer in the event of reaching the maximum fill level

5.5.1.4 Level gauge and a pressure gauge shall be installed at any product receipt station to detect a potential overfill condition.

5.5.1.5 Manual ESD buttons should be located at all product transfer points.

5.5.2 Overpressure Protection

5.5.2.1 Relief devices shall be sized for all applicable upset scenarios, fire scenario and for remote liquid overfill scenario to prevent exceeding hydrotest pressure.

5.5.2.2 The LNG vessel shall be protected from overpressure resulting from back flow from the downstream systems by at least one Class 1 check valve.

Note: There are six different seat leakage classifications as defined by ANSI FCI 70-2. Class I is also known as dust tight and can refer to metal or resilient seated valves.

All instrumentation and control equipment fitted to prevent the occurrence of pressure build runaway. The risk of hazardous operational situations shall be qualitatively assessed, and safety integrity levels (SILs) and safety measures are defined in accordance with IEC 61508 (Functional Safety of Electrical/ Electronic /Programmable Electronic Safety-related Systems).

This is required in order to avoid or control systematic failures and to detect or control random hardware failures or mitigate their effects.

5.5.2.3 Thermal relief valves shall be installed to protect sections of liquid service piping that may be isolated on both ends by valves.

5.5.3 Vent Dispersion

5.5.3.1 Vents shall be designed and located to mitigate consequence of release to personnel that may be in nearby work areas, neighbouring properties, process equipment or vehicles.

5.5.4 Separation Distances

5.5.4.1 The site layout should ensure adequate separation distances between the storage vessel and associated equipment to other process equipment, bulk offloading facilities and any occupied buildings.

5.5.4.2 The site layout shall generally be designed on the basis of adequately demonstrating ALARP in accordance with section 4.2.3

5.6 PASSIVE FIRE PROTECTION

5.5.1 Saddle supports for LNG horizontal storage vessels, with a saddle height greater than 300 mm (12 in), shall be fireproofed.

Note; Foam suppression and other arrangements for active fire protection are considered to be out of scope of this guidance.

SECTION 6 : VESSEL CONSTRUCTION AND INSTALLATION

6.1 GENERAL INSTALLATION REQUIREMENTS

6.1.1 All equipment shall be installed in accordance with any local legislative requirements, comply with the Pressure Equipment Directive and all equipment must bear the appropriate CE markings.

6.1.2 LNG VITs shall be installed outdoors and shall generally avoid traffic routes or thoroughfares. Access by unauthorized persons should be prevented.

6.1.3 The drainage of surface water from the place of installation shall be ensured. On sloping sites, an installation (e.g. a wall) may be necessary to prevent gas from penetrating over the place of installation down into lower rooms, ducts, shafts or air intakes.

6.1.4 Vessels and their components shall be protected against mechanical damage, e.g. by vehicle buffer bars, enclosures, safety distances. The protection of vessel supports against leaking cryogenic fluid should be considered.

6.1.5 Vessels shall be installed and operated in such a way, that employees or third parties are not endangered. Necessary minimum safety distances shall be observed; ISO 21009 Annex A requires that vessels containing a flammable inventory in excess of 50 tonnes will require a specific hazard study to define the required safety distances.

6.1.6 Vessels shall be installed so that the name plate is easily readable.

Appropriate warning signs regarding product hazards shall be displayed, e.g. in rooms, areas, or on vessels. The operating instructions shall also refer to the properties of the LNG.

6.1.7 The installation should allow inspection of vessels on all sides, and that adequate space is provided for maintenance and cleaning, as well as for emergency operations.

6.1.8 Vessels shall be installed in such a way that their filling operation can be carried out safely and easily and that all vessel controls shall be capable of being operated safely.

6.1.9 Vessels shall be erected in such a way that no inadmissible misalignment or inclination can occur due to:

- the actual foundations
- the inherent mass of the vessel including its contents
- external forces, e.g. seismic loads, wind loads.

6.1.10 Gas from pressure-relief devices or vents shall be discharged to a safe place.

6.1.11 Vessels shall be installed in locations where there is sufficient ventilation such that the formation of dangerous explosive gas-air mixtures or an oxygen-deficient/-enriched atmosphere is avoided.

6.1.12 The area/foundation under vessels, as well as below detachable connections and fittings shall be of non-combustible materials and free of oil, grease and other flammable contaminants.

6.1.13 To prevent a risk of brittle fracture, consideration should be given to the design temperature of the installation downstream of the installed or fitted vaporizing system and low temperature cut-off systems, if necessary.

6.2 WELDING

6.2.1 General requirements for welding shall be as specified for the construction of cryogenic vacuum insulated vessels as laid out in ISO 21009 part 1. This document requires that the welding method be appropriate and be carried out by qualified welders or operators, that the materials be compatible and that there is verification by a welding procedure test.

6.2.3 Welding procedures shall be approved in accordance with ISO 15614-1, or ISO 15613 as applicable. Welders and welding operators shall be qualified in accordance with ISO 9606-1 or ISO 14732 as applicable.

6.2.4 Any temporary attachments that have been welded to pressure bearing parts shall be kept to a practical minimum. Temporary attachments welded directly to pressure bearing parts shall be compatible with the immediately adjacent material.

It is permissible to weld dissimilar metal attachments to intermediate components, such as pads, which are connected permanently to the pressure containing part. Compatible welding materials shall be used for dissimilar metal joints.

All temporary attachments shall be removed from the inner vessel prior to the first pressurization. The removal technique shall avoid impairing the integrity of the inner vessel and shall be by chipping or grinding. Any rectification necessary by welding of damaged regions shall be undertaken in accordance with an approved welding procedure.

The area of the inner vessel from where the temporary attachments have been removed shall be dressed smooth and examined by appropriate non-destructive testing.

Any attachments on the outer jackets may be removed by thermal cutting as well as by the methods described above.

6.2.5 Some specific details for welded joints appropriate to LNG VITs conforming to this document are given in Annex F or EN 1708-1. These details show sound and currently accepted practice.

- The manufacturer, in selecting an appropriate weld detail, shall consider:
- the method of manufacture
- the service conditions
- the ability to carry out necessary non-destructive testing
- for cold strengthening, see Annex C, ISO21009-1
- for strengthening of VITs from austenitic stainless steels, see Annex C.
- Weld details may be used provided their suitability is proven by procedure approval according to ISO 15614-1 or ISO 15613 as applicable.

6.2.6 To avoid sub-standard welding of ferritic steels excess residual magnetism shall be avoided.

6.2.7 Where any part of a VIT is made in two or more courses, the longitudinal weld seams of adjacent courses shall be staggered. A minimum of 100 mm is recommended. Joggled joints may be used in stainless steels for circumferential welds only and plate thickness up to 8 mm. Backing strips may be used for circumferential welds only with no thickness restriction. When forming the joggled joints, reduction in toughness shall be considered for low temperature.

6.2.8 As the mechanical characteristics of work-hardened austenitic stainless steels can be adversely affected if the material is not welded properly, the additional requirements below shall be applied:

- the heat input during welding shall be not more than 1,5 kJ/mm per bead to be verified in the procedure qualification test
- the material shall cool down to a temperature of not more than 200 °C between passes
- the material shall not be heat treated after welding
- If post heat treatment is required it shall be demonstrated that the required material (e.g. mechanical, corrosion resistance) will not be adversely affected

6.2.9 Where non-welded permanent joints are made between metallic materials or non-metallic materials, or both, procedures shall be established in a manner similar to that used in establishing welding procedures, and these procedures shall be followed for all joints. Similarly, operators shall be qualified in such procedures and only qualified personnel shall then carry out these procedures.

Brazing procedures and brazing approvals can be found in ISO 13585: 2021 and EN 13134 or ASME, Section VIII, Division 1 or any equivalent standard. [Review / check standards applicable to welding of mild steels and for austenitic stainless steels, requirements, competency and certifications]

6.3 NON-DESTRUCTIVE TESTING (NDT)

6.3.1 General Requirements

Personnel undertaking non-destructive testing personnel shall be qualified for the duties in accordance with ISO 9712.

Non-destructive testing shall be performed according to ISO 17635 and ISO 5817, specifying general rules and standards to be applied to the different types of testing, for either the methodology or the acceptance level for metallic materials.

Non-destructive testing for volumetric imperfections is not required on the outer jacket of static cryogenic vessels.

6.3.2 Safety

Where radiographic inspection is required, it should be planned in relation to other work to ensure safety and avoid delay. Fabrications should be planned to enable portable spools and pipework to be transported to a purpose designed and built radiographic enclosure in line with the i-Ionising Radiation Regulations.

6.3.3 Phased array ultrasonic inspection in accordance with BS EN ISO 13588 or BS EN ISO 20601 may be used in place of radiography. The acceptance specification should take account of the additional information on imperfection sizes that is provided by the phased array ultrasonic method.

[Authors Note: There is an outstanding query around when radiography may be replaced by ultrasonics – most construction standards, including ISO 20009 indicate a preference or requirement for radiography, whilst the ASME standard on process piping (B31.3:2020) says that radiography may be replaced by ultrasonics as long as this is specified in the engineering design? The query has been left open and we will try to get a resolution as part of the industry

consultation process. Feedback from any reviewers with subject matter knowledge int his area would be appreciated.]

6.3.4 **Extent of Examination for Surface Imperfections**

All welds shall be visually examined in accordance with ISO 17637 and ISO 5817.

If any doubt arises, this examination shall be supplemented by surface-crack detection, e.g. penetrant testing according to ISO 3452-1 and ISO 23277.

Areas from which temporary attachments have been removed shall be ground smooth and subjected to surface crack detection.

6.3.5 **Extent of Examination for Weld Imperfections**

Examination of the inner vessel for inner-vessel weld seams shall be carried out by radiographic film examination in accordance with ISO 17636-1 and ISO 10675-1.

Other suitable methods according to ISO 17635 are applicable:

- to use radiographic techniques with digital detectors and processing according to ISO 17636-2.
- to use ultrasonic testing in accordance with ISO 17640 and ISO 11666 (and ISO 22825 for austenitic steels), or to use other methods according to ISO 17635

The extent of radiographic examination of main seams on the inner vessel shall be in accordance with ISO 21009, Table 6. See subclause 12.3.4 for acceptance criteria.

When hemispherical ends without a straight flange are welded together or to a cylinder, the weld shall be tested as a longitudinal weld. Any welds within a hemispherical end shall also be tested as longitudinal welds.

Note : Tables 6, Section 12.3.3, ISO 21009 pt1 provide detailed specification for the extent of radiographic examination

6.3.6 **Acceptance Levels**: for surface imperfections and fatigue loaded vessels are specified in ISO 21009 pt1 section 12.3.4. This provides detailed reference out to appropriate standards for testing and acceptance

SECTION 7 : PRE- SERVICE INSPECTION AND TESTING

7.1 INSPECTION AND TESTING DURING MANUFACTURE

7.1.1 The overall quality of construction and vessel integrated shall be assured by the application of a quality plan, setting out inspection and testing requirements during the construction of the inner vessel.

7.1.2 The importance of pre-service inspection and record keeping cannot be over emphasised, as this normally represents the only opportunity to assure the integrity of the internal structure of the vessels.

As outlined in section 9.3.1, due to nature of LNG, it is considered neither necessary or practicable to undertake detailed internal examinations as part of the written scheme of examination of the vessel, whilst the vessels is in service.

Therefore, there is normally only one opportunity to validate the integrity of the LNG VIT during its operational lifecycle.

7.1.2 **Inner Vessel Quality Plan: Inspection and Testing Stages**:

The following inspection stages shall be conducted during the manufacture of an inner vessel:

- verification of material test certificates and correlation with materials
- approval of weld procedure qualification records
- approval of welder's qualification records
- examination of material cut edges
- examination of set up of seams for welding including dimensional check
- examination of weld preparations, tack welds
- visual examination of welds
- verification of non-destructive testing
- testing production-control test-plates for welds and, where required, for formed parts after heat treatment
- verification of cleaning of inside surface of vessel
- examination of completed vessel including dimensional check
- pressure test
- in case of application of Annex C (pressure strengthening of vessels from austenitic stainless steels), inspection scope and requirements shall be adapted as specified in Annex C. verification of cleanliness and dryness of the static cryogenic vessel
- leak proofness tests ensuring the integrity of vacuum, and leak testing of external piping when it is connected to the inner vessel
- ensuring integrity of vacuum
- leak test of external piping
- checking documentation and installation of pressure relief device(s)

- checking installation of vacuum space relief device
- checking name plate and any other specified markings

7.1.2 **Outer Vessel Quality Plan: Inspection and Testing Stages**:

Quality control and pre-service inspection and testing shall be commensurate with the arrangements for the inner vessels and the requirements for meeting the design requirements set out in section 5

- The following inspection stages shall be conducted during the manufacture of an inner vessel

7.2 PRODUCTION CONTROL TEST PLATES

7.2.1 Production control test plates shall be produced and tested for the inner vessel as follows:

a) one test plate per vessel for each welding procedure on longitudinal joints except as specified in b)

b) after 10 sequential test plates to the same procedure have successfully passed the tests, testing may be reduced to one test plate per 50 m of longitudinal joint for 9 % Ni and ferritic steels and to one test plate per 130 m for other metals

7.2.2 Production control test plates are not required for the outer jacket. The results of the tests for the inner vessel shall be as follows:

- weld tensile test (T): Ret, Rm and A5 of the test specimens shall normally not be less than the corresponding specified minimum values for the parent metal, or the agreed values of the welding procedure approved
- impact test (IW, IH): this test shall be performed in accordance with the appropriate part of ISO 21028-1 and ISO 21028-2
- bend test (BF, BR, BS): the testing and the test requirements shall comply with ISO 15614-1:2017, 7.4.2 for steels
- macro etch (Ma): the macro etch shall show sound build-up of beads and sound penetration

7.2.3 **Extent of testing**: The number and type of test specimens to be taken from the test plate is dependent on material and thickness and shall be in accordance with the requirements specified in ISO 21009 pt1.

Note : Tables 4, and 5, Section 12.2.2, ISO 21009 pt1 provide detailed specification for the particular material and thickness applicable

7.2.3 The test plate shall be of sufficient size to allow for the required specimens including an allowance for retests.

7.3 DEFECT RECTIFICATION

7.3.1 **General**

Although unacceptable volumetric or surface imperfections may be repaired by removing the imperfections and rewelding, 100 % of all repaired welds shall be examined to the original acceptance standards.

7.3.2 **Manually Welded Seams**

When repairs to welds are carried out as a result of radiographic examination which is less than 100 %, in addition to the full radiography of repair, a radiographic image using a film (200 mm) shall be taken of either side of the repair to ensure the imperfection was isolated and not systematic. Where the imperfections are systematic and characterised by recurrence of the same imperfection, the extent of examination shall be increased to 100 % until the cause of the imperfections has been found and eliminated.

7.3.3 **Seams (Automatic Welding Processes**)

If any unacceptable imperfections are found by radiographic examination, all main weld seams shall be 100 % radiographically examined on all vessels produced with the same welding machine and welding procedure from the start of the production period or from the last accepted non-destructive test.

7.4 PRESSURE-TESTING

7.4.1 **General Requirements**: Every inner vessel shall be subjected to a pressure test and its leak tightness shall be demonstrated. This leak tightness may be demonstrated during the establishment of the vacuum or by a separate leak test at pressures up to 90 % of design pressure.

7.4.2 **Detailed Requirements for Cryogenic Vessels**: ISO 21009 pt1, section 12.5 provides criteria and formulae for determining the test pressure that should be applied to a particular vessel.

SECTION 8 : PRE-SERVICE CHECKS AND COMMISSIONING

8.1 GENERAL

ISO 21009 part 2 sections, 7.1 to 7.5 provides requirements for pre–service inspections, readiness checks and handover requirements.

The inspections, checks and commissioning process shall be carried out by a competent authorised person in accordance with a written procedure for bringing the installed equipment into service.

8.2 AS-BUILT SURVEY

The installed equipment must be physically checked against the detailed design drawings and site layouts to ensure that the installation records accurately reflect the as-bult status of the installation.

The drawings shall be redlined to reflect any deviations from the design drawings and layouts. The red-lines shall be used to update all site drawings to an as-built status.

8.3 PRE-SERVICE INPECTIONS

Prior to putting into service, the VIT and supporting infrastructure shall be inspected to ensure that:

- that marking and labelling of the vessel and associated equipment meet the requirements specified in ISO 21009-1
- all handover documents from the manufacturer and installer (s) are complete and comply with the requirements set out in section 8.4
- that equipment is in a state of operational readiness and is safe for service, in accordance with section 8.5
- checking the installation meets the requirements of section 6

8.4 DOCUMENTATION HANDOVER

All documents and drawings supplied by the installer and manufacturer shall be handed over to the site operator as part of the commissioning process.

Also, the vessel shall be accompanied by any vessel-specific documents and instructions for all items supplied, covering:

- operations
- auxiliary equipment
- inspection records
- routine inspection and maintenance
- register of equipment items and their technical specification
- recommended spare parts
- a serial number specific declaration of conformity from the manufacturer for the actual item
- Where multiple vessels are of the same type and manufactured under an identical process a certificate of conformity may be issued from an

independent notified body. A equipment type specific certificate approved by the manufacturer shall be used.

As appropriate, these documents shall be retained by the owner or user of the vessel.

The user shall have appropriate operating instructions available. Such instructions may be attached to the vessel in a permanent manner.

8.5 EQUIPMENT READINESS CHECKS

8.5.1 The following equipment readiness checks shall be performed in order to assure the safe operation of the vessel:

- Check devices against overpressure for availability, appropriate choice and setting, appropriate arrangement, safe venting location and, in so far as possible, for performance/correct operation.
- Check measuring devices for their availability and appropriate choice in respect of the suitability of the measuring range and, in so far as possible, for performance/correct operation.
- Check shut-off devices for availability, appropriate choice and arrangement in respect of pressure and temperature and, in so far as possible, for performance/correct operation.
- Check other fittings (e.g. fill couplings, gauges and controlling devices), in particular with regard to the medium to be supplied and vented; and where these are automatically driven or controlled, also their performance in the event of a power cut or loss of pneumatic supply. As a minimum, coupling types for oxidizing and non-oxidizing products should be different.
- All connections to the VIT shall be tested for leak-tightness before putting into service

8.6 PUTTING INTO SERVICE

8.6.1 This operation shall follow a written procedure, and the results of the steps involved shall be recorded (e.g. in a check list). Such lists shall be retained by the operating company.

8.6.2 The vessel and accessories shall be checked in accordance with sections 8.3-8.5

8.6.3 The vessel shall be purged with an appropriate gas until the gas emerging from the vessel is sufficiently dry and pure.

8.6.4 The vessel shall be cooled down according to the manufacturer's recommendations.

8.6.5 Steps shall be taken to avoid uncontrolled pressure rise due to rapid liquid evaporation.

8.7 PRE-FILLING CHECKS AND PRECEDURES

8.7.1 Prior to any filling the condition of the vessel shall be checked, especially the:

- data plate/product identification label
- correct coupling for the product; and

- condition of coupling and hose (not damaged, dirty, excessively iced).

8.7.2 An external visual inspection of the vessel and equipment shall be performed, to ensure:

- that the vacuum between inner vessel and outer jacket remains intact (checking of abnormal frosting on tank surface
- gas venting from a vacuum protection device is identified
- any relief valves that are continually venting are identified, repaired or controlled prior to filling.
- that if the vessel has lost vacuum, the owner of the vessel shall immediately investigate the cause of the vacuum loss. Where a vacuum loss is believed to be associated with an internal pipe failure, for example vapour escaping from the vacuum relief device(s), then the vessel shall be made safe by immediately reducing the pressure to atmospheric and emptying all cryogenic liquid in a safe manner. The reduction of pressure is the most significant action to reduce the level of hazard. For more information to differentiate between loss of vacuum and vacuum decay, see Appendix E of EIGA IGC doc 115/12.

8.7.3 The fill hose should be purged. Depending on the type of vessel, it may be filled by volume or by mass, to the level the vessel designed for, taking into account product density. The necessary measuring equipment shall be in good working order and within the calibration period where required.

8.7.4 If there is no residual pressure in the vessel prior to filling, it should be purged to remove possible contaminants.

8.7.5 If the vessel is warm, it should be cooled down gradually according to manufacturer's recommendations.

8.7.6 The purity of the residual product in the vessel shall be analysed and recorded where required by specification. Where the purity of the residual product is outside specification, the vessel should be purged until it meets specification.

8.7.7 After filling the vessel, mass or level of contents and pressure shall be checked and, if necessary, the vessel should be vented to reach the level required by specification. If required by specification, the vessel contents shall be analysed and recorded.

8.7.8 It shall be checked that all filling valves are closed, that no cold spots have developed, and that valves, piping and fittings are free from leaks.

SECTION 9 : OPERATIONS, MAINTENENANCE AND INSPECTION

9.1 GENERAL SAFETY REQUIREMENTS *(Based on ISO 12009)*

9.1. General

9.1.1 Identification labels and plates shall not be removed or defaced.

9.1.2 Appropriate warning signs regarding product and operational hazards and personnel protective equipment requirements shall be displayed.

9.1.3 Parts under pressure shall be disconnected only if they have been previously depressurized.

9.1.4 All surfaces which may come in contact with the product shall be kept free from oil and grease. For cleanliness requirements, see ISO 23208.

9.1.5 Leaking valves or connections should be depressurized before rectification. When this is not possible, leaking valves under pressure shall be tightened using suitable tools and procedures. Direct flame or intense heat shall never be used to raise the pressure or de-ice frozen components.

9.1.6 Valve outlets shall be kept clean, dry and free from contaminants.

9.1.7 Vessels and their accessories shall not be modified without proper authorization.

9.1.8 All activities shall be subject to the Management of Change (MoC) procedures outlined in section 9.8.

9.1.9 All activities shall be subject to a formal and documented risk assessment procedure, and be undertaken in accordance with the permit to work system applicable at the facility.

9.1.10 An independent competent inspecting authority must be appointed as part of the pre-service activities. They shall advise on and approve the WSoE to be applied to the VIT installation.

9.1.11 Safety Considerations

In all operations and training, the following safety considerations shall be taken into account:

- Small amounts of LNG will produce large volumes of vaporized gas. Spillage of LNG can also result in an oxygen deficient atmosphere. Provision is to be made for appropriate measures for this, e.g. ventilation.
- Vapourised LNG is highly flammable, so adequate firefighting equipment and trained operators must be available to mitigate the effects of any ignition. All practicable steps and operational procedures must be geared to reducing the probability of introducing uncontrolled sources of ignition
- Due to the possibility of cold embrittlement, cryogenic fluids shall not come in contact with materials (metals or plastics) which are not suitable for low temperatures.
- Because of their extremely low temperatures, cryogenic fluids will produce severe cold burns when coming in contact with the skin. Cold burns can also be produced from contact with uninsulated equipment and pipe.

- Oxygen enrichment due to liquefaction of ambient air can occur on the cold surfaces of uninsulated equipment which contain fluids with a boiling point lower than that of oxygen.

9.2 LNG TRANSFER/ FILLING OPERATIONS

9.2.1 Site operators or tanker drivers, rail or shipping operatives undertaking the fill / transfer operations shall be suitably trained and demonstrably competent to undertake the activity.

9.2.3 Written procedures and instructions shall be available which clearly outline the technical actions and safety considerations for the fill / transfer operation and movements and position of the transfer vehicle.

9.2.3 The procedure shall reflect the requirements set out in section 8.7, covering pre-service filling.

9.3 PERIODIC INSPECTIONS

9.3.1 General

No external or internal degradation mechanism is reasonably foreseeable on the inner vessel because of the nature of cryogenic fluids, their temperatures, the metallic materials of construction used, and the inner vessel is secured inside an evacuated outer jacket.

Therefore, under normal operational circumstances, no in-service inspection of the inner vessel or the inside surface of the outer jacket is required.

NOTE Corrosion allowance on surfaces in contact with the operating fluid or exposed to the vacuum interspace between the inner vessel and the outer jacket as well as inspection openings is not provided in the inner vessel or on the outer jacket.

The absence of a routine periodic internal inspection places a greater importance and duty of care on the site operator to ensure that all necessary inspections and tests were undertaken as part of the manufacturing and pre-installation processes.

All records of the original pre- service quality control shall be kept by the facility owner throughout the life of the plant and shall be made available, if required by the competent inspecting authority.

9.3.2 Vessel Inspection and Testing

All routine operational inspections and performance tests shall be documented within a Written Scheme of Examination and approved by the competent inspecting authority (see section 9.4). The approved WSE shall provide for, as a minimum:

- Periodicity of activities, or details of the Risk Based Inspection (RBI) regime where this methodology is applied
- an external visual inspection of the vessel and equipment
- functional check of valves
- leak tests under operating conditions
- assessment of any changes of the operational conditions of the installation and its surroundings

- assessment of the vacuum between inner vessel and outer jacket

9.3.2.1 Vacuum measurement should only be performed when the thermal performance is deficient as noted by vessel operation.

9.3.2.2 The inspection and tests shall be carried out by an authorized person.

9.3.3 **Inspection of Pressure-Relief Devices**

9.3.3.1 **General**

The examinations and the inspection intervals shall be determined by the competent inspecting authority according to the local regulations and operating conditions, taking into consideration the recommendations of the manufacturer and recognised best practice for over pressure protection devices.

The examination activities and intervals between inspections shall be specified and recorded within the WSoE.

ISO 21009 recommended inspection intervals are given in Table 2.

Type of Pressure-relief Device	Putting into service	Yearly	5 Years	10 Years
Pilot Operated	9.3.3.5	9.3.3.7	-	-
Reclosable	9.3.3.6	-	9.3.3.7	9.3.3.7
Thermal Reclosable	9.3.3.5	-	9.3.3.6	9.3.3.7
Non-reclosable	9.3.3.5	-	9.3.3.6	9.3.3.8

TABLE 2 — ISO 21009 RECOMMENDED TESTING AND INSPECTION INTERVALS

9.3.3.2 Material properties, corrosion by the medium or from the outside, and possible plugging shall be considered. An alternative to the performance test of the pressure-relief devices is to replace them. The inspections shall be carried out by an authorized person.

9.3.3.3 Inspection intervals may exceed five years if system and equipment performance tests demonstrate proper functionality, or where maintenance and inspection records indicate that incidence of failures is sufficiently low to provide the basis for an extension of testing intervals

9.3.3.4 **Certificates and Marking**

The certificates and marking or manufacturer’s declaration/data shall be examined by an authorized person for the following:

- conformity with drawings, specifications, type approval, as appropriate
- identification, type approval/marking
- suitability (fluids, size, temperature, pressure, setting)
- Manufacturing and pre-service inspection and testing records

9.3.3.5 **Visual Inspection**

The visual inspection shall include a check of certificates and markings in accordance with 9.3.3.4

Within the visual inspection, the following should be checked:

- general condition
- installation/orientation
- leak tightness
- cold spots
- loss of vacuum / vacuum caps in place
- vent location
- unobstructed discharge piping
- condition of coatings

9.3.3.6 **Performance Test**

The performance test shall include a visual inspection in accordance with the WSE. In addition, reclosable pressure relief devices shall either be replaced or undergo a functional test (lift or set pressure test) either in situ or off the vessel.

The performance test may be made with the valve installed or on the test bench. The results of the tests shall be recorded and kept at least until the next inspection.

9.3.3.7 **Changing Bursting Discs (inner vessel)**

Non-reclosable pressure-relief devices, where fitted, shall be replaced according to the instructions of the pressure relief device manufacturer.

9.4 SCHEMES OF EXAMINATION / INTEGRITY MANAGEMENT

9.4.1 **General Requirements**

Although not subject to the Pressure Systems Safety Regulations 2000, it is considered good practice to apply the model for examination required by the PSSR to LNG VITs. This should be supplemented by an annual visual inspection and any routine operational checks as set out in section 9.3.

The regulations require users and to demonstrate that they know the safe operating limits (principally pressure and temperature) of their systems, and that they are safe under those conditions.

They need to ensure that a suitable written scheme of examination (WSE) is in place before the system is operated, and that the system is examined in accordance with scheme.

The written scheme of examination is a document containing information about selected items of plant or within the boundary of the equipment system being considered.

WSEs are set and applied by a competent authority which is normally independent from the owner or operator's organisation. The owner shall be responsible for managing the scheme, ensuring that requirements are met and that the equipment is safely prepared for the examinations undertaken by the independent authority.

Typical contents of a WSE include:

- identification of the items of plant or equipment within the system
- those parts of the system which are to be examined
- the nature of the examination required, including the inspection and testing to be carried out on any protective devices
- the preparatory work needed for the item to be examined safely
- where appropriate, the nature of any examination needed before the system is first used
- the maximum interval between examinations
- the critical parts of the system which, if modified or repaired, should be examined by a competent person before the system is used again
- the name of the competent person certifying the written scheme of examination
- the date of certification.

The WSE is normally a 2-part document. Part 1 of the document should contain details of the examination and testing activities, normally based on a framework of "Working " and "Thorough" examinations. Part 2 records the register of plant items to which the scheme should apply and their individual periodicity for examination and testing.

9.4.2 **Typical Scheme**

9.4.2.1 **Object of Examination**

The object of the examination is to assess the condition of the system and any defects which may be found during the examination. The Competent Person should, if necessary, investigate the cause and approve the repair or remedy, stating whether the repair or remedy is of a temporary nature or permanent. If the repair is of a temporary nature the period of acceptance should be qualified until a permanent repair or remedy can be carried out.

9.4.2.2 **Initial Examination**

An examination carried out by the Competent Person before any system or part of a system is brought into service. This examination is necessary to ensure that the individual components have been installed in a safe manner, that access is not impeded and protective devices operate safely. In some circumstances the examination may be a full thorough examination or a working examination. A thickness survey and full dimensional check may be necessary to establish the safe operating limits.

9.4.2.3 **Thorough Examination**

A thorough examination comprises a careful and critical scrutiny of the vessels and associated equipment, in or out of service as appropriate, using suitable techniques and procedures, including testing where appropriate.

For LNG VITs where internal access is not usually practicable or possible, then ultrasonic thickness checks and other tests should be carried out to a recognised procedure in such a manner that a reasonable assessment of the internal /external condition can be made by the competent person.

Where the competent person requires a supplementary working examination, then this examination should be made as soon as practicable and shall include functional tests of the protective devices. This supplementary working examination will be deemed part of the said thorough examination.

9.4.2.4 **Working Examination**

A working examination should be carried out with the vessels under normal operating conditions and should take the form of an external visual examination, supplemented by the witnessing of functional tests of the protective devices using suitable techniques including testing where appropriate, as required by the Competent Person.

Working examinations shall be carried out at intervals detailed in part 2 of the Written Scheme, where no thorough examination has been made in that year.

9.4.2.5 **Intermediate Examination**

Intermediate examinations may be requested where specific components within the equipment system are assessed by the Competent Person carrying out an examination as being unsuitable for the normal period between examinations indicated in the written scheme of examination. Such examinations may require the system to be shut down for short periods to allow NDT on limiting components.

9.4.2.6 **Repairs and Modifications**

All substantial repairs or modifications affecting the vessel or protective devices should be approved by the Competent Person and carried out at least to the same standards as the original construction. Details of all repairs or modifications shall be documented in the report of the examination.

9.4.2.7 **Reporting (By the Competent Person / Inspector)**

A written report shall be sent to the user/owner within 28 days of the examination providing details of the condition of the system, or parts of the system, being examined.

Where defects are noted which could give rise to imminent danger the Competent Person shall make a written report immediately to the user/owner specifying the necessary repairs and within 14 days a report containing the same particulars to the enforcing authority.

The last report and any reports containing information regarding repairs and modifications shall be kept in the record system and together with the Written Scheme be made available.

9.5 VESSEL MAINTENANCE AND REPAIR

Any remedial works or routine repairs identified through the WSoE or routine operational checks shall be undertaken under a written procedure and in accordance with the permit to work system for the facility.

The repair procedure shall be reviewed and authorised in accordance with the formal process for Management of Change implemented at the facility (see section 9.8).

9.6 MAINTENANCE PAINTING AND COATINGS

The condition of paintwork or any other form of coating shall be monitored on a routine basis as part of the inspection scheme for the vessel.

Any remedial / repair painting or periodic full repainting of the vessel, supporting structures, associated pipework and ancillary equipment shall be undertaken in accordance with the Gas Industry standard, GIS/PA10:2022 (Specification for Maintenance Painting at Works and Site for Above Ground Pipeline and Plant Installations).

9.7 MAINTENANCE RECORDS AND DATA REVIEW

9.7.1 Retention and Review

All maintenance records, in the form of hard copy or computer held data shall be retained throughout the life of the plant and reviewed periodically by a competent engineer.

Such reviews shall identify any equipment failures and be subjected to a root cause analysis to ensure that the maintenance and inspection regimes continue to be fit for purpose.

9.7.2 Performance Monitoring

The dates of inspections, planned maintenance interventions and any associated Key Performance Indicators, shall be monitored to ensure that these are undertaken in accordance with the planned programmes and the WSEs for the installation.

9.8 MANAGEMENT OF CHANGE

9.8.1 MoC Objectives

Management of Change (MoC) is a process for evaluating and controlling modifications to a facility design, operation or activities. The process should be followed prior to the implementation of any engineering related change to make certain that no new hazards are introduced, and that the risk of existing hazards to employees, the public, or the environment is not knowingly increased.

The intention of this process is to identify and safely manage Engineering Changes that affect the original "design intent" of the installation and to maintain an audit trail from the original design through to the current status of the vessel and associated equipment.

9.8.2 Categories of Engineering Change

The MoC process shall be designed to address:

- A change in process containment material from the original design specification
- A change in duty, operation or process control when the original design intent is infringed.
- A change in operating procedures
- A modification albeit temporary or permanent to an existing facility including structural changes and / or additions. This category also applies to installation of temporary equipment and temporary repairs
- Permanent isolation or removal of an existing facility, equipment or installation

- Replacement of equipment (or parts thereof) that are not "like for like" and require drawing, certification or plant history records to be altered or updated, other than to facilitate planned maintenance.
- Repair or replacement of original manufacturers' equipment using non-standard parts or processes, except where the original equipment manufacturer (OEM) has provided written approval / acceptance to the satisfaction of the relevant Technical Authority.
- Isolation of a safety system(s) or circuits other than to facilitate planned maintenance, construction activity or dictated by operating procedures.
- A change to any safety equipment or any safety related equipment, device or system
- A connection into a shutdown system, either permanent or temporary
- A change in logic, software, relief valve set pressures, trips and ESD systems where the original design intent is infringed
- A change to software control systems
- Changes to maintenance and inspections and associated WSEs

9.8.3 Engineering Change Principles

The Change Process shall be designed to follow the steps outlined below:

- Identify and describe the justification and details of the required change
- Assessment of the validity and impact of the change by a technical competent person
- Authorisation by an appropriate business and technical authority
- Implementation of the required change to the required standard
- Monitoring and closure of the change to ensure that the implementation reflects the required design or engineering change, and that the change details have been correctly recorded

The process should also be designed to provide a suitable process for consultation and communication with any interested parties and employees.

The MoC process applied should also be appropriate and scalable, being commensurate with the size and complexity of the change.

9.8.4 Roles and Responsibilities

9.8.4.1 General

The process shall be organised so as to provide a facility for change request initiation, technical and business appraisal and overall control. This will require staff to be trained and designated with the appropriate roles and responsibilities

9.8.4.2 Initiation

Contractors and site visitors should be informed, as part of the site induction process, to report any concerns or requirements identified to a member staff.

All directly employed staff on the facility shall be trained to recognise the requirements for engineering change and to understand the process by which any change requirements are submitted for review by the appropriate technical and business authorities.

9.8.4.3 **Ownership and Management**

It is considered good practice to appoint a process owner to the overall management of change for the facility. The process owner or change manager shall have the overall accountability for ensuring the MoC process is fit for purpose, and embedded in the organization. They shall also ensure that:

- All change requests are properly documented and directed to the appropriate technical and business authorities in a timely manner
- Approved and authorised changes implemented according to the designated timeframes
- They support any internal or external audits associated with the MoC process

9.8.4.4 **Technical Appraisal**

All change requests shall be assessed by a (external or internal) technical authority who has the professional background and knowledge to fully understand any potential risks and impact of the required change and how this affects the original design criteria and specifications.

Modification costs should also be estimated, and a cost v benefit case prepared to support the required business appraisal.

9.8.4.5 **Business Appraisal**

Engineers and/ or managers with sufficient background and financial authority shall review the cost benefit of the change. They shall be responsible for providing appropriate financial budget to meet the cost of the authorised change and for the initiating the project and work to commit the physical changes required.

9.8.4.6 **Information and Communication**

The MoC process owner shall be responsible for recording and communicating the outcomes of any authorised changes, deferrals or rejections to the original initiator and any other interested parties.

SECTION 10 : DECOMMISSIONING AND DISPOSAL

10.1 WRITTEN PROCEDURES

10.1.1 All decommissioning operations shall follow a written procedure, and the results of the steps involved shall be recorded.

10.1.2 The procedure shall include the following:

- emptying of the vessel and depressurizing to a positive pressure not greater than 0,2 MPa (2 bar)
- checking of the process by monitoring pressure and mass, if necessary, verifying that no line is obstructed
- giving due consideration to the properties of the product involved

10.2 TEMPORARY OUT OF SERVICES AND MOTHBALLING

10.2.1 If the vessel is intended for further service, such records shall be retained by the owner company.

10.2.3 The decommissioned vessel shall be kept in a safe and serviceable condition by:

- the purging of the vessel and all piping and accessories with inert gas
- if the vessel is to be transported or stored, protective caps should be fitted on all open connections
- when in store, a slight positive pressure of dry inert gas shall be maintained in the vessel and the vessel shall be labelled accordingly.
- routine inspection and maintenance activities should continue throughout the out of service period, though these may be modified to reflect the mothballed status and lower risk inventory

10.3 PERMANENT DECOMMISSION AND DISPOSAL

10.3.1 If the vessel is to be scrapped, it shall be purged with inert gas to a positive pressure not exceeding 0.5 barg, and labelled accordingly, e.g. "Purged with Nitrogen — To be scrapped"

10.3.2 Product identification labels shall be removed, and the nameplates rendered unusable.

10.3.3 All scrapped metal and insulating material shall be disposed of in. accordance with local trade and hazardous waste regulations.

10.4 SITE CLEARING AND RESTORATION

10.4.1 The site should be cleared and restored to a "brown field" condition or as appropriate to the future intended use of the site.

APPENDIX 1: GLOSSARY OF TERMS

For the purposes of this Standard, the following definitions apply. The definitions are included as a general guide to terms used and are related to terms found in British Standards, etc.

All other definitions are given in IGEM/G/4 which is freely available by downloading a printable version from IGEM's website, www.igem.org.uk.

Term	Definition
Class rating	A number indicating the pressure strength of a component. *Note: Class ratings are used in ASME standards. See PN for the equivalent European system.*
Design pressure	The pressure on which design calculations are based. *Note 1: Design pressure is the target MOP.* *Note 2: Design pressure will be greater than or equal to MOP.*
Failure cause	The reason for a pipeline reaching a "limit state". Examples are external interference, external corrosion and growth of defects due to fatigue.
Failure mechanism	A potential cause of pipeline failure, for example corrosion, external impact, overpressure etc.
Failure probability	The likelihood that one or more failure mechanism will occur.
Maximum incidental pressure (MIP)	The maximum pressure which a system is permitted to experience under fault conditions, limited by safety devices.
Maximum operating pressure (MOP)	The maximum pressure at which a system can be operated under normal conditions.
Operating pressure (OP)	The pressure at which the gas system operates under normal conditions.

APPENDIX 2: ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
ACoP	Approved Code of Practice
ALARP	As low as is reasonably practicable
CDM	Construction (Design and Management) Regulations
CE	European Conformity (marking)
COPA	Control of Pollution Act
COMAH	Control of Major Accident Hazard Regulations
COSHH	Control of Substances Hazardous to Health Regulations
DEFRA	Department of Environment, Food and Rural Affairs
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
EIA	Environmental Impact Assessment
EIGA	European Industrial Gas Association
GS(M)R	Gas Safety (Management) Regulations
HAZID	Hazard Identification (Hazard and Risk Study)
HAZOP	Hazard Operation (Hazard and Risk Study)
HSA	Hazardous Substances Authority
HSE	Health and Safety Executive
HSWA	Health and Safety at Work etc. Act
IGEM	Institution of Gas Engineers and Managers
LIN	Liquid Nitrogen
LNG	Liquefied Natural Gas
MAPD	Major Accident Prevention Document
MDMT	Minimum Design Metal Temperature
MHSWR	Management of Health and Safety at Work Regulations
MoC	Management of Change (Procedure)
PESR	Pressure Equipment Safety Regulations
PSSR	Pressure Systems Safety Regulations
RBI	Risk Based Inspection
SCC	Stress Corrosion Cracking
SIL	Safety Integrity Level
VIT	Vacuum Insulated Tank
WSoE	Written Schem of Examination

APPENDIX 3: UNITS AND SYMBOLS

UNITS

barg	bar gauge
Kg	Kilogram
KJ/mm	Litre
L	Kilojoules per millimetre
mbar	millibar
MPa	megapascal
T	Tonne (metric)

APPENDIX 4: REFERENCES

Regulations:

Construction (Design and Management) Regulations:2015 (CDM)

Control of Major Accident Hazards Regulations: 2015 (COMAH)

The Planning (Hazardous Substances) Regulations 2015

The Management of Health and Safety at Work Regulations:1999 (MHSWR)

The Pressure Systems (Safety) Regulations;2000 (PSSR)

Pressure Equipment (Safety) Regulations:2016 (PESR)

The Dangerous Substances and Explosive Atmospheres Regulations;2002 (DSEAR)

European Directive 97/23/EC, Article 11, European Approval for Materials

IEC 61508-1: 2010, Functional Safety of Electrical/ Electronic /Programmable Electronic Safety-Related Systems - Part 1: General Requirements

Publications and Industry Standards:

ASME Standard, Section VIII, Rules for Construction of Pressure Vessels Division 1

EEMUA Publication 224:2013, A guide to risk-based procurement

EIGA IGC doc 115/12, Appendix E (European Industrial Gases Association)

Gas Industry Standard, GIS/PA10:2022 (Specification for Maintenance Painting at Works and Site for Above Ground Pipeline and Plant Installations).

British Standards Document: PD 8010-4:2012 Pipeline systems. Steel pipelines on land and subsea pipelines. Code of practice for integrity management

British Standards:

BS EN 10204: 2004, Inspection Documents for Metallic Products (Inspection Certificate 3.1b)

BS EN 12567: 2000 Isolating Valves for LNGBS EN 13445 Parts 1-11:2021/24: Unfired Pressure Vessels

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