— maintain all safety critical; loads (process instrumentation, fire and safety equipment and associated systems, MOV's (Mechanically Operated Valves), telecoms, warning lights, essential lighting, etc.);

— start and run the firewater jockey pumps;

— maintain sufficient power to the electric circular ring of the heating (if fitted) of the LNG storage tanks foundations, in case of above ground tank or to the needed electrical heating systems in case of inground tank;

— provide an instrument air and/or nitrogen supply if required for safety functions.

Emergency generator shall have a minimum of 24 h fuel supply in the "day tank" sited at the generator and be capable of being refuelled when running.

The designer should establish if main equipment items need a power supply to ensure safe shut and cool down.

12.1.4 Uninterruptible Power Supply (UPS)

An Uninterruptible Power Supply shall be provided.

It shall provide power to critical control and safety systems so that the plant may be kept in a safe condition for a minimum of 60 min.

In case of plant expansion, the UPS capacity shall be checked to ensure that the minimum autonomy is still maintained.

12.1.5 Lighting

Lighting shall be provided in plant areas where safe access and safe conditions for work activities is required at night.

An emergency battery lighting system shall be provided to allow the safe escape of staff from accessible areas of the plant in the event of a power and essential lighting failure, or an emergency situation.

12.2 Lightning and earthing

12.2.1 Lightning protection

Lightning protection shall be in accordance with EN 62305 (all parts).

The following installations shall be, as a minimum, protected against lightning:

— tanks and their accessories;

— marine transfer arms;

— buildings;

— flares and vents.

12.2.2 Earthing circuit

Earthing shall be in accordance with CENELEC standards, in particular HD 60364-5-54.

The design shall ensure personnel protection and avoid potential difference between metallic components and the possibility of spark generation in hazardous areas.

12.3 Cathodic protection

All underground/subsea metallic parts should be protected where necessary against corrosion using appropriate coating and/or cathodic protection in accordance with the relevant codes and/or standards.

In case of plant expansion, the anode beds shall be checked to ensure that the minimum loads are still covered.

12.4 Warning lights

Tanks and other elevated structures shall be fitted with warning lights to comply with air and safety navigation regulations.

The jetty shall have navigational lights in accordance with local marine regulations.

12.5 Sea water supply

12.5.1 Materials

Materials shall be carefully selected in terms of fluids and the site environment.

Particular attention shall be paid to the compatibility of materials to avoid any galvanic corrosion.

12.5.2 Water pumping

It is recommended that the number and sizing of cooling water pumps or seawater pumps is such that unavailability of a pump of the highest rated capacity will not prevent the water requirements of exchangers and cooling services from being met.

The design of the seawater intake often requires detailed study to ensure that the filtration and hydraulic requirements of the seawater pumps are correctly addressed.

Filtration shall be provided in accordance with pump and related equipment manufacturer requirements.

Water circuits are susceptible to internal corrosion and/or fouling by natural organisms. Measures to prevent this should be fitted if required. The discharge of water treated with anti- corrosion and anti-fouling chemicals shall be in compliance with the discharge permit(s) for the plant (see 4.2.1, 4.2.2 and 4.2.3). The discharge temperature of the water shall be in compliance with the discharge permit(s).

12.6 Gas contaminant removal plant

Some liquefaction plants require gas treatment to remove gas contaminants such as mercury, sulphur, carbon dioxide, mercaptans and aromatics from the incoming gas.

Facilities and procedures shall be in place for the secure handling, storage and recycling or disposal of these materials and their removal media if required.

Material Safety Data Sheets for the absorption and reactant media shall be provided and shall state specific requirements for safe disposal or recycling of the material in a “used” or “spent” condition.

12.7 Instrument air

When instrument air is used its supply shall be reliable. This shall usually mean the provision of at least two air compressors each capable of supplying the total requirement.

Instrument air supplies shall be guaranteed for the time interval needed to put the plant in a safe condition on failure of the main power source. This shall be for a minimum of 3 min. This may be achieved by for example, providing air receivers to provide the necessary storage.

If the instrument air compressors are electrically driven, at least one, capable of supplying the total requirements, should have its power supplied from the emergency power supply.

The air shall be dried to a dew point compatible with the plant minimum ambient temperature conditions. The dew point shall be at least −30 °C and 5 °C below ambient temperature (both referenced to atmospheric pressure).

The instrument air system is to be independent of the plant air or service air systems.

12.8 Fuel (utility) gas

An LNG plant may be equipped with a fuel gas system. The main applications depending on the type of the plant are the following:

— gas fired vaporizers;

— gas turbine or gas engine driven compressors and generators;

— steam boilers and process heaters;

— tank safety, as vacuum breaker gas;

— flare pilot gas and purge.

Fuel gas used within the plant shall not be odorized. Leak detection shall be provided by the gas detection system as 13.4.

12.9 Nitrogen system

Nitrogen can be produced on site or delivered as liquid nitrogen by road or rail.

Certain process conditions such as molecular sieve regeneration or for injection as a component in a make-up stream may require that a high quality nitrogen supply is used.

The nitrogen is used mainly for:

— gas treatment (calorific value adjustment);

— pressurization;

— equipment, LNG tank insulation space and piping purging;

— drying and inerting;

— rapid extinction of flares and vents;

— cooling;

— refrigerant cycle make up.

The liquefied nitrogen pipe-work shall be designed with cryogenic materials in accordance with recognized local codes and/or standards, examples of acceptable materials are given in EN ISO 16903.

Cross connection between gaseous nitrogen systems and air systems is not permitted for safety reasons.

12.10 Buildings

Building design and construction shall comply with the requirements of hazard assessment (see 4.4.2.5), the following standards and with local regulations, especially for seismic design:

— EN 1992-1-1;

— EN 1993-1-1;

— EN 1994-1-1;

— EN 1998-1.

For the electrical installations of buildings, see also [11].

Where identified in the hazard assessment, buildings shall be pressurized (see EN 60079-13 guidelines). Forced ventilation air intakes for buildings shall be fitted with gas detectors to shut down ventilator fans and inhibit start up to avoid any risk of sending gas into the building.

The permanently manned control rooms shall be designed to enable occupation for sufficient time for the emergency procedures to be put into effect and to permit evacuation to a safe location. The heating, ventilation and air conditioning system shall be designed to suit the possible received radiation flux (see 4.4.2.5 and Annex A).

Where buildings are designed for blast over-pressure the design shall consider the risk to personnel caused by the blast wave entering the building through ventilation inlets and outlets.

13 Hazard management

13.1 Inherent safety

13.1.1 Provision for minimum safety spacing

The safety spacing shall be calculated considering possible fire radiation levels and gas dispersion zones. The allowable exposure levels are specified in Annex A. Safety distances between LNG tanks, process units, control rooms etc. shall comply with the minimum requirements to achieve these threshold values.

13.1.2 LNG Plant layout

The siting of an LNG plant with respect to the surroundings shall be covered by a site location assessment, see 4.3.2.5.

The following clause concerning the plant layout uses the terms “hazardous areas” and “hazard affected areas”. In this context the hazard affected areas are those areas where those events described in 4.4 could arise. The term hazardous area applies specifically to those areas that are defined in 4.5.2.1 b).

The LNG plant shall be laid out to provide safe access for construction, operation, maintenance, emergency action and comply with the layout requirements identified in the Hazard Assessment according to 4.4.2.

Separation distances shall take into account, in particular:

— radiation flux levels;

— lower flammability limit contours;

— noise;

— blast effects.

The prevailing wind direction shall be considered in LNG plant layout. Where practicable, buildings and ignition sources should not be downwind of possible accidental and planned releases of flammable materials. They shall be located outside hazardous areas.

Plant buildings should be sited outside the hazard affected areas or designed to resist these accident scenarios. The building’s level of occupancy shall also be part of this evaluation.

The central control room shall be located outside process areas and should be outside hazardous areas. Furthermore, it shall be designed to operate during and resist those accident scenarios that have been identified in the Hazard Assessment.

For all equipment, such as air compressors, fired process equipment, gas turbines, diesel driven fire water pumps and emergency generators, the air intake shall be located outside zone 0 and 1 areas. Air intakes shall be fitted with gas detection which will trip the equipment.

The spacing between two adjacent tanks shall be the result of a detailed hazard assessment. This shall be a minimum of half the diameter of the secondary container of the larger tank.

Additional guidance on plant layout is given in the following reference [8], [9] and [49].

13.1.3 Escape routes

Escape routes shall be provided for all plant areas where a hazard to personnel may arise. Escape routes shall be laid out to encourage an intuitive response from personnel to lead them from high hazard areas to low hazard areas and shall consider that there may be some panic in an emergency situation. The design shall take into account the fact that when LNG is spilled a “fog” is created by condensation of atmospheric humidity.

13.1.4 Confinement

Confined or partially confined zones shall be avoided as far as possible, in particular:

— gas and LNG pipe-work shall not be situated in enclosed culverts when it is possible to avoid this for example where road bridges cross pipe ways;

— the space situated under the base slab of raised tanks, if any, shall be sufficiently high to allow air to circulate;

— where cable culverts are used they shall be filled with compacted sand and covered with flat slabs featuring ventilation holes to minimize the possibility of flammable gases travelling along the culverts through voids above the sand. As the sand settles the slabs will sink. They can be restored to their original elevation by adding sand.

13.1.5 Direct accessibility to valves and equipment

This is achieved by providing in the plant all the required safe accesses, paths, staircases (/ladders) and platforms, as required by the layout review(s) 4.5.3.

The road system should be developed to provide a direct access for the firefighting trucks and other emergency response vehicles.

13.1.6 Selection of appropriate electrical components according to the classified area

Electrical equipment to be installed in hazardous areas will be qualified in accordance with EN 60079 / IEC 60079 series according to Clause 2.

Availability of required certificates shall be carefully checked on an individual basis.

13.1.7 Spillage collection, including paving in hazardous area

Restricting the extent of a potential LNG or hydrocarbon leak is achieved by:

— limiting the volume of the possible accidental spills;

— containing these spills within defined impounding and spill collection areas, to prevent their spreading to other areas of the plant or outside the plant boundary and minimizing the vapour cloud dispersion distance;

— making provision to properly remove rainwater whilst LNG or hydrocarbon spill will be contained in the collecting systems and will not ingress into drains or other water courses;

— controlling leaks and spillage.

Where dispersion calculations show that a leak can escalate to a more serious incident fixed leak detection systems with advisory or executive action to stop the leak source, are required to isolate sections of plant and to shutdown sources of ignition.

The design of impounding basins shall be such that flammable fluids cannot enter the surface water drainage system. Spill detection devices and means to control the evaporation rate (e.g. foam generation see 13.6.5) should be provided. These channels and the impounding basin may be lined with an insulating layer to limit evaporation (see EN 12066).

Separation systems relying on the differential densities of water and LNG are not acceptable.

13.1.8 Retention systems in process and transfer areas

Liquid spills within process and transfer areas shall be confined within a spill collection area and shall be drained to an impounding basin.

Subject to the results of risk analysis, the impounding basin may be located in the vicinity of, or remote from, the spill collection area. The spill collection area and the impounding basin shall be connected by open channel.

For process areas, the spill collection system or impounding basin capacity shall be at least 110 % of the largest expected spill according to the risk analysis performed. Flash may be considered for capacity calculation. In case of plant expansion or plant debottlenecking, the spill collection system and impounding basin capacity shall be checked to suit the new inventories.

At transfer areas and in the interconnecting pipe-work, where there is a potential for leaks (valves, equipment or instruments), the impounding basin capacity shall be determined by risk analysis considering potential leak sources, flow rates, detection systems, manning levels and response times.

13.2 Passive protection

13.2.1 Fire proofing

Fire proofing shall be used to protect equipment, typically: ESD valves, safety critical control equipment, vessels containing quantities of liquid hydrocarbon and structural supports, which on failure would escalation the incident and/or endanger the activities of emergency response personnel. Equipment which can receive thermal radiation, in excess of that defined in Annex A, for a sufficient period to cause failure shall be provided with fire proofing protection. The fire proofing shall provide protection for the duration of the hazard event but shall as a minimum provide 90 min protection.

Fire protection in the form of insulation or water deluge shall be provided for pressure vessels, which can receive thermal radiation fluxes in excess of that defined in Annex A, to prevent such vessels failing and releasing superheated liquid, which can result in a BLEVE, (see EN ISO 16903).

It shall be recognized that pressure vessels subject to radiation from a major incident such as an LNG tank fire shall require protection for much more than 90 min. Protection for long duration incidents may not be achieved by insulation and a water deluge system is required.

The calculation of water deluge, insulation for fire protection of structures, etc. as protection against fires shall be performed for the fluid which gives rise to the highest radiation flux.

Fire proofing can be provided by:

— preformed or sprayed concrete;

— insulation materials made of mineral fibre, ceramic, calcium silicate or cellular glass;

— intumescent coatings.

Fire proofing shall be designed and executed in accordance with the appropriate standards (see [7] and [31]).

13.2.2 Embrittlement protection

The effect of low temperature fluid spills on adjacent plant, equipment and structural steel shall be assessed and measures taken to prevent incident escalation and/or endangerment of emergency response personnel, through suitable selection of materials of construction or by embrittlement protection.

Such protection shall be achieved by an appropriate material selection (concrete, stainless steel, etc.) or by a insulating with material that will protect the equipment and structural supports from cold shock. Insulation shall be designed and installed in accordance with appropriate standards and provision taken to protect outer surfaces from wear and tear.

Equipment and structural support elements should be protected in such a way that their function and form are not adversely affected during the plant operation.

13.3 Security

The security should be covered by:

— Anti-intrusion

  The anti-intrusion system should be installed along the fences to monitor undesired ingress in the plant.

— Access control

  An access control system shall be installed in order to control the access to the various areas of the plant.

  It may include badge readers, intercom, door contacts and anti-intrusion sensors.

  The access control system will consider the different access levels (control rooms, process areas, general facilities, etc).

The security control system should be linked to the CCTV to allow remote monitoring.

13.4 Incident detection and signalling

Systems shall be provided to detect possible accidental events, which could occur in the plant.

The arrangement of detectors shall be such as to always provide redundancy and to prevent false and spurious alarms. Voting technique arrangement may be used.

Events may include:

— Earthquake

  Where applicable seismic acceleration monitoring shall be provided, giving signals to automatically initiate the plant shutdown when the earthquake reaches a pre-defined level. This pre-defined level is chosen by the operator.

— LNG spillage, gas leakage, flame and smoke

  These detection systems are intended to rapidly and reliably detect any LNG spillage or flammable gas leakage and any fire condition in the plant.

  Continuously operating detection systems shall be installed at every location, outdoors and indoors, where leaks are credible.

  The following detection devices may be provided:

  — LNG spillage detection;

  — LNG spills should be detected by low temperature sensors, for example, resistance type device's or fibre optic systems. The sensors shall be, protected against accidental damage;

  — Flammable gas detection.

    The flammable gas detectors may be of the infra-red type, or of equivalent performance.

    Along critical fences, open path type gas detectors may be installed.

    For location of gas detectors, see [27].

  — Flame detection

    Flame detectors should be proven in the detection of the type and size of fire predicted flame detectors may be of the ultraviolet/infrared (UV/IR) type, or equivalent performance.

  — Heat detection

    High temperature detectors should be provided for protection of tank relief valves fires and activation of tailpipe extinguishing package(s) if provided.

    The heat detectors may be of the high temperature thermistor strip type, of the temperature-sensitive pneumatic type, or equivalent performance.

  — Smoke detection

    Smoke detectors may be of the double ionization chamber type, or equivalent performance.

— Manual call points

Manual call points shall be provided in the hazardous plant areas, typically those plant areas covered by flame and/or combustible gas detectors, and provided on likely escape routes from these areas.

— CCTV (Closed Circuit Television Camera) monitoring

Remote operated cameras should be installed for viewing all events which could occur in hazardous and unmanned areas.

Under abnormal circumstances the operator should have the ability to use these CCTV systems to analyse the situation.

The system shall be considered as a priority load and is connected to the UPS system. The system should automatically respond to alarms, and focus information presented on VDU's in the appropriate control room(s).

— Communication system

The control room operators shall be able to communicate with field operators via the terminal communication systems (specific mobile phones and radios).

Special consideration should be given to buildings with high noise levels where visual alarms should also be installed.

A combination of visual and sound alarms shall be installed in all plant locations.

Direct communication links should be available with the Port Authorities, the LNG carrier and the pipeline dispatching centre.

13.5 Emergency Shutdown System

The ESD system, which is fully described in the Clause 14, includes:

— a Safety Control System (SCS);

— a Fire, Spill and Gas Detection System (FSGDS).

The alarms initiated by the Fire, Spill and Gas Detection System (FSGDS) are reported by and perform the required automatic actions via the Safety Control System (SCS).

The SCS interface system gives the operator detailed information on areas involved in the hazardous event, type of hazard, concentration of gas, where in the area (if applicable), detector or loop involved, status of fire water pumps, status of protection systems, status of HVAC equipment involved (fans, dampers, etc.), wind force and direction, temperature and relative humidity, system faults, reduced safety in the fire zones.

The alarms received in the control rooms, details of automatic actions taken by the SCS together with detailed incident information and CCTV coverage, aid the operators in selecting appropriate operator controlled actions, such as:

— shut down or isolation of the process system involved;

— activation of appropriate remote operated fire protection systems;

— initiate emergency actions by operators with mobile/portable firefighting material.

13.6 Active protection

13.6.1 Active protection definition

The active protection should include:

— fire water mains network, with hydrants and monitors;

— spraying systems;

— water curtains;

— foam generators;

— fixed dry chemical powder systems;

— firefighting vehicle(s);

— portable/mobile fire extinguishers.

13.6.2 Fire water system

Water is employed in many firefighting systems, and has particular uses on an LNG plant. However, LNG pool fires are neither controlled nor extinguished by water. Application of water on a liquid surface will increase the vapour formation rate thus increasing the burning rate with negative consequences on fire control. On an LNG plant, under fire conditions, water may be used in great quantities for cooling storage tanks, equipment and structures which are subject to flame impingement or heat radiation due to a fire. As a result, the risk of escalation of the fire and deterioration of equipment can be reduced by early and concentrated cooling.

Plant surface water and fire water drainage systems and LNG spill collection systems shall be designed to minimize the possibility of fire water increasing the vaporization rate of any LNG spill. This may be achieved by plant area and fire water systems segregation. In the event that firewater run–off is contaminated provision shall be made to prevent the pollution of natural water-courses.

As a minimum, two fire water pumps shall be installed. Independent power sources shall be provided in such a way that full capacity can be delivered, taking into consideration the unavailability of one pump.

Fire water networks should be provided around all sections of the plant. Water supply systems shall be designed in independent sections so that in case of maintenance or damage of a section the water supply to other sections is not interrupted. Both fire pumps should not discharge to the network through a single header.

All these networks, including fire hydrants shall be maintained primed under a minimum pressure at all points for example by means of jockey pumps or an elevated tank.

Special provisions shall be taken to avoid any damage due to freezing; such as tracing.

Water supply systems shall be able to provide, at firefighting system operating pressure, a water flow not less than that required by the firefighting systems involved in the maximum single incident identified in the Hazard Assessment in 4.4 plus an allowance of 100 l/s for hand hoses. The fire water supply shall be sufficient to address this incident, but shall not be less than 2 h.

LNG plants (particularly impounding basins) shall be equipped with drainage systems capable of draining the volumes of water generated by these systems.

13.6.3 Spraying system

The importance of cooling each equipment item and the amount of water required will depend on the hazard assessment (see 4.4).

Where required, spraying systems shall distribute the water flow evenly onto the exposed surfaces. In this way equipment subjected to radiation shall not reach unacceptably high local temperatures.

Recirculation of used water may be considered where practicable and shall depend on its ability to remove the transferred heat in a fire of long duration while keeping the integrity and working ability of the unit. Precautions should also be taken to ensure that flammable materials are not returned with the re-circulated water.

The calculation of the incident water flow on each unit shall be carried out on basis of received radiation flux for each scenario defined in 4.4 using appropriate validated models in order to limit the surface temperature consistent with the integrity of the structure.

13.6.4 Water curtains

13.6.4.1 General

Water curtains may be used to mitigate gas releases and protect against radiant heat.

The aim of a water curtain system is to rapidly lower the gas concentration of an LNG vapour cloud in order to attain the lower flammability limit of gas in air.

Water curtains transfer heat to the cold natural gas cloud through contact between LNG vapours and water droplets.

In addition water curtains entrain large volumes of air that transfer additional heat, dilute the LNG vapour cloud, thus enhance its buoyancy thus facilitating its dispersion.

The effectiveness of a water curtain is reduced as the wind speed increases, but natural dispersion is increased at high wind velocities.

Effective performance of water curtains is dependent on many different conditions, i.e. nozzle type, water pressure, nozzle location, nozzle spacing.

Water curtains are known to mitigate heat radiation and gas cloud dispersion incidents. However they cannot be relied upon as the primary means of protection.

Water curtains could be installed at impounding basins to assist vapour dispersion. The design at the impounding basin should minimize the potential for water from the water curtains draining into the impounding basin.

13.6.4.2 Characteristics and location

It is recommended that water curtains are positioned as required by the hazard assessment, 4.4.

Water curtains can be located as close as possible to the area of possible spill and concentration of LNG taking into account plant requirements. The possibility of water curtain droplets entering the impounding areas should be minimized in order to avoid an increase in the LNG evaporation rate.

Water curtains may be positioned around the impounding areas. In this way they act as a barrier for cold natural gas clouds originating from LNG leaks.

Nozzle spacing should follow vendors’ recommendations.

13.6.4.3 Supply system and volume of flow

The recommended volume flow rate of water is 70 l/min/m run.