

Recommendations for refrigerated liquefied gas storage tanks

PUBLICATION 147

Edition 3

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Preface

Early designs of tanks for refrigerated liquefied gases were traditionally single containment, which means that the liquid containing tank was surrounded by a low bund wall at a considerable distance. Where double wall tanks were used the outer wall was mainly intended to contain the insulation.

Since the mid-1970s it has become increasingly common practice in a number of countries, including the United Kingdom, to surround the primary liquid container by a secondary container at a close distance. The secondary container is intended to prevent release of the liquefied products into the surrounding area in case of leakage or damage to the primary container. This philosophy results in increased safety for the surrounding area.

These tanks generally have secondary containers made from low temperature steel, pre-stressed concrete or reinforced concrete with an earth embankment. More recent developments have led to the publication of EEMUA 207⁽¹⁾ which gives recommendations for design, construction and operation of double concrete tanks.

Background

When Edition 1 of EEMUA 147 was published in the mid-1980s it was the first publication in the world to define the various types of Refrigerated Liquefied Gas (RLG) tanks available and define the full containment tank. It provided design and construction recommendations which were later adopted into a number of internationally accepted Standards. There are now numerous tanks that have been constructed to these Standards and operated successfully and safely for many years.

As a consequence of this, Edition 2 did not replicate this data but concentrated instead on recommendations on the operation, inspection and maintenance of RLG tanks, and included the new double concrete tanks design options.

The latest Edition 3 expands on the inspection advice and includes a new Section 7.5 External inspection. It draws on the recommendations given in its sister publication EEMUA 159: Above ground flat bottomed storage tanks. Guide to inspection, maintenance and repair.



1. Introduction

1.1 Scope

The purpose of this EEMUA Publication is to supply the outline information necessary for the categorisation, inspection and maintenance of single, double and full containment tanks for the bulk storage of refrigerated liquefied gases down to -165°C , and essentially at atmospheric pressure.

Liquids covered by the scope of this document include Liquefied Petroleum Gas (LPG), ethylene, ethane, Liquefied Natural Gas (LNG) and similar hydrocarbons, together with ammonia.

1.2 Definitions of terms

Bund wall

A low wall of earth or concrete surrounding the storage tank at a distance appropriate to contain spilled liquid.

Purchaser

Purchaser, for the purpose of this document, is the Company or its agents which prepare and agree a proposal with a Contractor or Contractors for the design, construction, testing and commissioning of a tank for storing a refrigerated liquefied gas. It is not the purpose of this document to define terms of reference or to allocate responsibilities between contracting parties when the Purchaser is not to be the owner or operator of the storage plant.

Boil-off

Boil-off is the process of vaporisation of very small quantities of refrigerated liquid by heat conducted through the insulation surrounding the storage tank.

Embankment

A bank of selected earth and other materials placed against the outer face of a reinforced concrete tank or high wall.

Contractor

The Contractor, for the purpose of this document, is the Company with which the Purchaser agrees a proposal for the design, construction, testing and commissioning of a tank for storing a refrigerated liquefied gas. The document, in the interest of simplicity, considers the Contractor as being responsible for all works, materials, equipment and service.

Roll-over

Roll-over is the uncontrolled mass movement of a stored liquid, caused by an unstable state of stratified liquids of different density, temperature or composition throughout the depth of the liquid. It is generally accompanied by a large release of vapour inside the tank.

Accidental loads

These loads include impacts from explosions, flying objects, acts of sabotage or fires.

Cryogenic temperature

Very low temperature (below -100°C).

2. Categorisation of storage systems

The first Edition of this Publication described the world's first categorisation of storage tanks suitable for storing refrigerated or cryogenic liquefied gases. The second Edition further develops this concept by introducing tank Type/Classes based on a safety evaluation. The smaller the risk during an incident the higher the classification, i.e. Class B represents higher risk compared to Class A. Storage categories and classifications are defined in this Chapter.

2.1 Definitions of containments

2.1.1 Single containment

Either a single or double wall tank designed and constructed so that only the containing element in contact with the refrigerated product is required to meet the low temperature ductility requirements for storage of the product. The outer wall (if any) of a single containment storage system is primarily for the retention and protection of insulation and is not designed to contain liquid in the event of product leakage from the inner container.

A single containment tank will be surrounded by a traditional bund wall to contain any leakage (See Figures 1 and 4).

2.1.2 Double containment

A double wall tank designed and constructed so that both inner and outer walls are capable of containing the refrigerated liquid stored. To minimise the pool of escaping liquid the outer wall should generally be located at a distance not exceeding 6 metres from the inner wall. The inner tank stores the refrigerated liquid under normal operating conditions. The outer tank contains the refrigerated liquid product leakage from the inner tank.

The outer tank will not be designed to contain vapour released due to product leakage from the inner tank (See Figures 1 and 5).

2.1.3 Full containment

A double wall tank designed and constructed so that both inner and outer tanks are capable of containing the refrigerated liquid stored. The outer wall is located at approximately 1 to 2 metres distance from the inner wall (See Figures 2 and 6 – 8).

The inner tank stores the refrigerated liquid under normal operating conditions. The outer roof is supported by the outer wall.

The outer tank is capable of containing the refrigerated liquid and vapour resulting from product leakage from the inner tank.

This category can be sub-divided into different classes:

- **Class A(1):** A full containment tank where the outer metal or concrete container/component may not be able to resist accidental loads from outside;
- **Class A(2):** As Class A(1), but the inner tank is constructed as a pre-stressed concrete container, without a metal liner;
- **Class B(1):** A full containment tank where the outer concrete container is designed and constructed to resist all accidental loads from outside, such as: impacts from explosions, flying objects, acts of sabotage or fires and the inner tank is – under normal operation – a liquid tight container; and
- **Class B(2):** As class B(1) but – but the inner tank is constructed as a pre-stressed concrete container, without a metal liner.

The following Figures give an indication of the available and developed tank categories. Types 1 and 2 correspond to single containment and Type 3 for double containment. Full containment is further divided into two Classes and then Types 4 to 11. Note that Type 11 is an in-ground type that has been primarily used in Japan.

2.1.4 Membrane tanks

Membrane tanks consist of a single wall pre-stressed concrete tank that is lined with a stainless steel membrane which is both liquid and gas tight.

The membrane is in turn welded to a carbon steel liner on the inside of the dome roof. There are both in-ground and above ground membrane tanks. (See Figure 3 and 9 – 10).

Most approval Authorities consider the above ground membrane tanks as equivalent to full containment tanks. However, other Authorities may instead treat them as single containment tanks and may impose the addition of a bund wall.

Membrane tanks are sometimes referred to as total integrity tanks.

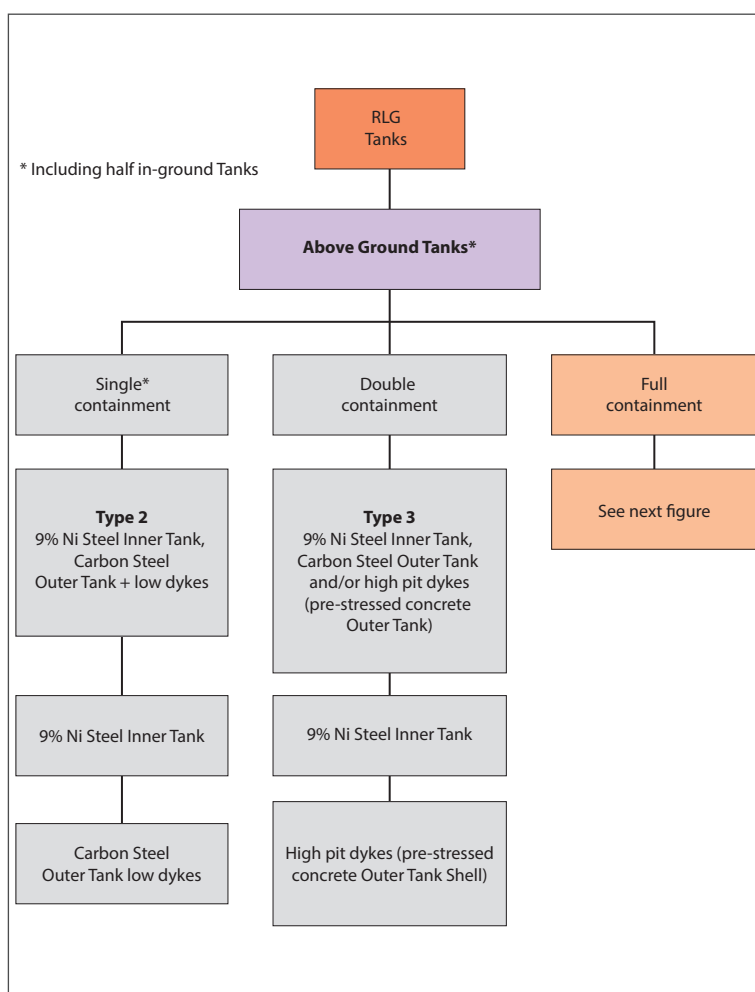


**Figure 1 Scheme of tank categories
for Refrigerated Liquefied Gas (RLG) products**

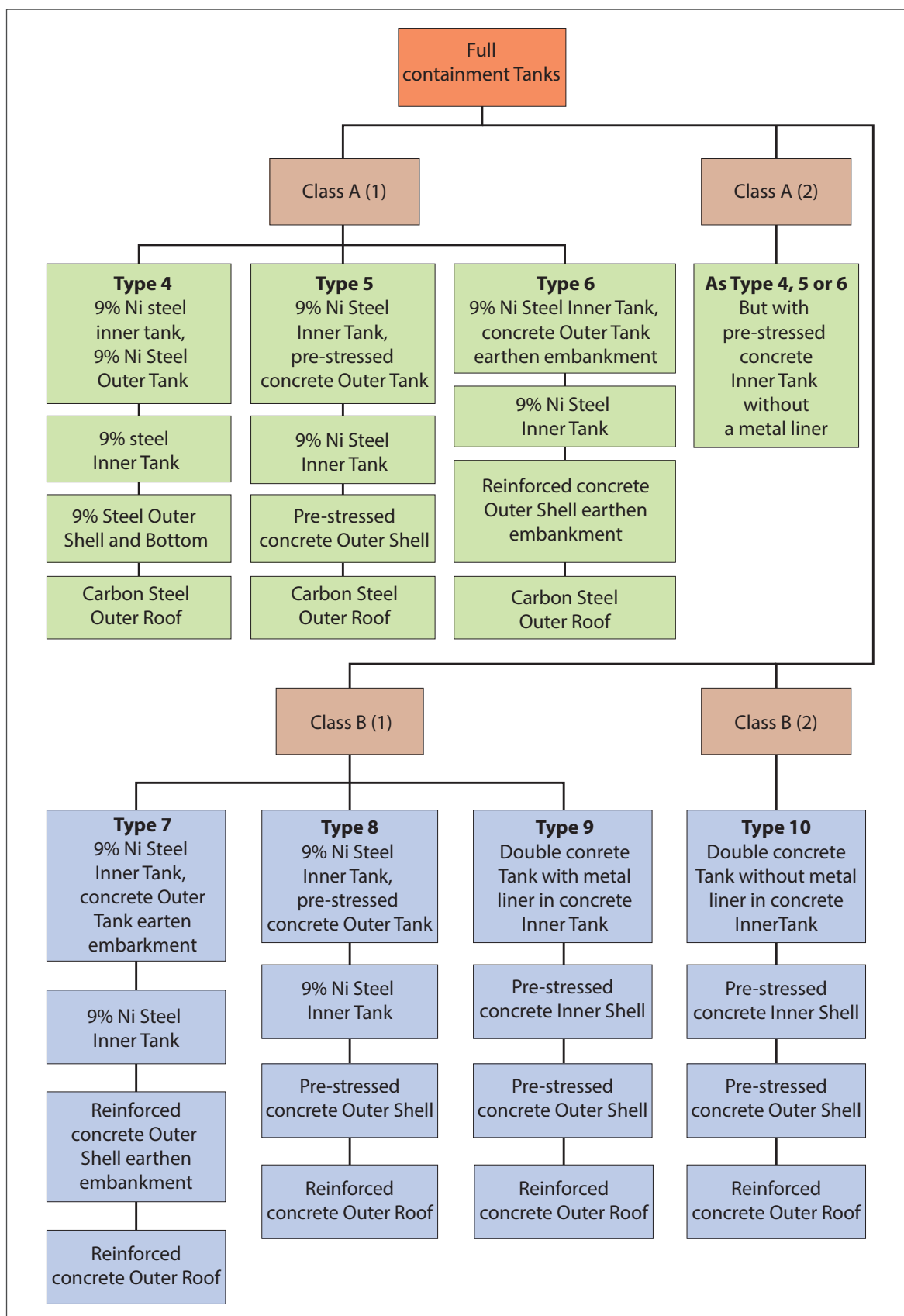


Figure 2 Scheme of tank categories for RLG products (cont.)

Note: only the shell of a concrete tank is pre-stressed. The floor is reinforced concrete

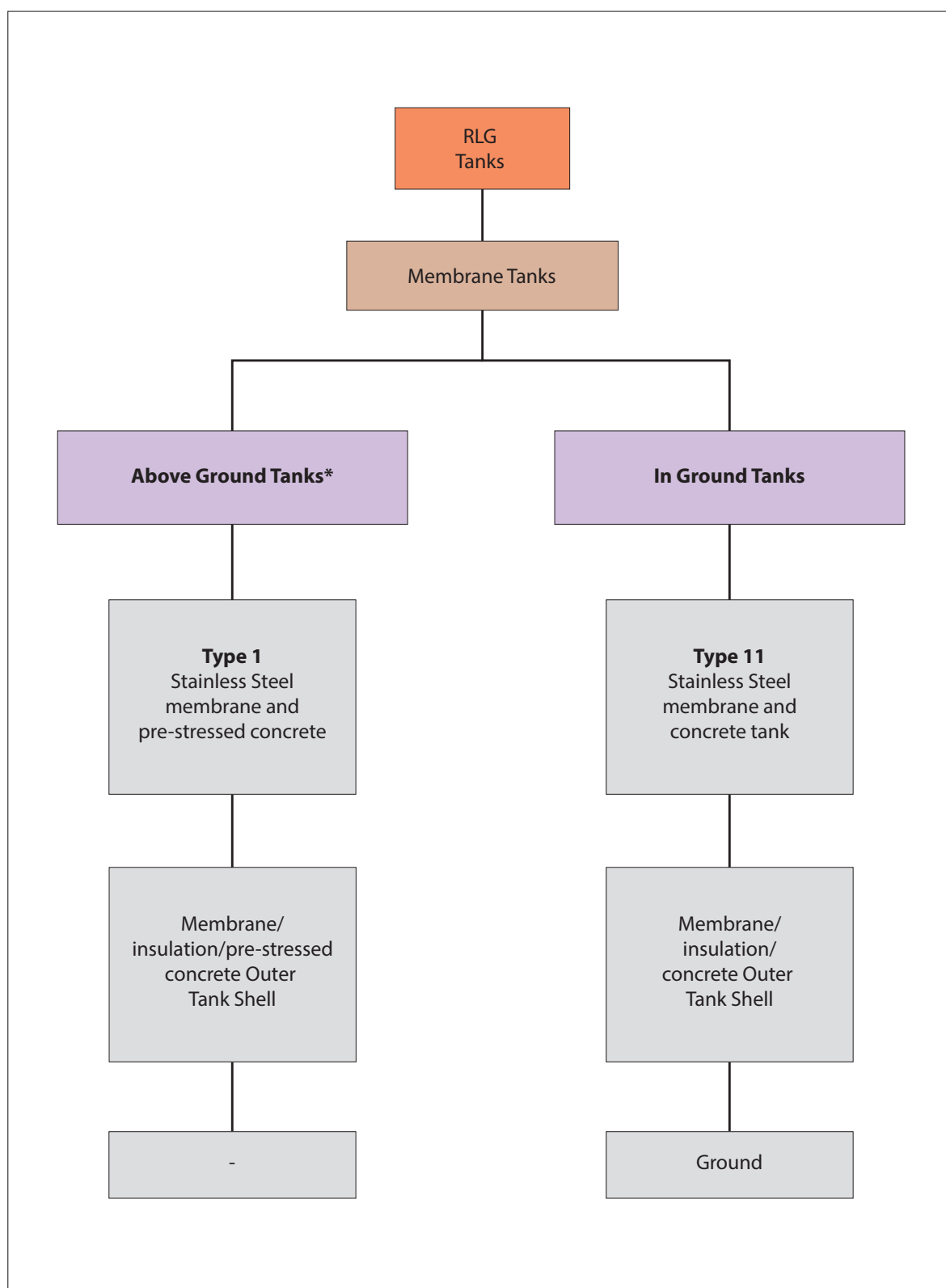


Figure 3 Scheme of tank types for RLG products (cont.)

Note: Stainless Steel and 9% Ni materials are usually only used for cryogenic storage tanks (e.g.: tanks storing LNG, LIN, LOX LAR, Ethylene, etc.). For low temperature storage tanks (e.g.: tanks storing LPG, Ammonia, etc.) low temperature carbon steel is generally used. The types of tanks and insulation shown are typical for LNG storage tanks. For other cryogenic or low temperature products only certain types of tanks and insulation are generally used.

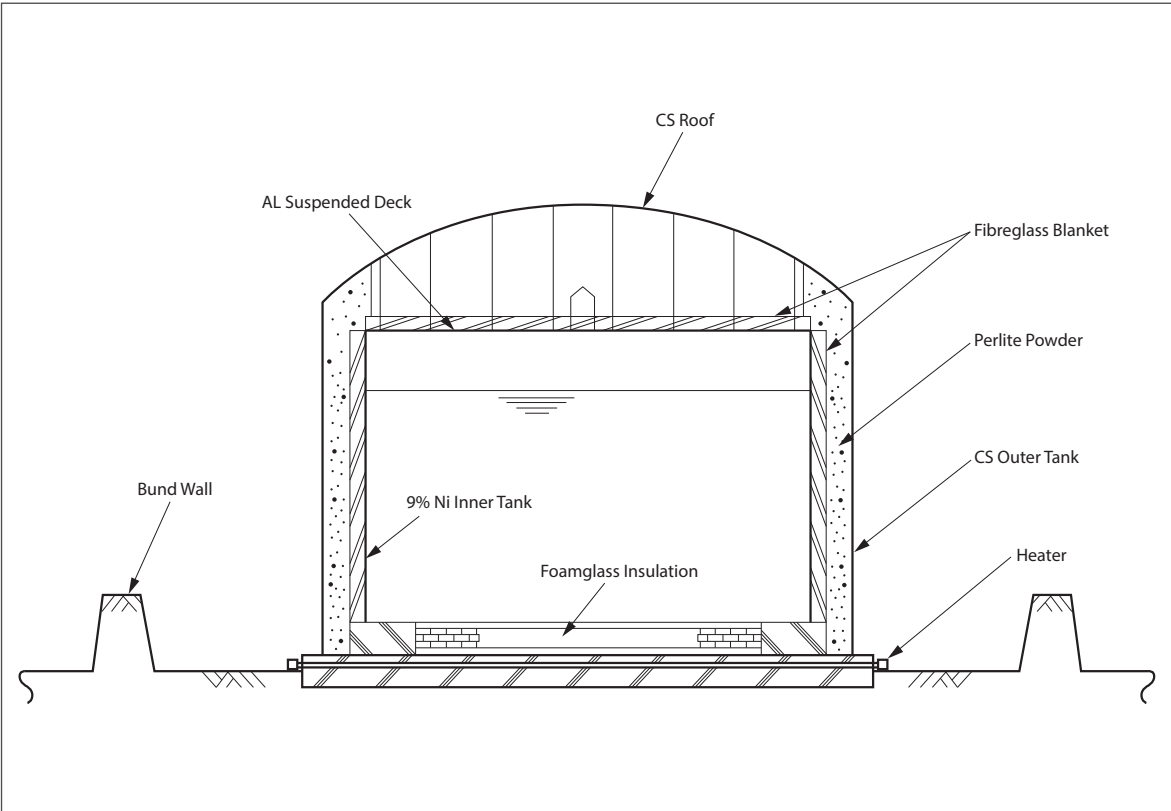


Figure 4 Typical detail of a Type 2 above ground single containment storage tank

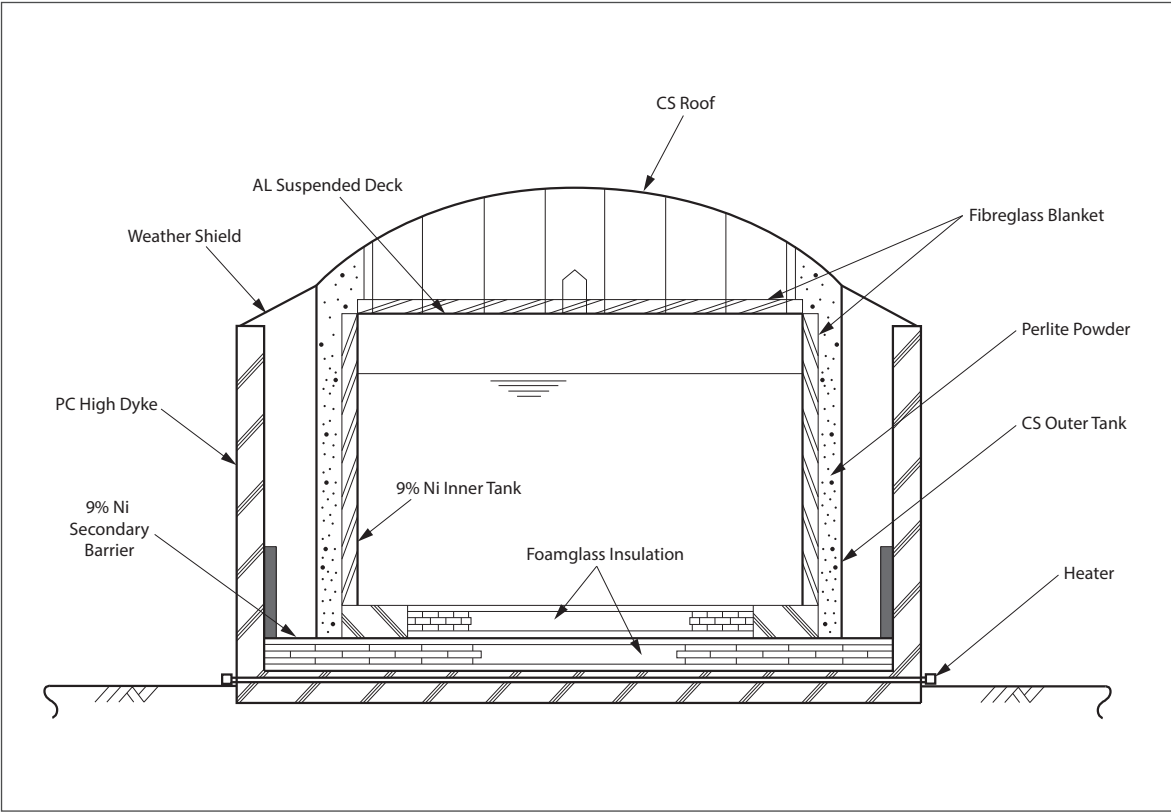


Figure 5 Typical detail of a Type 3 above ground double containment storage tank

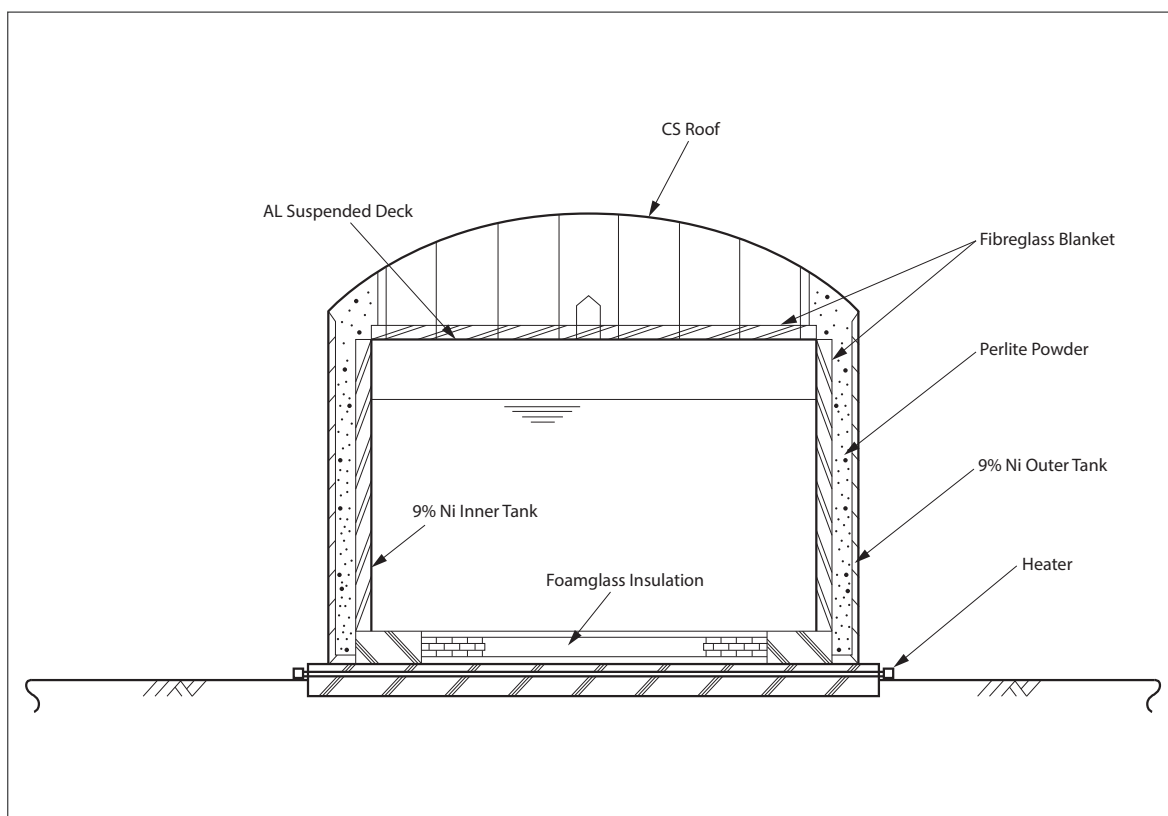


Figure 6 Typical detail of a Type 4 above ground full containment storage tank

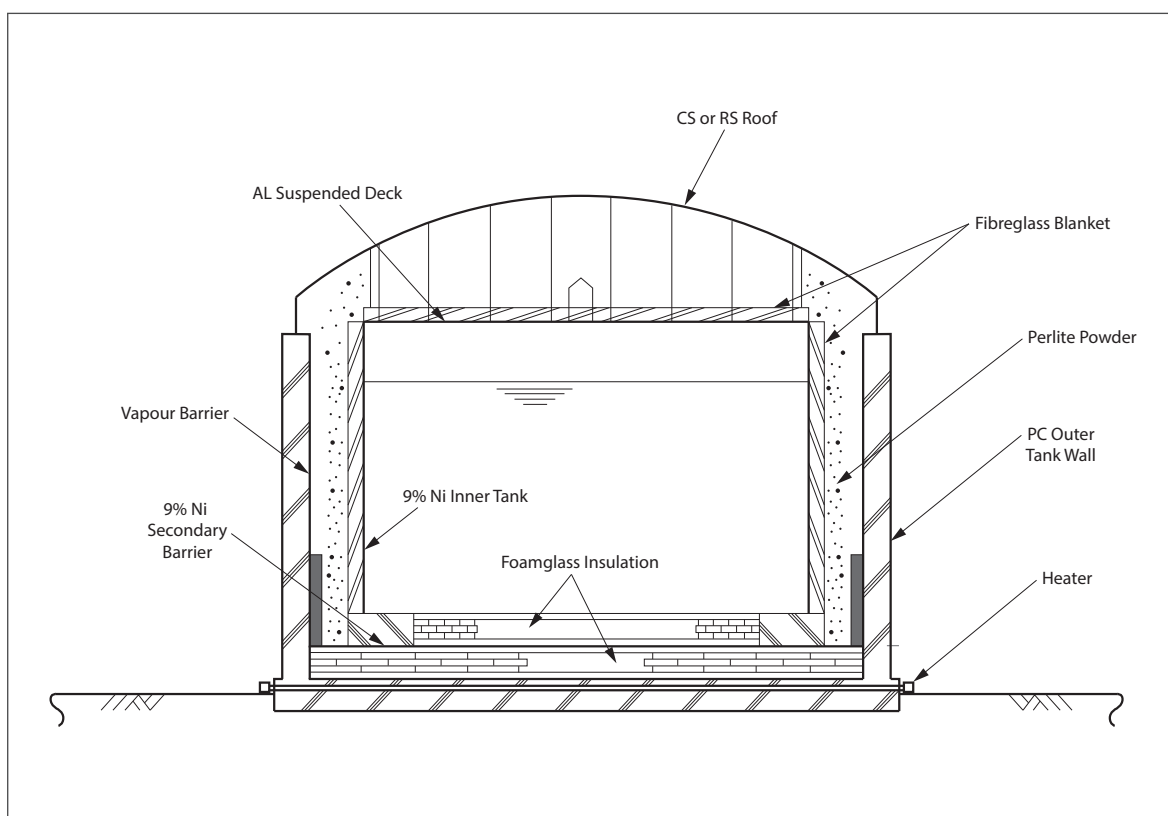


Figure 7 Typical detail of a Type 5/Type 8 above ground full containment storage tank

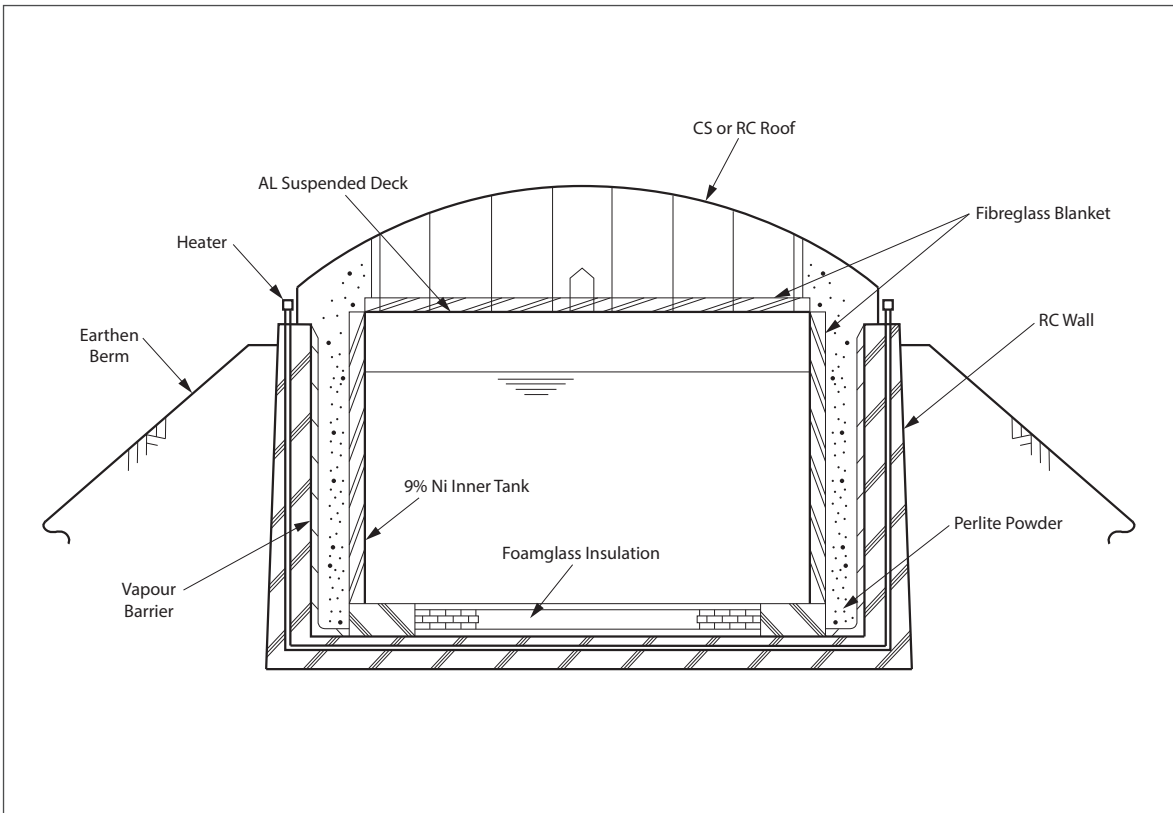


Figure 8 Typical detail of a Type 6/Type 7 above ground full containment storage tank

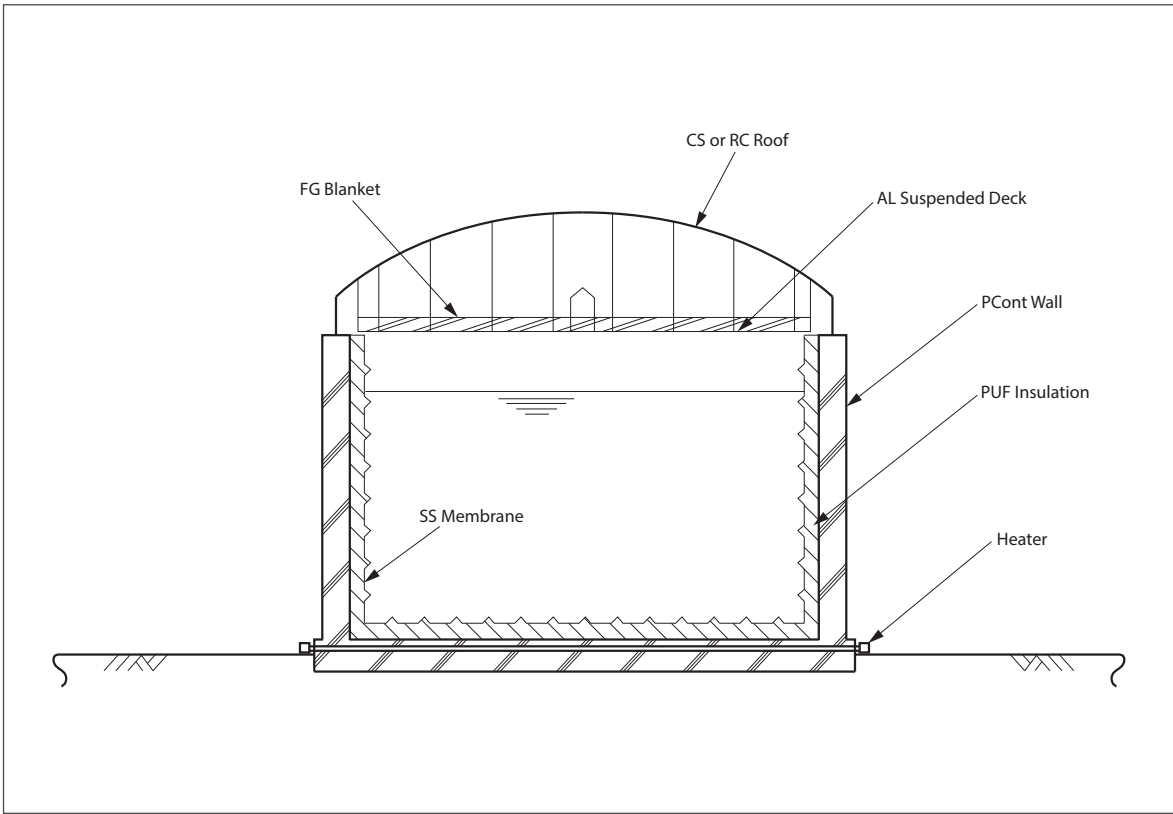


Figure 9 Typical detail of a Type 1 above ground membrane storage tank

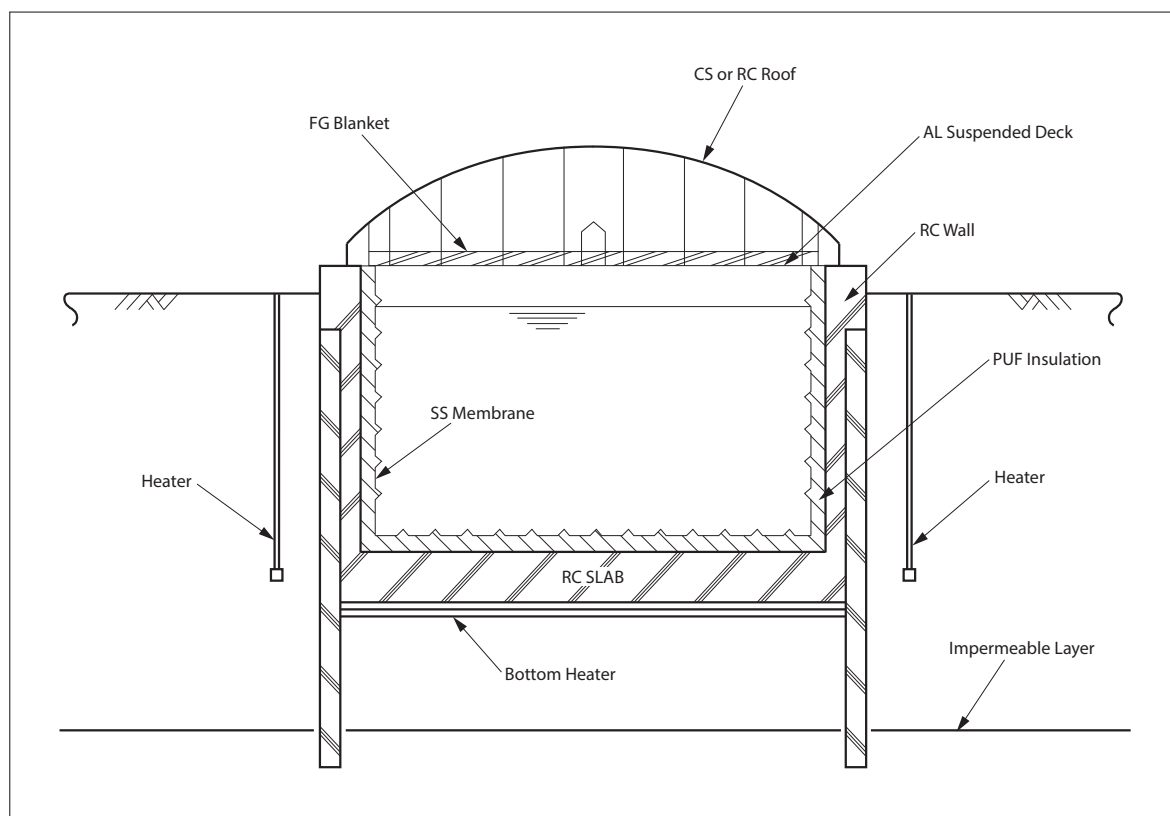


Figure 10 Typical detail of a Type 11 in-ground membrane storage tank

All such storage tanks are primarily designed and constructed to contain the refrigerated or cryogenic product under operational conditions. Tanks constructed with the steel outer roofs (whether constructed from 9% nickel steel or normal carbon steel) or steel outer tanks may not provide containment against accidental loads.

2.2 Double concrete tanks

A recent development supported by a number of civil engineering Contractors and engineering firms working in the cryogenic gas sector is the double concrete type of tank – see Figure 11. Here the 9% nickel steel inner tank is exchanged for a pre-stressed concrete inner tank. The concrete inner tank may or may not be equipped with an internal liner/liquid tight metal barrier depending on which concept was patented by the designer. At the time of this edition no European or International norms, Codes or Standards are available to provide best industry practice to guide the designer. This may lead to a weakening of

the exemplary safety record achieved by the gas industry using the existing types of storage tanks.

EEMUA Publication 207 is double concrete tank design guidelines which is the result of mutual work between its Storage Tank Committee and experts from the civil engineering and gas industries.

In the USA a civil code was published⁽²⁾ that included industry minimum design and construction requirements for concrete structures that can be exposed to cryogenic temperatures.

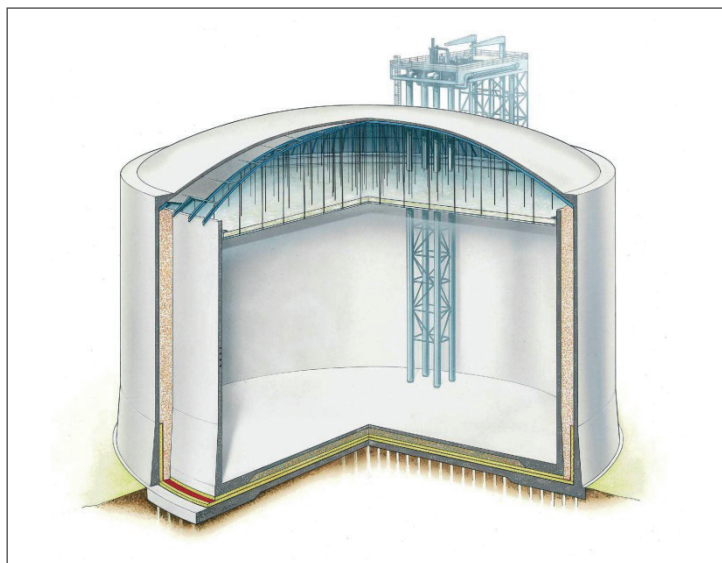


Figure 11 Artist impression of a double concrete tank with no liner

2.3 Refrigerated/cryogenic or pressurized storage

Large volumes of products that are in the gaseous phase at ambient temperature and have a flash point lower than 0°C are most economically stored at their boiling point in refrigerated or cryogenic storage. In this case storage takes place nominally at ambient pressure.

Where the volume of the stored/shipped product is small or availability of the product in the gaseous phase is required at short notice, then pressurised storage may be more economical. The re-gasification process of refrigerated and cryogenic liquids is not spontaneous.

Appendix I of EEMUA 190⁽³⁾, shown here as Figure 12, shows a decision flow chart and methodology to assist in achieving the most economical storage facility, i.e. refrigerated or pressurised storage.