POLYETHYLENE STORAGE TANKS FOR WATER AND CHEMICALS

1 SCOPE AND LIMITATIONS

1.1 Scope

This Standard specifies requirements for the design and manufacture of polyethylene storage tanks, exceeding 1900 litres that are rotationally moulded in one-piece seamless construction. The tanks are for aboveground, vertical installation and are capable of containing water, liquids used in food and beverage manufacture and chemical solutions at atmospheric pressure.

Methods for demonstrating compliance with this standard are given in Appendix A.

1.2 Objectives

The objective of this Standard is to –

(a) Ensure secure storage of water and other liquids or chemicals (see Clause 1.1);

(b) Ensure performance and workmanship of the finished tank is adequate for the intended application;

(c) Ensure fittings are suitable for the intended application; and

(d) Specify design criteria and material selection to ensure the above

1.3 Limitations

This Standard does not provide design criteria for –

(a) liquid contents heated above their flash points;

(b) liquid contents with service temperatures above -

(i) 40ºC; or

(ii) the rated service temperature of the tank material;

(c) superimposed pressure exceeding 0.25m head of water, or 2.5kPa, above the maximum recommended fill level;

(d) superimposed mechanical forces, such as seismic forces, wind load or agitation.

Where criteria in Items (a) to (d) apply, special design consideration shall be given.

A tank shall have provision for overflow of contents.

The tank material supplier shall be consulted where the anticipated service temperature of the liquid exceeds 40ºC.

Wall thickness for circular straight walled tanks may be determined by hoop stress data (see Appendix B). All other tanks shall be designed by appropriate engineering design methods. These methods may include finite element analysis (FEA).

This Standard does not apply to portable tanks for the transport of liquids.

2. REFERENCES

2.1 AS/NZS 4766: Polyethylene storage tanks for water and chemicals.

2.2 ASTM D1998-97: Standard Specification for Polyethylene Upright Storage Tanks.

2.3 ASTM D1238: Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer.

2.4 ASTM D2565: Standard Practice for Xenon Arc Exposure of Plastics Intended for Outdoor Applications.

2.5 ASTM D1693: Standard Test Method for Environmental Stress Cracking of Ethylene Plastics.

2.6 ASTM D4703: Standard Practice for Compression Moulding Thermoplastic Materials into Test Specimens, Plaques or Sheets.

2.7 ASTM D3209: Standard Test Methods for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Tup (Falling Weight).

2.8 Association of Rotational Moulders: Low Temperature Impact Test.

3. DEFINITIONS

3.1 Service Factor

3.1.1 Hydrostatic design basis

For Hydrostatic Design Basis, service factor is a number (less than 1.0) that takes into consideration all factors affecting the safe use of the tanks, which is then multiplied by the hydrostatic design basis to give the maximum design hoop stress (see Appendix B).

3.1.2 Finite Element Analysis (FEA)

For FEA, service factor is a number (greater than 1.0) that takes into consideration all factors affecting the safe use of the tanks by which the maximum permitted stress in the material is divided give the maximum design stress.

3.2 Service Temperature

The maximum expected temperature of the contents of the tank or ambient temperature, whichever is the greater (see Appendix B).

4. REQUIREMENTS

4.1 Materials

4.1.1 Base Polyethylene Material

Base Polyethylene material used shall contain anti-oxidants and UV stabilisers for the service life of the tank.

4.1.2 Polyethylene Colouring / Pigmentation

Pigments used must be compatible with the PE and should not exceed 0.4% dry blended or 1% compounded.

4.1.3 Reuse of material

Reground, recycled or reprocessed materials shall not be used under any circumstances.

4.1.4 Melt flow index (MFI)

Melt flow index of the polyethylene determined shall not deviate by more than 15% from the value nominated by the polymer manufacturer, when tested in accordance with ASTM D1238. An equivalent ISO Standard for MFI determination may by used

4.1.5 Carbon Black for UV Stability

Extruded polyethylene compounds, containing carbon black to provide UV stability, shall contain 1.5 ± 0.25% by mass of carbon black.

The average particle size of carbon black in the compound shall be less than 25 nm, and the maximum particle size shall not exceed 100 nm.

4.1.6 UV Resistance

The requirements of this Clause shall apply to base resins where base resins are UV stabilised. Where UV stabilisers are added at the final compounding stage, this Clause shall apply to powders.

The polyethylene compound shall contain UV stabilisers such that the natural compound will retain 50% tensile elongation after 8 000h of exposure in a Xenon-Arc weatherometer when tested in accordance with ASTM D2565.

4.1.7 Dispersion of additives and pigments

Anti-oxidants and UV stabilisers shall be extrusion compounded into the Polyethylene resins. Pigments shall be adequately dispersed into the PE resin so that there is no evidence of agglomeration, blotching or uneven dispersion.

4.1.8 Use of Fillers

Fillers or extenders shall not be used in the polyethylene

4.1.9 Light penetration

Pigments levels and dispersion of their potable water storage tanks shall be adequate to prevent light penetration, which will promote algae growth. The permissible amount of light that may penetrate the specimen shall be such that the total amount of light that will enter the tank over the entire exposed surface area shall be insufficient to promote algae growth in the water content of the tank.

One way to assess light penetration is to hold a cut-out up to a fluorescent light and assess if the shadow of fingers can be seen behind it.

4.1.10 Stress-cracking resistance

For chemical storage applications the polyethylene shall have a stress-cracking resistance of 500h minimum F50 with full strength test solution as given in ASTM D1693, Condition A, 100% Igepal. The test specimens shall be compression moulded as per ASTM D4703.

NOTES:

- Advice on the tendency of a chemical to cause stress cracking should be sought from the material supplier.
- The stress-cracking test is not used as an indicator of general chemical resistance of a polyethylene. The polyethylene supplier's, or moulder's, chemical-resistance chart should be referred to for information on the resistance of the polyethylene to specific chemicals or products, or testing of specific products or chemicals should be conducted.

4.1.8 Chemical Resistance

The suitability of the polyethylene base resin intended for use in chemical storage tanks shall be based on relevant chemical resistance data from base resin manufacturers. The suitability of the data shall be agreed between the base resin supplier and / or the compound supplier, the tank manufacturer and other parties, as required.

For each chemical storage tank, the manufacturer shall maintain the relevant chemical resistance data demonstrating the tanks suitability for the intended application.

NOTES:

- Due to the wide range of materials, service conditions, and chemical reagents, the suitability of a reagent to be stored in a polyethylene tank should be by agreement between the parties.
- Specimens for compatibility testing should be cut from compression-moulded plaques. If doubt exists as to the effect of the rotational moulding process (i.e. porosity), then rotationally moulded specimens may also be tested.

4.1.9 Materials in contact with drinking water and food

All materials and components used in the manufacture of tanks shall comply with the relevant food and water contact regulations, e.g FDA 21 CFR, or European regulation 2002/72/EC (as amended).

5. DESIGN

5.1 Mechanical Properties of Resin

5.1.1 Supply of material test data

Supply of material test data for design analysis should be agreed between the tank manufacturer and the raw material supplier, e.g. hoop stress data, but shall include the following:

(a) Raw Material name and Standard or Code;

(b) Short- and long-term physical properties relevant to the expected design life of the tank.

Material test data shall be derived from independently verifiable testing conducted in accordance with published standards.

NOTE: the data may be required for structural analysis.

Material properties used in design analysis shall be those for the tank resin.

5.1.2 Hydrostatic design stress

The hydrostatic design stress used to determine the minimum wall thickness at any fluid level shall be based on hoop stress data for the resin. The hoop stress data provides a hydrostatic design basis for the resin. The hydrostatic design basis shall be reduced by a service factor, to determine the actual hydrostatic design stress. The maximum service factor shall be 0.5 for wall thickness less than 9.5mm. For wall thickness equal to or greater than 9.5mm, the maximum service factor shall be 0.475. For example, if the hydrostatic design stress for the resin is 8.7 MPa, the hydrostatic design stress for a tank will be 0.475 x 8.7 = 4.1 MPa.

5.1.3 Derating

All tank hoop stress shall be derated for service above 23ºC.

NOTE: There is no generally accepted value of hoop stress.

5.2 Design Parameters

The design wall thickness shall be determined by appropriate engineering design methods, which may include finite element analysis, for the nominated service temperature. It can be calculated using the following:

The minimum required wall thickness (T) of a cylindrical straight walled shell (unsupported portion of a tank) at any fluid level shall be determined from the following equation:

$$T = \frac{P \times OD}{2\sigma}$$

Where

T = wall thickness, in millimetres

P = pressure, in megapascals ((0.0098 x SG x H)Mpa)

SG = specific gravity of fluid to be stored in the tank

H = height of fluid to be stored in the tank, in metres

OD = outside diameter of tank, in millimetres

σ = hydrostatic design stress in megapascals

Derating all tank hoop stress shall be derated for service above 23°C.

The minimum weights for specific tank sizes shall be:

2500 litre	-	40kg
5000 litre	-	75kg
10000 litre	-	180kg

The radius of the external surface bottom knuckle of a flat-bottom tank shall not be less than 15mm. The minimum thickness of the radius shall not be less than the maximum thickness of the cylinder wall. Bottom knuckles that are not a single radius shall be designed using appropriate engineering design methods, which may include finite element analysis.

Floor thickness design and installation recommendations shall be considered for tanks with fittings located in the tank floor. The tank manufacturer should supply relevant installation specifications / instructions.

5.3 Provision for overflow

Tanks shall have provision for overflow of contents, whereby the nominal diameter of the outlet shall not be smaller than the nominal diameter of the inlet.

5.4 Fittings

Fittings up to and including 50mm nominal diameter (DN), and overflows, may be installed without further structural design consideration of the tank shell.

Fittings over DN 50mm, excluding overflows, shall be designed into the tank shell by appropriate engineering methods, e.g Finite Element Analysis.

6. SPECIFIC TANK REQUIREMENTS

6.1 Dimensions

All dimensions shall be taken at the time of manufacture with the tank in the operating upright position, unfilled. Tank dimensions shall represent the exterior measurements.

6.2 Tolerances

6.2.1 Outside Dimensions

The tolerance for outside dimensions, including out of roundness, shall be ± 3% of the specified outside dimensions.

6.2.2 Tank wall and roof thickness

The average wall (side) thickness shall be the design thickness, or as given in the table below, based on eight equally spaced measurements from top to bottom.

For the roof and floor, 66% of the area must have a minimum thickness as given in the table below. The thickness of the roof must be sufficient to be able to support its own weight.

Tank Capacity	Minimum Average Wall Thickness	Minimum Thickness for 66% roof and floor
litres	**mm**	**mm**
2000	3.5	2.6
2200	3.5	2.6
2500	4.0	3.0
4500	4.6	3.5
5000	5.2	3.9
10000	6.5	5.0

Wall, roof and floor thickness shall be measured by ultrasonic equipment capable of measuring to an accuracy of 0.1mm.

6.3 Tank Capacity

The tank capacity shall not be less than the stated capacity. The tank capacity shall be the internal volume calculated with the tank in the vertical position and unfilled. The height of the tank shall be from the base to the invert level of the overflow of the tank.

Alternatively, the tank capacity may be determined by filling the tank with water and measuring the quantity to fill the tank to the invert level of the overflow.

NOTE: The useable volume in a storage tank will be dependent on the placement of the outlet.

6.4 Workmanship

At the time of manufacture, the finished tank surface shall be free, as practicable, from visual defects such as foreign inclusions, air bubbles, pinholes, crazing and cracking that will impair the serviceability of the vessel.

The surfaces shall be smooth, have a homogeneous appearance, and be free of any loose powder particles, and no obvious overcure, e.g. High gloss and discolouration on the inside surface.

NOTE: Due to differences in resins and in moulding conditions, the interior surface characteristics may vary.

Internal mould air temperature monitoring traces will be considered as a quality control record. These should be kept for at least as long as the warranty of the tank.

7. SPECIFIC REQUIREMENTS FOR FITTINGS

The suitability of fabricated nozzles, gaskets and other fitting accessories intended for use in chemical tanks shall be based on chemical resistance charts, or advice obtained from the fitting supplier, and shall be chemically compatible with the materials to be stored in the tanks.

The size, location and specification of inspection / access openings and fittings shall be agreed upon between the purchaser and the manufacturer.

NOTE: Manholes are typically located in the roof.

8. PACKING AND MARKING

8.1 Handling, storage and packing

Handling, storage and packaging of the tanks prior to dispatch shall be carried out in a manner that ensures the performance and workmanship requirements of this Standard are complied with.

8.2 Marking Requirements

The tank shall be legibly and permanently marked with the following information:

(a) Manufacturer's name or registered trademark

(b) Tank capacity, based on the fluid level used in the design criteria

(c) Maximum specific gravity of contents of tank (for non water tanks).

(d) Day, month and year of manufacturer.

(e) Number of Standard

9. SAMPLING AND COMPLIANCE WITH THE SPECIFICATION

NOTE: The use of processing data, such as internal air temperature measurements will be useful in proving consistentcy of tank manufacture.

For the purposes of this standard a batch shall be defined as:

For tanks greater than 5000 litres, a batch shall be one days production. For tanks less than or equal to 5000 litres, a batch shall be up to 10 tanks rotationally moulded using the same machine, from the same type, quality and levels of raw materials, including base resin and addtives (excluding pigments), in the form of powdered compounded material which have undergone similar processing conditions in their production to impart similar physical and chemical properties.

9.1 Sampling and testing

The minimum sampling and testing frequency is given in the table below.

Characteristic	Clause	Requirement	Test Method	Frequency
TYPE TESTS (TT) – TANKS				
Material Properties	4.1.4	MFI	ASTM D1238	Upon change of base resin
	4.1.9	Stress-cracking resistance	ASTM D1693 Condition A, ASTM D4703	Upon change of base resin
	4.1.5	Mass of carbon black – as UV Stabiliser	ISO 6964	Upon change of material including black carbon
		Carbon black particle size	ASTM D3849	Upon change of material including carbon black
	4.1.7	Dispersion of additives and pigments	ISO 18553	Upon change of base resin
	4.1.6	UV Resistance	ASTM 2565	Upon change of base resin, UV additive
	4.1.10	Chemical resistance	Chemical resistance data, or when specified, ASTM D543, ASTM D638	Upon change of base resin, UV additive
	4.1.11	Materials in contact with drinking water or food	FDA 21 CFR, 2002/72/EC or other applicable standards	Upon change of tank material
	5.1	Material test data	As supplied by base resin manufacturers	Upon change of compound resin
Dimensions	6	Tank capacity not less than stated capacity	Measurement and calculation	Upon change of dimensions
TYPE TESTS (TT) – FITTINGS				
Material Properties	4.1.11	Materials in contact with drinking water or food	FDA 21 CFR, 2002/72/EC or other applicable standards	Upon change of fitting material
BATCH RELEASE TESTS (BRT) – TANKS				
Workmanship	6.4	Free of defects	Visual Inspection	Each Tank

Moulding process evaluation	9	Impact strength	Measurement	Each Tank >5 000 litres and every 1st and 10th tank otherwise
Dimensions	6	Wall thickness, roof, floor, tolerances	Measurement	Each Tank >5 000 litres and every 1st and 10th tank otherwise 20 measurements distributed over the surface of the tank
Marking Requirements Handling, storage and Packaging	8.2 8.1	Marking Requirements No damage causing a tank not to comply with the performance and workmanship requirements	Visual Inspection Visual Inspection	Each Tank Each Tank
	4.1.8	Light Penetration	Visual Inspection	Each Tank

9.2 Batch release

A tank or batch or tanks can be deemed to have meet the requirements of the ARMSA Tank Standard if it has passed the batch release test.

10. METHODS OF TEST

10.1 Low temperature impact testing

10.1.1 Test Overview

There are two parts to the low temperature impact test which can be used. The first is a quantitative assessment of the rotomoulded tank, which gives a numerical impact strength of the part. A test mould can be used to produce a moulding at the same time as a tank, as long it is made using the same material as the tank mould, and the part is of the same thickness and construction. This should be carried out at least quarterly. The second works on a pass / fail basis but can only be done once a quantitative measurement has been carried out.

Samples are conditioned at -20°C, and then placed, inside surface down in the sample holder and immediately impact with a dart of specified weight and tip radius from a prescribed height. The sample is then inspected for failure on both sides. There are two types of failure:

a. Brittle failure, where the sample physically breaks or cracks at the point of impact. The sample has very little elongation

b. Ductile failure, where the dart makes a hole in the sample, and the material elongates or thins at the point of failure.

10.2 Low temperature impact test (quantitative)

10.2.1 Test specimens:

Cut at least ten specimens measuring at least 10cm by 10cm to fit into the specimen holder on the test apparatus. Label each one with a permanent maker and measure the thickness in the centre.

10.2.2 Conditioning

Test specimens shall be cooled in air at ambient temperature for 24 hours from the time of manufacture. For the testing they need to be conditioned at -20°C for at least one hour.

10.2.3 Apparatus

a) **Dart impact rig** as described in either ASTM D3029, or the ARM low temperature impact method.

b) **Freezer** capable of conditioning samples at -20°C

c) **Thickness gauge** to measure sample thickness

10.2.4 Procedure

Follow the procedure as given in either ASTM D3029, or the ARM low temperature impact test.

10.2.5 Minimum Impact Strength

Impact strength is calculated by the following:

Impact energy = height (in metres) x Dart weight (in kg) x Gravity (9.81m/s)
Impact strength = Impact energy / average sample thickness (in mm)

The minimum impact results for given wall thicknesses are given in the table below.

Wall Thickness	**Minimum impact energy**	**Minimum impact strength**
mm	**J**	**J/mm**
3	45	15
4	72	18
5	95	19
6	1210	20
7	147	21
8	168	21
> 8	> 168	> 22

10.2.6 Reporting

The following information shall be reported.

a) Identification of the tank

b) Date of test

c) Weight used

d) Number of failures (brittle and ductile)

e) Impact energy or impact strength

f) Batch numbers of raw materials used.

10.3 Low temperature impact test (quantitative)

10.3.1 Test overview

This method of testing can only be carried out once a quantitative test has been done so that the appropriate drop height can be calculated. This is a once off test for a tank, using a pass or fail basis.

10.3.2 Test specimens

Round samples are cut from either the inlet or outlet or the tank using an appropriate device. Do not use a hole saw as this leaves a hole through the centre of the sample, which has to be continuous.

10.3.3 Procedure

The same apparatus is used as for the quantitative testing. From the quantitative result, and using the impact energy value, calculate the height at which the dart should be dropped. This is given by the formula:

Height = Impact energy / (weight x 9.81)

Place the conditioned sample in a modified holder and drop the weight from the calculated height. Assess the sample to see if it passed or failed.

10.3.4 Reporting

The following information shall be reported.

a) Identification of the tank

b) Date of test

c) Pass or fail

d) Failure mode (brittle or ductile)

e) Batch numbers of raw materials used