BALMORAL TANKS

CYLINDRICAL STEEL TANK STANDARD SPECIFICATION

UK Designed and manufactured

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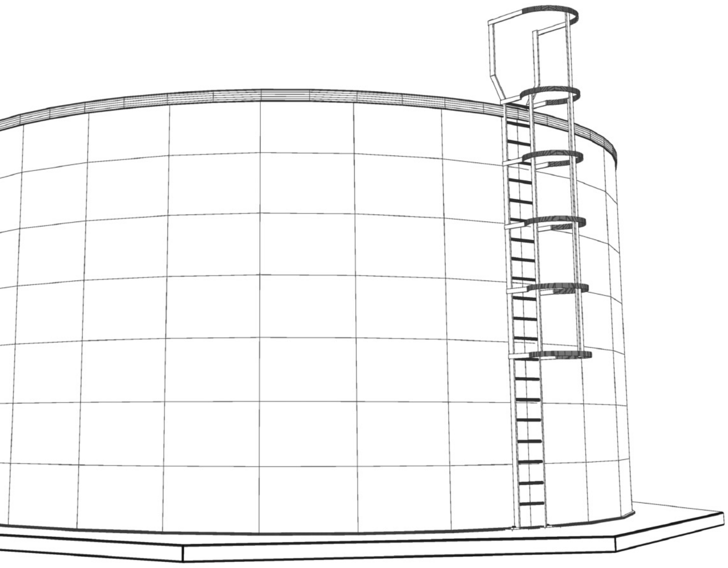

Balmoral Tanks

Balmoral Tanks specialises in the design and manufacture of GRP, steel sectional and galvanized cylindrical steel bolted liquid storage tanks. These tanks are primarily used for the storage of water in the potable water, fire sprinkler and irrigation markets.

The galvanized cylindrical tanks are site assembled using overlapping and bolted galvanized steel panels that are manufactured within the company's facility in the UK.

Depending upon the application or design code, a choice of either a synthetic rubber membrane liner or mastic is used to seal the tank together with a plastic coated trough deck roof cover.

These galvanized tanks provide an economical, reliable and low maintenance solution for water storage.

Experience gained through the supply of over 5000 tanks worldwide and our ISO 9001:2008 accreditation ensures consistent quality of product and service for the design, manufacture and installation of liquid storage tanks.

Scope

This document has been written to provide relevant information for cylindrical galvanized water storage tanks designed and manufactured by Balmoral Tanks.

These modular site bolted storage tanks are manufactured from galvanized steel panels and sealed using either internal synthetic rubber membrane liner or flexible mastic.

The tanks are typically used for:
- *Potable water storage*
- *Fire water storage*
- *Irrigation water storage*

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1 Tank overview

The tank shell is constructed from galvanized steel panels that are bolted together using bolts, nuts and washers. Panels are bolted together in a defined configuration with the thicker panels at the bottom of the tank where the liquid pressure increases.

Externally fixed rolled angles are provided as a means of securing the shell to the foundation, a means of fixing the roof to the shell and to provide additional shell stiffening as required.

The tank shell is sealed using either an internal synthetic rubber membrane liner or mastic seal between the overlapping plates.

A corrugated deck roof cover, ladder, platform, pipe-work and other accessories are supplied to meet specific requirements.

Tank panels and components can also be epoxy coated to meet particular aesthetic site requirements.

2 Tank design and key components

2.1 General design philosophy

Tanks are designed using the following criteria unless otherwise agreed:

- *Tank shell is designed to accommodate full hydraulic load minus the free-board*
- *Wind speed of 45 m/s (tank empty)*
- *Non seismic*
- *Live/roof load of 0.75kN/m*

2.2 Tank panels

Standard tank panels are manufactured from a pre-galvanized steel sheet, maximum thickness 5mm, with approximate overall dimensions of 2530mm, 2580mm or 2630mm long, dependent upon vertical bolt patterns, and approximately 1250mm high dependent on the sheet and tank shell design. 6mm, 8mm and 10mm tank panels must be manufactured in mild steel to standard EN10025.

Depending upon the galvanizing thickness required (see Balmoral Tanks Galvanized Information in separate document) the panel material will conform to the following standards:

- BS EN10327 pre-galvanized coating – 300g/m^2. *Standard thicknesses are 2mm, 2.5mm, 3mm, 4mm, 5mm. Sheets requirements above 5mm must use hot dipped galvanized material*
- BS EN10025 c/w hot dipped galvanized coating – 600g/m^2 to BS EN 1461. *Standard thicknesses are 2.5mm, 3mm, 4mm, 5mm, 6mm, 8mm and 10mm*

2.3 Top and bottom rolled angle

The top and bottom of every tank shell is fitted with a steel angle ring that is rolled to the specific diameter of the tank. The top angle ring stiffens and maintains the concentricity of the shell as well as creating fixing points for the roof sheeting. The bottom angle ring provides a section that can be fixed to the foundation, thus securing the tank shell to the concrete base.

The cross-section of the angles is 60x60x6mm and is supplied in lengths of 2420mm. Every angle is rolled, "toe-out", to suit the tank shell diameter. The vertical or rolled face of each angle has fixing holes to match the bolt pitch of the standard shell panel.

The horizontal or flat face of each bottom angle has slots to suit the appropriate size and number of hold-down bolts.

The angles are bolted to the tank shell through the horizontal seams and are positioned to miss the vertical bolt seams of the shell hoop. Splice angles strengthen the joint between the angles and create a complete ring. The top angle ring is secured with the horizontal face above the fixings of the top horizontal bolt seam.

The bottom angle ring is secured with the horizontal face below the fixing of the bottom horizontal bolt seam.

2.4 Wind stiffening angles

Any wind stiffening requirements are fulfilled by a galvanized leaf truss ring.

The size of leaf truss for any given stiffening ring is dictated by the stiffness requirement. The standard leaf truss depth is 80mm, however in some areas of high wind loading, leaf truss sizes can increase in both thickness and depth.

The leaf truss components link together as they wrap around the shell to create a solid stiffening ring, secured directly to the horizontal tank seam with a single bolt. Each sheet in a course requires five leaf truss sections and are designed to be fitted around other components.

2.5 Shell fixing

The tank is secured to the foundation with fixings that are located externally around the circumference of the tank shell.

The bottom angle is secured with either expanding mechanical anchors or chemically fixed anchors. Depending on the size of the tank and the wind loading overturning moment, the anchors will be either M12 and pass through the bottom angle, or M16 or larger and pass through clamping brackets. A minimum of two anchors per angle are fitted.

The anchor fixings have a Design Load = 0.6 x Minimum Specified Yield Strength. The magnitude of lifting force due to wind loading, and therefore the anchor fixing selection, can be determined from the following formula:

$$\text{Bolt design load} = \frac{4 \times \text{Overturning moment}}{\text{Diameter} \times (2\text{xSheets in hoop})} - \frac{\text{Total shell weight}}{(2\text{xPanels in hoop}}$$

2.6 Freeboard

A space between the top of the tank and top of the overflow assembly is created to account for slight variations in liquid level and sloshing that can occur from the filling process. This space is called the "Freeboard" and is set to a minimum of 150mm with greater allowances being made for larger tanks that may have an increased sloshing affect.

The freeboard may need to be further increased to comply with certain national standards, ie, Loss Prevention Certification Board's LPS 1276 approval standard requires "a minimum 50mm space between the maximum liquid level and the lowest section of the roof structure".

2.7 Dead water

Water can only be pumped out of the tank whilst the outlet is submerged. Dead water is the volume of water between the floor of the tank and the bottom of the suction arrangement.

2.8 Tank capacity

Tank shells are designed to withstand hydraulic pressures created by the contained volume of water.
The Effective Capacity is the usable volume of liquid within the tank.

Freeboard and dead water volumes must be subtracted from the wall height volume to gain the effective capacity.

The Effective Capacity in cubic metres is calculated as follows:

$$\pi/4 \times (\textit{Diameter(m)})^2 \times (\textit{Wall Height(m) - Freeboard(m) - Deadwater(m)})$$

2.9 Tank loads and stresses

The tank panels are overlapped and bolted along vertical and horizontal seams. Bolt pitches are spaced to optimise material and bolt yield whilst maintaining the required seal. The vertical seams are designed to withstand all hoop stresses caused by the static head of the contents. The horizontal seams are designed to withstand all vertical loads that are imposed on the shell.

The hoop stress that is caused by the static load of the contents is greater at the bottom of the tank, ie, the greater the depth of liquid, the greater the head of pressure. Where the hoop stresses increase beyond allowable levels, tank plate thicknesses increase as required. As plates thicken, the quantity of bolts within a seam pattern increases to disperse bearing stress on the shell material and shear stress on the bolts.

Vertical loads imposed on the shell are those transferred from the tank roof and the specified roof load. As with hoop stresses vertical loads are greatest at the bottom of the tank. A combination of the roof loads and tank shell weight must be dispersed through the horizontal bolt seam at the base of the tank. When vertical loads increase beyond allowable levels, a close horizontal bolt pitch will be used to reduce bearing and shear stresses.

4-nib bolts are used to fasten panels in the construction of the tank shell. The bolt Design Shear Stresses = 0.25 x Ultimate Tensile Strengths, which range from 510 to 1035 MPa and are used as the shear values require.

As required, additional strength is added in the form of wind stiffening angles to prevent the shell buckling. The angles are fixed around the outside of the tank on a horizontal bolt seam to create a complete stiffening ring. A wind speed of 45m/s is used unless otherwise stated. The analysis of wind stiffening requirements is on a tank by tank basis.

Under certain wind conditions there may be an overturning moment on the tank shell. This moment, is calculated at the base of the tank shell with appropriate anchor fixings being supplied to secure the shell to the foundation.

2.10 Foundations

The design of the concrete foundation is project and location specific and therefore does not form part of the tank supply for this specification. Normally the responsibility of others, the following guideline may assist with third party design.

The ground bearing pressure must be adequate across the whole area of the foundation to support the weight of the tank contents.

This load can be calculated as follows:

Tank wall height (m) x 9.81 x SG = kN/m²

There is also a non-uniform vertical load transferred through the bottom angle. This load is the sum of the tank shell weight (kN), the roof weight (kN) and the roof snow load (kN/m²). The total circumferential force is calculated as follows:

$$\frac{\text{Tank weight} + \text{Roof weight} + (\pi/4 \times \text{Diameter}^2 \times \text{Snow load})}{(\pi \times \text{Diameter})} = \text{kN/m}$$

When designing the foundation, these loads will need to be considered. However, on small tanks, the circumferentially dispersed vertical loads will be insignificant when compared to the weight of the contents.

The distance from the outside circumference of the tank to the edge of the foundation must be at least 300mm. If the tank is to be constructed with external jack lifting equipment a larger foundation will be needed to accommodate the jacks.

The finished foundation should be raised above the grade by approximately 150mm

2.11 Tank sealing

The tank shell is sealed using either an internally fitted synthetic BUTYL or EPDM rubber membrane liner. Alternatively, a polyurethane gun grade mastic that is applied between the panels together with an internal “seal-pour” of concrete on the base which is generally 150mm deep.

2.11.1 Mastic

A grey polyurethane sealant which has been designed specifically for sealing galvanized bolted tanks is applied between the overlapping panel areas.

The panels are subsequently bolted together and as the mastic cures a watertight seal is formed. A bead of mastic is also applied around the internal circumference of the base of the tank and this together with layer of concrete (seal-pour) provides the sealing mechanism.

Storage conditions and expiration dates need to be observed to ensure that the product will perform to expectations. Typically the product should not be stored above 20º C.

2.11.2 Liner

A synthetic rubber bag shaped membrane (liner) closely matching the internal dimensions of the tank is fixed to the top angle/panels.

Liner protection is provided by geo-textile or felt matting with a density of 250g/m³ which is placed on the base and approximately 300mm up the internal tank wall.

In addition all vertical and horizontal seams are covered with protective 375 micron self-closing polythene tape to protect the liner from possible damage/puncture.

A butyl synthetic rubber WRAS liner approved for use/contact with potable water with a nominal thickness of 1.0mm is used in potable water applications.

An EPDM synthetic rubber liner with a nominal thickness of 1.0mm is used in fire sprinkler and irrigation water tanks.

2.12 Trough deck roof

The tank roof is a rain, debris and light restricting cover that is designed to withstand both wind and snow loadings. The cover is not designed for foot traffic.

Two roof loadings are currently manufactured as standard, Light Duty (0.75kN/m²) and Heavy (1.8kN/m²). Both roofs withstand 45m/s wind speeds. Other roof loadings are available on request.

Light duty

The light duty trough deck roof is a free-span design that can be used on tanks up to a diameter of 18.6m. It consists of a framework of a “Z” and “C” section purlins and cellular beams. Depending on the tank diameter these items are used in various configurations to create a debris cover that can withstand snow loads of up to 0.75kN/m². The light duty framework is covered with 200 micron PVC coated mild steel, corrugated decking sheets.

Heavy duty

The heavy duty trough deck roof is also a free-span design that can be used on tanks up to a diameter of 12.4m. The design also uses “Z” and “C” section purlins and cellular beams. However, the roof can withstand snow loads of up to 1.8kN/m². The heavy duty framework is covered with pre-insulated roof decking sheets.

Column supported
For light duty roofs above 18.6m and heavy duty roofs above 12.4m a column supported trough deck roof is used. It is constructed from a framework of beams and "Z" and "C" section purlins that have columns to take the vertical load. The framework can then be covered with either light or heavy duty decking sheets, depending on the application.

2.13 Access ladders and platforms

Ladders and platforms, with an intermediate rest platform if required, are designed to meet local/national standards and specific tank specifications.

Ladders are manufactured from either aluminium or galvanised steel depending on requirements.

Normal practice is to include a 2.4m long removable "hook-on" ladder that can be removed from the bottom of the fixed ladder to prevent unauthorised access.

3 Standard tank accessories

3.1 Immersion heater

Dependent upon local climatic conditions and any risk of freezing, an electrical immersion heater may need to be installed beneath the mechanical in-fill valve to prevent the water freezing in the vicinity of the ball float valve assembly.

To meet the requirements of LPCB, immersion heater model RS102 is supplied.

3.2 Contents gauge

The contents gauge provides an easy means of determining the head of water within the tank and is fixed to a panel on the second ring of the tank wall. The gauge can be supplied complete with a brass no-loss connector which enables the gauge to be removed from the tank without loss of water.

Specification

Dial size	*150mm*
Sensing element	*Bourdon tube altitude type*
Wetted parts	*Brass/bronze*
Mounting	*Direct – back connection*
Case material	*Steel enamel black finish*
Bezel material	*Brass*
Connection size	[illegible]*" BSP*

3.3 Vortex inhibitor

A vortex inhibitor is used to prevent a vortex being formed within the pump suction pipe and thus preventing loss of flow and potential damage to the suction pumps. This is particularly critical in fire sprinkler tank applications.

- *For LPCB tanks an approved vortex inhibitor is fitted*
- *A galvanized steel vortex plate or GRP vortex inhibitor is supplied for all non-LPCB and FM approved tanks*

3.4 Equilibrium ball float valve

A ball float valve can be supplied to control the inflow and maximum volume of water contained within the tank. The valve is easily connected to the back plate attached to the ball valve housing. Valves from 50–300mm are available.

3.5 Ball valve chamber

Ball valve chamber is available to accommodate the equilibrium ball valve.

3.6 Flanges/Connections/Suctions/Brackets

A variety of pipe connection components are available to ensure efficient connection to third party pipework. They are normally galvanized but can also be epoxy coated. These include:

- *Drain connection*
- *Overflow arrangement*
- *Suction elbow connection*

3.7 Tank connections and fittings

The majority of connection openings for the tank are made on site. Openings are cut and/or drilled to suit site specific requirements but **connections should not cross a tank seam.**

Once the position of the connection has been determined the tank panel is cut to suit the outside diameter of the connecting pipe and holes drilled to match the bolting configuration of the connecting flanges.

For liner sealed tanks the liner is cut in the same manner.

A rubber gasket is fitted to both the inner and outer surface of the tank shell opening to provide a seal between mating surfaces.

Bolts are sealed using either mastic or approved sealing compound.

4 Galvanizing

4.1 Tank panels

Dependent upon the design code and/or the panel thickness, the panels will be galvanized to one of the following standards:

BS EN ISO 1461

- *Hot dip process*
- *Average 600g/m² galvanizing weight per side*
- *Panel thicknesses of 5mm to 10mm*

EN 10327 Z600

- *Mill galvanized*
- *Minimum 300g/m² galvanizing weight per side*
- *Panel thicknesses of 2mm to 5mm*

4.2 Surface finish

Panels that are galvanized to EN 10327 Z600 have a consistent bright shiny finish and are predominately used on tanks that are fitted with a liner.

Panels that require a hot dip galvanizing process will generally have a dull/variable finish which differs significantly from the mill galvanized finish.

Freshly galvanized steel progresses through a natural weathering process and the surface of the product will change and/or potentially be variable dependent upon the environmental and storage conditions to which the product is subjected.

4.3 Storage of galvanized panels

It is important that galvanized panels are handled and stored properly so that the aesthetic finish is maintained.

Adequate ventilation must be provided so that the build-up and retention of excessive water on the surface of the galvanized panels is avoided in order to limit the formation of surface staining.

5 Epoxy and polyester coatings

Galvanized tank panels and ancillary connections can be either epoxy or polyester coated to meet specific requirements, ie:

- *Potable water specification*
- *Colour match other site equipment*
- *Offer extended warranty*

6 Rubber tank liners

6.1 General

LPCB (Loss Prevention Certification Board) and FM (Factory Mutual) approved fire sprinkler tanks as manufactured by Balmoral Tanks incorporating a rubber liner that is manufactured from material generally known as EPDM.

WRAS (Water Regulations Advisory Scheme) approved potable water tanks as manufactured by Balmoral Tanks incorporating a rubber liner that is manufactured from material generally known as butyl. This material is a WRAS approved for use with potable water.

A butyl rubber liner manufactured from material that has received WRAS approval (BS6920) and is listed by the Water Byelaws Scheme as approved for use in contact with potable water is available for lining potable water tanks.

6.2 Material

EPDM and butyl are flexible synthetic rubber membranes that are respectively ideal materials for lining fire sprinkler tanks or potable water tanks. The sheeting provides a completely waterproof seal due its closely packed molecular structure making it extremely resistant to the transmission of liquids or vapour.

Both EPDM and butyl have outstanding ageing and weather-resistant properties. Their cross-linked molecular structure gives excellent ageing over a long period of time even when exposed to the atmosphere, sunlight, ultraviolet radiation and ozone. Strength and elasticity remains virtually unchanged over many years, without shrinking, hardening or cracking.

Refer to material specifications for further information related to the liner material.

6.3 Liner specification

Liner Material	1.0 mm EDPM or 1.0 mm butyl
Scrim reinforcement	1.5 mm thick reinforced EDPM/ butyl 100mm wide material Type 2 design, installed at the top of the liner
Eyelets	Brass type number 4 126 mm centres Fitted circ 40 mm from top of reinforcement scrim
Dimensions	Generally +50mm over tank dia and +100mm over tank height

6.4 Handling

Due to its high degree of flexibility, damage by rough handling is minimised, and the material readily adapts to surface irregularities. The material has excellent resistance to abrasive wear, tearing, flex-cracking and puncturing. However, it may be damaged by sharp tools, knives, etc, and it is recommended that clean rubber soled footwear is used when installing or inspecting rubber liners.

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A protective underlay, normally a geo-textile or felt material is always supplied and must be fitted on the tank base for extra protection against puncturing prior to installation of the liner. Strips of PVC material or similar should be used to cover the bolts securing the tank panels or other areas to prevent damage to the liner. As an option a full geo-textile or felt liner can be supplied.

6.5 Storage of tank liners

It is advisable to use the liners as soon as possible after they have been manufactured, as over a period of time the liner will develop creases. However, these creases are not permanent as the material has elasticity and memory which means that the main material will return to its original state.

The only exception to this is the reinforced band at the top of the liner which, by its nature, does not have memory due to the reinforcing scrim within the material. However, problems are minimised due to the combination of the high tear strength of the scrim, and large number of fixing eyelets assist in pulling the reinforcing scrim back into shape.

The following guidelines should be followed when storing the liner:

- *Liner is best stored indoors at ambient conditions*
- *The liner is normally supplied in a layer of geotextile matting, strapped on a pallet and shrink-wrapped for extra protection*
- *Additional protective crating can be supplied on request*
- *Do not stack items on top of the liner or immediately adjacent to it, even when it is in its packaging, as there is always the chance that a sharp item could puncture the liner. If in doubt provide additional protection*
- *Liner should not be moved around excessively as this creates a chance of the liner being damaged*

6.6 Repair

Although EPDM and butyl rubber liners are extremely tough and resistant to puncture, damage can occur. A repair can be carried out simply, quickly and economically on site. In most cases a repair using a heat/pressure process, similar to that used by the manufacturer, is utilised.

Refer to the "Liner tank assembly guide" for further information. Repair kits are available from Balmoral Tanks upon request.

6.7 Installation

Refer to the "Liner tank assembly guide" for installation instructions.

7 Liner repair

For punctures that are not immediately visible they can be located using a bright light placed on one side of the liner and viewed from the other - two people will be required for this.

Once the puncture has been located it should be marked so that a repair can be affected using a Stickseal patch.

Stickseal patches should only be used on flat supported areas where tensile stresses to the liner are minimal. It should not be used to repair a damaged liner that is likely to be folded or creased. If this is unavoidable the liner must be repositioned to ensure the repaired area is laid flat and free from folds.

7.1 Instructions for use

Normally the damage is a small puncture but if the damage is more extensive then ensure the damaged area is free from any jagged edges that are likely to continue tearing if any stress is applied. This is achieved by rounding off likely edges/tears with a sharp pair of scissors.

Clean the liner around the damaged area and at least 200mm beyond with a scouring pad and clean water. If the liner is older than five years then use a wire brush to reveal fresh membrane.

Ensure the cleaned area is completely dry by carefully heating the damaged area with a hot air gun.

Prepare a Stickseal patch making sure that the patch overlaps the damaged area by a minimum of 100mm on all sides. Also ensure that the corners of the patch are rounded to prevent uplift when applied.

Position the prepared patch centrally over the damaged area then, working from the centre outwards, apply the patch to the membrane using a suitable 40/50mm roller. Roll flat with an outward motion until the entire patch has been applied.

To prevent uplift of the Stickseal edge apply a 1cm bead of 5590 Lapseal sealant to the entire edge of the patch ensuring the bead overlaps the membrane and patch equally and to a depth of 4mm. This will protect the tacky exposed Stickseal edge from contamination and uplift and provide a secondary seal between the membrane and Stickseal patch.

Leave for a minimum of one hour for the Stickseal to harden before submersing in water.

8 Liner material specification: wras approved butyl

Physical properties	Unit	Requirements	Test Methods
Hardness	IRH	65±5	BS 903 A26
Modulus at 300% elongation	Mpa	min 4,5	BS 903 A2
Tensile strength	Mpa	min 9,0	BS 903 A2
Elongation at break	%	min 350	BS 903 A2
Tear strength	kN/m	min 23	BS 903 A3 C
Properties after aging	-	168h/121 C	BS 903 A19
Tensile strength	Mpa	min 7,5	BS 903 A2
Elongation at break	%	min 300	BS 903 A2
Ozone resistance 96h/30 C	-	No Cracks	BS903 A43
50 pphm and 80% elongation	-	max –30	BS 903 A25

Additional requirements

UK Approvals	Water byelaws scheme, approval to BS 6920 Test report M010093, List No 5044.
Thickness	Nominal ± 10%

9 Liner material specification: epdm

Physical properties	Unit	Req/typical	Value	Test Methods
Hardness	IRH	65 ± 5	65	BS903 A26
Modulus at 300% elongation	Mpa	5,0	6,9	BS 903 A2
Tensile strength	Mpa	min 9,0	10,1	BS 903 A2
Elongation at break	%	min 300	405	BS 903 A2
Tear strength	kN/m	min 30	37	BS 903 A3C
Properties after ageing	ºC		168/121	BS 903 A19
Tensile strength	Mpa	min 7,5	9,7	BS 903 A2
Elongation at break	%	min 300	345	BS 903 A2
Brittle point	ºC	max. –40	-53	BS 903 A25

Additional Requirements

Approvals	DIN 7864 part. 1 1984, Swedish Type Approval No 2224/82.
Thickness	Nominal ±10%

10 Effect of chlorinated water on butyl and epdm liners

10.1 Background

Butyl and EPDM liners have been used in water storage tanks since the mid 60's, and have a proven record of long service life.

However, to ensure maximum service life special attention must be given to the use of chlorines for sterilisation of the water.

10.2 Chlorine: basic information

Chlorine is very poisonous and will cause death even at low concentrations.

Chlorine is a very reactive oxidizing agent, which will react instantly with almost anything organic and most inorganic materials. Of the elements within the periodic system only Fluorine is more reactive. It is because of this powerful oxidizing property that chlorine is such an effective sterilizing agent. It is important to understand, however, that chlorine will react not only with the chemicals in water, but also with any organic material in the tank. Butyl and EPDM liners are such organic materials.

Chemically, chlorine is a halogen, and always wants to add an electron to its outer electron shell. This electron must be taken from another material, with which the chlorine reacts.

The chlorine dosed in water will always, when correctly dosed, initially react with materials in the water then with the materials in contact with the water, such as a liner, and the surplus volume of chlorine will evaporate from the water into the air as a poisonous gas.
At an ideal chlorine dosing level, the chlorine is completely consumed or neutralised by sterilising the bacteria and micro-organisms in the water. If the chlorine is not fully consumed by the water, the remaining chlorine will continue to react with the liners, reducing their life, until it is fully consumed or evaporated into the air.

10.3 Factors which influence liner degradation

As stated above, chlorine is extremely reactive and will react with all materials. However, four factors significantly influence the degree of attack on the liner material:

10.3.1 Concentration of chlorine

Linear relation.

10.3.2 Time exposure to chlorine

Linear relation.

10.3.3 Temperature

As a rule of thumb, a 10°C increase in temperature will double the effect of chlorine.

10.3.4 Liner installation quality

Folds and tensions in the installed liner will reduce life time, as folds will be the point of chlorine attack.

10.3.5 Liner resistance to chlorine

All flexible liners will be attacked by chlorine but those produced from fluorocarbon rubbers, fluor silicones and PTFE will a have "fair" resistance. However, these types of products are not commercially available and are significantly more expensive than butyl or EPDM.

Butyl and EPDM are considered "non-resistant" and butyl is rated as better than EPDM as butyl remains more flexible under chlorine attack and has extremely low gas permeability (chlorine is a gas). The maximum allowable chlorine concentration on Butyl and EPDM is 0.2ppm.

11 Hot dip galvanized sheet quality

11.1 Quality assurance

Balmoral Tanks insists upon the highest quality standards from its suppliers, who are required to process work to BS EN ISO 1461 standards. The requirements of these standards ensure that the zinc coating is continuous and of the required thickness together with an acceptable aesthetic appearance.

Quality assurance for the industry has been enhanced by the introduction of the BS EN ISO 9000 series of standards – 'Quality Systems' and where possible Balmoral's suppliers are accredited to this standard.

11.2 Coating weight or thickness measurement

The nature of the galvanizing process ensures that, in most cases, if the coating has formed, it will automatically be of sufficient weight to meet the requirements of BS EN ISO 1461. There are a number of inspection techniques which can be used when necessary.

11.3 Coating finish

The table below summarises variations in finish which may be observed and whether or not they are acceptable. The acceptability of the coating is, however, judged primarily on its long-term performance and corrosion resistance.

11.3.1 Galvanized finish

Appearance	Acceptability of protection (Not necessarily of appearance)
Dull grey coating (All alloy, no free zinc)	Acceptable
Cracking in pooled zinc	Acceptable
Rust stains	Not acceptable
General roughness	Acceptable within Balmoral standard
Lumpiness and runs	Acceptable within Balmoral standard
Pimples	Acceptable within Balmoral standard
Bulky white deposit (wet storage stain)	Acceptable (provided coating weight remains in compliance with BS EN ISO 1461)
Flux staining	Not acceptable
Bare spots	Not acceptable

11.3.2 Dull grey or dark grey coating

Silicon is sometimes added to steel as a de-oxidant during production and this speeds up the reaction between the steel and the molten zinc. When the galvanized article is removed from the bath, but still remains hot, the reaction may continue and convert all or part of the surface zinc layers to zinc-iron alloys. These are dark grey compared with the light grey of pure zinc although after a period of exposure the difference in grey colour becomes less pronounced.

The dark grey coating surface may develop staining after a relatively short period of exposure, even in mild, damp conditions. This is only a surface effect and does not indicate serious deterioration of the coating: the galvanized coating remains and continues to protect the steel.

11.3.3 Staining and discoloration by rust

Sound galvanized steel with many years of corrosion-free life remaining can sometimes be rust stained or discolored. This may give an incorrect impression that the coating has failed and may occasionally be visually unacceptable. It may be the result of one or more of the following factors:

- *Direct contact of galvanized articles with unprotected or inadequately protected steel, eg, galvanized steel sections fastened with unprotected, electroplated or painted steel bolts*
- *Deposits of iron and steel, dust and swarf from other operations or sources on the galvanized surface*
- *Water draining from unprotected or poorly protected steelwork, eg, from dam-aged areas on painted steelwork*
- *From cleaning residues in welds. During cleaning, acid may penetrate into the weld area via pinholes or other gaps in the welding*
- *Rusting of areas welded after galvanizing and subsequently left unprotected or inadequately protected*
- *Water running off other materials, notably metals such as copper and certain hardwoods, eg, oak. This effect may occur whenever water can dissolve materials from one surface and deposit them on the galvanized steel*

Discoloration and staining from most external sources have no effect on the life of the coating. However, affected areas may be cleaned to improve the appearance of the component. Generally, wire brushing or the use of a scouring powder will remove the stain and leave a sound galvanized coating.

11.3.4 General roughness

BS EN ISO 1461 demands that a galvanized coating shall be 'smooth' but points out that smoothness is a relative term and that coatings on fabricated articles should not be judged by the same standards as those applied to mechanically wiped products such as mill-galvanized sheet, tube and wire.

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An uneven coating is usually due to excessive or uneven growth of the alloy layers because of the composition or surface condition of the steel. An uneven coating is often thicker than a conventional coating and, therefore, has a longer life.

11.3.5 Lumpiness and runs
Lumps and runs caused by uneven drainage of zinc from an article when it is removed from the bath may occur due to shape or thinness of the component and are not harmful to the life of the coating. Sharp points of excess solidified zinc are not acceptable as they may present a hazard during handling.

11.3.6 Pimples
Pimples are caused by inclusions of dross (a pasty zinc/iron alloy residual that forms in the galvanizing bath) in the coating. These may arise from iron salts carried over on the work from the cleaning tank and unable to escape from the surface of the coating. Contamination may also arise from agitation of the dross layer at the bottom of the bath. Dross has a similar corrosion rate to that of zinc and its presence in the coating as finely dispersed particles is acceptable but major dross inclusions tend to cause brittleness of the coating and will be rejected based on Balmoral Tanks' standards.

11.3.7 Wet storage stain
Wet storage stain is the white corrosion products and dark stains which may be seen on the surfaces of newly galvanized articles when they have been closely stacked and stored or transported under damp or wet conditions. Where wet storage stain has formed, the coating beneath may be stained dark grey or black.

To minimise wet storage stain, zinc coated tank sheets are transported and stored under dry and well ventilated conditions prior to onward shipment to the tank construction site. If stored outdoors at site, the surfaces should not be in close contact: free circulation of air is necessary to prevent condensation and retention of moisture. Capillary action can attract water into closely contacting surfaces such as nested sheets. Components should not be stored in direct contact with the ground.

If heavy wet storage stain deposits do exist they should be removed. This can usually be achieved by brushing with a stiff bristle brush or light abrasives.

11.3.8 Flux and dirt staining
Where flux is used during the dipping process, flux residues may adhere to the surface after immersion and pick up moisture to form white corrosion products. Although this is a surface effect, flux stains may be detrimental to the life of the coating and are not acceptable to Balmoral Tanks' quality standards.

Dirt may be picked up on the surface of the coating from the site, truck beds or from contact with other articles. These are readily washed off to reveal a sound coating underneath and are not, therefore, harmful.

11.3.9 Bare spots
Balmoral Tanks' quality standard does not accept any bare spots. However due to the sacrificial action of zinc, small localised flaws up to 5mm maximum width are usually self-healing and have little effect on the life of coating.

12 Renovating damaged coatings

Small areas of damage may occasionally occur in transport and erection. Due to the sacrificial action of zinc, small localised flaws do not reduce protection. Nevertheless, it is often aesthetically desirable to renew the coating even over such small areas.

Adequate corrosion resistance will be achieved at any damaged area if a weight of zinc is deposited equivalent to the weight of the undamaged coating. The following techniques are acceptable according to BS EN ISO 1461:

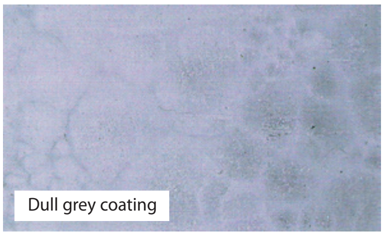
- *Thoroughly wire brush the affected area and apply sufficient coats of zinc rich paint (by brush or aerosol spray) to give a coating thickness at least equivalent to the original galvanizing*

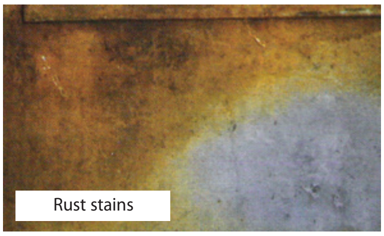
- *Grit blast the affected area and thermal zinc spray. A 100µm thermally sprayed zinc coating confers corrosion protection equivalent to an 85µm galvanized coating*

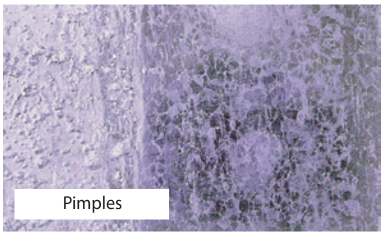
Zinc rich paint is much the simplest to apply, especially on site. Thermal zinc spraying is usually only economic when applied in the workshop.

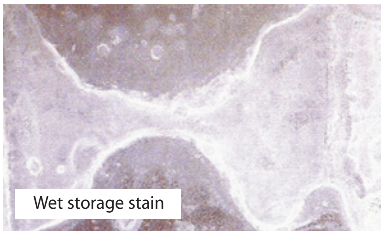
BS EN ISO 1461 requires that the coating thickness on renovated areas shall normally be 30µm more than the local coating thickness requirement for the galvanized coating. An exception to this is when the coating is to be over-coated and the renovated area requires an equivalent thickness.

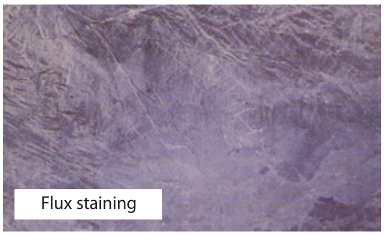
2.1 Examples of hot dip galvanized finish

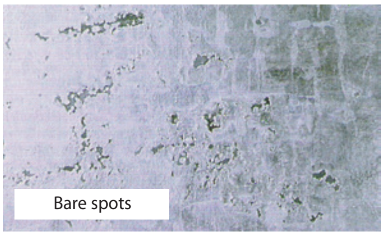












13 Galvanized products: zinc patina

Freshly galvanized steel progresses through a natural weathering process and the surface of the product will change and/or potentially be variable dependent upon the environmental and storage conditions to which the product is subjected.

During the first few weeks after an article has been galvanized it develops a natural protective patina. If allowed to develop properly, the patina itself provides a corrosion protection layer for the active zinc metal.

The formation of the zinc patina begins with the development of a thin layer of zinc oxide particulates on the freshly coated surface.

These particulates react with water, from rainfall or dew, to form a porous, gelatinous zinc hydroxide.

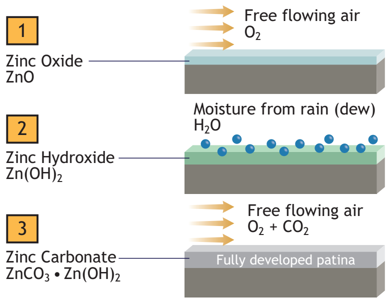
During drying, this product reacts with carbon dioxide present in the atmosphere and converts into a thin, compact and tightly adherent layer of corrosion products consisting mainly of basic zinc carbonate.

The rate of patina formation varies according to the environmental conditions. Typically, it takes approximately 6-12 months to fully develop.

13.1 Storage

Handling and storage conditions can inhibit the formation of the patina.

Storage areas that are high in humidity and lack air circulation tend to promote excessive growth of zinc oxide and zinc hydroxide. Adequate ventilation must be provided so that the build-up and retention of excessive water on the surface of the galvanized steel are avoided leading to the formation of wet storage stain - also referred to as white rust.



The zinc patina begins its development with exposure to oxygen in the atmosphere. Moisture from rain or humid air reacts with this layer to form zinc hydroxide. This layer then reacts with carbon dioxide present in the atmosphere to form the tightly adherent, insoluble zinc patina.

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14 Wet storage stain: prevention and cure

14.1 Introduction

One of the commonly encountered problems with galvanized coatings of all kinds is white storage stain - also referred to as white rust.

It is manifested as a bulky, white, powdery deposit that forms rapidly on the surface of the galvanized coating under certain specific conditions. White rust is usually detrimental to the galvanized coating's appearance.

The surface of galvanized coatings is almost 100% zinc. It is the durability of the zinc that provides the outstanding anti-corrosion performance for steel, yet zinc is a relatively 'reactive' metal. It is the stable oxides that form on the zinc's surface that determine its durability, and these oxides are formed progressively as the zinc is exposed to the atmosphere. Carbon dioxide in particular is a contributor to the formation of these stable oxides.

With newly galvanized steel, the zinc's surface has been subjected to little oxidation and is at its most vulnerable. For this reason, galvanizers use a chromate passivation in conjunction with its galvanizing operations to provide protection to the galvanized coating during the 'youth' period of the coating. This passivation coating provides short term protection to the zinc to give the stable oxides time to form on the surface.

14.2 White rust formation

Pure water (H2O) contains no dissolved salts or minerals and zinc will react quickly with pure water to form zinc hydroxide, a bulky white and relatively unstable oxide of zinc. Where freshly galvanized steel is exposed to pure water (rain, dew or condensation), in an oxygen deficient environment, the water will continue to react with the zinc and progressively consume the coating.
White rust can occur when galvanized products are nested together and tightly packed, or when water can penetrate between the items and remain there for extended periods.

14.3 Avoiding white rust formation on tank sheets

Balmoral Tanks takes the following steps to reduce the potential for the formation of white rust.

Foam strips are placed between the individual tank sheets that allow air to circulate between adjacent sheets and/or the edges of each pack of plates are sealed with adhesive tape.
Palletised sheets are covered with waterproof plastic to prevent the ingress of rainwater.

14.4 Treating galvanized surfaces affected by white rust

Once the galvanized surface has been attacked and the zinc hydroxide compounds have formed it is desirable to remove the oxide products from the surface because:

Their presence inhibits the formation of stable carbonate based oxides

They are unsightly.

The effect on the galvanized coating can range from very minor to severe and different levels of remedial treatment are available to deal with white rust problems at the various levels at which they are likely to occur.

The following treatments are recommended to deal with white rust on galvanized products and should be carried out prior to installation.

14.5 Light white rusting

This is characterised by the formation of a light film of white powdery residue.

Provided the items are well ventilated and well drained, white rust rarely progresses past this superficial stage.

It can be brushed off if required but will generally wash off in service under normal circumstances.

No remedial treatment is generally required for this level.

14.6 Moderate white rusting

This is characterised by a noticeable darkening and apparent etching of the galvanized coating under the affected area, with the white rust formation appearing bulky.

The galvanized coating thickness should be checked to determine the extent of attack on the coating.

In the majority of cases, less than 5% of the galvanized coating will have been removed and thus no remedial work should be required as long as the appearance of the affected area is not detrimental to the use of the product and the zinc hydroxide residues are removed by wire brushing. If the appearance is unacceptable, the white rust affected area can be treated as follows:

- *Wire brush the affected area to remove all white corrosion products*
- *Using a cloth pad wet with aluminium paint, rub the surface with the pad to apply a thin film of aluminium paint to the affected area to blend it with the adjacent unaffected galvanized surfaces*

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14.7 Severe white rusting

This is characterised by very heavy oxide deposits and items may be stuck together.

Areas under the oxidized patches may be almost black or show signs of red rust.

A coating thickness check will determine the extent to which the galvanized coating has been damaged.

Remedial treatment to reinstate the coating should be undertaken as follows:

- *Wire brush or buff the affected area to remove all oxidation products and rust if any*
- *Apply one or two coats of approved epoxy zinc-rich paint to achieve required dry film thickness of 100 microns minimum*

14.8 Summary

White rust is a post-galvanizing phenomenon that generally manifests itself as an aesthetic problem, particularly related to tank panels.

Its prevention lies in the manner in which it is packed, handled and stored prior to the galvanized product's installation and use at the final destination.

Balmoral Tanks take various precautions during the packing of galvanized tank sheets to minimise or eliminate the formation of white rust.

If white rust does form on delivered products, it is normally a reflection of the length of time and the environment in which the product has been stored since being dispatched from the Balmoral Tanks factory. It is not a reflection on the galvanized coating's performance and is more an aesthetic issue that can normally be easily rectified on site.

15 Liner approval

15.1 Potable Water Butyl liners are manufactured using WRAS approved materials.

WRAS APPROVED PRODUCT

BALMORAL TANKS

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