

Reservoir Design

Considerations

Fluid storage tanks come in many shapes, sizes and construction materials - design is mostly influenced by past history, local availability and cost. Tanks all share one common requirement to achieve their expected design parameters and service life - cost effective maintenance. A long-term view must be adopted to allow for all possible contingencies that may occur during a tanks operating life. Maintenance items include inspection, cleaning, recoating, and the repairing/upgrading of pipe-work, pumps and control equipment - initial design must include the ability for these functions to be carried out safely and cost effectively.

Location

An overview of the surrounding area should include future requirements as they arise, particularly encroaching urban development that will restrict vehicle access and waste disposal methods. Pumping and chlorination stations may also need to be built/upgraded at a later date.

Practicalities must not be compromised with aesthetics - access roads should accommodate tankers, trucks and work vehicles safely. Many tanks are situated adjacent to excavated earth banks, so all external wall areas should be accessible to scaffolding, ladders or mechanized digging/lifting equipment - landscaping and natural vegetation must not encroach on these areas, as mature trees can damage foundations, protective coatings and cause guttering systems to block up and overflow back into the tank.

Personnel carrying equipment can be injured from slipping or falling if required to traverse the steep slopes and landscaping that often surround tank perimeters - a level parking/working area with room to maneuver directly below the main roof platform will enable potable dedicated equipment to be lifted up by the most direct route thereby avoiding ground contamination.

Identification System

A key part of any inspection programme is accurate identification - most service reservoirs have been built without any standardized method of achieving this.

All tanks should be allocated a WS (water storage) number to enable management software to accurately discriminate between often-similar names. Tanks can be listed by age or alphabetically and should be designated WS 01 with the numbering running sequentially to the newest asset - this number should be restricted to two or three digits for simplicity and should be independent of larger alphanumeric general asset identification numbers.

To reference inspection positions, the numbers of a clock face should be stenciled both inside and outside on circular tanks. To assist divers carrying out inspections, numbers should be placed 500mm off the floor and also above the high water line. Corresponding numbers on the outside of the tank will reference external points of interest for the many personnel involved in day to day maintenance operations.

The **main entry hatch** is the 6 o'clock datum point and 180° to this is 12 o'clock, with the corresponding 90° points as 3 o'clock and 9 o'clock - the balance is divided up into remaining numbers or half numbers if dealing with larger tanks. A simple method of allocating the clock face positions is achieved by measuring the tank circumference both inside and out using a tracking wheel and then dividing the total measurement by twelve. Another circuit is then carried out starting from directly below the entry hatch and using the divided measurement to accurately pin point the numbers of the clock face in sequence.

Roof support posts should also carry an ID number - the centre post is marked as No1 and following numbers radiate out from there in a clockwise direction with No2 being nearest the 6 o'clock position.

External and internal penetrations should be labeled with their intended function - IN, OUT, SCOUR etc. and a valve operations manual should be compiled and stored onsite for quick reference to take all local factors into consideration. The valve stems should be colour coded and the rotation direction recorded - much experience has been lost during staff turnover/retirements and this can lead to valves being operated incorrectly during emergencies or when regular staffs are not available.

Depth markings should be painted alongside the internal ladder in half metre increments, so that the diving supervisor can maintain an accurate watch on any water fluctuations that may affect time schedules.

Refer to Appendix 1 – Identifying Safety.doc

Roofs, Platforms & Hatches

Key features should include:

- Guard rails extending at least six metres either side of the platform or any area used by personnel to operate or maintain the tank. Guard rails fitted with a hinged gate (often adjacent to rescue systems) **must be** secured in the closed position with a secure latching mechanism.
- A good size work area to set out cleaning, inspection and repair equipment.
- The platform can be cantilevered off the wall to simplify roof plumbing and create extra space on smaller tanks.
- Expanded mesh placed on top of the surrounding roof sheets to prevent impact damage from personnel and equipment. These panels should be removable so that accumulated leaf debris and dropped objects can be accessed.
- Roof sheets should be orientated to take advantage of prevailing winds and storms to sweep away leaf debris that can build up around hatches and platforms. Sheet direction will also affect drainage when hatches and vents are fitted into the roof – water can pond behind these fixtures.
- Box gutters running across the centre roof area should be avoided, as they are prone to vegetation and debris blockages of drainage points, causing storm water and contaminants to run back into the tank.
- The entry hatch to be a minimum of 1000mm wide by 1000mm long. This allows easy entry and exit of personnel wearing diving or confined space protective equipment. The cover must be secure, easy to lift and able to be latched into the open position to prevent accidental closure by wind or human error, while personnel are inside the tank.
- External stanchions or handrails to be fitted adjacent to the hatch for orientation/balance when descending or ascending the internal ladder - this will allow complete sealing of the hatch cover against debris or animal entry
- Hatches to have a continuous raised edge frame (50 mm+) and a corresponding overlapped cover to prevent storm water and foreign matter contaminating the tank.
- All hatch covers should be securely locked. Many locking lugs are fitted horizontally instead of vertically and due to a lack of clearance, many locks become inverted, exposing their mechanisms to the weather.
- A **vertical, uncaged** Nextep FRP internal ladder fitted in conjunction with a DBS Titan Arm that is rated to over 200 kg SWL - leaving off ladder cages and platforms compensates the cost of fitting an external rescue system and also makes the tank confined space compliant.
- Refer to Appendix 2 – Ladders into Confined Spaces.doc
- Tanks should be fitted with a lower sidewall entry point for conventional maintenance - this places the structure into a lower category of confined space when empty.
- More than one hatch on tanks over 20 metres in diameter to allow ventilation, light and introduction of specialised equipment – e.g. boats and scaffolding.

- Good ventilation will prolong roof framing design life and improve water quality by removing humid, chemical laden air that otherwise collects, condenses and returns to contaminate the water.
- Ventilation needs to be designed to encourage airflow across the total internal area – inlet vents must be included as well as exit points.
- Inlet vents should be orientated away from sources of contamination such as trees and dust areas. Fixed type ventilation points should be used in high wind areas instead of turbine type units, that can be easily damaged.

Internal Design Features

The most important factor is to store water in a high quality, hygienic environment - this cannot be achieved if internal fittings are heavily corroded or contaminated. While steel tanks and fittings are generally fully coated, concrete structures are often neglected - ductile iron pipe work, support brackets and metal ladders should all be epoxy coated before commissioning the tank.

- Metal materials used in contact with water should be **cathodically compatible** to minimize corrosion through electrolysis
- All metals should have a long life protective coating **suitable for immersion** - potable approved epoxies meet this requirement, but galvanizing **is not suitable**. Stainless steel items should be coated to limit the cathodic potential difference to adjacent metal fixtures, which will corrode prematurely due to the proximity of exposed stainless steel in sufficient volumes.
- Aluminium is also subject to corrosion - during extrusion, carbon particles attach to the surface and cause severe electrolysis and corrosion unless removed by thorough surface preparation.
- Refer to Appendix 3 – Internal Ladder Construction.doc
- GRP or HDPE can be used for pipe penetrations, overflow risers and supports.
- Roof support posts and other fixtures should be kept to a minimum to avoid trapping sediments and interfering with water circulation. Pipes should be positioned **under** the floor where possible and only the penetrations should be exposed within the tank. Raised edges of 100mm+ fitted to outlets should be limited to the pipe wall thickness only – concrete plinths cast around the pipe work penetrations will allow sediments to accumulate around the edges and enter the reticulation system
- Any horizontal fixtures such as platform landings and stairs should have perforated surfaces to prevent sediment build-up - ladder rungs/steps should be rounded instead of flat treads for the same reason.
- Any reinforcement of the wall/floor area where necessary should be a flat step and not sloped for efficient vacuuming. Roof post support bases should be similarly squared off as sloping edges are hard to clean around.

- **Protective screens** should be fitted on outlets to prevent accidental diver or worker entanglement - sufficient stand off to increase cross sectional area of the penetration is required to avoid increased suction developing if the penetration were accidentally covered. Safety screens made from HDPE are ideal, incorporating a raised edge to keep sediments from entering the pipe-work, in addition to providing strength and electrical isolation from adjacent metal materials.
- **Water circulation** within the tank should be designed to eliminate stale areas, promote efficient chlorine usage and avoid disturbing sediments already settled out on the floor area. Incoming water energy can be harnessed at no cost to **improve water quality**. Inlet penetrations in the wall or floor should have an HDPE nozzle fitted to direct the water flow upwards at 30 degrees+ and at 90 degrees to the wall - excessive circumferential water movement should be avoided as strong currents create entrapped areas of unmixed water in towards the centre of the tank.

Scour Systems

Tank cleaning is the most commonly performed maintenance function. It depends on a properly designed waste water disposal system to effect compliance with environmental guidelines - sediments cannot be deposited directly into storm water systems without treatment to reduce total solids loading. The following features will be of assistance:

- No scour trench in the floor - the extra structural expense is not necessary if diver cleaning is used.
- Scour penetrations to be minimum 150-200mm diameter and level with the floor for easy coverage with a vacuum plate - this is not possible when roof posts straddle a centre scour or trenches have close sides and irregular shaped penetration holes.
- The scour penetration should be close to the entry point for quick set up - vacuuming normally commences in this area so that extra hoses and equipment can be dropped onto the cleaned floor without disturbing sediment.
- On tanks over 50 metres in diameter, a second scour in the centre of the floor will allow vacuum equipment to be repositioned to finish off to the far wall without adding extra lengths of hose. Large steel tanks should have 75mm wall penetrations at 3, 6 and 9 o'clock positions to achieve a similar vacuum pattern - these should be mounted 1 metre off the floor and could be incorporated into personnel entry hatches or drilled through the wall using 'under pressure tapping' techniques.
- 'Through the wall' valves also serve a secondary purpose for the quick filling of fire tankers during emergencies.
- The external scour exit point must remain within the client property to avoid disputes with run-off water flooding adjacent areas.
- Levee banks to direct run-off water into settling-out areas are desirable - an earth dam with 4% of the reservoir capacity would allow turbid waste to settle out and clean water to pass on via a siphon system over the bank.

- Where space does not permit a dam, the scour should drain into a 2000+ litre inground sump - several options are now possible:
 1. The sump can drain to storm water for normal overflow conditions, but the addition of a simple penstock valve or ball plug can close off the sump and allow water to be diverted to a nearby sewer - surrounding urban development should include a sewer point adjacent to the tank for waste disposal.
 2. Alternatively, the sump could be isolated and it's contents pumped directly into a tanker or irrigated onto surrounding ground.
 3. 'Through the wall' scour exit points can be directly coupled to a discharge hose or pump for transfer to a sewer, tanker or irrigation area - when considering any hook-up, backflow must be eliminated as this would contaminate the potable water.

Floating Roof Tanks

When considering the installation of a floating roof, confined space issues must be addressed. Can personnel be safely introduced under a cover held up by air pressure alone? Any failure could lead to a drowning in shallow water when crushed underneath - diver cleaning offers many advantages, but good preparation before roof installation is necessary.

Multiple entry points allow the tank to be vacuumed in sections and permit the diver a means of quick escape in emergencies - the diver should not have to penetrate more than 50 metres from an opening.

Entry areas should be reinforced for at least four metres around the hatch and contain extra buoyancy to allow equipment to stay dry.

Sloping walls are hard to grip when being vacuumed and it is normal on an open basin for the tender to tow the diver parallel along the wall and work slowly down to the floor - with a floating roof this is not possible, so a sliding lanyard system needs to be fitted. Stainless steel eyebolts with no sharp surfaces can be installed at 10-15 metre intervals at the top sediment area level. A 5mm stainless steel cable is passed through these eyes and tensioned up - this allows the diver to attach a sliding lanyard to the cable and to vacuum sweeping areas of the wall before moving onto the adjacent area.

Appendix 1

Identifying Safety

Prior to commencing any diving operation, a series of hazard identification procedures need to be addressed - some of the main issues are the type and position of pipe-work penetrations.

A 'clock face' system was devised to divide the tank into identifiable areas of interest - this system is only accurate if markings are stenciled onto the exterior and interior areas of the tank. On the hazard identification 'walk-around', pipe work and valve positions can be noted accurately and the divers briefed accordingly.

The outside markings are of more importance than the internal identification - standing at the entry hatch, it is not possible to view any external pipe work relevant to its position. If the diver is aware a particular penetration is located at 9 o'clock for example, it can then be visualized and referenced against skylights, posts or fixed objects within the tank.

An internal numbering system is useful for inspection and safety purposes but it is not as easily achieved, unless the tank is empty for repairs or under construction - external numbering can be done at any time or included into anti-graffiti coating projects.

Many clients have implemented the numbering system and have benefited from more accurate asset inspections, while at the same time improving safety.

Appendix 2

Ladders into Confined Spaces

Risk assessment and compliance with Australian Standards will always be an important step in managing safety issues, however applying the appropriate Standard can be confusing at times - designers and regulatory authorities need to consider **all the hazards involved** if sensible outcomes are to be achieved.

Ladders fitted into confined spaces have different functional requirements than those addressed in the Australian Standard 1657-1992 (Fixed platforms, walkways, stairways and ladders). The traditional ladder system of sloping stiles, enclosed cages and fixed platforms is not suitable for safe entry and exit using a harness and fall arrest system. AS/NZS 2865:2001 (Safe working in a confined space) 6.4 states: **Any modification to a confined space shall not detrimentally affect the safe means of entry to, exit from, or work in a confined space.**

Confined Space access ladders should be designed as a **vertical structure system** to allow for clear entry and exit when being lifted/lowered in a harness (cages and platforms will not assist in this situation) – vertical ladders allow the person in harness to maintain balance and avoid ‘swing and rotation’ throughout the access operation.

A vertical ladder system will also prevent ‘Harness Trauma’, by allowing personnel to climb under control and not be fully suspended throughout the confined space access operation. Separate rescue hatches without a ladder below should be avoided in favour of a combined access area with all the necessary resources placed into one location.

A Nextep FRP vertical ladder and a DBS Titan Arm combination provides the ideal system for safe access and rescue capability – it places the safety component inside the confined space and the rescue component of the system on the outside of the hazard area where it can be operated by the standby members of the team.

Appendix 3

Internal Ladder Construction

Most ladder systems in tanks and immersed structures are constructed from unsuitable materials, and their design does not meet confined space requirements.

Corrosion within a tank reduces water quality by direct contamination and reduced oxygen levels - both galvanised mild steel and fabricated aluminium will corrode heavily when immersed in potable or raw water.

Stainless steel is more corrosion resistant, but it can cause cathodic corrosion to adjacent tank structures when immersed - reinforcing fabric in concrete tanks is subject to corrosion attack if an electrical connection is made when attaching a stainless steel ladder system. Steel tanks are likewise subject to cathodic corrosion unless effective insulation procedures are carried out. Most stainless steel ladders have round bar rungs that are difficult to grip when wet, so safety is compromised for corrosion resistance.

Nextep FRP ladder systems have a 50-year life projection when immersed, and many have been in service for over 25 years with no signs of deterioration. FRP is lightweight, easy to install and remains neutral to cathodic corrosion. The rung design is ergonomic, non-slip, and the yellow colouring is safe to use in low light conditions.

Divers can remove most existing ladder systems while a tank or structure remains online, and the refitting of an FRP vertical ladder system can be carried out at the same time – a dedicated rescue frame such as the DBS Titan Arm, rated at 200+ kg provides the external safety component of the system and provides a high level of safety to any confined space access operation.

Confined Space compliance within enclosed and immersed structures cannot be ignored, and older ladder systems do not meet this requirement. An ergonomically safe to climb vertical ladder system used in conjunction with personnel protective equipment and operator training is the only reality in today's workplace.