The Municipality of the Village of Lions Bay

Water Storage Facility Replacement Pre-Design Report

Prepared by:

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September, 2017

Project Number: 60546407

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Revision History

Revision #	Date	Revised By:	Revision Description
1	01/08/17	Semyon Chaymann	Draft #1
2	28/08/17	Graham Walker	Draft #2 – Separated from Water System Review and Analysis
3	01/09/17	Graham Walker	Draft #3 – For Infrastructure Committee Review
4	22/09/17	Semyon Chaymann	Final

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September 22, 2017

Naizam Jaffer
Public Works Manager
Village of Lions Bay
400 Centre Road
Lions Bay, BC V0N 2E0

Dear Mr. Jaffer:

Project No: 60546407

Regarding: Water Storage Facility Replacement
Pre-Design Report

Please find attached the Pre-Design Technical Memorandum for the Village of Lions Bay Water Storage Facility Replacement project. If you have any questions please contact Graham Walker at 604.444.6436

Sincerely,
AECOM Canada Ltd.

Graham Walker

Quality Information

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Senior Engineering Manager

David Main
Senior Manager

Executive Summary

The Municipality of the Village of Lions Bay has retained AECOM Canada to evaluate configuration options and recommend a replacement strategy for the four water storage facilities – Harvey, Phase IV, Phase V, and Highway. The Village is interested in replacing, removing and/or modifying the existing tanks without compromising the water system's ability to meet acceptable level of service.

The Water Storage Facility Replacement: Water System Review and Analysis Report (AECOM, 2017) completed a thorough analysis of the existing water distribution system using the Village's InfoWater hydraulic model and proposed three options for tank replacement as follows:

Option 1: Full Replacement

- Replace the existing Harvey, Highway, Phase IV, and Phase V tanks.

Option 2: Partial Replacement

- Replace the Harvey and Highway tanks;
- Remove the Phase V tank and redefine the PZ 271 Zone;
- Remove the Phase IV tank and replace with a permanent PRV station.

Option 3: Harvey Only Replacement

- Replace the Harvey tank;
- Remove the Phase V tank and redefine the PZ 271 Zone;
- Remove the Phase IV tank and replace with a permanent PRV station;
- Remove the Highway tank and replace with a permanent PRV station.

The previous report evaluated each option's impact on the water distribution system's ability to meet minimum pressure demands and fire flow requirements. That report concluded that each option is able to meet the Village's requirements. However, some system fire flow deficiencies were not due to water reservoir issues and therefore all three options also required linear pipe upgrades to meet fire flow requirements.

This Pre-Design Technical Memorandum outlines the construction materials, constructability, maintenance and cost considerations of the project in order to provide the Village a recommendation of the most beneficial option both for short term implementation but also throughout the operational life of the asset. A life cycle cost analysis was completed to estimate the investment requirements for each option at present value.

Based upon the aforementioned analyses, AECOM recommends the Village proceed with the implementation Option 2 including the following:

- Replace the Harvey and Highway tanks with Prestressed Reinforced Concrete Tanks;
- Remove the Phase V tank and redefine the PZ 271 Zone;
- Remove the Phase IV tank and replace with a permanent PRV station.

This option will reduce the O&M requirements for servicing existing hard-to-reach storage facilities while not significantly diminishing the existing level of service to the Village. We also recommend that the following projects be considered for operational enhancements and constructability as they are related to the work but not required:

- If Magnesia Tank replacement is not to be considered in near term, consider adding 0.15ML of capacity to the Harvey Tank to compensate for fire flow storage shortfall in the Magnesia Tank. Storage would not be functional until a connection on Mountain Drive between the Magnesia Creek and Harvey Creek supplies was completed. Further analysis would be required to determine which linear pipe upgrades, if any, would be required to meet system requirements under this configuration;

- Implement water quality improvements including operational changes which may include automation of a connection on Mountain Drive between the Magnesia Creek and Harvey Creek supplies to allow for further circulation of tank water to reduce water age and stagnation within both the tanks and the system;

- Replace the 200mm water main from Upper Bayview Road to Timbertop Road including the Alberta Creek crossing to remove the redundant and challenging to access portions of the pipeline which currently lead to the Phase V tank site;

- Replace the asbestos cement water main on Upper Bayview Road as there are risks associated with modification of the pipe during the new tie-ins which would be completed during the modifications of the pipe network for the Phase IV replacement PRV;

- Develop a long term strategy for construction of equalization tanks throughout the system to eliminate stacked PRVs and in turn reduce pressure surges, pipe fatigue and the risk of water main breaks.

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Project: Water Storage Facility Replacement
Client: The Village of Lions Bay
Date: July 2017
Created By: Semyon Chaymann
Reviewed By: Brett DeWynter (P.Eng)

The Municipality of the Village of Lions Bay

Water System Overview

Figure 1: The Village of Lions Bay Water System Overview

1. Introduction

The Municipality of the Village of Lions Bay has retained AECOM Canada to evaluate configuration options and recommend a replacement strategy for the four water storage facilities – Harvey, Phase IV, Phase V, and Highway. The Village is interested in replacing, removing and/or modifying the existing tanks without compromising the water system's ability to meet acceptable level of service.

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1.1 Key Terms and Definitions

Table 1 provides a summary of key terms (with abbreviations) and definitions used throughout this report.

Table 1: List of Key Terms and Abbreviations

Term (Abbreviation)	Definition
Average Daily Demand (ADD)	Annual water demand from all sources averaged to a single day (used, for example, to determine water licensing requirements).
Fire Underwriters Survey (FUS)	Standard criteria developed by the Insurance Industry to evaluate fire services, including minimum fire flow and fire storage requirements.
Headloss	The head, pressure or energy (they are the same) lost by water flowing through a pipe, bend/deflection, valve, etc. as a result of friction.
Hydraulic Grade Line (HGL)	The surface or profile of water flowing. The level water would rise to in a small vertical tube connected to the pipe. (HGL = elevation + pressure)
Leakage ("water loss")	Water lost from the system through cracks in water mains, unseated valves, loose end-caps, misaligned joints, reservoir cracks, overflows. (can occur on municipal water mains and on private services)
Million Litres (ML)	1 ML/day refers to 1 million litres of water per day
Maximum Day Demand (MDD)	Highest daily water usage over the entire year.
Peak Hour Demand (PHD)	Highest water usage for any given 1-hour period, over an entire year.
Pressure Reducing Valve (PRV)	A control valve that automatically reduces the inlet pressure in a water main to a set downstream pressure.
Pressure Zone (PZ)	A water service area (controlled by a reservoir, tank, or PRV) in which all the users have the same static HGL. Water cannot flow from one PZ to another without passing through a PRV or another control valve.
Water Age	Length of time that water is within the distribution system, measured from point where chlorination is introduced.
Unit Conversions	
Pressure **Psi to "m" or "kPa"**	1.0psi = 0.69m = 6.9kpa (so 100psi = 69m = 690 kPa)
Volume **Litres to gallons**	3.79 Litres = 1.0 US gallon and 4.54 Litres = 1.0 Imp. gallon
Flow Rate **L/s to gpm**	1.0 L/s = 15.9 USgpm = 13.2 Imp. gpm

1.2 Village of Lions Bay Water System Overview

The Village of Lions Bay is situated between Vancouver and Squamish, approximately 11km north of Horseshoe Bay along Howe Sound. The Village operates and maintains a water supply and distribution system that is responsible for providing water to their 1334 residents for potable (domestic), irrigation and fire protection usage. Water supply for the Village is drawn from two local creeks – Harvey Creek and Magnesia Creek. The water is treated and conveyed to the consumers through the following distribution system infrastructure:

- 17km of water main (various sizes and materials)
- 2 water treatment plants (Harvey Creek WTP, Magnesia Creek WTP)
- 8 water tanks (5 of which contain potable water and 3 of which contain non-potable water)
- 2 raw water intakes (Harvey Creek, Magnesia Creek)
- 529 property connections
- 13 pressure reducing valve arrangements
- 72 hydrants
- 250 valves

The system is separated into eighteen (18) pressure zones. The boundaries along the pressure zones consist of a series of closed valves and pipes, and pressure regulating valve (PRV) stations to decrease the pressure to an acceptable range for delivery of water to users.

2. Tank Replacement Options

2.1 Replacement Options

The first option, Option 1: Full Replacement, essentially maintains the status quo for the Village without removing or reconfiguring any infrastructure. The project will however provide significant upgrades to both reliability of the system, operational flexibility, and safety for the public works staff. The existing Harvey, Highway, Phase IV, and Phase V Tanks will all be replaced with infrastructure to meet the future demands of the Village.

The second option, Option 2: Partial Replacement, for water storage facility replacement is to decommission Phase IV and Phase V Tanks and install a PRV in place of Phase IV. To increase access and reduce maintenance costs it is advised to install the PRV near the existing access road turnoff at Upper Bayview Road. To mitigate the reduction in total storage capacity Harvey and Highway Tanks need to be upgraded to provide sufficient equalization and fire storage for the ultimate 2045 scenario.

The third option, Option 3: Harvey Only Replacement, builds off of the second option while also including the removal of the Highway Tank from the system and the replacement with a permanent PRV station.

If either Option 2 or 3 are selected, the project would also ideally include the reconfiguration of the zone supplied by Phase V Tank including installation of 400m of new 200mm diameter ductile iron water main across Alberta Creek from Upper Bayview Road to Timbertop Road. The project would remove redundant pipes which currently go to the Phase V Tank site and provide renewal of the Albert Creek crossing. The option provides scheduling risks due to

the requirement for approvals under regulatory bodies of government (i.e. Water Sustainability Act) for the construction of a new creek crossing.

2.2 Tank Storage Sizing

In the Water Storage Facility Replacement: Water System Review and Analysis Report (AECOM, 2017), the required tank capacities were calculated based on the MMCD standards. The required storage tank capacity is the sum of fire storage (A), equalization storage (B), and emergency storage (C) which as defined as the following:

- Fire storage (A) – This is the amount of water required to extinguish fires within the service area of a tank. This storage is based on the worst case fire flow land use scenario in the service area.
- Equalization storage (B) – This is the amount of storage required for normal water consumption (25 % of MDD).
- Emergency storage (C) – The emergency storage requirement of 25% of (A) + (B).

The Phase IV, Phase V, and Highway water storage facilities are acting as equalization tanks and do not provide sufficient fire flow storage for the area they supply. Each of these three tanks and the remaining pressure zones on the south side of the Village's water distribution system is reliant on the Harvey Tank to provide stored water in the event of a fire. As such, the size of the Harvey Tank increases incrementally as other tanks are removed from the system in the options outlined within this report as shown in Table 2. For the sake of this analysis it was assumed that each of the three equalization tanks will have a capacity of 0.1 ML.

Table 2: Harvey Tank Required Storage Volume

Replacement Option	Storage Volume (ML)
Option 1 – Full Replacement	1.98
Option 2 – Partial Replacement	2.18
Option 3 – Harvey Only Replacement	2.28

The total volume of storage in the Harvey fed system is 2.28ML. With the current Average Day Demand at 0.93ML, the upgraded storage capacity will be able to provide over two days' worth of emergency storage. The suggested tank configurations would provide sufficient fire storage capacity for the Harvey Creek supplied areas, as indicated by the 2045 Scenario results described in the Water Storage Facility Replacement: Water System Review and Analysis Report (AECOM, 2017). Further information and figures are provided within that report for the layout of the water system and of the proposed options for water storage facility replacement.

Under the current system configuration which isolates the Magnesia and Harvey systems there is a 1.06ML storage shortfall in the Magnesia Tank primarily due to fire flow requirements for the school. The capacity of the Magnesia Tank was scheduled as a low priority upgrade in the Infrastructure Master Plan (AECOM, 2016) as capacity could be addressed elsewhere in the system. We are not aware of imminent plans to replace or upgrade the Magnesia Tank and therefore the capacity could be addressed through this project which would allow the entire Village to be reliant on the Harvey Tank to provide stored water in the event of a fire. In such scenario the Harvey Tank required storage volume would have to account for the 0.15ML increase due to insufficient fire storage at Magnesia Tank resulting in a 2.13ML storage capacity, as presented in Table 3. Additionally, an automated control valve would need to be installed between the existing Magnesia and Harvey fed systems along Mountain Drive, which would allow for sharing of tank storage capacity to meet the fire flow requirements.

Table 3: Harvey Tank Required Storage Volume without Magnesia Tank Upgrades

Replacement Option	Storage Volume (ML)
Option 1 – Full Replacement	2.13
Option 2 – Partial Replacement	2.33
Option 3 – Harvey Only Replacement	2.43

It is cost effective to have only one tank provide majority of the fire flow storage capacity for the system. However, this also reduces system redundancy as the system would not have backup storage if the Harvey Tank was out of service. The 0.15ML of storage could also be installed elsewhere in the system through an equalization tank but would still require connectivity between the two water supply systems to share fire flow.

2.3 Constructability Considerations

The following provides a summary of factors influencing the replacement strategy that are outside the hydraulic performance of the system which were considered in order to provide appropriate recommendations based on all options.

2.3.1 Condition Assessment

The existing reservoir tanks are in fair to poor condition with the last full inspection including the draining of the tanks being completed in 2004 by AECOM (previously EarthTech).

Phase IV and Phase V Tanks are both showing poor concrete condition with exposed reinforcing cages. The tanks are not equipped to provide safe access and egress into the tanks which limits the Village's ability to safely maintain the facilities. Algae growth is accumulating on the exterior of the tanks. There is visual evidence of moisture propagation through the tank walls including delamination of concrete on the reservoir walls. The existing PRV sheds are also in generally poor repair, some pipes have significantly corroded, valves which are likely inoperable, and no site power or communications.

The Highway Tank is similar to the Phase IV and Phase V Tanks with regards to condition including efflorescence and corrosion staining on vertical cracks. There are issues with the safety of the valve chamber and significant corrosion of the internal components within the tank. From discussion with the Public Works staff, it was noted that the Highway Tank is not aesthetically pleasing and due to its prominent location within the Village it has been a concern for local residents. Several attempts have been made to improve the aesthetics of the site including the removal of the roof of the structure after its collapse.

The Harvey Tank is the newest of the four tanks being reviewed as part of this project and is also of the largest volume and therefore highest construction costs. Critical defects were identified on the Harvey Tank in 2004, such as extensive water leakage, which reportedly required urgent attention. A repair plan was then developed to seal the gap between the precast panels which appears to have not been completely successfully. No subsequent remedial work was undertaken to seal the gap between the precast panels since the initial attempt made in 2006. It is also understood that strengthening and seismic retrofit work was not completed.

Since then the Harvey Tank was left without further investigation until spring 2017 when there was portions of the concrete infill which were dislodged from the structure prompting the Village to proceed with a further investigation

which was completed by WSP in their memorandum dated April 24, 2017. The report found that the panels of the reservoir in fair condition but that the joint seals have failed. The recommendations of this review included the full condition assessment of the structure requiring access to both the inner and the outer surfaces of the walls and that the roof structure also be included within the assessment work. It is noted that the recommendations of the WSP report may have been made prior to the knowledge of the Village receiving funding for the CWWF and thus may have been focused on repairing the infrastructure sufficiently to allow it to maintain in service while a replacement strategy was developed.

Although it might be feasible to retrofit the existing Harvey Tank this option will not likely provide the long term reliability of new construction due to unknowns of existing tank deficiencies and the high costs associated with fully exploring and deciphering these issues. Furthermore, insufficient design information is available to determine the complete design which leads to further challenges in upgrading the structure to meet seismic resiliency requirements.

2.3.2 Site Access and Construction Traffic

The Village has historically struggled with slope failures on the access roads to their water supply system; particularly on the Harvey Creek intake roadway. These landslides are a significant cost in emergency works for the Village while also exposing the community to significant risk in the event that maintenance or repairs are required at the infrastructure while it is inaccessible with the roadway blocked. The site access road which is used to reach Phase IV and Phase V Tanks is very steep, narrow making it challenging for public works crews to reach the site through the year in particular during times of heavy rainfall or snow. Removal of the Phase IV and Phase V Tanks from the systems significantly reduces the access concerns for the water system. Reconfiguration of the PZ236 zone with a PRV adjacent to Upper Bayview Road will remove the access issues currently associated with the Phase IV site. The access road will likely still be maintained to access the water main and Alberta Creek crossing but with the assets reduce the frequency access would be minimize.

Site access is a significant schedule risk to the project due to the likely challenges to complete work during the winter months particularly if the winter has snowfall and below zero temperatures like the last year. Lastly, removal of the Phase IV and Phase V Tanks removes the requirement to construct or trench power to the higher levels of the access road which departs from Upper Bayview Road.

The roads throughout the entire Village are generally steep and narrow with minimal room for construction staging and construction traffic. Traffic management plans should ensure that sufficient signage and flagging staff to provide warnings to local traffic of heavy traffic. Concrete pours may need to be scheduled at off-peak hours due to traffic which may delay concrete delivery truck timing as they will likely be dispatched from at least 30 minutes away and travel times can vary significantly depending on the place of origin (i.e. North Vancouver, Squamish, or further into Vancouver region).

2.3.3 Disruptions

Minimizing water service disruptions will be a critical aspect to the staging of the project and may need to be prescriptively stipulated as part of the construction procurement process. The Village's system generally does not have redundancy in supply to pressure zones. The result of this is that there will be water outages and the requirement to provide temporary water supply at times of transition between the existing system and the upgrades works to be completed as part of this project.

The Village has limited land within the Village for new water storage tank construction. In the forested areas above the residences, but owned by the Village, there are significant costs to construction of new sites due to the tree clearing, earthworks and rock blasting which would be required. For example, the cost of replacement of the

Harvey Tank changes significantly if a location is required, opposed to reconstructing in the current location. The downside of reconstruction on the existing tank location is that the water system will have reduced storage capacity during construction which reduces the amount of water available for firefighting if it were to be required. As such, it would be an unacceptable level of risk to take the existing Harvey Tank out of service during summer or early fall months while water usage is high and the risk of fire is significantly greater than it generally is during the late fall and winter. Furthermore, it is recommended to leave the other three tanks (i.e. Phase IV, V & Highway) in service until after construction of a Harvey Tank replacement is complete.

We have identified the connection to the existing asbestos cement pipe on Upper Bayview Road as a potential risk and worth considering removal and replacement within the scope of this work as connection to the pipe will be required as part of the system reconfigurations. The current best practice in the Lower Mainland to remove asbestos cement pipe when associated works involve connection to, crossing or disturbance of the pipe. We have also identified the existing Alberta Creek pipe crossing adjacent to the Phase V Tank as a likely replacement as part of the reconfiguration of the PZ 271 zone. The reconstruction would provide system resilience and eliminate pipe assets higher in the alpine which will continue to be challenging to maintain in the future.

2.3.4 Safety

The existing altitude and pressure reducing valve chambers within the Village do not meet WorkSafeBC regulatory requirements for safe access and egress. We will work with the Village to develop a standard valve chamber design which can be implemented through the Village as PRV chambers are replaced to ensure consistency and safety. The industry trend is currently to eliminate the requirement for confined space entry altogether by bringing the valves above grade in a kiosk or control building. For example, the Highway Tank site is a prime candidate, with or without tank replacement, to reconstruct the control valves for both the PZ107 and PZ75 zones within the site as part of the upgrades. Even the newer PRV station at the Harvey Tank does not meet WorkSafeBC requirements and therefore we will review options for retrofitting or reconstruction of the chamber.

2.4 Construction Form and Materials Analysis

We completed a review of the available tank and reservoir material options which would meet the requirements of the Village which included the following parameters:

- Product durability and expected service life of tank system;
- Resilience of the design and elimination of potential for QC/QA issues;
- Resistance to damage from seismic events including horizontal and vertical ground accelerations, the sloshing of the water and the overturning moments;
- Constructability of the proposed solution including site access;
- Adaptability and the flexibility of the system for repair in the event of damage;
- Long term maintenance requirements including the frequency of significant repair works;
- Sustainability of the product focusing on low impact material choices;
- Expertise in the local market with the materials and systems.

When evaluating options it is important to remember the nature of concrete water tanks which have a wet, cool interior, and a hot, dryer exterior which results in differential temperatures and moistures. The three construction materials and tank systems which were identified as the most likely to meet the above criteria and which were further evaluated were the following:

- Option No.1 - Fused Glass Lined Bolted Steel Tanks (AWWA D103)
- Option No.2 - Conventional Cast-In-Place Concrete Tank
- Option No.3 - Prestressed Cast-In-Place Concrete Tank (AWWA D110 Type I)

2.4.1 Glass-Fused Bolted Steel Tank (AWWA D103)

Bolted steel tanks are sent to site as individual steel sheet panels and then assembled to form the tank of the required diameter and height. The tank is constructed upon a concrete base slab which provides a sturdy working surface.

The steel plates require a protective layer due to the materials susceptibility to corrosion. Traditionally steel tanks were painted and epoxy coated but these works required regular maintenance to prevent corrosion. The use of glass-fused-to-steel was developed for tanks more than 70 years ago and has been installed in thousands of municipal water systems.

The glass-fused-to-steel lining is impermeable to liquids and vapors. The bond between the two materials controls undercutting caused by corrosion and offers excellent impact and abrasion resistance. The factory-applied silica glass coating forms a hard, inert barrier for the interior surfaces. The coating can also be applied to the exterior surfaces to guard against weather, corrosion and from which graffiti can easily be removed.

The system relies on cathodic protection system which consists of sacrificial anodes that mitigate corrosion and provide protection to internal submerged surfaces of the tank. The cathodic protection system is incorporated into the tanks warranty. The system is simple, reliable and requires only minimum inspection and maintenance. More information and product brochures on the product have been supplied in Appendix A and a breakdown of the pros and cons of the system are provided in Table 4 below.

Table 4: Pros & Cons of Glass-Fused Bolted Steel Tanks

Pros	Cons
• Low initial capital investment cost. • Fast construction due to premanufactured panels which would minimize reservoir downtime during construction. • Turnkey procurement process with the manufacturer providing the design, material supply and acting as subcontractor during installation. • Construction of by panels minimizes the construction equipment mobilization and concrete truck traffic. • Customizable dimensions and appurtenances to meet project requirements. • If required the tank could be expanded, disassembled or relocated.	• 50 year design life. • Interior glass finish and exterior coating subject to damage during shipping construction. • Maintenance includes the replacement of cathodic protection and failure to complete maintenance can lead to expedited corrosion. • Recoating of the exterior of the tank required every 20-25 years at a cost of ~$125,000. Options are available for glass lined exteriors but these would be subject to damage and vandalism. • Bolt holes and sheet seems have the potential for corrosion and need to be monitored and resealed. • Cannot be buried and needs to be kept clear for visual observation.

2.4.2 Conventional Reinforced Concrete Tank

Reinforced concrete is the standard for reservoir and tank construction across the world due to the durability of the product and adaptability of the materials which can be designed to meet the requirements of most projects. The vast majority of water retaining structures throughout the Lower Mainland is constructed using conventional reinforced concrete designs. Conventional reinforced concrete tanks still rely on reinforcing steel bars to provide the concrete with strength in tension and as such the steel must be protected from moisture. The steel is protected by the concrete but can be corroded through cracks in the concrete and if left unchecked will cause the tank to fail significantly prior to the end of its service life such as the existing Harvey Tank which is in poor condition and according to our records developed leakage issues within 25-30 years post construction.

Although it is not a new means of construction, the technology surrounding conventional reinforced concrete tank design has significantly improved since the time of the construction of the Village's Phase IV and V Tanks in the 1960s. Notably concrete mix designs have been improved to minimize shrinkage cracking and admixtures have been developed which allow the concrete to self-heal over time as retained particles swell to close cracks when hydrated. We have provided a breakdown of the pros and cons of the system are provided in Table 5 below.

Table 5: Pros & Cons of Conventional Concrete Tanks

Pros	Cons
• 100+ year design life. • Industry wide accepted method of construction with local expertise in the Lower Mainland. • Surface finishes are highly durable and require minimal maintenance. • Resilient as concrete mixes perform self-healing to close cracks to prevent leakage. • Design customized to meet exact project requirements and site dimensions.	• Moderate - High capital investment cost • Wall thickness is significant to meet seismic and shrinkage requirements. The extra concrete increases construction traffic and material costs. • Quality and long term reliability of product is largely dependent on concrete supplier and contractor competency. • Typically delivered through design, bid, build procedures which can extend project schedule. • Susceptible to cracking under temperature gradients such as warm ambient temperatures against cold stored water temperature.

2.4.3 Prestressed Reinforced Concrete Tank (AWWA D110 Type I)

Prestressed reinforced concrete tanks are a strand-wound, circular potable water storage tank as defined as Type I in ANSI/AWWA Standard D110. The existing Harvey Tank was constructed of precast panels which were brought to site and then post-tensioned once onsite which has significant vertical joints in between concrete panels. The proposed prestressed reinforced tank is cast-in-place with the wall being constructed in two parts; an interior corewall and an exterior fiber reinforced shotcrete exterior surfacing.

In short, concrete does not have strength in tension and when this occurs the concrete will crack while being held together by the reinforcing steel. The objective of a prestressed tank is to keep the concrete in compression to limit the development of cracks. The interior corewall incorporates vertical prestressing threadbars to counter the vertical bending moments caused by the differential temperature and dryness conditions that will exist between the interior

and exterior of the tank wall. Secondly, the tank is wrapped in prestressing steel strands which provide a circumferential compression on the tank. This feature in combination with vertical compression results in bi-axial compression and will provide superior performance and longevity of the concrete structure.

Due to the prestressed nature of the tank the thickness of the walls and the amount of reinforcing steel is considerably less than that of conventional cast-in-place concrete tanks. The final concrete product benefits from this due to the lack of reinforcing congestion which blocks the flow of concrete, leaving voids in the concrete. Furthermore, the concrete is able to be poured into access windows prevent concrete segregation from tall pours from the top of the wall which further improves the quality of the cast-in-place concrete.
More information and product brochures on the product have been supplied in Appendix B and a breakdown of the pros and cons of the system are provided in Table 6 below.

Table 6: Pros & Cons of Prestressed Concrete Tanks

Pros	Cons
• 100+ year design life. • Mitigates risk of crack development due to keeping concrete in compression and thereby extending service life. • Risk of construction quality issues minimized due to constructability increasing the likelihood of a durable product for the long term. • Narrow wall thickness which reduces construction traffic and material costs. • Surface finishes are highly durable and require minimal maintenance. • Resilient as concrete mixes perform self-healing to close cracks to prevent leakage. • Turnkey procurement process with the manufacturer providing the design and acting as subcontractor during installation.	• High capital investment cost • Specialized machinery required for prestressing of exterior circumferential strands. Clearance around the perimeter of the tank required during construction. • Typically delivered through design, bid, build procedures which can extend project schedule. • Susceptible to cracking under temperature gradients such as warm ambient temperatures against cold stored water temperature.

2.4.4 Recommendations

Based on the review summarized in the previous sections, we compiled a decision matrix which outlines the relative performance of each option in the previously established design criterion. The matrix is presented in Table 7.

The annual cost per year of estimated service life was significantly higher for the glass-fused bolted steel than for the other concrete two options. The conventional concrete is the least costly option, primarily due to uncertainty of costs for specialized equipment and reduced market competition. Due to the high cost of the glass-fused bolted steel we do not recommend this option for the Village.

The two concrete products are comparable in resilience because the estimated service life for two products exceeds 100 years. The prestressed concrete has the advantage of less likelihood of maintenance issues developing due to QA/QC issues. In conclusion, we recommend that the Village proceed with the design of a prestressed concrete tank for the replacement of the Harvey Tank. If the project budget does not allow for the capital expenditure then the prestressed concrete tank could be tendered as an alternate to conventional concrete which would allow the Village to determine their preferred material based on the received bid pricing.

Table 7: Tank Material Option Comparison Matrix

Criterion	Option 1 (Glass-Fused Bolted Steel)	Option 2 (Conventional Concrete)	Option 3 (Prestressed Concrete)
Resilience			
Estimate Service Life	50 yrs.	100+ yrs.	100+ yrs.
Meets Minimum Seismic Design Requirements	✓	✓	✓
Minimize Damage from Seismic Event	✗	✗	✓
Maximize Durability of Finished Surface	✗	✓	✓
Constructability			
Material Re-Use or Remobilization	✓	✗	✗
Minimize Construction Operational Impacts	✓	✗	✗
Minimize Construction Schedule	✓	✗	✗
Local Expertise and Experience	✗	✓	✗
Maximize Locally Sourced Materials	✗	✓	✓
Maintenance			
Minimize QA/QC Issues	✗	✗	✓
Minimize Maintenance Requirements	✗	✓	✓
Ability to Self-Heal Leaks	✗	✓	✓
Method of Manual Leaks Repair	Replace	Patching	Patching
Costs			
Capital Cost	$0.7M	$1.0M	$1.3M
Maintenance Costs	$125k / 25yrs	Minimal	Minimal
Annual Cost Per Year of Service[1]	$20k	$10k	$13k

[1] *Estimated inflation rate of 1% for all future maintenance activities required to meet stipulated service life.*

2.5 Lifecycle Cost Analysis

The lifecycle cost analysis allows the Village to make a more informed decision regarding the selection of the preferred option for water storage facility replacement by adding an economic evaluation of the three proposed servicing options as well as three proposed tank material options. The summary of lifecycle cost analysis for the preferred option is presented in Table 9. Appendix C provides variations of the same table (Tables 9A, 9B, and 9C) based on lifecycle costs associated with all three tank material options. The following assumptions were made in calculating the estimate costs.

Unit Rates
The construction costs for the water storage facilities were obtained based on the estimates received from the potential suppliers and pricing from past projects. Additional $70, 000 was added to the Highway Tank update option to cover possible excavation, aesthetic structures, or new site development. The unit rate for PRV is assumed to be $150,000 per valve. A linear meter of water main is assumed to cost $750m for a 200mm diameter ductile iron water main. These construction values are an estimate and subject to further review and revision.

Annual Operation and Maintenance Cost
The O&M cost was estimated based on the National Water and Wastewater Benchmarking Initiative average maintenance hours for water reservoirs, pressure reducing valve stations, and water mains. Typical O&M annual activities are presented in the Table 8.

Overhaul Maintenance Allowance
This cost is associated with substantial periodic corrective maintenance, which requires maintenance outside the scope of regular preventative maintenance activities but not necessarily a complete replacement of the asset. This Overhaul Maintenance Allowance (OMA) for PRVs and water mains is calculated based on 10% of the capital cost and it is assumed that this corrective maintenance is required every 15 years. The OMA for the water storage facilities is based on 25% of the capital cost and it is assumed that corrective maintenance is required every 50 years.

Net Present Value
To calculate Net Present Value (NPV) 2% annual inflation rate was assumed. Estimate service life was assumed to be Tanks 100 years, PRVs 30 years, and water mains 70 years; similar estimates were assumed in the 2016 IMP.

Table 8: Annual O&M Activities by Asset

Asset	Typical O&M Activities	Estimated Hours Per Year	Annual O&M Cost[2]
Water Storage Reservoir	• Reservoir Security and Maintenance Inspection • Reservoir Draining and Cleaning • Y-Strainer Cleaning and Inspection • Control PRV Tear-Down and Inspection • Vegetation Control • Critical Equipment Corrective Maintenance • Facility and Auxiliary Equipment Corrective Maintenance • Critical Equipment Emergency Maintenance • Facility and Auxiliary Equipment Emergency Maintenance	190 Hours (small tank) OR 280 Hours (large tank)	$8,000 (small tank) OR $12,000 (large tank)
Pressure Reducing Valve (assembly)	• Pressure Reducing Station Monthly Inspection • Pressure Reducing Station Vegetation Control • Y-Strainer Cleaning and Inspection • Basket Strainer Cleaning and Inspection • Control PRV Tear-Down and Inspection • Control Valve Test • Critical Equipment Corrective Maintenance (PRVs) • Facility and Auxiliary Equipment Corrective Maintenance • Critical Equipment Emergency Maintenance (PRVs) • Facility and Auxiliary Equipment Emergency Maintenance	60 Hours	$ 2,500
Water main[3]	• Inspection of Exposed Mains • Mains Flushing • Mains Corrective Maintenance • Mains Emergency Maintenance	0.25 Hours per meter	$ 7.50 per meter

[2] *Calculated based the Village of Lions Bay 2017 fully burdened labour rate of $41.55 per hour*
[3] *Based on per meter of 200m diameter ductile iron pipe*

Table 9: Summary Lifecycle Cost for Three Water Storage Facility Replacement Options

	Construction Cost	Annual Operation and Maintenance Cost	Overhaul Maintenance Allowance	Net Present Value
Option 1 – Full Replacement				
Upgrade Harvey (1.98ML)	$ 1,450,000	$ 12,000	$ 362,500	$ 2,940,000
Update Phase IV (0.10ML)	$ 230,000	$ 8,000	$ 57,500	$ 730,000
Update Phase V (0.10ML)	$ 230,000	$ 8,000	$ 57,500	$ 730,000
Update Highway (0.10ML)	$ 300,000	$ 8,000	$ 75,000	$ 850,000
Option 1 Totals	***$ 2,210,000***	***$ 36,000***	***$ 552,500***	***$ 5,250,000***
Option 2 – Partial Replacement				
Upgrade Harvey (2.18ML)	$ 1,475,000	$ 12,000	$ 368,750	$ 2,980,000
Upgrade Highway (0.10ML)	$ 300,000	$ 8,000	$ 75,000	$ 850,000
Replace Phase IV with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Decommission Phase V	$ 40,000			$ 40,000
Option 2 Totals	***$ 1,965,000***	***$ 22,500***	***$ 458,750***	***$ 4,100,000***
Option 3 – Harvey Only Replacement				
Upgrade Harvey (2.28ML)	$ 1,500,000	$ 12,000	$ 375,000	$ 3,030,000
Replace Phase IV with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Replace Highway with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Decommission Phase V	$ 40,000			$ 40,000
Option 3 Totals	***$ 1,840,000***	***$ 17,000***	***$ 405,000***	***$ 3,530,000***
Optional System Improvements				
Install new water main (400 m of 200mm DI across Alberta Creek)	$ 300,000	$ 3,000	$ 30,000	$ 680,000
PRV Automation for Water Quality Improvement	$ 200,000	$ 2,500	$ 20,000	$ 280,000
Increase Harvey Tank by 0.15 ML to accommodate Magnesia shortfall	$ 225,000			$ 225,000
Optional Total	***$ 725,000***	***$ 5,500***	***$ 50,000***	***$ 1,185,000***

2.6 Requirement for Equalization Tanks Analysis

The Village's steep topography leads significant changes in pressure as every metre of elevation drop results in an increase of 1.42 psi of pressure under static conditions. As a result the Village's system is segregated into 18 pressure zones each with a valve to reduce the pressure from the above high pressure zone down to the lower pressure zone below. Municipal system best practice recommends the use of an altitude valve in combination with anan equalization tank in order to protect the water system from sudden surges in flow and pressure. Transient forces are changes in pressure caused by the momentum of water, which is essentially a non-compressible fluid, and are often referred to as "water hammer". A pressure reducing valve (PRV) can be used without an equalization tank to provide separation between pressure zones but it provides no absorption of transient forces. Furthermore, the "stacking" of PRVs where there are multiple PRVs separating pressure zones in series and without equalization tanks causes further exasperates the issue of transient forces within the system.

On August 22, 2017 AECOM conducted field hydrant flow testing with the primary objective of trying to quantify the transient forces and the resulting impact on the existing Village water system which includes a combination of variety of zones, some which are supplied through a PRVs and others supplied by an equalization tank. The Highway Tank, which is being considered for removal, was tested by drawing flow from a fire hydrant in the PZ75 zone to which is supplies flow. The test results, as shown in Figure 2, found that the pressure in the upstream zone (Res Hyd.2) remained constant during the flow test while the pressure below the tank in the zone with the fire test (Res Hyd.1) was subject to a smooth drop in pressure until the test was concluded.

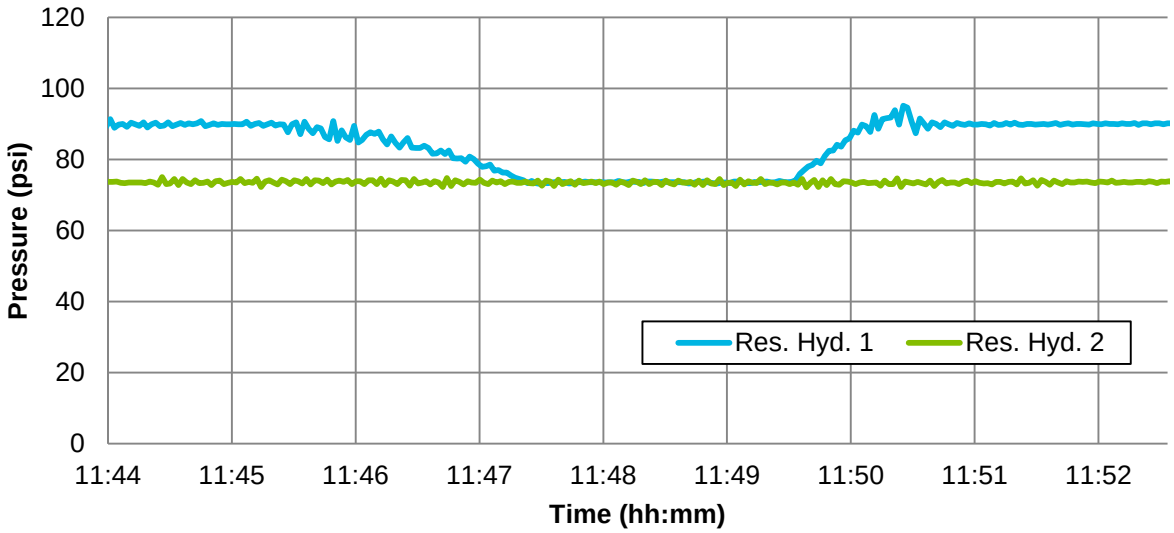


Figure 2: PZ75 Fire Flow Test (Aug 22, 2017)

In contrast to these results we compared them against the test results from the PZ86 zone which does not have an equalization tank and instead has a system of stacking PRVs which cascade flow all the way from Harvey Tank without storage. The test results, as shown in Figure 3, found that the pressure in the upstream zone (Res Hyd.2) fluctuated upwards of 30 psi during the flow test while the pressure below the PRV in the zone with the fire test (Res Hyd.1) was subject to a smooth drop in pressure until the test was concluded. The fluctuation is caused by a rapid opening and closing of the PRV valve as it attempts to regulate pressure in the downstream system which is often described as valve chatter.

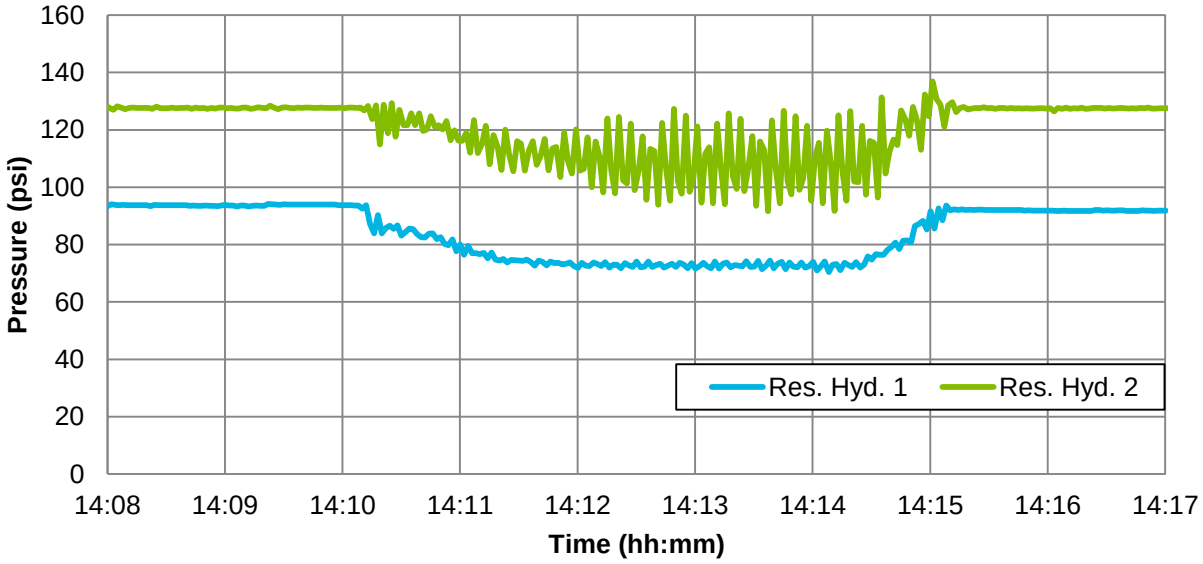


Figure 3: PZ86 Fire Flow Test (Aug 22, 2017)

Cyclical transient loadings caused by valve chatter causes strain on the pipe and therefore reduce the pipe life expectancy. Pipe fatigue will lead to premature pipe failure which within a water system leads to disastrous pipe breaks which can cause a significant risk to both life and property along with service interruptions. To avoid these effects water mains would require premature replacement without sufficient pipe condition data which is also costly to acquire. Water mains are challenging to assess their condition due to their lack of access points and the fact that it is a pressurized system. Although technology in this field has improved significantly in the past decade it is still far behind that of the techniques available for gravity sewer systems and significantly more costly.

Unfortunately there is insufficient data available to determine the extent or frequency of these transient loadings within the Village of Lions Bay water system. Further testing would be required to calculate with certainty the reduced service life of the pipes, hydrants, valves, and other components of the Village water system. In the absence of this information we have estimated a range of costs based on a reduced service life of between 5 – 25% of water mains, valves, hydrants and PRVs within the entire water system as shown in Table 10. The replacement values and estimated service lives were taken directly from the Village of Lions Bay: Infrastructure Master Plan (AECOM, 2016). Based on this analysis it was found that there would be an increase of between $12,000 - $61,000 due to the damage caused by transient forces within the water system.

Table 10: Estimated Annual Costs Due to Damage from Transient Surges

				Annual Premium for Decrease Service Life	
Item	Replacement Value	Estimated Service Life	Annual Renewal Cost	5% Decrease in Service Life	25% Decrease in Service Life
Water mains[4]	$11,760,000	70 years	$168,000	$8,842	$44,210
PRVs	$1,950,000	30 years	$65,000	$3,421	$17,105
SUB-TOTAL	**$13,710,000**		**$233,000**	**$12,263**	**$61,315**

[4] *Inclusive of fittings, valves, hydrants etc.*

We have compared that the cost of installation and maintenance of equalization tanks through the entire Village water system, which would require one tank for each pressure zone. Alternatively, a common practice is to eliminate stacked PRVs within a system and limit the number of PRVs between equalization tanks to one. The estimated annual renewal cost for a the equalization tanks is shown below in Table 11 with the estimated annual cost for each zone to have a tank at $52,000 and with the elimination of stacked PRVs (resulting in 5 total equalization tanks) at $20,000. We have not included land acquisition or other costs beyond the physical infrastructure within this analysis. However, the estimates also assume a 50 year service life for the tank and as discussed in previous sections a 100+ year service life is achievable with concrete structures.

Table 11: Estimated Annual Costs for Equalization Tank Assets

Item	Quantity	Unit	Unit Rate	Replacement Value	Estimated Service Life	Annual Renewal Cost
Tanks (Full Equalization)	13	each	$200,000	$2,600,000	50 years	$52,000
Tanks (Partial Equalization)	5	each	$200,000	$1,000,000	50 years	$20,000

In order to minimize valve chatter and pressure surges within the system it is recommended to install equalization tanks throughout the entire Village water distribution system which, when working in combination with an altitude valve, absorb these transient forces and therefore reducing the pressure variations within the water distribution system. However, based on the financial assessment recognize that a revised objective of installation of enough equalization tanks within the system to eliminate stacked PRVs may be in the best interest of the Village financially.

2.7 Recommended Option

To summarize the three water storage facility replacement options presented above, Table 12 presents a high level overview of the strengths and weaknesses of each replacement option.

Table 12: Strengths and Weaknesses of the Three Water Storage Replacement Options

Replacement Option	Strengths	Weaknesses
Option 1	- Reduced PRV/valve chatter - High initial construction cost - No operational changes for Public Works staff	- Does not address limited available fire flow for ICI users; water main upgrades are required - The maintenance and access to water storage facilities remains a challenge for the village - Highest initial construction and lifecycle cost
Option 2	- Low maintenance requirements for tanks replaced with PRVs - Improved access to critical infrastructure - Reduced O&M costs compared to existing system configuration - Potentially the lowest lifecycle cost when accounting for longevity of the distribution system	- Does not address limited available fire flow for ICI users; water main upgrades are required - Possible PRV chatter in PZ 236 & PZ 160

Replacement Option	Strengths	Weaknesses
Option 3	- Lower maintenance requirements for Highway tank replaced with PRV - Lowest initial construction cost and operational costs	- Does not address limited available fire flow for ICI users; water main upgrades are required - Possible PRV chatter in PZ 236, PZ 160 & PZ 75 - Cascading PRVs is not recommended without confirmation of system operations which may lead to PRV chatter and pressure surges which reduce the longevity of the water distribution system components

Based upon the aforementioned analyses, AECOM recommends the Village proceed with the implementation Option 2 including the following:

- Replace the Harvey and Highway Tanks with Prestressed Reinforced Concrete Tanks;
- Remove the Phase V Tank and redefine the PZ 271 Zone;
- Remove the Phase IV Tank and replace with a permanent PRV station.

This option will reduce the O&M requirements for servicing existing hard-to-reach storage facilities while not diminishing the existing level of service to the Village. We also recommend that the following projects be considered for operational enhancements and constructability as they are related to the work but not required:

- If Magnesia Tank replacement is not to be considered in near term, consider adding 0.15ML of capacity to the Harvey Tank to compensate for fire flow storage shortfall in the Magnesia Tank. Storage would not be functional until a connection on Mountain Drive between the Magnesia Creek and Harvey Creek supplies was completed. Further analysis would be required to determine which linear pipe upgrades, if any, would be required to meet system requirements under this configuration;
- Implement water quality improvements including operational changes which may include automation of a connection on Mountain Drive between the Magnesia Creek and Harvey Creek supplies to allow for further circulation of tank water to reduce water age and stagnation within both the tanks and the system;
- Replace the 200mm water main from Upper Bayview Road to Timbertop Road including the Alberta Creek crossing to remove the redundant and challenging to access portions of the pipeline which currently lead to the Phase V tank site;
- Replace the asbestos cement water main on Upper Bayview Road as there are risks associated with modification of the pipe during the new tie-ins which would be completed during the modifications of the pipe network for the Phase IV replacement PRV;
- Develop a long term strategy for construction of equalization tanks throughout the system to eliminate stacked PRVs and in turn reduce pressure surges, pipe fatigue and the risk of water main breaks.

Appendix A

Glass Fused Bolted Steel Tank Supporting Information

CST

THE GLOBAL LEADER IN STORAGE AND COVERS SOLUTIONS


CST

CST

CST is the unrivaled global leader in storage tank and cover solutions. A dynamic combination of the world's leading coated steel tank and aluminum cover companies, CST is home to world class brands including Aquastore®, Harvestore®, HydroTec®, BulkTec® and PetroTec®, Vulcan, Temcor and Conservatek.

CST promises the complete package of people, products and technical expertise to fulfill customer needs. You can trust CST to deliver the right tank and cover recommendation for the right long lasting solution. Count on CST for a new level of excellence in storage tanks and covers.

Evolution of CST

1890's

Columbian Steel Tank Company

1940's

A.O. Smith Corporation

Harvestore

1960's

Temcor

Weaver Reclaimer Systems

Aquastore Tanks & Domes

1970's

Conservatek

Peabody TecTank

Vulcan Tank

1990's

Columbian TecTank

Engineered Storage Products Company

2000's

CST

CST STORAGE

CST Storage offers the only complete product line of advanced tank coatings. CST Storage is better positioned to efficiently provide its global customers with the right tank for the right application, no matter the coating – Vitrium™ glass-fused-to-steel and OptiBond™ epoxy coating system. Complete Storage Solutions are backed by engineering resources located in multiple centers of influence to provide project expertise. CST Storage brings the most experienced team of construction and field service personnel through our network of dealers and representatives to delivers successful installation from start to finish.

With a legacy of almost 120 years and over 250,000 tanks in 125 countries, no other company can match CST's design, manufacturing and construction experience.

CST COVERS

CST Covers is the worldwide leader in designing, manufacturing and constructing custom aluminum covers and structures for municipal and industrial storage and architectural applications. CST Covers represents the combined proud traditions of the world's two leading aluminum cover companies Temcor and Conservatek. Together we have supplied over 15,000 covers in more than 50 different countries.

CST Covers offers multiple structural, high strength aluminum design solutions including domes, vaults, extruded flat covers, formed plank covers, truss supported covers, space frames as well as custom products specifically designed for customers unique applications.

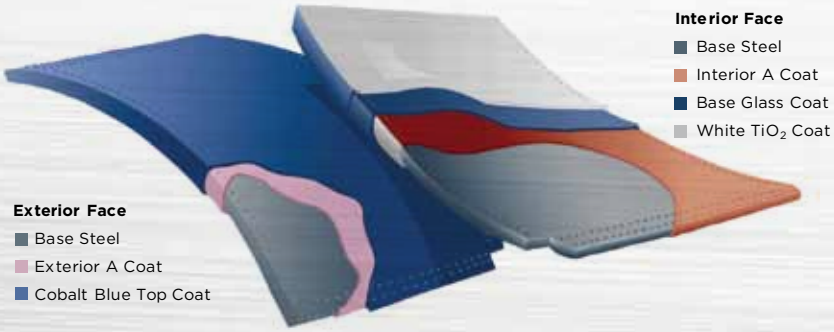
WORLD CLASS COATING TECHNOLOGIES

All CST tanks are engineered and manufactured in factory controlled environments. The result is precise steel panel production teamed with optimized coating processes. CST has invested millions in completely modernizing and automating fabrication lines in ISO 9001 certified facilities. CST's state-of-the-art operations deliver the best coated steel tanks on the market.

VITRIUM GLASS-FUSED-TO-STEEL

Vitrium™ glass-fused-to-steel, featured in Aquastore® and Harvestore® brand tanks, is the premium coating in the storage tank market. It is a single, strong, integrated glass and steel material fused together at 1,500° F (815° C) in a controlled process furnace. The physical properties of Vitrium are specially suited for municipal and industrial liquid applications. The hard, inert barrier on both the interior and exterior tank surfaces guards against corrosion. Impermeable to liquids and vapors, it controls undercutting caused by corrosion and offers excellent impact and abrasion resistance.

Physical Properties
Vitrium Glass-Fused-To-Steel Technologies

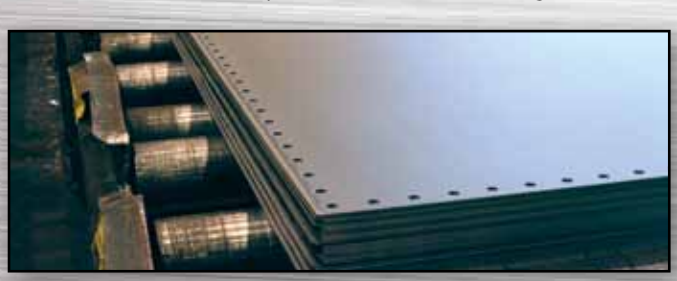


Vitrium™

Vitrium technology combines the outstanding chemical and physical resistant properties of titanium dioxide-enhanced (TiO_2) glass with a highly engineered, ultra-fine glass bubble structure for durability and flexibility. Vitrium glass-fused-to-steel coatings range from 7-15 mils/180-380 microns exterior and 10-18 mils/260-460 microns interior in thickness.

Glassing Process

A new, state-of-the-art porcelain enameling furnace was recently installed by CST. As the world's largest porcelain enameling furnace, it improves quality, saves energy, increases production and speeds delivery of glass-fused-to-steel products to customers. In all, five advanced temperature control zones regulate the coating process to produce high quality sheets every time.



Stage 1: Steel panels are prepared to specification

Stage 2: Panels are coated with Vitrium glass coating

Stage 3: Glass coating and steel panels are fused together at 1500° F (815° C)

Stage 4: Glass-fused-to-steel sheets are quality tested and prepared for shipment

AQUASTORE – GLASS TANKS WITH A HEART OF STEEL

Aquastore tanks are the premium choice for storage in the municipal and industrial water, wastewater and industrial liquid markets. Proven in the field for more than 30 years, no other tank lasts longer or has greater lifetime value than an Aquastore tank.

Consider these advantages:

- NEVER NEEDS PAINTING
- Minimal maintenance required over tank life
- Will not corrode or rust
- A guaranteed tank performance warranty
- Turn key services from approval drawings to tank testing
- No need for cranes or other large equipment for construction
- Can be constructed in remote or secluded locations
- Minimal environmental construction site impact
- Minimize lost construction days associated with weather delays or field-applied coatings
- Design for future expansion or relocation
- Remove graffiti easily
- Lowest life cycle cost

AQUASTORE® Tanks & Domes

Glass Chart

Category	Specifications
Outside Sheet Color	Cobalt Blue, Desert Tan, Forest Green, Sky Blue, White
Nominal Thickness	Interior: 10-18 mils, 260-460 microns Exterior: 7-15 mils, 180-380 microns
Service Range	140° (60° C) @2-11 pH–subject to verification, depending on specific products stored
Abrasion Resistance	Taber-8 mg loss (CS-17, 100g, 100 cycles)
Elasticity	Young's Modulus 12 x 10^6
Permeability	Impermeable to gases and liquids within normal operating temperature ranges
Thermal Conductivity	20.4 BTU in/hr ft^2 °F
Cleanability	Smooth, inert, glossy, anti-stick
Hardness	6.0 Mohs
Adherence	Over 5,000 psi to base steel
Impact Resistance	24 inch-lb.
Corrosion Resistance ASTM B-117	Excellent, virtually unaffected by most waste waters, brines, sea water, sour crude, salt spray, organic and inorganic chemicals
Continuity Testing	In accordance with EN 28765, up to 1500V

THE CST OPTIBOND EPOXY COATING SYSTEM

CST utilizes premium epoxy coating technology that provides maximum corrosion resistance and long tank life. Our experience has led to continuous technology and process improvements that has resulted in the finest epoxy coating available in the storage tank industry. The OptiBond™ Epoxy Coating System is derived from years of in-field experience and performance data.

A PROPRIETARY PROCESS

CLEANING

Stage 1:
- Parts are degreased and rinsed
- Precisely controlled hot air drying and pre-heating at an optimum temperature for a precision coating process

Stage 2:
- Parts surfaces are then blasted with engineered grit material
- Rugged 3-D surface topography is created for better powder coating acceptance and increased durability and long-term coating performance
- A high velocity air curtain removes residual particulate

COATING

Stage 3:
- Parts are powder coated with our proprietary electrostatic booth within precise environmental controls
- Parts are cured at a controlled temperature to maximize the cross-link bonding of the epoxy particles

Stage 4:
- Uniquely engineered Polyurethane topcoat is applied for UV protection on exterior surfaces for extra durability and longevity
- Sheets are cured at controlled temperature to yield the final product

QUALITY CONTROL

Parts are subjected to a rigorous quality control inspection with a high voltage defect testing procedure. This will identify any defects, inclusions and thin areas in the coating. No other company has a higher process and quality control standard than CST!

OptiBond™

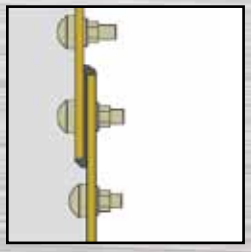
HYDROTEC, BULKTEC AND PETROTEC BRAND TANKS FEATURE THE CST OPTIBOND EPOXY COATING SYSTEM

HydroTec® tanks deliver the highest quality at the lowest cost per gallon. CST has perfected HydroTec tanks to be the most economical choice in municipal and industrial liquid storage without skimping on tank value and durability.

Expansive engineering capability and unmatched design experience make BulkTec® tank systems the best option to contain dry bulk materials. BulkTec tanks systems are manufactured to exact requirements for maximum abrasion resistance and smooth material flow (mass or funnel). Custom components and factory-welded configurations are also available.

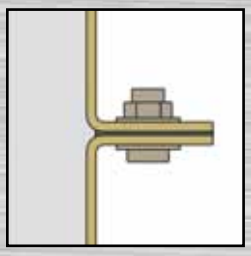
CST originated its business in the oil industry back in 1893 by pioneering the use of bolted steel storage tanks for petroleum applications. Today, CST is the only monogrammed API-12B tank manufacturer in the world. PetroTec® tanks are custom designed to meet the rigorous conditions associated with complex and volatile substances like petroleum.

OPTIBOND EPOXY TANK DESIGNS



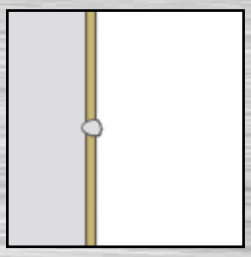
Flat Panel Bolted

- Leading design for bolted steel tanks around the world
- Manufactured, erected and in operation up to three times faster than field welded or concrete applications
- Equipped to handle large volumes up to 6,000,000 gallons (22,712,470L) and beyond



Chime Panel Bolted

- Economical
- Features factory formed flanges at horizontal seams for added structural strength
- Special gaskets and sealants create leak-proof joints
- CST has the only API-12B monogrammed chime panel bolted tank design on the market



Factory Welded

- Available in sizes that are 6′ (1.83m) to 15′ (4.57m) in diameter and up to 85′ (25.9m) tall
- Taller units available in multi-piece designs
- Shipped as one unit or multi-piece units
- Can be specified with internal and/or external factory coating
- Mass or funnel flow loads
- Custom engineering and quick fabrication

GALVANIZED TANKS

Galvanized tanks are a cost effective way of storing water when other types of tanks are not practical. Constructed of quality galvanized steel using quality controlled processes, these types of tanks can be supplied with a roof cover, galvanized access ladder and platform, and inlet/outlet connections. Insulated walls and roof cover are also available. CST is an FM and LPCB approved manufacturer.

CYLINDRICAL

Cylindrical galvanized tanks are constructed with horizontally oriented galvanized sheets. They are manufactured from mill galvanized steel or hot dipped steel in accordance with the customer's specifications including ASTM, ASME , BS EN 10204 or BS EN 1461:1999 standards. Cylindrical galvanized tanks can also be sealed using liners manufactured from either EPDM or BUTYL synthetic rubber membranes. Liners manufactured from BUTYL rubber have received approval from the UK Water Regulators Advisory Scheme (WRAS) in accordance with BS6920, for use in the storage of potable water.

RECTANGULAR VERSATANK

VersaTank's® rectangular shape offers design versatility enabling sprinkler water storage tanks to be installed where traditional cylindrical designs cannot easily be accommodated. Almost any shape can be designed with obstructions such as building support columns easily encapsulated within the tank. The sheets are assembled on site using lap joint and galvanized silo bolts. VersaTank is supplied with a galvanized corrugated low profile roof cover that is plastic coated on the external side.

WELDED TANKS

CST welded tanks are fabricated from epoxy factory-coated steel, aluminum or stainless steel at our ISO-Certified manufacturing facility. CST's special tank outfitting facilities can assemble all necessary equipment in and on the tank and completely test the entire system before shipping throughout the world.

CST also offers Component-In-Tank (CIT) solutions for welded tanks. CST engineers can design welded tanks to support internal equipment for application needs.

Standardized manufacturing of CST welded tanks ensure process consistency and enhanced product quality. No other company can match CST's global presence, its ability to fully outfit a tank before it is shipped and worldwide service.

CONSTRUCTION

The ability to provide a customer with a storage tank, cover or architectural solution does not end with merely manufacturing and delivering the components. CST's global team of channel partners as well as CST's own crews are capable of constructing our products and servicing them throughout their life.

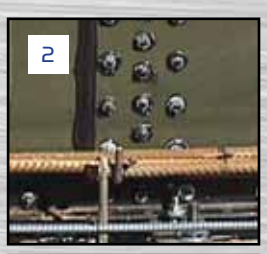
FLAT PANEL TANK CONSTRUCTION

1. First ring of panels and roof are safely constructed at ground level
2. Tank is jacked up and successive rings are constructed
3. The final ring is constructed and tank is lowered onto foundation ring

CHIME PANEL TANK CONSTRUCTION

1. First ring of panels is constructed directly on the foundation
2. Successive rings are constructed by craning panels on lower rings
3. Cover is constructed on the ground and craned into place

FOUNDATION DESIGNS



Foundation designs are done in-house and are customized to customer needs and storage application. Depending on tank specifications, the typical foundation can be one of the following.

1. Slot Mount

Used for lower profile tanks, particularly suited for wastewater treatment applications

2. Curb Mount

Used for lower profile tanks, well suited for tower mounted storage tanks

3. Embedded Starter

Used for larger municipal and industrial applications and higher seismic applications

4. Modified Starter

Combines Embedded Starter for large tank and higher seismic features with Slot Mount convenience

COVERS

CST Covers is the worldwide leader in designing, manufacturing and constructing custom aluminum covers and structures for architectural, environmental and industrial applications. With the proud heritage of Temcor and Conservatek, CST Covers offers multiple aluminum design solutions including domes, flat covers, vaults and space frames. CST's professional engineering staff will design the right customer cover solution for your application.

WHY ALUMINUM?

The unique properties of aluminum make it far superior to other materials and alloys used for covers due to its:

- **Corrosion Resistance:** Aluminum is inherently corrosion resistant versus other alloys. It will last the lifetime of the structure and will not need to be painted or repainted for protection from the atmosphere.
- **Low Lifetime Maintenance Cost:** With no corrosion or the need to repaint to protect the structure over time, there is little-to-no maintenance costs associated with an aluminum dome.
- **Clear-Span Capability:** Aluminum's lightweight characteristics allows for larger clear-span cover capability than structures utilizing steel, concrete and other materials.
- **Fast & Low-Cost Construction:** Creative design and lightweight components provide for installation in 1/3 the time it takes to install other cover systems. Less time, labor and equipment needs combine for a low total cost of installation.
- **Design Flexibility:** Aluminum's excellent strength-to-weight ratios and creative component design yield covers and structures that cannot be achieved with other materials.

ALUMINUM DOMES

An aluminum dome's superior structural design gives it many advantages. Using proprietary variations of geodesic geometry, our aluminum domes are noted for their ability to meet exacting live load requirements by providing greater stiffness and strength, pound-for-pound, than any other dome geometry system.

CST domes can be designed for snow loads of up to 165 pounds (74.84kg) per square foot and wind loads of more than 150 mph. And, our unique panel design is specifically engineered to support loads as much as 500 pounds (226.8kg) on any one square foot. CST's professional engineers can design domes as large as 1000 feet (304.8m) in diameter or greater. They are used in a variety of applications including:

- Water
- Wastewater
- Petrochemical Terminals
- Bulk Storage Facilities
- Architectural Structures

CST cover systems are supported by engineering expertise that recognizes each dome system boasts its own unique characteristics. The result is cost-effective designs that allow for error-free fabrication and construction.

Material Comparison Chart

Aluminum vs. Alternative Materials	Aluminum	Steel	Concrete	Fiberglass
Corrosion resistance	●		●	
Resistance to ultraviolet and ozone degradation	●	●		
Will not rust, spall or tear	●			
Clear span capability	●			
Low profile construction capability	●			
Simple and fast construction	●			●
Low lifetime maintenance costs	●		●	
Easily customizable for accessories and penetrations	●			

FLAT COVERS

Our innovative clear span aluminum flat cover roof systems can help wastewater and other facilities control odors and provide a safe working environment for operators. They are built to withstand harsh, humid treatment plant environments. CST's flat cover roof systems require little to no maintenance and can be easily retrofitted with an array of appurtenances that allow them to interface—not interfere—with plant equipment and operations. They can be manufactured in a wide variety of shapes and sizes without compromising their precise fit and performance.

Our flat panel covers are designed to be self-supported (clear span) or supported with beams and trusses. CST Covers has multiple design configurations to choose from depending on your application:

EXTRUDED FLAT PANEL ALUMINUM

Our extruded panel cover design is available in clear spans up to 18 feet (4.57m) and custom designed to meet your project's specific functional and design loading requirements. All aluminum design constructed of 6061-T6 and 6063-T6 aluminum structural members and 6063-T6 sheets ensures quality, durability and longevity.

FORMED FLAT PANEL ALUMINUM

Our formed panel cover design is available in clear spans up to 30 feet (9.14m) and custom designed to meet your project's specific functional and design loading requirements. By using quality 5052-H32 aluminum panels and 6061-T6 structural members along with the proper sealant and gaskets, CST Covers ensures ultra-low maintenance for the life of the cover.

Flat Cover Features

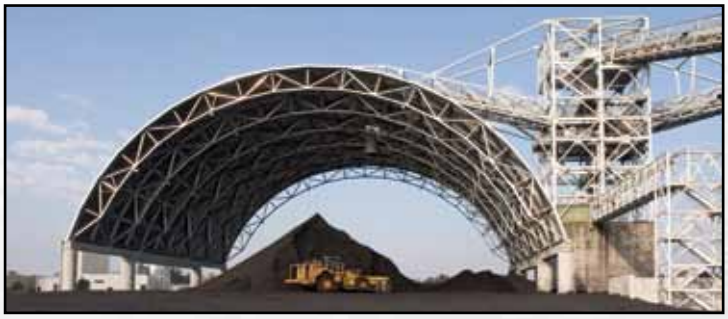
Feature	Extruded Cover	Formed Cover
Removable	●	●
Gasketed panels	●	
Reduced air volume	●	●
Slip resistance	●	●
Low deflection	●	
Lifting Handles/Devices	●	●

CUSTOM COVERS

CST Covers has designed, engineered and manufactured many types of specialty covers over the past 50 years for all types of unique applications. The design flexibility and strength of aluminum allow us to create large truss supported devices for basins of virtually any size and shape. We have created custom covers for all types of raw material storage. No matter how unique your application demands, CST Covers can custom design the right solution.

VAULT COVER

CST custom aluminum vaults can be designed to meet the demands of almost any bulk storage application. Aluminum is the ideal material to handle outdoor applications where the entire structure is exposed to the elements. CST vaults are designed to accommodate many different reclaimer system used in bulk storage facilities.



RESERVOIR COVER

Large water basins and reservoirs are a particularly difficult challenge to cover effectively to meet surface water regulations. CST aluminum specialty covers have been effectively designed to cover some of the largest water reservoirs as well as non-standard shapes. You don't need a new reservoir, you just need the right cover solution.

CONSTRUCTION

CST aluminum domes can be constructed in a variety of methods. The most common are outside-in, used mainly with jack-constructed storage tanks and inside-out, where the dome is constructed from the center outwards and is lifted into place. Certain specialty covers are constructed with proprietary jacking and crane systems specifically designed for fast, easy and safe construction of your aluminum dome.

INSIDE-OUT COVER CONSTRUCTION

1. Inner frames and panels are constructed and raised by a pole crane
2. Remaining frames and panels are constructed outward until dome is complete

OUTSIDE-IN COVER CONSTRUCTION

1. Outside frames and panels are constructed directly on the walls of the structure
2. Frames and panels are constructed inward until dome is complete

ARCHITECTURAL APPLICATIONS

CST aluminum covers offer unique options for architectural applications. Advancements in lightweight, high-strength aluminum allow for a wide variety of configurations and cover options. Proprietary systems like OMNI*HUB® and GEO*HUB® allow for novel 2D and 3D space frame solutions while proven dome and truss systems have long been the global standard for large cover applications. CST has the ability to bring architects' and engineers' cover concepts to reality through products, engineering, precision manufacturing and a reputation for durability and service.

Arts & Science

Leisure & Gaming

Social Service

Transportation

Signature & Custom Services

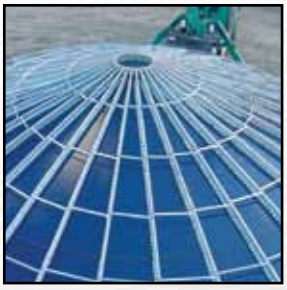
OTHER ROOF AND COVER OPTIONS

CST offers a full line of steel membrane roof options. Depending on the application, CST is your one stop source to fulfill almost any coated storage tank roof need.

Steel Roofs

Sloped Steel Roofs
A very common and economical roof design when no design pressure is required and under standard roof loads. It can be epoxy coated, stainless steel or other alloys as specified. Large diameters can use multiple column supports.

Trough Deck Roof
A free span truss support roof designed to keep out debris. Designed for low roof loads. Can be column supported in larger diameters. The trough deck design is an economical choice when design specifics allow for its application.



Externally Supported Roof (ESR)
The most common roof design in the industry with a smooth internal roof surface and no rafters. Used when moderate to high pressure or vacuum design limits are anticipated. It is also preferred when there are heavy load conditions expected from mixers and/or other ancillary equipment is installed in the cover.

Knuckle Roof
An option for smaller diameter storage tanks, a knuckle roof is best suited for lighter pressure and vacuum applications with no load bearing requirements. They are fabricated with glass-fused-to-steel coating or stainless steel to provide excellent gas zone longevity.

Membrane Covers

Single Membrane Covers
Designed to operate in applications with low gas pressures where there is not a design requirement for a fixed steel or aluminum cover. Generally requires a pole and strap support system to keep membrane elevated above slurry.

GeoFrame™ Supported Membrane Cover (GSM)
Unique proprietary design incorporates a geodesic aluminum strut support frame in lieu of post and struts provides a clear, obstruction-free cover. Used in single and dual membrane configurations with low-medium pressures.

Dual Membrane
Designed to operate in applications with low to moderate gas pressures where there is not a design requirement for a fixed steel or aluminum cover. Multiple layers and optional center support structures are utilized depending on design considerations.

Membrane Gas Holders
Gas holders are commonly used in conjunction with other storage vessels to store and regulate gas from the process. The gas can then be regulated and delivered to a power generation process, compressor or flare.

APPLICATIONS/MARKETS SERVED

Potable Water

- Above ground storage tanks
- Composite elevated storage tanks (CET)
- Aluminum geodesic domes
- Reservoir covers
- Flat cover systems for all size storage tanks and basins
- Desalination storage tanks and covers
- Municipal and industrial applications

Wastewater

- Storage tanks for clarifiers, trickling filters, aeration, flow equalization and sludge
- Sequencing batch reactor tanks (SBR)
- Storm water retention storage
- Aluminum domes and flat covers for all types of storage tanks and basins
- Launder covers

Industrial Liquid

- Bolted steel storage tanks
- Welded silos for wide variety of industrial liquids
- Steel sloped, trough deck and knuckle roofs
- Aluminum domes and flat covers for all types of storage tanks

BioEnergy

- Complete line of storage tanks and covers for anaerobic digesters
- Storage tanks and silos for biofuels
- Storage silo and reclaimer systems for biomass handling
- Dual membrane and steel tank biogas storage systems
- Custom engineered to meet developer specifications

Dry Bulk

- Bolted steel storage tanks for all types of industrial mining, minerals and agricultural dry bulk materials
- Welded steel silos for bulk material processing
- Custom aluminum structures for large bulk storage and conveying systems
- Drive-through and train-through designs
- Domes for bulk terminal storage facilities
- Reclaimer systems for non-free-flowing materials

Petroleum

- API storage tanks for exploration and production
- Drilling fluids and liquid chemicals
- Frac water storage, recycling and waste processing
- Frac sand storage and processing
- Aluminum domes and covers for terminal storage tanks of any material/type construction

Power Generation

- Demineralized water storage
- FGD chemical process and storage tanks
- Liquid fuel storage tanks and silos
- Process water and wastewater handling
- Vault covers for coal storage and other fuels
- Aluminum domes for fuel conveying equipment

Fire Protection

- Sprinkler system water storage
- Industrial and commercial facilities
- Combination potable and fire protection reservoirs
- Cylindrical and rectangular storage solutions

Agriculture

- Grain and haylage silos for feeding operations
- Unloaders for feed processing
- Slurry holding and processing tanks
- Storage tanks for dry and liquid fertilizers and additives
- Tanks and covers for digesters and biogas production

ACCESSORIES

LADDER, CAGE AND PLATFORM

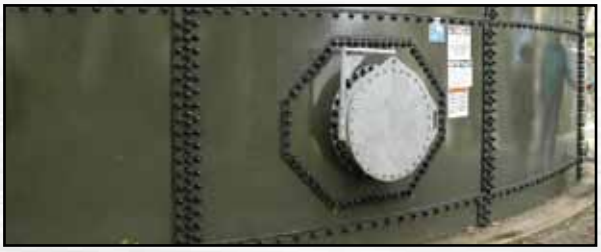
Tank ladders are constructed of aluminum rails and rungs with hot-dip galvanized cages and step off platforms. Ladders with locking safety cage doors are available.

GRAVITY VENTS

CST tank gravity vents are designed to allow for air exchange during filling and emptying. They are equipped with corrosion-resistant bird and insect screens.

SIDEWALL MANWAYS

Tank manways are designed in accordance with AWWA D103 standards. They are 24 inches (61 cm), 30 inches (76 cm) or 36 inches (91 cm) in diameter and are manufactured with hot-dip galvanized or stainless steel.



HANDRAILS AND WALKWAYS

Hot-dip galvanized handrails and walkways can be constructed on tanks and covers to allow access. All are designed to meet required worker safety specifications.

DORMERS

Dormers can be included as part of CST aluminum cover designs for those applications that require regular entry. Roof and sidewalls are all constructed from aluminum. Doors are available in corrosion resistant materials.

SKYLIGHTS

Skylights are available for insertion into CST aluminum cover designs when natural light is needed. Skylights are manufactured from clear and durable materials to withstand the elements.

Other accessories include staircases, nozzles, baffles, level indicators and cathodic protection in addition to many others options.

WEAVER RECLAIMER SYSTEMS

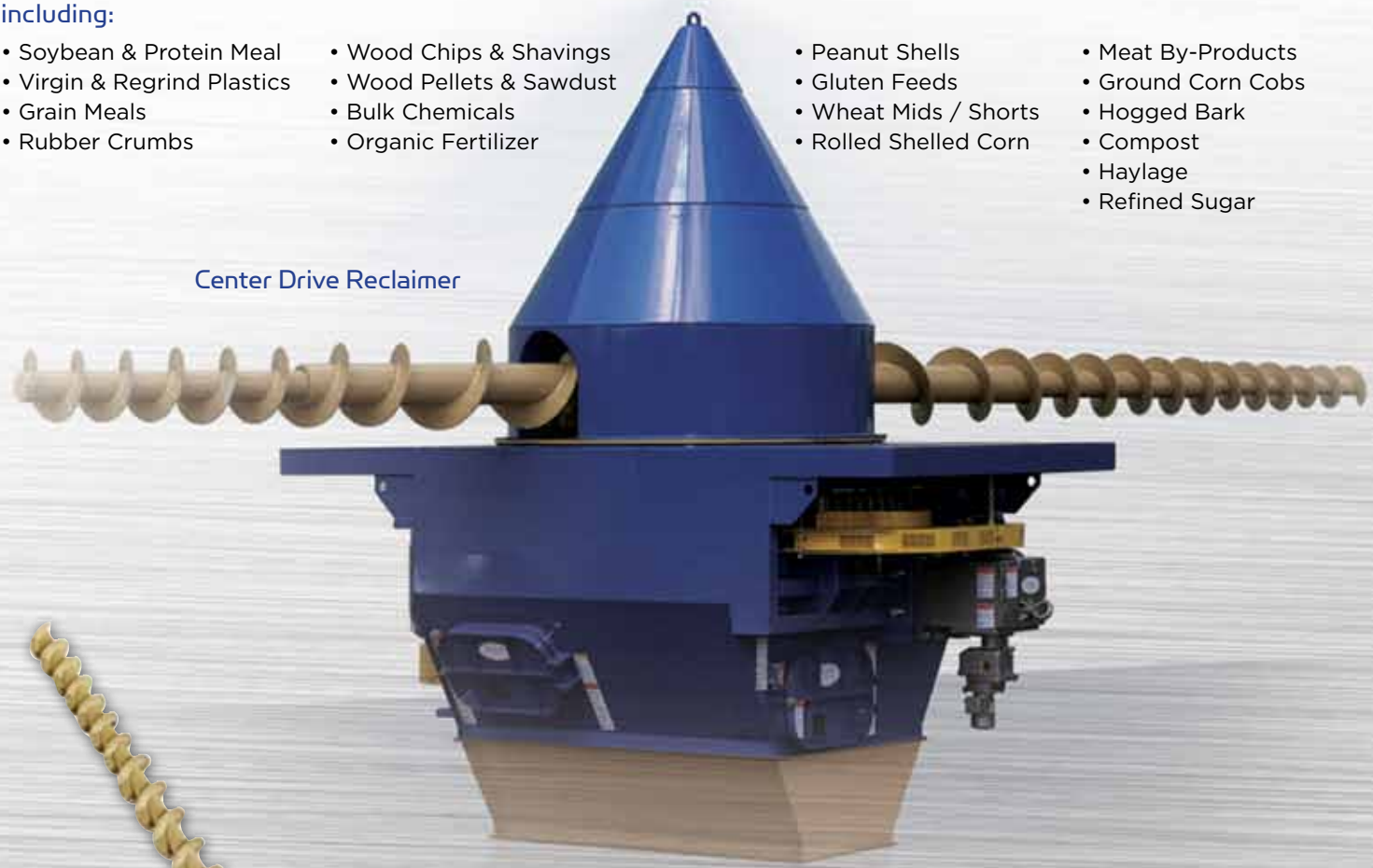
CST Weaver Reclaimers have been performing in industrial applications since 1962. Combined with the vast CST tank, silo and cover product lines, we provide our customers with a complete storage and reclaimer system that is unmatched in the industry.

The Weaver Reclaimer product line includes center drive, ring drive and conical hopper configurations that will meet the needs of almost any tough storage and discharge application. CST's professional engineering staff will work you to pick the right configuration and model of reclaimer to team with our industry leading storage silos for a system that will perform to your specifications.

Weaver Reclaimers and CST dry bulk silos have been field-proven with hundreds of different materials including:

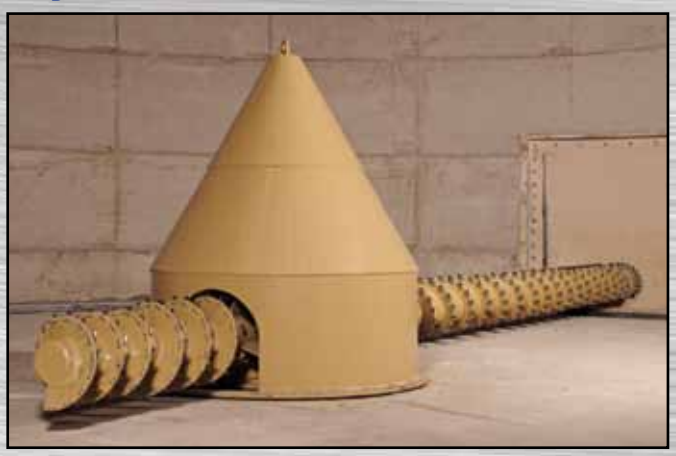
- Soybean & Protein Meal
- Virgin & Regrind Plastics
- Grain Meals
- Rubber Crumbs
- Wood Chips & Shavings
- Wood Pellets & Sawdust
- Bulk Chemicals
- Organic Fertilizer
- Peanut Shells
- Gluten Feeds
- Wheat Mids / Shorts
- Rolled Shelled Corn
- Meat By-Products
- Ground Corn Cobs
- Hogged Bark
- Compost
- Haylage
- Refined Sugar

Center Drive Reclaimer



Conical Silo Reclaimer

Ring Drive Silo Reclaimer



WORLDWIDE AVAILABILITY

CST Global Manufacturing and Offices

When it comes to coated tanks and aluminum covers, you get the highest engineered quality, best service, longest product life and greatest value from CST. Contact CST for all your global tank and cover requirements.

CST Global Headquarters
9701 Renner Boulevard
Suite 150
Lenexa, KS 66106 USA
Phone: +1-913-621-3700
Fax: +1-913- 621-2145

Go to CSTIndustries.com
for information on sales service offices.

CST

Edgecoat II™

Technical Data Sheet

CST

AQUASTORE®

EDGECOAT II™ is a result of CST's commitment to an ongoing product development and improvement program. This continuous innovative Edgecoat technology is the ONLY process in the world that provides optimum glass encapsulation on all (4) four sides of the sheet edges. CST took the best Edgecoat technology in the world and made it better with Edgecoat II.

Following Porcelain Enameling Institute guidelines (PEI-101), Edgecoat II™ sheets are mechanically rounded to specific radii that provides maximum glass adhesion to steel. The combination delivers the maximum corrosion resistance of Vitrium™ glass coating with the greatest protection on every sheet.

QUALITY ISO 9001 CERTIFICATION

PROUDLY MADE IN AMERICA

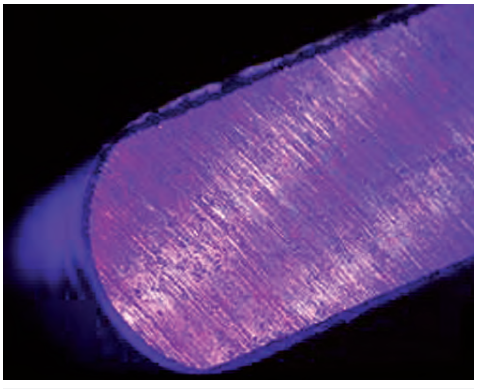
Advancement in
Coating Technology

CST

	Edgecoat II™ - NEW	Others
Sheets	All rectangular sheets (including starter sheets and floor panels)	None
Edge Profile	Engineered radius per Porcelain Enameling Institute guidelines (PEI-101)	None
Edge Coating	5 mils of glass coating	None

EDGECOAT Specification Detail:

Edge Coat: Sheet edges are rounded in profile per Porcelain Enameling Institute Technical Manual PEI-101 to enable the same glass coating to all (4) four sides of the sheet and provide full encapsulation of the sheet edges with the optimal glass thickness for full sheet edge protection.

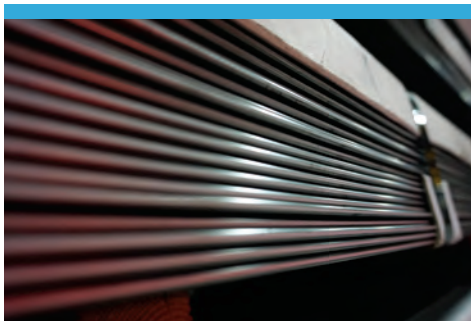


Cross Section Photo of Rounded Edge

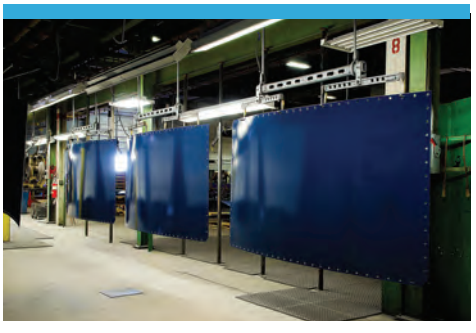
Quality

In the mid 1990's, CST recognized the necessity of sheet edge protection and that sealant/caulking was not a sufficient means of protecting the edges. With a significant investment in research, engineering and state of the art manufacturing technology, the FIRST and ONLY Edgecoat system was developed. CST is the ONLY bolted tank company that provides this process and this level of product quality.

CST continues to invest in the highest level of R & D for product improvement. Our customer commitment remains to provide the best quality product available in the market today for all water and wastewater applications.



Engineered Edge



5 Mils Glass Encapsulation on Every Sheet Edge

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Call 815-756-1551 or visit us online at aquastore.com to find an authorized dealer near you.

QUALITY ISO 9001 CERTIFICATION

PROUDLY MADE IN AMERICA

AQUASTORE®

READ 2016 PUBLISHED CASE STUDIES HERE

WHAT'S INSIDE MATTERS

DON'T SETTLE FOR LESS THAN THE BEST

SPECIFY VITRIUM™ PREMIUM TiO_2 TECHNOLOGY

The interior of ALL Aquastore® tanks feature proprietary Vitrium™ coating technology enhanced with titanium dioxide for the toughest glass available.

GET THE QUALITY YOU DESERVE

- Tough TiO_2 glass formulation provides longer life
- White interior is easier to inspect than darker coatings
- Electrostatically applied base coat application ensures consistent quality
- Factory certified "holiday-free" sheets
- Designed for use in both cold and hot climates
- Designed, fabricated, shipped and supported within the USA

AQUASTORE®

Call today **(815) 756-1551**
or visit **aquastore.com**

Never Tapped Out: Tanks Withstand the Test of Time

Take a drive down I-65 south of Nashville and about the time the strains of country music give way to a chorus of songbirds and crickets you'll know you've crossed the line into Marshall County, Tennessee. Towns like Chapel Hill, Cornersville, Petersburg and county seat Lewisburg dot the map, serving up the charm and peaceful existence of rural America just an hour from Nashville's bustling urban center.

35-year-old Aquastore Tank

Marshall County is named for Supreme Court justice John Marshall, formed in 1836 when parts of four counties were joined together. Its residents display a reverence for history—as evident in the antebellum home of Confederate Gen. Nathan Bedford Forrest, the 1913 Dixie Theater, the county courthouse built in 1929 and the Ladies Rest Room, once a quiet haven in the county seat of Lewisburg where women from rural areas could enjoy rest and relaxation.

This is a place where "built to last" means something. And while historic landmarks draw widespread appreciation and praise, other structures are just as enduring and as important. Like the massive tanks that help transfer the county's water supply from the source to the tap. The Aquastore® tank is the unsung hero of Marshall County because it performs an essential service day-in, day-out, and year after year while asking very little in return.

The Marshall County Board of Public Utilities chose Aquastore for the first time in 1981 and never regretted the decision. In fact, they came back for more. When it comes to servicing the county's 31,000 residents, the utility puts its trust in three Aquastore tanks that carry 555,619 gallons of capacity. The tanks are 35, 15 and 3 years old and you'd have a hard time telling the oldest from the newest.

Take a closer look at Marshall County's tanks and you'll see that a tank isn't just a tank. There's a big difference.

While concrete tanks frequently leak and steel tanks suffer corrosion, Aquastore tanks never show signs of aging because they're built by a patented glass-fused-to-steel process that makes them airtight and durable.

"We get a lot of humidity and changing weather which can be rough on tanks," says Tommy Whaley, Superintendent of the Marshall County Board of Public Utilities. "One of our tanks sits in the woods and the mildew just sloughs off of it, unlike a steel tank."

Whaley and his crew know the Aquastore tank is built for the long haul and very little maintenance is required to keep it in tip-top shape.

"I've been in the water system service for a while and have seen these tanks require virtually no maintenance compared to painted steel tanks," he says. "You have to do a lead abatement on those old steel tanks which means sandblasting all the way down to the steel and applying several coats of an epoxy based paint."

15-year-old Aquastore Tank

Whaley figures that over a 20-25 year period the county saves $100,000 per tank on painting alone.

"Today's paint fails a lot easier than the glass coating, which maintains its appearance and luster," he says. "Even our oldest tank still looks like new."

But there's more to the story than appearance and maintenance. Whaley prefers the Aquastore because it's easier to construct than concrete tanks or bolted steel tanks. When the county launched an ambitious plan a few years ago to expand water service to more rural areas the decision to go with Aquastore was a no-brainer.

County workers installed 68 miles of new lines, upgraded existing lines and a pumping station and called in the experts from Aquastore to build a new 300,000 gallon elevated storage tank on Highway 99 in the Chapel Woods subdivision, which replaced a 110,000 gallon ground storage tank from 1986.

"We kind of hated to see the old tank go because it was in great shape; we just needed more capacity," Whaley says.

Indeed, the county expanded its storage by 177,000 gallons when it put up the new tank in 2013, measuring 42 feet high and 28 feet in diameter. The new Chapel Woods tank is a few feet taller and wider than the county's next largest tank, built in 2001.

Don't be fooled by its size, however. The new, larger tank was erected with relative ease thanks to the superior construction methods of the Aquastore. The Aquastore's aluminium geodesic dome is lifted off the ground by a jacking system so the panels can be installed underneath. All in all there are far fewer headaches and less labor than with steel or concrete tanks.

"I'm always amazed at the minimal effort it takes to build a tank," says Whaley. "Generally you have all kinds of hazards way above the ground but I don't recall seeing anyone climb the Aquastore tank."

And if anything goes wrong Whaley knows Southeastern Tank is just a phone call away.

"It's pretty rare, but we had a seal leak on one of the tanks and Southeastern repaired it for no charge even though it was beyond warranty," says Whaley. "They really stand behind their product."

345 Harvestore Drive | DeKalb, IL 60115 | Phone: 815.249.4059 | Fax: 815.756.1659 | www.cst-storage.com

3-year-old Aquastore Tank

"It's nice to hear Tommy say that because we always try to look at the big picture," says Dustin Dowdy, Director of Sales at Southeastern Tank. "We know a leak or malfunction could spell bigger problems down the road for the customer so it's in everyone's best interest to jump on the problem."

Marshall County water has 3,600 connections and Whaley knows he has 3,600 opportunities to delight customers every day, or 3,600 opportunities for failure. But the only number he's really concerned about is 1: his #1 choice for potable water storage is Aquastore. "Aquastore is the standard for comparison, and there really is no comparison."

Benefits of CST's Aquastore® glass-fused-to-steel tanks:

- No painting for life of tank
- Will not corrode or rust
- Lowest total life cycle cost compared to concrete & welded
- Turnkey services from approval drawings to tank testing
- Faster construction
- No need for cranes or other large equipment for construction
- Expandable
- Interior & exterior easily cleaned
- Tank can be easily relocated
- Available in diameters from 11 feet (3.3 m) to 204 feet (62.2 m) and capacity from 20,000 gallons (75 cu m) to over 6 million gallons (22,700 cu m)
- Specific tank designs, options and accessories to meet customer needs
- Industry best warranty
- White interior coating
- Multiple color options
- Authorized network of local Aquastore Dealers for convenient service and support

CST Contact Information:

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Global Marketing Director
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kmathis@cstindustries.com

Southeastern Tank
Dustin Dowdy
Director of Sales
615.466.5220
dustin@setank.com

Extreme Climate Proves a Good Challenge for 35-Year Old Aquastore® Tank at Snowshoe Mountain

Visitors who come to Pocahontas County in West Virginia each winter hope for one thing: snow…and lots of it. The world-famous Snowshoe Mountain Resort is known for skiing, and thousands of visitors flock here every year to enjoy its picturesque views and winter attractions.

What visitors see when they arrive is beautiful West Virginia mountains featuring ski resort, trails, forest and opportunities to enjoy the snow. However, what visitors don't see is probably one of the most vital, and interesting, features of Snowshoe Mountain.

The Cheat Mountain Water Company, a private utility, is responsible for care of the potable water needs of Snowshoe Mountain and the surrounding area. Pocahontas County Public Service District provides for some of the area's wastewater needs. It would be hard for winter visitors to imagine the summer days that reach 100 degrees Fahrenheit here, as well as the extreme climate changes from cold to heat at Snowshoe Mountain, which make the care of water and wastewater infrastructure a challenge.

The challenging climate also makes it surprising to find that the Water Plant's oldest potable water tank, an Aquastore tank provided by Mid Atlantic Storage Systems capable of storage for 500,000 gallons recently celebrated 35 years in service without significant maintenance.

During the past 35 years the increasing number of visitors to Snowshoe Mountain has required the Water Company to expand operations. In 2003 Snowshoe Mountain vertically expanded its existing 2,000,000 gallon equalization (EQ) tank, originally built in 1998, to accommodate an additional 1,230,000 gallons. In 2004 a new 500,000 gallon potable water tank was installed next to the original.

In 2009 when the water company moved overflows and installed replacement sheets, it was surprised to find upon inspection that the interior of the 35-year old Aquastore tank was in near perfect condition.

"Aquastore tanks feature a unique glass-fused-to-steel interior and exterior coating, which is the most durable coating available," said Jim Wary, Regional Sales Manager for Mid Atlantic Storage Systems. "The glass withstands the extreme cold in the winter, as well as the extreme heat of heat of summer. And these tanks never need to be re-painted. Given the good maintenance performed regularly by the water company, it wasn't surprising to find this tank in excellent condition and able to continue performing well for what we hope will be many years to come."

Routine maintenance of the tank has included re-edging the coated sheet edges, as well as adding exterior bolt caps. A total of less than $10,000 has been spent in maintenance over 35 years.

Mid Atlantic Storage Systems has provided all but one of the storage tanks for Snowshoe Mountain. In addition to the aforementioned tanks, a wastewater tank at Hawthorn Valley capable of storing 46,000 gallons as well as a potable water tank at Hawthorne Valley with a capacity of 25,000 gallons have been erected. The performance of these tanks, as well as the excellent service provided by Mid Atlantic Storage Systems, would make it easy to choose Aquastore products in the future.

Products like Aquastore storage tanks partnered with quality operators like the Cheat Mountain Water Company and Pocahontas County PSD allow public water and wastewater services to operate smoothly behind the scenes, and allow thousands of residents and visitors to enjoy the many attractions at Snowshoe Mountain every year.

Benefits of Glass-Fused-To-Steel:

- Lowest maintenance requirements over tank life
- Greater lifetime value versus welded or concrete tanks
- Faster construction – Easy assembly without cranes or special equipment
- Expandable to accommodate future requirements
- Available in diameters from 11 feet (3.3 m) to 204 feet (62.2 m) and capacity from 20,000 gallons (75 cu m) to over 6 million gallons (22,700 cu m)
- Specific tank designs, options and accessories to meet customer needs

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Standing Tall in Sopchoppy: Aquastore® Tank Is Built to Last

Deep in the Apalachicola National Forest in the Florida panhandle where U.S. 319 makes a crank-handle turn lies the community of Sopchoppy. It's an Indian name that means "dark water" or "twisted river." In fact, the Sopchoppy River is one of the most pristine in the whole state and it attracts a crowd for boating, kayaking and fishing.

Just 40 miles southwest of Tallahassee but a world away from the hustle and bustle, Sopchoppy is home to about 400 people who prefer the peaceful life and look forward to the annual Worm Grunting Festival, where worms are coaxed to the surface of the earth and harvested for bait.

Years ago the Carrabelle, Tallahassee and Georgia railroad rumbled through here but it shut down and was later replaced by a scenic trail. All that remains today is the old depot, built in 1891 and lovingly restored in recent years. In fact, Sopchoppy is one of few communities that boasts a school gymnasium on the National Register of Historic Places.

A good chunk of Wakulla County's utility needs are served by the City of Sopchoppy. Public Works Director Leonard Tartt figures about 10,000 individuals get their water from his district via 4,000 connections. The district pumps about 21 million gallons of water each month—sourced from seven wells fed by the The Floridan Aquifer, which lies deep below the state, replenished by rainwater filtering through hundreds of feet of sand and rock.

Not quite as old as the Floridan Aquifer but just as critical to the area's needs is the city's Aquastore glass-fused-to-steel storage tank. Built in 1985, the tank has withstood the test of time and the elements and looks and performs like new. Sopchoppy has four other tanks—all steel—and Tartt says they don't compare to the Aquastore when it comes to durability, appearance and the low cost of maintenance.

"The Aquastore tank has more than performed as advertised in every aspect," says Tartt. "By comparison, the steel tanks fade over time and need to be repainted and they need more repair than the Aquastore."

The Florida Department of Environmental Protection requires that tanks be inspected and pressure washed every five years, and Tartt says the only repairs made to the Aquastore are re-caulking some seams. During the same period the steel tanks have had to be sandblasted and repainted several times to ward off corrosion.

"At $80 dollars a gallon the cost of paint really adds up," he says.

Aquastore tanks are built by CST—the world's largest provider of modular, factory coated bolted storage tanks for dry bulk and liquid applications for many markets. The Aquastore is made of glass and steel fused together at 1,500°. With its inert, inorganic coating the Aquastore withstands heat, cold and moisture and maintains its

luster compared to steel tanks which require painting and the Aquastore Tank is easier to clean and maintain than concrete tanks that are susceptible to corrosion of reinforcing steel, cracking and mildew.

“The Sopchoppy tank is among the first Aquastore water tanks our company built in Florida and it continues to make us proud,” says John Viale, Territory Manager at Florida Aquastore, CST Storage’s exclusive turnkey provider of Aquastore Tanks throughout Florida, southern counties in Georgia, the Caribbean, Central and South America. “It looks and performs like new and I know Leonard gets the most out of its 239,000 gallon capacity.”

In fact, during the warm months the district uses the tank almost to capacity day in and day out.

“I’ve never had problems with it even though in the peak of summer the turnover will be 225,000-230,000 gallons a day,” says Tartt. “Then we’ll throttle it back a bit during the winter.”

Compared to elevated tanks, erecting an Aquastore is a snap. The geodesic dome is hoisted into place while panels are assembled underneath. Jacks are used to lift the tank higher to make room for additional panels. No one has to leave the ground and the Aquastore can be installed in the tightest of spaces.

Tartt also prefers the Aquastore for its compatibility with other specialized systems. For example, the district installed an aerator inside the tank to filter the water and help remove hydrogen sulfide from the water and the sulfur smell that comes with it. Other elements like iron and calcium are easier to deal with because they’re easy to wash off the tank surface.

Leonard Tartt has lived in Wakulla County all his life. He served on Sopchoppy’s city council and was the mayor before taking over the public works role. He’s seen quite a bit in his time and has a good perspective on what’s built to last.

“Everybody looks at the bottom line nowadays, but I also look at quality and historical performance, what’s worked and what hasn’t,” says Tartt. You can get a fire hydrant that will pass codes but less costly but will it last 50 years? It’s basically the same thing. You have a little added cost with ground storage because you need service pumps. But when you consider the tradeoff the Aquastore comes out ahead every time.”

The CT&G Railroad may not have survived in these parts, but odds are good for the Aquastore tank, which is still performing at a superior level at age 31.

Quick Facts:
Dimensions: 42’ diameter x 23’ tall
Capacity: 239,000 gallons
Erected: 1984-85

Benefits of CST's Aquastore® glass-fused-to-steel tanks:

- Lowest maintenance requirements over tank life
- Provides storage capacity for almost any system – up to 1.5 million gallons with overflow elevations up to 200-feet high
- Greater lifetime value versus welded or concrete tanks
- Fastest construction methods
- Impermeable to liquids and vapors
- Glass-fused-to-steel controls undercutting caused by corrosion
- Extremely UV-resistant
- Glass-fused-to-steel is twice as hard (6.0-7.0 Mohs) as any field-applied coating system
- Bond rating 12.5 times stronger than any zinc-epoxy-urethane system
  Specific tank designs, options and accessories to meet customer needs
- Benefits of particular product can be listed here

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What Does a Water Tank Have in Common with a Kitchen Gadget?

Ron Popeil coined the phrase “set it and forget it” to sell those amazing kitchen gadgets. But the phrase applies to more than slow roasting a rotisserie chicken.

Take water storage, for example. When you’re a rural district serving a vast area with limited resources and staff, you need to be able to trust your equipment. You want to know your tanks and pumps are humming 24/7 month to month and year to year because you don’t have the time to constantly check on them.

The Aquastore® tank from CST was designed with that in mind and it’s the preferred choice of districts like Millstone in southern Illinois. Ken Richards, district manager, needs to ensure every single one of his 2,400 customers spread throughout a 2,080 square mile area are satisfied all the time. Proper storage is critical to water quality and Richards relies on Aquastore because it’s the industry’s leading tank for durability, reliability and low maintenance.

In fact, Millstone has an Aquastore tank that’s over 20 years old. It’s performed so well they opted to buy another one.

“We took it offline for retooling and decided to build a second tank to meet our long-term demand,” says Richards. “We put the new tank online to handle storage while the old one was undergoing maintenance.”

Richards marvels that workers didn’t have to detach a single panel for retooling, which saves time and money. Not having to repaint does, too.

“Typically, repainting a tank has to be done in the summer and you need to plan for roughly three months of down time,” says Dave Hemauer, project manager at Cady Aquastore. “But it took only nine days after the tank was drained and washed out to rehab and make improvements to the older Aquastore tank. After a few days of sealer curing time, the tank was ready for sanitizing and bacteriological testing and back in service.”

Hemauer adds this maintenance can be done any time of year.

The folks at Millstone are counting on both their Aquastores to withstand extreme weather conditions and continual use—unlike concrete or steel tanks. Refined metals and concrete break down or oxidize over time. Corrosion can impact the life of a tank, so the materials used in the tank’s construction make a difference in its longevity. Consider the Aquastore difference:

1. A panel of high strength low carbon steel is blasted and alkaline cleaned.
2. The edges of the panel are beveled and then it’s sprayed with a stainless steel alloy.
3. The panel is sprayed with a specially formulated slurry that gives it durability, consistency and impermeability. Unlike powder coatings or paint, the slurry is inorganic so it blocks corrosion.
4. The panel is then fired at temperatures above 1,500° F (815° C) to fuse the porcelain coating and the steel.
5. Tests are conducted to verify integrity and durability, including high voltage testing to detect discontinuities.

"We prefer the Aquastore because it's impervious to the weather and the chemicals in water," says Joe Boyke, project manager at Clarida & Ziegler Engineering, which is consulting on Millstone's expansion. "I've built 35 to 40 Aquastore tanks in my career and I've never seen corrosion, cracking or failure like you see with concrete and steel tanks."

The glass-fused-to-steel system was designed in anticipation of the wear and tear a liquid storage tank will undergo in its lifetime. By constructing a tank in a way that's resilient, CST has devised a solution that requires far less maintenance over time. A municipal water provider in South Dakota recently estimated that maintenance for a glass-fused to steel tank over a 60-year span would cost $266,000 compared for $906,000 for a painted welded tank.

Millstone's Aquastore tank is a beauty. Sporting a deep blue luster that won't fade, it stands 28 feet tall and 81 feet in diameter and features an aluminum geodesic roof and cathodic protection bars on the interior. The glass-fused-to-steel panels were forged in CST's factory in DeKalb, Illinois and shipped to the site, where they were assembled one level at a time. Scissor lifts were used to raise the dome while panels were secured underneath.

"Aquastore beats other tanks when it comes to construction," says Andy Rainwater, project manager at Clarida & Ziegler Engineering. "There's no need for scaffolding because all work can be performed from the ground and the panels fit easily together."

Rainwater credits Cady Aquastore, the area's exclusive CST dealer, for much of the success behind Millstone's tanks.

"They're always really responsive—whether it's repair, cleanout or if we just have questions," he says. "They're also an essential partner when we need help with a spec or if we have specific design challenges."

Millstone is preparing to grow and Aquastore helps make it possible. The district sells water to nearby prisons and communities and the boundaries of its service area will soon be extended.

"We're rehabbing our treatment plant and the Aquastore tanks will be the centerpiece," says Richards.

Benefits of CST's Aquastore® glass-fused-to-steel tanks:

- No painting for life of tank
- Will not corrode or rust
- Lowest total life cycle cost compared to concrete & welded
- Turnkey services from approval drawings to tank testing
- Faster construction
- No need for cranes or other large equipment for construction
- Expandable
- Interior & exterior easily cleaned
- Tank can be easily relocated
- Available in diameters from 11 feet (3.3 m) to 204 feet (62.2 m) and capacity from 20,000 gallons (75 cu m) to over 6 million gallons (22,700 cu m)
- Specific tank designs, options and accessories to meet customer needs
- Industry best warranty
- White interior coating
- Multiple color options
- Authorized network of local Aquastore Dealers for convenient service and support

OptiDome® geodesic aluminium domes are the preferred cover solution for any storage application. Aluminum dome structures are superior to other cover designs of alternate materials due to: corrosion resistance, low lifetime maintenance cost, clear-span capability, fast and low cost construction and design flexibility.

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Fertile Ground: Aquastore® Braces for North Texas Boom

In 2008 a headline in the Denton (TX) Record-Chronicle read “Small towns disappearing across the North Texas prairie.” The article was prophetic. The inexorable growth of the Dallas-Ft. Worth metroplex is reshaping a part of our nation that was once the provenance of horse trainers and peanut farmers. In recent years the term “North Texas” has become a fixture in the American lexicon as the character of this area is transformed from rural and remote to a dynamic urban-suburban cluster with a progressive identity.

The US-380 corridor in northeast Denton County is well positioned to benefit from this growth. The area’s population has exploded since 2000 as residents escape the congestion of the cities to the south for a more bucolic lifestyle. They live in towns like Cross Roads and Oak Point, with easy access to jobs, shopping and recreation in nearby Denton, Frisco, Lewisville, McKinney and Plano. Even downtown Dallas is only 50 miles away—practically around the corner in Texas-size terms.

The Mustang Special Utility District board anticipated this migration years ago and planned accordingly. For their water handling and storage needs they chose Aquastore® by CST, the industry’s premiere glass-fused-to-steel tank. Unlike concrete and steel tanks, the Aquastore tank needs virtually no maintenance, never needs repainting, and can withstand the harsh Texas elements like no other.

But maybe the most important feature of the Aquastore is its versatility and expandability, which Mustang needs to meet the water demands of a growing population. The district started a half century ago with 50 customers and today serves more than 12,500 customers. During that time, the district has installed three Aquastore tanks that collectively have 2.75 million gallons of capacity.

You’d never know these tanks are 16 and 9 years old. While a concrete or steel tank shows signs of age and diminished performance, the first Aquastore tank built in 2000 and the second and third built in 2007 perform and look like new, according to the utility’s operations manager Aldo Zamora.

When Zamora arrived at Mustang in 2004 the original Aquastore tank had been in service for a few years and the challenge of expansion was looming. With the topic of a new tank on the table, careful due diligence was in order.

“My general manager Chris Boyd and I flew up to the CST factory in DeKalb, Illinois and watched them manufacture the tank panels,” says Zamora. “What we witnessed made our decision very obvious.”

Chris and Aldo have been working with CST’s exclusive distributor Texas Aquastore for over 15 years because they prefer CST’s glass-fused-to-steel tank and the multi-step fabrication process that makes it special:

1. A panel of high strength low carbon steel is blasted and alkaline cleaned.
2. The edges of the panel are beveled and then it's sprayed with a stainless steel alloy.
3. The panel is sprayed with a specially formulated slurry that gives it durability, consistency and impermeability. Unlike powder coatings or paint, the slurry is inorganic so it blocks corrosion.
4. The panel is then fired at temperatures above 1,500° F (815° C) to fuse the porcelain coating and the steel.
5. Tests are conducted to verify integrity and durability, including high voltage testing to detect discontinuities.

The glass-fused-to-steel system was developed to meet the wear and tear a liquid storage tank will experience in its lifetime. The Aquastore tank is resilient and gives water districts and other industries with liquid storage needs a solution that requires minimal maintenance with the lowest lifecycle costs.

Unlike other bolted steel tanks the Aquastore is virtually seamless, which reduces the likelihood of leaking from within or contamination from the outside.

Additionally, "with concrete you never know where a crack will appear and you can spend a lot of time and money trying to patch and control them," says Zamora.

The Aquastore's glass-fused-to-steel composition makes it durable with a rich permanent finish that never needs painting. Water districts across the country report they save thousands simply by never having to repaint because the Aquastore retains its original luster.

Zamora says Aquastore saves the district $8,000 to $10,000 a year in maintenance since the tanks are crack-resistant and don't need repainting. The district's other ground storage tanks require costly sandblasting and painting with a special polyurethane every five to eight years. In addition, older tanks with lead paint require remediation, a budget item utility managers don't have to fund with the Aquastore.

Structural issues that could be overwhelming with a concrete or steel tank are almost a no-brainer with the Aquastore. Zamora says that recent floor maintenance to an Aquastore tank was "painless" and cost efficient because the Aquastore disassembled and reassembled easily.

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CST anticipated everything when it designed the Aquastore: the weather, construction requirements and other limitations. Quality control is also built in to the Aquastore which means Zamora can take quality to a level he can't attain with other tanks.

"I can take samples directly from the tank because the dealer bored a hole for me to install a tap," he says. "It's also ideal if you need to install piping and tie into another well."

Zamora knows that kind of adaptability will be crucial when the district needs to extend its service once again to meet residential and commercial growth. It doesn't have to erect another tank; it can simply expand one of its existing tanks. The roof of the Aquastore tank can be easily detached and raised so additional panels can be installed below it.

The US-380 corridor in Denton County is undergoing a lot of change, which means the arrival of new homes, new businesses and new infrastructure. With all this "new," it's satisfying to know Mustang Special Utility District can count on its Aquastore tanks to service a rapidly growing customer base over the long haul.

"The Mustang staff is great to work with—eager stewards of our natural resources and always looking out for the best interests of their community," says Texas Aquastore Sales Manager John Pappalardo. "Texas Aquastore looks forward to being a part of Mustang's continued expansion as plans for growth continue with amazing traction. Mustang has plenty of horsepower to propel them into the future!"

Benefits of CST's Aquastore® glass-fused-to-steel tanks:

- No painting for life of tank
- Will not corrode or rust
- Lowest total life cycle cost compared to concrete & welded
- Turnkey services from approval drawings to tank testing
- Faster construction
- No need for cranes or other large equipment for construction
- Expandable
- Interior & exterior easily cleaned
- Tank can be easily relocated

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- Available in diameters from 11 feet (3.3 m) to 204 feet (62.2 m) and capacity from 20,000 gallons (75 cu m) to over 6 million gallons (22,700 cu m)
- Specific tank designs, options and accessories to meet customer needs
- Industry best warranty
- White interior coating
- Multiple color options
- Authorized network of local Aquastore Dealers for convenient service and support

OptiDome® geodesic aluminium domes are the preferred cover solution for any storage application. Aluminum dome structures are superior to other cover designs of alternate materials due to: corrosion resistance, low lifetime maintenance cost, clear-span capability, fast and low cost construction and design flexibility.

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One Customer, Many Tanks

Watts Bar is like most rural utility districts. It serves 6,100 customers in parts of five counties in Southeastern Tennessee, between Knoxville and Chattanooga. But one thing makes Watts Bar different from most utilities: its largest customer is a nuclear reactor.

The Watts Bar Nuclear Plant, part of the Tennessee Valley Authority (TVA), sits on 1,700 acres and produces 1,150 megawatts of electricity—enough to power 650,000 homes. When the second reactor opens this year it will double that output. The plant also uses a lot of water. So much water that Watts Bar utility maintains an unusually large storage capacity. Containing all that water is a big job, but Aquastore® tank from CST is up to the task. In fact, the utility has 14 Aquastore's with a total capacity of more than 5 million gallons.

While the nuclear plant draws water directly from the Tennessee River for cooling, it relies on Watts Bar utility for every drop of water used on a daily basis by its 1,000+ employees. When a nuclear reactor is relying on you for its water, you can't afford service interruptions, mechanical issues or contamination. That's why Watts Bar Utility District has relied on Aquastore tanks since the first tank was installed in 1988.

Aquastore's glass-fused-to steel technology is the water and liquid storage leader—outperforming concrete, steel bolted and elevated tanks. More than 100,000 have been installed in over 70 countries around the world. It's resistant to extreme weather and leakage and retains its brilliant luster for decades, which means it doesn't have to be repainted.

"Not having to paint means we potentially save millions of dollars over just a few years' time," says Wesley Barger, Assistant Manager at Watts Bar Utility District. "We just finished painting our one elevated steel tank for $330,000. Imagine if all our tanks required painting. That kind of expenditure just isn't justifiable or sustainable."

Barger continues: "Having to ask your board to approve over $4.5 million for tank painting would not go over well."

Barger credits Southeastern Tank, the area's exclusive Aquastore distributor, for making his life easier. He says he's continually impressed by the service and attention he receives.

"Every once in a while something random happens and they're Johnny on the spot," Barger says. "For example, when a cable on a tank level snapped they were out here the next day to replace it."

Even the bigger maintenance jobs don't give Barger gray hairs: "We took two of the older tanks out of service to fix a bracket supporting an overflow pipe and to add cathodic protection and a sampling port. Southeastern did it all, including sweeping out the tanks, in a matter of days."

Barger also appreciates the functional, elegant design of the Aquastore. Each panel is forged in CST's DeKalb, IL manufacturing facility.

1. A panel of high strength low carbon steel is blasted and alkaline cleaned.
2. The panel's edges are beveled and its surface sprayed with a stainless steel alloy.
3. Next, the panel is sprayed with a specially formulated slurry that gives it durability, consistency and impermeability. Unlike powder coatings or paint, the slurry is inorganic so it blocks corrosion.
4. The panel is then fired at temperatures above 1,500° F to fuse the porcelain coating and the steel.
5. Tests are conducted to verify integrity and durability, including high voltage testing to detect discontinuities.

Barger and his father, general manager Mickey Barger, have witnessed the Aquastore's efficient construction many times over. The Aquastore is built using hydraulic jacking, which allows for top-down construction that's safer and faster and takes up less space than traditional steel tank erection.

"Most of our customers own two or three tanks so Watts Bar is truly unique," says Dustin Dowdy, Director of Sales at Southeastern Tank in Nashville. "With 14 tanks, their lifecycle cost savings can add up quickly, which satisfies their board and customers.

Dowdy and his staff prepared a lifecycle cost analysis on Watts Bar's tanks by gauging how much money has been saved on maintenance.

"We assumed what it would cost to maintain welded tanks of similar capacity by calculating the cost per square foot over two 15-year cycles," says Dowdy. "It added up to millions of dollars in maintenance costs. That's money that can be spent on new infrastructure."

Whether it's a second nuclear reactor coming online or new home construction, Watts Bar Utility District keeps the taps flowing in southeastern Tennessee and it starts with state-of-the-art storage technology from CST and Aquastore.

Benefits of CST's Aquastore® glass-fused-to-steel tanks:

- No painting for life of tank
- Will not corrode or rust
- Lowest total life cycle cost compared to concrete & welded
- Turnkey services from approval drawings to tank testing

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- Faster construction
- No need for cranes or other large equipment for construction
- Expandable
- Interior & exterior easily cleaned
- Tank can be easily relocated
- Available in diameters from 11 feet (3.3 m) to 204 feet (62.2 m) and capacity from 20,000 gallons (75 cu m) to over 6 million gallons (22,700 cu m)
- Specific tank designs, options and accessories to meet customer needs
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OptiDome® geodesic aluminium domes are the preferred cover solution for any storage application. Aluminum dome structures are superior to other cover designs of alternate materials due to: corrosion resistance, low lifetime maintenance cost, clear-span capability, fast and low cost construction and design flexibility.

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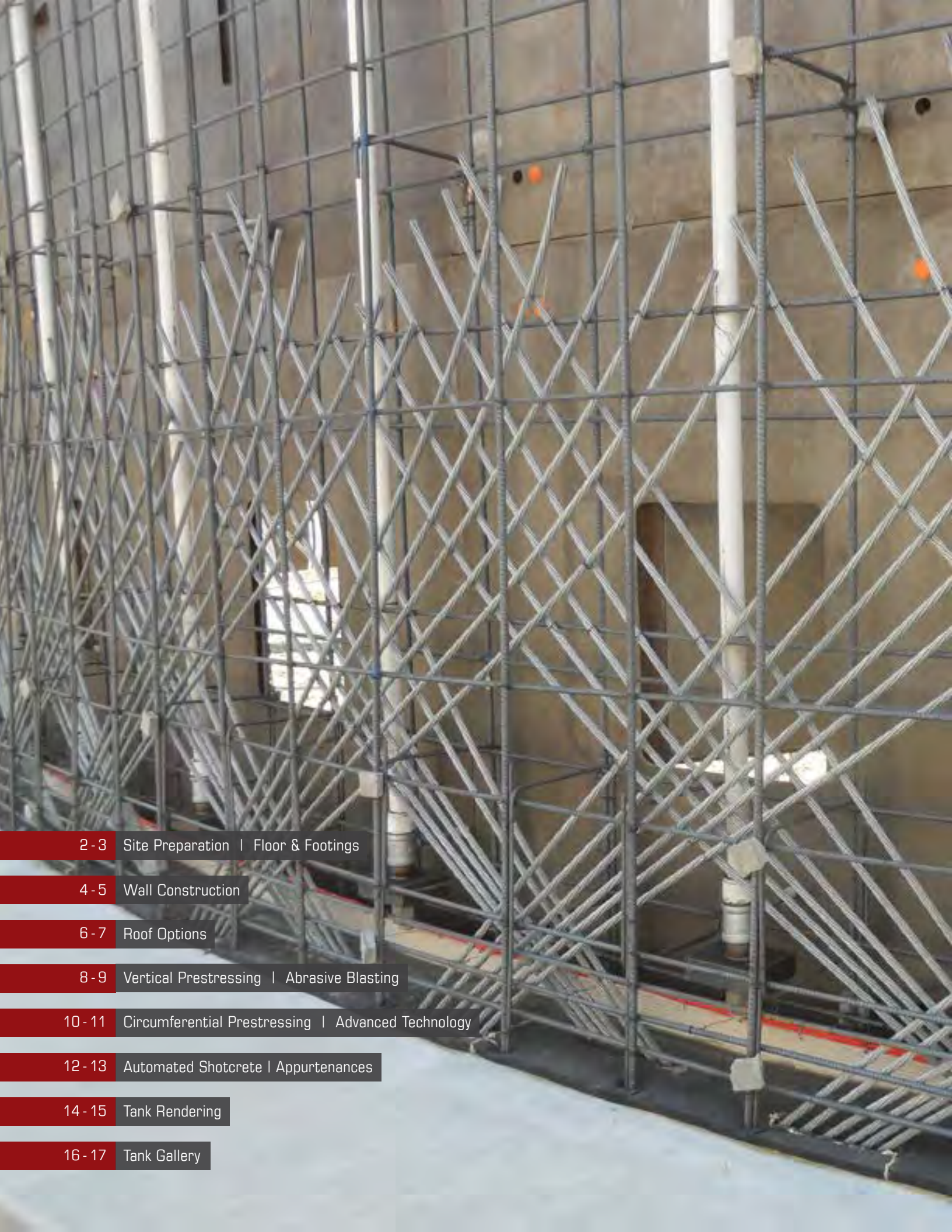
Appendix B

Prestressed Concrete Tank Supporting Information

DN TANKS

CONSTRUCTION PROCEDURES

AWWA D110 Type I Prestressed Concrete Tanks



DURABILITY FOR GENERATIONS TO COME

At DN Tanks, we understand that a liquid storage tank is a critical component of infrastructure that serves a variety of storage needs, such as a community's potable water source, fire suppression source, an important step in the treatment of wastewater, a consistent source of recycled water, as well as many other uses. Each of these tanks are instrumental to the communities they serve.

DN Tanks' prestressed concrete storage tanks are individually designed with a full structural analysis to meet specific project needs. Quality, durability, and efficiency are ensured through specially trained and skilled field crews, advanced prestressing technology, and professional project management.

Over 50 years of experience are ingrained into each AWWA D110 Type I prestressed concrete tank. Our years of commitment and focus in the prestressed concrete tank industry have cultivated expertise in engineering, estimating, project management, and construction. From project development and design assistance to construction and prestressing, DN Tanks' dedicated team is ready to provide support services to ensure a successful tank project. We measure success by our lasting partnerships with clients and communities.

KEY ATTRIBUTES OF DN TANKS' AWWA D110 TYPE I PRESTRESSED CONCRETE TANKS

- **Tank Capacities** - from 40,000 gallons to 50 million gallons (MG) and above
- **Custom Dimensions** - water heights from 8' to over 100' and diameters from 25' to over 400'
- **Siting Options** - at grade, partially buried, differentially backfilled (hillsides), fully buried (with multi-use capabilities)
- **Seismic Resilience** - proven performance through Loma Prieta, Nisqually and Northridge earthquakes to name a few
- **Enhanced Ductility** - anchored flexible base and roof connections
- **Bi-axial Wall Compression** - provides longevity, durability and liquid tightness
- **Best Long-term Value** - coatings aren't required thus eliminating routine maintenance costs and down-time burdens
- **Reinvesting in the Local Economy** - use of materials, labor and equipment from within the community
- **Enhanced Water Quality** - concrete inherently insulates, keeping liquids at a more consistent temperature

SITE PREPARATION

A properly prepared subgrade is essential to tank construction. Before the structural tank design begins, a licensed geotechnical engineer prepares a site specific geotechnical report. The report provides design parameters that include bearing capacity, anticipated settlements, seismic criteria, and recommended subgrade and foundation preparation.

- Subgrade preparation for each tank is completed in accordance with the civil site plans and the site specific geotechnical report
- Piping connections that penetrate through the floor (e.g. inlet, outlet, overflow, etc.) are encased in underslab concrete pipe blocks
- A waterstop is incorporated between the floor and pipe block to ensure a liquid tight connection
- Wall and roof pipe penetrations can be easily incorporated

FLOOR & FOOTINGS

A typical prestressed concrete tank floor consists of the following features:

- A cast-in-place, highly-reinforced, concrete membrane floor with a slight upward slope to the center allows for drainage
- Monolithic or large section pours limit joints to improve tank performance and achieve construction efficiency
- A thickened perimeter wall footing to transmit the concentrated wall loads to the subgrade beneath
- A permanent PVC waterstop at all joints for water tightness
- Seismic base restraint cables are developed into the perimeter footing to account for site specific seismic loading
- Structural observation is performed by a Registered Engineer prior to the concrete pour
- Experienced field crews place the concrete and ensure it is vibrated, screeded, and finished to meet the project specifications

CAST-IN-PLACE WALL CONSTRUCTION

Prestressed concrete places steel in tension and concrete in compression, allowing for both materials to resist forces in their ideal states. The corewall is designed to account for project specific parameters and loadings. A typical tank corewall consists of a 10" minimum uniform thickness. For larger capacity tanks, walls may be thicker and tapered on the inside face to accommodate increased loads.

FEATURES OF AN AWWA D110 TYPE I WALL

Enhanced Operational and Seismic Performance

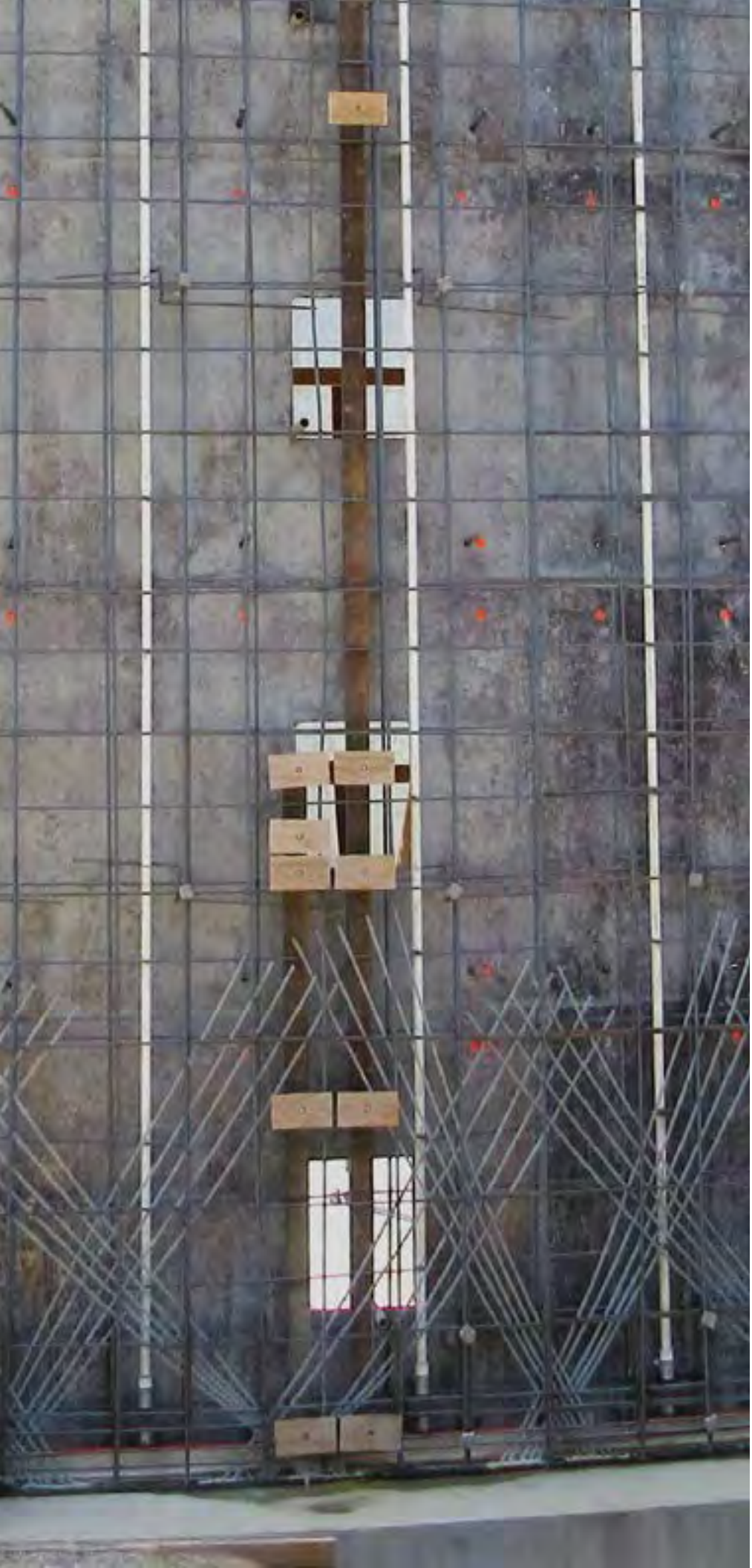
- "Anchored flexible base" connection between the floor and wall (similar to a base isolation system) enhances ductility and reduces bending moments from hydrostatic, thermal, and seismic forces, allowing these structural elements to act independently
- Seismic base restraint cables anchored into the footing extend into the corewall, providing load transfer during a seismic event

Quality Control

- Circumferential wall forms curved to the specific tank radius are equipped with equally spaced pour windows to enhance quality control, reduce overall drop height, and allow ease of access for concrete placement and vibration
- Walls are poured full height in up to 50' wide circumferential sections
- Rebar congestion is significantly reduced, promoting more efficient inspection and concrete placement

Liquid Tightness and Durability

- Vertical prestressing threadbars cast in the wall provide vertical compression and minimize vertical bending moments caused by differential temperature and dryness conditions
- Horizontal joints are eliminated and vertical joints are minimized to provide superior water tightness
- All construction joints incorporate permanent PVC waterstops



ROOF OPTIONS

Prestressed concrete tanks can be designed with a variety of roof options.

FLAT ROOF FEATURES

- Low profile cast-in-place, two-way flat slab roof minimizes visibility
- Option to bury or accommodate multi-use structures such as parks, recreation facilities, pump stations, etc. on the tank roof
- An anchored flexible wall/roof connection allows for thermal expansion of the roof slab while also providing seismic restraint
- Evenly spaced concrete columns, designed with drop panels and footings, support the roof and transfer the corresponding loads
- A slight upward slope to the center, matching the floor, provides drainage

DOME ROOF FEATURES

- A clear-spanning concrete dome with no interior supports or obstructions can easily accomodate various equipment needs
- Typical dome height is 10% of the tank diameter
- Continuous reinforcement is incorporated in both radial and circumferential directions
- Circumferential prestressing applied at the dome ring places the dome in permanent compression

VERTICAL PRESTRESSING

AWWA D110 Type I tanks incorporate vertical prestressing threadbars within the wall to provide vertical compression and counteract bending. Features include:

- High-strength steel threadbars are either 1 ¼" or 1 ⅜" diameter depending on corewall thickness
- Threadbars are equipped with a screwed-on nut anchor at the top and bottom to eliminate stress concentrations
- Each threadbar is housed inside of a rigid PVC pipe to allow for proper installation
- A hydraulic ram is used to tension the threadbars after the concrete walls are poured
- Threadbars are tensioned to 137 kips or 173 kips for the respective diameter, with a tight force tolerance of 1.5%
- Force and elongation recordings are electronically and instantaneously produced for each vertical threadbar, documenting the applied stress
- After tensioning, threadbars are pressure grouted from the bottom up with a two-part epoxy to achieve a fully bonded system and corrosion protection

ABRASIVE BLASTING

Prior to starting circumferential prestressing and shotcrete operations, DN Tanks' advanced abrasive blasting system roughens the exterior corewall surface. System features include:

- Automated hydroblasting applies water at a high pressure of up to 40,000 psi to etch the wall to a precise roughened finish, providing a superior bonding surface
- An automated system reduces jobsite hazards, optimizes construction schedule and provides a consistent finish
- Hydroblasting is environmentally friendly as it requires very low water usage and eliminates dust

CIRCUMFERENTIAL PRESTRESSING

Circumferential prestressing is the heart of the tank structure, counteracting the liquid load and placing the tank wall in 200 psi residual compression. DN Tanks' significant industry advancements includes the automated machine application of tensioned, hot-dip galvanized, ⅜" diameter 7-wire strand. By placing the strand in tension, and thereby the concrete wall in compression, the prestressed concrete tank incorporates both materials in their ideal states.

The mechanical prestressing system allows application of a consistent prestressing force of 14,950 pounds with a tight tolerance of 1.5% of MUS. This greatly exceeds the AWWA minimum standard accuracy of 7% of the applied force. Strand is tensioned to 70% of MUS, placing the wall in permanent bi-axial compression to withstand the varying operational hydrostatic loads, as well as thermal and seismic dynamic loads.

BENEFITS OF STRAND-WRAPPING:

- Improved accuracy & efficiency
- Tighter force tolerance
- Electronic spacing & recording
- Fewer splices
- Increased shotcrete bond
- Greater safety factor

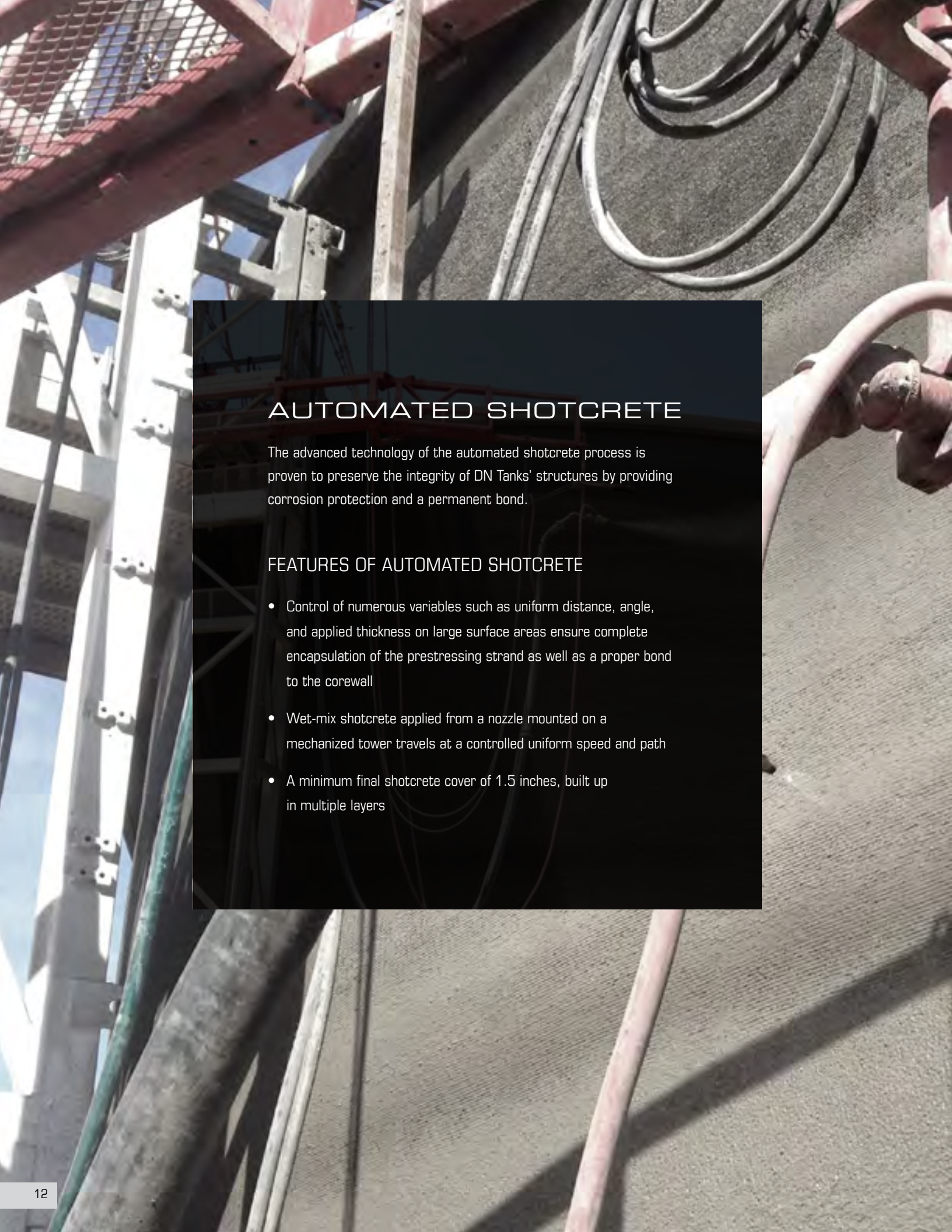
ADVANCED TECHNOLOGY

DN Tanks' state-of-the-art circumferential prestressing equipment is able to perform multiple sophisticated tasks with one simple, automated, quality-controlled unit. In-line calibration and stress monitoring are utilized to provide complete accuracy in every step of the process.

ELECTRONIC MONITORING & CONTINUOUS RECORDING

Continuous electronic recording and instantaneous self-correcting force application are essential to ensure the proper stress is applied to the prestressing steel. The prestressing steel places the concrete into permanent compression and resists all hydrostatic loads. It is imperative that the stress is applied accurately. The automated system offers:

- Computerized, continuous electronic force readings for the highest quality control
- In-line calibration allowing for instantaneous control of the force applied
- A record of the force readings submitted to the Owner, providing confidence that the most critical part of the hydrostatic resistance has correctly been applied



AUTOMATED SHOTCRETE

The advanced technology of the automated shotcrete process is proven to preserve the integrity of DN Tanks' structures by providing corrosion protection and a permanent bond.

FEATURES OF AUTOMATED SHOTCRETE

- Control of numerous variables such as uniform distance, angle, and applied thickness on large surface areas ensure complete encapsulation of the prestressing strand as well as a proper bond to the corewall
- Wet-mix shotcrete applied from a nozzle mounted on a mechanized tower travels at a controlled uniform speed and path
- A minimum final shotcrete cover of 1.5 inches, built up in multiple layers

APPURTENANCES

Prestressed concrete tanks can accommodate a variety of accessories, such as roof and wall access hatches, interior and exterior ladders, vents, safety railings, level sensing equipment, or specialized security hardware. Our experienced team can help recommend and install appurtenances to meet specific project requirements.


1 PVC Waterstop
2 Elastomeric Wall-Base Bearing Pad
3 Tank Foundation
4 Vertical Prestressing Threadbars Housed in PVC Pipe
5 Cast-in-Place Concrete Corewall
6 Seismic Base Restraint Cables
7 Continuous Circumferential Reinforcing
8 ⅜" Ø 7-Wire Galvanized Circumferential Prestressing Strand
9 Shotcrete Encasement
10 Roof Shear Can
11 Wall Shear Can
12 Elastomeric Wall-Top Bearing Pad

Center Pin	13
Base Unit and Engine	14
7-Wire Galvanized Strand Reel	15
Adjustable Tower	16
Automated Shotcrete Arm and Nozzle	17
Stressing Head	18
Operations Cabin	19

DN TANKS SHOWCASE

DN TANKS

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August 25, 2017

Graham Walker
AECOM

Reference: Prestressed tank and Bolted Steel tank comparison

Dear Mr. Walker,

We understand that you are preparing a comparison of tank options. As we have discussed, there are significant design differences between our prestressed concrete tanks and glass-lined bolted steel tanks. For an economic comparison, a prestressed concrete tank will provide longer term service with negligible maintenance. The design life of a prestressed concrete tank is 100+ years, far exceeding that of a prefabricated steel tank.

Based on the limitations discussed herein, it is almost certain that a bolted steel tank will require replacement during the useful life of the concrete tank. The cost of tank replacement for the bolted steel option should be the basis for the primary economic benefit for concrete.

The AWWA M42 Manual for Steel Water Storage Tanks addresses design life of a bolted steel tank. The Manual acknowledges that, *"…the anticipated life of a bolted steel tank is usually limited by the effective life of the protective coating and cathodic protection system. If the coatings are not abused or damaged, the anticipated life expectancy of bolted tanks is more than 30 years."*

The following is a typical basis of comparison of prestressed concrete tanks with prefabricated bolted steel tanks. This comparison illustrates the benefit of selecting a prestressed concrete tank based on the "better value conclusion" considering cost, longevity, operating benefits, site considerations, and durability.

We hope that you consider the information presented and conclude that prestressed concrete provides the best value and performance for the tank requirements.

A Contrast of Product Design Philosophies

The primary contrast between the two systems relates to product design. Prestressed concrete tanks are conservatively designed for actual site conditions and all loading requirements for each specific project. They are designed and constructed specifically to preclude damage and maintenance.

Bolted steel tanks, however, are limited by the manufacturing process with a priority for lowest cost through standardization and prefabrication of components. Bolted steel tanks are not

designed to prevent damage, but rather for ease of repair. The priority for prefabrication results in important limitations as noted below:

Limited Plate Thickness - The steel plate thickness for bolted steel tanks, typically less than for a traditional welded steel tank, is limited by machine capability for shear punching of bolt holes. This standardized process allows field assembly, but introduces limitations in the marginal design of the system. Since plate thickness cannot be increased to accommodate critical design requirements, the requirements are transferred to extraneous items or operations. For example, rather than designing the steel shell for total windload, the design requirement is transferred to external truss stiffeners. Also, rather than increasing plate thickness to handle ice design, the requirement is transferred to an operational restriction to limit ice formation.

Glass Coating - The primary corrosion protection of the steel for bolted tanks is from the factory coating. While this is generally a quality process accomplished at a manufacturing facility, once the plate leaves the safety of the plant, it is subject to normal wear and tear and abuse. This is confirmed by review of requirements for handling and shipping of the plates. Damage due to shipping and tank erection is touched up using the sealant provided for plate joints; not with the glass coating.

**It should be noted that, although the manufacturers of glass-coated bolted steel tanks have improved the corrosion protection by adding coating to the plate edges, this coating does not exist on the plate edges within the bolt holes. The only corrosion protection of the plate within the bolt openings is by sealants and the cathodic protection system, both requiring maintenance.

Site Placement Restrictions - Bolted steel tanks are not designed to accommodate earth backfill. This is due to the lack of shell strength as well as concerns about corrosion. Further, the foreword of the D103 Standard for factory coated bolted steel tanks states specifically that:

> "Annual inspection and maintenance is important if maximum tank life is to be attained…In particular, accumulation of dirt and weeds which may trap moisture and accelerate corrosion should be removed."

This statement, in and by itself, is confirmation of the limitations of placement of bolted steel tanks. Prestressed concrete tanks are designed to resist both the force of backfill and, as well, are unaffected by dirt and weeds. Typical installation involves a combination of partial or differential bury.

If tank placement requires the floor elevation below the proposed finish grade, it becomes necessary to design and construct retaining walls to protect the tank from the site. The cost of the retaining walls will outweigh much of the

savings, if any, between bolted steel and concrete. Prestressed concrete tanks are designed to receive backfill, and do not require retaining walls.

Vandalism Damage - A related issue to impact damage of the factory coating is that of vandalism. Glass-lined tanks are regularly damaged by rocks, bricks, and gunshot. While the contention has been made that the steel plate will not likely fail when impacted, the manufacturers of glass-lined bolted steel tanks verify that the glass coating will fail and repair is required on the inside following these events. Responding to the issue, one manufacturer of these tanks provides standard procedures for temporary repair to damaged plates. For interior tank damage, the tank must be removed from service.

Temporary repairs are made externally using the plate sealant. The manufacturer advises that this same sealant be used to patch the delaminated glass on the interior of the tank by taking the tank off-line (if possible). The tank manufacturer advises further that replacement plates are available for more complete repair. The tank is removed from service (again, if possible), the damaged plate is removed, and the replacement plate is installed.

It is notable that prestressed concrete tanks are designed to preclude vandalism problems rather than being designed for ease of repair.

Cathodic Protection Requirements - Bolted steel tanks are dependent upon cathodic protection system to control corrosion. *It is our understanding that The manufacturer's extended 10-year warranty is invalid without installation and operation of the cathodic protection system.* Cathodic protection systems require regular maintenance and operating costs. With continuing incidences of glass damage, most existing glass-lined tanks have been retrofitted with cathodic protection systems and water recirculation systems in an attempt to prevent further damage to the tanks. Both types of systems require regular maintenance, and are subject to failure.

SUMMARY

By making a long-term investment in concrete, the client eliminates the compromises in design associated with bolted steel tanks. Our tanks constructed in accordance with AWWA Standard D110 have performed without the need for maintenance and allow assurance of performance and durability. DN Tanks' long successful track record of experience is the result of a proven quality tank product designed for long-term durability and exposure to actual climate conditions.

The philosophy at DN Tanks is to build the best quality product to provide for long-term performance and eliminate the necessity for maintenance of tanks in the future. We hope that the client shares the commitment of investing for the future and we look forward to the opportunity to build the tank under consideration.

Sincerely,

DN TANKS | *Generations Strong*

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August 25, 2017

Graham Walker
AECOM

REFERENCE: Prestressed and Conventionally Reinforced Concrete Tanks Comparison Letter

Dear Mr. Walker:

Thank you for your interest in prestressed concrete tanks. We have developed this letter that presents the features of prestressed concrete tanks. I offer the following information for your consideration:

INFORMATION ON DN TANKS AS A TANK DESIGNER AND BUILDER

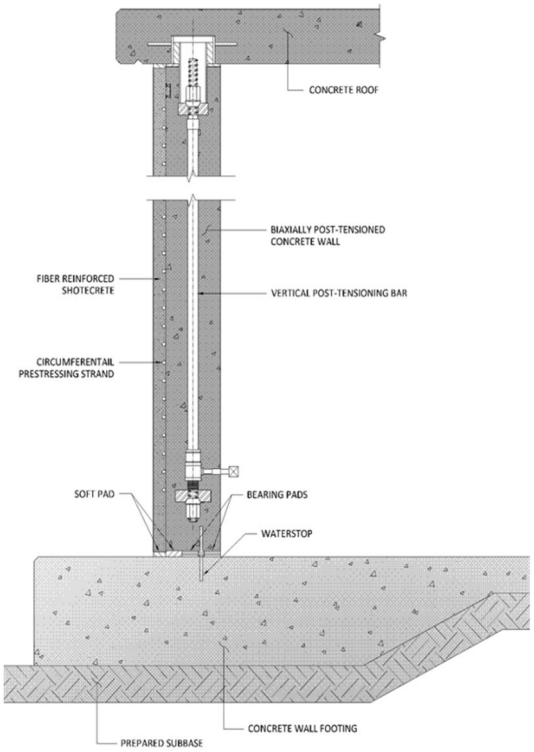
DN Tanks is a tank manufacturer specializing in the design and construction of prestressed concrete tanks. DN Tanks has constructed more than 2,700 tanks since 1930's with capacities ranging from 40,000 gallons to 40,000,000 gallons. DN Tanks has significant experience in the high seismic regions of the Western US. To date, all of DN Tanks 700 Western tank structures have performed successfully in every major earthquake since our first project built.

DN Tanks designs and constructs a strand-wound, circular prestressed concrete potable water storage tank as defined as Type I in ANSI/AWWA Standard D110. The tank is designed and constructed in accordance with the following standards and codes: ANSI/AWWA D110; ACI 350; ACI 350.1; ACI 350.3; ACI 372R, ASCE 7, International Building Code and Local Codes.

CONCEPTS BEHIND THE DESIGN OF A PRESTRESSED CONCRETE TANK

Wall Design with Vertical Compression:
The cast-in-place corewall included as part of the standard design for the AWWA D110 Type I prestressed tank is poured in full height sections. Horizontal joints are not utilized and vertical joints are minimized. The wall incorporates circumferential prestressing strand, vertical prestressing threadbars, along with mild steel circumferential and vertical reinforcement. The nature of concrete water tanks with a wet, cool interior, and a hot, dryer exterior (differential temperature and dryness), results in vertical bending within the wall which can negatively affect the performance of the concrete over time. AWWA D110 Type I tanks incorporate 200 psi residual compression using vertical stressing to counter the vertical bending moments caused by the differential temperature and dryness conditions that will exist between the interior and exterior of the tank wall. This feature in combination with circumferential compression results

in bi-axial compression and will provide superior performance and longevity of the concrete structure.



Pictures: Anchored flexible base connection improves seismic and static performance. Restraint cables are shown splayed into the corewall. Vertical threadbars are housed in the white PVC pipes. With reduced mild reinforcing, wall concrete is placed through pour windows greatly enhancing the final product.

DN Tanks' wall design incorporates an "anchored flexible base" connection between the foundation and the wall. A "base isolation" style connection reduces bending moments that are induced by hydrostatic, thermal, and seismic forces since the tank wall is separated from the wall footing by a neoprene bearing pad. The anchored flexible connection at the wall base enhances operational and seismic performance of the tank by allowing the floor and wall to act independently of each other. This detail for concrete tanks was developed over 40 years ago and has been included in thousands of installations. Seismic base restraint cables are developed within the foundation and wall. These restraint cables are utilized for transferring large loads between the floor and wall, directing the loads in-plane of the wall during seismic events. This detailing provides ductility and has led to superior performance of prestressed tanks during standard operation as well as during seismic events.

Further, the DN Tanks prestressed wall will be poured in 48-foot (14.6304 m) circumferential sections with a 6-inch (152.4 mm) PVC waterstop installed at all vertical wall joints and between the floor and the wall to ensure watertightness. Walls will be poured full height through form

openings spaced no greater than 8 feet (2.4384 m) apart. This assists in proper concrete placement, quality control and assurance.

Wall Design with Circumferential Compression:

The circumferential prestressing design will be based on an analysis of the static and dynamic load cases. The static load considers the effects of the water load, and differential temperature and dryness and requires the wall to maintain a minimum residual compression of 200 psi. The second load case is for the dynamic load experienced during the design level earthquake. The hydrodynamic facets include the axisymmetric hoop loads including the impulsive, convective and vertical forces imposed on the wall as the water is accelerated within the tank. The final compressive stress on the wall generated by the prestressing and backfill are checked to ensure that it does not exceed 45% of $f'_{c.}$

Picture: DN Tanks Automated Prestressing Machine

AWWA D110, Type I tank walls remain in 200 psi residual vertical and circumferential compression through the use of prestressing. By keeping the walls in permanent bi-axial compression the tank can withstand the varying operational hydrostatic loads, as well as thermal and seismic loads without cracking. Because the prestressing is at the heart of functionality and quality for a prestressed water storage tank, it is imperative that a high level of standards be specified for the prestressing material and application. As a result, DN Tanks uses electronically monitored prestressing machines ensuring consistent and accurate force application through a mechanical stressing process. All circumferential prestressing reinforcing material shall be a galvanized 7-wire strand for higher quality, durability, redundancy, and corrosion protection. DN Tanks prestressing machines have in-line calibration and stress monitoring to ensure a consistent prestressing force of 14,950 pounds (66,500 N) with a tolerance of +/-320 pounds (1,423 N). Utilizing an automated shotcrete system to ensure quality application, shotcrete is then applied to the galvanized strand with a minimum cover over the strand of 1.5-inch (25.4 mm).

DISCUSSION: Comparison Between Prestressed And Conventionally Reinforced Tanks

The following presents a short comparison between conventionally reinforced concrete and prestressed concrete storage tanks. Although both prestressed concrete and conventionally reinforced tanks use concrete as their primary component, we hope to illustrate herein the vast differences in performance between the two alternatives.

Tension verse Compression:

The most obvious, and most significant, difference between the two types of tanks is that the concrete is allowed to go into tension in for a conventionally reinforced tank, and is continuously kept in compression a prestressed concrete tank. As previously mentioned, a prestressed tank will have its corewall held in compression under not only hydrostatic but also under thermal and seismic loadings. In contrast, the concrete in a conventionally reinforced tank will be placed into tension under these same conditions. When concrete is tensioned, cracking and subsequent leakage can result. Unfortunately, there is no national tank code that says exactly how much tension the conventionally reinforced concrete tank is allowed to undergo. Allowable tensile stresses for the reinforcing steel are also somewhat ambiguous in the codes. In a conventional tank, even if in the concrete and reinforcement tensile stresses are kept low and the reinforcement is closely spaced to minimize cracking, over long periods of time the small cracks that do develop will tend to migrate toward one another.

Fixed Connections verse Anchored Flexible Connections:

If the alternative tank under consideration is a circular conventionally reinforced tank, fixed moment connections at wall/floor interface and at the wall/roof interface are most commonly employed. Although these fixed connections may reduce the hoop stress and bring down the required wall thickness and circumferential steel requirements, these reductions do not come without a penalty. By rigidly tying the floor, wall, roof and base together, large bending moments will be induced in each of these components under hydrostatic, temperature and seismic loadings. Because of these moments, the problem of cracking is again possible.

If the alternative tank under consideration is a rectangular conventionally reinforced tank, there will be an additional potential for cracking. In a rectangular tank, the hydrostatic load is not resisted by a uniform hoop stress as it is in a circular tank. Instead, the water must be held back by a retaining wall cantilevered off the floor. This cantilevered wall produces large moments in the floor and wall, which again promotes cracking. Since it is so difficult to fully resist the water load just by a cantilever from the floor, the wall is often also tied to the roof so it is fixed at its base and top. Although this helps the wall carry the water load, it can promote significant cost increases in the roof. If the roof is not buried, the thermal expansion of the roof can create serious structural problems at the wall to roof connection. If the roof is buried to minimize the thermal load, the roof must be strengthened at a significant cost to carry the backfill.

Another place of concern is the stress concentrations that occur at the sharp corners of the tank wall. These stress concentrations are extremely difficult to accurately analyze and design for. This is one reason why you normally see pressure vessels for gas and other liquids follow the form of a circle, not a square. All these stress concentrations and moment conditions that produce tension can ultimately result in leakage. The evidence of this leakage can best be illustrated by two simple observations:

1) You will rarely, if ever, see a large conventionally reinforced tank above grade where all its inadequacies will be in full view.

2) The allowable leakage loss rate can be as much as the full capacity of the tank each year.

In contrast, many large prestressed tanks (up to 20 MG) have successfully been built above grade. These tanks have shown no signs of cracking or leakage.

Even though we could receive similar short-term cost benefits by using rigid connections, prestressed concrete tank designs incorporate free connections at the base and top of the wall. Even with free moving connections, the wall will still be subject to some circumferential and vertical bending moments due to differential temperatures between the inside and outside of the wall. To counteract these effects, our design adds vertical prestressing plus circumferential prestressing above and beyond that required for the hydrostatic loads. This is to keep the concrete crack-free in both the vertical and circumferential directions, which is something a conventionally reinforced concrete tank cannot claim.

Prestressed Concrete Tanks – Enhanced Seismic Performance:
An important component to consider for reservoirs located in seismically active zones is their capacity to absorb energy and to sustain cyclic loading during a seismic event. The design of prestressed concrete tanks takes into consideration horizontal and vertical ground accelerations, the sloshing of the water and the overturning moments. With the majority of DN's tanks located in the Western United States in areas of high seismic activity we have never experienced any earthquake induced problems. Consider specifically the 1994 Northridge earthquake, where DN Tanks had numerous tanks located in close proximity to the epicenter. None of these tanks exhibited any major structural damage. Possibly the most dramatic test of a DN tank was a 10.0 MG, 40' tall tank located within 10 miles of the epicenter of the Northridge earthquake. This tank is completely above ground and was full at the time of the earthquake. In addition to this tank, DN had approximately two dozen tanks within a 30 mile radius of the epicenter that performed excellently.

SUMMARY OF BENEFITS OF PRESTRESSED CONCRETE TANKS:

1. Enhanced operational and seismic performance as roof and footings do not have fixed connections. Floor to wall and wall to roof are designed utilizing an “anchored flexible base”. This allows for all three components of the tank structure to move independently of each other.

2. Significantly improved wall pouring capabilities. Conventionally cast in place tanks typically have significant amounts of reinforcing in the walls. With standard forms for conventional cast-in-place tanks, pours are commonly required from the top of the form.

This poses a significant challenge to properly consolidating the full height of a potentially 20' to 30' tall wall with tremendous mild reinforcing congestion. These challenges have a high likelihood to reduce the quality of the wall. With reduced mild reinforcing in a prestressed concrete tank wall, pour windows can be easily utilized, which greatly enhances the final product.

3. Prestressed concrete tank walls are in bi-axial permanent compression. Tanks are designed to be in 200 psi residual compression, ensuring a long lasting leak free wall. Reinforced concrete tanks introduce tension into the walls which could lead to cracking over time.

4. Prestressed concrete tanks with exposed roofs have excellent performance with temperature and dryness stress variations. As the wall to roof also utilizes an anchored flexible connection, the slab is free to expand and contract with the thermal variations. This is opposed to a conventionally reinforced concrete tank where thermal loads in the roof can induce bending moments when rigidly connected.

5. Circular prestressed concrete tanks provide enhanced water quality. The circular shape provides for natural and efficient turnover of water in the tank with no dead spots. This is opposed to square or rectangular concrete tanks which can have "dead zones" towards the corners of the tank. These zones can create a significant water quality issue and promote bacteria growth.

Please feel free to contact me if you have any questions or if I can be of any further assistance.

Sincerely,
DN TANKS | *Generations Strong*

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Appendix C

Lifecycle Cost Estimates for Tank Replacement Options based on Tank Materials

Table 9A: Summary Lifecycle Cost for Prestressed Concrete Tanks

	Construction Cost	Annual Operation and Maintenance Cost	Overhaul Maintenance Allowance	Net Present Value
Option 1 – Full Replacement				
Upgrade Harvey (1.98ML)	$ 1,450,000	$ 12,000	$ 362,500	$ 2,940,000
Update Phase IV (0.10ML)	$ 230,000	$ 8,000	$ 57,500	$ 730,000
Update Phase V (0.10ML)	$ 230,000	$ 8,000	$ 57,500	$ 730,000
Update Highway (0.10ML)	$ 300,000	$ 8,000	$ 75,000	$ 850,000
Option 1 Totals	***$ 2,210,000***	***$ 36,000***	***$ 552,500***	***$ 5,250,000***
Option 2 – Partial Replacement				
Upgrade Harvey (2.18ML)	$ 1,475,000	$ 12,000	$ 368,750	$ 2,980,000
Upgrade Highway (0.10ML)	$ 300,000	$ 8,000	$ 75,000	$ 850,000
Replace Phase IV with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Decommission Phase V	$ 40,000			$ 40,000
Option 2 Totals	***$ 1,965,000***	***$ 22,500***	***$ 458,750***	***$ 4,100,000***
Option 3 – Harvey Only Replacement				
Upgrade Harvey (2.28ML)	$ 1,500,000	$ 12,000	$ 375,000	$ 3,030,000
Replace Phase IV with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Replace Highway with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Decommission Phase V	$ 40,000			$ 40,000
Option 3 Totals	***$ 1,840,000***	***$ 17,000***	***$ 405,000***	***$ 3,530,000***
Optional System Improvements				
Install new water main (400 m of 200mm DI across Alberta Creek)	$ 300,000	$ 3,000	$ 30,000	$ 680,000
PRV Automation for Water Quality Improvement	$ 200,000	$ 2,500	$ 20,000	$ 280,000
Increase Harvey Tank by 0.15 ML to accommodate Magnesia shortfall	$ 225,000			$ 225,000
Optional Total	***$ 725,000***	***$ 5,500***	***$ 50,000***	***$ 1,185,000***

Table 9B: Summary Lifecycle Cost for Glass-Fused Bolted Steel Tanks

	Construction Cost	Annual Operation and Maintenance Cost	Overhaul Maintenance Allowance	Net Present Value
Option 1 – Full Replacement				
Upgrade Harvey (1.98ML)	$ 850,000	$ 12,000	$ 212,500	$ 5,320,000
Update Phase IV (0.10ML)	$ 230,000	$ 8,000	$ 57,500	$ 730,000
Update Phase V (0.10ML)	$ 230,000	$ 8,000	$ 57,500	$ 730,000
Update Highway (0.10ML)	$ 300,000	$ 8,000	$ 75,000	$ 850,000
Option 1 Totals	***$ 1,610,000***	***$ 36,000***	***$ 402,500***	***$ 7,630,000***
Option 2 – Partial Replacement				
Upgrade Harvey (2.18ML)	$ 875,000	$ 12,000	$ 218,750	$ 5,430,000
Upgrade Highway (0.10ML)	$ 300,000	$ 8,000	$ 75,000	$ 850,000
Replace Phase IV with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Decommission Phase V	$ 40,000			$ 40,000
Option 2 Totals	***$ 1,365,000***	***$ 22,500***	***$ 308,750***	***$ 6,550,000***
Option 3 – Harvey Only Replacement				
Upgrade Harvey (2.28ML)	$ 900,000	$ 12,000	$ 225,000	$ 5,540,000
Replace Phase IV with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Replace Highway with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Decommission Phase V	$ 40,000			$ 40,000
Option 3 Totals	***$ 1,240,000***	***$ 17,000***	***$ 255,000***	***$ 6,040,000***
Optional System Improvements				
Install new water main (400 m of 200mm DI across Alberta Creek)	$ 300,000	$ 3,000	$ 30,000	$ 680,000
PRV Automation for Water Quality Improvement	$ 200,000	$ 2,500	$ 20,000	$ 280,000
Increase Harvey Tank by 0.15 ML to accommodate Magnesia shortfall	$ 225,000			$ 225,000
Optional Total	***$ 725,000***	***$ 5,500***	***$ 50,000***	***$ 1,185,000***

Table 9C: Summary Lifecycle Cost for Conventional Concrete Tanks

	Construction Cost	Annual Operation and Maintenance Cost	Overhaul Maintenance Allowance	Net Present Value
Option 1 – Full Replacement				
Upgrade Harvey (1.98ML)	$ 1,150,000	$ 12,000	$ 287,500	$ 2,440,000
Update Phase IV (0.10ML)	$ 230,000	$ 8,000	$ 57,500	$ 730,000
Update Phase V (0.10ML)	$ 230,000	$ 8,000	$ 57,500	$ 730,000
Update Highway (0.10ML)	$ 300,000	$ 8,000	$ 75,000	$ 850,000
Option 1 Totals	***$ 1,910,000***	***$ 36,000***	***$ 477,500***	***$ 4,750,000***
Option 2 – Partial Replacement				
Upgrade Harvey (2.18ML)	$ 1,175,000	$ 12,000	$ 293,750	$ 2,480,000
Upgrade Highway (0.10ML)	$ 300,000	$ 8,000	$ 75,000	$ 850,000
Replace Phase IV with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Decommission Phase V	$ 40,000			$ 40,000
Option 2 Totals	***$ 1,665,000***	***$ 22,500***	***$ 383,750***	***$ 3,600,000***
Option 3 – Harvey Only Replacement				
Upgrade Harvey (2.28ML)	$ 1,200,000	$ 12,000	$ 300,000	$ 2,520,000
Replace Phase IV with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Replace Highway with PRV (200mm)	$ 150,000	$ 2,500	$ 15,000	$ 230,000
Decommission Phase V	$ 40,000			$ 40,000
Option 3 Totals	***$ 1,540,000***	***$ 17,000***	***$ 330,000***	***$ 3,020,000***
Optional System Improvements				
Install new water main (400 m of 200mm DI across Alberta Creek)	$ 300,000	$ 3,000	$ 30,000	$ 680,000
PRV Automation for Water Quality Improvement	$ 200,000	$ 2,500	$ 20,000	$ 280,000
Increase Harvey Tank by 0.15 ML to accommodate Magnesia shortfall	$ 225,000			$ 225,000
Optional Total	***$ 725,000***	***$ 5,500***	***$ 50,000***	***$ 1,185,000***

About AECOM

AECOM (NYSE: ACM) is built to deliver a better world. We design, build, finance and operate infrastructure assets for governments, businesses and organizations in more than 150 countries.

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