

***Alternative Construction Details
for Extended Life of Welded
Steel Storage Tank Roofs***

AWWA CA-NV SECTION FALL CONFERENCE

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Over 35 years of experience in the tank industry. Extensive experience in estimating, engineering, coatings, and project management of storage tank projects with special emphasis in seismic design aspects, structural detailing and code requirements. Leslie currently serves as the chair of the AWWA Task Force for development of a new standard titled Standard for Welded Carbon Steel Flat-bottom Tanks for Water Storage and is an active member of the AWWA Task Forces for D100, D102, D103, D104, and D106, as well as the General Tank Standard and the Standard for Stainless Steel Bolted Tanks for Water Storage, both under development. Leslie is an inventor on two tank related patents and has been a speaker for numerous industry seminars.

■ OBJECTIVES

- Identify the options for roof construction details available
- Understand how those options improve the conditions for the application of protective coatings
- Understand how the improved conditions result in enhanced corrosion protection of the roof structure and reduce long-term maintenance requirements.
- Initiate the conversation for change
- Overview of considerations
 - High level review, not a detailed user manual
 - Focus on ground-supported, welded steel tanks designed and constructed to AWWA D100

■ Background

Types of Welded Steel Water Tanks

- Elevated
 - AWWA D100 – steel tank and support structure
 - AWWA D107 – steel tank on a concrete pedestal
- Ground supported
 - AWWA D100 – reservoir
 - AWWA D100 – standpipe
 - Focus of today's presentation

- **AWWA Welded Steel Tank Standards**
 - Differences Between AWWA D100 and AWWA D107
 - Seal Welding
 - AWWA D100 does not require seal welding of the roof laps or roof plates to the supporting structural members or stiffeners. D100 does require seal welding of all interior joints below the TCL.
 - AWWA D107 requires seal welding of all exposed interior and exterior joints including the roof laps and roof plates to any supporting structural members or stiffeners.
 - AWWA D100 states that priming or painting of contact surfaces between roof plates and rafters is not required unless specified.
 - AWWA D102 coating system requirements exclude those areas that are defined as inaccessible.

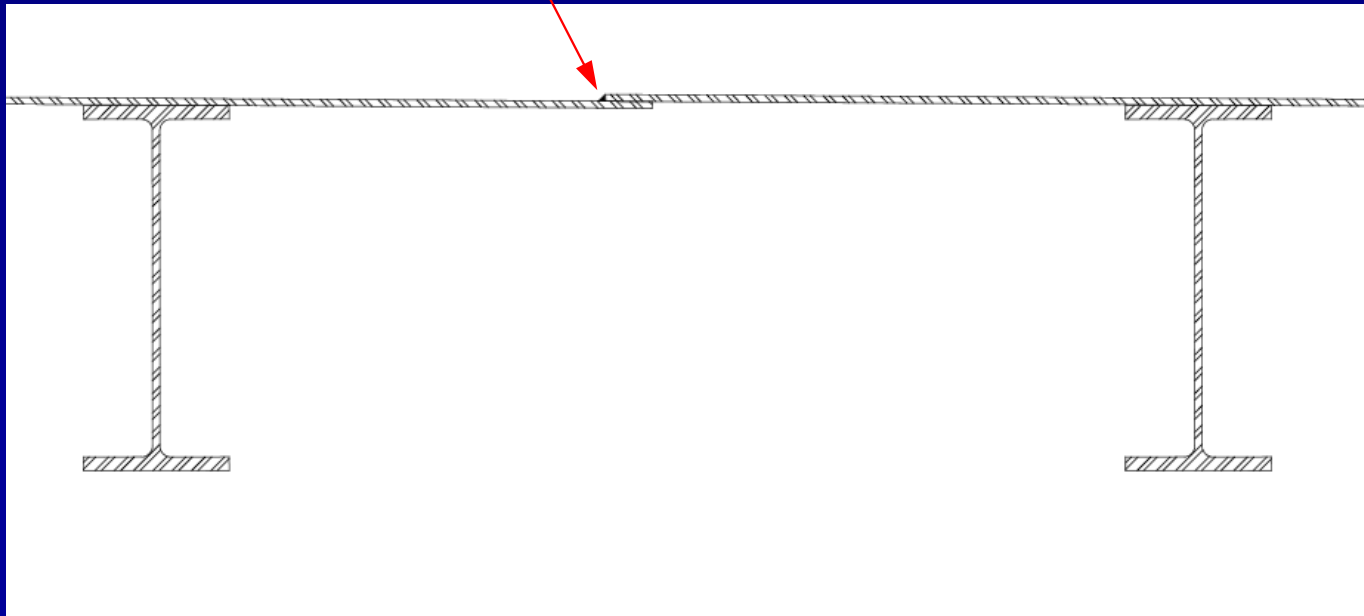
- Conventional Construction Details for Ground Supported Reservoirs
 - Center column supporting rafters.
 - Radial framing members, crowded at center.
 - Bolted or welded structural connections.
 - Intermediate columns between center and tank shell, if needed.
 - Structural bracing.
 - Roof plates laid on rafters, welded only to shell.
 - Roof plate lap joints and roof-to-shell joint welded topside only.

■ PHOTOS GO HERE

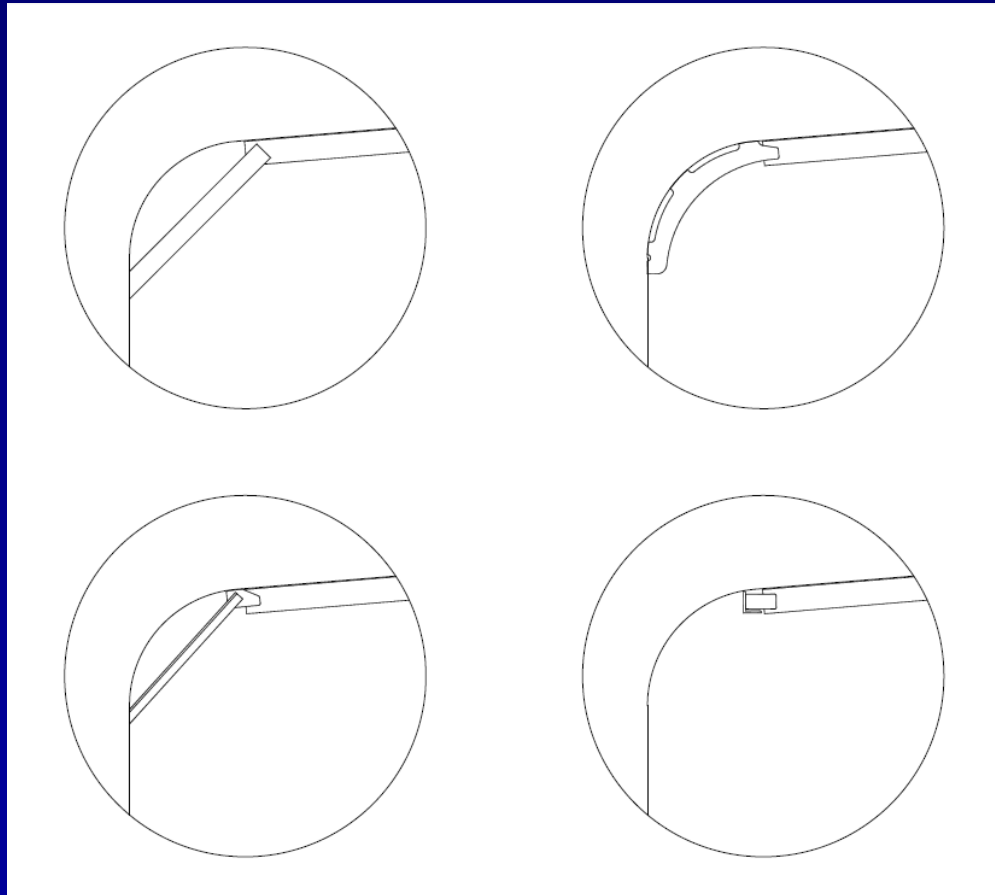


■ CONVENTIONAL ROOF PL CONSTRUCTION

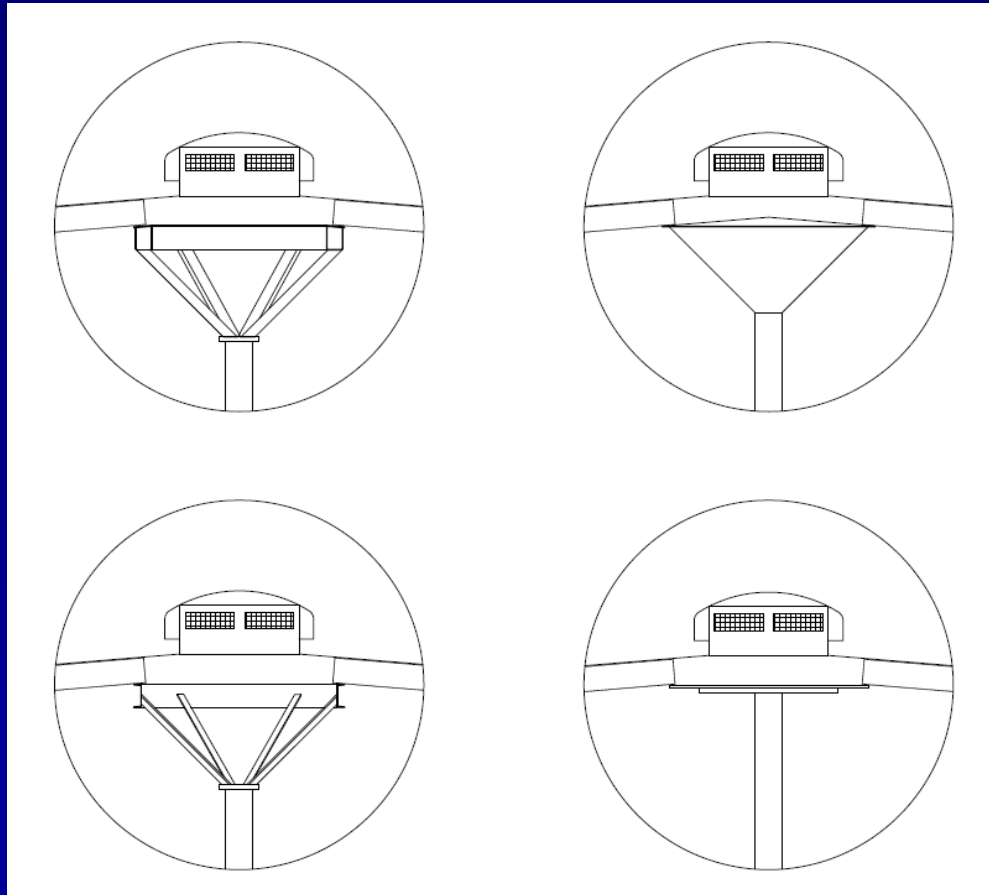
ROOF PLATE
WELDED ON
TOP SIDE OF
JOINT ONLY.



■ KNUCKLE FRAMING CONFIGURATIONS



■ CENTER SUPPORT CONFIGURATIONS



■ INDUSTRY CHANGE

- What is 'Conventional'?
- Who can implement change?
- Constructor Recommendations
- Prior efforts – patents
- Resistance to change
 - Eye of the beholder
- Public utility v. Industrial facility
 - Project Notes
 - Water utility tank projects (0.200 MG up to 6.000 MG)
 - Sloshing wave resistance
 - Industrial tank roof replacement

- **AWWA Standards = Minimum Requirements**
 - AWWA standards are consensus based standards representing the minimum requirements considered necessary for a product to provide satisfactory service in the water industry.
 - These standards do not necessarily represent best practice.
 - The AWWA standards are intended to be supplemented by project specifications when a purchaser/specifier desires to exceed the minimum requirements.

- AWWA Welded Steel Tank Standard for Standpipes and Reservoirs

- AWWA D100 provides minimum requirements for the design, fabrication, construction, inspection and testing of welded steel storage tanks. The minimum requirements of this standard result in a tank that will provide satisfactory service under the design load conditions specified by the model building codes. It is intended to provide safe and reliable service under normal conditions of operation when designed in conformance with this standard.

■ AWWA Steel Tank Coating Standard

- AWWA D102 provides minimum requirements for surface preparation and coating application for steel storage tanks. Although the minimum requirements of this standard have provided satisfactory service for many water utilities for many decades, there are certain aspects of tank coating systems that can be improved when special roof construction details are specified that exceed the minimum requirements of AWWA D100.

■ AWWA Steel Tank Coating Standard

– Special Topics

- Inaccessible Areas – only some of the methods that we will discuss today eliminate inaccessible areas from the tank roof structure while the remainder of the options still have inaccessible areas. When an option is selected for new construction that will not require full seal welding but will include inaccessible areas, shop applied coatings should be specified
- Coatings for inaccessible areas must be properly specified. AWWA D102 contains extensive commentary guidance on inaccessible areas and the issues surrounding coating specifications for such cases. Refer to D102 commentary if this applies to your project.

- Roof styles for ground-supported welded steel tank roofs
 - Roofs for standpipes and reservoirs may be provided in several styles and with many options in design details or specific features. If the project specification only specifies the type, then the roof will likely be constructed only to meet the minimum requirements of the applicable tank standard.
 - Two basic types of roofs
 - Self-supporting roofs
 - Stiffened
 - Unstiffened
 - Supported roofs

■ Self-Supporting Roofs

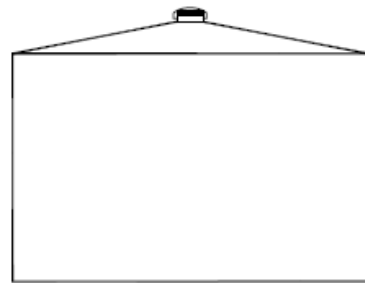
– Types

- Conical
- Toriconical
- Umbrella
- Dome
- Torispherical
- Elliptical

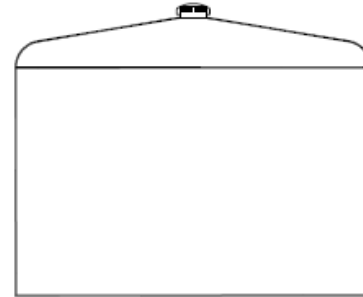
– Methods of Stiffening

- Unstiffened
- Stiffened with welded bars
- Stiffened with welded beams or channels
- Stiffened with integral formed members

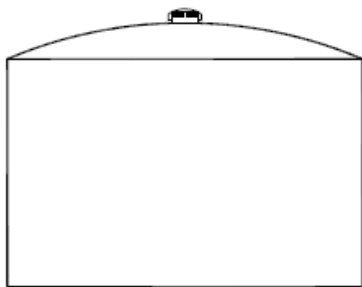
■ SELF-SUPPORTING ROOF STYLES



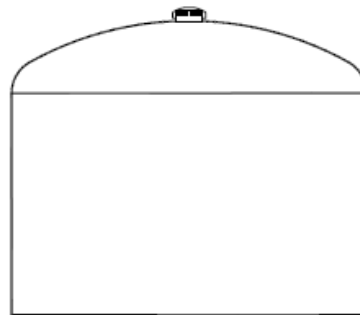
CONICAL



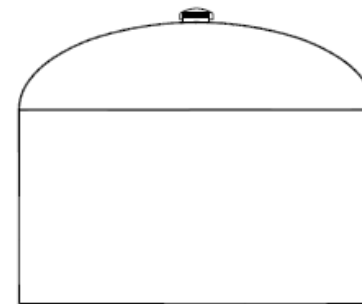
TORICONICAL



UMBRELLA
or DOME



TORISPHERICAL
(umbrella or dome)



ELLIPTICAL

■ SELF-SUPPORTING ROOF STYLES



■ Supported Roofs

– Types

- Conical
- Toriconical (knuckle roof)

– Supporting Members

- Rafters
- Girders
- Columns
- Base plates
- Footings

■ SUPPORTED ROOF STYLES



- What are your options for more than minimum requirements?
 - New construction
 - Existing construction
 - Rehabilitation projects

- Options for new construction –
Specify details that exceed AWWA D100 minimum requirements
 - Specify reverse shingled laps (if not seal welded).
 - Caulk accessible interior roof plate lap joints and perimeter joints with suitable NSF 61–certified caulking material compatible with the coating system.
 - Note that due to thermal movement of the roof plates, caulking of the roof to rafters will not completely effective.
 - Self-supported roof. Specify self-supported if practical for the tank size.
 - Unstiffened self-supporting cones ($D \leq 50$ ft) diameter
 - Unstiffened umbrellas or domes ($D \leq 90$ ft)
 - Low-pitch, stiffened self-supporting cones with integral stiffeners ($D \leq 80$ ft)

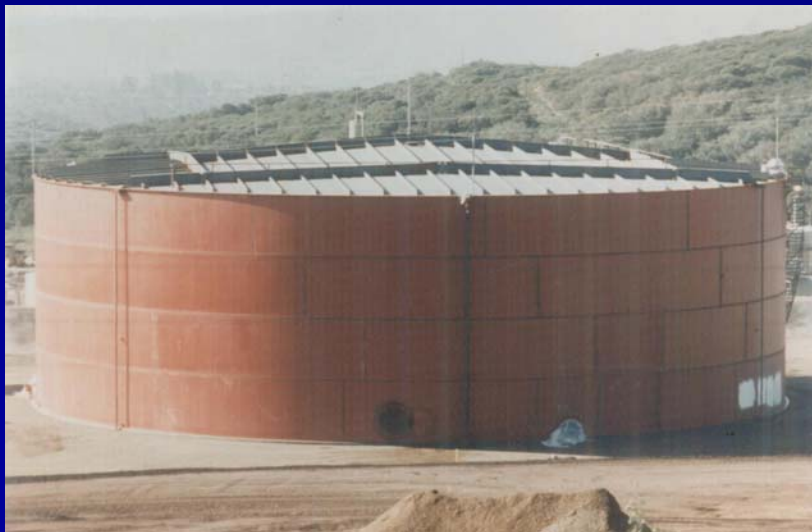
■ New Construction Options (continued)

- Seal welding
 - Seal welding roof seams
 - Seal welding roof structure to roof plates.
- Roof structure configuration that makes all plate joints accessible for welding.
 - No center column
 - Rafters not contained in the high volume breather vent flow space
 - No rafter congestion at center
 - Use radial plate seams
 - Land seams between framing members
 - If seal welding structure to roof plate, can land seams above framing members.

■ New Construction Options (continued)

– Seal welding

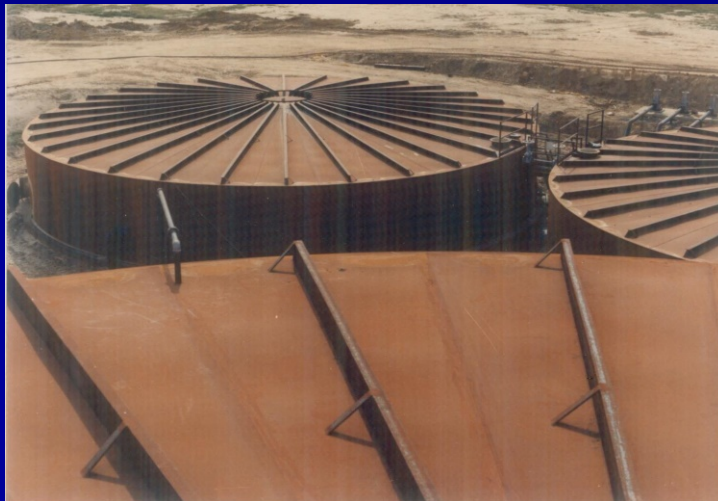
- Seal welding roof seams
- Rectangular v. radial structure configurations



■ New Construction Options (continued)

■ External roof structure

- Access for inspection and maintenance not restricted.
- Maintenance activities may be performed while tank is in service.
- Top flange bracing may be required.
 - Snow region considerations
 - Debris removal



■ New Construction Options (continued)

- Improve coating performance in inaccessible areas with an integrated plan and detailed specifications.

- Structure configuration

- Location of structural members (inside or outside)

- Column locations

■ Notes on Seal Welding

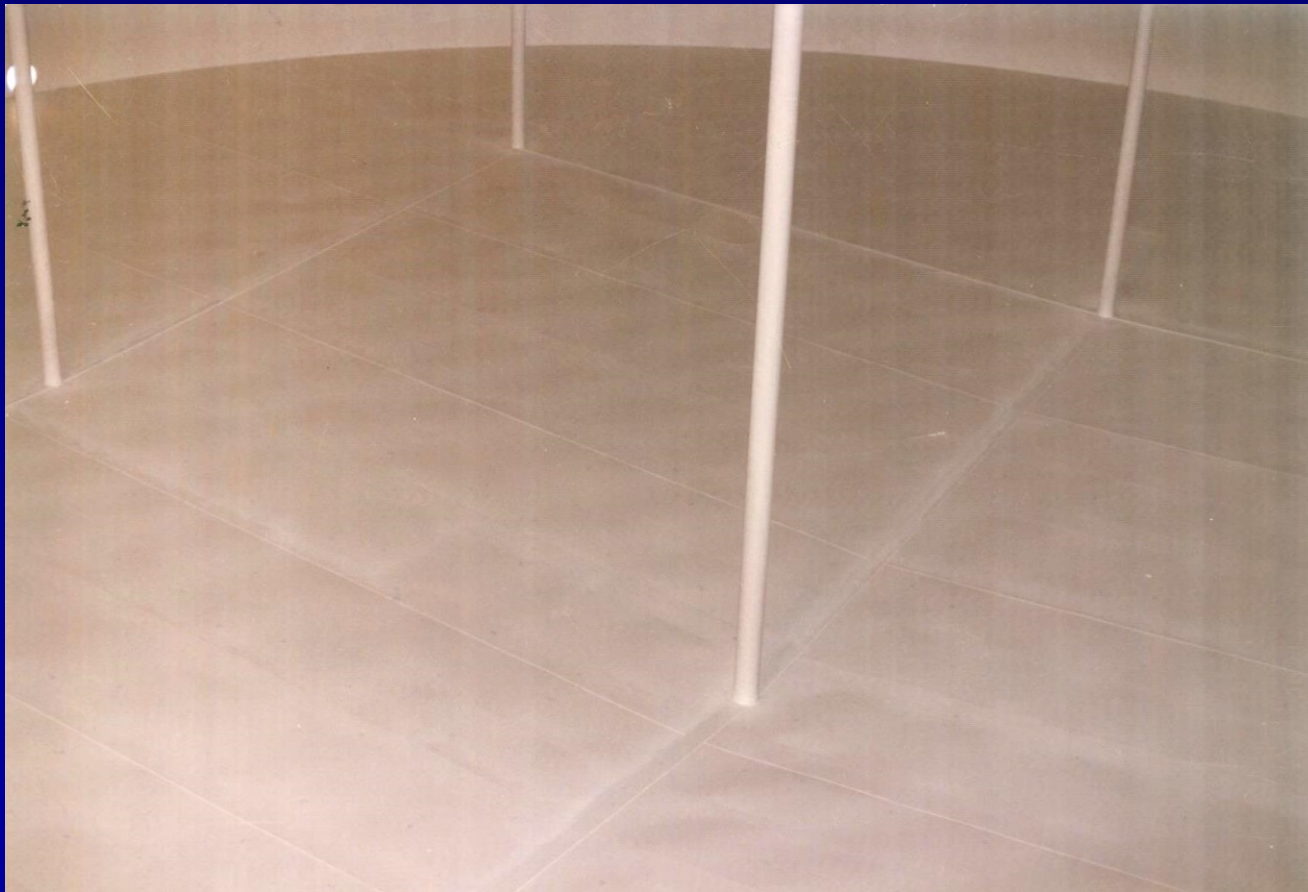
- Weld shrinkage considerations

- Plate distortion / rippling

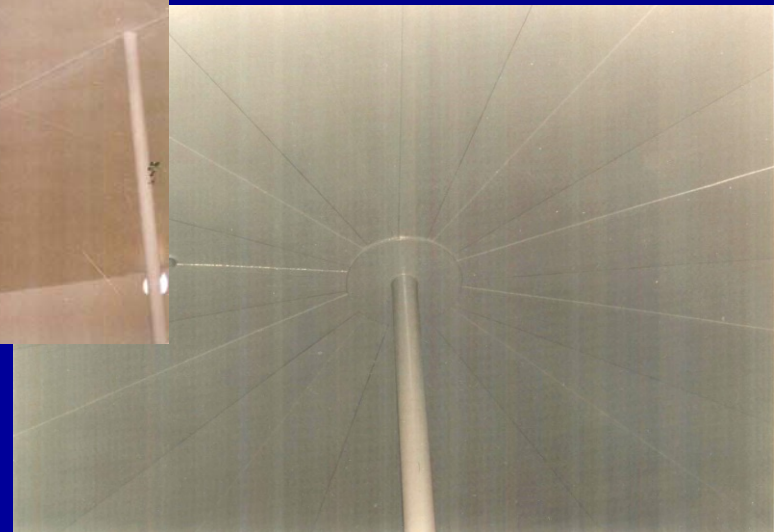
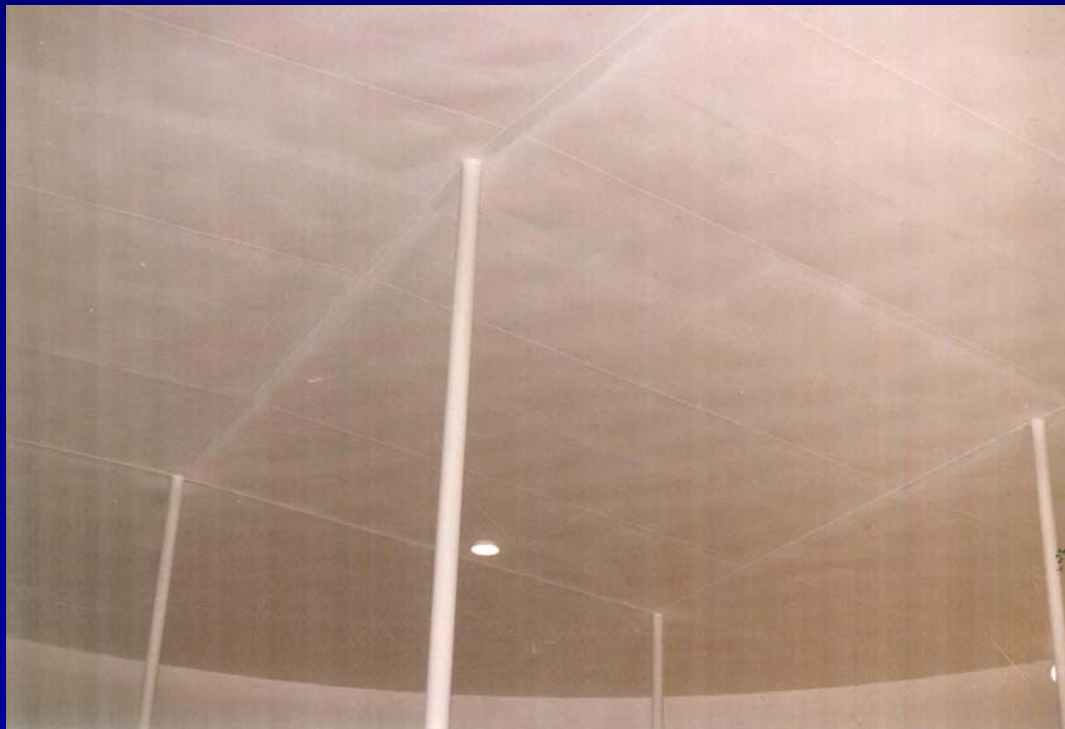
- Structural considerations

- Differential settlement of columns may necessitate column footings.

- **New Construction Options** (continued)
 - Would these surfaces be easy to paint?



- **New Construction Options** (continued)
 - Especially when it is the roof!



- Options for Existing Construction – Specify rehabilitation of the roof to create conditions for improved coating performance.
 - Similar to new construction but limited to treatment of tank seams and points of contact of roof components.
 - Caulk roof seams
 - Seal weld accessible interior roof plate joints
 - Seal weld accessible rafter-to-roof-plate joints

■ Options for rehabilitation projects

– Same options as for Existing Construction and the following:

- Repair existing structure in place
- Repair roof plates using patch plates
- Replace individual components of roof structure
- Replace entire roof

■ Reference List for Roof Design Options

- The following is a listing of several alternate roof construction options that enhance the conditions for surface preparation and coating application of protective coatings.
- The options are listed in approximate order from least expensive up to most expensive with the difficulty of proper coating application decreasing as you progress.
- These options will reduce long-term maintenance costs and increase design life for interior surfaces of tank roofs.

■ Reference List for Roof Design Options (continued)

1. Conventional roof construction (D100 minimum requirements) with all exposed components painted after tank construction is complete.
2. Conventional construction in Item 1, but with all lap joints reverse shingled.
3. For a tank to be constructed using conventional roof construction, specify shop priming of all non-slip-critical bolted connections, tops of all rafters, and underside of roof plates. Note that this will require an exception for weld zones.

■ Reference List for Roof Design Options (continued)

4. For a tank to be constructed using conventional roof construction, specify shop application of the complete coating system of all non-slip-critical bolted connections, tops of all rafters, and underside of roof plates. Note that this will require an exception for weld zones.
5. In combination with Option 1, 2, 3 or 4 above, add caulking of accessible interior roof plate lap joints, perimeter joints, tee joints and contact points between rafters and roof plates with suitable NSF/ANSI 61–certified caulking material compatible with the coating system.

■ Reference List for Roof Design Options (continued)

6. For small-diameter tanks (approximately 50 ft diameter, depending on roof load and roof height limitations), use self-supported cone roofs with all interior and exterior roof plate joints seal welded.

Note: roof slope between 2:12 and 9:12 corresponding to roof height between about 8% and 38% of tank diameter.

7. For medium-size tanks (generally up to about 85 ft diameter), use self-supported dome or umbrella roofs with all joints seal welded.

Note: roof radius varies between 120% of tank diameter and 80% of tank diameter corresponding to roof height between 11% and 18% of tank diameter.

■ Reference List for Roof Design Options (continued)

8. Roof construction using formed integral structural members with all internal and external plate joints and structure-to-plate joints seal welded.
9. Roof construction using formed integral external structural members with all internal and external plate joints and structure-to-plate joints seal welded.
10. Roof construction using external attached structural members with all internal and external plate joints and structure-to-plate joints seal welded.

■ Reference List for Roof Design Options (continued)

11. Seal welding of interior roof plate lap joints, interior roof plate perimeter joints, and rafter-to-roof plate joints with tank being constructed so that all such joints are accessible.
12. In combination with Option 1, 2, 3 or 4 above, seal weld accessible interior roof plate lap joints, perimeter joints, and tee joints.
13. In combination with Option 1, 2, 3 or 4 above, seal weld accessible interior roof plate lap joints, perimeter joints, tee joints and contact points between rafters and roof plates

■ Reference List for Roof Design Options (continued)

14. For large-diameter tanks, use self-supported stiffened dome or stiffened umbrella roof with all joints seal welded.

■ COST IMPACTS

Approximate costs of roof construction options

- Conventional construction: 10% to 35% of tank construction cost (depending on tank size and shape)
- Enhancements: increase roof construction cost by 10% to 50% of cost basis for conventional roof (roof only)
 - depends on tank configuration and enhancements chosen
- Increases tank construction by about 1% up to 15% to 18%
- Increases total cost of installation (including paint and foundation) by about 1/2% to 10%
- Increases total project cost by about 1/4% to 5-7% depending on total project scope
- Projects vary, get budget quotes for your specific requirements

■ Additional Considerations

- Know your water chemistry
 - Sulfur or chlorine
- Know your regional climatic exposure
 - Arid, coastal, industrial
- Know the coating performance history for the roofs in your tanks
 - Variations based on water type
 - raw water, treated water, finished water
 - Problems areas in coating maintenance
 - All structural components, near center vent, near shell vents, tops or ends of rafters
- Resources
 - AWWA D102, Appendix A, commentary on inaccessible areas.
 - AWWA D102-14 Commentary, Table A.1, provides a discussion of roof construction options with additional issues to consider

■ SUMMARY

- There is no universal answer appropriate for every tank project.
- Know your standards, what is included and what is not
- Review your water system's experience with roof maintenance issues and costs
- Review your tank inspection and maintenance plans
- Determine which roof constructions enhancements are viable for your project's design life
- Select the enhanced roof construction details best suited for your project goals

- **SUMMARY** (continued)
 - Prepare detailed specifications to insure that you receive the details that you want, not just the minimum requirements from the referenced AWWA standards.
 - If you are unsure about which details are best for your tank project, ask for prices on one or two alternative configurations when seeking bids on your new tank construction project.
 - Unconventional methods to achieve different results
 - A quote from Albert Einstein:
 - *We can't solve problems with the same kind of thinking we used when we created them.*
 - In other words, don't keep using the same old process and details and expect different results.

By employing some of the methods of improved construction details for welded steel tank roofs described in this seminar in conjunction with detailed project specifications and contract drawings, the tank owner can develop an construction strategy that will greatly extend the practical life of the tank roof, reduce maintenance costs, and enhance the utility's asset preservation plan.

DISCUSSION