

Tank Talk®

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Storage Tank Engineering Updates for Owners and Operators of Industrial Tanks

Floating Roof Design Considerations

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The American Petroleum Institute (API) Standard 650 prescribes minimum design requirements for internal and external floating roofs. However, the minimum API requirements address floatation considerations only. They do not address the dynamics of flooding or prescribe minimum design practices to account for these dynamics. In terms of allowable stress criteria, API 650 states, "If calculations are required by the purchaser, the allowable stress criteria shall be jointly established by the purchaser and the manufacturer as part of the inquiry." As a result, there is wide variation in the approaches to floating roof design, and wide variation in the durability and reliability of the finished product.

Most floating roof designers and manufacturers consider the flooded liquid load—rain water or the stored product—as a static load on the roof and make simplifying assumptions about the response of the roof to these loads. These assumptions may not be technically correct. One of the most common assumptions is that the floating roof acts as a rigid, rather than a flexible, disk, in resisting the dynamic loads tending to overturn it. While this assumption may be sufficiently accurate for small floating roofs, it is typically not accurate for larger roofs.

Tank owners and operators should be aware that compliance with the minimum requirements of API 650 does not necessarily ensure that a floating roof will perform reliably or tolerate unanticipated loading conditions that can often occur. The following are some conditions that API 650 does not specifically address:

Gas Bubbling Effects Gas in the inlet lines can result in bubbles entering the tank during filling operations, particularly when high filling rates are used. As such bubbles make their way to the surface of the liquid, they can impose significant uplift loads on

the roof and cause turbulence under the roof. In the process of venting these bubbles at the perimeter seal or through deck penetrations, liquid product is typically splashed on top of the roof. In extreme cases, this can lead to sinking of the roof. The potentially damaging effects of gas bubbles can often be mitigated by a combination of proper placement and details of the inlet discharge, design of the roof for unbalanced loading, and control of the filling operations. In some cases, strategic design and placement of additional venting can help reduce the potential for damage.

Seal Friction Seal friction should be considered in the structural design of floating roofs. As technology improves toward the goal of a "zero emissions" storage tank, roof perimeter seals must become less prone to leakage. Normally, but not always, tighter seals mean higher friction between the seal and the tank shell. Thus, the design of the seal connection to the roof, and the roof itself, should consider the effects of seal friction.

Flexible Nature of Most Floating Roofs Most floating roofs, particularly those of large diameter, are more flexible than one might expect. In particular, the roof must have sufficient stiffness in the circumferential direction at the perimeter of the roof to resist progressive deflection as the deck and/or pontoon compartments fill with liquid as the result of a leak or splashing of liquid onto the roof. This is not necessarily a simple problem as the loading is dynamic and difficult to accurately predict. Nevertheless, there are design techniques in use to account for this type of loading.

Seismic Loading Floating roofs are typically not expected to remain undamaged in a "design seismic event" because to accommodate such high forces would usually result in a cost-prohibitive design. Nevertheless, the design of roofs in seismically

active areas should incorporate details to minimize the risk of damage in a seismic event. Adequate freeboard to accommodate the predicted sloshing wave is one way to mitigate the risk of damage to or sinking of the roof.

Proper engineering design and construction for the above conditions will help to ensure a durable and reliable floating roof. If the purchaser simply specifies that the floating roof be in accordance with API 650 and does not provide complete technical specifications addressing the above and other considerations, the evaluation of the most cost-effective design among competing manufacturers becomes very difficult.



John Lieb, P.E. is a nationally recognized expert in the design of plate structures including specialty plate structures for petroleum, chemical, and granular industries throughout the world.

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Industry Update

ASME Bulk Solids Standard Development Update.

In Tank Talk Issue 34 – Spring 2001, TIC notified readers that the American Society of Mechanical Engineers (ASME) was developing a standard for structures that contain bulk solids. Progress on this standard is well under way thanks to the voluntary efforts of the committee members. This new standard will include provisions for design, fabrication, and construction of welded and bolted steel containers for bulk solids in much the same way that the ASME Boiler & Pressure Vessel Code does for pressure vessels, or API Standards 650 and 620 do for petroleum and petrochemical tanks and vessels. This standard will fill an important need in the US and in other countries where there are no widely recognized industry standards for bulk solids containers. The development of this standard was initiated by a request from the “Process Industry Practices (PIP)” Group.

The scope of the standard will initially be limited to cylindrical containers that may include conical hoppers or other axisymmetric elements. Concrete and non-cylindrical containers will not be included in the first issue of the standard. The major sections of the standard include General Requirements, Design and Materials, Examination and Testing, Fabrication and Erection, Flow and Loadings, with Appendices for Coatings and Linings, Overpressure (Venting) Considerations, and Foundations.

The Committee preparing the Standard is organized in a Project Team fashion with each Project Team Leader responsible for his or her assigned section or appendix. Typically, the individual Project Team members have special expertise in the sections on which they are working, but all members have considerable experience in one or more areas of bulk solid container design, fabrication, and erection. Similar to other ASME Committees, the Structures for Bulk Solids Committee consists of approximately 1/3 Users (of bulk solids containers), 1/3 Manufacturers, and 1/3 General Interest members, such as Consulting Engineers. The Committee includes international membership to ensure that the provisions of the Standard are technically consistent with bulk solids standards or codes already in use in other countries.

Although significant progress has been made on the Standard, there is still a lot of work to do before it is approved for publication. Some of the sections are developed to the point that they have been balloted at least once. Other sections are not yet developed to the point that they can be effectively balloted. The Committee meets on a regular basis to review progress. ASME has created an Internet web site for the new Standard. Information and access instructions the web site can be obtained from Umberto D’Urso of ASME by calling (212) 591-8535. More information about the Structures for Bulk Solids Committee can be obtained by calling or e-mailing John Lieb, who chairs the ASME/ANSI Committee, at (630) 226-0745, lieb@tankindustry.com, or by calling Umberto D’Urso.

Attending ILTA in Houston? Stop by and visit with the TIC representatives at Booth 805

API 650 External Pressure Design Appendix

In the near future, API will publish an appendix to API Standard 650 that will prescribe requirements for the design of tanks that operate at negative internal pressures (vacuum). Tanks designed and constructed in accordance with API 650 are considered adequate for negative pressures up to 1-inch water column gage. However, many tanks need to be capable of withstanding greater vacuum pressures, whether for normal or for upset operating conditions.

At the request of the “Process Industry Practices (PIP)” Group, the API Subcommittee Pressure Vessels & Tanks undertook the development of a new appendix. The new appendix will satisfy the need for an industry standard for the design of tanks that must safely withstand greater than 1-inch water column and up to 1-psig vacuum pressures.

The technical bases for the provisions of the new appendix are derived from several well-known documents including a proprietary DuPont Engineering Standard; ASME Code Case 2286; Welding Research Council Bulletin 406; ASME Boiler & Pressure Vessel Code, Section VIII, Division 1; AISI Steel Plate Engineering Data; and other API publications. The appendix will prescribe rules for designing and constructing a tank for a specified design external pressure and will include rules for combining that specified pressure with other loadings, including wind that may occur simultaneously. The appendix allows options for increasing a tank’s resistance to external pressure by using circumferential stiffeners or by increasing the shell thickness, or by using a combination of the two methods.

The appendix provides the equations necessary to calculate the thickness of self-supporting roofs for both conical and dome roofs, the thickness of the shell, the sizes and spacing of end and intermediate circumferential stiffeners, and the weld size for stiffener attachment welds. In addition, guidance on bottom evaluation, but not prescriptive equations, is included. For example, the appendix will address the condition of a nearly empty tank sited in a containment area, or dike that is subject to flooding.

The appendix will also include an example design illustrating the use of the equations.

This appendix is known as Appendix V and is in the final stages of the API approval balloting process. This appendix will fill a need in the aboveground storage tank industry for standards of design and construction for tanks that are subject to vacuum loading.

TIC’s John Lieb chaired the API Task Group that developed the new appendix. Any questions should be directed to John by calling (630) 226-0745 or e-mailing lieb@tankindustry.com.

Changes in ASME Standard for Aluminum

The ASME committee for Aluminum Tanks is disbanding, according to Steve Braune, committee vice chair. The standard will, however, be developed by the API Storage Tank Committee.

TIC Welcomes Steve Braune—Manager, Eastern Region



Steven L. Braune, P.E., has joined Tank Industry Consultants to assist with water and industrial projects throughout the United States, with emphasis on the states along the eastern seaboard. Steve’s previous experience includes more than thirteen years with large, international tank fabricators and constructors. For the past sixteen years, he has been with AEC Engineering where he provided project management for select industrial and municipal clients, and acted as senior engineering consultant to their engineering staff, providing technical support for marketing and sales efforts.

Steve is a member of the American Petroleum Institute (API) Subcommittee Pressure Vessels and Tanks. He is an API 653 Certified Aboveground Storage Tank Inspector. He teaches API 653 and 510 preparatory classes for Code West and speaks on tank-related topics at industry events. He is also actively involved in several American Society of Mechanical Engineers (ASME) committees.