



## Fundamentals of Double Bottom Tanks

**Double bottom tanks provide better control of tank corrosion and better leak detection and monitoring. Phil Myers explains the new Appendix I to API Standard 650 that covers double-bottom tanks' basic requirements.**



### **Aboveground storage tank farms utilize double bottom technology**

Appendix I of API 650 provides the requirements for tanks with release prevention barriers (RPBs). By far the most common form of Appendix I tank bottoms are double bottoms. These are used on old single bottom tanks that now require new bottoms. However, API 650's Appendix I also addresses RPB tank bottoms for new tanks. We do not address these here as Appendix I provides adequate guidance for these.

### **Evolvement of double bottom tanks**

The double bottom has its roots in the regulatory and industrial arenas and began as a compromise to the needs and wants of regulators and industry. In the late 1980s, a major refinery responded to regulatory pressure due to leaking tanks and alleged contamination of ground waters by inventing the double bottom tank.

From the regulatory perspective, the idea is simple yet sound and comes from the idea of double wall ships that came into heavy use after the Valdez incident. From the industry perspective, the solution was good because it gave the tank a new bottom without excessive costs and added many useful tools for the tank owner, including better control of tank corrosion, better leak detection and monitoring and credit from the regulatory perspective.

Because of the widespread and increasing use of double bottoms to renovate tanks, the Tank Committee of the American Petroleum Institute (API) wrote a new Appendix I to API Standard 650 that covers double bottoms' basic requirements. It should be understood that this is a performance-based specification and does not cover the rationale behind the various designs, nor does it provide pros and cons of these systems.

### **External corrosion is evident Anatomy of a double bottom**



While Appendix I of API 650 shows many different configurations, only a few basic methods have survived the test of time. Each has advantages and disadvantages. I will point out some of these and explain why my company, Chevron, has selected a specific type.

**Figure 1** shows old spent bottoms and dead shells that are the basic double bottom configuration (items 4,5,6). When the bottom is corroded and at the end of its useful life one typically removes the old bottom and replaces it. However, the double bottom allows the tank owner to leave the old bottom in place and use it as a “form” to install the new bottom.

The new bottom (items 1, 2, 3 in Figure 1) is installed by “slotting” the shell and inserting the bottom plates into it and making the new corner weld (shell-to-bottom weld) as shown in Figure 1. In the early days of double bottoms, owners sometimes would require fillet welding the bottom to the inside of the shell. This is prohibited by API 650 because it leads to early failures. Therefore, the shell slotting method must be used.

When a new bottom is installed, an RPB should be included (items 7, 8, 9 of Figure 1). Not only does the RPB prevent galvanic-corrosion problems that occur between the new steel in the new bottom and the old steel in the original bottom, but it also provides leak detection and leak-monitoring functions. Because the cost is negligible compared to the overall project cost, the RPB should be used on all double bottom installations. The RPB Chevron uses is 80-mil, high-density polyethylene (HDPE).

It is debatable whether the opening under the slot of the new bottom plates should be seal welded and/or caulked (item 10 in Figure 1). While keeping water, especially contaminated or corrosive water, out of the space is important to reduce underside corrosion, there are problems with this. Sealing the space is difficult, can give a false sense of security and creates accelerated corrosion by retaining moisture in the space, which would have no way to evaporate or escape.



**Figure 1: Typical double bottom design**

### **Design options**

Various double bottom designs have come into common use. While all these systems meet the requirements of API 650's Appendix I, it is useful to compare these options before deciding on a particular design. The figures in this article show in more detail the differences.

There are two basic categories of design and construction:

- **Category A**—Sand or Concrete Spacer

The distinguishing feature of this category is the material used, which reduces the need for cathodic protection.

- **Category B**—Structural Grille.

This category has two subcategories: the first uses large standard structural shapes to form the spacer, called the grille; the second uses a wire mesh combined with a vacuum-monitoring system. The most common design is category A. Category B has been used but primarily in specific industries or in special cases.

One way to conceptualize the double bottom is by breaking it into functional components: the form, the RPB liner, the spacer and the leak-detection system.

## **The form**

The real advantage of the double bottom is that the old corroded bottom can be left in place. It becomes the form that can be used to install concrete or sand to be the spacer material between the old bottom and the new bottom.

New bottoms should not be installed directly on top of old bottoms because galvanic corrosion cells would be created. In the early days of double bottom installations, many owners installed the new bottom directly on top of the old bottom and were surprised to learn that the new bottom corroded in about one third to one half the expected life.

## **The RPB liner**

Any material that is compatible with the stored material and that will prevent liquid passage may be used as a liner. The most common material has turned out to be HDPE.

Typically, a layer 80-mils thick is used. This thickness is required for handling and has the ability to resist puncturing from sharp objects—sticks, gravel and debris—that are difficult to remove prior to laying the liner. Except in severe cases where the old bottom is corroded to the point that jagged edges remain, the liner can be placed directly over the old bottom. In the case of a jagged edge, a geotextile fabric may be used to act as a cushion between the old bottom and the liner.

While HDPE is the most common material, other materials are also used. Sometimes, a direct-spray coat of polyurethane is used. Other materials and elastomers also can be used. Each has some advantages and disadvantages. HDPE seems to provide an adequate liner at the lowest cost.

One often hears arguments that better materials with higher compatibility, less swelling, higher tensile strength and lower permeabilities should be used for the liner. It must be remembered that the liner is a backup system for the new bottom and should rarely have to contain a leak if managed in accordance with API 653.

Also, the liner will never have much pressure on it, regardless of the leak size. Because the leak-detection system must direct the leak to the perimeter of the tank, the pressure on the liner is limited to a few inches of water column, a fraction of a psi. There is no need to treat the liner as though it will be used for pressurized immersion service.

## **The spacer**

The spacer, which is the material between the old bottom and the new bottom, is typically placed on top of the liner and is typically three to four inches thick and has the following functions:

- It raises the new bottom and keeps the underside dryer. This reduces puddling as well as corrosion.
- Because settlement occurs on almost all tanks, it allows for “regrading” the new tank bottom to a profile that the owner wants.

- It provides an “interstitial space” or a collection area where leaks from the new bottom can accumulate and be directed to leak-detection ports. While sand, steel or other media may be used, Chevron chose concrete as the spacer material upon which to install the new or second bottom. This material gives control over the slope of the tank bottom, allowing better water drainage, and reduces corrosion due to stagnant water in the tank bottom.



### **Figure 3: Spacer design**

There are several good reasons why concrete is used:

- It is alkaline, and it actually reduces corrosion rates from the underside. In many inspections, I found the concrete extended tank-bottom life by 25 percent to 50 percent due to reduced underside corrosion attack.
- It provides a good, hard work surface that not only speeds construction of the remaining tank but also maintains good permanent slope for water drainage. This is important to prevent standing water in tank bottoms, which tends to cause corrosion problems. Concrete allows cleaner, water-free products for fuels.

### **Liner design issues**

There are two schools of thought on liner installation. The first is that the liner should be flat and trimmed to the inside diameter of the tank deadshell as shown in **Figure 2**. While the tank bottom still functions as intended, the liner has caused certain problems.



### **Figure 2: The incorrect method of installing a double bottom**

One problem is that, if a leak occurs, there can be short-circuiting to the ground if the attachment between the liner and the deadshell fails. Another problem is that false indications of a leak are possible if previous oil contamination works its way back up through the old bottom and around the liner back into the leak-detection system. While not common, this has occurred often enough to cause a redesign of the bottom liner to form a “bathtub” as discussed below.

**Figure 4** illustrates all the designs that depend on an elastomeric liner, such as 80-mil HDPE, to form a circular disk that functions as the RPB and that is terminated to the “deadshell.” The problem of short circuiting or leaking at the periphery is a significant problem to overcome.



### **Figure 4: Liner installation methods**

The nailing method (see item C in Figure 4) typically uses “percussion pins” that are driven at high velocity through the liner and through the old bottom. There are several problems with this. This process makes a hole completely through the liner and RPB so that if there is a leak in the bottom and the pin or nail head works loose a leak could develop in the liner. Another method uses glue or caulking (see item B in Figure 4). In reality, few if any materials stick to HDPE. Also, removal of old

double bottoms shows that there had been some shrinkage of the liner over time. Any glue, even if it could be made to stick, would peel loose, and the seal would be broken.

The second school of thought on liner installation is to create a “bathtub” out of the liner that is at least one to four inches high (see item A of Figure 4). This is done by wrapping the liner on the inside of the deadshell, seaming it together and fastening it to the deadshell. We use a steel batton strip to seal the liner to the deadshell. This involves using stud welding to bolt the batton strip to the shell. This technique creates a bathtub by “heat seaming” all seams to the point at the top of the batton strip. In this system, we do not depend on caulking to provide a tight joint. There are a number of other designs in the field, some of which are proprietary. These should be evaluated using the criteria provided in this article and performing a cost/benefit analysis to see if they are worthy of installation.

### **Open vs. closed system**

Most double bottom systems are open, which we define as not welding or caulking the underside of the new bottom plates, as well as leaving the leak-detection nozzles open. However, there has been a perception that closed systems must be better, especially from the regulatory perspective.

The closed system is defined as one in which the leak-detection space, or interstice, between the new and old bottom is sealed closed. This requires the ports to be closed, using valves, and the junction between the deadshell and the new bottom (the stub of the shell under the new bottom) to be sealed by caulking or seal welding.

There are significant problems with closed systems. Making a weld that actually seals the new bottom to the “deadshell” or the stub that is left after cutting the new bottom is almost impossible. In most cases, there is inadequate room to make the weld. The weld is, therefore, of poor quality and would not keep water out. Due to the difficulty of making this weld and to the nature of fillet welds, which are the welds that have been used to seal the interstitial space by welding to the underside of the new floor, this seal weld is prone to have cracks and flaws. Because this is the most highly stressed region in the tank, it makes the possibility of a serious failure much more likely.

From the principle of fracture mechanics, crack growth or sudden propagation occurs in the presence of flaws and stress. Flaws and stress are likely with the weld. It is for this reason that API Standard 650 makes such stringent nondestructive examination requirements for the topside fillet welds in this highly stressed area. It would be basically impossible to verify the integrity of the underside weld at this location.

Sealing the bottom space has caused catastrophic bottom failure by pressure pumping the trapped air in the interstice. If and when a failure develops, no matter how small, the air in the sealed space can become pressurized by the head of liquid on top of the bottom. When reducing pressure by lowering the liquid level, the air expands the bottom. Even slight changes in pressure cause the large flat areas (the old and new bottom) to bulge. Slight pressures can be caused by temperature changes, a leak or other factors.



**Leaks in caulking create corrosion problems**

Sealing the bottom space defeats the principles of early leak detection. It violates API 650 's Appendix I requirements for making leaks detectable at the perimeter. Complying with this requirement requires the addition of an electronic sensor to monitor the interstice. This creates design complexity and potential system failure.

It was originally thought that water and corrosion could be minimized on the underside of tank bottoms, reducing underside attack. Due to the large size of the tank double bottom space and the humidity of the air, however, when the bottom is sealed into a closed system, water will condense on the underside of the tank bottom plates, causing accelerated corrosion. This is similar to a crawl space in a house when moisture damages the flooring unless adequate ventilation is provided.

For this reason, open systems may be superior by allowing ventilation to remove any moisture that enters the space. Even if the bottom could be perfectly sealed and constructed with no moisture, the concrete itself has moisture that evaporates from it and creates a humid, corrosive environment where the space is not allowed to breath. No studies have been done that conclusively show that open or closed systems are superior from a corrosion perspective.

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