EBAA IRON Connections™
TECHNICAL DATA FOR THE WATER AND WASTEWATER PROFESSIONAL

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FLEXIBLE CONNECTION TO LIQUID STORAGE TANKS

INTRODUCTION

Retrofitting existing tanks with flexible expansion joints offers immediate and relatively economical benefits when seismic upgrading is necessary. The addition of flexible tank connections is easily justified in the design of new installations. This paper will discuss the application and advantages of such connections.

RIGID AND VULNERABLE

Numerous studies have been conducted on the response and survivability of liquid reservoirs subject to seismic shaking. A common mode of failure is depicted in nearly every account, failure of the storage structure due to failure of a rigid connection. In many cases the tank connection was made with flanged cast gray iron fittings bolted to other flanged appurtenances and subsequently to flanged piping leading underground. This type of system allows no freedom of motion. During seismic shaking, one or more of the flanges or fittings is almost certain to fail.

A second mode of failure commonly observed is joint separation of unrestrained repair type couplings and flange coupling adapters. Restraint of all joints is necessary under conditions of seismic strain.

Sudden ground motion due to earthquakes is arguably the most extreme test of these structures and their related underground piping. While no system or structure is without some degree of exposure to the risk of damage due to these extreme forces, it is prudent to provide a means of isolating the motion of the tank shell and the piping. Let's look at what causes the connection failure and what can be done to decrease this potential for failure.

DIFFERENTIAL MOTION

The tank foundation and the adjacent underground piping are often considered to move with an amplitude and frequency similar to the soil itself.

The motion of the flexible tank shell is affected by numerous factors including but not limited to:

- the ratio of liquid height to shell radius
- shell thickness and stiffness
- the presence or absence of perimeter anchors
- impulsive and convective forces imposed by the liquid
- available freeboard
- seismic response of supporting soils

While seismic wave passage is placing strains on the underground piping, and the tank shell is moving to its own beat, the unfortunate fittings at the interface are feeling the crunch. Literally.

Isolating the motions of these rivaling structures as well as relieving the forces created by this differential motion can be accomplished.

ADDING FLEXIBILITY

The interaction between the tank shell and adjacent piping has not gone unnoticed. Past attempts have been made to isolate the motions by the use of unrestrained repair couplings, bellows type expansion joints, ball joints, and offset pipe loops. Although these devices and combinations of products have their appropriate application in the piping industry, none were designed or intended for such rigorous service. The coupling approach falls short due to the fact that most are designed for a limited amount of deflection and little if any expansion. Bellows joints are generally designed to accommodate small amounts of axial movement and slight deflection and are typically used to isolate higher frequency vibrations. Ball joints alone can be beneficial but the design requires three joints to assure a full range of motion. The offset pipe loop, although popular in the high temperature applications of industries such as oil refining, is difficult to support without restricting the motion.

The conclusion: while some flexibility is better than none, an integrated connection system is designed specifically for the mitigation of earthquake damage is needed.

AN ENGINEERED SOLUTION

In the mid 1980's EBAA Iron recognized this need for a flexible connecting system and began producing the FLEX-TEND® flexible expansion joint. The FLEX-TEND system was designed from the start with earthquakes in mind. Tank connections, fault crossings, bridge crossings, and numerous building connections have been protected through the use of this product.

The FLEX-TEND system typically used for tank connections, consists of two ball and socket joints separated by an integral expansion joint. This configuration allows movement in any direction as well as the required expansion. The details of its design and other attributes are covered in the Connections™ bulletin FT-1 as well as the product brochure.

GENERAL DESIGN CONSIDERATIONS

In order for the FLEX-TEND connection to act as isolation between the moving bodies it must be restrained to and supported by the flexible shell on one end, while the other end is restrained to and supported by the piping. The most important aspect of the installation is that the FLEX-TEND joint <u>must</u>

be free to move in any direction without hindrance of support structures or other rigid components.

Supporting the weight of the FLEX-TEND, fittings, and valves on the side of the tank shell may require reinforcing of shell at the outlet. You may wish to contact the tank manufacturer for recommendations on this. Support of the other end of the assembly can often be accomplished by the pipe alone in the case of smaller sizes. Further soil bearing area can be provided by the use of concrete or similar pads under and around the pipe. Since these structures are tied to the piping and not the tank, their motion should follow that of the soil-pipe interaction.

In general, FLEX-TEND connections are best made in the above ground piping due to the absence of external soil resistance as the unit moves. It should be noted though, that the FLEX-TEND assembly is suited for direct burial if necessary. In the case where it is desirable to bury the unit, provisions can be made to reduce soil resistance. These include shallow depth of burial, slope sided trenches, and cohesionless granular backfill such as sand. The reduction of soil resistance can also be enhanced by the use of one or more layers of polyethylene wrap. All FLEX-TEND assemblies are shipped with an 8 mil tube of polyethylene.

One of the most important features of the double ball FLEX-TEND is the incorporation of the expansion joint between the flexible ball joints. This expansion joint, like all expansion joints, acts as a hydraulic cylinder when under pressure. The thrust force generated must be accommodated and can be done by the use of external thrust blocks or other structural means.

ADJACENT FITTINGS

Now that the tank connection is being designed to move and accommodate motion, further consideration must be given to the surrounding joints and fittings. A brief list of considerations is as follows:

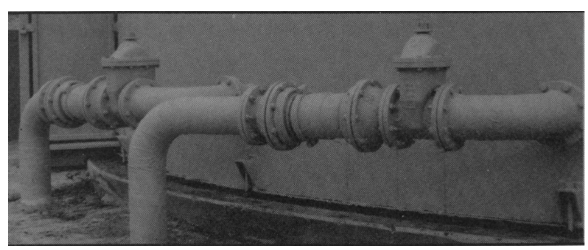
- All fittings and appurtenances should be of a ductile material such as Ductile Iron or steel.
- Cast gray iron fittings and especially gray iron flanges must be avoided.
- Tees and crossed should be avoided if possible due to the number of forces and moments that they may be subject to.
- All joints must be restrained in order to prevent joint separation during shaking and also to transfer the motion to the FLEX-TEND assembly.
- The use of restrained mechanical joints is desirable over the use of flanged joints both in terms of resilience and field fabricated repair. One exception to this is the end of joint of the FLEX-TEND assembly. In this case, bending moments are relieved by the adjacent ball joint.
- Evaluate each component not only for its strengths, but also for its ease of removal and repair.

SUMMARY

The names: Loma Prieta, Landers, and Northridge all evoke engineering inquiry from the technical community as well as emotional response from the people who survived. When the dust settled and the damage tolls were taken, it was found that each of these seismic events put the FLEX-TEND system to the test. No failures of FLEX-TEND joints were reported. None of the adjacent piping and appurtenances they were installed to protect were damaged. In the cases of tank connections, the water was retained and ready for use in fighting fires as well as supplying hospitals and communities. While no fitting or manufacturer can guarantee these results all of the time, the FLEX-TEND system has proven its worth.

REFERENCE LIST

ASCE, The Current State of Knowledge of Lifeline Earthquake Engineering, American Association of Civil Engineers, New York, NY, 1977.
ASCE, Guidelines for the Seismic Design of Oil and Gas Pipeline Systems , American Society of Civil Engineers, New York, NY, 1984.
ASCE, Advisory notes on Lifeline Earthquake Engineering, American Society of Civil Engineers, New York, NY, 1983.



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