HIDDEN CONSIDERATIONS FOR ALUMINUM INTERNAL FLOATING ROOF DESIGN

White Paper

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BACKGROUND

Since their inception during the 1950's, the performance demands of aluminum internal floating roofs have evolved along a path that has closely followed that of their overall acceptance within the industry. The general perception regarding the applicability of an AIFR has certainly evolved as well, having been a relatively unproven product during the early days following their introduction into the market. In those days, of course, steel was the primary material of choice for a number of reasons, but particularly for any service deemed to have the potential to introduce operational conditions that an aluminum IFR supposedly could not withstand.

This early era sentiment appears to have finally subdued (though not eradicated), and as a result It seems that the aluminum internal floating roof of today is expected to meet higher standards of performance than their predecessors, having entered territory that was previously exclusive to steel. There is no doubt that the service history of early AIFR users aided this acceptance, and it is clear that as the industry has adapted to deal with the evolution of regulatory controls, volatility of stored products, and operational challenges. Aluminum internal floating roof designs have followed suit to remain a viable alternative to steel.

Experience and understanding has propagated ideas, and technology has provided the tools for their implementation. Minimum requirements and recommended practices have also evolved from these lessons-learned to aide in their overall acceptance and performance. However, many of the design particulars for an AIFR are still left to the individual designer and/or manufacturer, which can place the Purchaser in a difficult position.

STANDARDS & MANUALS

Industry standards (such as the API Standard 650) selectively provide detailed criteria for only the more commonly acknowledged areas of concern (design loading and buoyancy ratio), while mentioning other important considerations (such as pumping rates) only in passing. There is much more related to the performance of an AIFR, both during operation and when out-of-service, that must be taken into account by the designer. These hidden issues are most often directly related to both the specified and anticipated operating conditions, which may not be covered (or even mentioned) by the referenced design standard. And though the minimum recommended requirements must not be overlooked, a quality AIFR will include features that were specifically developed to accommodate for these hidden factors.

An aluminum IFR is subjected to loading in a variety of ways, both in the static and dynamic conditions. It is common for inexperienced designers to consider only the static condition. This can lead to operational performance issues and potentially even failure of the AIFR. Typically the obvious and hidden factors of consideration are constant for both the static and dynamic cases and must be addressed under each scenario.

Appendix 'H' of API Standard 650 provides guidance for handling the more obvious design considerations of minimum loading, primary loading combinations and buoyancy. There is a section within Appendix 'H' entitled "Joint Design"; however it is more related to acceptable components and details rather than specific structural requirements.

API-650 defers the specific design requirements for the structural components of the AIFR to the **Aluminum Association Aluminum Design Manual**, and the proper use of this document is absolutely critical for addressing hidden design factors. Among many other things, this manual provides:

- Design strength allowables for the various available grades of aluminum
- Minimum safety factors for various applications and
- Design formulas for determining resultant forces within the roof structure

It serves to provide a level playing field for the structural design of an AIFR, which becomes critical when addressing critical hidden factors such as:

- Quantity and plumbness of fixed roof support columns
- Quantity and type of deck penetrations
- Variances in rim gap (i.e. excessive shell "out-of-roundness")
- Obstructions (in the rim space or otherwise)
- Quantity of tank cycles
- Pumping rates (both inlet and outlet)
- Potential for turbulence from upsets (due to roof "burping")
- Ambient and operational temperature
- Properties of the stored product

ADDITIONAL CONSIDERATIONS

Factors that are related to the AIFR rim space (the annular space between the floating roof rim and the tank shell) are extremely critical to the operation of the floating roof. An aluminum IFR is heavier around the perimeter due to the weight of the rim member and perimeter seal(s). This additional weight, coupled with the added factor of seal friction (or "drag" force), create an interesting challenge for the roof designer.

The static condition is easily evaluated by summing the forces in the vertical direction at the calculated center of mass as a target value for the perimeter buoyancy design. Dynamic forces introduced into the rim seal area can create issues that are simply not recognized by the static condition design process (Figure 1).

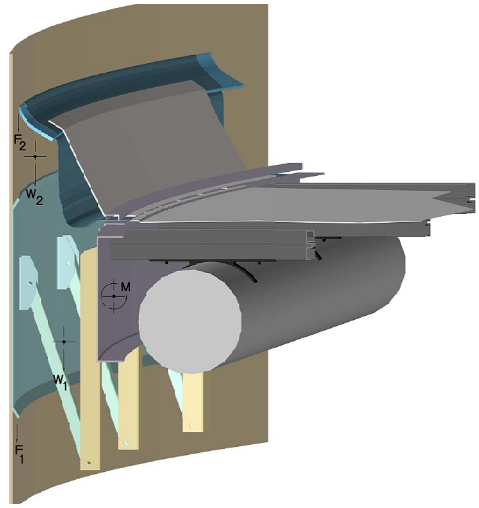

Figure 1: Resulting Forces Due To Rim Space Loading

Depending upon the type of seals utilized, the drag forces can become rather substantial, and can be amplified by those pesky hidden factors of varying rim space, shell imperfections/

obstructions, and product residue build-up. These forces not only act in the vertical plane tangential to the rim member, but at a location eccentric from the rim centroid sufficient enough to create a bending moment in the member. This moment should be considered when evaluating the bending stress and flexural rigidity of the rim member (in addition to the perimeter buoyancy) as this additional force can position the roof lower into the product than desired (Figure 2).

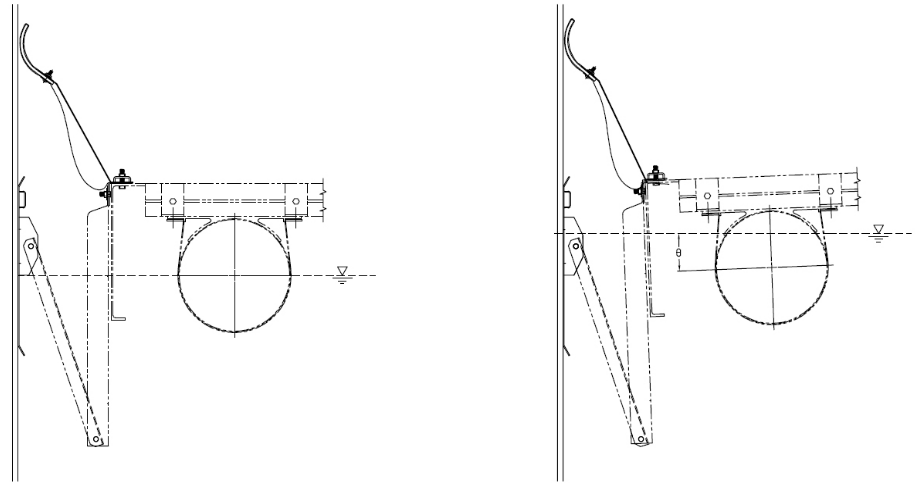

Figure 2: Design AIFR Floating Position (Left) Versus Forced Low Floating Position (Right)

The same type of loading can be induced by multiple fixed roof support columns and deck penetrations as well, particularly when these members are not reasonably plumb or the AIFR is shifted off-center by a shell with varying rim space. In all of these regions of the roof the adjacent structural framework should be evaluated and possibly reinforced, as the load transfer from the rim and penetration well(s) can be enough to impose high stress concentrations into the associated connections and force the roof to float on a non-level plane. In many cases, the framework and adjacent pontoons can assist with resisting these loads, and additional structure and flotation may be required. At minimum the associated connections must be properly designed to either transfer or absorb the resulting bending moment, along all three global axes. This often includes torsional moment resulting from the roof trying to maintain equilibrium. All of this means that the end gussets for conventional skin-and-pontoon roofs must be sufficiently reinforced, and that non-conventional skin-and-pontoon roofs should have adequately sized bolts, clips and pontoon attachments. This also means that the effect upon the conventional roof pontoon itself must be evaluated since it is often expected to behave as a structural member.

Other dynamic forces that must be considered include the potential for roof upset during operation. This can be extremely damaging to an AIFR, and the initial challenge is developing a reasonable estimate of the force potential. This is most commonly related to the possibility of an unexpected vapor slug being introduced into the tank, so working with the tank owner is critical to estimating the upset forces with any reasonable degree of certainty. This particular loading scenario is one that could lead a designer into a philosophical debate regarding the best design solution between adding either rigidity or flexibility. Though this will typically be somewhat dependent upon the particular manufacturer and style of roof, experience may indicate that the better philosophy is simply a combination of the two properties strategically located within the make-up of the roof.

Another dynamic force that imposes similar thrust-type loading upon an AIFR is related to the operational pumping rates (both inflow and outflow). With respect to inflow, the potential for directional, high-velocity flow inflicting damage upon the roof is difficult to address structurally. In these instances, often the best solution is the use of a properly designed inlet diffuser to slow and disperse the product flow away from the roof and rim space. High inlet rates that are not properly diffused can force product onto the top-side of the deck, either via the rim space or through deck penetration wells. Although it is generally recommended that the inflow rate be limited until the roof is floating, this isn't always feasible. When this is the case, or when an inlet diffuser is not utilized, the more robust roof with strategically designed components is the best solution.

High outflow rates can be just as damaging as inflow, however this is more related to the potential for negative pressure to develop beneath the roof deck when resting on supports and is relatively simple to address structurally by simply applying the load uniformly across the roof. This loading scenario was formally recognized when it became a recommended design consideration in Appendix 'H' of API Standard 650 with the release of the 1st Addendum to the 11th Edition (November 2008). In either flow case, care must be taken to ensure that adequate venting is provided, and it is common practice to concentrate the AIFR venting in the area(s) immediately near these nozzles. This is considered the safest and best practice, with the idea being to mitigate any potential for pressure build-up near the source before the levels become critical.

CONCLUSION

The utilization of aluminum internal floating roofs appears to have reached an all-time high within the industry, as they are now given consideration for service conditions that were previously not considered. The applications for which they are now being utilized pushes the envelope as specified design and operational conditions continue to be more and more demanding.

Although industry standards (such as API Standard 650) have evolved to provide more detailed, prescriptive methods for the design of AIFR's, there are still several hidden factors that should be considered above and beyond these minimum requirements. Recognition of these factors, and properly designing to account for them, should be the standard practice within the industry. This should be an important component of the process when a Purchaser is evaluating the various AIFR models on the market.

Just as design expectations and operational demands continue to elevate, the capabilities of an AIFR must also be elevated to meet these demands. This will fall directly to the design, manufacturing and construction capabilities of the respective AIFR supplier. Designing an aluminum internal floating roof in the most efficient and cost effective manner to meet current and future operational demands requires more than simply following the basic, "cook book" methods prescribed by applicable industry standards. Proper consideration of the hidden factors discussed should be part of the minimum design requirements for an aluminum internal floating roof in order to increase the probability for a long, trouble-free service life.

ABOUT HMT

HMT was founded in 1978 with the objective of providing better technology to the aboveground storage tank market. HMT's founders sought to create products which not only solved the emissions problems of the day but also eliminated the operational issues created by the existing floating roof and seal technologies.

This spirit of innovation and product improvement continues to this day, and HMT's solutions have evolved far beyond just emissions and operations. Our products have also been engineered to provide significant benefits in the form of increased working capacity, reduced heel, improved tank safety, increased life span, reduced emissions, and reduced maintenance.

HMT is the global leader in aboveground storage tank solutions. HMT brings a distinct level of innovation and service to the tank industry through a unique approach of partnering with customers to optimize tank operations. Knowing that every customer's need is different, we use our decades of experience to customize solutions that help tank operations become more efficient, more productive and more profitable.

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