Keeping you Covered

Jeff Heath, Matrix Applied Technologies, USA, examines floating roof technology and how to maximise safety, compliance and profit while minimising risks and operating costs.

Tank owners are under increasing pressure to maximise safety, regulatory compliance and profit while minimising capital expenditures, operating risks and maintenance expenses. Some might deem this to be an impossible task, however, with increasingly restrictive regulations and a continuous focus on improving operating margins, the pressure is only likely to grow. Against this backdrop, when it comes to deciding which floating roof technology to employ, it can be tempting to accept unproven claims about newer materials or designs and equally tempting to stick with the 'tried and true' carbon steel roof. Yet, in either case, owners may be spending more than necessary up front or taking on unnecessary future operational and maintenance costs. Ultimately, the right choice for both material and roof design are situation specific, and making that choice means understanding the options. Tank owners should take a careful look at immediate priorities, as well as the total lifecycle cost of the various options available in order to make the best decision.

Figure 1. Carbon steel, which is the most prevalent and durable choice for floating roofs, also carries the highest initial capital cost and comes with other potentially significant lifecycle costs. It can also present safe entry issues.

Figure 2. Aluminium internal floating roofs (IFRs) provide a durable, cost effective alternative to traditional carbon steel IFRs.

Figure 3. Skin and pontoon designs for floating roofs are the most prevalent in the industry and can be designed to support 1000 point loads.

Roof types and characteristics

Carbon steel

Carbon steel has been the material of choice for floating roofs since the 1920s, and is the most prevalent material in use today. It is extremely versatile for internal and external applications and is available in different grades and price levels. While steel is the heaviest material used, modern steels have also been developed with a better strength to weight ratio than those used in the past.

Steel is structurally proven and can be designed to meet or exceed requirements for all existing aboveground storage tank (AST) standards. The double deck external floating roof is generally considered the most durable. Additionally, a steel roof can be designed to withstand virtually any load condition, so has become the material of choice for applications where excessive snow, wind, rain, and other conditions, may be a concern.

Steel roofs tend to be a welded construction, so can be expensive, however, they also provide a durable, vapour-tight seam. Concurrently, the need for support legs reduces some emissions effectiveness and usable capacity, while the relatively large profile needed to meet buoyancy requirements also creates a large 'heel' of non-accessible product. Additionally, required support legs place point loads on the tank bottom (although generally distributed via bearing pads), which can also create a safety concern as there is no practical way of inspecting leg integrity before entry.

Efforts in recent years have focused on minimising the pontoon depth in order to reduce the profile, but this can be risky and leaves the integrity of the roof dependent on the experience and competence of the design engineer.

As with anything steel, corrosion is a legitimate concern on both the topside, due to environmental conditions, and the underside as a result of vapour pockets that form due to roof flexibility. Carbon steel roofs also require periodic inspection and maintenance and, if the roof is external, will require roof drains. Roof drains can often go unmonitored and commonly fail due to malfunction, poor design, and/or poor selection.

One benefit of carbon steel floating roofs is the proven and widely accepted non-destructive examination (NDE) methods that ensure overall quality and integrity during construction. In addition to the capital cost

Figure 4. Installation of an aluminium geodesic dome on an open top tank can increase options with respect to IFR selection.

Figure 5. Suspended aluminium floating roofs introduce numerous safety benefits and increase usable capacity over leg-supported roofs.

of carbon steel, when evaluating the total lifecycle cost, it is important to factor in the need to coat and recoat the roof on a periodic basis – an expense that can be significant.

Aluminium floating roofs

Aluminium has been used for architectural purposes since the early 1900s and used increasingly for floating roofs since the mid-1970s, although exclusively for internal floating roofs. Raw material pricing for aluminium varies based on the commodities market, but finished goods pricing, i.e. the manufactured and installed cost, is typically competitive and significantly less expensive than carbon steel. Multiple structural alloys, grades and sizes are available, while structural shapes can be customised, limited only by extrusion press capabilities. Aluminium roofs are also available in various skin and pontoon models, and in the relatively new full contact panel type designs with elements either bolted or welded together. As such, aluminium internal floating roofs have become increasingly common as a viable alternative.

Aluminium is roughly equivalent in strength to stainless steel and structurally very efficient due to its high strength to weight ratio. That said, it has lower durability than steel and its limited fatigue strength is also a key structural limitation. Several models on the market today are touted as 'heavy duty' or '1000 lb roofs', but the vast majority are light to medium duty roofs, in structural terms. Those marketed as heavy duty are certainly heavier – and more expensive – but potentially unnecessary depending on the operations of a tank.

Akin to steel, aluminium is also susceptible to corrosion. For example, aluminium is vulnerable to microbiologically induced corrosion, often present in alcohol-based products such as ethanol and methanol. However, passivation, a technique used to create a natural shielding outer layer of self-oxidation, can provide protection in instances where the stored product is not alcohol-based. This property can be further enhanced through manual methods such as anodising, making aluminium an even more attractive alternative to steel.

Aluminium roofs, similar to their steel counterparts, also require routine inspection and occasional maintenance and repair, particularly in the pontoons. Skin and pontoon designs are, typically, easily repaired and components can be replaced without hot work, whereas welded versions are not so easily repaired and the replacement of components can be difficult and generally involve hot work.

Due to their design, aluminium roofs are susceptible to collecting product on the topside, which, even with installed deck drains, can overcome the local buoyancy and lead to a potential sunken roof. Furthermore, stability, needed for walking, is dependent on design.

Some versions of aluminium roofs feature a 'honeycomb' cellular or foam core. This is a popular design element due to economy, but the performance history of these types of roofs has been mixed. The cells, for example, can trap vapour, making the panel 'hot', meaning this condition can go undetected by conventional monitoring methods. Alternative designs feature open cavities or uncovered panels that allow for easy hydrocarbon detection; however, these designs have also shown mixed performance capabilities, specifically sinking, and are generally price prohibitive.

Aluminium roofs can be either leg supported or suspended by cables or chains. Suspended roofs help increase usable capacity, eliminate point loading from the tank bottom, provide a clear space beneath the roof for entry and work, and allow for a topside connection for inspection via the tank roof, reducing concerns over safe entry during out of service periods.

Finally, the most common method of fitting the panels made from aluminium is to bolt them. Recently, however, some have been successfully welded. The motivation behind the welded version is generally emissions driven, but the cost benefit must be carefully considered. Aluminium welding requires a higher level of skill than steel welding, specialised and even customised equipment, and specialised testing methods, which, accordingly, are more expensive. If the welding is incomplete or there are contaminants, the results can be cracked or failing welds and a sunken roof.

Craft expertise in aluminium is less common than with steel roofs, so precision engineering and design are critical to ensuring an accurate and efficient installation in the field.

Composite floating roofs

The third material used more recently in floating roofs is composite. Composite roofs are made with a combination of fibreglass and resin – fibreglass reinforced plastic (FRP), glass reinforced plastic (GRP), or glass reinforced epoxy (GRE) – all describe a woven or chopped framework of fibreglass embedded in a polymer, most commonly a thermosetting resin. These resins mostly come in three varieties: epoxy, vinyl ester or polyester.

While the inherent corrosion resistance and lightweight structural properties make this a very attractive material to use in floating roofs, there are other substantial considerations to be made before a decision is reached. Generally, composite roofs have been cost prohibitive and slow to gain acceptance in the industry.

Technical considerations

When deciding which type of roof to install there are numerous considerations, however, there are five broad elements: design loading, stored product, operations plan, emissions profile and budget.

Design loading

This includes wind loading, seismic effects, snow and rain accumulation, and operational loads. Common wisdom dictates that the more durable and heavy a roof, the more capable it is in managing various loads. So, while steel offers the best overall capability, it is not without its issues. For example, snow accumulation on an external steel floating roof can mean differential loading and potential capsizing. Aluminium, on the other hand, is generally only used as an internal floating roof owing to its relatively lightweight nature. The medium to heavy duty aluminium roofs currently on the market are more than capable for several loading scenarios and, when used internally or paired with a geodesic dome, they are a cost effective and efficient alternative to carbon steel.

Stored product

The properties of the stored product must also be considered in order to ensure compatibility, more so when the owner is considering a roof made from aluminium or composite. Likewise, the Reid Vapour Pressure (RVP) of a product may dictate how robust the roof must be in order to prevent bubbling and pressure buildup beneath the deck. With a steel roof, the product stored will have a greater impact on which type of coating to apply to prevent corrosion. With aluminium or composite the roof material itself may dictate which product(s) can be stored.

Operations plan

This third consideration refers to the cycle frequency and the inlet/outlet rates of the tank. Cycle frequency is key, especially with respect to internal floating roofs made of aluminium or composite. Aggressive cycle frequency puts more strain on the floating roof, particularly at the rim, so, in conjunction with an appropriate seal selection, the floating roof should be durable enough to withstand these loads. Filling and emptying rates also need careful evaluation, especially with lightweight internal floating roofs, in order to understand the forces imparted on the roof itself.

Emissions profile

There is no question that selecting the correct combination of floating roof, seal and fixed roof can

Table 1. Technical specifications and considerations

Specifications	Steel	Aluminium	Composite
Tensile strength (PSI)	58 000	45 000	30 000
Density (LBS/IN3)	0.283	0.098	0.055
Strength/weight ratio	0.07	0.10	0.13
Considerations	**Steel**	**Aluminium**	**Composite**
Rating (1 = good; 2 = better; 3 = best)			
Design loading	3	2	1
Stored product	3	2	1
Operating plan	3	2	1
Emissions profile	1	3	3
Budget	1	3	1

save significant money and result in faster payback on capital investment. That said, understanding Environmental Protection Agency (EPA) and other governmental regulations is imperative, even if provided by an independent expert. For example, while manufacturers may claim a 'full contact' roof is the answer for all emission concerns, the real answer lies in the type, quantity of sources and levels of emissions, whether employing a full contact roof or not.

Budget

Finally, when considering budget, one must consider both the capital budget used to construct and install the roof, as well as the ongoing operating budget used for maintenance of the tank and roof over its lifecycle. While minimising capital outlay may help on the front end, it may very likely result in greater expense in roof repairs, coating, outright replacement or emissions over the lifecycle of the asset. Accordingly, conducting a full cost of ownership analysis, while it may require additional time, is a best practice that will save money in the long run.

Conclusion

It is essential to understand the advantages and disadvantages of each material, their benefits and limitations, and how to optimise choices that suit its limitations and are appropriate for its application. In doing so, operators can maximise safety, compliance and profit while minimising spend, risks and operating costs.

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