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Digester Cover Design – Framework and Plates verses Membrane

Digestion cover designs that have used a structural framework of trusses, purlins, center compression (gas dome) ring, and rim skirt column sections have been a standard product that have proven their capabilities for more than 70 years. Their dependable operation, durability and ability to be easily rehabbed are well known. The structural framework receives and supports the various loads that the cover experiences. The framework workings together with the roof plates, and ceiling plates if present, provide a strong integral design. The plates also serve an operational role of containing the digester gas, and if ceiling plates are present, submerge scum.

A newer cover design is the "membrane" style that came on the scene in the early 1980's. In the membrane design, the plate work, tension ring at the cover perimeter, and center compression (gas dome) ring are considered to be the structural components of the cover. On larger diameter covers one or two additional intermediate tension rings are sometimes added to the structure. The lightweight beams used in the cover assembly are usually considered to only be for erection purposes and are not considered as adding anything to the structural design. The design of the cover is said to be based on shell design theory. The plate work then serves two roles, one to provide the load bearing structure for the cover, and two, to contain the gas and if required submerge the scum. The dependability of their operation, their durability and longevity, and their ability to be rehabbed is still being determined.

Installation Comparison:

The membrane style cover consists of a larger quantity of pieces that need to be off-loaded from the trucks, fit up, aligned, and welded during erection. The quantity of pieces to be handled especially goes up if intermediate tension rings are used in the design. Installation of the membrane cover involves more extensive temporary supports and scaffolding as compared to a trussed cover. There is considerably more overhead welding during the erection of a membrane cover when compared to a trussed cover.

Some of the newer designs for larger diameter covers have eliminated the intermediate tension ring by incorporating rolled rectangular tube section beams that span from the outer tension ring to the center gas dome. Although this reduces the number of pieces and amount of welding, these longer, heavier beams are harder to handle when taking off the truck and when installing in place on the cover. A crane is necessary to unload and move them. This can involve more laborers to guide and steady the lift than compared to using a simple forklift truck that can be used for smaller members.

The receiving and assembly of component parts for truss style covers is easy and erection costs known. Components are small enough to off-load from the trucks with a few laborers and forklifts. Although the purchase price of a membrane cover may be less than a trussed cover due to its lighter weight, overall initial cost of a membrane cover can be more due to higher erection and installation costs.

Structural Comparison:

In considering the structural adequacy of the membrane shell, good design practice dictates that the engineer must ensure that the design analysis evaluates plate buckling from concentrated local loads such as from live load during maintenance, guide system loads from wind or unbalanced snow loads, installed appurtenances, etc. Thin plates can withstand tensile forces but have very limited capability in resisting the compressive forces that tend to buckle thin plates. They experience compressive forces from the above local loads as well as from a situation where the cover has a vacuum under it.

Even though the "erection" beams are theoretically not considered to play a structural role, they do in fact exist and do carry load during the operation of the cover and cannot be ignored. Whereas trusses have separate top and bottom chords and transfer forces as a distributed force couple to the rim and gas dome, the "erection" beams transfer concentrated moments and forces to the rim and gas dome. The design engineer must evaluate these concentrated moments and forces for local buckling, bending and shear effects in critical operating conditions. The actual configuration of the cover should be evaluated, not the theoretical configuration.

Consideration must also be given to cover stability and binding during vertical travel. Membrane covers are inherently more flexible than trussed style covers and design analysis should look at overall cover deformation as well as local deformation from guide shoe or roller forces that occur from wind, during unbalanced loads, and during critical abnormal operating conditions.

A serious consideration is corrosion. When the plates on a membrane cover corrode, not only is the concern with escaping gas but also whether the structural integrity of the cover has been compromised because the plates are performing both containment and structural support roles. With the trussed cover the concern is not as great as the framework will still carry substantial load if the plate work corrodes. With the membrane cover, the strength of the whole structure should be re-evaluated for adequacy when there is corrosion. Because of this a corrosion allowance should be incorporated into the membrane design. If the corrosion is extensive, the whole cover will need to be replaced. For a trussed cover, only the ceiling or roof plates would have to be repaired or replaced by ordinary means.

The structural members of a trussed cover are easy to inspect, as they are located in the attic space. They can be inspected without dewatering the digester. Since the structural members of a membrane cover are the roof plates themselves, the tank must be dewatered for a complete inspection, as the bottom side of the plates must be viewed.

Functional Comparison:
Trussed covers that use ceiling plates have a natural attic space which acts as a barrier to escaping heat. Membrane designed covers do not have an attic space and therefore can have higher operating costs due to additional heat loss. Sometimes a membrane cover’s skirt is extended upward and a partial horizontal roof is added forming a pontoon. This roof only covers part of the entire top surface of the membrane cover. Membrane covers must then utilize external insulation on its top surface with a protective roofing system that increases installation and maintenance costs. If a leaking roofing system is not detected and repaired, corrosion will occur on both sides of the roof plate, accelerating cover failure. Insulation can be placed in the attic space of a trussed cover where it will be protected from the weather and other possible sources of damage.

Ballast for a trussed cover can be placed in its attic space if it is not placed at the bottom of the cover’s rim skirt. Because there is no attic space in a comparable membrane cover, the ballast must be placed on top of the membrane cover. The ballast is then exposed to the weather and can crack and spall over a period of time. Exposed ballast on top of the membrane cover can collect debris, impede the elimination of snow from the roof deck and present increased area exposed to wind, all resulting in an unbalanced cover and increased maintenance. This membrane cover will also have a higher center of gravity, than the trussed cover, making it less stable.

Trussed covers have a relatively flat roof, approximately 1-3/4 inch rise in a 12 inch run, which makes a trussed cover safer to walk on to do repairs or inspections. Spherically domed membrane covers can be dangerous to walk on when the cover surface is wet, necessitating expensive walkway and even handrail, arrangements for the safety of the workers.

Summary:
There are many anecdotes of the long enduring capabilities of trussed covers. One experience that demonstrates the structural integrity of a trussed cover is of an older 65-foot diameter floating cover built in the mid-seventies. In 1999 the cover was converted to a fixed cover with the additions of a skirt extension, supports and lateral restraints, and anchorage. Three years after the conversion a situation occurred where the cover experienced an over-pressure condition. One side of the cover lifted a considerable number of inches. The lateral restraints and anchorage failed. The cover then dropped and jammed back into place. When the cover was inspected to plan repairs, no damage was found to the cover itself, none to the trusses, gas dome, or welds. Even ultrasonic testing of the truss welds revealed no cracks. The cover was relatively easy to repair at a reasonable cost. Whether a twenty-five to thirty year old membrane cover would have survived this situation without considerable damage is questionable.

Although a membrane cover may have a lower purchase price due to its lighter weight, the trussed cover is more economical in the long term due to the membrane cover’s subsequent costs for erection and installation, more difficult maintenance, critical structural inspections, repairs, and potentially shorter functional life.

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