Slosh mitigation and shape retention and load transfer

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Laplace building, ground floor, salle Renaudeau.

Erik Jeroen Eenkhoorn (10-Aug-1957)

- University of Twente, Mechanical Engineer 1980 & MBA 1985

- Shell E&P; project manager 1982 -1997, with postings in
- Brunei, Singapore, Netherlands, Nigeria and Sri Lanka

- “Accede”, the “Cairbag” company, based in the Netherlands
- Founder and Director since 1997; research and development of
- Slosh mitigating products; “bags” in tanks

- University of Twente, Enschede, The Netherlands
- PhD Candidate Liquid semi-dynamics
- Thesis: ”Liquid slosh mitigation and products thereto”.

- Father of Daan (16) and Fern (11)

To slosh or not to slosh?

Is sloshing unavoidable?

Is slosh mitigation, or even elimination, the prime or ultimate objective of liquid dynamics R&D?

The focus of researches and scientists appears to be on improving the predictability of sloshing behaviour and of the apparent unavoidable consequences of sloshing.

Such consequences primarily relating to the integrity of the liquid containment system.

Introduction to slosh mitigation

Slosh mitigation fundamental principles are based on:

- Liquid load securing
  - Based on forces, pressures balances, i.e. load transfer, and
  - Effected prior to transportation,

rather than

- Energy dissipation by the liquid
  - Based on dampening of liquid
  - During transportation

Introduction to slosh mitigation

Slosh mitigation products for horizontal cylinder-shaped mobile tanks are based on the application of inflatable components which are either of a:

- Fixed Volume Type
- Variable Volume Type

rather than:

- Baffle plates
- Oval shaped tanks with a lower centre of gravity

Introduction to slosh mitigation

Inflatable components are key to slosh mitigation products

As they

- Can be inserted into the tank via a manhole in a non-inflated condition
- Can be inflated to any volume which is equal to the tank volume minus a fixed or range (0-100%) of liquid volumes

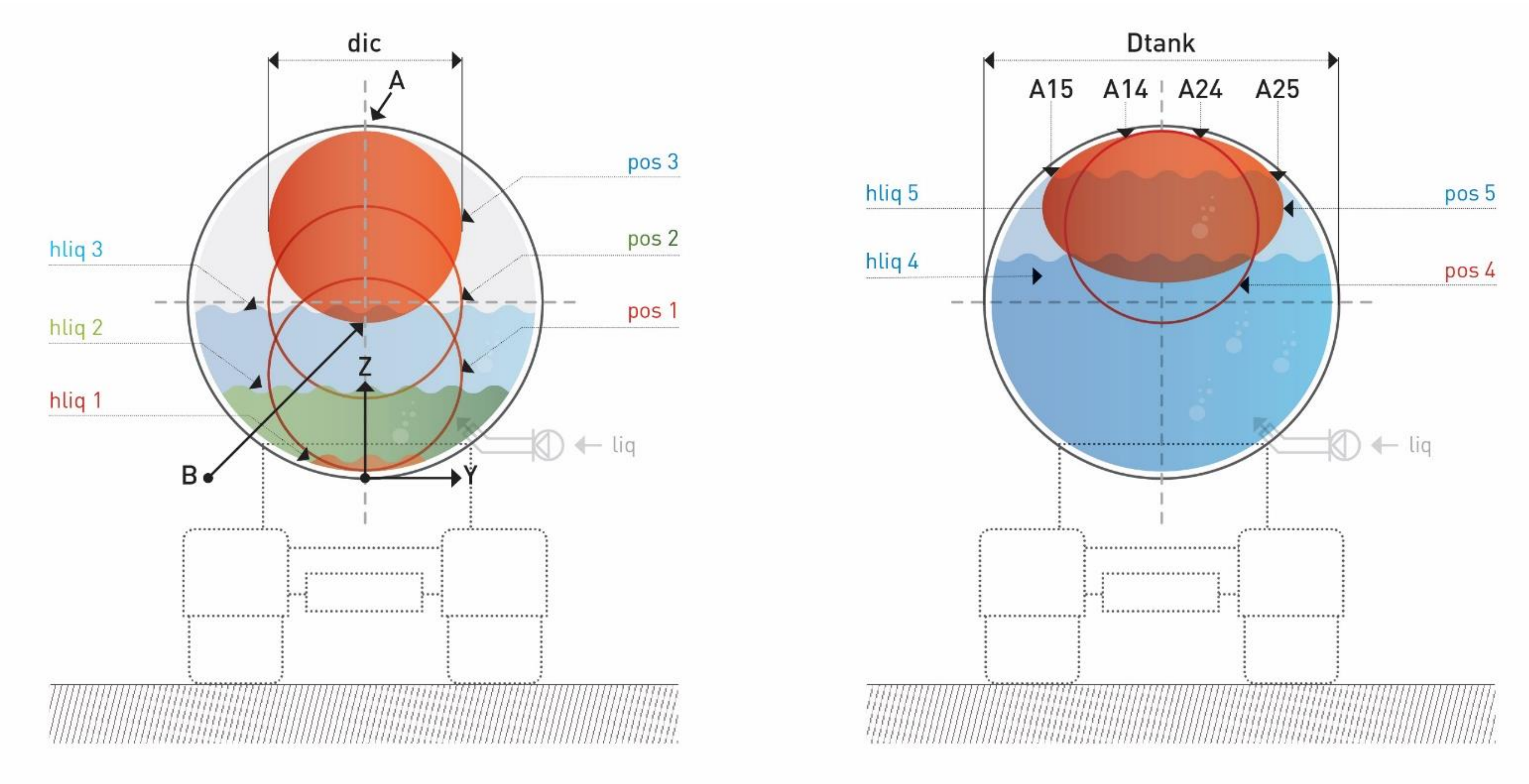
But most importantly

- Will ensure shape retention and transfer loads without delay under dynamic transportation conditions, when
- Properly designed, fabricated and supported by the functionally appropriate pneumatic and electronic sub-systems

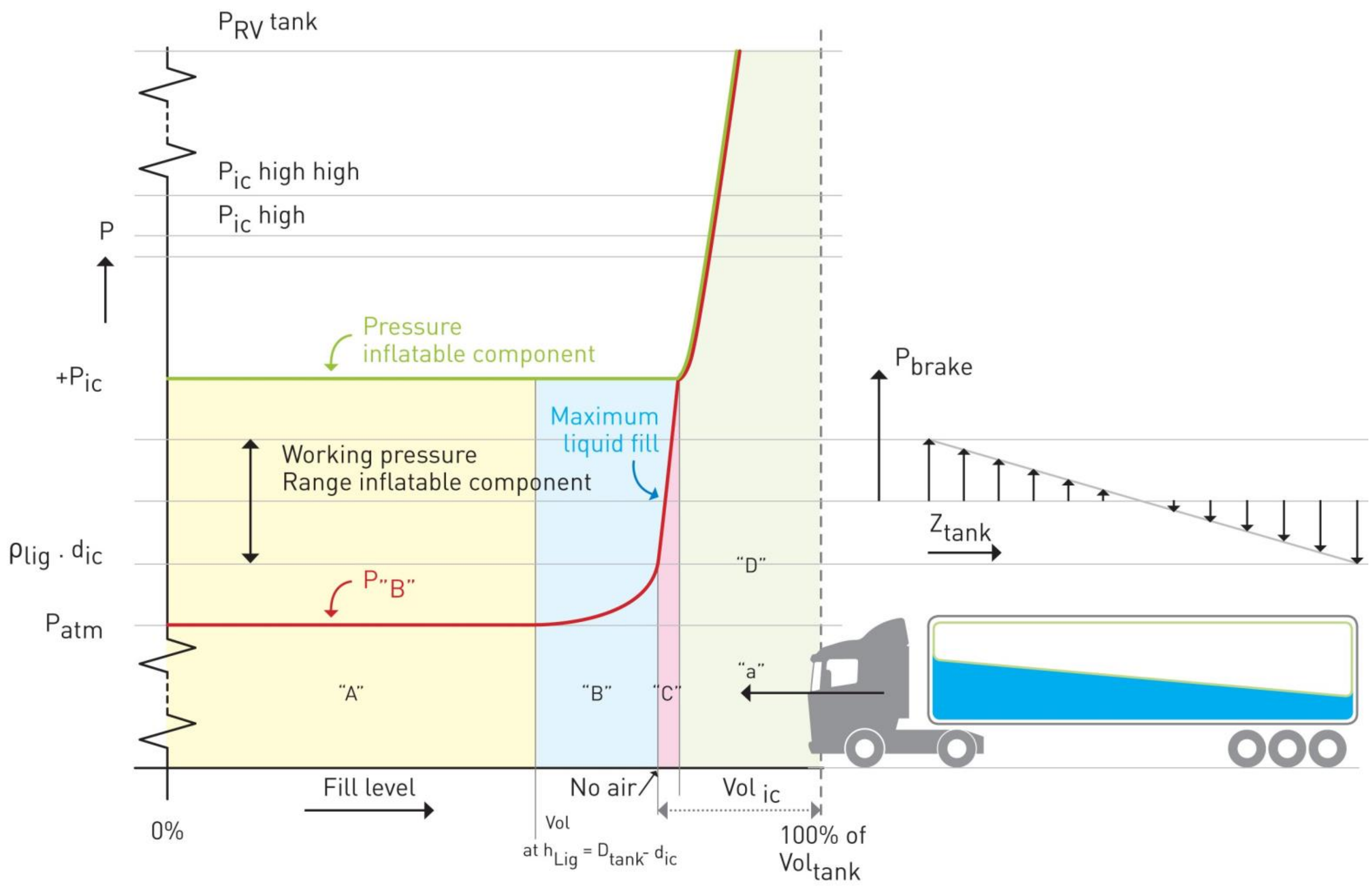
While

- Being made of a rubber or thermoplastic material
- Of high “Young” modulus ($E > 10^8$ N/m^2)
- Which shall be chemically compatible with the liquid

Fixed volume inflated component

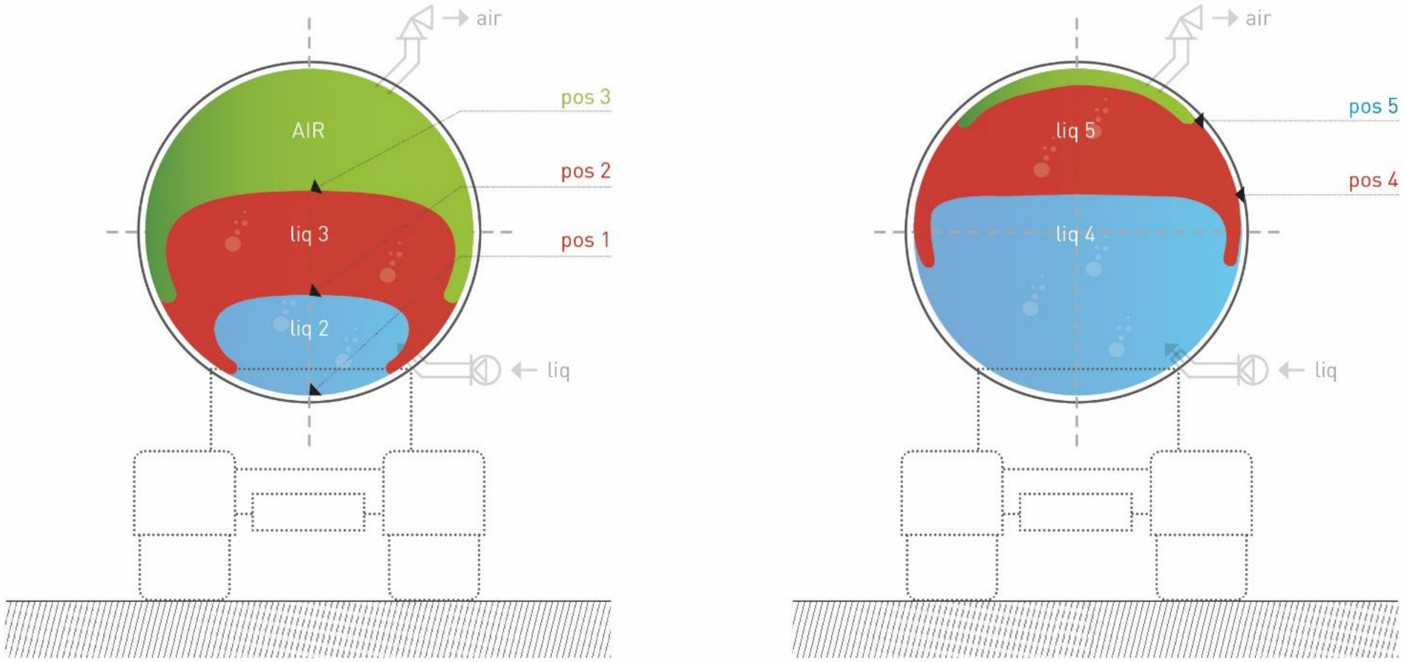


Liquid fill rate and pressures

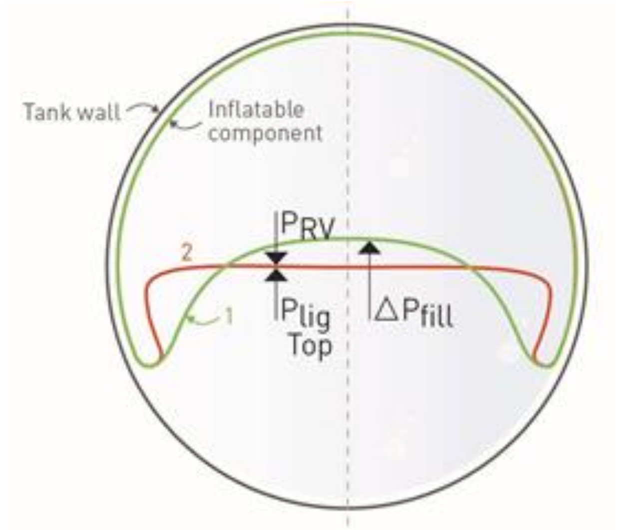


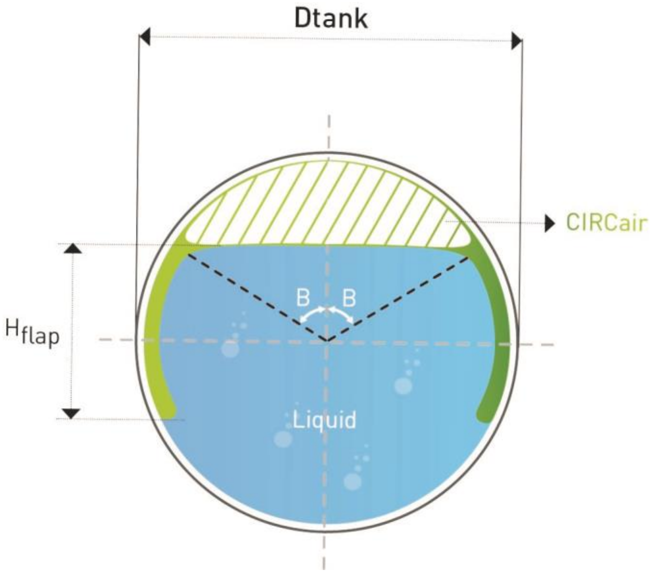
Load securing during liquid fill process

A Variable Volume Inflated component deflating during the liquid fill process

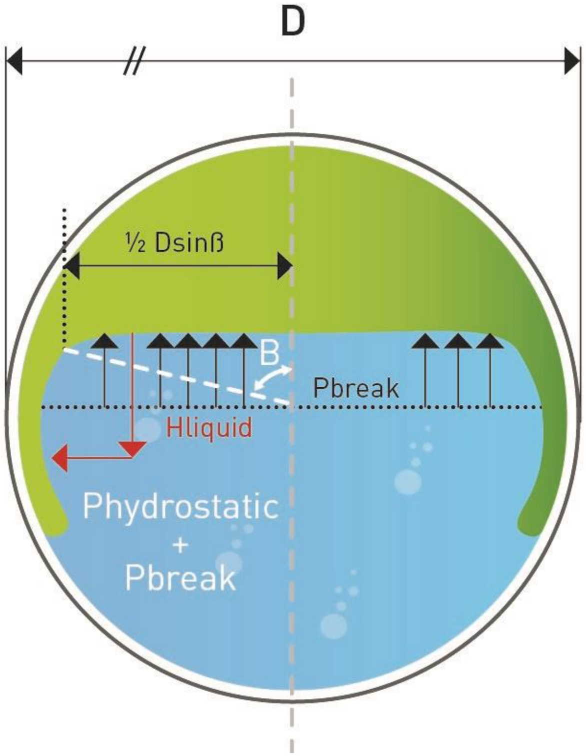


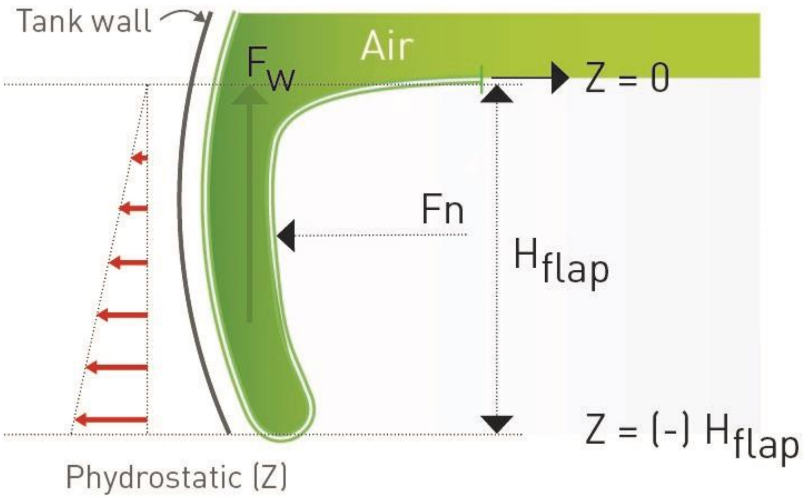
Load securing during liquid fill process



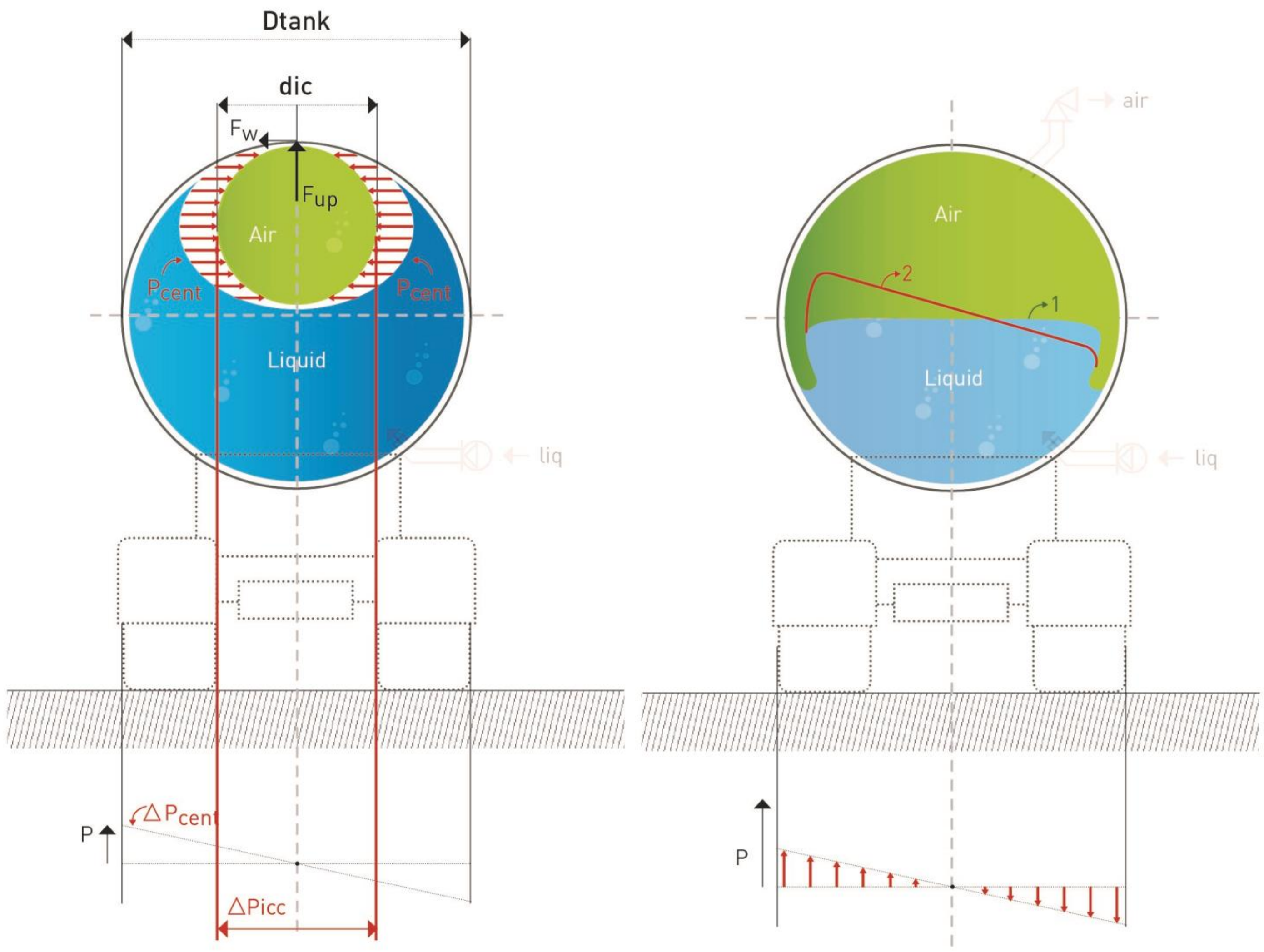


Load securing during breaking





Load securing during driving through a curve



Use of elementary fundamentals in slosh mitigation

Component stress and internal pressure: $\sigma\ 2t = P_{ic}\ d_{ic.}$

Component stress and strain: $\sigma = E\ \varepsilon$.

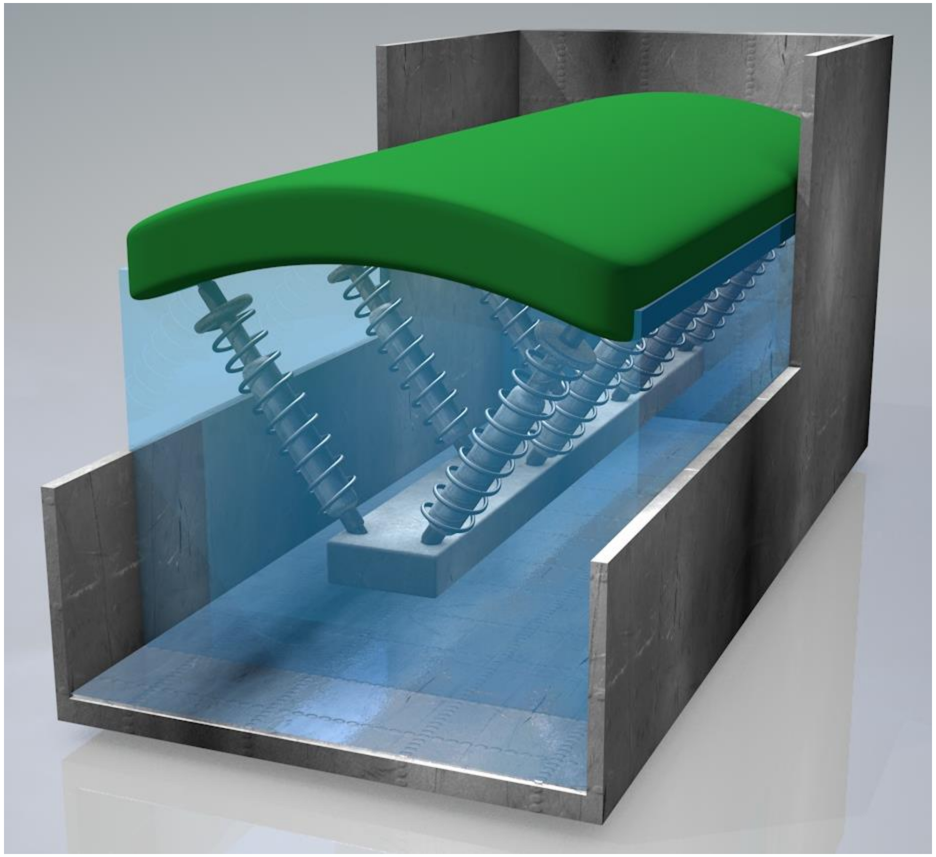
Hydrostatic pressure: $P_{\text{"B"}} = \rho_{\ liq}\ \{h_{liq}$ -/- $(D_{tank} - d_{ic})\}$.

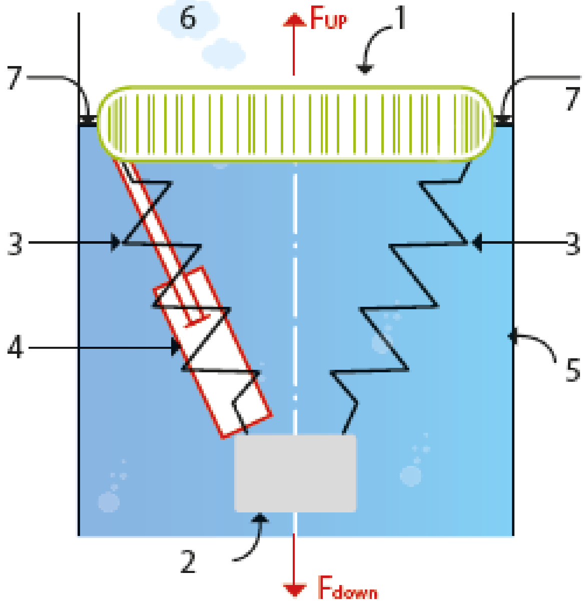
Upward force on submerged component: $F_{up} = \rho_{liq}\ V_{liqd}\ g$.

Geometric calculations: $H_{flap} = \frac{1}{4}\ D\ \{\pi\ (1 - (2\beta/360) - \sin\beta\}$.

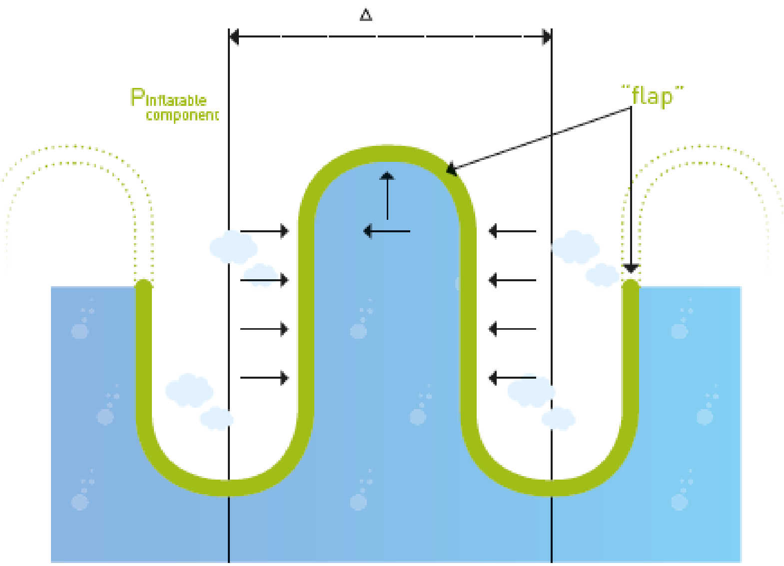
Brake and centrifugal forces: $F = m\ a$ and $F_c = m\ v^2/r$.

Load securing in rectangular tanks





Load securing in random shaped tanks



Conclusion

Sloshing of liquids being transported can, and generally should, be mitigated or even eliminated.

Thank you for your attention.