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Liquid Propellant Storage

- Already described storage for gaseous propellants
- What about liquids like hydrazine?

- Issues
  - pressurization method
  - preventing gas from entering storage tank outlet

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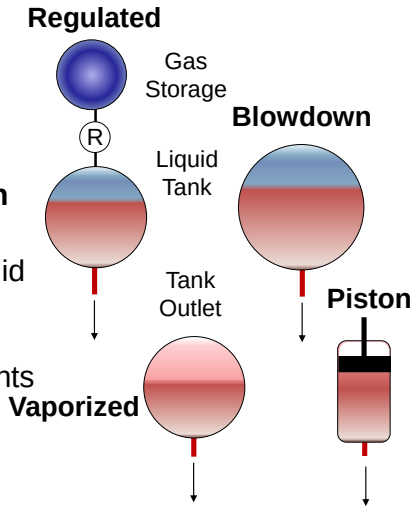
Typical Thruster Pressurization Options

1. Externally stored inert gas pressurization, **regulated**
   - constant tank pressure
2. Internally stored inert gas pressurization, **blowdown**
   - tank pressure drops
   - larger tank for same liquid mass
3. **Vaporized** propellant
   - only for volatile propellants
   - pressure limited to p_{vap}
4. **Piston** driven
   - less common



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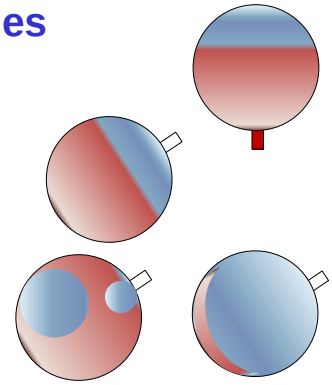
Ullage Bubbles

- With simple tanks difficult to guarantee liquid wets outlet
  - in gravity field, vehicle orientation can change
  - in zero-g, ullage bubbles can float or wetting can inhibit liquid
- If (inert) gas enters thruster, thrust and pressurization gas lost
- How to prevent?



Ullage ≡ tank volume not occupied by liquid

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Positive Expulsion Methods

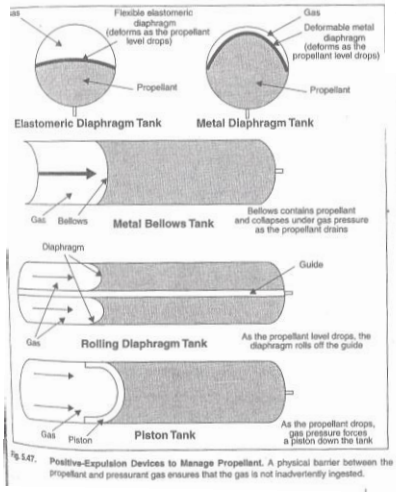


Fig 5.17. **Positive-Expulsion Devices to Manage Propellant.** A physical barrier between the propellant and pressurant gas ensures that the gas is not inadvertently ingested.

- Mechanically separate pressurization gas and liquid propellant

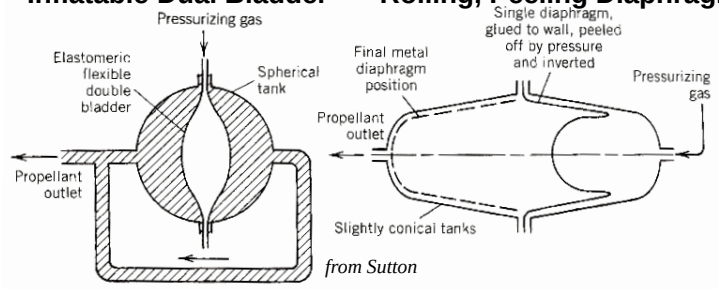
Table 5.16. **Advantages and Disadvantages of Positive-Expulsion Devices for Propellant Management.**

	Metal Diaphragm Tank	Rolling Diaphragm Tank	Piston Tank	Rubber Diaphragm Tank	Metal Bellows Tank
Advantages	• High volume efficiency • Good center of gravity control • No ullage volume • No sliding seals • Proven design	• Low mass • Low cost • Low Δp during expulsion	• Extensive database • Low Δp during expulsion • Design adapts easily to growth	• Extensive database • Low Δp during expulsion • Not cycle limited • Proven design • High expulsion efficiency	• No sliding seals • Good center-of-gravity control • Proven design • Good compatibility • Hermetically sealed
Disadvantages	• High mass • High cost • High-expulsion Δp • Optimizes only for special envelope	• Inspection of internal welds is difficult	• High cost • Low volumetric efficiency • Critical tolerance on shell • Sliding seals possible blow-by	• Compatibility limits on propellants	• High mass • High cost • Limited cycle capability • Low volumetric efficiency
Typical applications	• Spacecraft control & maneuvering • Launch vehicles • Upper stages • Missiles	• Missile intercep-tors • Maneuver-ing mis-siles	• High acceleration missiles	• Spacecraft control & maneuvering • Launch vehicles • Upper stages	• Missiles • Spacecraft • Launch vehicles

from Humble, Henry and Larson, ***Space Propulsion Analysis and Design*** *(1995)*

Positive Expulsion Methods

Inflatable Dual Bladder **Rolling, Peeling Diaphragm**



from Sutton

- Other advantages of positive expulsion
  - prevent pressurizing gas from dissolving in propellant
  - allows hot, reactive pressurizing gas (e.g., gas generator)

Surface Tension Devices

- Use capillary attraction to maintain liquid at tank outlet
- Typically made of fine mesh, stainless steel wire screens near tank outlet
  - used alone, work best in low acceleration applications (surface tension vs. intertial forces)

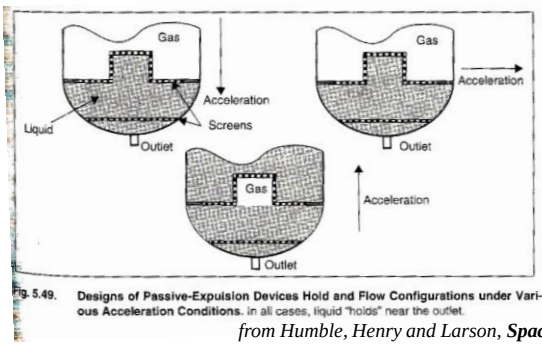


Fig. 5.49. **Designs of Passive-Expulsion Devices Hold and Flow Configurations under Various Acceleration Conditions.** In all cases, liquid "holds" near the outlet.

from Humble, Henry and Larson, ***Space Propulsion Analysis and Design*** *(1995)*