An Introduction to Aerosol Propellants

Diversified CPC International, Inc.

Aerosol Products Do Not Contain CFCs
An Introduction to Aerosol Propellants

Aerosol Product System

(Slides in this section courtesy of DuPont)
Figure A-1-6 An aerosol can (cutaway view). When the plunger (1) is pressed, a hole in the valve (2) allows a pressurized mixture of product and propellant (3) to flow through the plunger’s exit orifice.
(Source: Fire Protection Handbook, 18th edition)
Aerosol Product System

A Typical Homogeneous Aerosol

Solution of Active Ingredients, Solvents and Propellants
Aerosol Product System

A Typical Heterogeneous Aerosol

Suspension of Powder in Liquefied Gas Propellant
Liquified Gas
Aerosol Product System

Aerosol with a Liquefied Gas

25 psig

25 psig
Aerosol Product System

Aerosol with a Permanent Gas

- 100 psig
- 75 psig
- 50 psig
Aerosol Product System

Pressure Drop During Discharge

- Permanent Gas
- Liquefied Gas

psig

Full Can
75% Full
50% Full
25% Full
Empty Can
Aerosol Product System

Pressure Versus Original Fill

Starting pressure perm. gas

Constant pressure liquefied gas blend

Minimum operating pressure

Full Can | 75% Full | 50% Full | 25% Full | Empty Can

90% Product Fill

75% Product Fill

50% Product Fill

25% Product Fill
Aerosol Product System

Filling Methods

Cold

Pressure

Under-the-Cap
Aerosol Product System

Pressure Filling Thru Valve Without Activator Button

- Piston
- Propellant
- Seal
Aerosol Product System

Pressure Filling Thru Activator Button

Piston

Propellant

Seal
Aerosol Product System

Under-the-Cap Filling

1. Add Product
2. Pull Vacuum on Can
3. Charge Propellant
4. Crimp Valve Cup

Vacuum

Propellant
An Introduction to Aerosol Propellants

Basic Propellant Properties
Basic Propellant Properties

- Pressurize the aerosol package

- Influence the form in which the product is discharged:
  - Foam
  - Stream
  - Spray
Basic Propellant Properties

Propellants also can act as:

- Solvent
- Diluent
- Viscosity Modifier
- Freezant
- Refrigerant Refill Liquid
- Electronic Duster
- Alarm Agent (boat horn)
- Specialty Degreaser
Basic Propellant Properties

Properties Conferred to Aerosol Products by Propellants:

• Pressure is created. Normal range is 0.7 to 9.8 bars @ 21.1°C (10 to 142 psig @ 70°F)

• Atomization can be produced. Droplet sizes range from below 1 µm to 125 µm (and higher to include streaming aerosols)

• Improvement in performance. Aerosol insecticides have been reported to be more effective than equivalent pump sprays.

• Flammability is generally increased (except 134a)
Properties Conferred to Aerosol Products by Propellants:

- **Adjustment of Foam Density**: Increasing propellant concentration generally produces lower density foams in the case of mousses, shaving creams, etc.
- **Adjustment of Foam Stability**: By adjusting the propellant and solvent used, quick breaking foams can be produced, or foams can be created that remain visually unchanged for days.
To produce a spray, the propellant must have sufficient dispersive energy to overcome the surface tension of the liquid mixture, plus the cohesive and adhesive forces.

Dispersive Energy of a Propellant is generally related to:

- Pressure
- Molecular weight (lower MW propellants generally exhibit better dispersancy, with exceptions due to interactions of the propellant/solvent system.)
Basic Propellant Properties

Nitrogen gas: Virtually no solubility in liquids

- Will produce only a liquid stream
  - water/saline solution for rinsing hydrophilic contact lenses
  - petroleum distillates (wasp & hornet killers)
- The liquid stream produced by N2, CAIR and similar compressed gases can be converted to coarse sprays by outfitting the valve with a mechanical breakup actuator
Basic Propellant Properties

Carbon Dioxide (CO2) dissolves up to about 2.6 - 2.9% in petroleum distillates

- Can produce a medium to coarse spray which gets more coarse as the molecular weight of the base product increases.
It may be advantageous to use as little propellant as possible to allow the inclusion of a maximum amount of the product. This may not always be practical:

- A larger amount of lower pressure propellant will often give a smoother, less “blasty” spray
- This also allows for the use of valves with a larger orifice - which can be important to help eliminate clogging by powder-containing formulas
Basic Propellant Properties

- Provides more reserve propellant for vapor-tap aerosols and allows for possible product misuse, such as inverting the container.
- Reduces viscosity of the formulation and in some cases reduces or eliminates unwanted foaming tendencies.
- Organic Solvents will exert a pressure-reducing effect on the propellant, possibly necessitating a higher pressure propellant or else a higher concentration of propellant in the formula.
Basic Propellant Properties

Aerosol Product Formulation Considerations

- Vapor Pressure
- Spray Characteristics
- Solubility
- Flammability
- Corrosion
Three Categories of Aerosol Propellants
Categories of Aerosol Propellants

- Compressed Gases
- Soluble Gases
- Liquefied Gases
Compressed and Soluble Gas Propellants
Compressed and Soluble Gases

<table>
<thead>
<tr>
<th>Properties</th>
<th>Nitrogen (N₂)</th>
<th>Compressed Air</th>
<th>Carbon Dioxide (CO₂)</th>
<th>Nitrous Oxide (N₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor Pressure</td>
<td>N/A&lt;sup&gt;a&lt;/sup&gt;</td>
<td>N/A&lt;sup&gt;a&lt;/sup&gt;</td>
<td>844.7 (58.2)</td>
<td>759.7 (52.38)</td>
</tr>
<tr>
<td>(psig 70°F, 21°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(bar 70°F, 21°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td>N/A&lt;sup&gt;a&lt;/sup&gt;</td>
<td>N/A&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1485 (102.3)</td>
<td>1420 (97.8)</td>
</tr>
<tr>
<td>(psig 130°F, 54°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(bar 130°F, 54°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiling (°F)</td>
<td>-320.4 (-195.8)</td>
<td>-317.8&lt;sup&gt;b&lt;/sup&gt; (-194)</td>
<td>-109.2&lt;sup&gt;c&lt;/sup&gt; (-78.4)</td>
<td>-127.4 (-88.5)</td>
</tr>
<tr>
<td>(at one atm) (°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid Density (g/ml)</td>
<td>0.00114&lt;sup&gt;d&lt;/sup&gt; (@25°C)</td>
<td>0.00129&lt;sup&gt;d&lt;/sup&gt; (@25°C)</td>
<td>0.713 (@25°C)</td>
<td>0.913 (@25°C)</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>0.967</td>
<td>1.000</td>
<td>1.530</td>
<td>1.530</td>
</tr>
<tr>
<td>Gas Density (Air = 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Solubility</td>
<td>0.015 (@25°C)</td>
<td>0.018 (@25°C)</td>
<td>0.759 (@25°C)</td>
<td>0.588 (@25°C)</td>
</tr>
<tr>
<td>(vol./vol. at 1.00 atm. abs.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9.1

- a. Not Applicable. (Gas cannot be condensed by pressure.)
- b. Initial boiling point of mixture.
- c. Actually, the sublimation point; solid to gas
- d. The densities for nitrogen and compressed air are for the gaseous phase, since they cannot be liquefied under pressure at these temperatures.
Liquefied Gas Propellants
Liquefied Gas Propellants

Customer Needs and Reformulations

DME

134a

152a

Hydrocarbons
# General Liquefied Gas Propellant Comparisons

<table>
<thead>
<tr>
<th></th>
<th>Hydrocarbons</th>
<th>DME</th>
<th>HFCs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flammability</strong></td>
<td>Flammable</td>
<td>Flammable</td>
<td>152a is Flammable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>134a is Non-Flammable</td>
</tr>
<tr>
<td><strong>Toxicity</strong></td>
<td>Low (OK for</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Food Products)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Solvency</strong></td>
<td>Poor</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Density</strong></td>
<td>Low</td>
<td>Low</td>
<td>Intermediate</td>
</tr>
<tr>
<td><strong>Solubility</strong></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>In Water</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>VOC</td>
<td>VOC</td>
<td>GWP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(134a only)</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>LOW</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
</tbody>
</table>
Liquefied gas propellants expand substantially from a liquid to a gas when released to the atmosphere. Vapors are heavier than air.

<table>
<thead>
<tr>
<th>Liquefied Gas Propellant</th>
<th>Vapor (lb/ cu.ft)</th>
<th>Liquid (lb/ cu.ft)</th>
<th>Vapor/Liquid Ratio</th>
<th>Vapor/Air Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane</td>
<td>0.116</td>
<td>28.41</td>
<td>245</td>
<td>1.55</td>
</tr>
<tr>
<td>Isobutane</td>
<td>0.154</td>
<td>32.36</td>
<td>210</td>
<td>2.05</td>
</tr>
<tr>
<td>N-butane</td>
<td>0.155</td>
<td>33.44</td>
<td>216</td>
<td>2.07</td>
</tr>
<tr>
<td>DME</td>
<td>0.119</td>
<td>41.18</td>
<td>346</td>
<td>1.59</td>
</tr>
<tr>
<td>Dymel 152a</td>
<td>0.171</td>
<td>56.78</td>
<td>332</td>
<td>2.28</td>
</tr>
<tr>
<td>134a</td>
<td>0.264</td>
<td>76.26</td>
<td>289</td>
<td>3.52</td>
</tr>
<tr>
<td>Air @ 70F</td>
<td>0.075</td>
<td>N / A</td>
<td>N / A</td>
<td>1.00</td>
</tr>
</tbody>
</table>
# Properties of DME and HFC Propellants

<table>
<thead>
<tr>
<th></th>
<th>DME</th>
<th>HFC-152a</th>
<th>HFC-134a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Formula</td>
<td>CH$_3$OCH$_3$</td>
<td>CH$_3$CHF$_2$</td>
<td>CF$_3$CH$_2$F</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>46.1</td>
<td>66.0</td>
<td>102.0</td>
</tr>
<tr>
<td>Boiling point (°F)</td>
<td>-13.0</td>
<td>-13.0</td>
<td>-15.7</td>
</tr>
<tr>
<td>Vapor Pressure @70°F (psig)</td>
<td>63.0</td>
<td>63.0</td>
<td>71.0</td>
</tr>
<tr>
<td>Liquid Density @ 70°F (g/cc)</td>
<td>0.66</td>
<td>0.91</td>
<td>1.21</td>
</tr>
<tr>
<td>Flammability in air</td>
<td>LEL 3.3</td>
<td>UEL 18.0</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flash Point (°F)</td>
<td>-42.0</td>
<td>-58.0</td>
<td>none</td>
</tr>
<tr>
<td>Kauri-Butanol value</td>
<td>60</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Solubility in Water (wt.% @ 70°F, autogeneous pressure)</td>
<td>35.0</td>
<td>1.7</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Propellant Blends Vapor Pressure

LOW
Shave Cream
Gels and Mousse
Oven Cleaner
Perfume

MEDIUM
Hard Surface Cleaners
Furniture Polish
Deodorant Sprays

HIGH
Air Fresheners
Automotive products
Flying Insect Spray
Spray Paint
Hydrocarbon Propellants
Hydrocarbon Propellants

Hydrocarbon Propellants
Organic Compounds
Derived from Natural Gas Liquids
(liquefied under pressure)

CH$_4$ Methane
C$_2$H$_6$ Ethane
C$_3$H$_8$ Propane
C$_4$H$_{10}$ Butanes
C$_5$H$_{12}$ Pentanes
# Properties of the Hydrocarbons

<table>
<thead>
<tr>
<th></th>
<th>Propane</th>
<th>I-Butane</th>
<th>N-Butane</th>
<th>I-Pentane</th>
<th>N-Pentane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Formula</td>
<td>C₃H₈</td>
<td>C₄H₁₀</td>
<td>C₄H₁₀</td>
<td>C₅H₁²</td>
<td>C₅H₁²</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>44.1</td>
<td>58.1</td>
<td>58.1</td>
<td>72.2</td>
<td>72.2</td>
</tr>
<tr>
<td>Boiling point (°F)</td>
<td>-43.7</td>
<td>10.9</td>
<td>31.1</td>
<td>82</td>
<td>97</td>
</tr>
<tr>
<td>Vapor Pressure @ 70°F (psig)</td>
<td>109.3</td>
<td>31.1</td>
<td>16.9</td>
<td>-3.1</td>
<td>-6.2</td>
</tr>
<tr>
<td>Liquid Density @ 70°F (g/cc)</td>
<td>0.51</td>
<td>0.56</td>
<td>0.58</td>
<td>0.62</td>
<td>0.63</td>
</tr>
<tr>
<td>Flammability in air</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEL</td>
<td>2.2</td>
<td>1.8</td>
<td>1.9</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>UEL</td>
<td>9.5</td>
<td>8.4</td>
<td>8.5</td>
<td>7.6</td>
<td>7.8</td>
</tr>
<tr>
<td>Flash Point (°F)</td>
<td>-156</td>
<td>-117</td>
<td>-101</td>
<td>-60</td>
<td>-40</td>
</tr>
<tr>
<td>Kauri-Butanol value</td>
<td>15</td>
<td>18</td>
<td>20</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Solubility in Water</td>
<td>0.007</td>
<td>0.008</td>
<td>0.008</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>(wt.% @ 70°F, autogeneous pressure)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Vapor Pressure of Liquefied Gases
Solubility of Butane and Propane in Water
Liquid Density of LP Gas Blends

- n-Butane/Propane Blends
- n-Butane/Isobutane/Propane Blends
  (Based on Blends containing a mixture of 40% isobutane and 60% n-Butane by weight and blended with Propane.)
- Isobutane/Propane Blends

Volume Percent of Propane in Blend

Density, Pounds / Gallon @ 60°F
Hydrocarbon Propellants

Standard Hydrocarbon Propellant Blends
Standard Hydrocarbon Blends

Hydrocarbon Blend Components

N-Butane A-17

Propane A-108

IsoButane A-31
Standard Hydrocarbon Blends

Diversified CPC International
Three Major Types
Typical Hydrocarbon Blends

- A-46 (15.2% Propane / 84.8% Isobutane)
- NP-46 (25.9% Propane / 74.1% N-butane)
- NIP-46 (21.9% Propane / 31.3% Isobutane / 46.8% N-Butane)
Standard Hydrocarbon Blends

Typical Hydrocarbon Blends

- A-31
- NP-31
- NIP-31
- A-46
- NP-46
- NIP-46
- A-70
- NP-70
- NIP-70
- A-85
- NP-85
- A-108
Hydrocarbon Propellants

Processing
1 - Fractionation of Selected Feedstocks

2 - Hydrogenation and Stabilization
   - Conversion of Unsaturated hydrocarbons
   - Elimination of trace alcohol or peroxide compounds

3 - Catalytic Desulfurization

4 - Dehydration and Sweetening
Processing of Hydrocarbon Propellants
Processing of Hydrocarbon Propellants
Processing of Hydrocarbon Propellants
Processing of Hydrocarbon Propellants
Processing of Hydrocarbon Propellants
Processing of Hydrocarbon Propellants
An Introduction to Aerosol Propellants

Propellant Cost
Cost Comparison

Hydrocarbons
1x

DME
2x

152a
4x
Cost Comparison

DME
2x

Hydrocarbons
1x

134a
5 - 7x

152a
4x
Characteristics of Hydrocarbon Aerosol Propellants

- Low Relative Cost
- Stability and Purity
- Low Odor
- Range of Boiling Points
- Wide Range of Vapor Pressures
- Low Toxicity
- Versatility and Efficiency
- Natural Compounds
- Flammability
- Environmental (VOC)
Flammability, the principal disadvantage, is controllable
An Introduction to Aerosol Propellants

V O C Issues
Low VOC Propellant Options

Non VOC Propellants
- 152a
- 134a

Low VOC Blends
- DME - Water Based
- DME/HC/Water
- HFC/Hydrocarbon

Adjust Pressure
Use higher vapor pressure hydrocarbon propellant and reduce fill volume
VOC Reduction Strategies

- Add more non-VOC concentrate
- Add more water
- Replace VOC Solvent with non-VOC solvent
- Formulate with a higher vapor pressure propellant and use less gas in the can
- Replace VOC Propellant
- Formulate based on relative reactivity
Low VOC (Liquefied Gas) Propellant Alternatives

• Aqueous Aerosols
  – DME
  – DME/Hydrocarbon
  – Dymel 152a
  – Dymel 152a/Hydrocarbon
  – Dymel 152a/DME

• Anhydrous Aerosols
  – Dymel 152a
  – Dymel 152a/Hydrocarbon
Custom Blends

IsoPentane

A31/IsoPentane

A31/N-Pentane

A17/N-Pentane

134a/DME

A80/DME

A17/DME

Pentane/DME

152a/A17

152a/A31

152a/A46

152a/A17/DME

152a/A31/DME

134a/A31

134a/A17
• Approximately 30 basic hydrocarbon propellant blends prior to VOC Issue
• Over 250 custom binary (2-part) and ternary (3-part) blends today to meet low VOC demands
Low VOC Propellant Shipments
US EPA Supports Hydrocarbon Propellants

“Hydrocarbons are acceptable substitutes as propellants in the aerosol sector. Hydrocarbons have several environmental advantages over other substitutes. For example, they have zero ozone depletion potential, and because of their extremely short atmospheric residence times, they are estimated to have insignificant impact on global warming. Yet their reactivity contributes to formation of tropospheric ozone. The Agency has assessed this effect, however, and found that the increase in volatile organic compound emissions (VOCs) from these substitutes will have no significant effect on tropospheric ozone formation.”
Unfortunately, the US EPA forgot to tell California!
Photochemical Reactivity Concepts

- Reactivity - Measure of a VOC’s potential to react in the atmosphere and lead to the formation of ozone
- Use of “lower reactive” VOCs may provide means for ozone reduction benefit where mass-based VOC reductions alone are not sufficient for attainment or feasible
- Flexible approach that gives manufacturers more reformulation options

Maximum Incremental Reactivity Scale

- Allows comparison of VOC reactivities
- Basis for scale is peer-reviewed
- Scientific basis sufficient to use reactivity in a more detailed manner
NO CFCs
(CAPCO)
It’s OK to Spray!
NO CFCs
An Introduction to Aerosol Propellants

Transportation
Delivery of Aerosol Propellants

1 - Truck Transports

2 - Railroad Tank Cars

3 - DOT Cylinders
   - 1#  (laboratory sample)
   - 20#  (barbecue size)
   - 100#
   - 200#
   - 420#
An Introduction to Aerosol Propellants

Transportation - Trucks -
Transportation - Trucks
Transportation - Trucks
Transportation - Trucks
Transportation - Trucks
Transportation - Trucks
Transportation - Trucks
An Introduction to Aerosol Propellants

Transportation
- Rail Cars -
Transportation – Rail Cars
Transportation - ISO Containers -
Transportation – ISO Containers
Transportation – ISO Containers
Transportation – ISO Containers
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Transportation
- Cylinders -
Transportation - Cylinders
Transportation - Cylinders
An Introduction to Aerosol Propellants

Liquefied Gas Propellant Tank Farm Operations

* Propellant Delivery and Unloading
Tank Farm Operations

SAMPLE VALVE AND ROTOGAGE
Tank Farm Operations
Tank Farm Operations
Tank Farm Operations

Flow Indicator

ESV
Tank Farm Operations

TYPE N550 EMERGENCY SHUTOFF VALVES

- LATCH ASSEMBLY
- OPERATING LEVER
- CABLE ATTACHMENT
- FUSIBLE ELEMENT
- TFE-GRAFHITE PACKING
- POPPET
- SEAT DISC

Type N550 in the open position
Tank Farm Operations
Tank Farm Operations
Tank Farm Operations
Tank Farm Operations

AUX. SUCTION LINE

LIQUEFIED GAS TRANSFER PUMP

PUMP DISCHARGE LINE

VAPOR BALANCE LINE

TRANSPORT TRUCK PUMP - PTO DRIVEN
Tank Farm Operations

Gas Transfer Compressor
Tank Farm Operations

Internal Safety Valve (pneumatically operated)
Tank Farm Operations

SHUTOFF FOR INTERNAL VALVES
Tank Farm Operations
Tank Farm Operations

Driver must remain with the vehicle during the entire unloading operation!

An attendant from the customer should remain close by as well to react quickly to any plant-related issues that may arise.
Tank Farm Operations
Emergency Shutoff Valve (Pneumatically Operated)
Tank Farm Operations

TYPE N560 EMERGENCY SHUTOFF VALVES

HARDENED STAINLESS STEEL PIPE THREADS
MAIN POPPET
EXCESS FLOW SPRING

EXTENDED NIPPLE (N560 Only)
PILOT VALVE
SEAT DISC
PISTON
FUSE PLUG
WRENCHING HEX

PNEUMATIC CLOSURE ACCESSORIES

FISHER CONTROLS TANK CAR ESV
Tank Farm Operations

GAS TRANSFER COMPRESSOR
Figure 2.21(b) Compressor Liquid Traps. In part (a), the floats rise with the liquid level and close the valve at the top. In part (b), the float actuates a switch which shuts off the compressor motor.

LIQUID TRAPS FOR COMPRESSOR SUCTION LINE
(For Tank Car Unloading, the “Supply Tank” is the Tank Car and the “Receiver Tank” is the Propellant Storage Tank)
Tank Farm Operations

Liquid Transfer Using a Gas Compressor
(Tank Car Unloading)

Vapor Recovery Operations
Propellant Storage Tanks, Equipment and Safety Systems
Storage Tanks, Equipment, & Safety Systems
Storage Tanks, Equipment, & Safety Systems
Storage Tanks, Equipment, & Safety Systems
Storage Tanks, Equipment, & Safety Systems
### Installation of LP-Gas Systems

**Table 3-2.2.2**

<table>
<thead>
<tr>
<th>Water Capacity Per Container Gallons (m³)</th>
<th>Mounded or Underground Containers [Note (d)]</th>
<th>Aboveground Containers [Note (f)]</th>
<th>Between Containers [Note (e)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 125 (0.5) [Note (a)]</td>
<td>None [Note (b)]</td>
<td>None [Note (c)]</td>
<td>None</td>
</tr>
<tr>
<td>125 to 250 (0.5 to 1.0)</td>
<td>10 ft (3 m)</td>
<td>10 ft (3 m)</td>
<td>None</td>
</tr>
<tr>
<td>251 to 500 (1.0 + to 1.9)</td>
<td>10 ft (3 m)</td>
<td>10 ft (3 m)</td>
<td>3 ft (1 m)</td>
</tr>
<tr>
<td>501 to 2,000 (1.9 + to 7.6)</td>
<td>10 ft (3 m)</td>
<td>25 ft (7.6 m)</td>
<td>3 ft (1 m)</td>
</tr>
<tr>
<td>2,001 to 30,000 (7.6 + to 114)</td>
<td>50 ft (15 m)</td>
<td>50 ft (15 m)</td>
<td>5 ft (1.5 m)</td>
</tr>
<tr>
<td>30,001 to 70,000 (114 + to 265)</td>
<td>50 ft (15 m)</td>
<td>75 ft (23 m)</td>
<td>(¼ of sum of diameters of adjacent containers)</td>
</tr>
<tr>
<td>70,001 to 90,000 (265 + to 341)</td>
<td>50 ft (15 m)</td>
<td>100 ft (30 m)</td>
<td></td>
</tr>
<tr>
<td>90,001 to 120,000 (341 + to 454)</td>
<td>50 ft (15 m)</td>
<td>125 ft (38 m)</td>
<td></td>
</tr>
<tr>
<td>120,001 to 200,000 (454 to 757)</td>
<td>50 ft (15 m)</td>
<td>200 ft (61 m)</td>
<td></td>
</tr>
<tr>
<td>200,001 to 1,000,000 (757 to 3 785)</td>
<td>50 ft (15 m)</td>
<td>300 ft (91 m)</td>
<td></td>
</tr>
<tr>
<td>Over 1,000,000 (3 785)</td>
<td>50 ft (15 m)</td>
<td>400 ft (122 m)</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2.8 Marking Required by 2-2.6.5 as Given on a Nameplate. Container listing [in this example, by Underwriters Laboratories Inc. (UL)] is optional.
MANUFACTURER’S DATA PLATE FOR LPG STORAGE TANK
Figure 2.17(c) Float Type of Variable Liquid Level Gauge.
Storage Tanks, Equipment, & Safety Systems

Liquid Level Gauges
Storage Tanks, Equipment, & Safety Systems

Liquid Level Gauges
Storage Tanks, Equipment, & Safety Systems

Figure 2.17(a) Rotary Type of Variable Liquid Level Gauge.

Figure 2.17(b) Rotary Gauge Face.
SAFETY RELIEF VALVES

Storage Tanks, Equipment, & Safety Systems
SAFETY RELIEF VALVES
INTERNAL SPRING SAFETY RELIEF VALVE
Storage Tanks, Equipment, & Safety Systems

EXTERNAL SPRING RELIEF VALVE

- Retainer
- Spring
- Valve Body
- Poppet
- Seat
Figure 2.12 ASME Container Relief Valve Manifolds. The container requires three relief valves. The manifold contains four. By manipulating the handwheel or lever, an internal clapper-type valve can be rotated to isolate any one of the four relief valves for testing, maintenance, or replacement.
Storage Tanks, Equipment, & Safety Systems

Hydrostatic Relief Valve
Storage Tanks, Equipment, & Safety Systems

Pressure Rise in a Constant Volume Vessel or Pipe

- **Pressure Increase from 24 to 1800 psig as temperature rises from 0 to 200 °F**

  *(Basis-100% Propane Liquid Full at 130 °F)*
stopped or reversed. Both valves of double backflow check valves shall comply with this provision.

Figure 2.14 Operation of Backflow Check Valve.
Storage Tanks, Equipment, & Safety Systems
Storage Tanks, Equipment, & Safety Systems

Storage Tank Safety Valves
Storage Tanks, Equipment, & Safety Systems

Storage Tank Safety Valves
Storage Tanks, Equipment, & Safety Systems

Storage Tank Safety Valves
Pipe and Pipe Fittings

- Carbon Steel schedule 80 pipe and 2000# forged steel fittings are recommended to be used throughout the propellant storage and handling system for maximum safety and maintenance flexibility.

- Pipe joints may be threaded, flanged or welded. Welded joints are preferred to minimize the potential for leaks, especially in long piping runs or piping that is hard to reach for inspection.
Pipe and Pipe Fittings

- Piping must be designed and installed in accordance with NFPA 58 and ASME B31.3 Chemical Plant and Petroleum Refinery Piping.
- Cast Iron fittings must not be used. (Malleable or ductile iron may be used for equipment handling liquefied gas propellants).
- All materials must be inert to the chemical action of the propellant.
- Metal or Spiral wound metal gaskets required.
Pipe and Pipe Fittings

- Piping should be installed above ground and must be well supported and protected against damage.
  - Buried piping requires special protective coating systems and cathodic protection. Buried piping is generally not recommended due to corrosion, settling and difficulty with leak detection. For buried piping considerations, see NFPA 58, Chapter 3 (section 3-2.12)
- Grounding of the piping system is recommended.
- Piping Systems must be properly labeled.
Pipe and Pipe Fittings

• Elastomers
  – Hydrocarbons and Hydrofluorocarbons
    • Buna-N, Neoprene and Butyl Rubber acceptable
  – Dimethyl Ether (DME)
    • Teflon® is a suitable plastic sealant
    • Kalrez® and Ethylene Propylene (EP) are the best elastomers for DME service
Forged Steel Sch. 80 Pipe and 2000# Fittings
2.5.2 Pumps.

2.5.2.1 Pumps shall be designed for LP-Gas service and may be of rotary centrifugal, turbine or reciprocating type.

Figure 2.20(a) Sliding Vane Positive Displacement Pump.
Storage Tanks, Equipment, & Safety Systems

Figure 2.20(c) Operation of Sliding Vane Pump.

a. Vanes move out, trapping liquid at the pump inlet.
b. Liquid is transferred toward the outlet between the vanes.
c. As the vanes move back into their slots, liquid is discharged through the outlet.
Figure 3.11(b) Typical Pump and Meter Installation.
Storage Tanks, Equipment, & Safety Systems
Storage Tanks, Equipment, & Safety Systems
The theoretical maximum release of 3 different hydrocarbon propellants @ 70 °F to the atmosphere through a 0.25” diameter opening has been calculated to be:

<table>
<thead>
<tr>
<th>Hydrocarbon</th>
<th>Pressure (psig)</th>
<th>Vapor (ft3/sec)</th>
<th>Liquid (gal/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane</td>
<td>108</td>
<td>12.20</td>
<td>28.60</td>
</tr>
<tr>
<td>Isobutane</td>
<td>31</td>
<td>5.94</td>
<td>14.39</td>
</tr>
<tr>
<td>N-butane</td>
<td>17</td>
<td>4.66</td>
<td>10.50</td>
</tr>
</tbody>
</table>
Storage Tanks, Equipment, & Safety Systems

- Heat Detector
- Internal Safety Valve
- Back Flow Check Valve
Storage Tanks, Equipment, & Safety Systems

FISHER CONTROLS INTERNAL SAFETY VALVE (PNEUMATICALLY ACTUATED)
Storage Tanks, Equipment, & Safety Systems
Storage Tanks, Equipment, & Safety Systems
Fire Protection
Neutral Flammability of Common Aerosol Propellants

- LEL and UEL (lower and upper explosive limits) are tabulated below:

<table>
<thead>
<tr>
<th>Propellant</th>
<th>LEL</th>
<th>UEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane</td>
<td>2.2</td>
<td>9.5</td>
</tr>
<tr>
<td>Isobutane</td>
<td>1.8</td>
<td>8.4</td>
</tr>
<tr>
<td>N-Butane</td>
<td>1.9</td>
<td>8.5</td>
</tr>
<tr>
<td>Dimethyl Ether</td>
<td>3.4</td>
<td>18.0</td>
</tr>
<tr>
<td>Dymel 152a</td>
<td>3.9</td>
<td>16.9</td>
</tr>
<tr>
<td>R 134a</td>
<td></td>
<td>non-flammable</td>
</tr>
</tbody>
</table>

- Auto ignition temperatures range from 662 °F for DME to 940 °F for Propane. (Note: The temperature of an idly burning cigarette is over 1000 °F).
Fire Protection
Fire Protection
Fire Protection

Automatic Detection Systems
General Safety Practices

• Unlike LPG used in fuel applications, flammable liquefied gas propellants are Colorless and Odorless gases. You cannot smell a gas leak.

• Consideration should be given to installing automatic detection systems such as combustible gas detectors, Infrared flame detectors, and rate-of-rise temperature detectors. These systems can be used to automatically close shut-off valves, activate plant alarm systems, notify emergency personnel and activate fire protection systems in the event of an emergency.
Automatic Detection Systems

COMBUSTIBLE GAS DETECTORS
Automatic Detection Systems

SEARCHLINE 500
Open Path Infrared Hydrocarbon Gas Detector

Sieger, the world leader in combustible gas detection, presents SEARCHLINE 500 - an intensely practical gas detection system incorporating all the experience of over 30 years in gas detection and of many hundreds of open path installations throughout the world.

SEARCHLINE 500 combines infrared technology with the latest in microprocessor technology to provide a system of hydrocarbon gas detection that is uncomplicated in operation and requires minimal maintenance.

The basis of SEARCHLINE 500 open path gas detection is simple - you are more likely to detect significant leaks of hydrocarbon gases with open monitoring than with any other system of comparable price available today.

Sieger SEARCHLINE 500's innovative technique projects an infrared beam over distances of between 35 and 650 feet, detecting potentially explosive or environmentally harmful leaks of hydrocarbons anywhere in the beam. This is true whether the escaping gas is of a localized high concentration or of a lower concentration over a wider area - either way you need to know about the leak, and either way SEARCHLINE 500 will provide an alarm.

Sieger SEARCHLINE 500 units are available approved and certified to North American CSA and UL standards. SEARCHLINE 500 offers a 4-20 mA signal output which is compatible with standard PLC or DCS systems. The output is also compatible with a variety of Sieger control equipment.

Quality assurance is assessed to ISO 9001, and is backed by a most committed worldwide sales and service organization, itself assessed where appropriate to ISO 9002.

THE GIFT OF SIGHT!
Automatic Detection Systems

Rate of Rise Heat Detector
Automatic Detection Systems

- HEAT DETECTOR
- INTERNAL SAFETY VALVE
- BACK FLOW CHECK VALVE
Automatic Detection Systems
Automatic Detection Systems

IR FLAME DETECTOR
Fire Protection
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Water Deluge Systems
Fire Protection
Water Cannons / Monitor Nozzles
Water Cannons / Monitor Nozzles
Water Cannons / Monitor Nozzles
Water Cannons / Monitor Nozzles
Water Cannons / Monitor Nozzles
Fire Protection
Insulation
Fire Protection - Insulation
Fire Protection - Insulation
Fire Protection - Insulation
An Introduction to Liquefied Gas Aerosol Propellants

Fire Protection Mounded Storage
Mounded Storage
Mounded Storage
Mounded Storage
Mounded Storage
Mounded Storage
Fire Protection
Underground Storage
Underground Storage

Figure 3.5(a) Typical Large ASME Container Underground Installation. Cathodic protection is not always needed.
Propellant Tank Farm Safety

The Fire Triangle

Fuel

Oxygen

Energy

The Fire Triangle
Propellant Tank Farm Safety

Codes and Safety Guides

- NFPA 58: LP Gas Code
- NFPA 30B: Manufacture and Storage of Aerosol Products
- CSMA Publication: “Hydrocarbon, Dimethyl Ether and other Propellants: Considerations for Effective Handling in the Aerosol Plant and Laboratory”
  (new edition published in 1999)
Aerosol Propellants:

Considerations for Effective Handling in the Aerosol Plant and Laboratory

Chemical Specialties Manufacturers Association
Safety Issues with Flammable Liquefied Gas Propellants

- Flammable
- Liquefied Gas
- Sudden Release of Pressure
- Low Boiling Points
- Expansion Ratio
- Heavier than Air
- Vapors are Colorless and Odorless
- BLEVE
Propellant Tank Farm Safety

General Safety Practices

• Proper Pressure Ratings for Storage Tanks and Equipment

• Storage Tanks must be fitted with safety relief valves set to discharge at container design pressure

• Storage Tanks must have liquid level, pressure and temperature gauges

• Container openings for Liquid and Vapor service must be fitted with excess flow or backflow check valves as appropriate
General Safety Practices

• Hydrostatic relief valves must be present between isolation valves where liquid could be trapped in the piping.

• There must be emergency shut-off valves and protective bulkheads at transport loading and unloading stations.

• At least one 20 lb. BC type portable fire extinguisher should be located at the storage area.

• Adequate Fire Protection must be provided for storage tanks.
General Safety Practices

- Electrical Equipment and connections must be explosion proof (NEC Class I, Division I or II, Groups C & D). Note: Group D for Hydrocarbon propellants and HFCs; Group C for Dimethyl Ether (DME).

- There must be adequate clearances between propellant storage containers, other groups of storage containers, buildings, and flammable liquid storage areas. See NFPA 58 for details.

- Security Fencing with at least two separate access gates should be present around storage tanks or around the entire facility.
Consideration should be given to installing automatic detection systems such as combustible gas detectors, Infrared flame detectors, and rate-of-rise temperature detectors. These systems can be used to automatically close shut-off valves, activate plant alarm systems, notify emergency personnel and activate fire protection systems in the event of an emergency.
Environmental, Health, & Safety Issues

- Title V - Clean Air Act Operating Permits
- OSHA PSM - Process Safety Management
- EPA RMP - Risk Management/Worst Case Scenario
- Yearly Emission Reporting
- Right-to-Know Reporting
- Employee Training
Diversified CPC International, Inc. offers custom regulatory compliance programs to meet OSHA PSM (*process safety management*) and EPA RMP (*risk management program*) regulatory requirements.

**An Introduction to Liquefied Gas Aerosol Propellants**

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  - Safety Audits
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  - EPA Risk Management Plan (RMP)
  - OSHA Hazard Communication Standard

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Questions
Thank you for sharing this time with us!