Dispelling the Myths of Heat Transfer Fluids

Kevin Connor – The Dow Chemical Company
Heat Transfer – Chill Water Loop

Secondary Coolant (Heat Transfer Fluid)

Primary Refrigerant

Expansion Device

Air Handler

Evaporator

Condenser

Pump

Compressor
The Need for “Antifreeze”

- Water is almost a perfect fluid…
  - Excellent heat transfer
  - Excellent health & safety
  - Low cost
- **BUT** water freezes at 0°C / 32°F
- Antifreeze protects system piping and components from damage caused by freezing
  - Volume expansion due to ice crystals generates pressure which ruptures pipes and can destroy equipment
Heat Transfer Fluid “Wish List”

- Effective freeze protection
  - Freezing point below -40°C / -40°F
- Efficient heat transfer over broad temperature range
  - -15°C to 125°C / 0°F to 250°F
- No harmful effects (health, safety, environment)
  - Non-toxic, non-flammable, environmentally benign
- Non-corrosive / non-destructive to materials
  - 20+ year fluid life
- Low cost
  - Low power consumption, low capital cost, and low maintenance
Choice of Heat Transfer Fluids

- Salt based (brines)
  - Lithium bromide
  - Calcium chloride
  - Magnesium chloride
  - Sodium chloride
  - Potassium acetate
  - Potassium formate
  - Potassium carbonate
  - Betaine

- Alcohols & Glycols
  - Methanol
  - Ethanol
  - Ethylene glycol
  - Propylene glycol
  - 1,3-propanediol
  - Glycerin

- Non-aqueous Fluids
  - Mineral oils
  - Synthetics
Impact on Freezing Point

Data from Melinder 2007
“Thermophysical Properties of Aqueous Solutions Used as Secondary Working Fluids “
Impact on Corrosion

15% Methanol

15% Propylene Glycol

Water
Corrosion

• All salts are very corrosive
  – Long term protection is impossible even with corrosion inhibitors

• Glycols or alcohols (without corrosion inhibitors) are corrosive to most metals
  – Oxidize to form acids $\rightarrow$ low pH $\rightarrow$ acidic pH is corrosive
  – Must use correct type of corrosion inhibitor technology

• Corrosion damage can occur in less than 2 years
  – Worse for high temperatures and high exposure to air or dissolved $O_2$
Corrosion Control

• Corrosion can be limited by control of key environmental variables
  – Design & Operation
    – Materials
    – Temperature & exposure to O₂
  – Fluid Chemistry
    – Corrosion inhibitors & pH
    – Fluid purity
• Maintain metal in passive rather than active state
  – Corrosion rate 1000 times lower
## Impact on System Efficiency

### Physical Properties @ 10°C/ 50°F

<table>
<thead>
<tr>
<th>Fluid Description</th>
<th>Freezing Point ( °C )</th>
<th>Thermal Conductivity (W / m.K)</th>
<th>Volumetric Heat Capacity (kJ / L.K)</th>
<th>Viscosity (cP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>water</td>
<td>0</td>
<td>0.582</td>
<td>4.18</td>
<td>1.3</td>
</tr>
<tr>
<td>Methanol *</td>
<td>- 7.5</td>
<td>0.525</td>
<td>3.86</td>
<td>1.3</td>
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<tr>
<td>12 wt%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethanol *</td>
<td>-7.5</td>
<td>0.500</td>
<td>3.83</td>
<td>2.7</td>
</tr>
<tr>
<td>15 wt%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylene Glycol *</td>
<td>-7.5</td>
<td>0.501</td>
<td>3.94</td>
<td>2.0</td>
</tr>
<tr>
<td>19 wt%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propylene Glycol *</td>
<td>-7.5</td>
<td>0.484</td>
<td>3.86</td>
<td>2.8</td>
</tr>
<tr>
<td>20wt%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycerol *</td>
<td>-7.5</td>
<td>0.481</td>
<td>3.97</td>
<td>3.1</td>
</tr>
<tr>
<td>26wt%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral Oil</td>
<td>-15 (pour pt.)</td>
<td>~0.16</td>
<td>~1.6</td>
<td>~28</td>
</tr>
<tr>
<td>(VG2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Data from Melinder 2007 “Thermophysical Properties of Aqueous Solutions Used as Secondary Working Fluids “
System Performance

• Adding antifreeze to water negatively impacts system performance
  – Must trade performance for freeze protection
• Reduced heat transfer efficiency
  – Antifreeze decreases thermal conductivity & specific heat
  – How much will system performance be reduced?
    – Regrettably there is no “one size fits all” answer
• Increased power consumption
  – Antifreeze increases viscosity → affects pump horsepower and fluid flow
Impact on Health & Safety

- Methanol and ethylene glycol are classified as moderately toxic
  - About 125 mLs is lethal dose for typical sized adult
- Industrial ethanol (not for consumption) is denatured
  - Can contain methanol, pyridine or other (toxic) denaturants
- Only propylene glycol is formally approved by FDA
  - Direct food additive – essentially non-toxic
  - Generally Regarded As Safe (GRAS)
- Alcohols are low boiling fluids with low flash points
  - Flammability and fire safety concerns
Fire Safety

RCRA hazardous waste (ignitable)

OSHA hazardous material (flammable)

Flash point temperature [deg F]

LFL “pure” ethanol = 4%
Flash pt = 13°C / 55°F
Advantages of Using Glycol

- Effective Freeze Protection
- Non-corrosive (if properly formulated)
- Relatively Efficient Heat Transfer
- No Adverse HS&E Effects
  - Health – Low toxicity (PG fluids)
  - Safety – Non-flammable
  - Environment – Readily Biodegradable
- Relatively Low Cost
Advantages of Choosing Dow

• Dow heat transfer fluids are properly formulated with corrosion inhibitors and pH buffers which
  — Passivate metal surfaces $\rightarrow$ prevent corrosion
  — Neutralize degradation compounds $\rightarrow$ prevent pH drop
  — Thermoxidatively stable $\rightarrow$ provide long term protection

• Avoid cooling tower inhibitor packages
  — Designed for water — not glycol

• Avoid automotive coolant inhibitors
  — Designed for relatively short fluid lifetimes
DOWTHERM™ SR-1 Fluid

- Ethylene glycol-based fluid (95%)
- Fluorescent pink
- Efficient heat transfer
  - -28° to 120° C
- Provides freeze / burst protection
  - -51° C / -60° C (depending on concentration)
- Dow is the oldest back-integrated supplier of glycol based heat transfer fluids:
  - DOWTHERM™ SR-1 originated in the late 1940’s
DOWFROST™ Fluid

- Propylene glycol-based fluid (96%)
- Water white
- Low toxicity – fully complies with FDA & NSF regulations
  - Made with DOW PuraGuard™ Propylene Glycol USP/EP
- Efficient heat transfer
  - -18° to 120° C
- Provides freeze / burst protection
  - -51° C / -60° C (depending on concentration)
Advantages of DOW PuraGuard™

• DOWFROST™ is the only inhibited glycol made with DOW PuraGuard™ Propylene Glycol USP/EP, a pharmaceutical grade of monopropylene glycol with a specified purity of 99.8% or greater
• Competitive products are made with lower quality PG
  - Fluid lifetime & safety are compromised
• Industrial grade PG or bio-derived PG can have:
  - High aldehydes & dioxolanes → odor forming compounds
  - High ethylene glycol & diethylene glycol → toxic compounds
DOWFROST™ HD Fluid

- Propylene glycol-based fluid (94%)
- Fluorescent yellow
- Fortified inhibitor package versus regular DOWFROST™
  - Does not have same FDA / NSF approval
- Efficient heat transfer
  - -18° to 135° C
- Provides freeze / burst protection
  - -51° C / -60° C (depending on concentration)
- Available as concentrate or premixed solution
  - Customer blends available from Dow distributors
DOWFROST™ GEO 20

- Propylene glycol-based fluid (20 vol%)
  - Fluorescent yellow
- Designed for Geothermal Heat Pumps
  - Lower concentration means lower pumping cost & higher heat transfer efficiency
  - Excellent corrosion protection
  - Bio-static concentration (will not support bio-degradation / bio-fouling unless diluted)
- Operating range:
  - 23° to 212° F with 18.5° F freeze point
- Drum & smaller packages available from Dow distributors
Which Product Do I Choose?

- Ethylene glycol (EG) is moderately toxic
  - ~½ cup is lethal to an average size adult
- Propylene glycol (PG) is essentially non-toxic
  - Approved by FDA as direct food additive
- Use DOWFROST™ for low toxicity needs
  - Food processing (DOWFROST™ only)
  - Schools or hospitals (DOWFROST™HD)
- Use DOWTHERM™ SR-1 for other applications
  - EG provides better performance (heat transfer & pumping power) → lower cost option
# Avoid Poorly Formulated Products

<table>
<thead>
<tr>
<th>Metal</th>
<th>Test Data</th>
<th>ASTM Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>1.6</td>
<td>10</td>
</tr>
<tr>
<td>Solder</td>
<td>9.2</td>
<td>30</td>
</tr>
<tr>
<td>Brass</td>
<td>3.7</td>
<td>10</td>
</tr>
<tr>
<td>Steel</td>
<td>199</td>
<td>10</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>297</td>
<td>10</td>
</tr>
<tr>
<td>Aluminum</td>
<td>88</td>
<td>30</td>
</tr>
</tbody>
</table>
Tips for Proper Operation

- Use purified water (distilled, de-ionized) for dilution
- Install and maintain “correct” glycol concentration
  - Over-dilution → causes corrosion & bio-fouling
  - Too concentrated → causes poor heat transfer
- Operate within recommended temperature ranges
  - Over-heating → compromises fluid life
- Test your fluid regularly
  - Good fluid maintenance helps prolong the life of your system
Water Quality

• Salts cause corrosion
• Hardness causes scales & sludge
• Requirements for dilution water
  - Chlorides <25 ppm
  - Sulfates <25 ppm
  - Total hardness (as \( \text{CaCO}_3 \)) <100 ppm
Over-Dilution

- Over-dilution causes corrosion and bio-fouling
  - Glycol degradation
  - Unpleasant odors
- Minimum concentration
  - 20% - 25%
- Maximum concentration
  - 60% - 65%

Bio-fouling - customer sample with 11% propylene glycol
Over-Heating

- Fluid degradation and corrosion increase as temperature increase
  - Fluid life compromised
- Temperature limits
  - Max bulk: 250 F to 350 F
  - Max film: 300 F to 400 F

Increased time / temperature, exposure to $O_2$ / air
Dow Analytical Service

- Free service if system contains more than 250 gallons of DOWTHERM™ SR-1 / DOWFROST™
- Sample analysis kits are available from Dow
  - “2 PAK’s” and “6 PAK’s”
- Send samples to Dow laboratory and receive comprehensive analysis & report within 2 weeks
- Detailed analysis:
  - Glycol concentration & freeze point
  - Corrosion inhibitors, pH, various contaminants
  - System maintenance recommendations
Sample Kits
**Example Report**

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**The DOW CHEMICAL COMPANY**

**Heat Transfer Fluids**

**Sample Analysis Report**

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This is a copy of the report for:

Distributor: Not Available

Sample Label Description: Lastko

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<table>
<thead>
<tr>
<th>Appearance:</th>
<th>New Data</th>
<th>Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Fluorescent yellow</td>
<td>---</td>
</tr>
<tr>
<td>Clarity</td>
<td>clear</td>
<td>---</td>
</tr>
<tr>
<td>Sediment</td>
<td>none</td>
<td>---</td>
</tr>
</tbody>
</table>

| Concentration & Freeze Point: | 33 | 23-60 |
| Phosphoric Glycol | --- | --- |
| Mole % PG | --- | --- |
| 10 °C (50 °F) | --- | --- |

| Corrosion Inhibitors: | New Data | Acceptable |
| Iron oxidizer (phosphate) | acceptable | --- |
| Copper inhibitor (azole) | --- | --- |
| Fluid pH | 8.8 | --- |
| Reserve Alkalinity | 17.2 | --- |

| Corrosives & Scale Promoters: | New Data | Acceptable |
| Chloride | ppm Cl⁻ | 30 | <100 |
| Sulfate | ppm SO₄ | 0 | <750 |
| Total Hardness | ppm CaCO₃ | 15 | <100 |
| Copper corrosion rate | miles per year (mpy) | 0.08 | <0.8 |

| Contaminants & Other Glycols: | New Data | Acceptable |
| Nitrate | ppm NO₃ | 0 | <100 |
| MEG | ppm MEG | 97 | <100 |
| Ethylene Glycol | ppm% E.G. | 0 | <1 |
| Butylene Glycol | ppm% B.G. | 0 | <1 |
| Triethylene Glycol | ppm% TEG | 0 | <1 |

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**FLUID MAINTENANCE RECOMMENDATIONS:**

This fluid is in good condition and is suitable for continued use. No adjustments or inhibitors are needed at this time.

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* denotes a registered trademark of the Dow Chemical Corporation.

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The Dow Chemical Company • Thermal Fluids Testing Lab • 1621 N. Swede Road • Midland MI 48646

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**Solutions for life.**

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29 Heat Transfer Fluids
The Bottom Line

• Glycol based fluids provide excellent overall protection
• Understand the impact that glycol has on water
  • Trade off between performance versus freeze protection
• Select and use a properly formulated glycol based fluid
  • Specifically designed for HVAC applications
• Correctly installed and maintained DOWTHERM™ and DOWFROST™ inhibited glycol heat transfer fluids can help protect your system for 20+ years