CO₂ Technology Insertion into Production of U.S. Army Tactical Vehicles

23-24 Feb 2005

VDA Winter Meeting
Saalfelden, Austria

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CO₂ Technology Insertion into Production of U.S. Army Tactical Vehicles

• Army Benefits of CO₂ Technology
• HMMWV Cooling Profiles
• M1114 Up-Armored HMMWV System
• CO₂ System Design
• 2004 Test and Demonstration events and results
• Determination by the Program Executive Officer
• 2nd Generation CO₂ System Design
• Transition to Production
Program Executive Officer CS & CSS

Top 24 Research and Development Priorities for Tactical Vehicles

November 2004

#1 is Armor

#3 is “Cool the Force”

with “EPA-Compliant Refrigerants”
Army Benefits of CO₂

**Environmentally Friendly**
- Non Ozone Depleting
- Zero Net Global Warming
- Non Flammable
- Non Toxic
- EU Compliance

**Better Performance**
- Reduced Weight
- Reduced Volume
- Quicker Pulldown
- Deeper Pulldown
- Instant Heat

**Reduced Logistics Burden**
- No Refrigerant Recovery/Recycling
- Certified Technician Training 40 CFR 82 F
- Inexpensive; Widely Available
- Vent to Atmosphere

**Reduced Weight**
- Reduced Volume
- Quicker Pulldown
- Deeper Pulldown
- Instant Heat

**Vent to Atmosphere**
Tactical Vehicle Cooling
2 Approaches

M1114 Up-Armored HMMWV
MACS-type system

Command Shelter HMMWV
ECU-type system

Ambient = 125°F / 52°C
Inside = 90°F / 32°C, 50% RH
Army Tactical Vehicles -- “Highway Driving”
Army Tactical Vehicles -- “City Driving / Idling”

M1114 HMMWV

Source: Army Times 2004
Current M1114 Production R-134a System
After-market Installation

- HMMWV comes to armoring facility
- Compressor is already installed

- Fan / Coil assemblies are added
- Hoses lay on the floor (covered)

- The condenser is in the rear fender area, cooled with electric fans.

Requirement: “Achieve 20°F (11°C) Pulldown”
(from ambient to mixed interior cabin temperature)
Army CO$_2$ Program Guidance for M1114 HMMWV

- Test baseline R-134a system
- Design CO$_2$ to fit within existing M1114 configuration
- Maximize capacity and performance
- Minimize space and weight claims
- Test CO$_2$ system
- Demonstrate to Industry and Senior Army Leadership
1st Generation CO₂ HMMWV

System Schematic

- Front Gas Cooler
- Rear Evaporator
- Rear SLHX
- Exp. Device
- Front Evaporator
- Exp. Device
- UNDERHOOD
- SLHX/Accumulator
- Compressor
- FRONT REGISTER
- GAS COOLING UNIT
- REAR REGISTER

Note: expansion devices are both orifice tubes.
2004 Test and Demonstration Events

• June 2004 Modine Wind Tunnel Testing
• June/July 2004 SAE Alternate Refrigerants Systems Symposium Tests
• Sep 2004 Death Valley Road Load Cooling Tests
• Nov 2004 Demonstrations for the Army Program Executive Officer and Deputy Under Secretary of Defense
• Jan 2005 Yuma Wheeled Vehicle Rodeo
Wind Tunnel Testing

June 2004

120°F/49°C 20% RH
Pulldown Comparison

M1114 HMMWV
20 mph

Temperature °F

Elapsed Time, h:mm

R134a Interior
R134a Rear
CO₂ Interior
R134a Front
CO₂ Front
CO₂ Rear
Phoenix SAE Alternate Refrigerants Symposium

June / July 2004

CO₂ Cooling on M1114 HMMWV

- Avg Interior Temp
- Avg Front Discharge Temp
- Avg Rear Discharge Temp

Temperature, °F

Elapsed Time

- 87°F
- 52°F
- 45°F
SAE Phoenix -- Comparing the 2 HMMWVs, R-134a and CO₂

July 2004

City Idle

Highway
20-40 mph

Elapsed Time [min.]

Temperature [°F]

R134a Interior

CO₂ Interior

R134a F/R
Evaporators

CO₂ F/R
Evaporators
Vehicle convoy ready to depart
Nevada DOT maintenance facility

R-134a vehicle followed by CO₂ vehicle
followed by chase vehicles

Stovepipe Wells
Second Vehicle 1-hr Soak; Static A/C Test

Death Valley, CA

Roadside engine cooling stop

Vehicle convoy ready to depart
Nevada DOT maintenance facility
TEST RESULTS - DEATH VALLEY

IDLE COOLDOWN

8 Sep 04 HMMWV

Temperature, °F

Elapsed Time

- Ambient
- Headliner
- Discharge Air
- CO2
- R134a
Death Valley National Park Field Test

September 2004

Temperature, °F

Ambient

Headliner

Discharge Air

CO2

R134a

Elaborated Version:

Death Valley National Park Field Test

September 2004

Temperature, °F

Ambient

Headliner

Discharge Air

CO2

R134a

Elaborated Version:

Death Valley National Park Field Test

September 2004

Temperature, °F

Ambient

Headliner

Discharge Air

CO2

R134a

Elaborated Version:
Significant CO₂ HMMWV Visibility for Senior Army / DoD Leadership Nov 2004 - Jan 2005

- Program Executive Officer CS&CSS (★★)
- Deputy Under Secretary of Defense (Adv Sys Concepts)
- Deputy Chief of Staff for Logistics, G-4 (★★★★)
- Army Chief of Transportation (★★)
- Commander TACOM (★★)
- Technical Director, TARDEC
Determination by the Program Executive Officer
Nov 2004
Next Step for CO₂ Technology for Army Tactical Vehicles

• Will not conduct Fleet Testing in the 2005 cycle
• Make 2\textsuperscript{nd} Generation Improvements and Retest
• Improve Reliability and Durability (N-V-H)
• Make it Affordable - See it Commercialized (in EU?)
• Spin it off to prototypes of other Vehicles and ECUs
• (Future Family of Tactical Trucks)
2\textsuperscript{nd} Generation CO\textsubscript{2} HMMWV Design

Directed Air Nozzles

Dual Rear Evaporators

Higher Displacement Compressor
Next Planned CO₂ Project for U.S. Army Tactical Vehicles

*Typical "Jumbotransport"*

- Heavy Expanded Mobility Tactical Truck (HEMTT)
- Palletized Loading System (PLS)
- Heavy Equipment Transporter (HET)
### Unit Cost

<table>
<thead>
<tr>
<th></th>
<th>Compressor</th>
<th>Heat Exchangers</th>
<th>Total System</th>
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<tbody>
<tr>
<td><strong>Prototype</strong></td>
<td>$$$$$</td>
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<tr>
<td><strong>Production</strong></td>
<td>$$$</td>
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... What we pay today for 1 or 2 ...

... The cost must incrementally drop to take the decision for a fleet test ...

The cost must incrementally drop again ... ... to take the production decision.
<table>
<thead>
<tr>
<th>Production HMMWV Volume ( # / yr )</th>
<th>Projected Unit Cost To Be Determined</th>
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<tbody>
<tr>
<td>1</td>
<td>$$$$$</td>
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<tr>
<td>10</td>
<td>$$$$</td>
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*We can pay higher unit costs...for what is important to us...*(Lower weight, superior performance, logistics support savings...*)
*But on the order of X% to XX%..., not XXX%.*...
And in conclusion,

- $CO_2$ cooling technology has been shown to work and work well.

- Still need to demonstrate long-term reliability, durability, and good system control, through some level of vehicle fleet testing (Production Qualification Testing).

- Get the unit cost to within an acceptable range.

- Follow the industry lead.

- Place $CO_2$ into Army tactical vehicle production where and how it makes most sense.

Thank you for your attention!