

# DuPont DP-1 Next Generation Refrigerant MAC Global Industry Solution

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## ***DuPont's DP-1 is a leading candidate to become the future MAC global industry solution***

- Environmentally sound (zero-ODP, very low GWP, low LCCP)
- Meets F-Gas requirements for MAC
- Very encouraging acute toxicity results, non-flammable
- Passed initial thermal stability, materials compatibility and lubricant miscibility
- Multiple OEM and Tier I testing in progress with consistent results
- Targeted for all climates and all vehicles
- Potential for cost effective global transition across entire MAC value chain due to compatibility with conventional R134a MAC system technology



# *Agenda*

- **DP-1 Properties**
  - Environmental/Safety
  - Toxicity
  - Stability/Compatibility
  - Industry Testing
- **Path Forward**



# ***DuPont Leading Refrigerant Candidate: DP-1***

- **Two component non-flammable blend**
  - Unique, innovative approach
  - Major component: non-flammable, fluorine based new compound
  - Minor component: commercially available refrigerant
- **Very encouraging toxicity data**
- **Zero-ODP, Very low GWP**
- **Operating conditions similar to R134a**
- **Compatible with conventional mobile air conditioning technology**



# ***DP-1: Superior Environmental/Safety Properties***

- **Zero-ODP**
- **Very Low GWP:**
  - Estimated at 40 (well below EU 150 limit)
  - Provides margin for uncertainty involving future changes in GWP determination (SAR, TAR, SROC)
  - Experimental 3<sup>rd</sup> party measurements in progress
- **Low LCCP versus enhanced CO<sub>2</sub> and enhanced 134a**
- **Non-flammable by ASHRAE Std 34 and ASTM 681 under all required scenarios**



## DP-1: Excellent Toxicity Results to Date

- Commercial compound has low toxicity
- New compound has low acute toxicity, longer term tests in progress

	Test	Type	New Compound	R134a	R12
Acute	Ames	Acute Genetic - Mutagenic	Passed	Passed	Passed
	Chrome AB	Acute Genetic - Chromosomal	Passed	Passed	Passed
	LC-50 (Rat)	Acute 4 hour inhalation to 50% lethality	>750,000 ppm	>359,300 ppm	>800,000 ppm
	Cardiac Sensitization	No Effect Level	25,000 ppm	50,000 ppm	40,000 ppm
	Cardiac Sensitization	Threshold Level	50,000 ppm	75,000 ppm	50,000 ppm
Sub-Acute/ Chronic	In Vivo Micronucleus	Genetic	Passed	Passed	Passed
	Full Developmental	Developmental	In Progress	Passed	Passed
	1-Gen	Reproductive	In Progress	Passed	Passed
	28-Day, 90- Day	Repeated Dose Sub-Chronic Inhalation	In Progress	90 Day No effect level 49,500 ppm	Reported 90 Day No effect level 810 ppm, 10,000 ppm



# ***Toxicity and Environmental***

- **New Compound Toxicity**

- Acute tests complete - low acute toxicity
- Sub-acute and chronic tests in progress - target results mid'07 except for 2-Gen and 2-Year (planned start 2H'07)

- **Environmental Tests in Progress**

- GWP measurement
- Octanol-water partition coefficient
- Acute Fish (trout)
- Acute Daphnia
- Acute Algae

- **Toxicity and environmental test program designed to meet country registration requirements including REACH**



## **DP-1: Excellent Thermal Stability at 175°C for Two Weeks**

	<b>DP-1 Only</b>	<b>DP-1+ Dry PAG</b>	<b>DP-1 + PAG + 1000 ppm Water</b>
<b>Rating</b>	<b>0</b>	<b>0</b>	<b>0-1</b>
<b>Aluminum</b>	No change	No change	No change
<b>Copper</b>	No change	No change	No change
<b>Steel</b>	No change	No change	Very faint tan-gray film
	<b>DP-1 Only</b>	<b>DP-1 + Dry POE</b>	<b>DP-1+ POE + 1000 ppm Water</b>
<b>Rating</b>	<b>0</b>	<b>0</b>	<b>0-1</b>
<b>Aluminum</b>	No change	No change	No change
<b>Copper</b>	No change	No change	No change
<b>Steel</b>	No change	Very faintly dulled, still clean and lustrous	Very faintly dulled but still clean and lustrous

- No stabilizers were used

- Uncapped PAG and POE

- Tested dry and at 1000 ppm water

- No decomposition after 2200 hours in system test

Rating: 0 = no changes  
1 = light changes

\* **ASHRAE 97-99 at standard industry test temperature**



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## ***DP-1: Excellent Thermal Stability at 200°C for Two Weeks - 30,000 ppm Water***

Single End-Capped PAG

Double End-Capped PAG

DP-1

R134a

DP-1

R134a



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## DP-1: Excellent Plastics Compatibility

- Compatible with PAG at 100°C for two weeks

Refrigerant	Plastics	Rating*	24 h Post Weight Chg. %	Physical Change
DP-1	Polyester	1	3.6	0
	Nylon	0	-1.1	0
	Epoxy	0	0.7	0
	Polyethylene terephthalate	1	2.8	0 - 1
	Polyimide	0	0.6	0
Refrigerant	Plastics	Rating*	24 h Post Weight Chg. %	Physical Change
R134a	Polyester	1	4.5	0
	Nylon	0	-1.2	0
	Epoxy	0	0.0	0
	Polyethylene terephthalate	1	4.2	0 - 1
	Polyimide	0	0.4	0
<b>Rating</b>	0 = best weight gain < 1 and physical change = 0			
	1 = borderline weight gain 1-10 and/or physical change = 2			
	2 = incompatible weight gain > 10 and/or physical change = 2			



## DP-1: Excellent Elastomers Compatibility

- Compatible with PAG at 100°C for two weeks

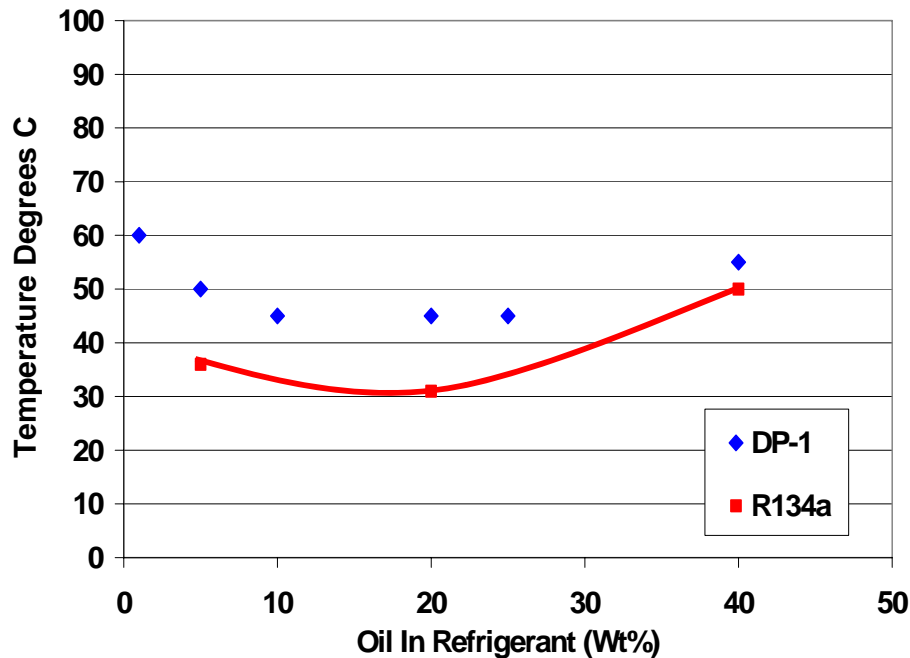
Refrigerant	Elastomers	Rating*	24 h Post Linear Swell %	24 h Post Weight Gain %	24 h Post Delta Hardness
DP-1	Neoprene WRT	0	-4.4	-2.6	3
	HNBR	0	5.8	6.9	-5
	NBR	0	-5.7	-1.4	3
	EPDM	0	-3.5	-1.8	1.5
	Silicone	0	5.4	3.8	-10
	Butyl rubber	0	-2.3	-0.1	-1.5
Refrigerant	Elastomers	Rating*	24 h Post Linear Swell %	24 h Post Weight Gain %	24 h Post Delta Hardness
R134a	Neoprene WRT	0	-3.8	-2.4	2
	HNBR	0 -- 1	8.6	9.8	-11.5
	NBR	0	-1.4	1.3	-1.5
	EPDM	0	-3.3	-1.3	0
	Silicone	0 -- 1	1.7	2.3	-10.5
	Butyl rubber	0	-3.1	-1.1	-2

- \* 0 = < 10% weight gain and < 10% Linear swell and < 10% hardness change  
 1 = > 10% weight gain or > 10% Linear swell or >10% hardness change  
 2 = > 10% weight gain and > 10% Linear swell and > 10% hardness change

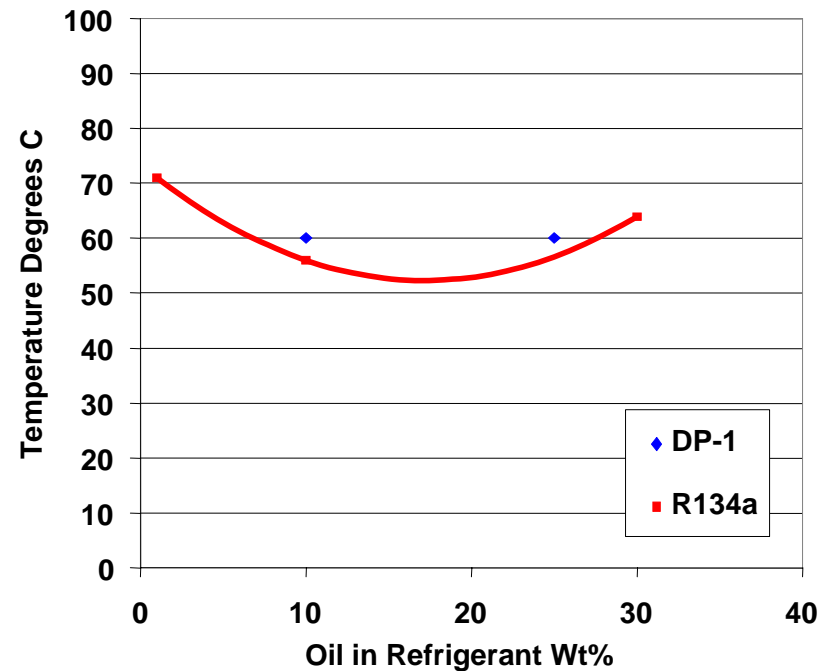


# DP-1: Excellent Miscibility with PAG and POE Lubricants

Miscibility of 130 cst Uncapped PAG With DP-1 and R134a



Miscibility of 46 cst Uncapped PAG With DP-1 and R134a

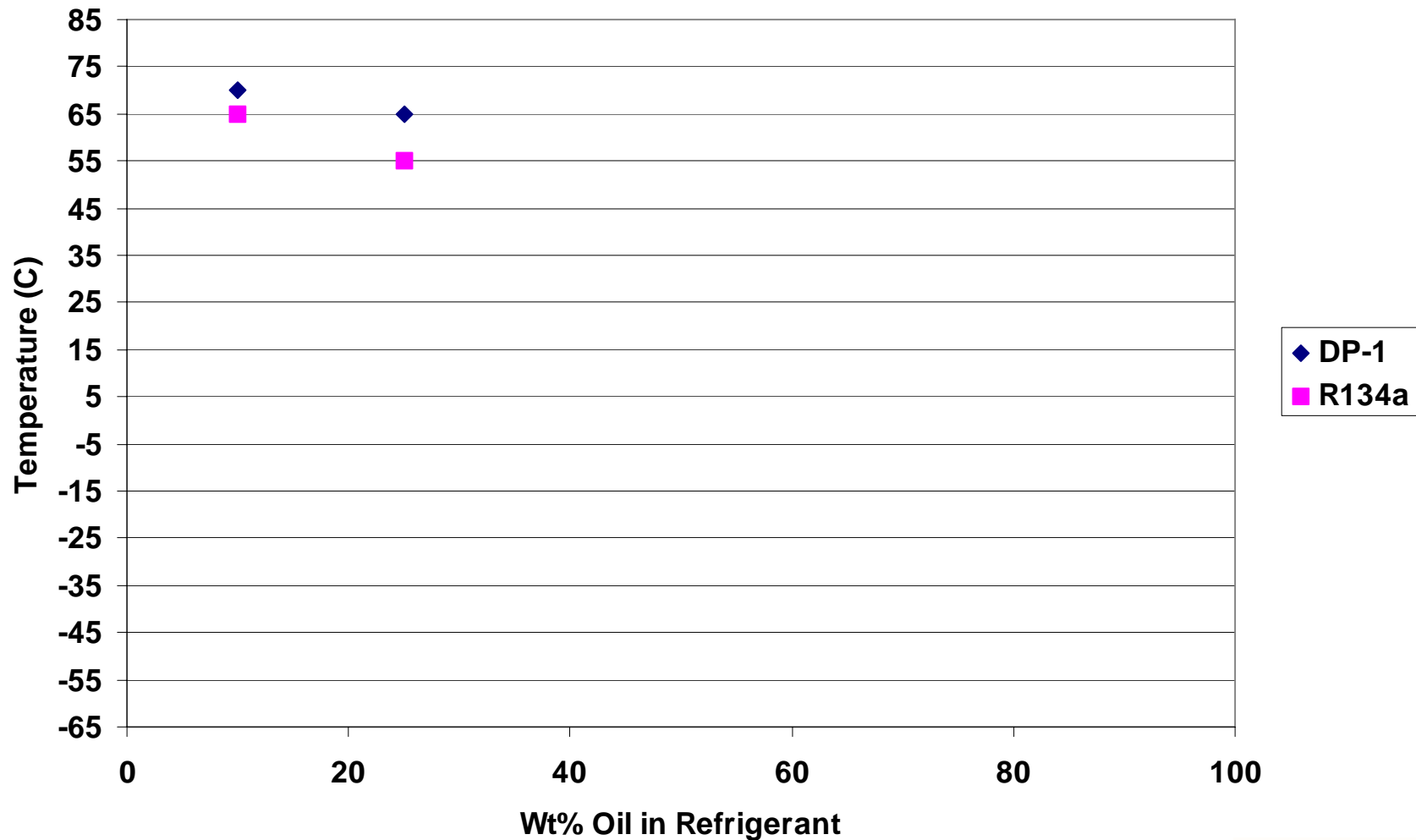


POE 68 cst Lubricant Test: Completely miscible from - 40°C to 65 +°C

\*Ref: R134a-PAG miscibility lit. data, The Dow Chemical Co.

# ***DP-1: Excellent Miscibility with Single End-Capped PAG Lubricant (tested -65C to 80C)***

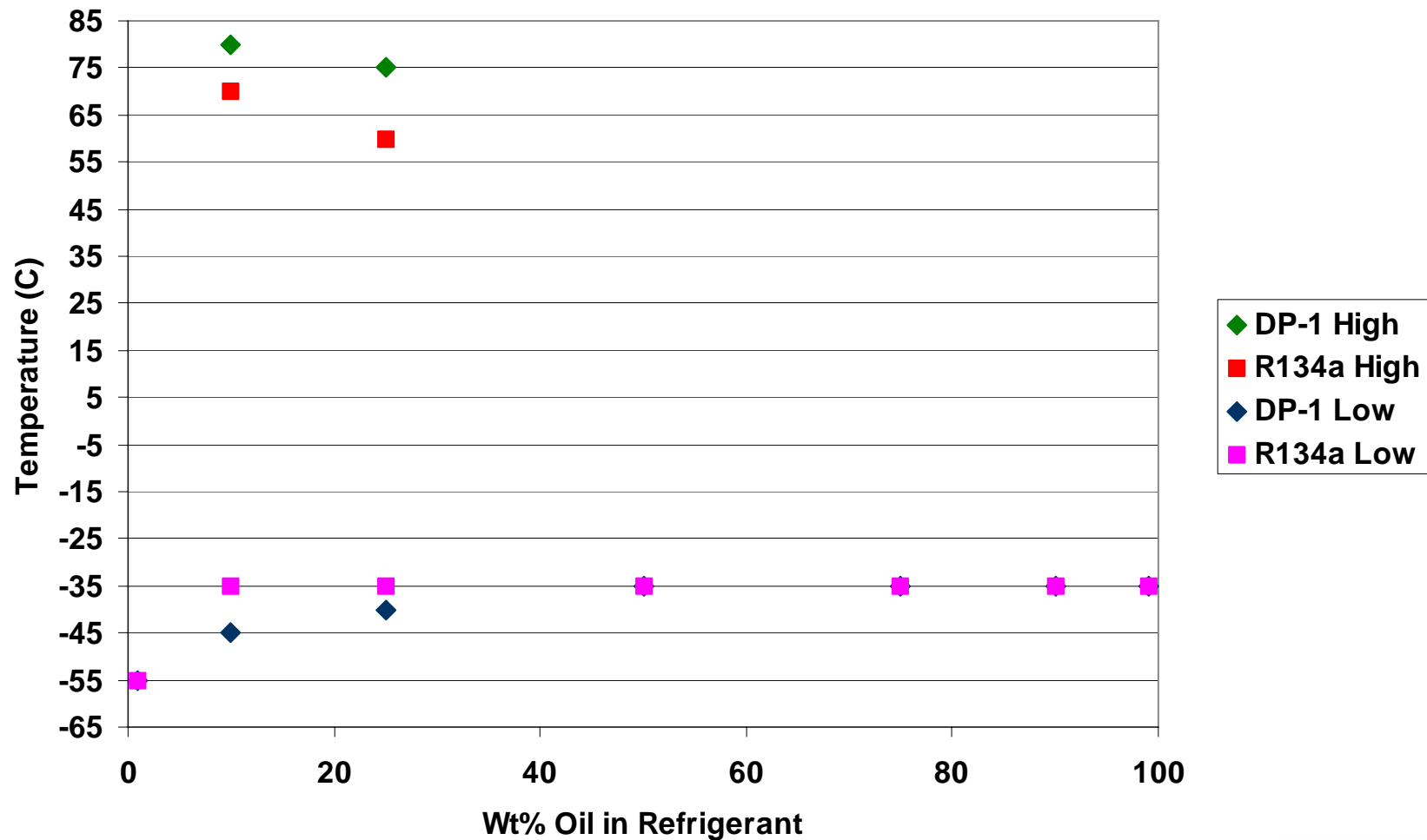
R134a and DP-1 Miscibility with Single End-capped PAG



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# *DP-1: Excellent Miscibility with Double End-Capped PAG Lubricant (tested -65C to 80C)*

R134a and DP-1 Miscibility with Double-end Capped PAG



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## **DP-1: Thermodynamic Cycle Performance Comparable to R134a**

- Cycle performance modeled at a/c conditions:
  - Condenser for Subcritical= 54°C
  - Evaporator = 5°C
  - Liquid line or Gas Cooler Temperature = 50°C
  - Suction Temperature = 15°C
  - Isentropic Efficiency = 100%

Candidate	Evap Press (kPa)	Cond Press (kPa)	Compr Disch T (C)	T Glide (C)	Capacity (kJ/m3)	COP	Cap Rel to 134a	COP Rel to 134a
R134a	350	1470	68	n/a	2250	4.38	100%	100%
DP-1	320	1380	64	4	2050	4.33	91%	99%
CO2	3970	13000	124	n/a	12100	2.09	537%	48%

Temperature glide is similar to R407C which has been used successfully in stationary air conditioning systems for 10+ yrs. DP-1 also performed well in an R134a production vehicle with no system changes and has potential for further optimization.



# Industry Test - Bench Scale #1

## - Optimization - EEV adjustment

### Operating Conditions

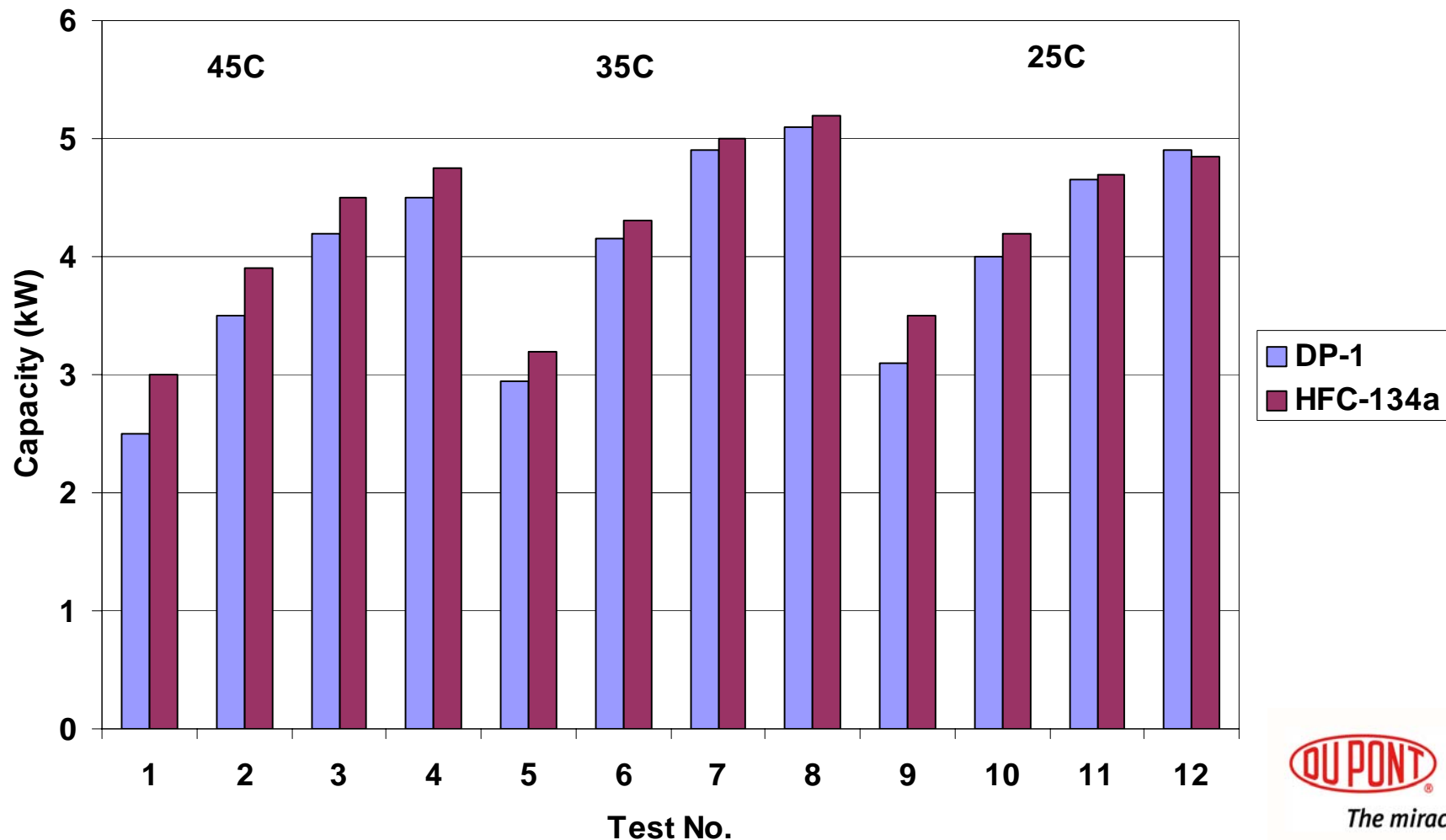
Test No	Compressor rpm	Condenser		Evaporator		
		T(C)	Speed (m/s)	T (C)	Humidity (%)	Volume (m3/h)
1	900	45	1.3	35	40	325
2	1500	45	2.7	35	40	325
3	2500	45	4.3	35	40	325
4	4000	45	4.3	35	40	325
5	900	35	1.3	35	40	325
6	1500	35	2.7	35	40	360
7	2500	35	4.3	35	40	360
8	4000	35	4.3	35	40	360
9	900	25	1.3	25	80	325
10	1500	25	2.7	25	80	325
11	2500	25	4.3	25	80	325
12	4000	25	4.3	25	80	325



## Industry Test - Bench Scale #1

- Optimization - EEV adjustment
- Modest capacity deficit (5-10%) versus R134a

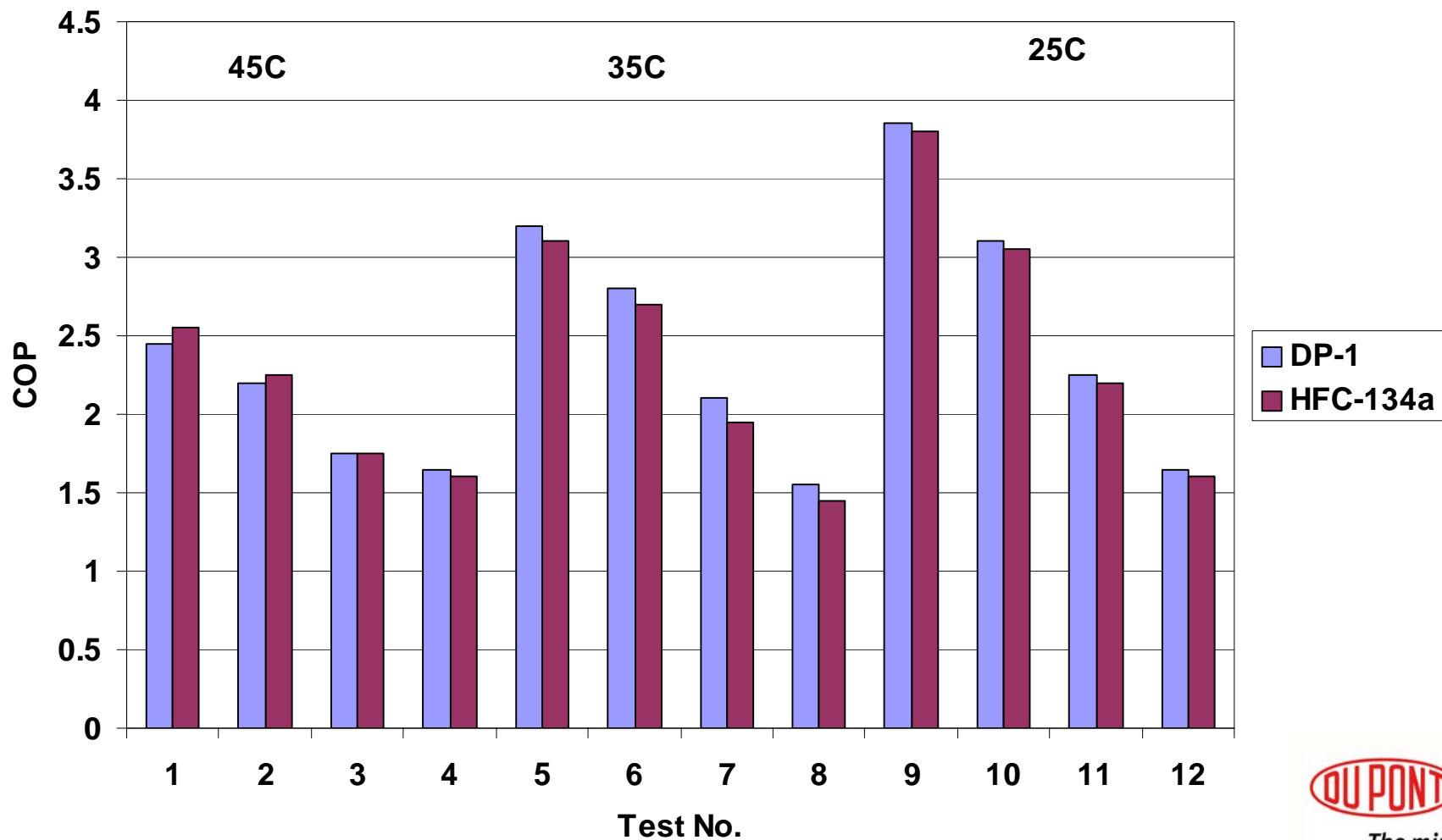
Cooling Capacity



## Industry Test - Bench Scale #1

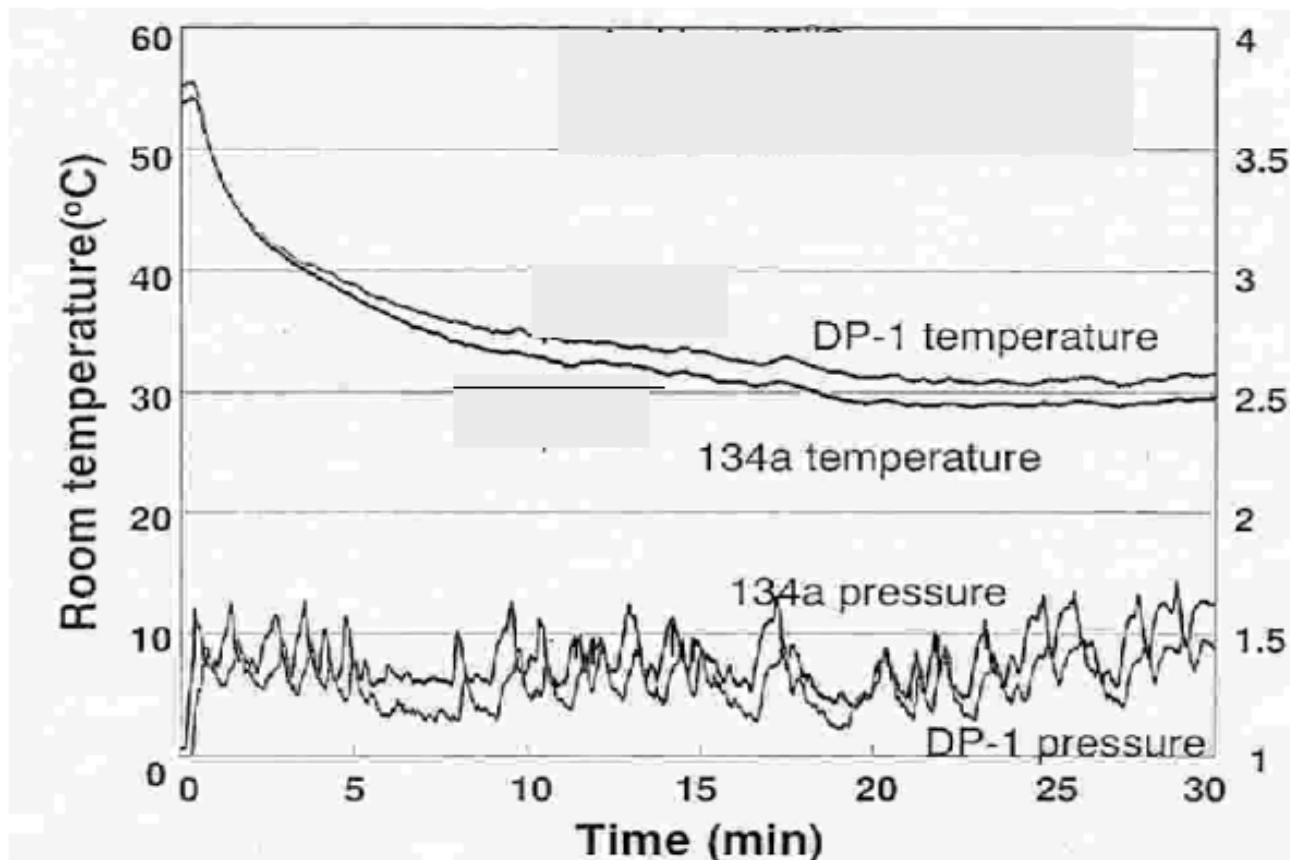
- Optimization - EEV adjustment
- COP Equivalent to R134a

COP



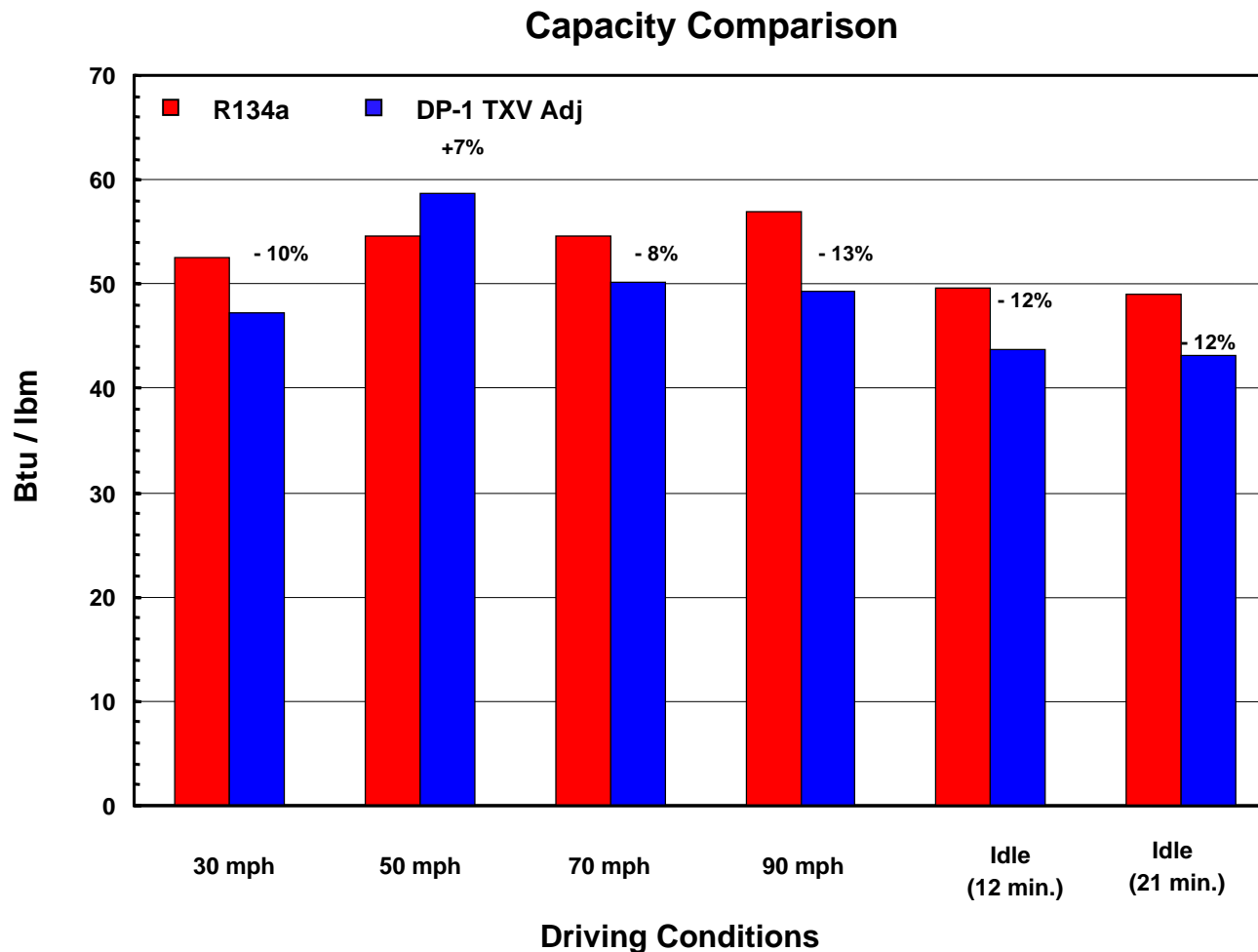
## Industry Test - Compact Vehicle #1

- Optimization - TXV Adjustment
- DP-1 pulldown temperature modestly higher (1.5°C) than R134a
- DP-1 cooling capacity slightly (~6%) lower than R134a



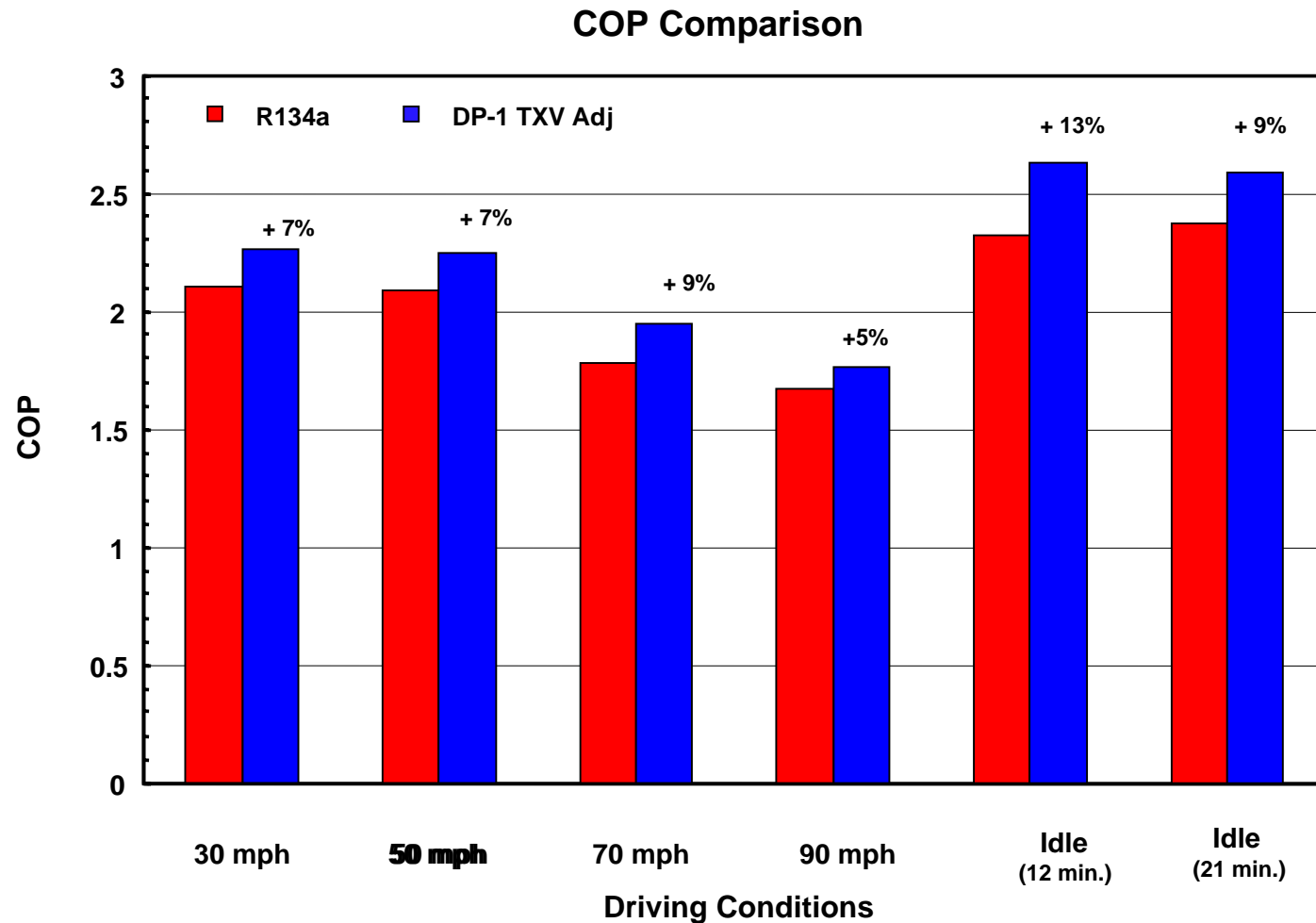
## Industry Test - Compact Vehicle #2

- Optimization - TXV Adjustment
- Modest Capacity Deficit (-8%) versus R-134a



## Industry Test - Compact Vehicle #2

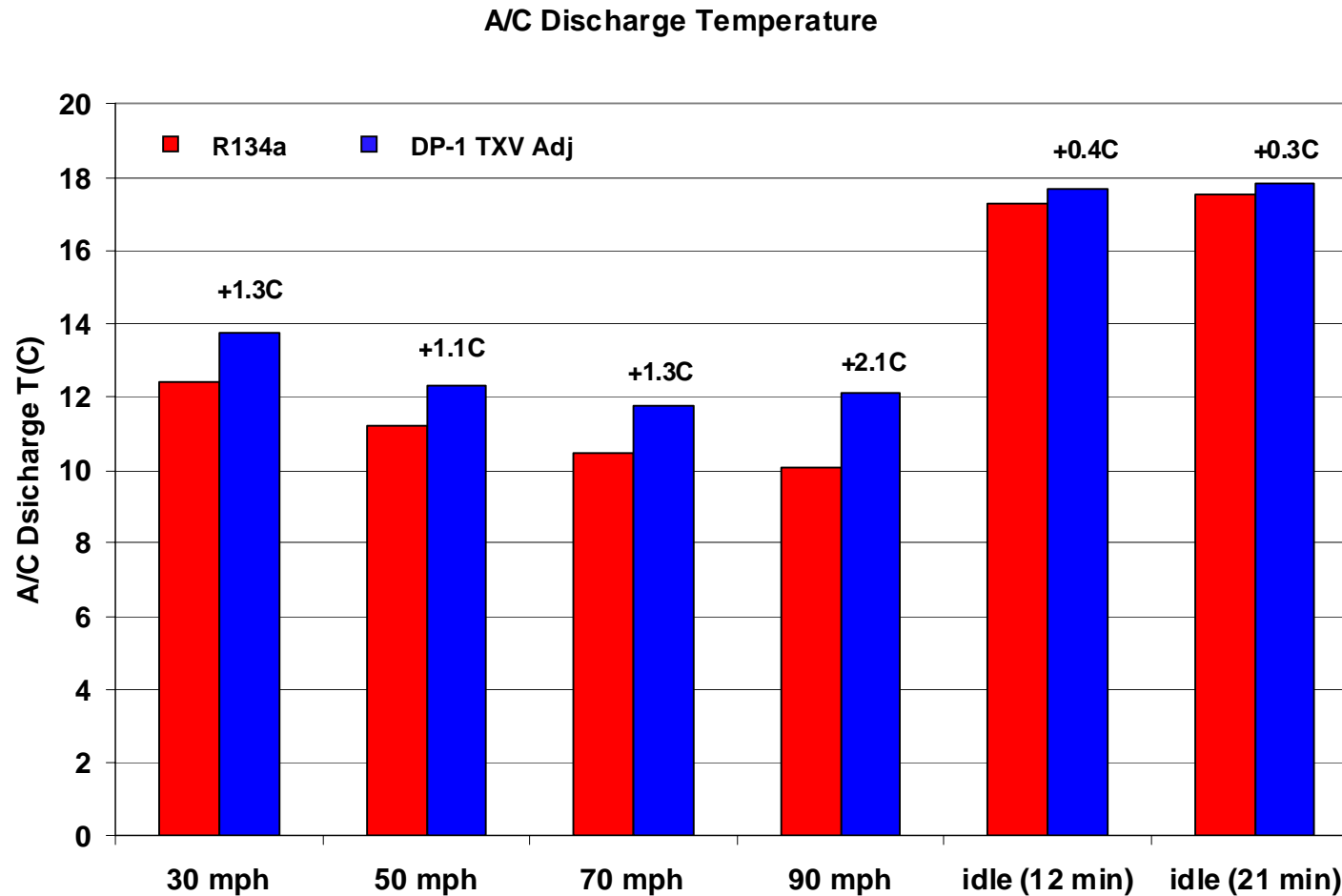
- Optimization - TXV Adjustment
- Modest COP Average Increase +8%



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## Industry Test - Compact Vehicle #2

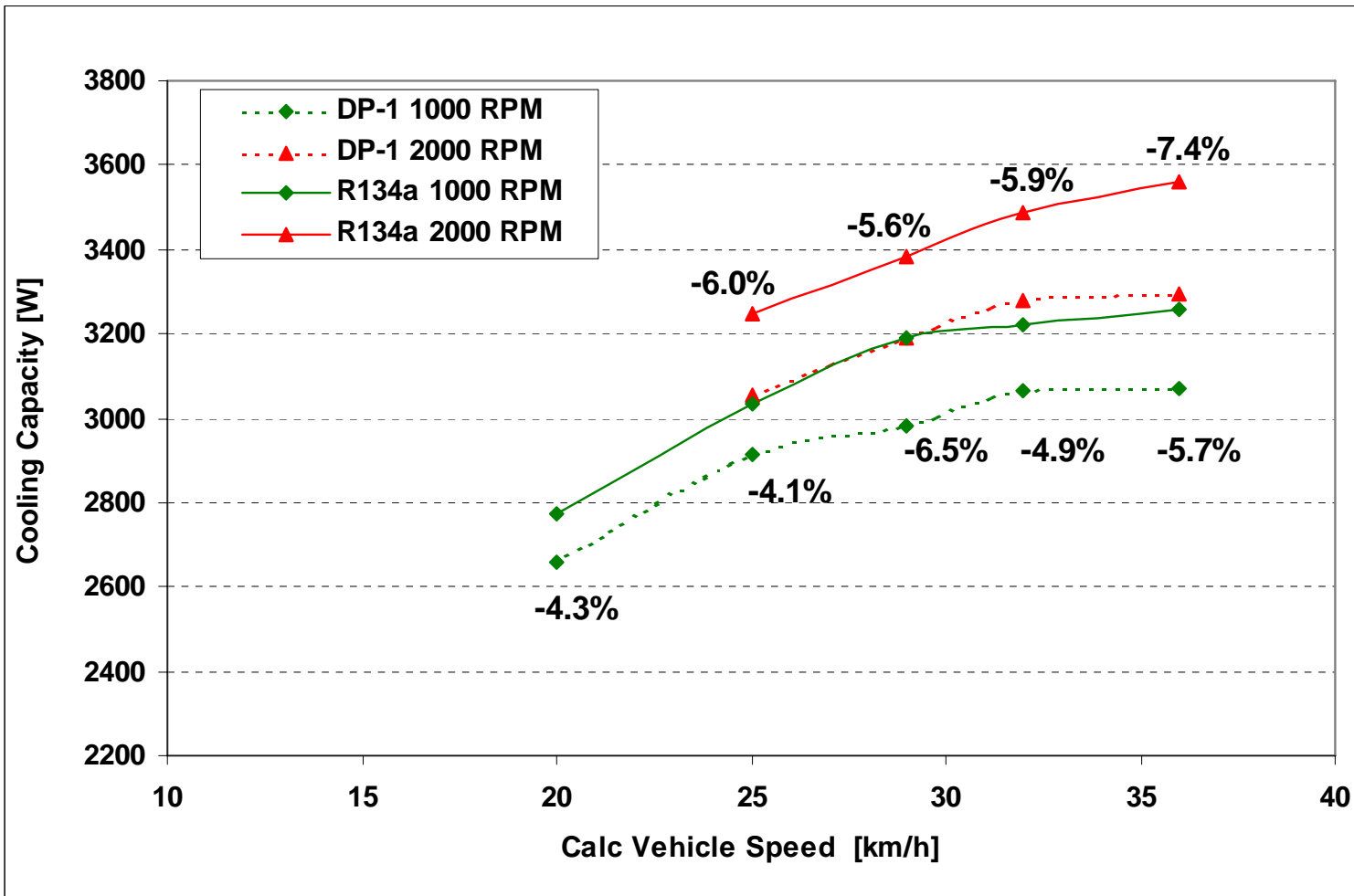
- Optimization - TXV Adjustment
- Modest Air Discharge Temperature Increase (1.1°C)



# Third Party System Test

-Optimization - TXV Adjustment

-Slight Capacity Deficit for DP-1 versus R134a (-5.6%)

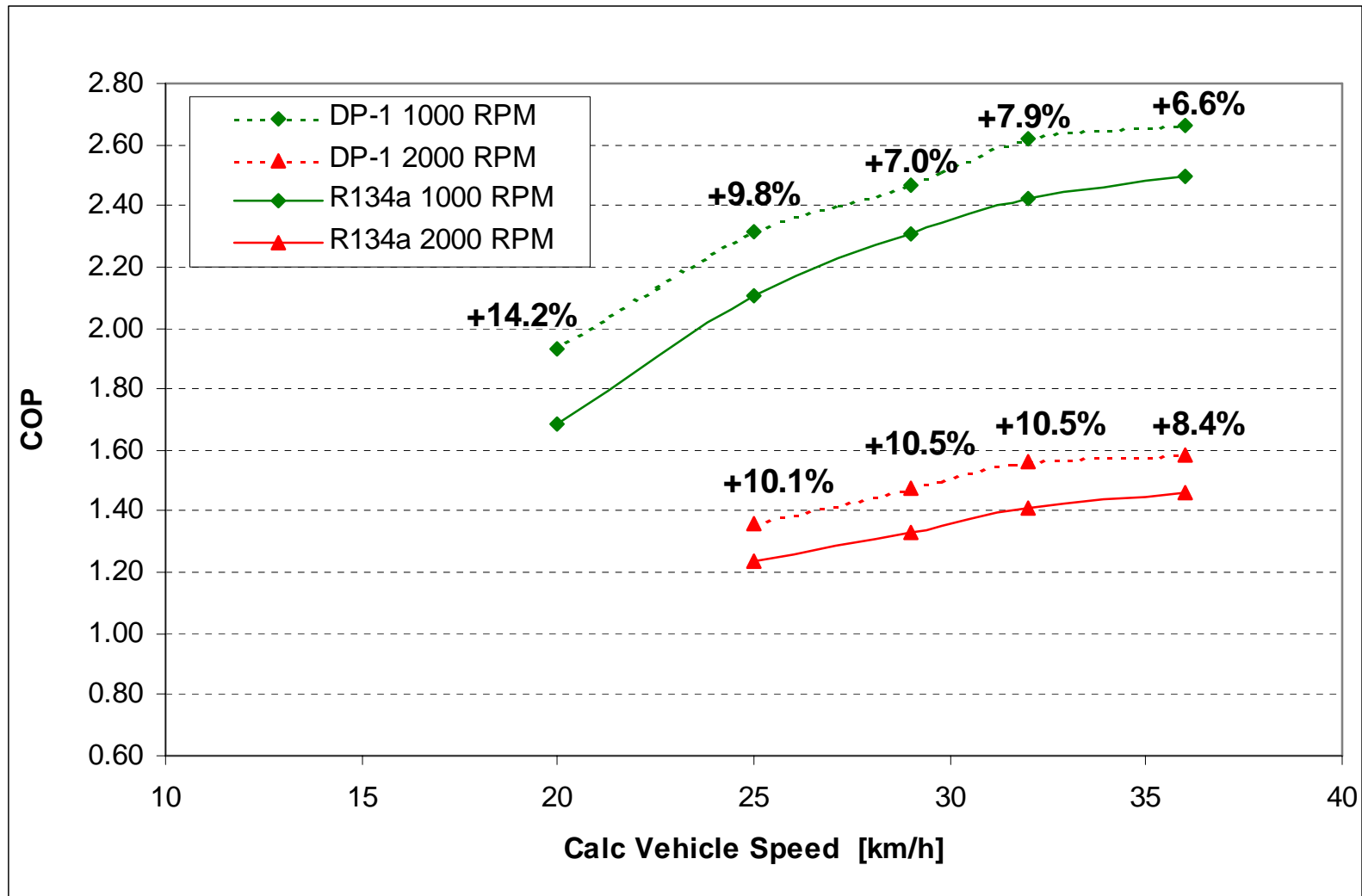


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# Third Party System Test

-Optimization - TXV Adjustment

-Good COP Increase for DP-1 versus R134a (+ 9.4%)



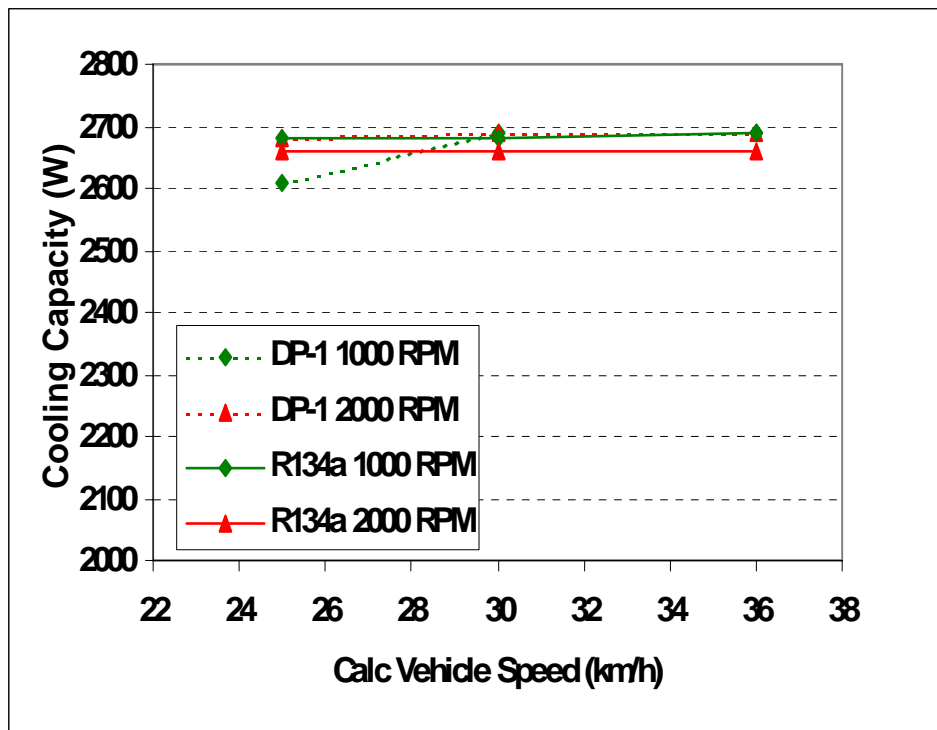
## ***Growing industry confidence in DP-1***

- **OEM and Tier 1 evaluations to date show promising results**
- **~10 OEMs and ~5 Tier 1 testing in progress**
- **Bench scale tests and vehicle test with TXV adjustment show promising results**
  - Energy efficiency (COP) equivalent or better than R134a
  - Modest capacity deficit of approximately 5-8%
- **Third party tests demonstrated additional improvements with further soft optimization (evaporating pressure, subcool, compressor control) and appropriate component selection**
  - Achieved equivalent capacity and better COP

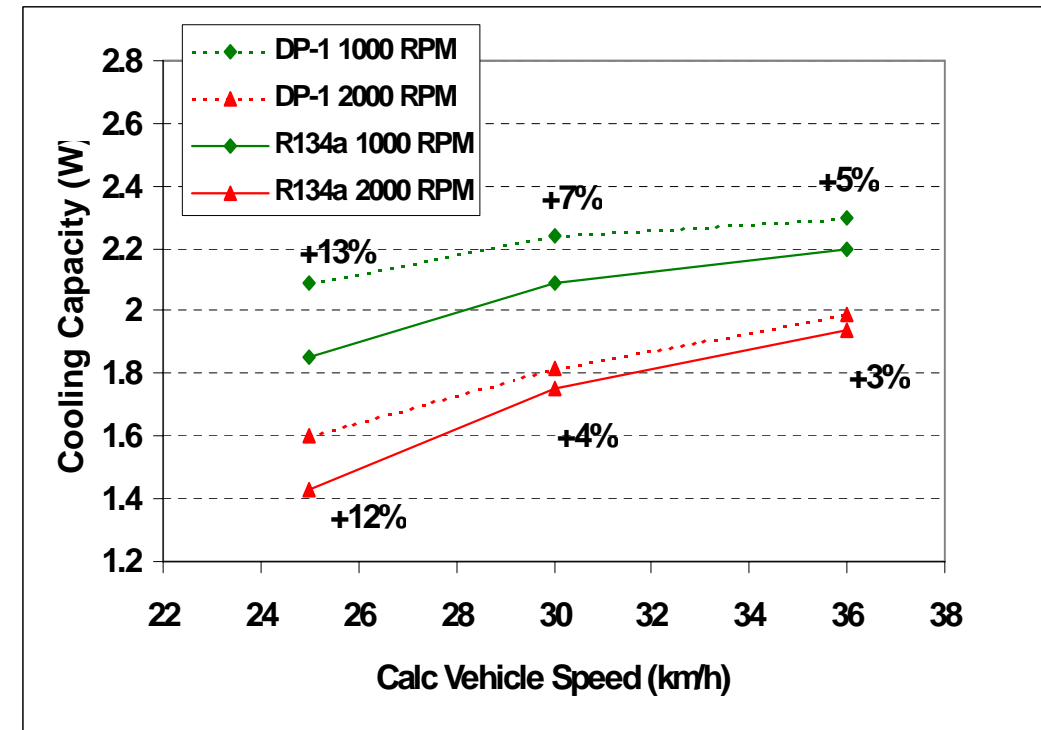


# Third Party Test - Additional improvements with further soft optimization and appropriate component selection

DP-1 Capacity equivalent to R134a



DP-1 average COP 7% better than R134a



# *DuPont is aggressively pursuing the next generation MAC global industry solution*

## Path Forward

### Internal

- Keep priority on toxicity testing
- Complete environmental testing
- Continue component testing and optimization
- Focus on process technology development to support a future commercialization plan that meets F-Gas requirements.
- Develop commercialization plans to meet MAC Directive R134a phase-out schedule, contingent upon global convergence to DP-1

### External

- Broaden evaluations to additional OEMs and Tier 1 suppliers
- Support component level testing per OEM guidance
- Continue to support third party system/component testing and optimization
- Provide periodic updates at [www.refrigerants.dupont.com](http://www.refrigerants.dupont.com)



# *Thank you!*

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