Auto AC-1

Replacing R-134a in automotive A/C

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Auto AC-1 composition and short history

At a glance:

- Nonazeotropic refrigerant
  - new and existing fluids
- Designed as a ‘drop-in’
  - Similar thermodynamic characteristics to R-134a
- No additives in refrigerant
- Expected to be compatible with existing engineering materials
- Designed to be non-flammable

History

- Ongoing refrigerant and process development as part of day to day business
- Development activity stepped up in response to renewed industry interest 2005/2006
  - Some apparent disadvantages of R-744 identified at OEM level
- Partnership approach adopted through SAE and industry in 2006
- Now a strategic focus for INEOS

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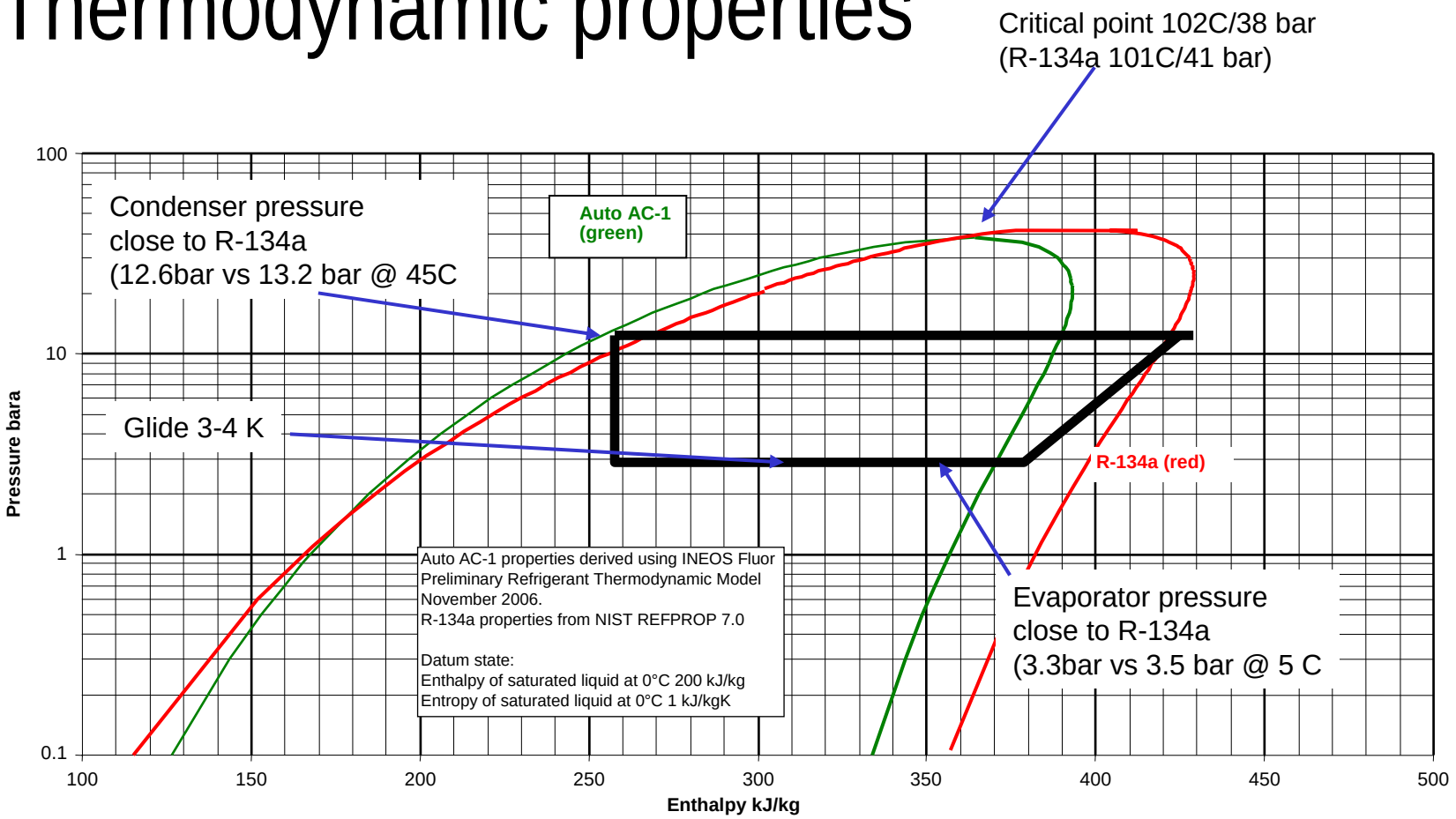
Thermodynamic properties



Outline Mollier Chart for INEOS Fluor Auto AC-1 and R-134a

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Theoretical performance comparison

	Auto AC-1	R-134a
COP	3.28 (101%)	3.25 (100%)
Capacity kJ/m^3	2080 (97%)	2143 (100%)
Discharge temperature °C	87.7	82.6
Mass flow kg/hr	293	258

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Environmental performance

	Auto AC-1
ODP value	0
GWP	<150
Atmospheric lifetime	<20 days for new species
Decomposition process	OH- reaction mechanism
Decomposition products	Currently being measured but expected to be similar to other HFCs
Process for recovery & recycle	Objective to recycle locally where possible Handling practices: existing equipment expected to be usable. Liquid transfer of fluid from vessel to vessel

COP close to R-134a for low LCCP compared to alternatives

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Toxicity & safety

- Toxicity is being characterised via a traditional toxicology programme with some complementary novel approaches
  - Promising results to date (next slide)
- Designed to pass ASHRAE flammability assessment per Standard 34 for zeotropic refrigerants using 100°C test conditions
- Programme takes into account REACH requirements

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Toxicity - Auto AC-1

- Ames negative
- Does not appear to be significantly metabolised via the most likely metabolic route
  - Novel in vitro comparison to reference compounds of known toxicity
  - Provides a good initial screen complementary to more conventional acute/chronic toxicity testing
- Very low acute toxicity
- 28 day inhalation test
  - Using protocols designed to maximise potential to detect any toxicity to critical target organs
  - Target results available for June 2007

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Material compatibility of Auto AC-1

- Material has similar solvency properties to R-134a and other common HFCs
  - Hildebrand parameter (cohesive energy) very close to that of R-134a
  - suggests no major differences in behaviour to elastomers and polymers
- Programme of compatibility testing through INEOS internal work, work with industry partners and SAE CRP150 projects
- Lubricant stability being assessed by ASHRAE autoclave tests at 175°C/2 weeks and other conditions as SAE and development partners require
  - both PAG and POE lubricants being screened for current and future application options
- Expect to have identified lubricant(s) and screened materials by June 2007

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Lubricant testing

- Currently working on PAG lubricants as prime focus
  - goal of identifying suitable lubricant from existing formulations
  - Some testing already carried out on POE and PAG with promising results
  - Testing of several options (both POE and PAG) continues at INEOS labs
  - SAE CRP150 testing starts at external labs next month
- Durability tests on MAC units (PAG/POE) and hermetic systems (with POE) starting soon through rest of H1 2007

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Thermal Stability

illustrative POE results

Condition	Lubricant	BEFORE TEST			AFTER TEST		METALS % WEIGHT CHANGE			
		Moisture (ppm)	T.A.N (mgKOH/g)	Colour (Hazens)	T.A.N (mgKOH/g)	Colour (Hazens)	Copper	Aluminium	Steel	Cu wire
175ºC	RL32H	35.70	0.01	10	0.03	20	-0.01	0.17	-0.01	0.02
175ºC	RL32H	35.70	0.01	10	0.02	20	0.00	0.08	0.00	0.05
204ºC	RL32H	23.50	0.01	10	0.28	60	-0.01	0.23	-0.03	-0.40
204ºC	RL32H	23.50	0.01	10	0.75	60	-0.03	1.09	-0.03	-0.54
R-134a 204ºC	RL32H	23.50	0.01	10	0.34	50	-0.01	0.26	-0.02	0.10
204ºC	None						-0.01	-0.02	-0.01	-0.28
204ºC	None						0.00	0.06	0.00	-0.03
204ºC	None						-0.01	-0.07	0.00	-0.02
175ºC	RL32H wet	2086	0.01	10	0.87	40	0.00	0.90	-0.01	-0.04
175ºC	RL32H wet	2086	0.01	10	0.35	40	0.01	0.26	0.01	-0.01

Initial testing work used POE as it's a more aggressive combination (hydrolysis etc)

-results broadly comparable to R-134a

- data on PAG being worked up for initial release to industry partners

-Material testing at 175C and 204C

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A/C performance

- Tests of hermetic appliances at range of evaporator conditions with ~25°C ambient show “drop-in” performance close to R-134a
  - Capacity 95-105% of R134a depending on cycle
  - COP 95-105% of R134a
  - At 0 °C to 5 °C evaporator condition, COP typically same, capacity same or slightly higher
- MAC bench test data received from 3rd party taken at 35°C ambient show that over a range of compressor speeds:
  - COP equivalent to R-134a and capacity 90-95% of R-134a with only charge size and TXV modification carried out

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A/C performance in cars

- Dynamic (tunnel) tests ongoing through work with partners
  - First test completed week 4, second test completed week 6
  - Results being reviewed now
- Road trials planned as next part of these trials
- Equipment optimisation studies planned through SAE CRP150 (March start) and with other partners
- Further updates available through the year

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Timeline: Compared to R-134a Development

- R-134a had 6 yrs work 1974-80
  - Restarted 1986 with goal of commercial production by 1990
  - Beneficial production from first manufacturing plant Oct 1990
  - PAFT toxicity assessment complete end 1992.
  - Overall programme effectively 12 years (only 4 years for commercial production project)
- Clearly we have to move more quickly for this project
  - More challenging timescale
  - Parallel development of toxicity, application and process engineering
  - Rapid assessment process e.g. with SAE CRP150
  - Open approach to sharing development information with OEMs
- Decision timeline aligned with industry

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Conclusions

- Auto AC1 designed to enable rapid adaptation by industry
  - Expected “drop-in” performance close to R-134a with optimisation to yield improvements
  - glide, capacity, COP and direct GWP balanced to help rapid adaptation of existing system designs
  - Safety and toxicity is being thoroughly tested
    - studies to date encouraging
  - Operating pressures similar/lower to R-134a in system and in storage
  - Environmental performance is promising
    - Through low GWP with close match of R-134a COP and other key properties
- Beneficial partnership with industry and SAE helping assessment process

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