EAAC

17-18 September 2012

FRANKFURT, GERMANY

Advanced Dual Level Vehicle Heat Rejection System for passenger car

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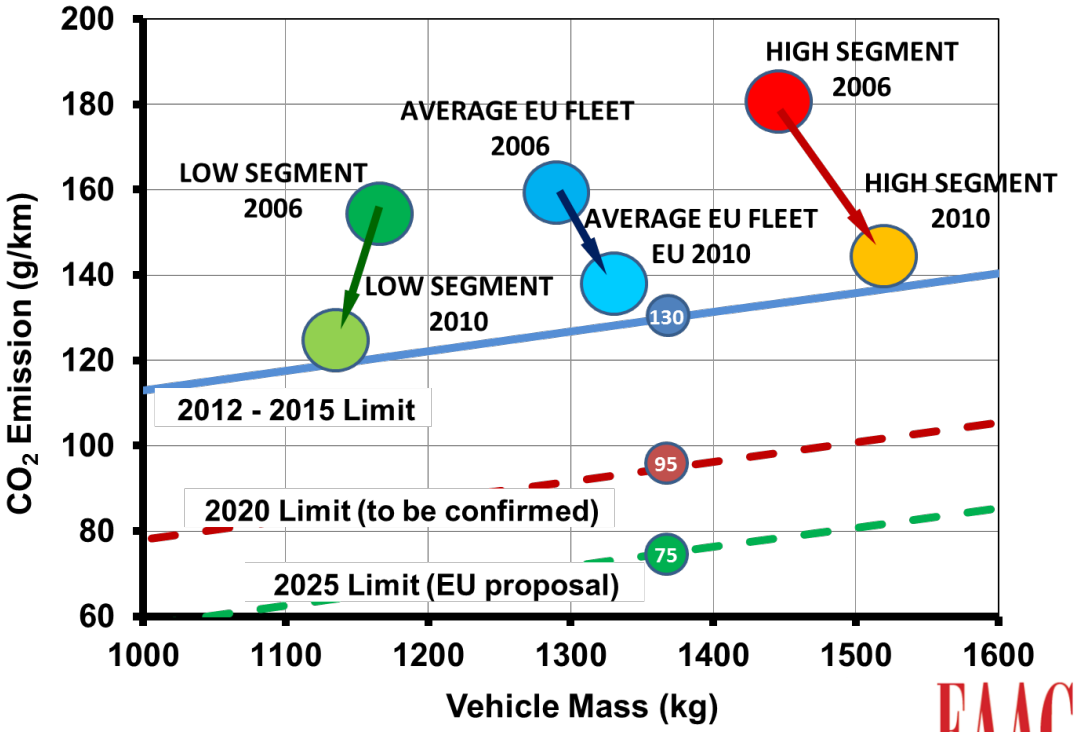
Scenario and Intrduction

The EC Regulation EC 443/2009 asks to reduce the CO2 emissions of road transports in a relevant way within the 2020.

The challenge is even more harder for small cars (A and B segments) where effective and sustainable solutions are required to keep the vehicles price under reasonable limits

The **heat management** is becoming even more relevant to assure the **powertrain performance improvement and evolution** minimizing the impact on the vehicle lay out, **cooling drag** and cost



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Concept

Business as Usual: each subsystem has its own cooling system where the fluid-to-be-cooled is brought in the front of the vehicle and then back in the engine compartment

Dual Level cooling: the charge air cooler, the condenser and the other subsystems are liquid cooled and sharing the same low temperature cooling loop – based on a simplified version of the system Valeo presented in 2003[1]

The concept enables to

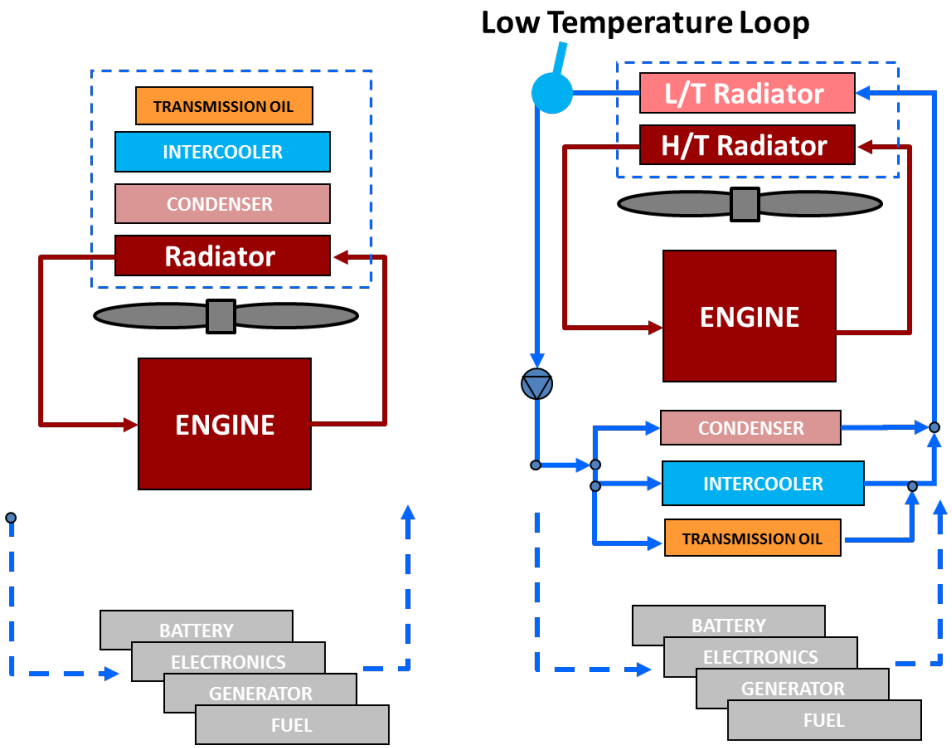
- standardize the vehicle thermal module and optimize the aerodynamics;
- activate the fan only on the basis of the average needs;
- reduce the "fluid-to-be-cooled" amount (e.g. air conditioning refrigerant);
- integrate the fluid coolers in the subsystems (e.g. charge air cooler)
- share the cooling loop cost among the systems;
- simplify the electronics, e-motor and batteries cooling in case of hybrid powertrain
- limit the damage in case of small accidents;
- reduce the refrigerant charge and leak rate

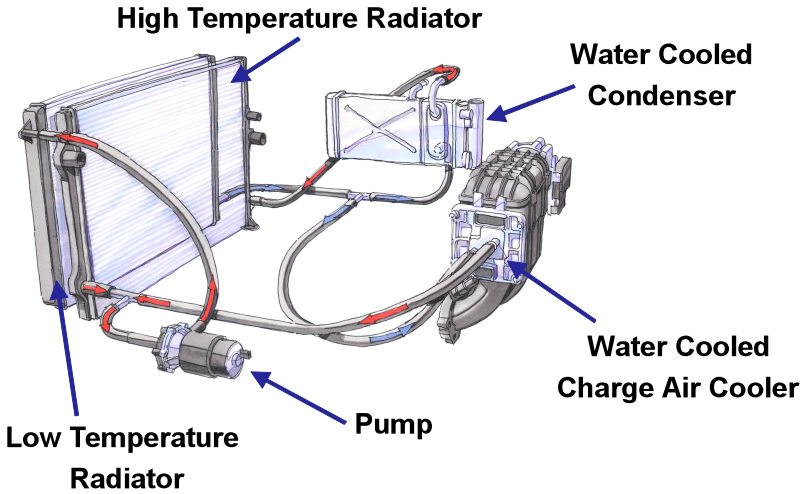
[1]UltimateCooling™ new cooling system concept using the same coolant to cool all vehicle fluids, N.S. Ap et al., Vehicle Thermal Management Systems, 2003, Brighton (UK), C599/0101/2003

Dual Level Cooling

The system has been prototyped on Fiat Punto Evo 1.3 l Diesel and 1.4 l gasoline

The presentation is focused on the system developed for the 1.3 l diesel being the results of the 1.4 l gasoline very similar





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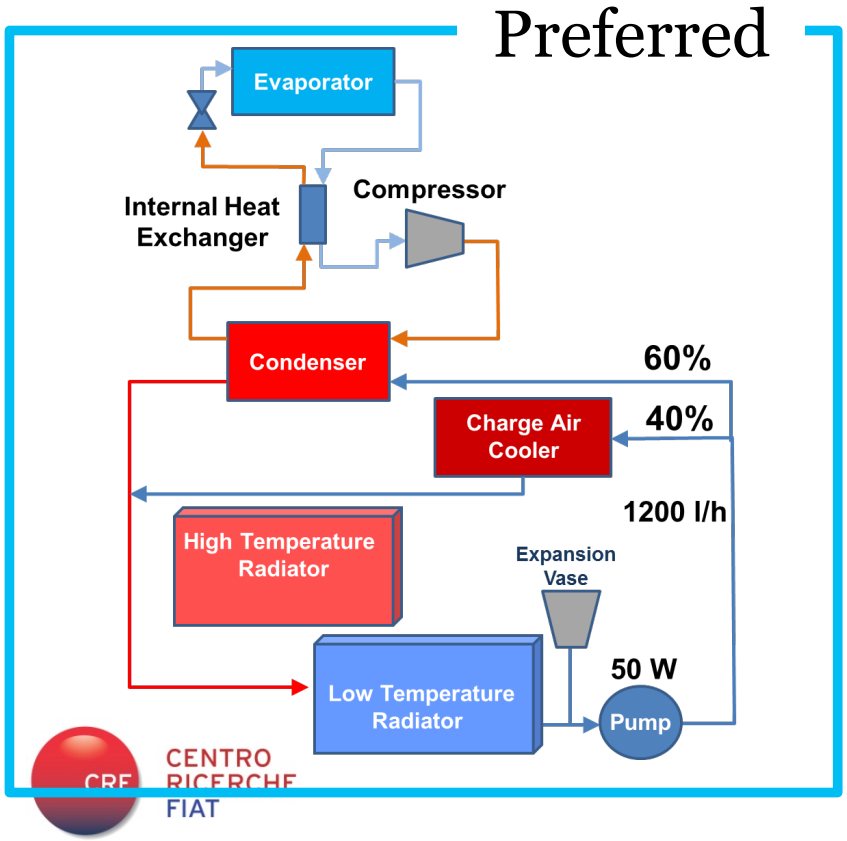
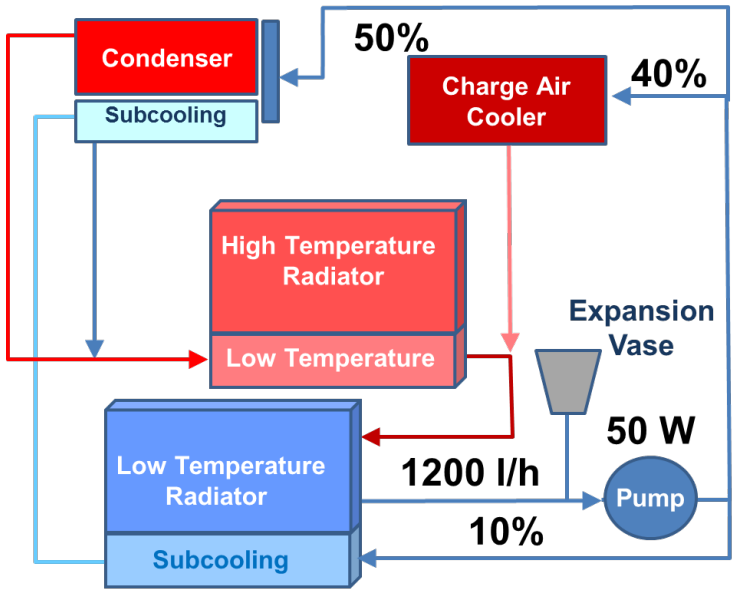
Prototype System

The **high temperature** loop is almost **unchanged** while a low temperature loop is devoted to changer air cooler and condenser cooling.

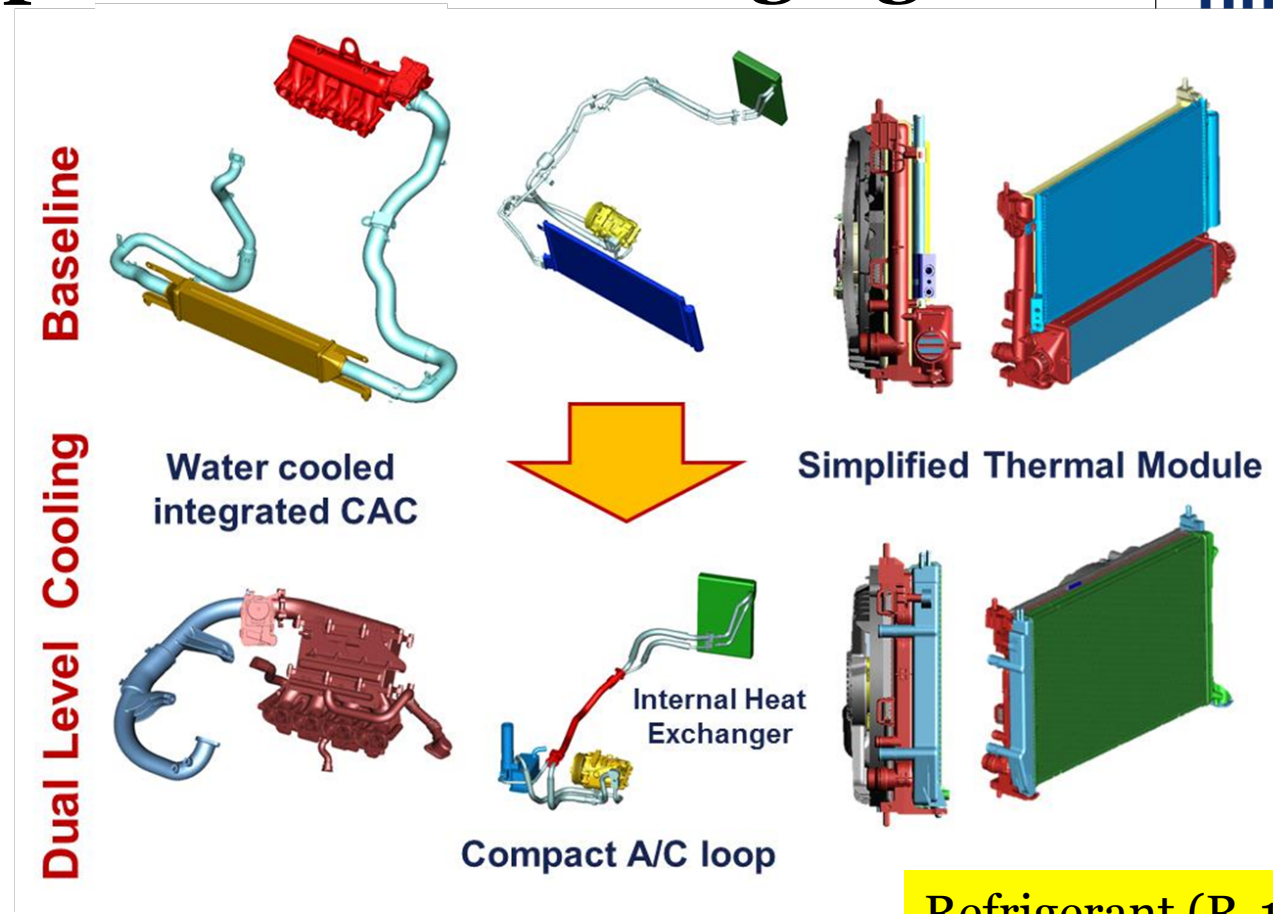
An electrical pump assures the coolant flow in the low temperature loop while, to keep the system simple, no valves have been integrated.

The configuration with **the internal heat exchanger** (IHX) has been preffered to the one with subcooling branch





Components and Packaging

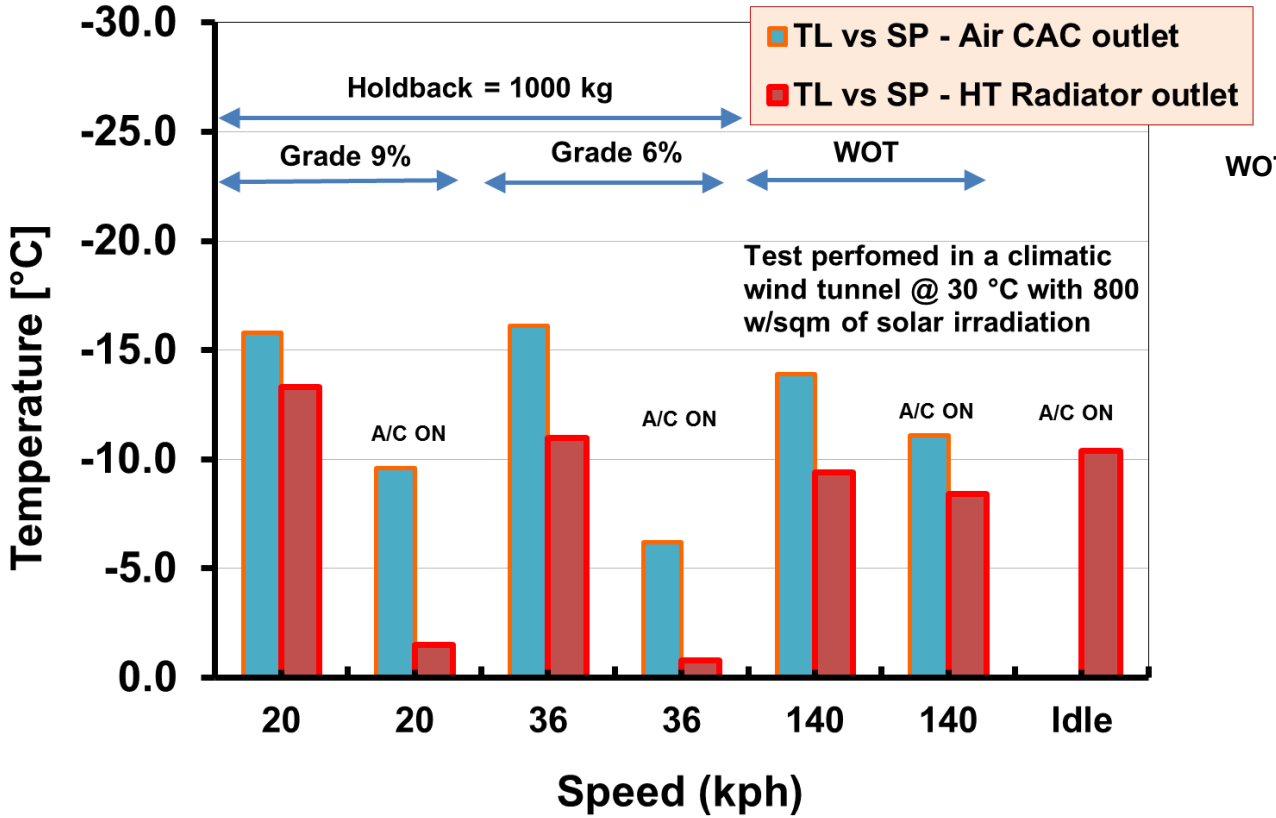


Heat Exchangers	Standard Production			Two levels System		
	width	height	thickness	width	height	thickness
	mm			mm		
High Temperature Radiator	620	395	16	620	390	16
Low Temperature Radiator				620	388	16
Charge Air Cooler	450	98	52	213	110	67
Condenser	620	298	16	138	70	67

Refrigerant (R-134a) charge reduced up to the 30%.

Heat Rejection - II

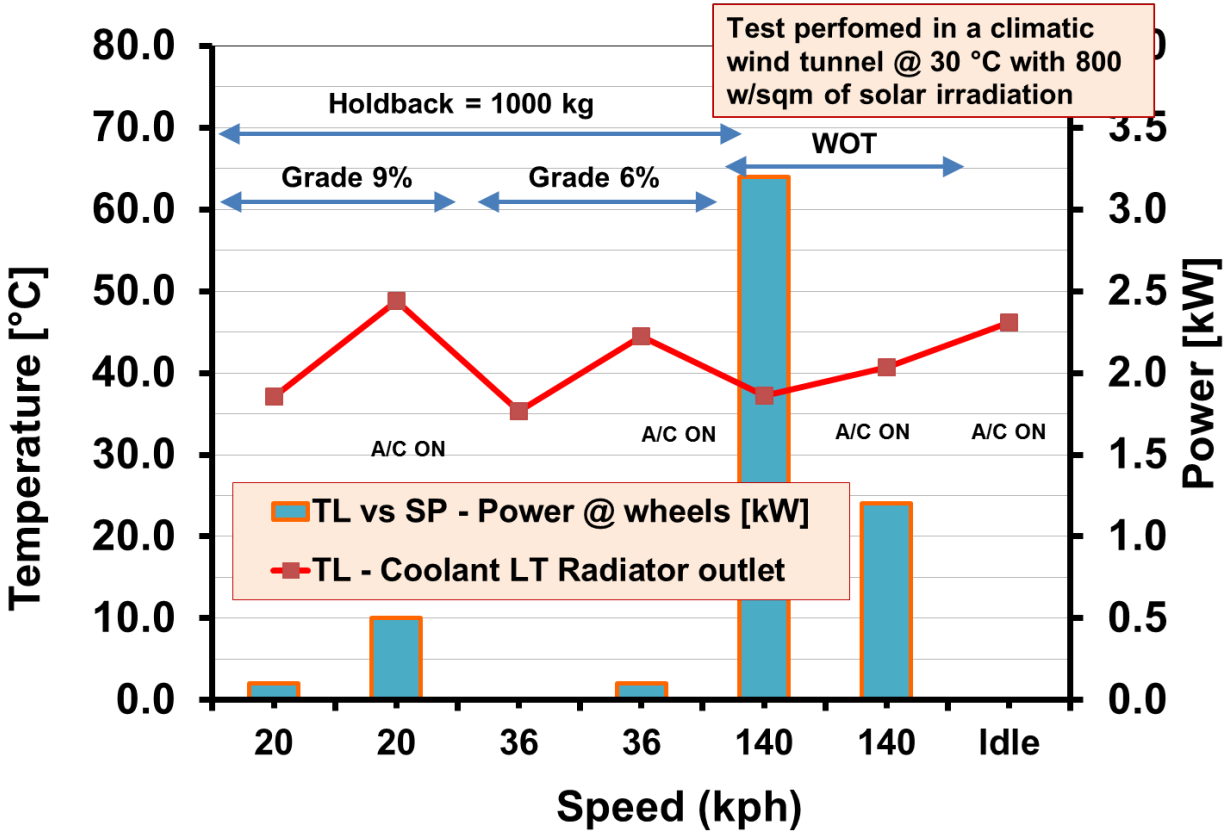
The Dual Level (TL) system allows to keep the coolant temperature equal or lower than the baseline system (SP) and the Low Temperature loop values guarantees lower engine air inlet temperature in all the conditions.



WOT = Wide Open Throttle

Heat Rejection - I

The Dual Level (TL) allows to increase the maximum power thanks to the lower air intake temperature



WOT = Wide Open Throttle

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Cool Down – A/C performance

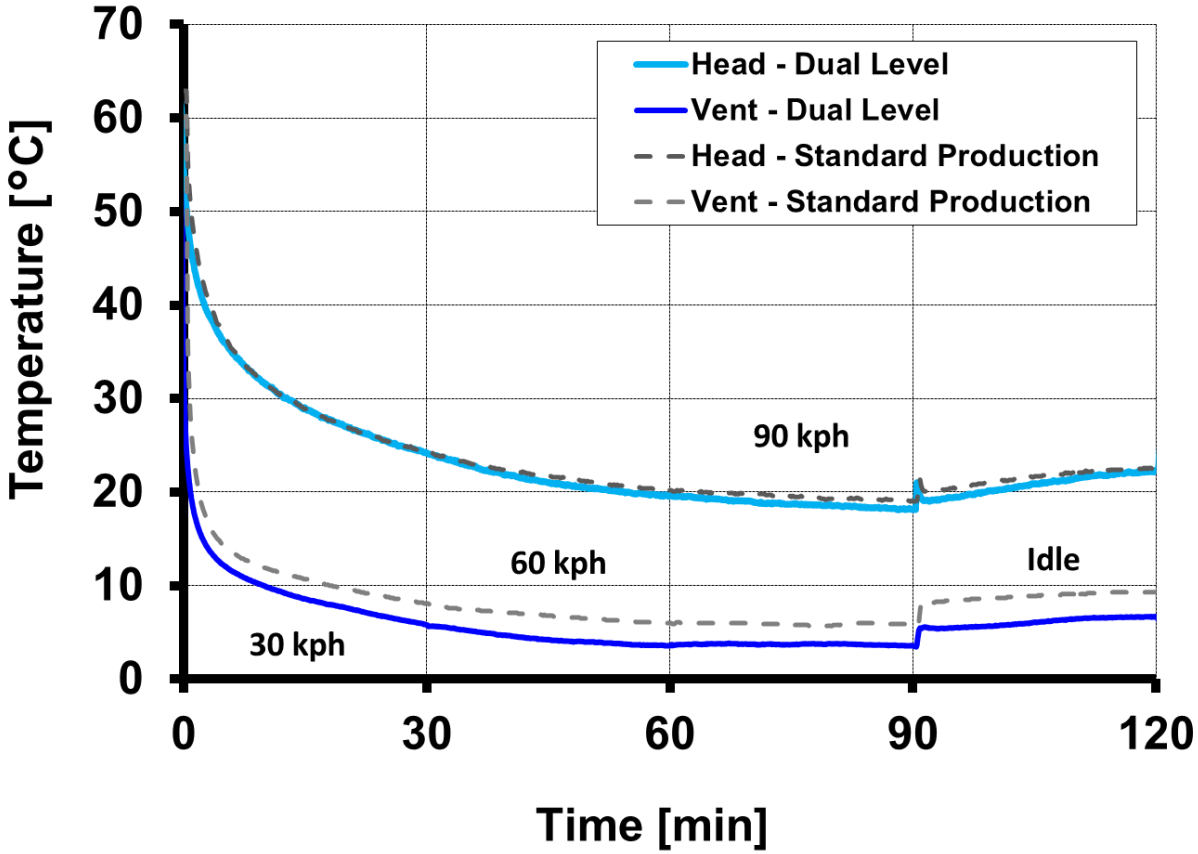
The A/C cooling performance has been evaluated in a climatic wind tunnel set as follows

- Ambient: 43 °C and 30% R.H.
- Irradiation: 900 W/sqm
- Soaking: head level air at 60 °C

The test starts once the soaking condition are achieved with the air conditioning regulated at full power in re-circulation mode

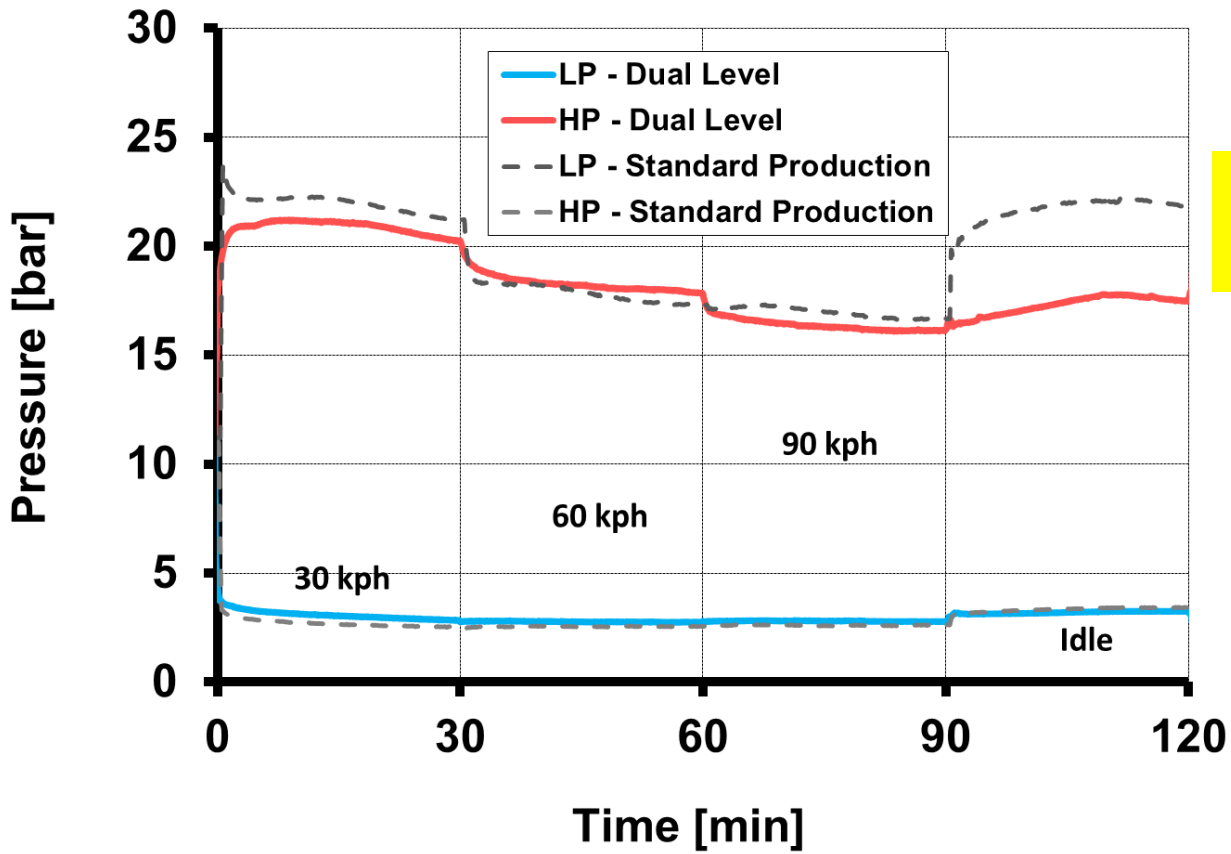
Time [min]	Speed [km/h]	Wind velocity [km/h]	Gear
0 min.	32	32	2
30 min.	64	64	3
60 min.	96	96	5
90 min.	0	3 to 8	N

Cool Down – A/C performance Temperatures



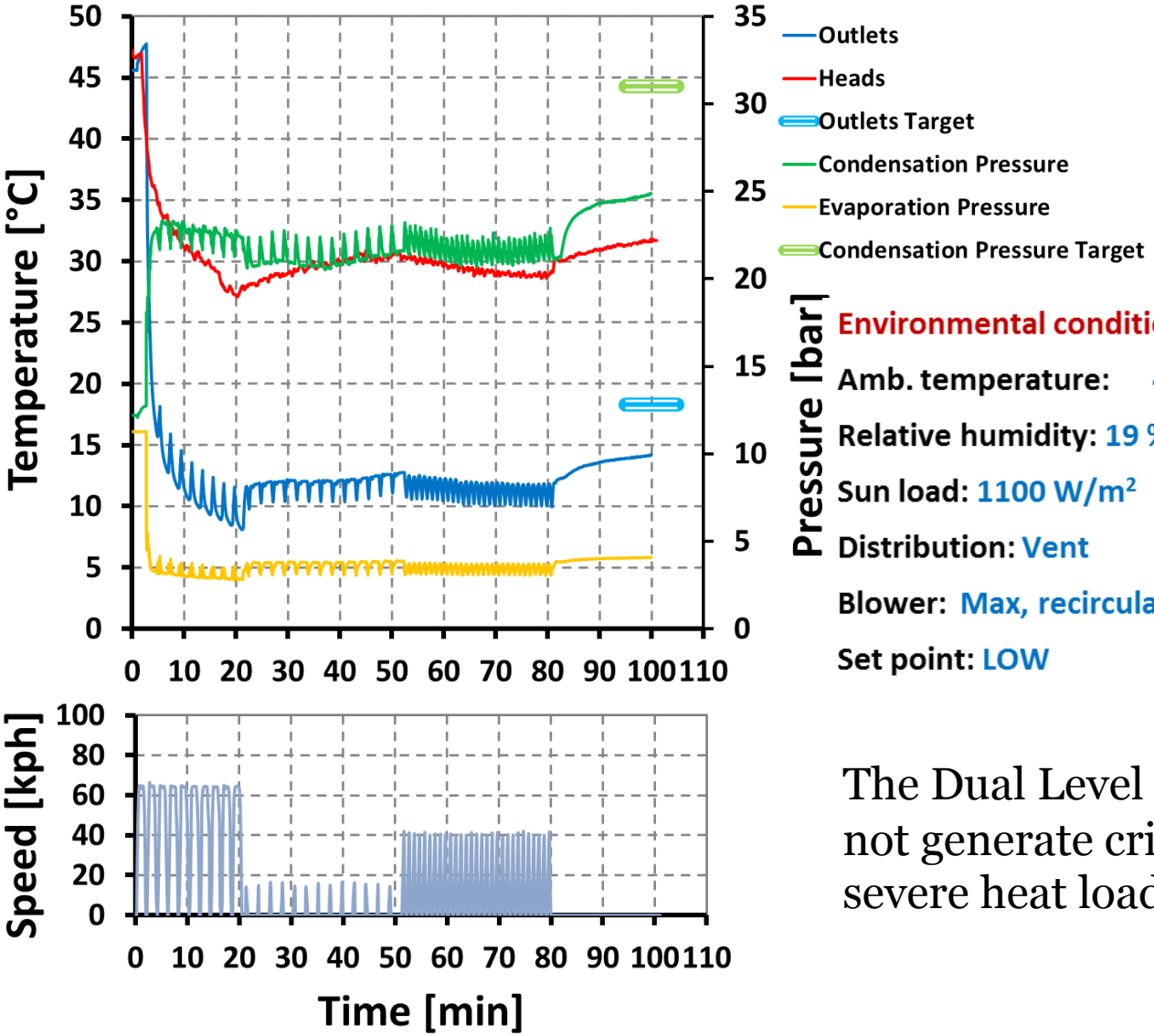
The A/C cooling performance are slightly affected by the system

Cool Down – A/C performance Pressures



The HP is lower at idle speed: lower consumption

A/C Performance – Severe Heat Load



Environmental conditions

Amb. temperature: 49 °C

Relative humidity: 19 %

Sun load: 1100 W/m²

Distribution: Vent

Blower: Max, recirculation

Set point: LOW

The Dual Level cooling system does not generate criticism also during the severe heat load test

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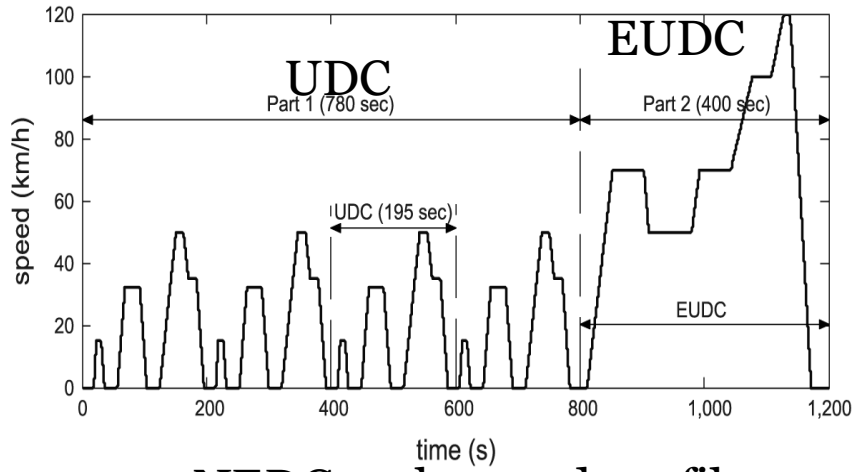
Fuel Consumption

The Two Levels cooling system **improves the homologation fuel economy (NEDC cycle) and has a positive effect on the air conditioning energy demand** at 28 °C – 50% R.H.



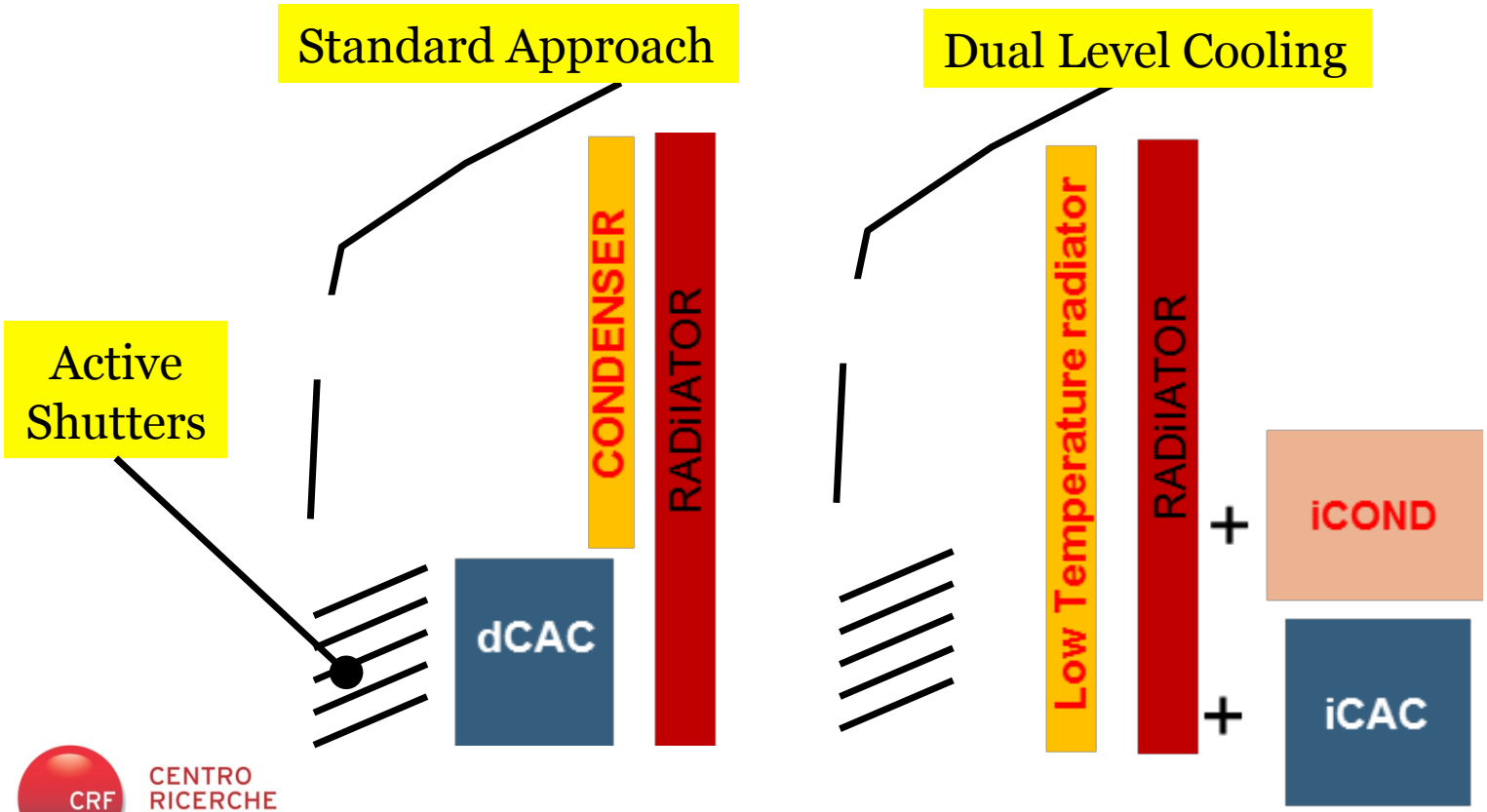
NEDC cycle speed profile

			Fuel Consumption [l/100 km]		
	Conditions	TEST	UDC	EUDC	NEDC
Baseline	20 °C	Homologation	5.3	3.5	4.2
	28°C - 50% R.U.	A/C OFF	4.4	3.0	3.5
		A/C ON	6.5	4.1	5.0
Two Levels	20 °C	Homologation	5.1	3.1	3.9
	28°C - 50% R.U.	A/C OFF	4.3	2.9	3.4
		A/C ON	6.2	4.0	4.8

The reported results are the average value of at least three repetitions.

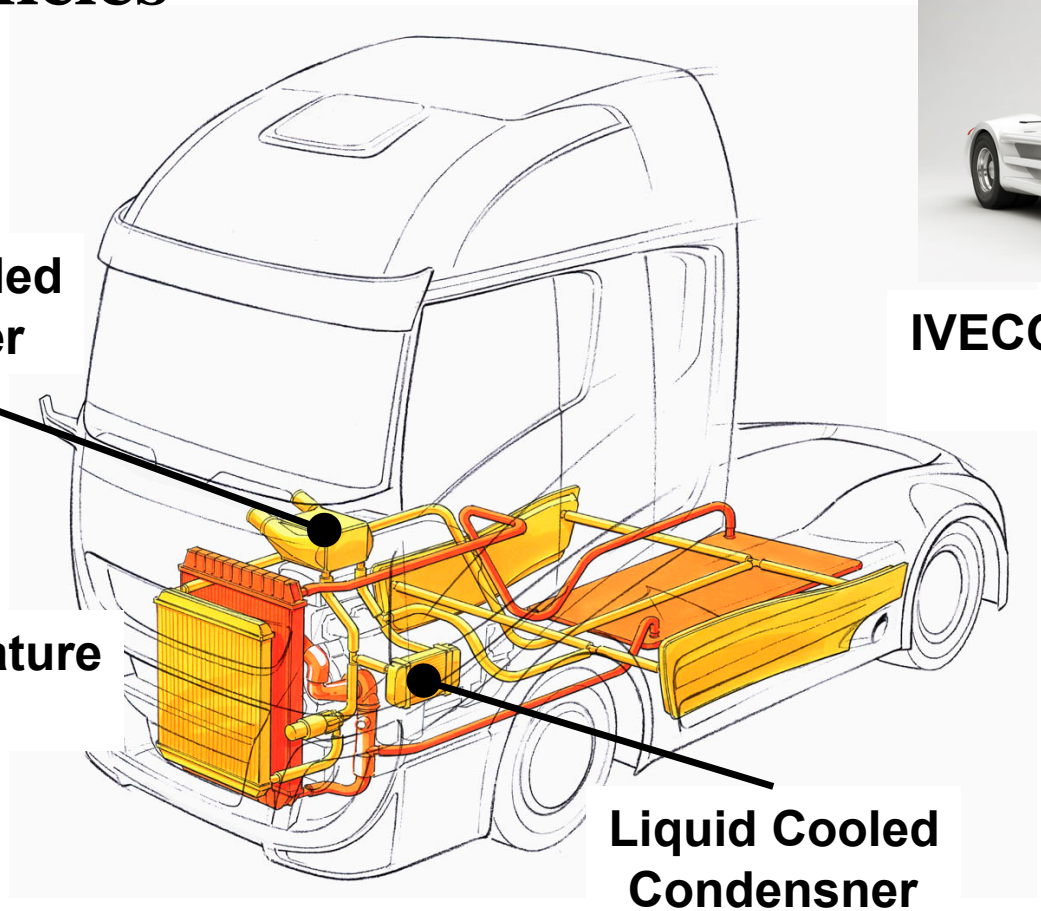
Dual Level Cooling and Active grid shutters

The dual level cooling allows to better exploit the active grid shutters effectiveness thanks to the low temperature loop thermal inertia and minor geometrical constraints



Next Steps

The same approach is under development for **heavy duty truck** application and **off-road vehicles**

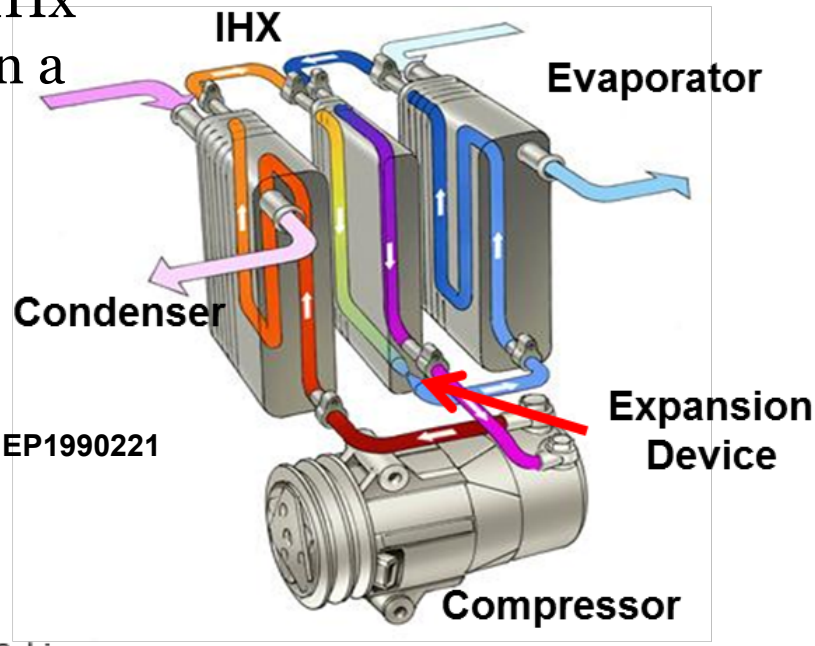


IVECO Glider Concept
IAA 2010

Compact Refrigeration Unit - I

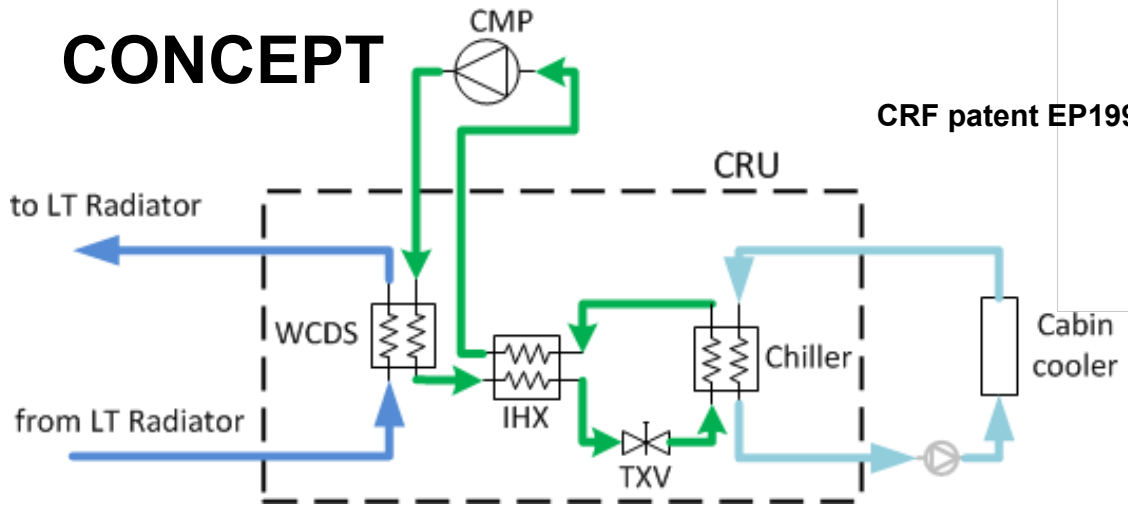
Condenser, evaporator, expansion device, IHx and eventually compressor are integrated in a compact module

In case of e-compressor the unit can be **sealed** and **pre-charged**



CRF patent EP1990221

CONCEPT



CONCEPT - 2009

TIFFE. Thermal Systems Integration For Fuel Economy

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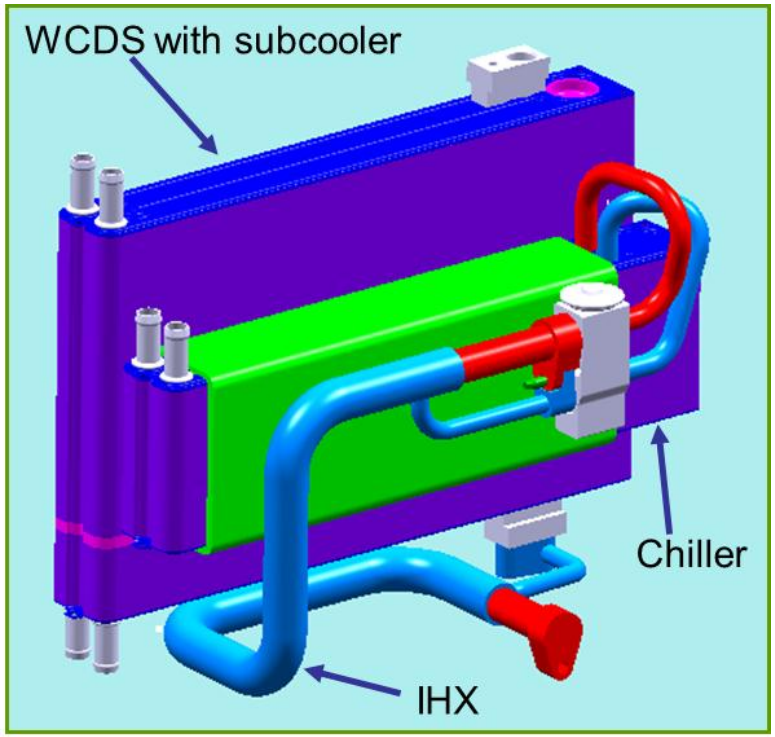
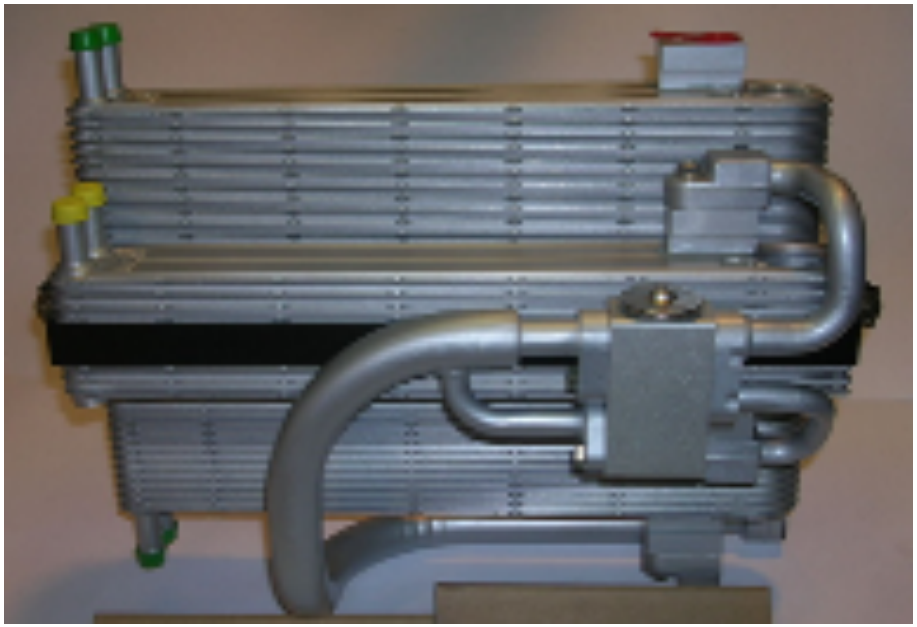
Compact Refrigeration Unit - II



FIRST PROTOTYPE 2012



Conclusions

The Dual Level cooling system:

- has a positive effect on homologation fuel economy and reduces the air conditioning fuel consumption (28 °C – 50% R.H.)
- enables the refrigerant charge reduction of up the 30% (depending on the baseline layout)
- enables the simplification and standardization of the front end module reducing the damage in case of small accidents.
- Improvement and evolution are under development (e.g. heavy duty truck and off- road vehicle application, integration with Compact Refrigeration Unit)

- ➢ The results have been achieved without any specific engine calibration
- ➢ It is expected that a proper engine calibration and optimized system control strategies enable further fuel economy and performance improvement.
- ➢ The overall weight does not change if the system is properly sized
- ➢ The removed parts and cost saving due to the refrigerant charge reduction (HFO-1234yf) can compensate the cost of the new components (e.g. e –pump)

THANK YOU!

Carloandrea Malvicino

Project Management - Fuel Economy & Vehicle Systems Efficiency

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