TEWI ANALYSIS

FOR

FUTURE A/C SYSTEMS SELECTION

C.Petitjean, M.Ben Yahia, G.Guyonvarch, R.Beauvis

Valeo Climate Control

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A/C SYSTEM TEWI ANALYSIS

KYOTO PROTOCOL

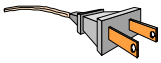
WE KNOW

New engine development

fuel high efficiency

hybrid

fuel cells



New systems

New components

WE NEED

New refrigerant

New servicing

WE USE

TEWI Analysis

Together in ARTF

A/C SYSTEM TEWI ANALYSIS

TEWI calculations

Total Equivalent Warming Impact

DIRECT CONTRIBUTION = refrigerant emission directly to the atmosphere

- Leak at assembly lines
- Leak in use (at connections, compressor seals, hoses,..)
- Leak at servicing
- Leak at accident
- End of life emission (if no recovery)

INDIRECT CONTRIBUTION = emission of green house gas due to fuel consumption

- Fuel consumption due to system weight
- Fuel consumption due to system power request relative to:

  local climate, driving profile, system use profile, system management,...

A/C SYSTEM TEWI ANALYSIS

SYSTEMS CONSIDERED

R134a current ICP: A/C system equipped with internally controlled compressor

R134a low leak ECP: A/C system with improved sealing and externally controlled compressor

R134a tight ECP : A/C system with externally controlled compressor and sealed as requested for C02

R134a electric: A/C system with electrical compressor

R134a module: A/C system with electrical compressor and water cooled condenser

CO2 current: current A/C system with C02

CO2 future: A/C system with C02 well sealed (with no poor performance due to leakage)

A/C SYSTEM TEWI ANALYSIS

DIRECT CONTRIBUTION RESULTS

Total life time = 10 years

	R134a Current ICP	R134a Low leak ECP	R134a Tight ECP	R134a Electric	R134a Electric module
Optimal refrigerant Charge (g)	750	600	500	500	350
Critical leak (g)	400	250	100	150	100
Number of re-fill	3	1	0	1	0
Leak at assembly line 0.5% (g)	3.75	3	2.5	2.5	1.75
Leak in use (g)	1333	500	33	300	100
Leak at servicing (g)	52.5	17.5	0	17.5	0
Leak at accident(g)	75	60	50	50	0
End of life charge remaining (g)	617	350	467	350	250
Charge recovered(g)	0	245	420	315	225
End of life emission (g)	617	105	47	35	25
Total life Emission (g)	2081	686	133	405	127
Total life Eq.CO2 emission (kg)	271	89	17	53	16

A/C SYSTEM TEWI ANALYSIS

ACCEPTABLE LEAKAGE FOR THE CO2 SYSTEM

Theory: direct emission of CO2 gas is not a problem for the environment due to its GWP

Reality: refrigerant losses remain a problem due to acceptable limits (high & low) for CO2 charge :

low limit is imposed by: - high sensibility of transcritical cycle to low charge (efficiency)
- acceptable frequency for servicing

high limit is imposed by: - safety at high pressure (soak conditions): no large reserve acceptable
- toxicity ?

CURRENT CONCLUSION

For CO2 system, we need very well sealed components (compressor seals, hoses, connections)
If the same technology is applied to the R134a system the leak will be 30 times less than for C02
considering physical properties and pressure of the two gases
so that direct contribution for R134a system will be low

THE CHOICE BETWEEN SYSTEMS IS ESSENTIALLY CONCENTRATED AROUND ENERGY CONSUMPTION EFFICIENCY IN DYNAMIC CONDITIONS

A/C SYSTEM TEWI ANALYSIS

FUTURE IMPROVEMENT AROUND DIRECT CONTRIBUTION

1 - Precise measurement of the compressor leak in real conditions

2 - Valeo clim Service deployment

- Affiliated repair shop network for European country (FRANCE, SPAIN, ITALY, GERMANY)
- Procedures for servicing and training of technicians
- Tools for A/C system diagnostic

AIRTEST
Air Filter checking

CLIMTEST
Refrigerant charge checking

CLIM ON LINE
A/C system for diagnostic and repair

A/C SYSTEM TEWI ANALYSIS

ASSUMPTION FOR INDIRECT CONTRIBUTION

- **Reference Climate**: Francfort (50%) and Malaga (50%)
- **Driving profile**: 2/3 urban and 1/3 extra-urban
- **Average car speed**: 40 km/h
- **Annual distance**: 16000 km
- **A/C system usage versus outside air temperature**

Outside T° (°C)	12,5 < T° < 17,5	17,5 < T° < 22,5	22,5 < T° < 27,5	27,5 < T° < 32,5	32,5 < T°
A/C system use % of time	30 %	60 %	90 %	100 %	100 %
Recir mode use % of time	-	-	-	25 %	50 %
Evaporator air flow Kg/h	150	150	150	350	550

- **Air T° at the condenser or the gas cooler**: T°out + 10°C at idle
- **Air velocity at the condenser or the gas cooler (m/s)**: 1,5 + 0,025 x car speed (km/h)

A/C SYSTEM TEWI ANALYSIS

RESULTS OF INDIRECT CONTRIBUTION

	R134a Current ICP	R134a Low leak ECP	R134a Tight ECP	R134a electric	R134a Electric module	C02 current	C02 future
System weight (kg)	15	15	15	20	22	25	18
Alternator efficiency	0.5	0.5	0.5	0.8	0.8	0.5	0.5
Belt efficiency	0.95	0.95	0.95	-	-	0.95	0.95
Eq CO2 annual due to weight (kg of CO2)	20	20	20	27	30	34	24
Eq CO2 annual due to system power (kg)	56	48	48	40	48	55	45
Total Life Eq CO2 for indirect emission (kg)	770	690	690	670	780	890	690

A/C SYSTEM TEWI ANALYSIS

FUTURE IMPROVEMENT OF INDIRECT CONTRIBUTION ESTIMATE

Improvement will concern calculation of A/C systems power consumption in dynamic conditions including:

- control of the compressor (externally controlled compressor or electrical compressor)
- transient phase along real driving cycle (Stop and Go, taking into account irreversibility)
- power consumption of each component along real driving cycle

For 134a systems (mechanical and electrical)

Last development of VALEO Freshair software (VTMS97 paper n°971783, SAE98 paper n°980288) will be used

For C02 systems

component models + test bench and CWT experiments will be used

? MAIN QUESTION ?

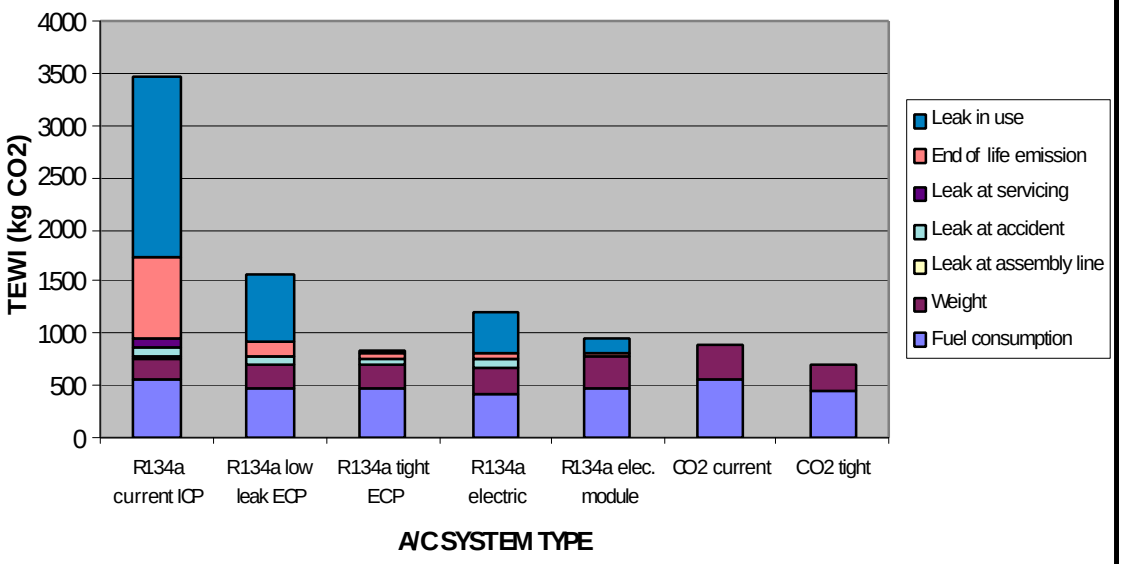
is the transcritical cycle more unstable than the subcritical (more energy irreversibility) in real dynamic conditions ?

If yes ==> Difficulties to adapt the optimal refrigerant cycle in real time to the dynamic conditions

Difficulties to link in real time control of the A/C system to the engine control

A/C SYSTEM TEWI ANALYSIS

TEWI RESULTS



A/C SYSTEM TEWI ANALYSIS

CONCLUSION

Valeo climate control will continue:

- to improve 134a systems (energy efficiency and servicing)

- to investigate more C02 systems

- to investigate what will be the most adequate A/C system for new engines in the future

in order to contribute to a clean environment