

SAE Alternate Refrigerant Cooperative Research Project

Project Overview

SAE Phoenix Symposium July 2003



Purpose of the ARCRRP

To investigate the efficiency and performance of production systems and alternate refrigerants.

Alternate Refrigerant Cooperative Research Program (ARCRP)

- **Established in 2001 by the SAE Interior Climate Control Standards Committee.**
- **Part of the international automotive air conditioning industry's response to HFC-134a (R134a) being listed as a global warming gas in the Kyoto Protocol.**
- **The SAE Interior Climate Control Standards Committee selected the Air Conditioning and Refrigeration Center at the University of Illinois at Urbana-Champaign to conduct a series of mobile air conditioning system performance tests.**

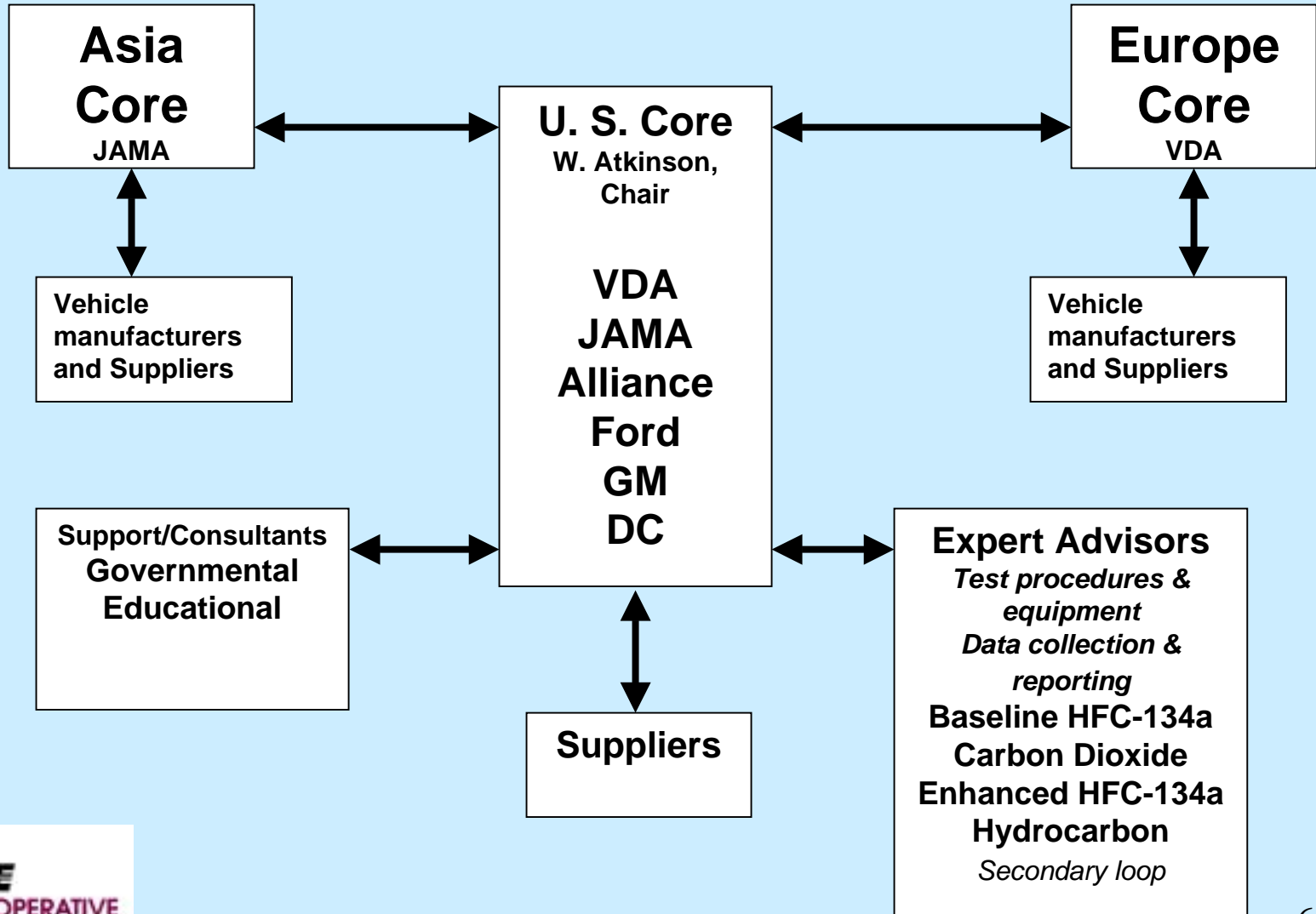
Project Sponsors

- **The Program was funded by a consortium of 25 industry stakeholders.**
- **Including vehicle manufacturers, air conditioning suppliers, and governmental agencies.**

SAE Cooperative Research Program

- **A shared industry test program provided the industry with comparable technical information at least cost.**
- **Testing new technologies in a cooperative effort of this nature affords the opportunity for all vehicle makers and system suppliers to learn more about potential future systems.**

ARCRRP Organization



Systems Tested /Expert Advisors

- **Systems Evaluated**
 - Baseline HFC-134a
 - R744 (CO₂)
 - Enhanced HFC-134a
 - Secondary Loop (Hydrocarbon)
- **Expert Team**
 - Hans Fernqvist -- Volvo Car Corporation
 - Bill Hill -- General Motors Corporation
 - Juergen Wertenbach – DaimlerChrysler Corporation
 - Steve Lepper -- Ford Motor Company

Expert Team Responsibilities

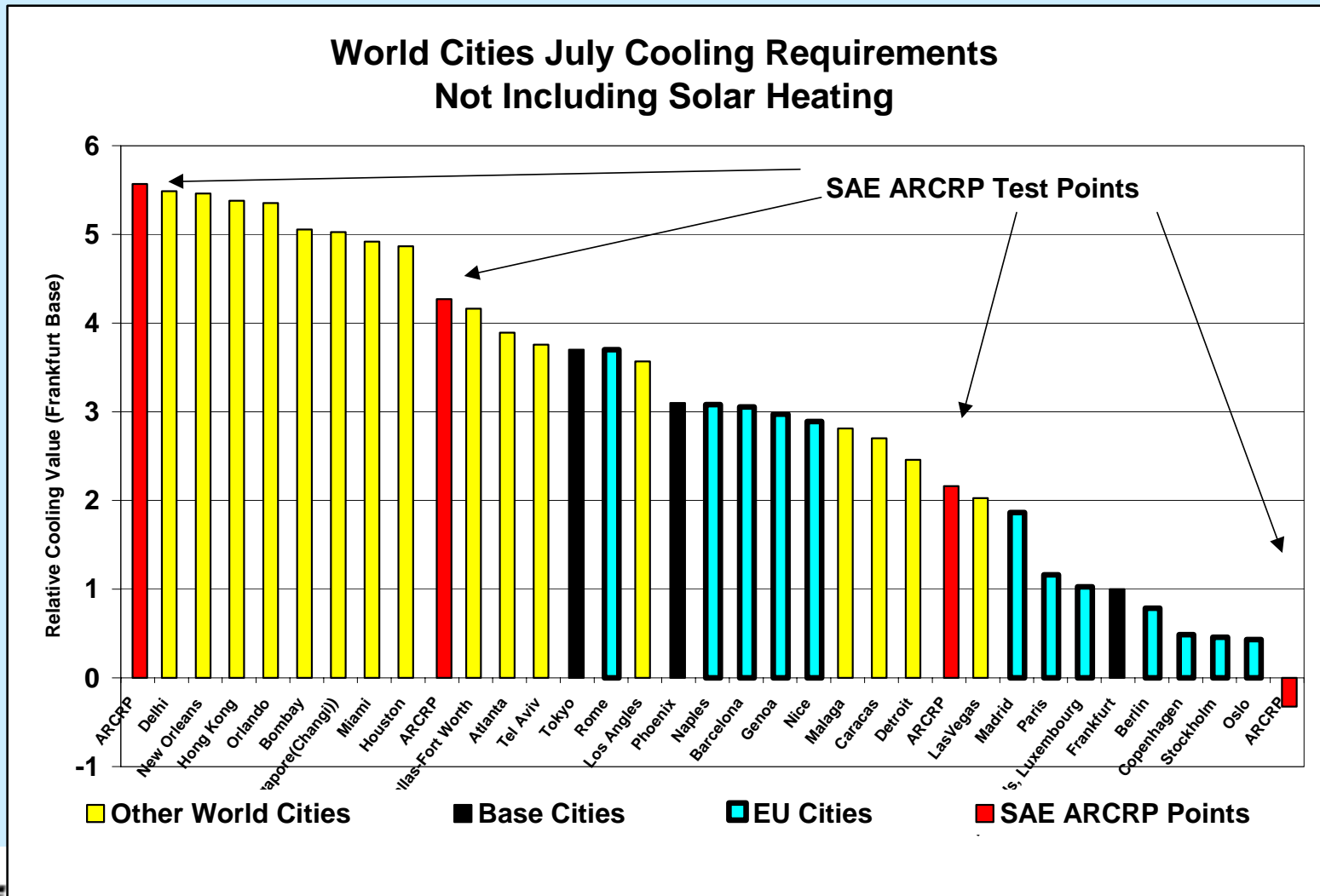
- The “Expert Team” selected the components for each refrigerant circuit evaluated.
- The “Expert Team” was responsible for oversight of all testing and reporting of the data.
- The “Expert Team” supervised the University of Illinois team members for procedures, operation and instrumentation.

U of I Team Members

- **Pega Hrnjak, Professor**
- **Xinzhong Li, Visiting Scholar**
- **Dejan Beatovic, Engineer**
- **Andy Musser, Graduate Research Assistant**
- **Stefan Elbel, Graduate Research Assistant**
- **Chris Seeton, Graduate Research Assistant**
- **Kevin Traeger, Graduate Research Assistant**
- **Jing Che, Visiting Scholar**
- **Andy Pastor, Undergraduate Research Assistant**

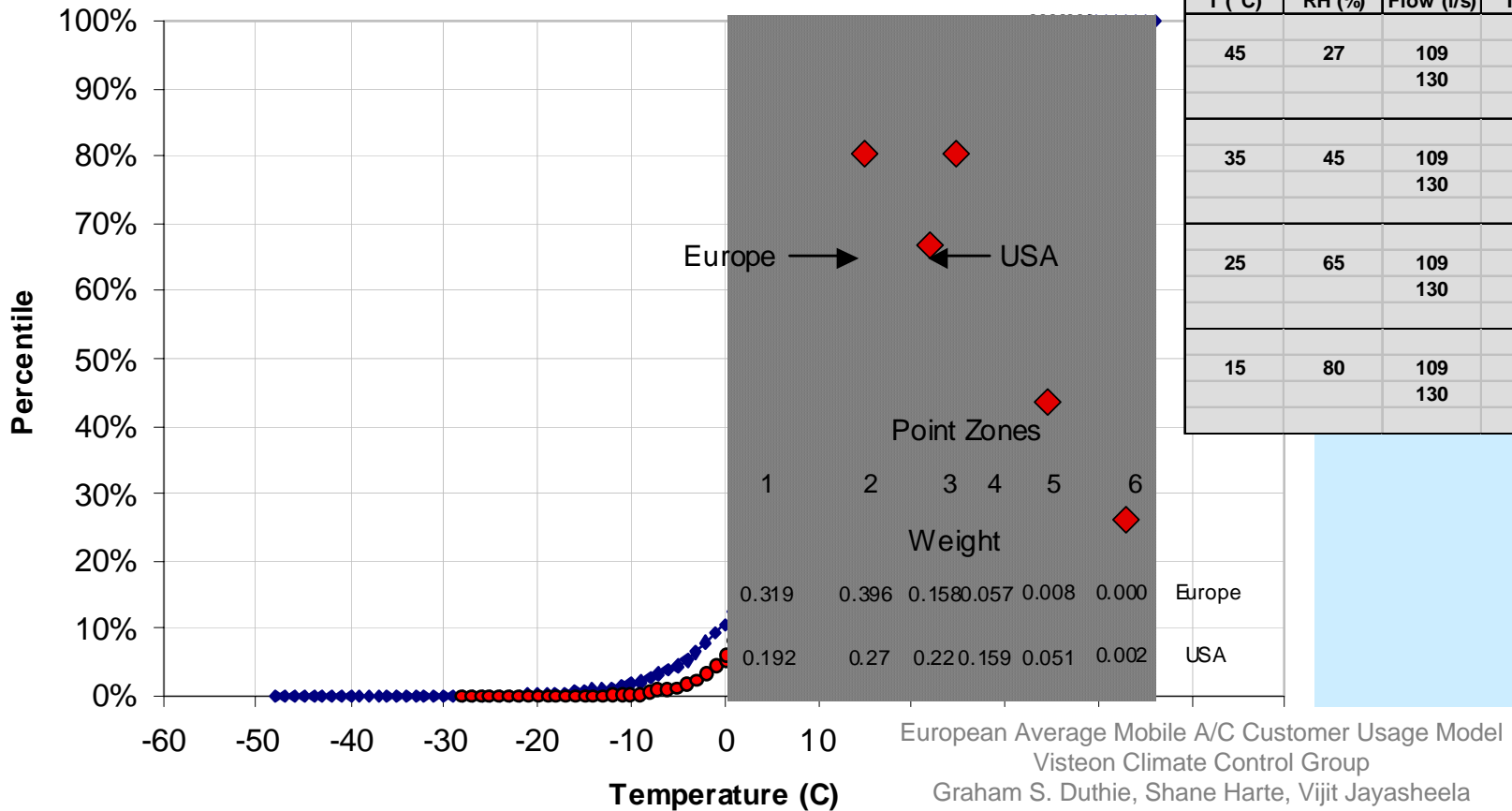
“Relative Cooling Value” (no solar load)

Month of July for many world cities and ARCRP test points



Basic Matrix – 5 °C Control or Equal Capacity

Temperature (C) vs. Percentile



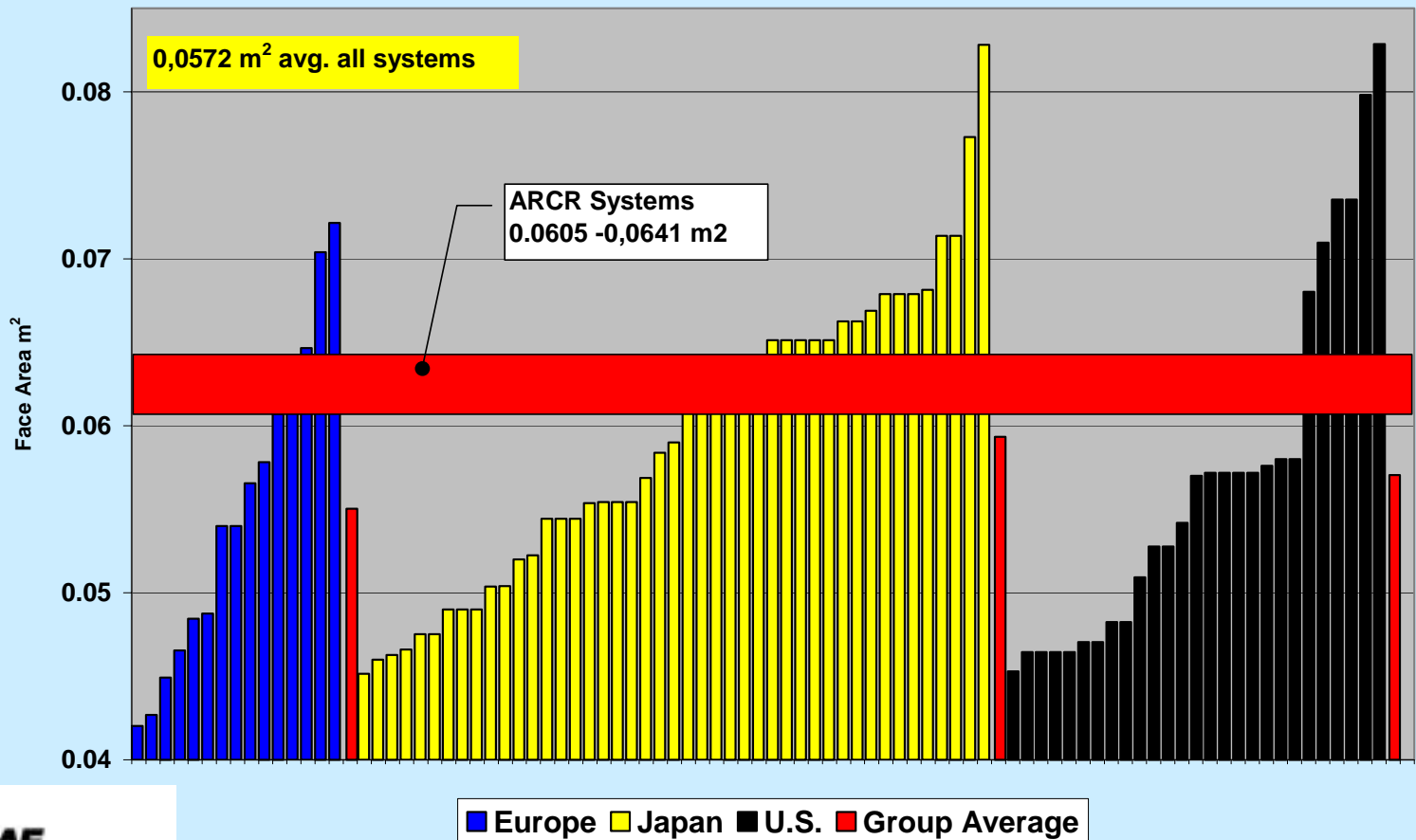
Basic Test Point Matrix					
Evaporator Air			Cond/Gas Cooler Air		Comp
T (°C)	RH (%)	Flow (l/s)	T (°C)	Flow (l/s)	rpm
45	27	109	45	425	900
		130		850	1500
				1320	2500
35	45	109	35	425	900
		130		850	1500
				1320	2500
25	65	109	25	425	900
		130		850	1500
				1320	2500
15	80	109	15	425	900
		130		850	1500
				1320	2500

Curves are population and trip time of day weighted.



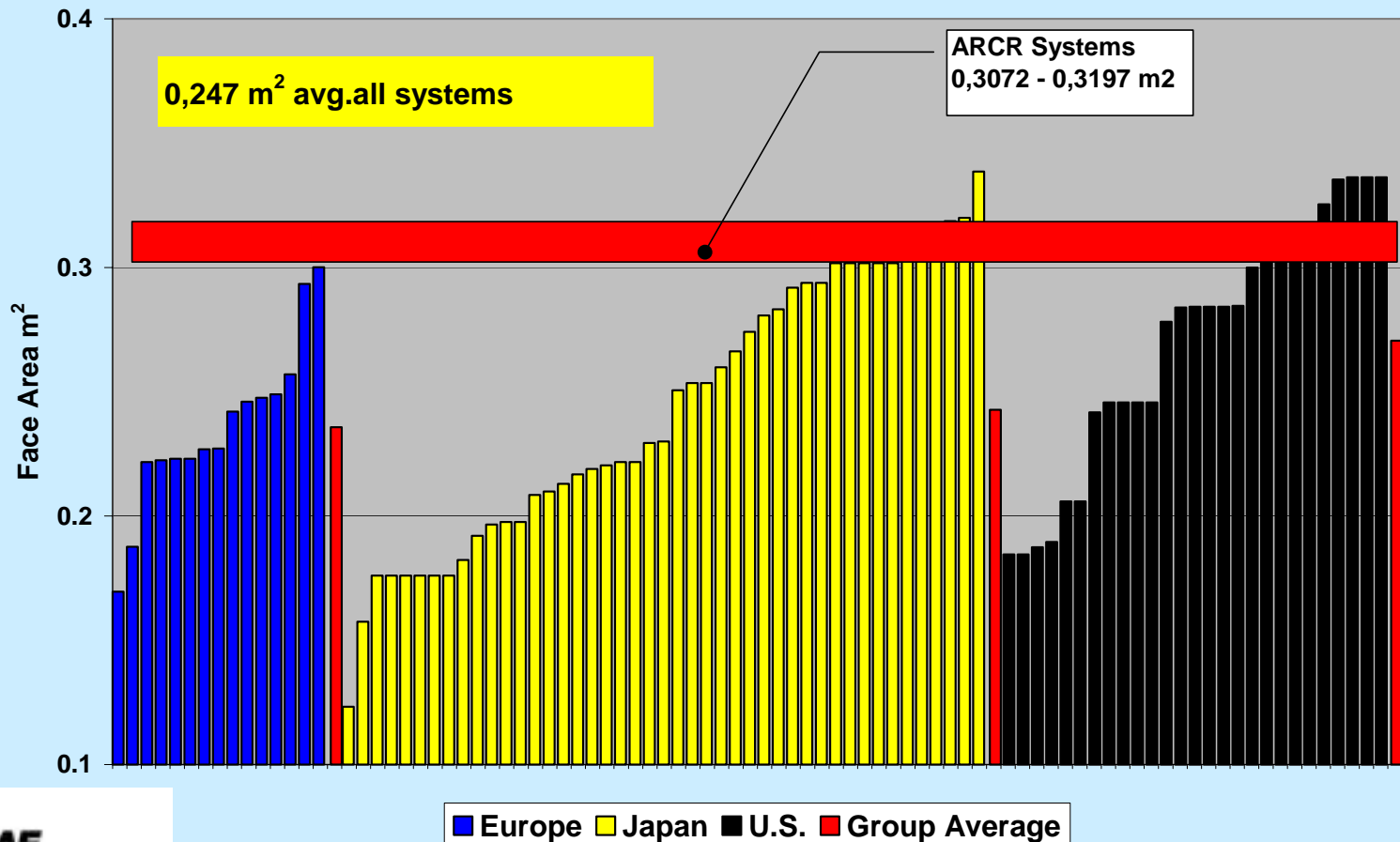
World Industry Evaporator Size

Evaporator Face Area



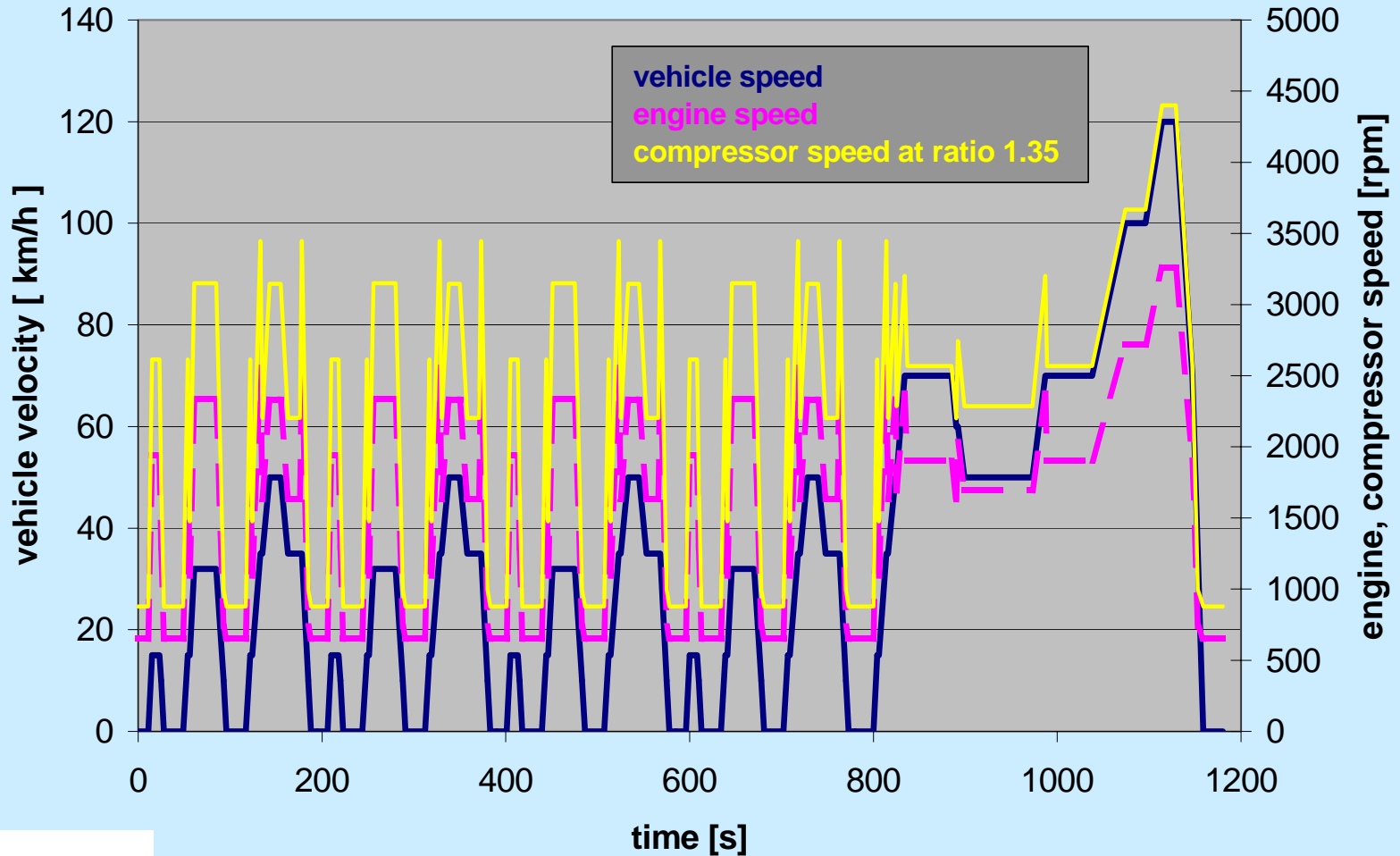
World Industry Condenser Size

Condenser Face Area

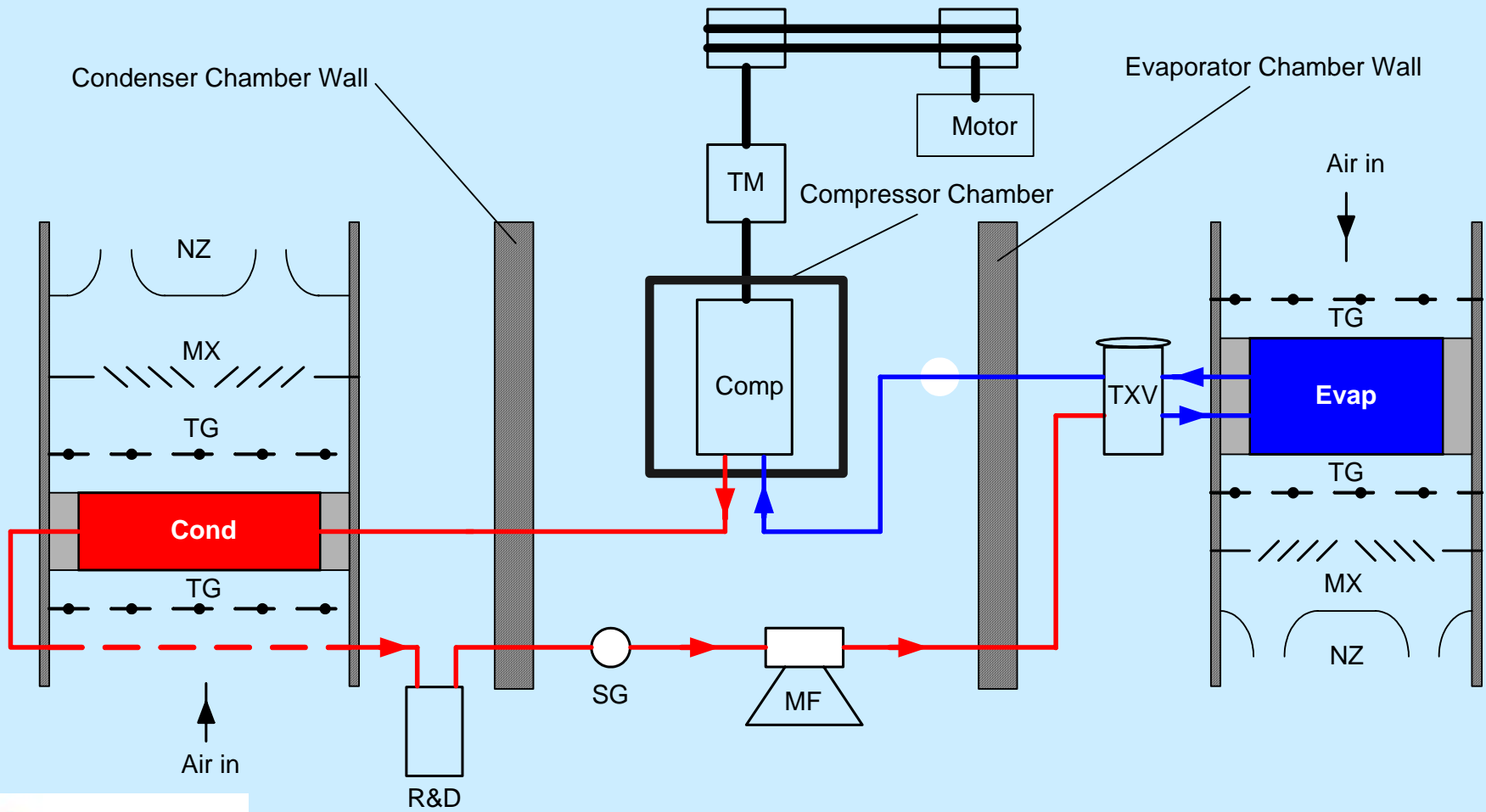


Engine and Compressor Speeds

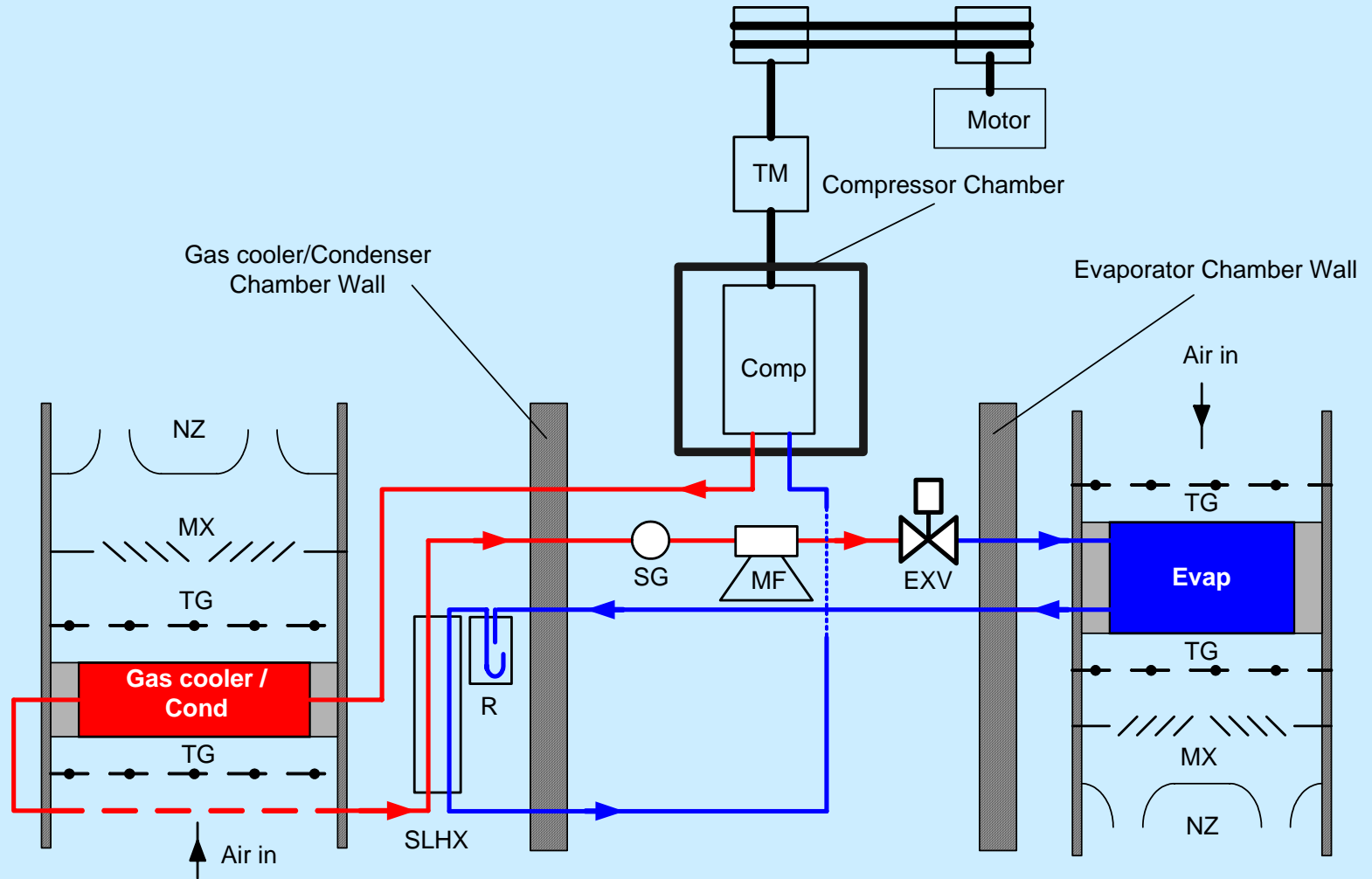
European Combined Drive Cycle



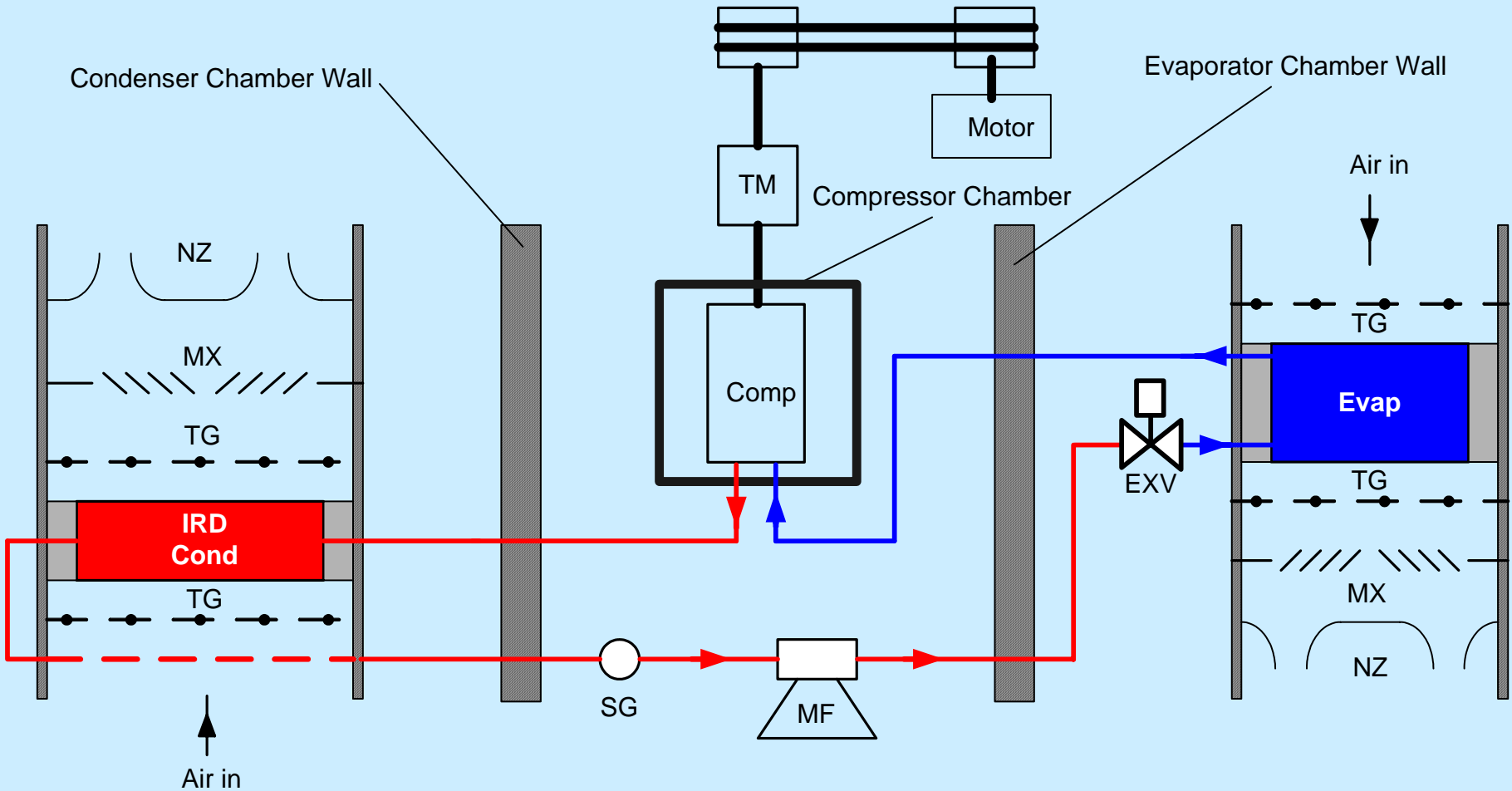
R134a Baseline System



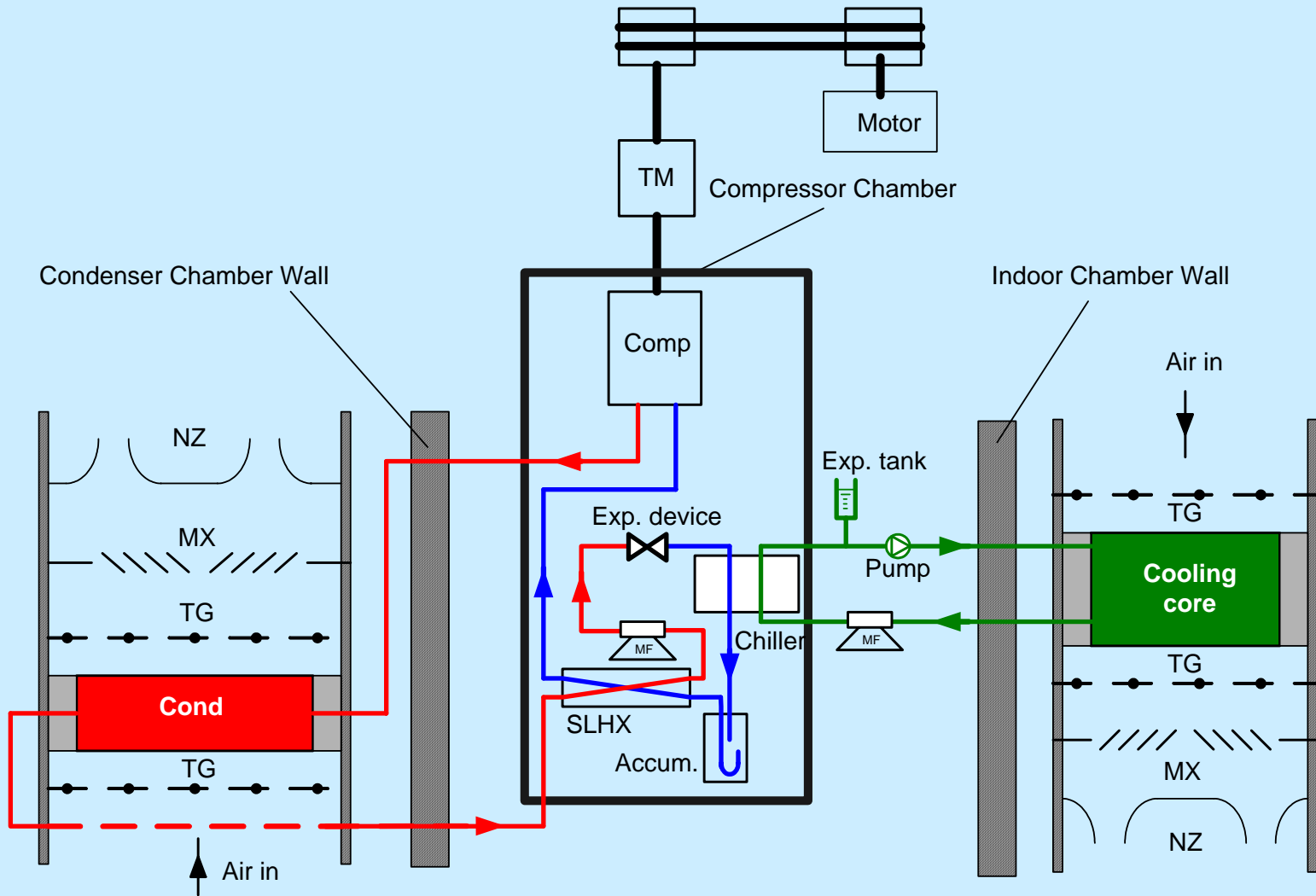
R744 System



Enhanced R134a System



R290 Secondary Loop System



Evaluation tests

- **Steady state**

- Repeatable and accurate measure of Capacity and COP at maximum capacity and equal capacity conditions.

- **Soak & Cooldown**

- Three major parameters to adjust facility to real vehicle performance: constant load, thermal mass and rate of cooling.

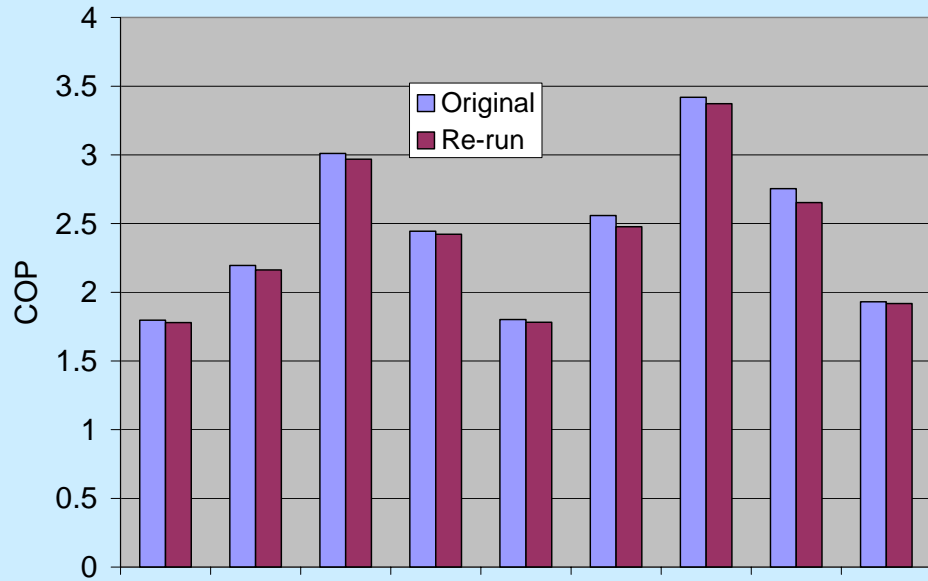
- **Transient**

- 1500 rpm to 900 rpm to 3500 rpm (rate 500 rpm/s);

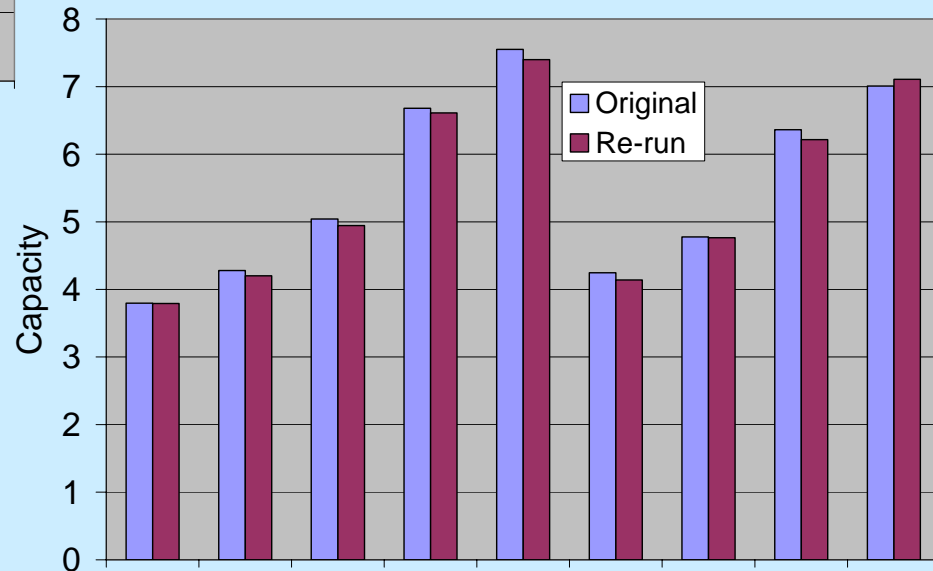
- **Restriction**

- Evaluate sensitivity of each system to air flow obstruction
- Restrictions representing bumper and engine placed at different distance from the condenser/gas cooler

COP and Capacity Repeatability of R134a Baseline System after 18 Months



System removed and re-installed on the test bench



Summary Results

Overall comments/conclusions

- **This first cooperative test program has produced comparable and accurate results in an independent lab with systems using automotive components constructed for use with different refrigerants.**
- **The test facilities used should become standard for future evaluations of this nature. Some effects such as: pressure drops, oil circulation ratios, and higher compressor rpm should also be considered.**

Summary Results

Overall comments/conclusions

- **Potential for Improved Test Conditions to make the results closer to the vehicle:**
 - Run all tests with barrier restrictions to more closely approximate real world conditions.
 - Run with increased evaporator inlet air temperatures to simulate heat pickup at idle conditions in vehicle testing.
 - Run tests with energy analysis during soak and cool-down testing.
 - Determine how to run stabilized tests at low loads so accurate compressor loads can be determined.
 - Based on Visteon ambient analysis, consider changing the test points to better comprehend the ambients and humidity ranges that are typical of customer usage.
 - Run some increased speeds for these test points.
 - Run some tests to simulate re-circulation air load at high ambients and low evaporator airflow at high ambients.

Possible Follow-up Activities

- Evaluate new system improvements
 - Enhanced R134a
 - Enhanced CO2
 - Enhanced secondary loop
 - HFC152a
 - Others?
- Enhanced model developed for public domain usage
- Energy Consumption in re-circulation mode
- Low load accuracy/control improvement
- Enhanced data at elevated condenser inlet temperature
- Data on non-uniform airflow affects on both condenser and evaporator
- New test points based on Visteon data...focus on more moderate/low loads
- System refrigerant emissions measurement methods
- Sensitivity of system to heat exchanger size/shape
- Others?