SAE International

2010 SAE Phoenix Refrigerant and System Efficiency Symposium
Indirect Emissions Workshop

July 14-15, 2010
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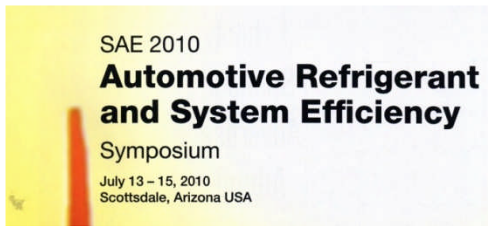
Organizers



At the request of regulatory agencies and the ICCSC members, the SAE Interior Climate Control Standards Committee (ICCSC) established an MAC Indirect Emissions Workshop activity. It was held during the **SAE 2010 Automotive Refrigerant and System Efficiency Symposium** in Scottsdale, AZ**.**

The purpose of the workshop was to discuss issues that can affect development of a common global industry test procedure to measure MAC fuel consumption and CO2 emissions related to MAC usage.

Current regulatory agency proposals are considering the use of a modified SC03 or steady state speed test, with A/C on and off, to determine actual A/C energy efficiency of vehicle MAC systems. Industry hopes that one global procedure can be agreed upon.

Discussions with the U.S EPA, California Air Resources Board and the EU have indicated that they all feel a common test procedure would be advantageous and would result in a global environmental and economic benefit when considering the indirect emissions caused by MAC systems.

The face-to-face Phoenix Workshop, with MAC industry representatives, regulatory authorities, and vehicle manufacturers, reviewed proposed regulatory test procedures and shared available industry information on testing.

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Workshop Presentations:

Test procedure development Mobile Air Conditioning (MAC) Klaus Steininger, EC	File PDF A1
Impact of Test Facility Variables in Mobil Air Conditioning FE Validation David Knott, Jacobs	File PDF A2
Drive Schedule Development for Measuring MAC Fuel Consumption John P. Rugh, NREL	File PDF B1
MAC Indirect Emissions Workshop Roman Meininghaus, ACEA	File PDF B2
Derivation of A/C Credits in the Light- Duty Greenhouse Gas Rule Brian Nelson U.S. Environmental Protection Agency	File PDF C1
Technologies for Reducing MAC Indirect Emissions: From AB 1493 Credits to a LEV III Standard Leela Rao, CARB	File PDF C2
Impact of Glass Variations on MAC Loads Mukesh Rustagi, PGW Rob Vandal, Guardian, Tony Shaw, Pilkington	File PDF D1
Significance of Glazing Thermal Conductivity for MAC Indirect Emissions and EV Battery Performance Steve Gasworth and Triloka Tankala SABIC Innovative Plastics	File PDF D2
Impact of Vehicle Architecture on MAC Indirect Emissions Ward Atkinson -- Bill Hill	File PDF D3 &
Workshop 14 July Summary	File PDF

Based upon the Thursday afternoon meeting a plan was proposed to have further discussions by Webex on MAC testing requirements.

The SAE Web site has all the presentations made during the meeting. Each presentation is identified by a file name indicating the presenter.

Test Equipment Impact

The use of test chambers for determining MAC energy consumption is very complex. The first issue is repeatability of test results between chambers that would be used for comparison for MAC energy consumption. The use of existing vehicle emission test chambers [other than SC03 chambers] does not reflect accurately MAC load, including solar loading, airflow over the vehicle and into the engine compartment, and airflow into the body cowl inlet of the vehicle.

The second issue is repeatability of data in a given test chamber can be difficult and require repeated testing for accurate results. The MAC fuel consumption is typically 5-10% of the total fuel consumed, so measuring it precisely requires a measurement of the fuel consumed with MAC on and MAC off. Subtracting these two relatively large numbers [each with a given inaccuracy] to get the differential can result in a compounding of errors.

In addition, if solar simulation is included the vehicle test for a vehicle product line that includes 2 and 4 door and van models having different glazing configurations, all of these have a different impact on performance results. The additional influence of interior color of surfaces that have direct solar impingement, such as instrument panel and rear shelf areas have a major affect on the performance of the MAC. This makes the selection of vehicle types for testing of a given architecture very complex and potentially a large test burden on the vehicle OEMs.

The questions,

"What is determining factor in establishing energy consumption?"

"Is real occupant comfort a criteria to determine when the system cooling load can be reduced?"

"Is breath temperature a true reflection of customer comfort?"

As mentioned in the last section of the workshop, comfort is highly subjective and includes a lot of factors out of control of the MAC system engineer.

To develop a detail procedure for testing of MAC fuel consumption, the following criteria need to be considered:

- Need to define MAC system control settings:
  - Manual
  - Automatic
    - Type of temperature program setting
    - Air Selection
      - Recirculation
      - Outside air [OSA]
      - Dual Zone temperature control

Test facility areas to consider:

Basic specifications for facilities

Solar lamp requirements

Light bank reflect true solar load spectrum loading

Correct heat load on profile of vehicle surfaces

Roof - Instrument and rear shelf areas - engine compartment hood

Compensation for distance from light banks

Vehicle configuration – Small, SUV vehicles, sports cars

Blockage corrections/Airflow over the vehicle
Distance to the nozzle for front end re-circulation
Instrumentation requirements
Correlation between facilities and "real world"
Vehicle types required
Select key vehicle parameters
Define band of acceptance
Breath vs. discharge air temperatures
Define Road Test Process
Develop test facility simulation
New emissions test vs. Replacement test
Facility capacity issues
Timing for testing vs. design freeze of systems

Vehicle Test Setup
How are panel outlets positioned?
Directly toward temperature measurement location?
What breath level temperature is required**?**

Drive Schedule Impact

Constant speed vs. Transient Speed
Need Pros/Cons
Impact of transient load vehicle and MAC control factors
Soak and Cool-down vs. steady state
Solar load per ISO13837?
Metrics to use
MPG, l/100 km/, l/hour
Fuel consumed by vehicle vs. fuel consumed by MAC
"Real World" effect vehicle profile windows open vs. closed

Impact of different engine efficiencies
Global procedure vs. localized procedure(s)
Hybrid and electric vehicle considerations

MAC Hardware Impact on Fuel Consumption

The test schedule and ambient requirements should accurately reflect the real world fuel consumption of alternative MAC technologies. Furthermore, the impact of other vehicle technologies that reduce MAC load should be considered:

- Heated and Cooled Seats
- Ventilated cabin
- Use of lighter colors in interiors
- Solar glass, reflective glass, polycarbonate materials in glazing surfaces

Vehicle Architecture Impact

Vehicle Interior and Exterior Colors
Glass/Polycarbonates
Ventilated seats
Ventilated passenger compartments
Other capacity reduction strategies
Considerations of customer usage

- Trip length
- Soaks vs. steady state
- Blower preferences
- Mode preferences
- Battery cooling
- Temperature rise from body cowl at air inlet
- Temperature at condenser inlet due to engine compartment airflow patterns

Consumer Benefits

While not discussed directly in the workshop, the following customer benefits should be considered in any new regulation. The question of what benefits are derived from a test chamber comparison of A/C system on and off may well send the wrong information to the consumer. How will the results be reflected in the vehicle label and consumer materials provided to the customer?

Since the test comparison may not be an indication of “Real World” use, the consumer may well become misinformed as to the actual fuel use and this may impact customer safety due to their psychological discomfort and adverse driving habits that may result from not using the A/C system.

When operating at road speeds, and after achieving occupant comfort, the energy requirement for comfort is much less than required for soak and cooldown conditions.

Comparing vehicle body profile drag coefficient when operating with windows open vs. closed can result in increased energy requirements. In some cases the windows closed and use of the MAC system in providing occupant comfort have had similar energy requirements as operating windows open and no MAC operation. This type of energy comparison cannot be made in test facilities that have limited aerodynamic capabilities.

Appendix A
The following is the current SCO3 test facility requirements

§ 86.161-00 Air conditioning environmental test facility ambient requirements.
The goal of an air conditioning test facility is to simulate the impact of an ambient heat load on the power requirements of the vehicle's air conditioning compressor while operating on a specific driving cycle. The environmental facility control elements that are discussed are ambient air temperature and humidity, minimum test cell size, solar heating, and vehicle frontal air flow.

(a) Ambient air temperature.

(1) Ambient air temperature is controlled, within the test cell, during all phases of the air conditioning test sequence to 95 ±2 °F on average and 95 ±5 °F as an instantaneous measurement.

(2) Air temperature is recorded continuously at a minimum of 30 second intervals. Records of cell air temperatures and values of average test temperatures are maintained by the manufacturer for all certification related programs.

(b) Ambient humidity.

(1) Ambient humidity is controlled, within the test cell, during all phases of the air conditioning test sequence to an average of 100 ±5 grains of water/pound of dry air.

(2) Humidity is recorded continuously at a minimum of 30 second intervals. Records of cell humidity and values of average test humidity are maintained by the manufacturer for all certification related programs.

(c) Minimum test cell size.

(1) The recommended minimum environmental exhaust emission test cell size is width 20 feet, length 40 feet, and height 10 feet.

(2) Test cells with smaller size dimensions may be approved by the Administrator if it can be shown that all of the ambient test condition performance requirements are satisfied.

(d) Solar heat loading.

(1)(i) Acceptable types of radiant energy emitters that may be used for simulating solar heat load are:

(A) Metal halide;

(B) Quartz halogen with dichroic mirrors; and

(C) Sodium iodide.

(ii) The Administrator will approve other types of radiant energy emitters if the manufacturer can show they satisfy the requirements of this section.

(2) The height of the minimal cell size will dictate the type of radiant energy source that will satisfy the spectral distribution and uniformity definitions of this section.

(3) Radiant energy specifications.

(i) Simulated solar radiant energy intensity is determined as an average of the two points measured at:

(A) Centerline of the test vehicle at the base of the windshield.

(B) Centerline of the vehicle at the base of the rear window (truck and van location defined as bottom of vertical window or where an optional window would be located).

(ii) The radiant energy intensity set point is 850 ±45 watts/square meter.

(iii) The definition of an acceptable spectral distribution is contained in the following table:

Definition of the Spectral Distribution
Percent of total

	Spectrum	
Band width (nanometers)	**Lower limit (percent)**	**Upper limit (percent)**
<320	0	0
320–400	0	7
400–780	45	55
>780	35	53

Note: Filter the UV region between 280 and 320 wave lengths.

(iv) The angle of incidence of radiant energy is defined as 90 degrees from the test cell floor.
(v) The requirements for measuring the uniformity of radiant energy are:

(A) The radiant energy uniformity tolerance is ±15 percent of the radiant energy intensity set point of 850 watts/square meter.

(B) The uniformity of radiant energy intensity is measured at each point of a 0.5 meter grid over the entire footprint of the test vehicle at the elevation of one meter including the footprint edges.

(C) Radiant energy uniformity must be checked at least every 500 hours of emitter usage or every six months depending on which covers the shorter time period; and every time major changes in the solar simulation hardware occur.

(vi) The radiant energy intensity measurement instrument specifications (minimum) are:

(A) Sensitivity of 9 microvolts per watt/square meter;
(B) Response time of 1 second;
(C) Linearity of ±0.5 percent; and
(D) Cosine of ±1 percent from normalization 0–70 degree zenith angle.

(e) *Vehicle frontal air flow.* The Administrator will approve frontal air flow based on “blower in box” technology as an acceptable simulation of environmental air flow cooling for the air conditioning compressor and engine, provided the following requirements are satisfied.

(1) The minimum air flow nozzle discharge area must be equal or exceed the vehicle frontal inlet area. Optimum discharge area is 18 square feet (4.25×4.25), however, other sizes can be used.

(2) Air flow volumes must be proportional to vehicle speed. With the above optimum discharge size, the fan volume would vary from 0 cubic feet/minute (cfm) at 0 mph to approximately 95,000 cfm at 60 mph. If this fan is also the only source of cell air circulation or if fan operational mechanics make the 0 mph air flow requirement impractical, air flow of 2 mph or less will be allowed at 0 mph vehicle speed.

(3) The fan air flow velocity vector perpendicular to the axial flow velocity vector shall be less than 10 percent of the mean velocity measured at fan speeds corresponding to vehicle speeds of 20 and 40 mph.

(4)(i) Fan axial air flow velocity is measured two feet from nozzle outlet at each point of a one foot grid over the entire discharge area.

(ii) The uniformity of axial flow tolerance is 20 percent of the fan speeds corresponding to vehicle speeds of 20 and 40 mph.

(5) The instrument used to verify the air velocity must have an accuracy of 2 percent of the measured air flow speed.

(6) The fan discharge nozzle must be located 2 to 3 feet from the vehicle and 0 to 6 inches above the test cell floor during air conditioning testing. This applies to non-wind tunnel environmental test cells only.

(7) The design specifications discussed in paragraphs (e)(1) through (e)(5) of this section must be verified by the manufacturer prior to conducting certification air conditioning tests.

[61 FR 54897, Oct. 22, 1996, as amended at 70 FR 40434, July 13, 2005]