CO_2 Emission Quantification from Vehicle Air Conditioning Operation in California-Specific Conditions

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AIR RESOURCES BOARD

Presentation Outline

- Current tailpipe emissions measurement
- ARB's interest in indirect emissions for mobile air conditioning systems
- The team
- The project
  - Collecting user data
  - Processing user data and developing test protocol
- Summary

Current Emissions Measurement Under A/C Operation

- Current emission inventory and vehicle certification needs are based on the Federal Test Procedure (FTP)
  - SC03 component is intended for NOx, HCs, CO
  - Accounts for mobile air conditioning use at max setting
  - Uses 850 W/m^2 solar lamps
  - Maybe not optimized for some configurations and conditions, California-specific operation, etc.
  - May not capture some system improvements (e.g. efficiency improvements at less-than-max settings)
- Not fully appropriate for a/c indirect emission measurement needs

Allowance Criteria for MACS with Reduced Indirect Emissions

(under ARB's GHG Emission Regulations for New Vehicles)

- **Reduces compressor usage by better managing the balance between outside and recirculated air**
- **Reduces reheat by using an externally controlled compressor that may be *i*) variable displacement, *ii*) variable speed (e.g. - electric motor), *iii*) fully cycling fixed displacement**
- **Utilizes other high-efficiency components**

Allowances for Optional Indirect A/C Emission Reductions

	Qualify as an "A/C System with Reduced Indirect Emissions"	Switch to a refrigerant with a GWP of 150 or less
Allowance in CO_2-equivalent grams per mile	7.5 to 11	Maximum of 0.5

The calculated indirect emission allowance is proportional to maximum A/C compressor displacement. The range for each allowance is based on system to system variation in compressor displacement.

Need for Indirect Emissions Measurement Tool

- To improve, we want a real-world, performance-based protocol
  - To account for operational, system and other variations
  - To allow manufacturers to capture benefits of system improvements as allowances
  - To more accurately capture effects of California-specific operation

Need for Indirect Emissions Measurement Tool (continued)

- Procedure must be robust yet readily useable
  - If possible, avoid requirements for sun lamps, psychrometric wind tunnels, and other technical complexities
  - Should be a simple augmentation to existing FTP if possible

Team Selection

- As collaborators, we selected a team from CSUN and UIUC
  - CSUN, Prof. Tim Fox
    - in-use data collection
  - UIUC, Prof. Clark Bullard and Prof. Pega Hrnjak
    - in-lab scenario development and evaluation

Determine Test Vehicle Instrumentation Requirements for A/C Activity Data Capture -CSUN

Pilot Vehicle Proposed Instrumentation List

Ambient Driving Environment

- Temperature
- Humidity
- Pressure
- Solar Intensity - roof mounted
- GPS - antenna roof mounted

Interior Cabin environment

- Solar intensity - center of dash
- Ceiling air temperature
- Glazing temperature(s) - 2 to 6 places
- Humidity
- Driver door opening event
- Passenger door(s) opening event
- Air duct(s) discharge temperature

AC System Control Monitoring

- Evaporator blower voltage
- Condenser fan voltage
- Blend door position
- AC mode indicator? - vehicle dependent ???
- Variable displacement compressor control
- Fixed displacement compressor clutch on/off

AC System Thermal Monitoring

- Condenser air inlet temperature
- Outside cabin air inlet temperature
- Evaporator return (recirc) air temperature
- Heater core outlet air temperature
- Evaporator air outlet temperature
- Evaporator relative air flow indicator
- Heater core relative air flow indicator
- Condenser inlet air flow speed
- Evaporator return relative humidity
- Expansion device inlet temperature
- Evaporator refrigerant inlet temperature
- Evaporator refrigerant outlet temperature
- Compressor suction temperature
- Compressor discharge temperature
- Mid-condenser tube temperature
- Compressor inlet/outlet pressure(s) - if available

Other Parameters

- Compressor RPM
- Engine RPM
- Drive line RPM (in lieu of vehicle speed)
- Engine Control Module (ECM) intercep
- Data system housekeeping status

Pilot Vehicle for Activity Data Capture -CSUN

- Pilot vehicle for instrument evaluation
  - Extensively instrumented
  - Tested in CSUN's environmental chamber
  - Driven in broad selection of conditions for 60 days
  - Purpose is to verify instrumentation selection, effectiveness and robustness
  - CSUN and UIUC will evaluate results
  - Results to serve as basis for UIUC laboratory work

CSUN's Environmental Test Chamber

Chamber Attributes:

10' x 18' x 26'

-20F to 140F

0 to 95% RH

2,500 cfm fresh air

Dyno: 2000 – 5500 lb

Vehicle Selection and Operation-CSUN

- 4-5 vehicles (including pilot) for operational data collection
  - Leased and operated over 12-month period
- Selected to represent a reasonable cross-section of vehicles
  - Possibly mid-size and full-size cars, minivan, pickup
  - Range of MAC configurations (e.g., fixed and variable displacement compressors)
  - Instrumentation optimized from pilot vehicle results
- "Loaned" to selected drivers for 1-month periods
  - Rotated between Northern and Southern California
  - Data logged throughout period

Task of Opportunity: Direct Emissions Measurement -CSUN

- Plan to measure refrigerant charge at beginning and end of project
  - To ensure fully charged systems at start
  - To give a measure of leakage over the project period
- Methodology still under consideration
  - Considering improved remove/recharge methods per SAE

Pilot Vehicle Data Analysis- UIUC

- UIUC will analyze the pilot vehicle data
  - Examine for adequate data rates, especially to capture system transients
  - Optimize instrumentation for type and quantity
- Recommend to CSUN improvements for on-road data vehicles instrumentation

Replicate Pilot Vehicle Data On Bench System- UIUC

- The detailed pilot vehicle data will be replicated on benchtop system
  - Will determine compressor torque requirements (can't be measured on-vehicle)
  - Compressor torque is key to linking a/c operation to engine CO_2 emissions performance

UIUC Lab Test Facilities

Analyze On-Road Data- UIUC

- Data from all vehicles will be analyzed throughout test period
  - Data will be analyzed for quality, consistency
  - Data will be examined for operating characteristics (e.g. fraction of time system is in pulldown operation)
  - Data will be used to guide development of test protocol

Develop Test Protocol Options- UIUC

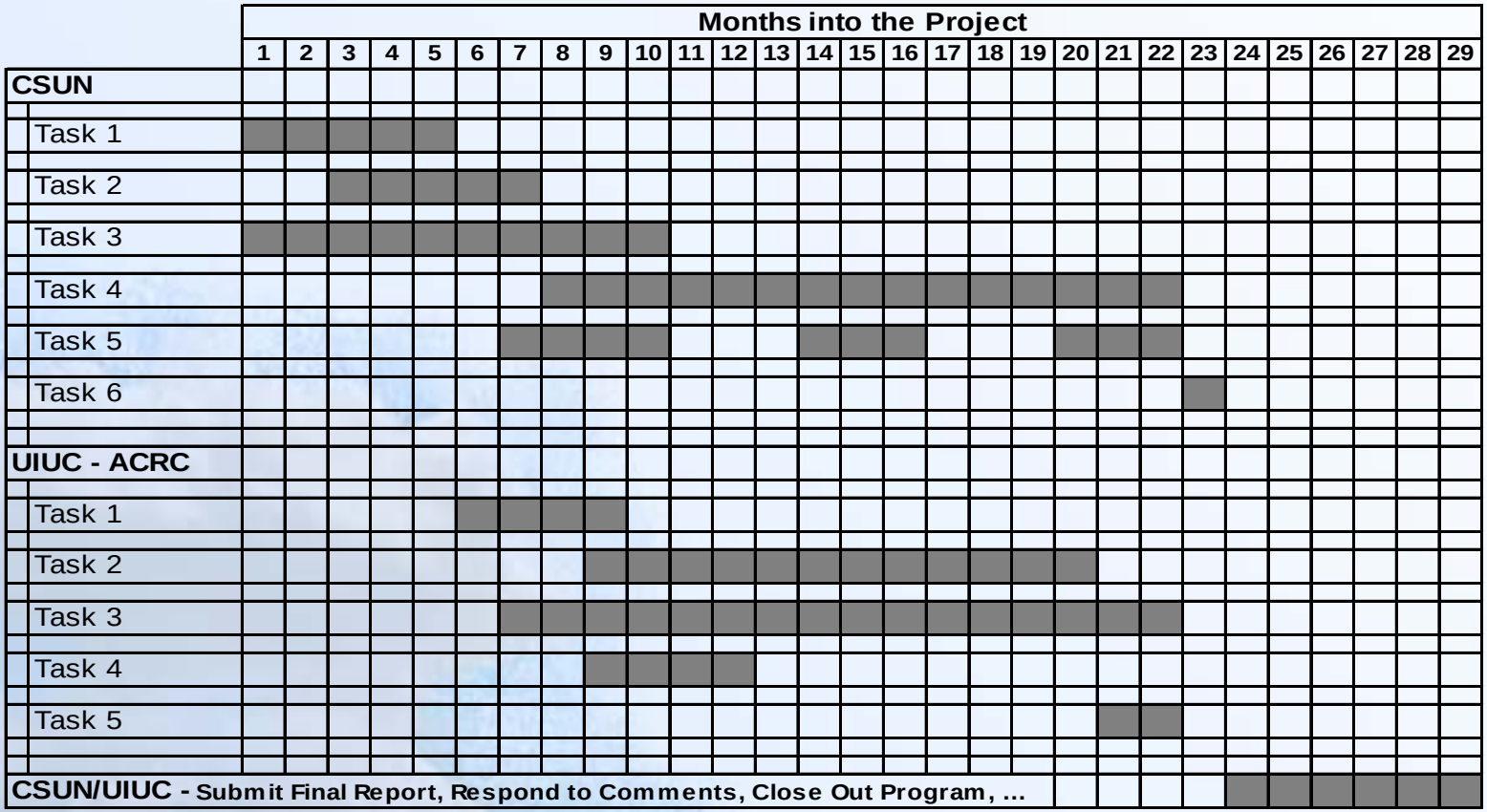
- FTP with a/c on
  - A/C operation based on project data (e.g., control settings)
  - Would require separately measuring then replicating cabin sensible/latent loads, infiltration, etc.
- FTP with a/c off and pulley external load
  - Based on lab evaluation of compressor torque requirements of on-road operation data
  - Would avoid need for cabin load replication

Test Protocol Demonstration-CSUN

- Final proposed protocol will be demonstrated
  - In CSUN's environmental chamber on dyno
  - Proof-of-concept, due to facility limitations
  - May undergo further validation testing at ARB facilities
- Input from global efforts will be fully considered

Project Duration ~2.5 years

Project Timeline



Summary

- The project will develop a significant dataset that will be valuable in understanding how a/c systems operate in California
- These data will aid development of a simple but viable and effective CO_2 emissions test protocol for more accurately determining a/c system indirect emissions