

#### Affect of Windows Down on Vehicle Fuel Economy as compared to AC load

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1



- Rolling the windows down in a vehicle increases the drag and the vehicle fuel consumption
- If the customer turns the AC off to save fuel, and rolls the windows down, fuel consumption may not improve as much as customer expects
- This study examines the affect of windows down on fuel economy and vehicle drag for a full size Sedan and Sport Utility vehicle
- It presents the estimated affect on fuel economy from the drag measurements as well as the measured fuel consumption in a vehicle



#### **GM Aerodynamic Wind Tunnel**







✤Vehicle was run in zero degree yaw and in 12 degree yaw.

Equations were generated to predict estimated force resulting from cross winds with windows down and windows up.

Force was used to calculate estimated fuel economy base on GM internal program.



#### **Aerodynamic test results**



- Tests run at speeds of 50, 80, 110 km/h
- Vehicle in yaw and normal position
- Results compared with and without windows down
- Drag numbers converted to equivalent energy at the wheels based on GM internal analysis





## Comparison of Drag vs AC power



## Comparison of Drag vs AC power



# Comments - Aero vs Compressor Load



- SUV is affected much more by cross winds and windows down as compared to the Sedan.
  - Aero drag differential power between windows down and up is not affected significantly by ambient.
- The cross-over point (compressor power less that aero power) for both the Sedan and the SUV is between 15-20°C ambient.
  - Cross-over is at higher ambient at higher speed.
  - Affect of windows down is greater than running the AC at these lower ambient.



#### **GM Desert Proving Grounds**







- Stabilize the vehicle interior at the test condition.
- Reset the average fuel economy calculator on the driver's information center readout (DIC).
- Run for two laps [16 km.] of the circular track and record average fuel economy at the end of each lap.
  - Change the control settings and vehicle speed and repeat.
  - Tests were run in outside air and re-circulation modes on high blower and Medium blower in outside air, 24°C set point.
- Record all weather data for the time of the test run to use in the fuel economy calculations from the aerodynamic laboratory.



#### Vehicles



Full size Sport Utility

- ➢Engine Size 8.1 liter V8
- AC system description
  - ✓ Swashplate compressor-fixed
  - ✓ Orifice Tube system
  - ✓ Rear Evaporator [2-evaporator system]
  - ✓ Automatic system
- Full size Sedan
  - Engine Size-4.6 liter V8
  - AC system description
    - ✓ Scroll compressor-variable
    - ✓ Orifice Tube system
    - ✓ Automatic system





- Tests run at GM Desert Proving Grounds at speeds of 50, 80, 110 km/h
- Average wind speeds 5-12 km/h
- Test ambient varied from 20-40 deg C
- Tests run with various settings of AC system and with AC OFF and windows down

Only one of these is shown as an example here





Total Energy Consumed by a vehicle is a complex balance of many loads

Drive Train Losses [f(Gear ratios, transmission slip, etc.)]

- >Powertrain efficiency [f(Engine temperature, valve losses, etc.)]
- >Aerodynamic Drag [f(Windows, front end airflow, frontal area etc.)]
- ≻Tire rolling resistance [f(Surface temperature, tire profile, material, etc.)]
- ► Braking [f(Brake drag, friction materials, etc.)]
- >Accessory Loads [f(HVAC, Alternator, Power steering, etc.)]

\*Affects are different for cars and trucks



#### **Fuel Consumption - SUV**





#### **Fuel Consumption - Sedan**





# **Comments/Conclusions**

- Key considerations
  - Results are Dependent on
    - ✓ Vehicle, transmission, and engine efficiency
    - ✓ Powertrain control strategy for fuel economy and drivability
    - ✓ Drive Cycle

- ✓ Ambient Temperature ✓ Tire temperatures
  - ✓ Wind Velocity
- ✓ And others Road Testing variation requires multiple runs and has significant variation. Precise control of conditions required.
- Windows down can be a significant real impact on fuel consumption
  - Varies as a function of wind velocity and average direction
  - More of a factor in lower drag vehicles [20% on sedan vs 8% on SUV]
  - Penalty of AC ON at higher ambient as compared to Windows down is not significantly different for SUV or Sedan [5-10%]

