

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

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# Background

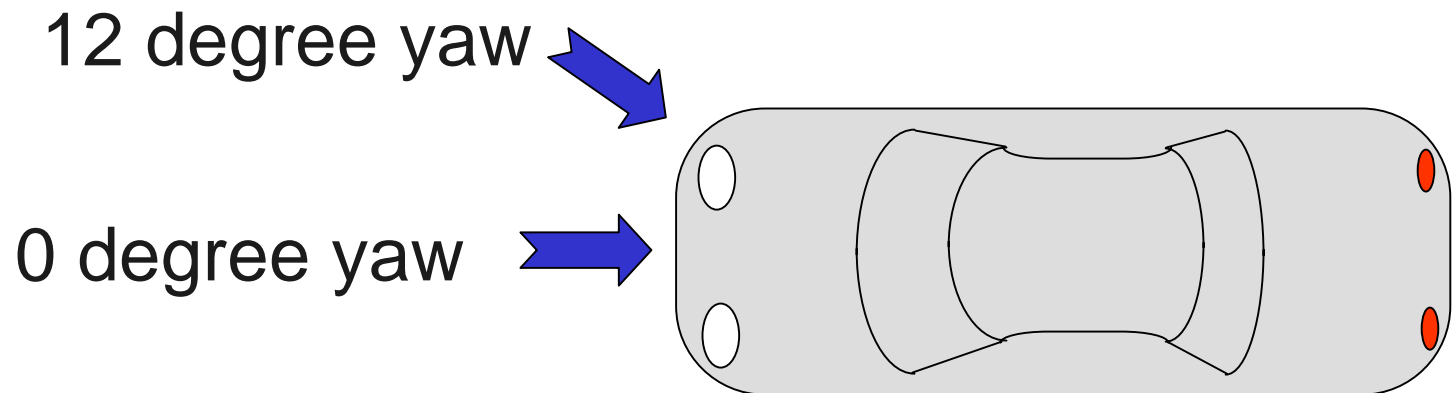


- ❖ Rolling the windows down in a vehicle increases the drag and the vehicle fuel consumption
- ❖ If the customer turns the AC off to save fuel, and rolls the windows down, fuel consumption may not improve as much as customer expects
- ❖ This study examines the affect of windows down on fuel economy 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





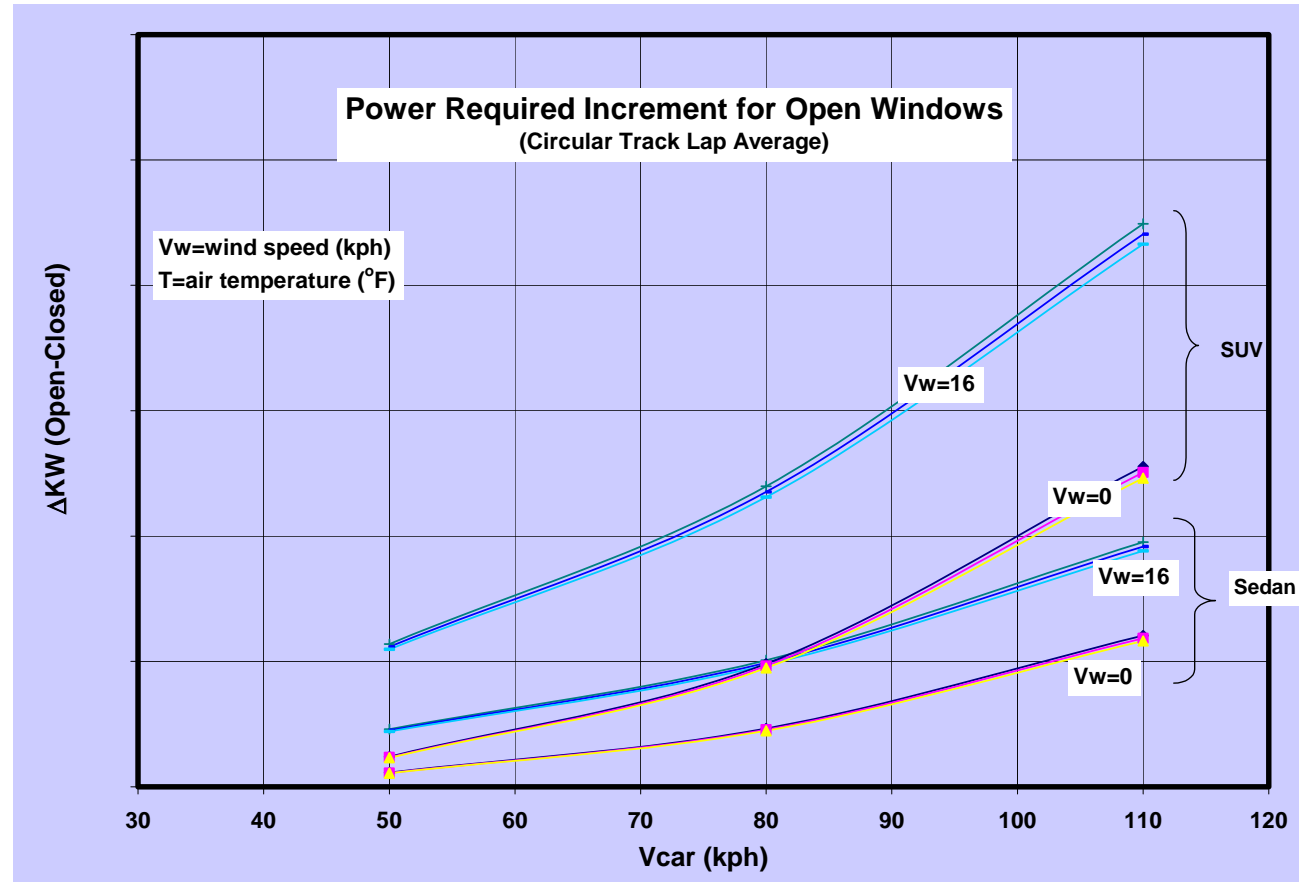
- ❖ Vehicle was run in zero degree yaw and in 12 degree yaw.
- ❖ Equations were generated to predict estimated force resulting from cross winds with windows down and windows up.
- ❖ Force was used to calculate estimated fuel economy base on GM internal program.



# Aerodynamic test results



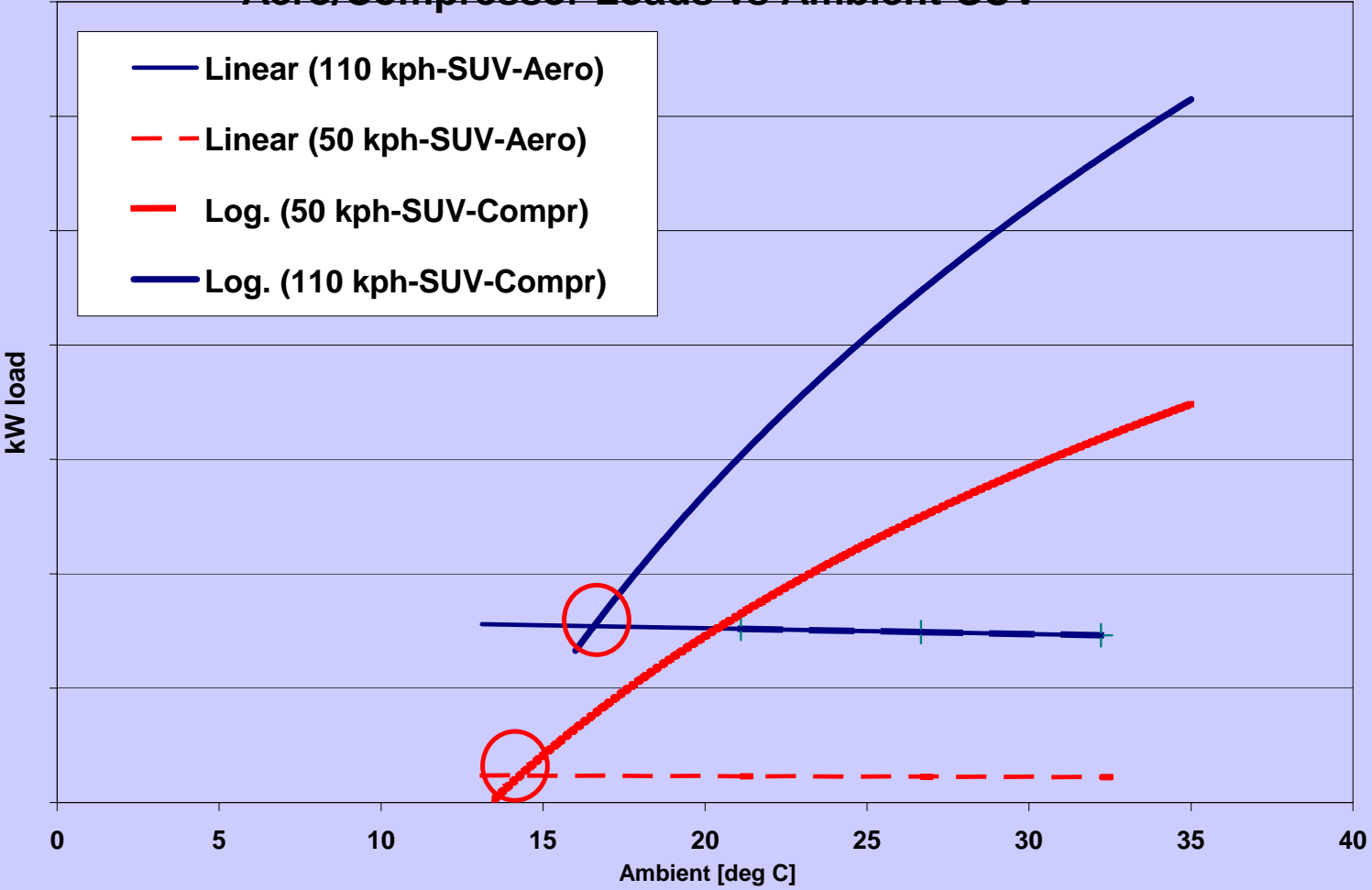
- ❖ Tests run at speeds of 50, 80, 110 km/h
- ❖ Vehicle in yaw and normal position
- ❖ Results compared with and without windows down
- ❖ Drag numbers converted to equivalent energy at the wheels based on GM internal analysis



# Comparison of Drag vs AC power



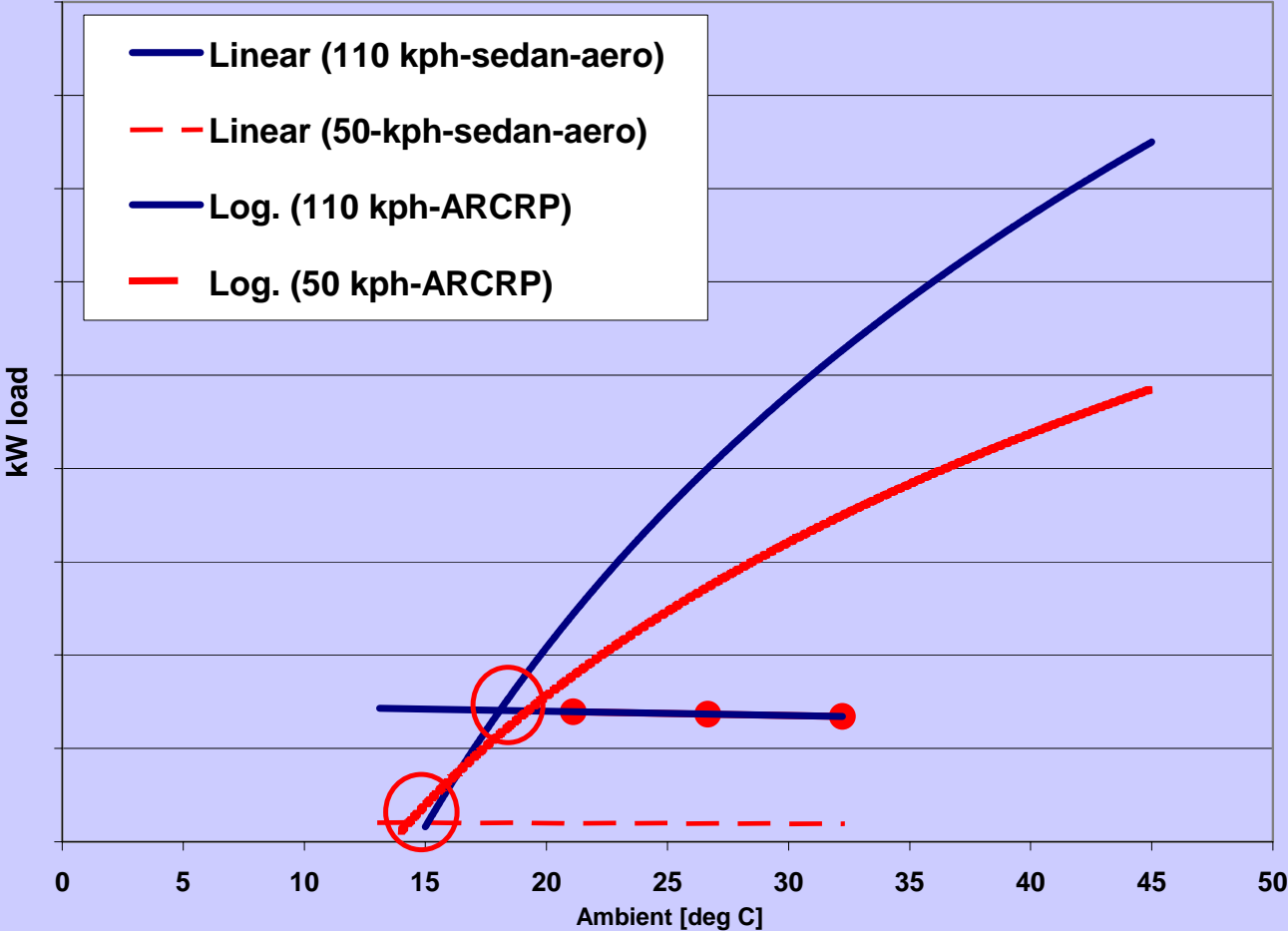
### Aero/Compressor Loads vs Ambient-SUV



# Comparison of Drag vs AC power



### Aero/Compressor Loads vs Ambient-Sedan

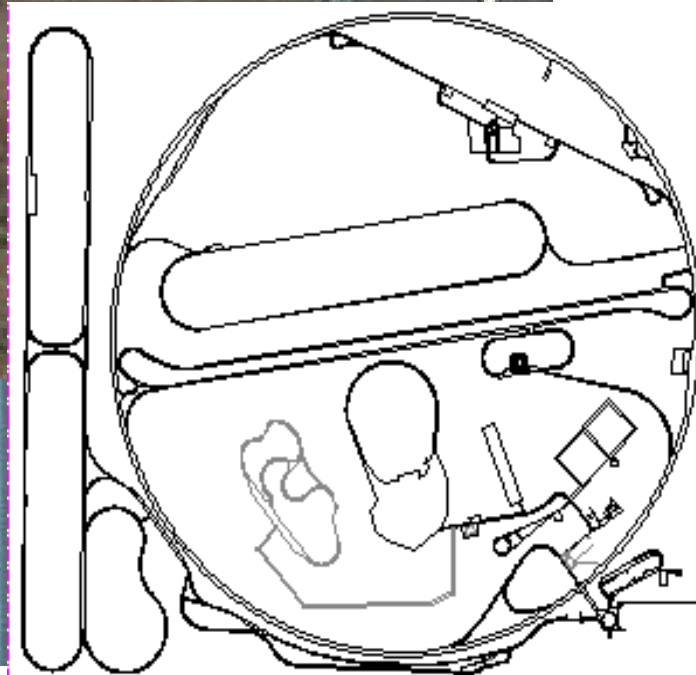


# Comments - Aero vs Compressor Load



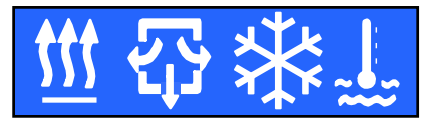
- ❖ SUV is affected much more by cross winds and windows down as compared to the Sedan.
  - Aero drag differential power between windows down and up is not affected significantly by ambient.
- ❖ The cross-over point (compressor power less than aero power) for both the Sedan and the SUV is between 15-20°C 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.



## ❖ 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

# Road Test Results



- ❖ 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

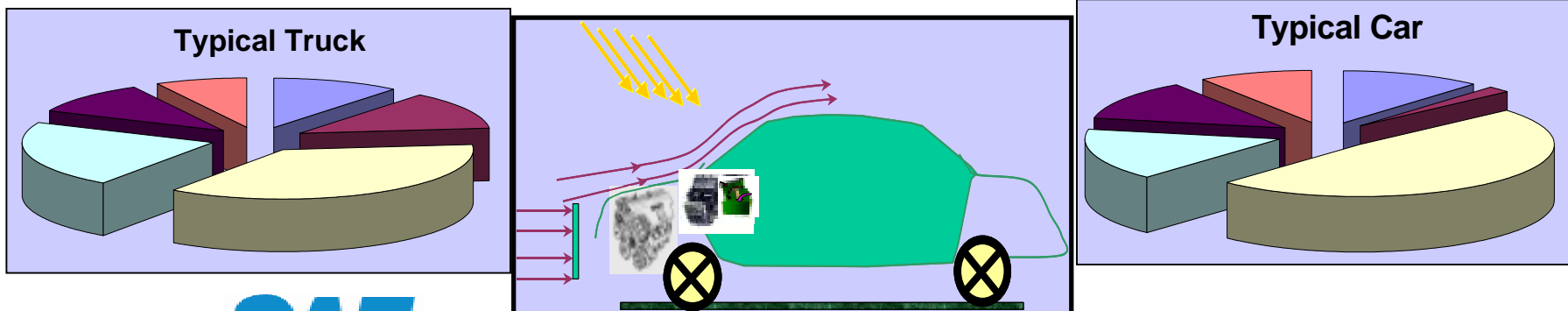
# Vehicle Energy Balance



❖ 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.)]

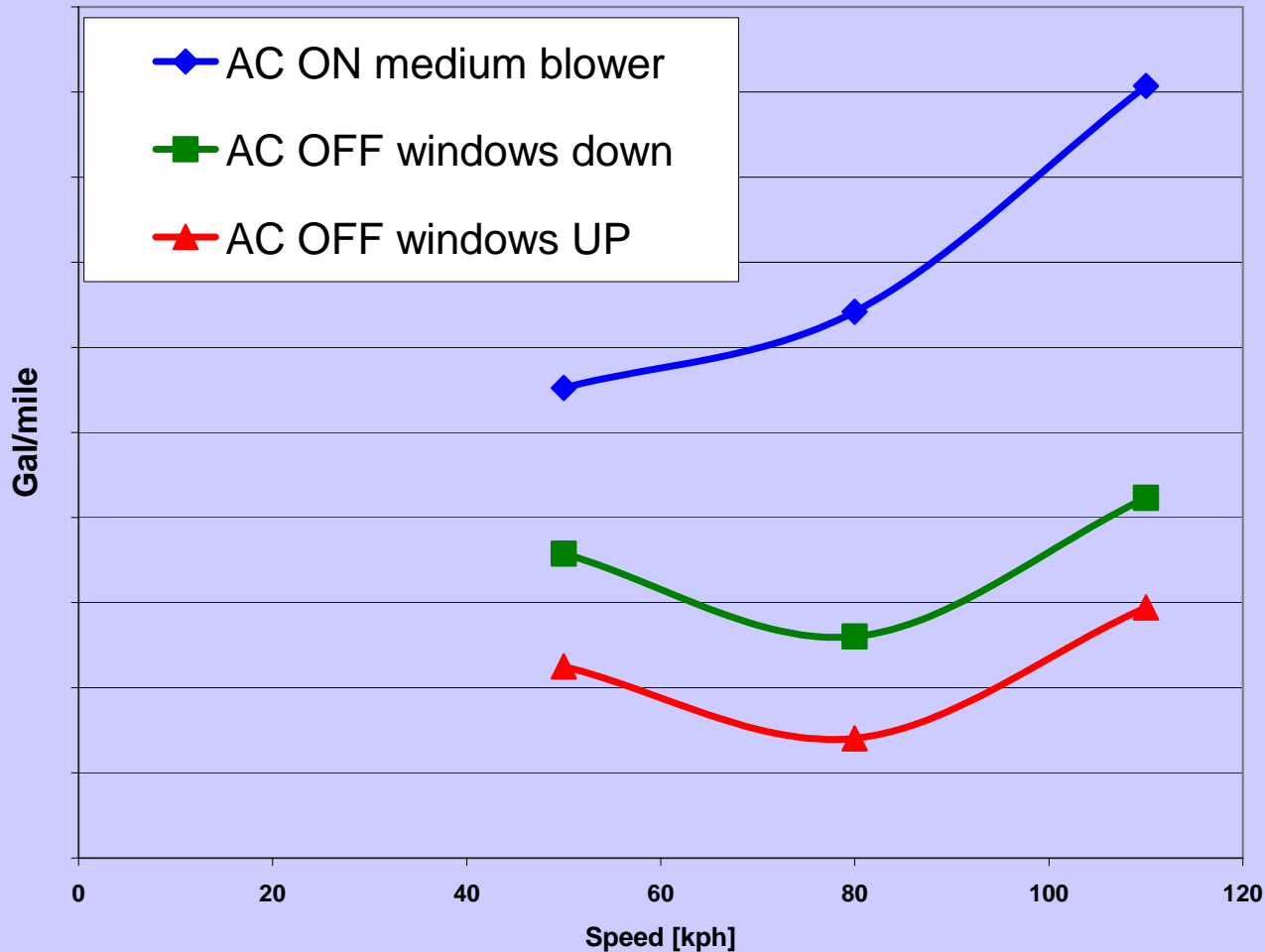
❖ Affects are different for cars and trucks



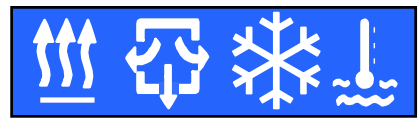
# Fuel Consumption - SUV



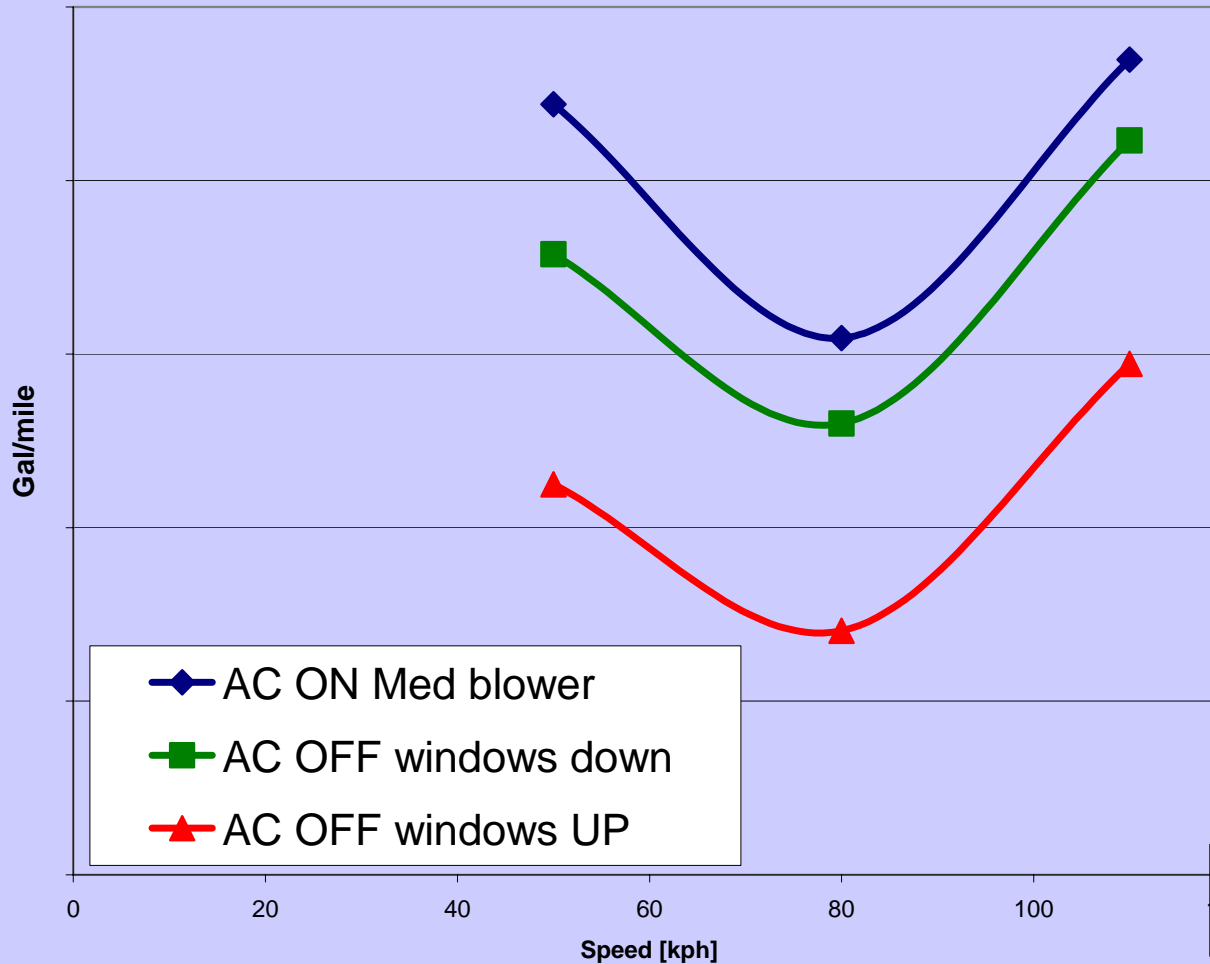
Fuel Consumption at ~30 deg C - SUV



# Fuel Consumption - Sedan



Fuel Consumption at ~30 deg C - Sedan



Note: Sedan shifted to 3<sup>rd</sup> gear at 50 kph



## ❖ 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%]