# THE MOVES APPROACH TO MODELING EVAPORATIVE EMISSIONS

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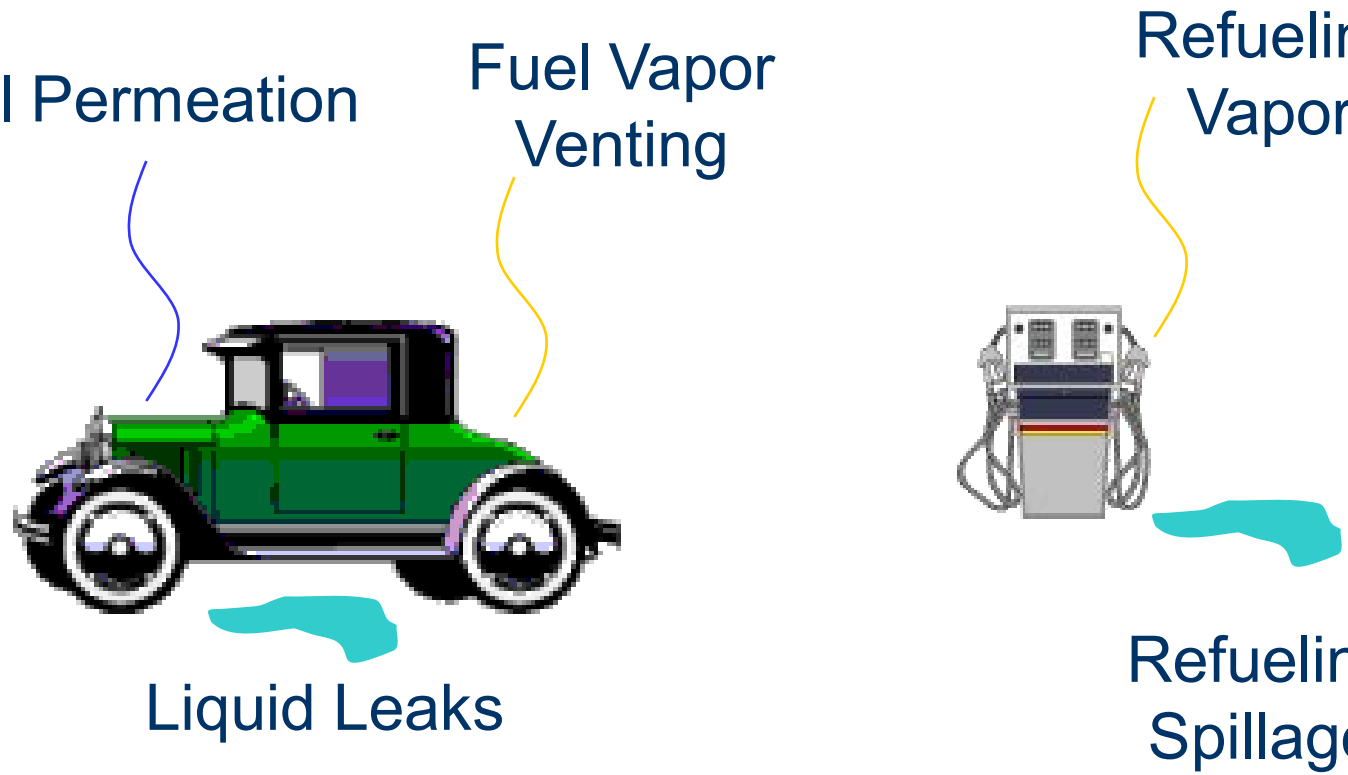
# Acknowledgements


- Connie Hart, EPA
- Prashanth Gururaja, EPA
- Jarrod Brown, EPA
- David Brzezinski, EPA
- John Koupal, EPA

# Evaporative emissions a combination of many processes



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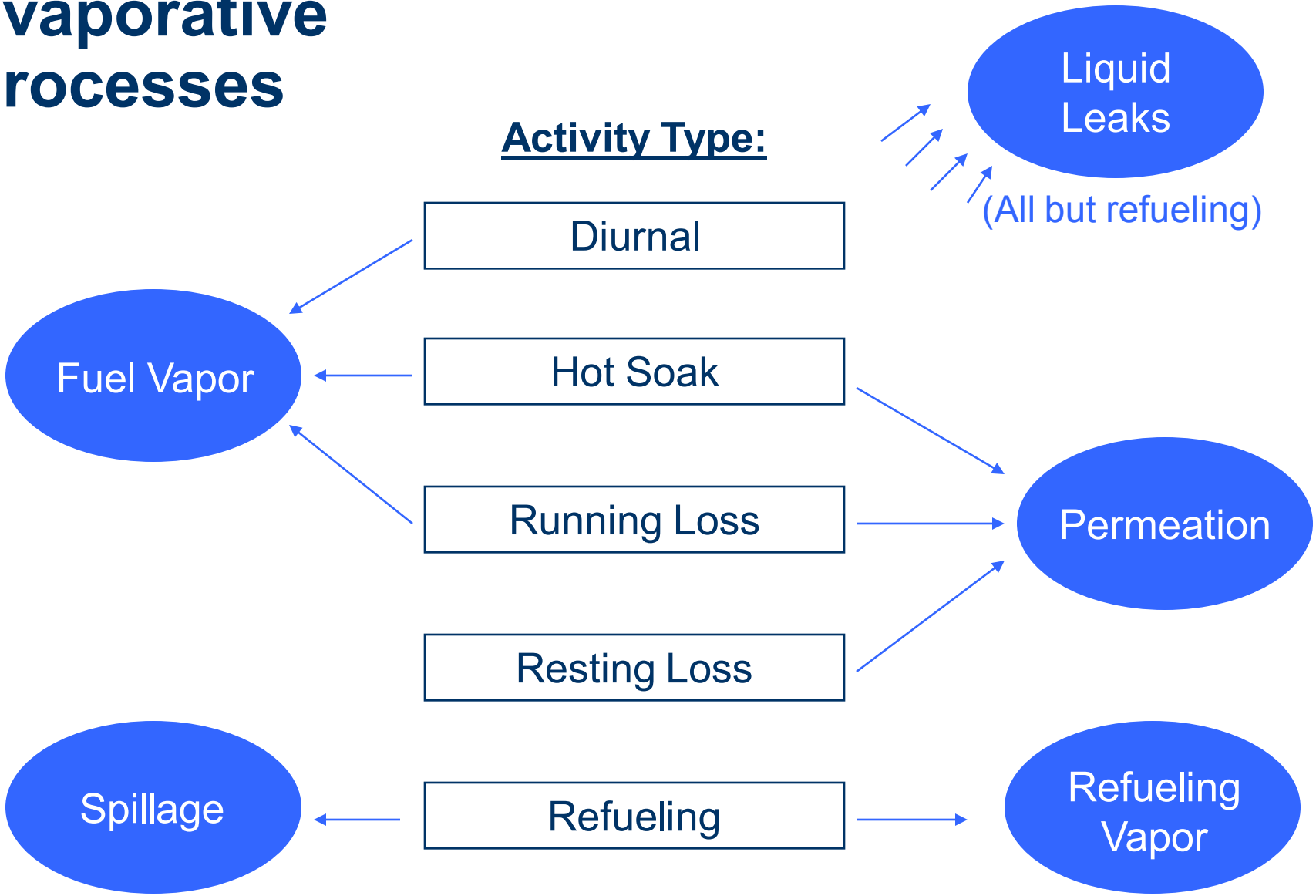
# Objectives for MOVES evaporative component

- **Use most recent data**
  - CRC E-77 suite of programs
- **Better allocation of evaporative emissions by space and time**
  - Evaporative emissions no longer coupled to VMT
- **Dynamically consistent activity information**
  - Trip starts, trip ends, soak times, trip times by hour
- **Explicit treatment of Ethanol permeation**
  - Important for Renewable Fuel Standard (RFS)

# Mapping Evaporative Processes



# Activity Approach

- **Time basis for activity**
  - Source hours parked (SHP)
    - Split into “cold soak”, “hot soak” modes
  - Source hours operating (SHO)
    - For “running” mode
- **Allocated independently of VMT**
  - Distribution of hours parked (when, how long) calculated within MOVES via sample trip data
  - Geographic allocation factor can account for commute and parking patterns

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# Fuel Tank Temperature is Central

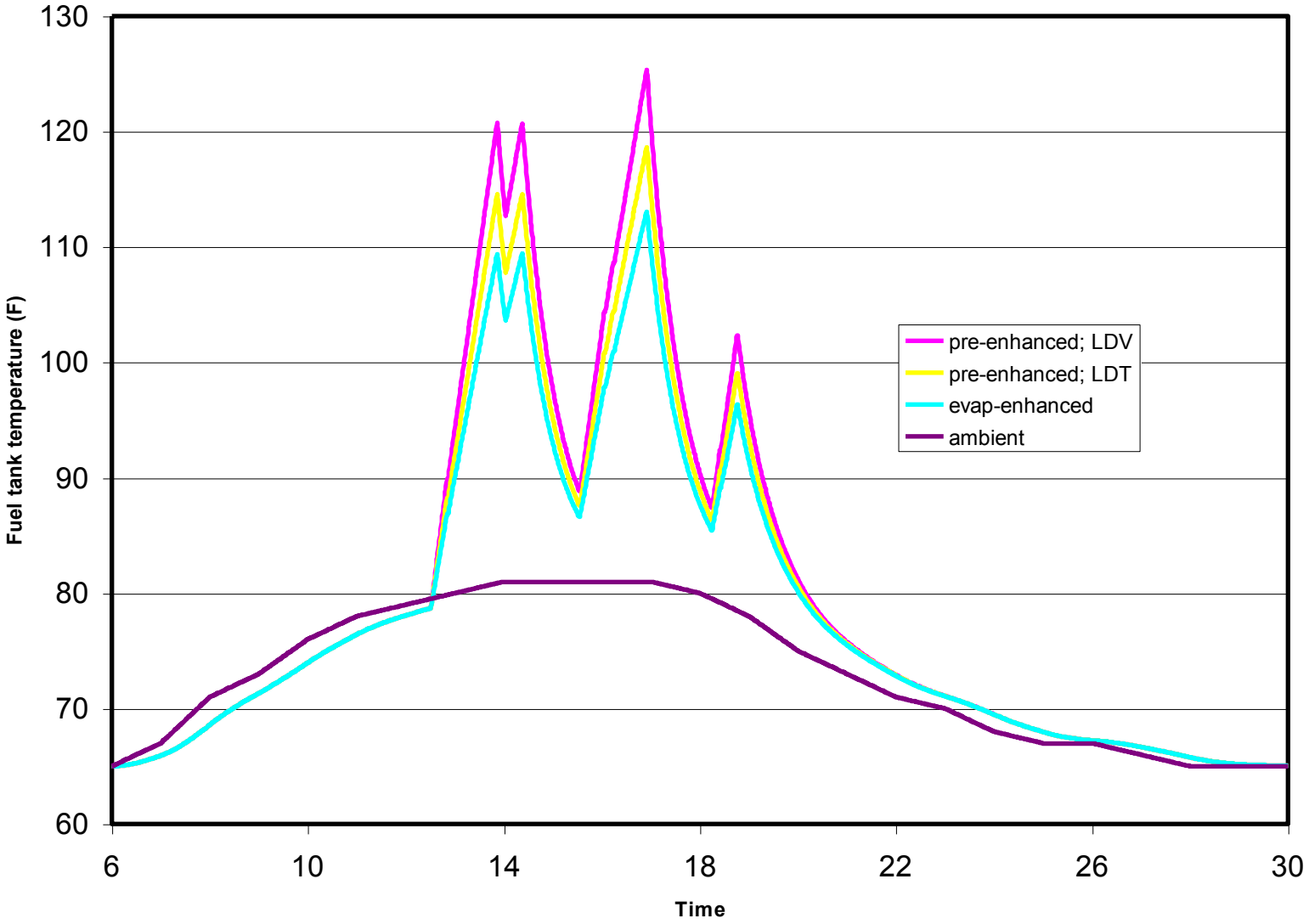
- Fuel temperature main driver for permeation and vapor venting emissions
- Depends on day-to-day vehicle operating pattern
- MOVES estimates real-world fuel temperature based on sample trips
- Hourly averages by mode (cold soak, hot soak, operating) used to calculate emissions

# Fuel Tank Temperature Algorithm

- **Data and background obtained from**
  - CRC E-35
  - SAE 930078 “Running Loss Temperature Profiles”
  - Certification Fuel Tank Temperature Profiles
- **Parked (cold soak & hot soak)**
  - tank temp related to ambient by linear, first-order differential equation
  - Initial temp for each soak needed
    - Ambient if start of day
    - Ending temperature of previous trip if hot soak
- **Operating**
  - Depends on length of trip, model year group, vehicle type, temperature at end of previous soak period
  - The degree of temperature rise varies inversely with start temp

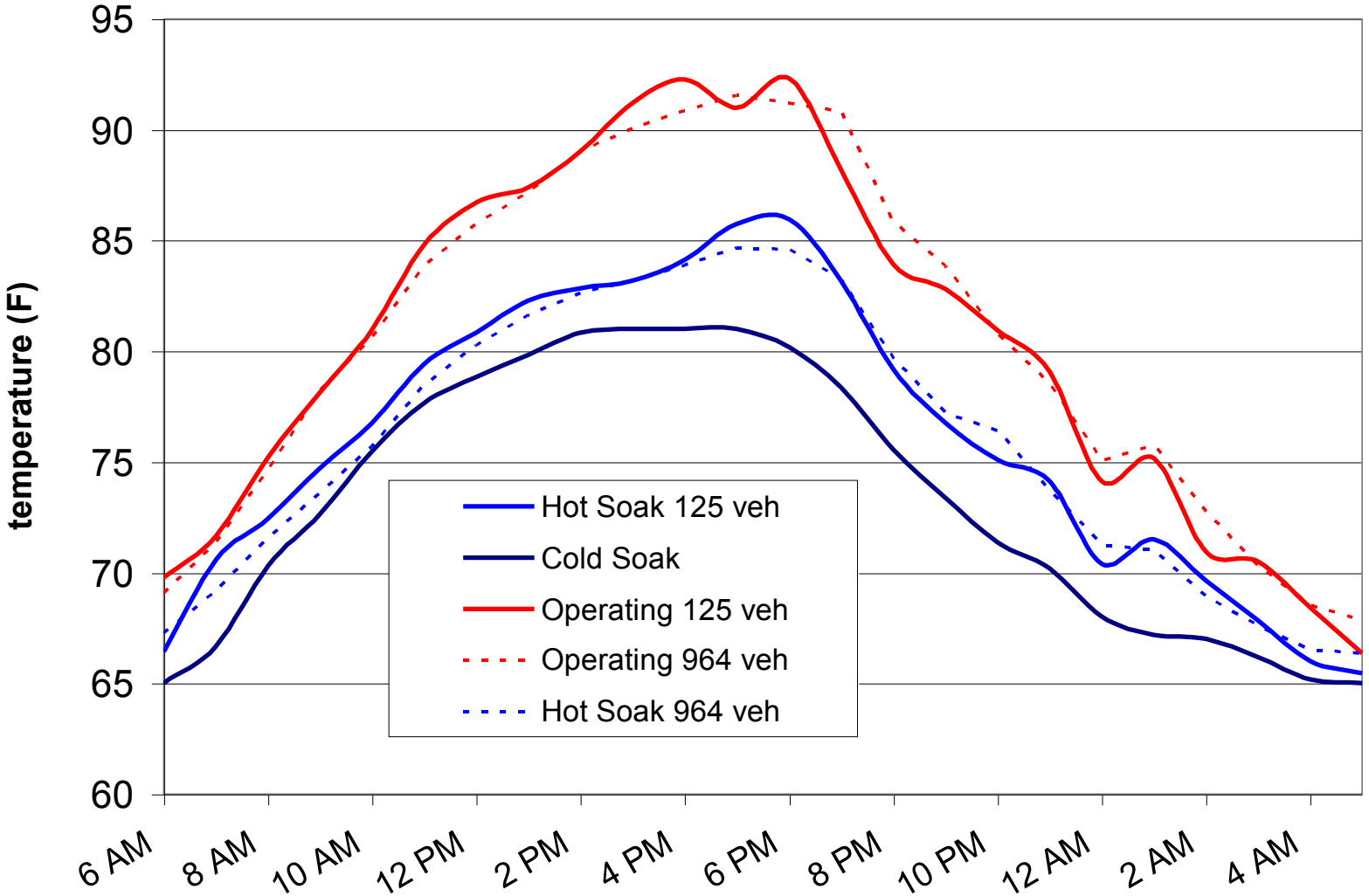
# Estimated Fuel Tank Temperature Profile For a Single Vehicle

## Washtenaw County Typical July Day



# Estimated Average Fuel Tank Temperature Based on Sample Trips

## Washtenaw County Typical July Day



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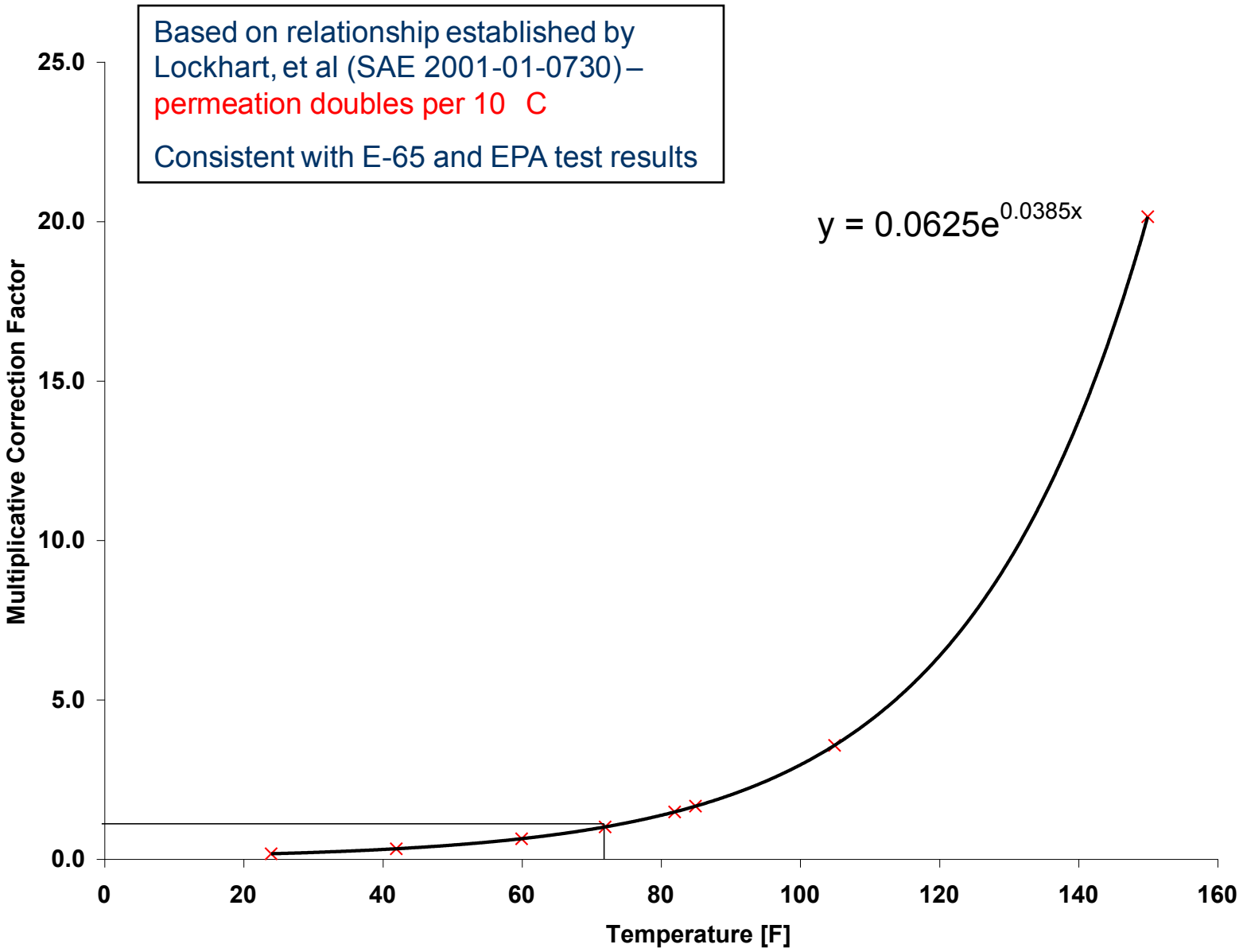
# Evaporative Emission Sources

- **Historical EPA Testing (Mobile Source Observation Database)**
- **Recent CRC Programs**
  - E-9, E-35, E-41, E-65, E-77
- **EPA Compliance Data (enhanced evap)**
- **E-77 suite of programs**
  - Pilot program to focus on aging enhanced vehicles
  - Includes permeation testing, “off-cycle” diurnal
- **Ethanol effects on permeation**
  - Updated in MOVES2010a with E-77-2 and 2b data

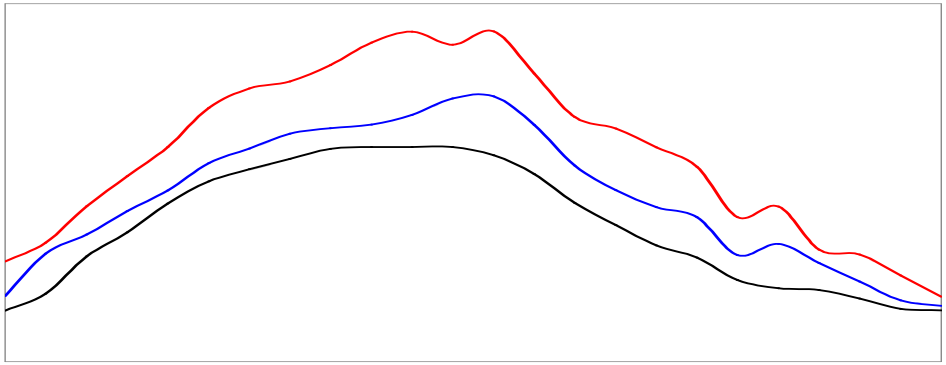
# Permeation

- **Base rates @ fuel temp = 72**
  - Same base rate for Cold, Hot soak, and Operating
- **Adjustments: fuel temp, EtOH**
  - Data provided from CRC E-77 programs

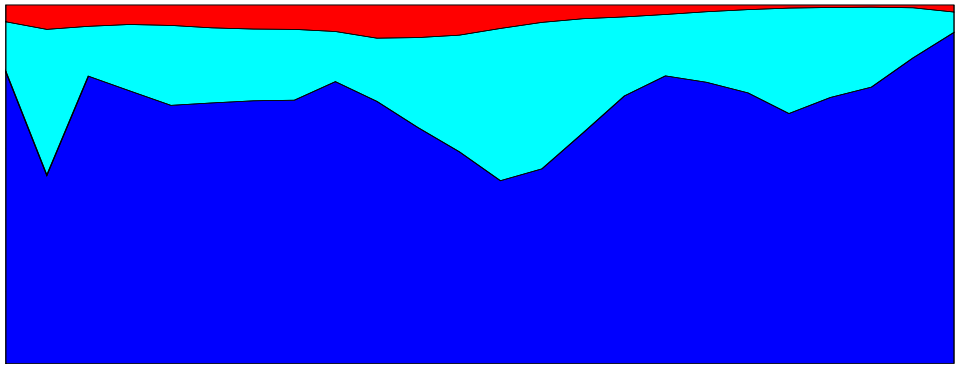
# Permeation Tank Temperature Adjustment



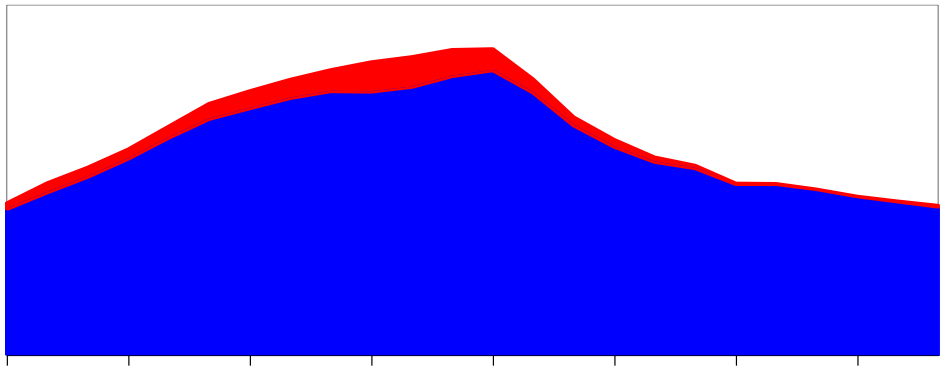
# Illustration of Permeation Calculation - Washtenaw County Example



Average Fuel Temp
**operating**
**hot soak**
**cold soak**



Activity Distribution
**operating**
**hot soak**
**cold soak**




Total Permeation HC
**operating**
**parked**

# Fuel Vapor Venting

- **Hot Soak & Running**
  - Average available gram/hour emission test results
  - Hot Soak Emissions$_{hour}$ = SHP * hot soak rates
  - Running Emissions$_{hour}$ = SHO * running rates
- **Cold Soak (diurnal)**
  - Tank Vapor Generated (TVG) ≈ f (Δ temp, RVP, EtOH)
    - Reddy, SAE Paper 892089
  - Cumulative HC emissions ≈ f (TVG)
  - Cold Soak Emissions$_{hour}$ =

$$SHP * \sum_{\text{Initial hour}} (cumHC_{hour} - cumHC_{initial\ hour}) * \text{fraction of soaks starting in initial hour}$$

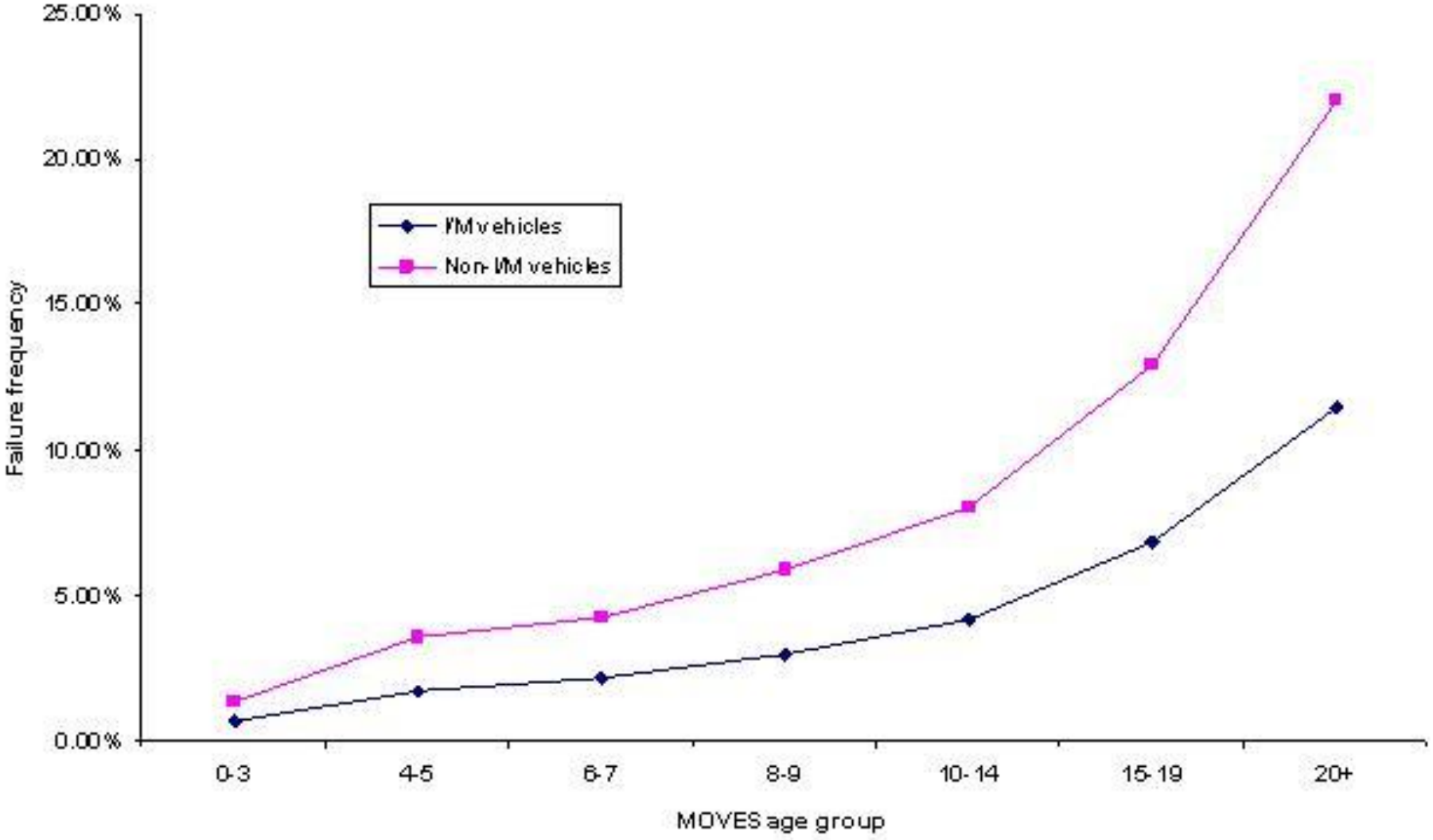
# Cold Soak (Diurnal) Cont.

- **Tank Vapor Generated (TVG)**
- **Tank Vapor Vented (TVV)**
  - Canister Breakthrough
  - Vapor Leaks
  - Other non-liquid fuel vapor losses

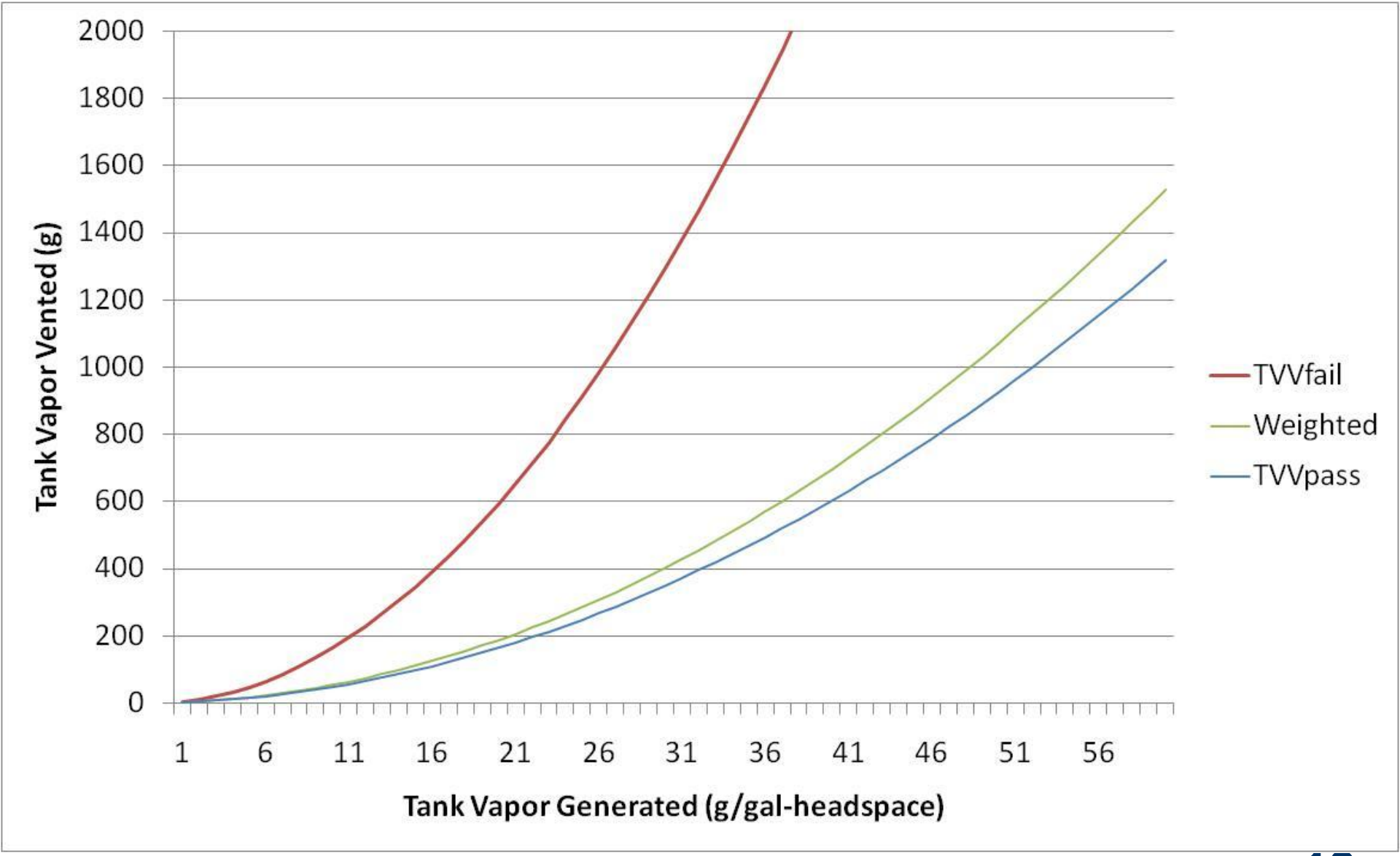
# Fuel Vapor Venting for I/M

- **Two base rates for Cold Soak and Hot Soak**
  - Non I/M and I/M
- **Develop I/M weighting based on types of tests performed at I/M stations**
  - pressure test failure, gas cap failure & non-gross liquid leak rates for pre-OBD vehicles
    - Sources: BAR roadside studies, CRC E-9/35/41, API/CRC liquid leak survey

# Evaporative failure frequencies for I/M and non-I/M vehicles in the Phoenix area. This figure shows model years 1978 to 1995.



# Illustration of MOVES Tank Vapor Venting Rates and Weighting



# Liquid Leaks

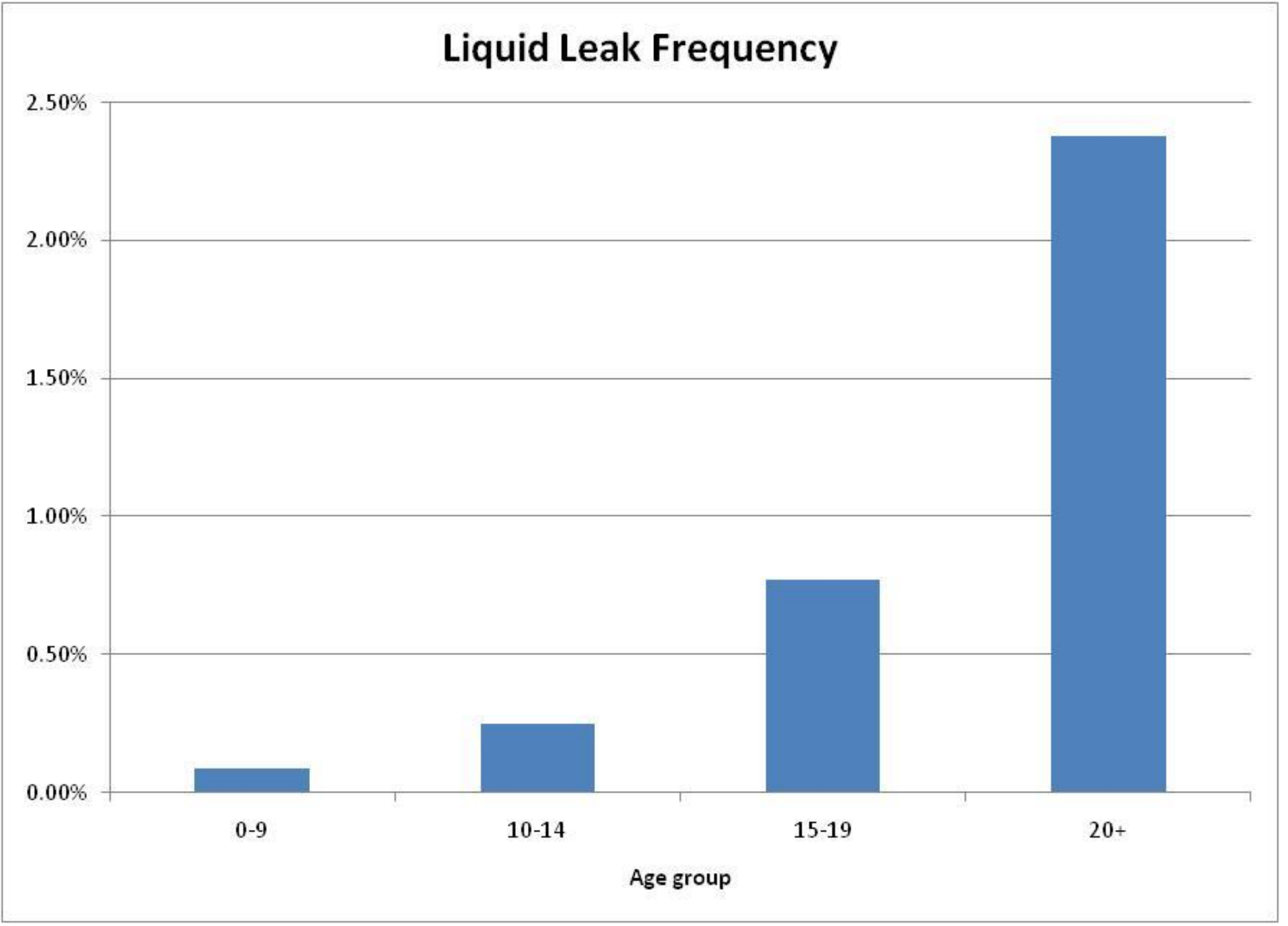
- **Gross leaks – i.e. dripping fuel**
  - Less severe leaks accounted for in Vapor Venting rates
- **Small frequency but very high emissions**
- **Rates in MOVES account for absolute emissions & frequency**
- **Absolute emission rates from confirmed leakers found in 1990's CRC evap programs**
  - Independent of model year (a drop is a drop)

| Cold Soak g/hr | Hot Soak g/hr | Operating g/hr |
|---|---|---|
| 9.85 | 19.0 | **178** |

# Liquid Leak Frequencies

- **Frequencies do depend on age**
- **Data sources:**
  - API study (1997)
  - California Bureau of Automotive Repair
    - Smog Check program conducts visual inspection

| Age 0-9 | Age 10-14 | Age 15-19 | Age 20+ |
|---|---|---|---|
| 0.09% | 0.25% | 0.77% | 2.38% |

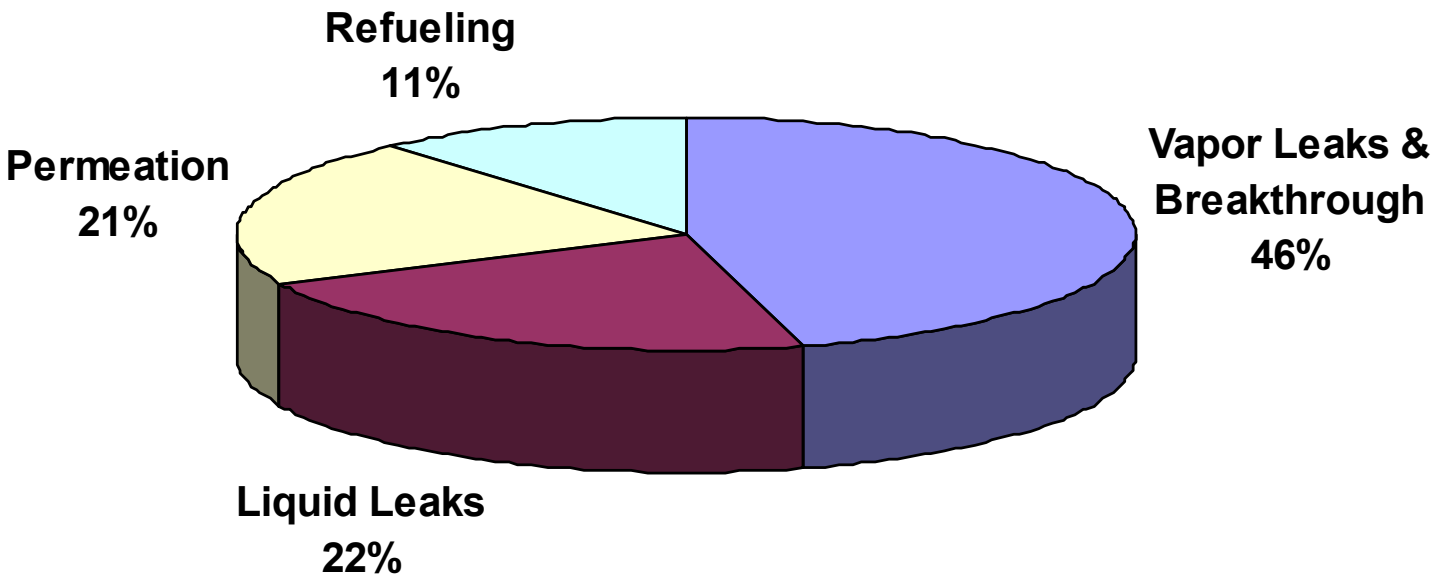

Liquid Leak Frequency
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
0-9
10-14
15-19
20+
Age group

# Refueling

- **Tank Vapor Displacement & Spillage**
- **g/gallon emission rates * fuel consumption**
  - allows refueling emissions to reflect changes in fuel consumption as estimated by MOVES
- **Adjusted by model year (Onboard Refueling Vapor Recovery) and location (Stage II Vapor Recovery)**

# Projected Evap Inventory Breakdown

## July 2022 Ozone Episode
## Wilmington, NC (modeled with 7 RVP E10)




Source: MOVES2010a

# Future MOVES Evap

- **Key improvements**
  - Model vapor venting to reflect multiple day diurnals
    - How Tier 2 vehicles load and break through canister
    - How many vehicles are soaking for extended diurnals
  - Refine deterioration rates for Tier 2 vehicles
    - Vapor leaks (emission rate, and prevalence)
    - Liquid leaks (emission rate, and prevalence)
  - Understand insufficient vapor canister purge
    - How do vehicles purge the canister during real world driving?

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# Evaporative Emissions Modeling in MOVES

- **Located at:**
  - http://www.epa.gov/otaq/models/moves/movesback.htm
- **Contact:**
  - Hawkins.David@epa.gov
  - 734-214-4760

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# Thank You!