Technology Demonstration of a Prototype Low Carbon Monoxide Emission Portable Generator

GIE+Expo, Louisville, KY
October 26, 2012

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Overview

- What is the U.S. CPSC?
- Generators: Why CPSC Is Concerned
- CPSC Portable Generator Project History
- Technology Demonstration
- Conclusions
- Q & A

U.S. CPSC

- CPSC is an independent regulatory agency created "to protect the public against unreasonable risks of injury associated with consumer products."[1]
  - Develops voluntary consensus safety standards in cooperation with industry
  - Adopts and enforces mandatory standards or bans consumer products if no feasible voluntary standard would adequately protect the public
  - Obtains the recall of products and arranges for their repair, replacement, or refund
  - Conducts research on emerging and potential product hazards
  - Informs and educates consumers through the media, state and local governments, private organizations, and responding to consumer inquiries

[1] Section 2(b)(1) of the Consumer Product Safety Act, 15 U.S.C. §2051(b)(1).

What Is a Consumer Product?

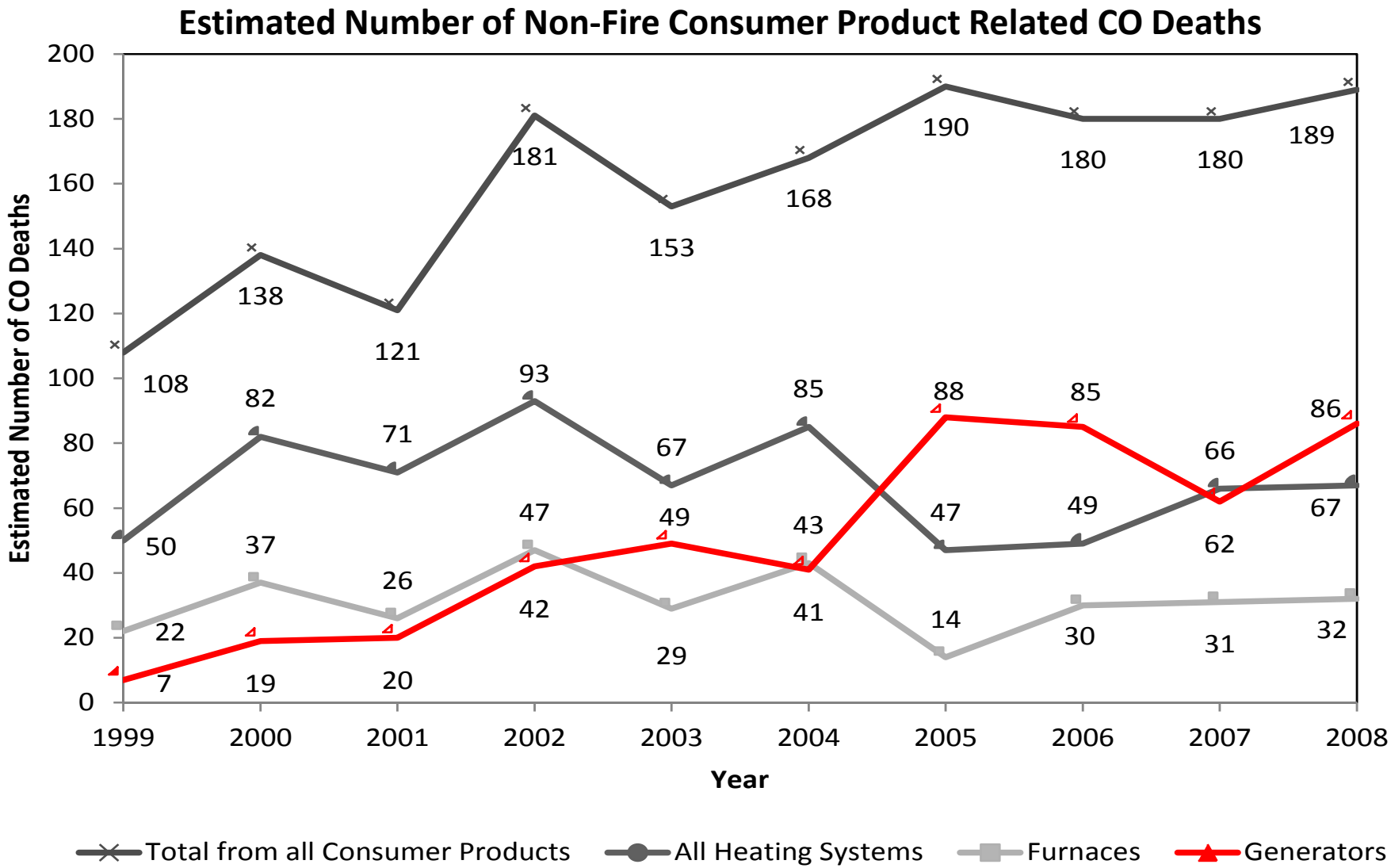
- Jurisdiction over thousands of consumer products under the Consumer Product Safety Act

- Excludes some products covered by other federal agencies, such as:
  - Cars and related equipment (NHTSA)
  - Boats (Coast Guard)
  - Airplanes (FAA)
  - Food, drugs, medical devices, cosmetics (FDA)
  - Firearms (ATF)
  - Pesticides (EPA)
  - Tobacco Products (ATF)

Four Types of Safety Concerns

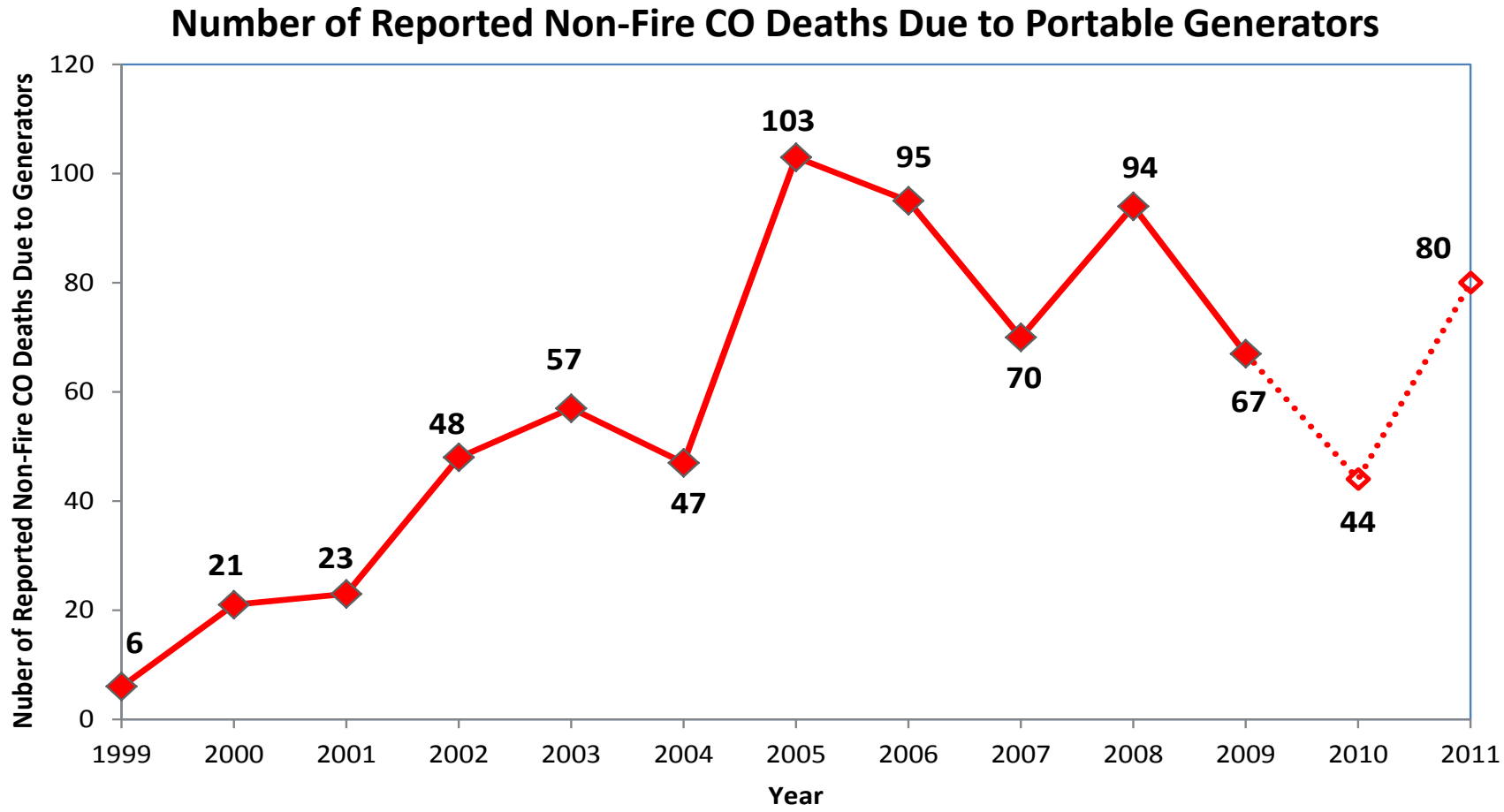
- Product fails to comply with a *mandatory safety standard or ban* under the CPSA
- Product fails to comply with *voluntary standards* relied upon by the Commission
- Product *contains a defect* which could create a *"substantial product hazard"*
- Product creates an *"unreasonable risk"* of serious injury or death

Generators: Why CPSC Is Concerned



Source: Hnatov, Matthew, *Non-Fire Carbon Monoxide Deaths Associated with the Use of Consumer Products, 2008 Annual Estimates*, U.S. Consumer Product Safety Commission, Bethesda, MD, December 2011

More Data Supports Our Concern…



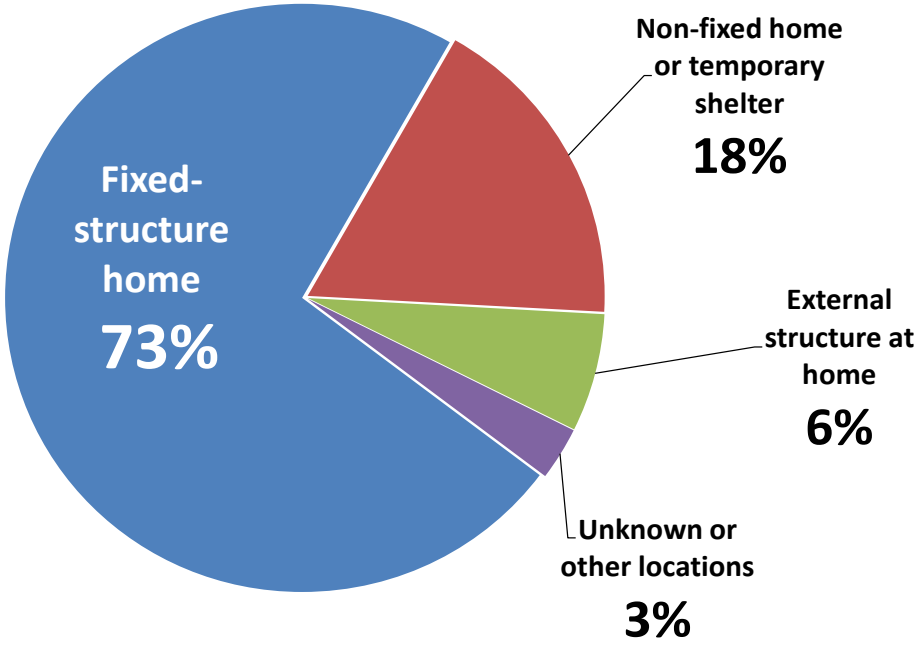
Reporting for years 2010 and 2011 is considered incomplete and islikely to change in future reports.

Reporting for years 1999-2009 is considered largely complete but may change to a relatively small extent in future reports.

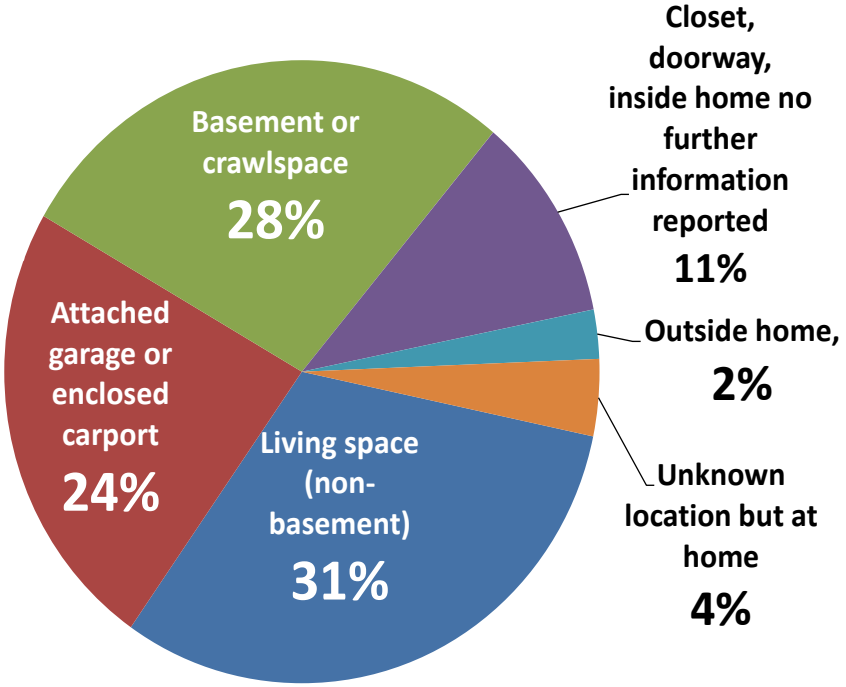
Source: Hnatov, Matthew, *Incidents, Deaths, and In-Depth Investigations Associated with Non-Fire Carbon Monoxide from Engine-Driven Generators and Other Engine-Driven Tools, 1999-2011*, July 2012.

Some of Our Hazard Analysis…

Location where incident occurred



Specific location of generator in incidents that occurred in fixed-structure homes



CPSC Portable Generator Project History

- 2003: Began participation as nonvoting member on STP for UL 2201, to advocate for requirements to address CO hazard
- 2004: Hosted roundtable to discuss hazard and solicit ideas
- 2006: Released staff report, "Review of Portable Generator Safety" and briefed Commission, recommending that most reliable way to reduce the CO poisoning risk is to reduce CO emission rate

  Staff's goal is not to reduce the CO emission rate to make generators safe to run indoors but, to reduce it enough, such that CO poisoning symptom onset is delayed, and the rate of progression of worsening symptoms is significantly reduced to provide a longer time interval for exposed occupants to escape before being incapacitated.
- 2006: Commission voted to approve ANPR to investigate technologies to reduce hazard
- 2007: FR for mandatory label, effective May 2007
- 2006 to present: Performed, documented, and released report on technology demonstration

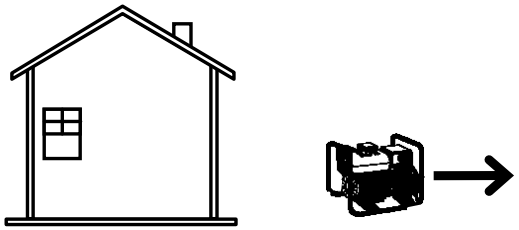
Mandatory Label

⚠ DANGER

Using a generator indoors CAN KILL YOU IN MINUTES.

Generator exhaust contains carbon monoxide. This is a poison you cannot see or smell.

NEVER use inside a home or garage, EVEN IF doors and windows are open.



Only use OUTSIDE and far away from windows, doors, and vents.

2-Part Technology Demonstration

Develop Prototype

Durability Test Engine in Generator

Conduct Certification Emission Testing at End of Life

Operate Generator in Attached Garage

Model Health Effects on Occupants

Determine Time Interval for "Egress"

Prototype Development

University of Alabama

Design specifications:

- Adapt existing emission control technology on 5.0 kW generator
- 30 g/kW-hr target CO emission rate
- Do not negatively impact engine power output, engine durability, maintainability, fuel economy, and risk of fire/burn
- Maintain compliance with EPA emission standard to which engine was originally certified

Prototype configuration:

- Modified 8.2 kW (11 hp) Class II engine with 500-hour rated useful life, certified to EPA Phase 2 standard
- Adapted EMS with closed loop EFI
- Calibrated for stoichiometric (14.6) AFR at all loads
- Integrated 3-way catalyst, primarily to target NOx reduction, into shrouded muffler

Durability Testing

Load Profile derived from EPA 6-mode test cycle in 40 CFR part 1065

Mode	1	2	3	4	5	6
Engine Power	100%	75%	50%	25%	10%	No load
Weight Factor	0.09	0.20	0.29	0.30	0.07	0.05

Hourly Load Profile Applied Throughout 500-hour Durability Program

Mode	1	2	3	4	5	6
Load Bank Setting (kW)	5.5*	4.7+	3.2+	1.5+	0.6+	No resistive load
Duration (minutes)	5.5	12.0	17.5	18.0	4.0	3.0

** highest sustainable load without tripping generator's circuit breaker (found to be 500 watts greater than generator's advertised rated power output.)*

+ derived by applying alternator efficiency curve to engine's rated power of 8.2 kW

Durability Testing Conclusions

- After 500 hours, compared to the unmodified OEM unit, the prototype demonstrated:
  - 93% reduction of CO
  - 30% reduction of HC+NOx
  - 20% reduction in average fuel consumption
  - Surface temperature of prototype's muffler shroud was 110°C max, compared to 434°C for the OEM's unshrouded muffler surface.

- On the prototype engine:
  - 220°C max cylinder head temperature, below the engine manufacturer's limit
  - Exhaust manifold gas temperature at all modes was within the catalyst manufacturer's recommended operating range.

End-of-Life Emission Testing

Intertek Carnot Emission Services

- Facility is lab-to-lab correlated with EPA and major manufacturer emission test facilities.

- Conducted exhaust emission testing in accordance with EPA regs to verify Phase 2 compliance on:
  - Prototype engine with muffler with integrated, aged catalyst
  - Prototype engine with muffler without catalyst

- Performed tests with the engine installed in the generator
  - Determined the engine power achieved for each mode during durability program

End-of-Life Emission Testing Conclusions

- With catalyst muffler:
  - HC+NOx was 6.7 g/kW-hr → 45% below Phase 2 standard
    16% below Phase 3 standard
  - CO was 6.0 g/kW-hr → 95% CO emissions reduction compared to the published certification data for the unmodified engine
  - <240°C max cylinder head temperature, below the engine manufacturer's limit
  - Exhaust manifold gas temperature at all modes was within the catalyst manufacturer's recommended operating range
  - Delivered a maximum power of 7.9 kW, within 0.3 kW of the advertised rated power for the unmodified OEM carbureted engine

End-of-Life Emission Testing Conclusions

- Muffler w/o catalyst:
  - HC+NOx was 13.0 g/kW-hr → above Phase 2 standard
  - CO was 28.1 g/kW-hr

- Correlation of engine fuel consumption in the generator to the dynamometer revealed max sustainable load on generator was 75% of full engine power.

Dynamometer testing at mode 1 does not represent consumer use. The CO emission rate of the engine at the loads it achieves in the product is what is important. The prototype engine produced less than 25 grams/hour of CO at each mode of the load profile applied to the generator.

2-Part Technology Demonstration

Develop Prototype

Durability Test Engine in Generator

Conduct Certification Emission Testing at End of Life

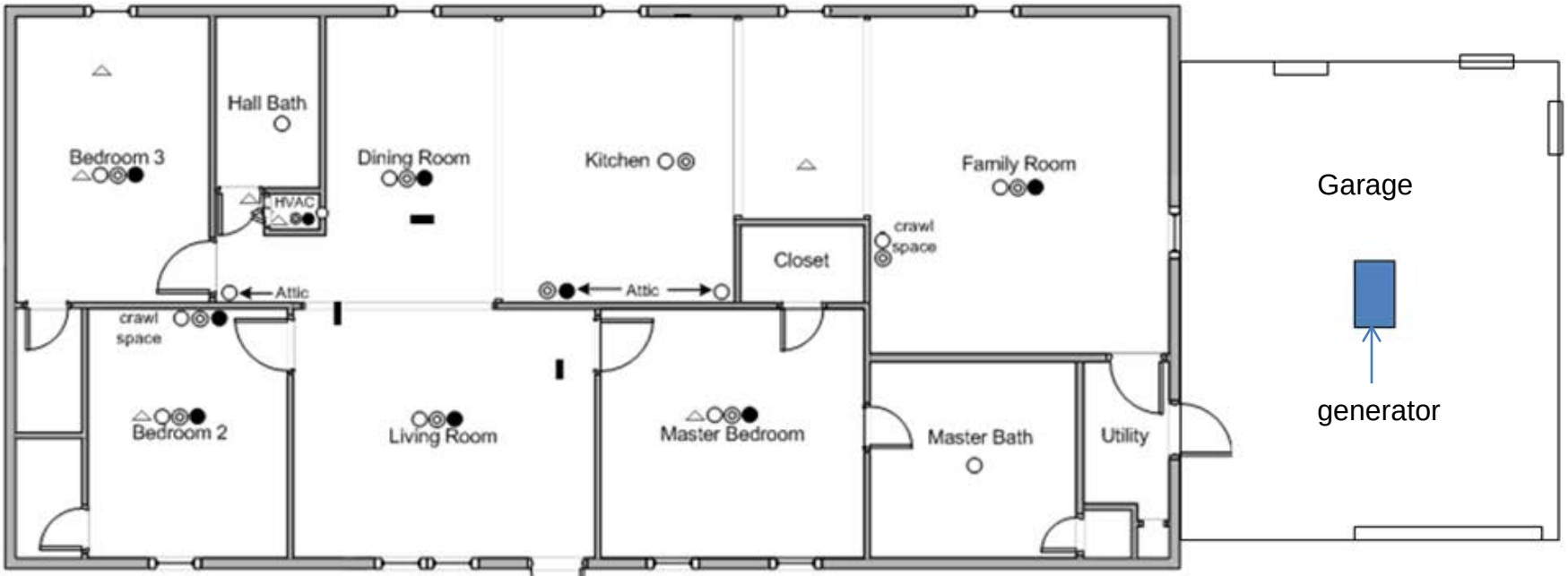
Operate Generator in Attached Garage

Model Health Effects on Occupants

Determine Time Interval for "Egress"

Operate Generator in SFH Attached Garage

National Institute of Standards and Technology (NIST)

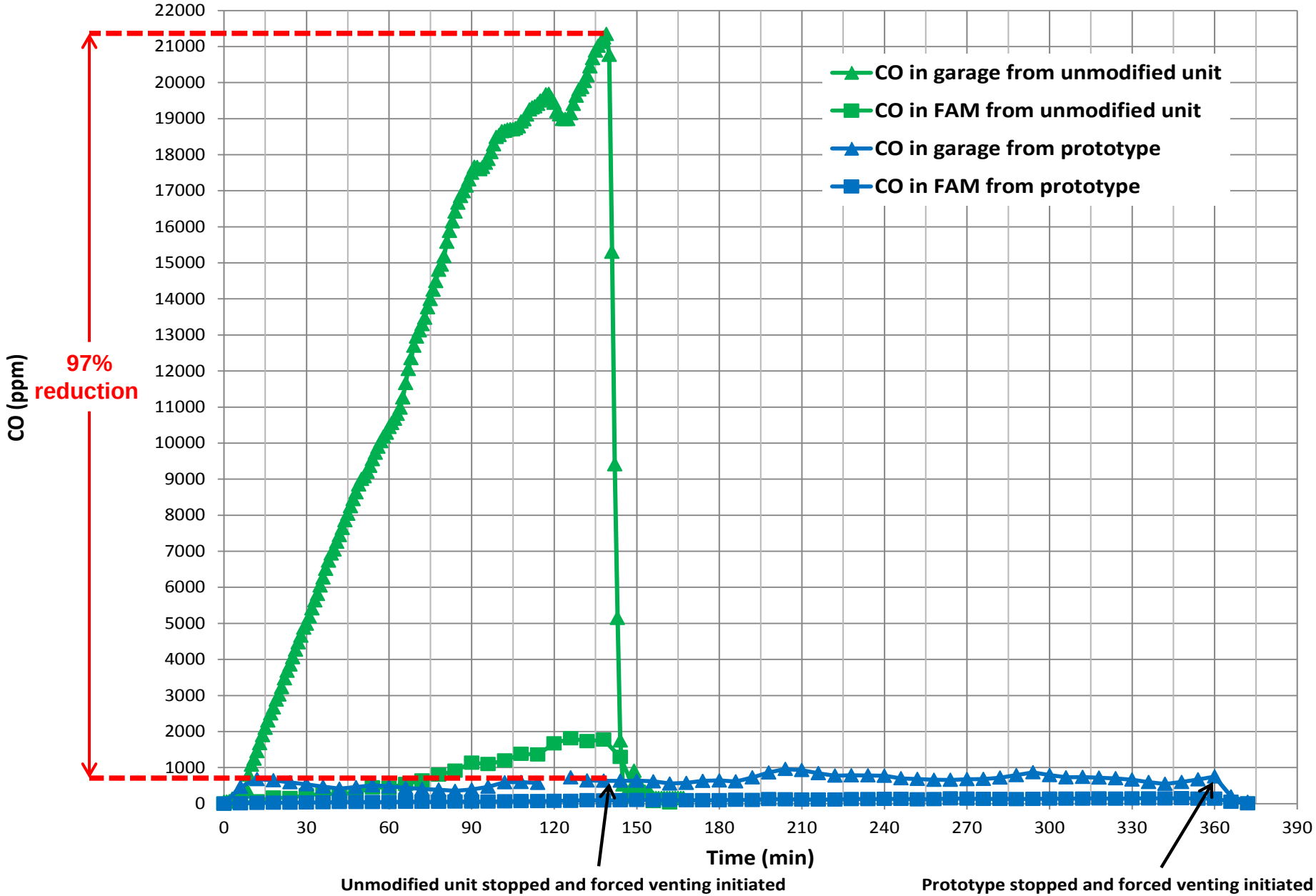


4 scenarios tested to compare prototype with catalyst to OEM unit

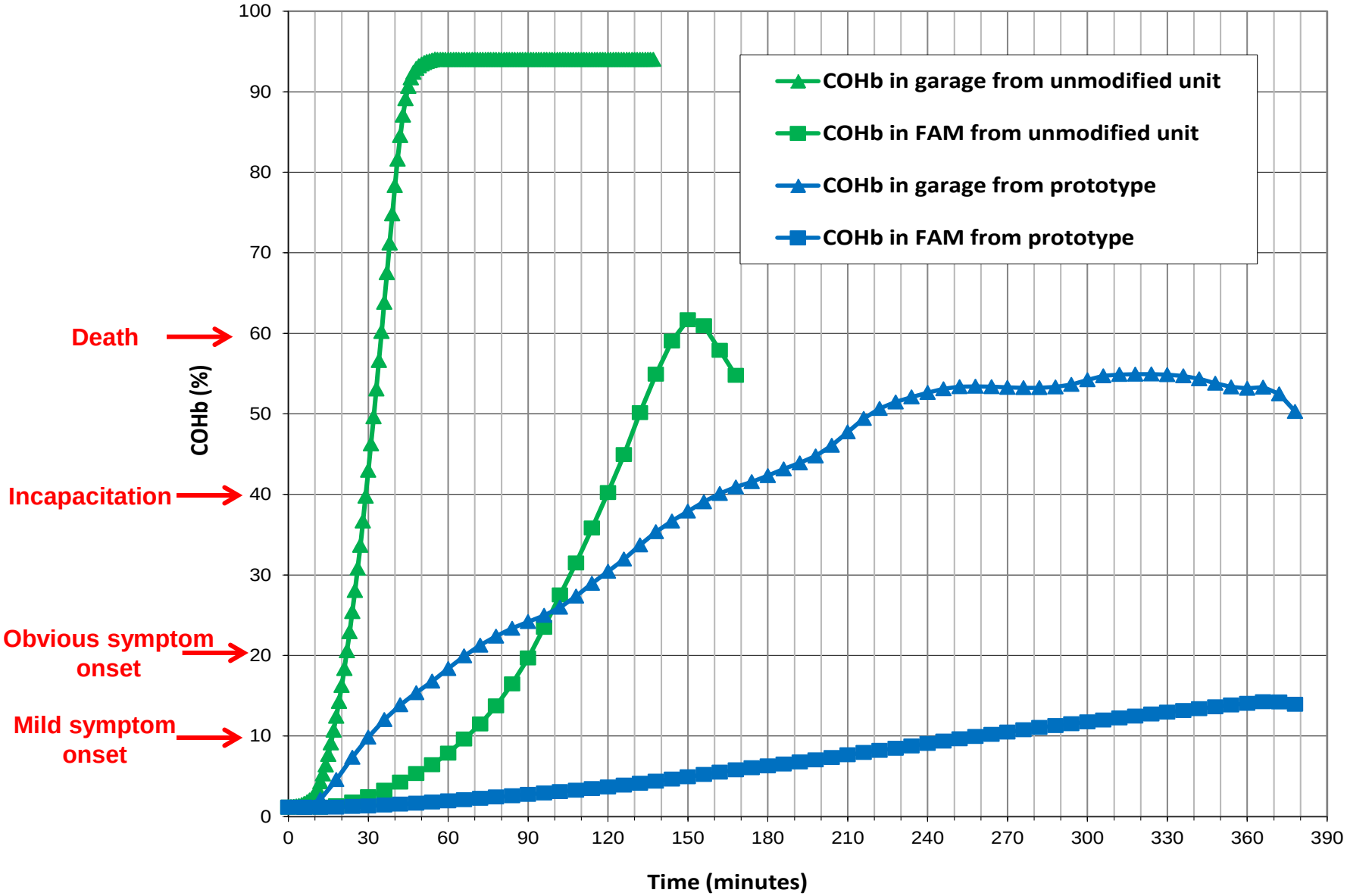
(varied by positions of bay door, utility door, HVAC fan)

Garage and Family Room CO Concentration Profiles

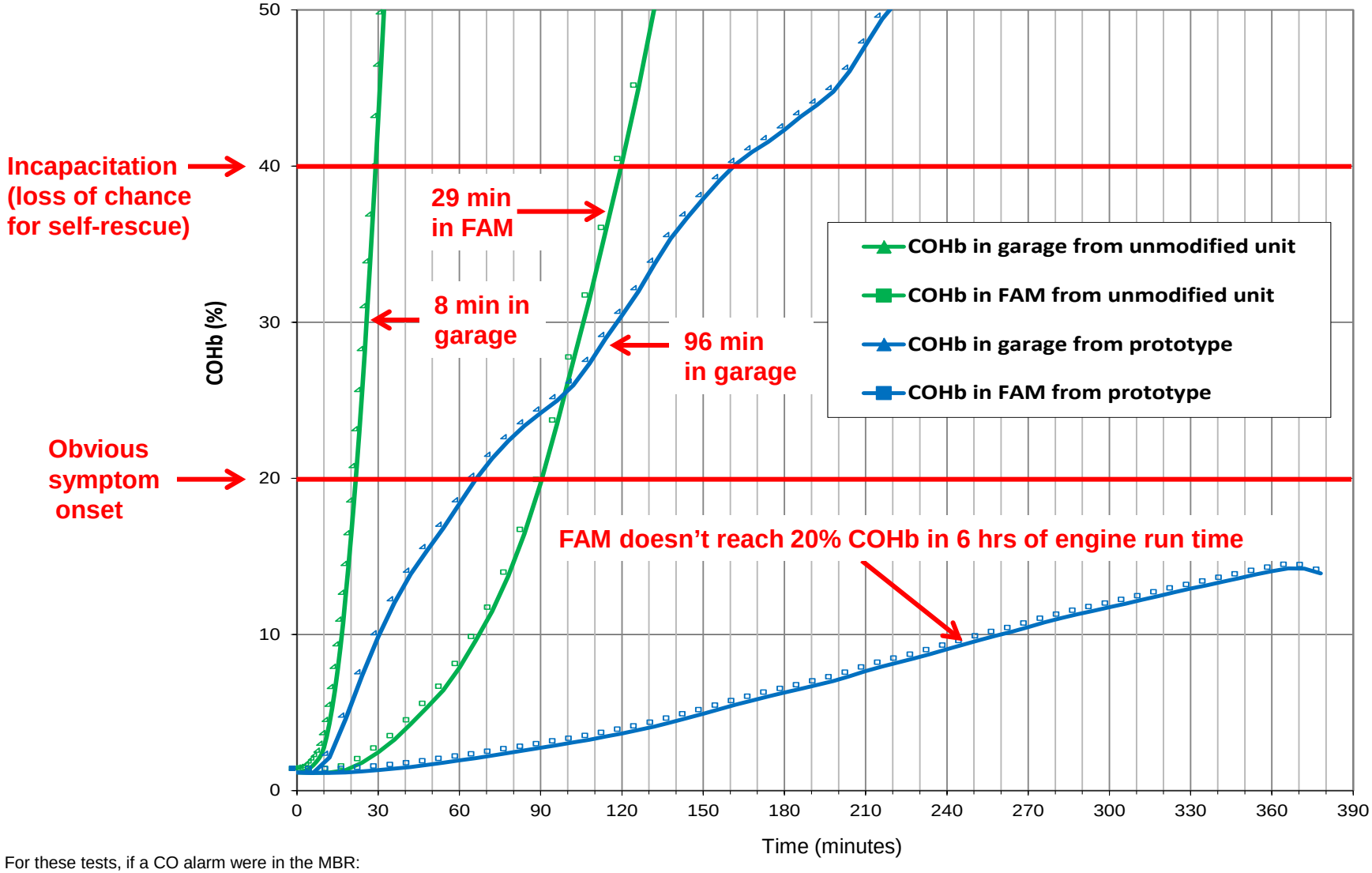
Garage Bay Door Fully Closed, Garage/Utility Room Door Fully Closed, and HVAC Fan On



Health Effects Modeling



Time Intervals for "Egress"



For these tests, if a CO alarm were in the MBR:

- With the unmodified unit in the garage, the CO concentration in the garage at the time of alarm activation would be 18,500 ppm. This would incapacitate anyone who entered the garage within 3 minutes.
- With the prototype in the garage, the CO alarm activation criteria was not met. However, staff projects that it would activate at 400 minutes, assuming the CO in the MBR remained above 70 ppm. The CO in the garage at that time is projected to be below 1,200 ppm, a level defined by NIOSH as being *Immediately Dangerous to Life and Health* (IDLH, "An acute respiratory exposure that poses an immediate threat of loss of life, immediate or delayed irreversible adverse effects on health, or acute eye exposure that would prevent escape from a hazardous atmosphere within 30 minutes.".

Conclusions

- Prototype reduced the CO emission rate by 93% - 97% → more time for victims to escape.
- Dependent on human behavior, but additional time expected to result in fewer deaths.
- Urging manufacturers to voluntarily implement CO emission reduction control strategies to produce a significantly reduced CO emission rate when installed in the product.
- Prototype used same commercially available, low-cost EMS used in Asian market for powered scooters and small motorcycles and used by EPA in Phase 3 development work over 6 years ago.

Questions?

- Staff report "Technology Demonstration of a Prototype Low CO Emission Portable Generator" available online at:

  http://www.cpsc.gov/library/foia/foia12/os/portgen.pdf

  (Or go to www.cpsc.gov and search for "Technology Demonstration")

- Please send your comments to CPSC's Office of the Secretary, cpsc-os@cpsc.gov by November 13, 2012.

- For further info:

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