UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
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Memorandum

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Through:	Mary Ann Danello, Ph.D., Associate Executive Director, Directorate for Health Sciences (HS) Lori E. Saltzman, M.S., Division Director, HS
FROM:	Sandra E. Inkster, Ph.D., Pharmacologist, HS
SUBJECT:	Health hazard assessment of CO poisoning associated with emissions from a portable, 5.5 kilowatt, gasoline-powered generator.

Outline

This memorandum presents (1) an overview of the CO poisoning hazard associated with consumer products, with emphasis on generator-related concerns, and (2) a preliminary health hazard assessment of the CO poisoning severity that can be expected if a 5.5 kilowatt gasoline-powered generator is operated in the basement of a hypothetical single family home.

Background

The U.S. Consumer Product Safety Commission (CPSC) has long been concerned with the problem of accidental, non-fire related carbon monoxide (CO) poisoning associated with consumer products. Reducing the rate of unintentional CO poisoning deaths associated with consumer products is a strategic goal of the agency. Staff employs a multi-faceted approach to combat CO poisoning, including working with relevant standards authorities and industry to improve source product performance standards, undertaking consumer information and education campaigns, and encouraging the development and use of secondary intervention devices (i.e., residential CO alarms). In addition, the staff actively tracks and investigates CO poisoning incidents and issues an annual report on the estimated number of CO poisoning deaths associated with consumer products. These efforts have contributed to a reduction in consumer product-related CO poisoning deaths in past years. CPSC and other interested parties have endeavored to promote consumer awareness of the fact that commonly used residential combustion products (e.g., furnaces, space heaters, and ranges) can generate hazardous CO exposures under certain circumstances. Though typically, such products are designed to produce relatively low levels of CO when operating normally, CO deaths are known to have resulted when the products have generated high levels of CO due to either improper installation, poor maintenance, inappropriate use, and/or compromised ventilation systems.

In the mid 1990s, CPSC staff collaborated with several other safety agencies to produce a joint safety alert highlighting the CO poisoning hazard associated with use of small gasoline-

It should be noted that this memo reflects the analysis of CPSC staff and staff opinions. They have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

powered engines and tools (NIOSH, 1996, Pub. No 96-118). The National Institute of Occupational Safety and Health (NIOSH) was the lead agency coordinating this initiative, reflecting the fact that, at that time, a large number of known victims were using the products (e.g., pressure washers, concrete cutters, compressors, generators, etc) in occupational settings. Important findings noted in the safety alert were a lack of awareness of the CO hazard among the user population, and the fact that some users were aware that ventilation was needed, but frequently underestimated exactly what constituted adequate ventilation. The safety alert recommended that tool manufacturers and rental companies put targeted warning labels on the products with suggested wording "carbon monoxide produced during use can kill, do not use indoors or in other sheltered areas." Though helpful to consumers, the safety alert was aimed at the worker population.

During the late 1990s, there was some concern that the advent of the new millenium ("Y2K") might result in widespread computer failures and associated power outages. In response, consumer sales of portable, light duty gasoline-powered generators increased. These products are widely available to consumers at most home-improvement stores (Donaldson, 2004). Current environmental CO emissions control requirements, applicable to engine classes that include most portable, gasoline-powered, generator-type engines, allow exhaust to contain high levels of CO when operating normally (519 to 610 g/kW-hr)[1]. Although the Y2K fears of widespread computer failure and power outages were not realized, CPSC staff had serious concerns that increased consumer use of generators could result in an increase in CO poisoning deaths and injuries. In FY 2002, CPSC staff started a new project specifically intended to address CO poisonings involving the product category of small engine-driven tools.

The most recent data report from CPSC's Directorate for Epidemiology, Division of Hazard Analysis (Carlson, 2004) notes that CPSC staff is aware of 258 CO-poisoning fatalities involving various types of engine-driven tools that occurred between January 1, 1990 and December 31, 2003, and which were reported to CPSC as of March 1, 2004. Generators account for the majority of cases, being associated with 228 deaths (88%). It should be noted that, in 1999, the 10th revision of the International Classification of Disease (ICD-10) became effective, resulting in changes in the classification of CO-related deaths. Prior to 1999, CPSC did not routinely collect death certificates associated with engine-driven tools. Since 1999, CPSC has collected death certificates associated with all CO poisonings. The changes could affect the number of CO poisoning deaths reported to CPSC. For the period January 1, 1999 through December 31, 2003, CPSC received 120 report of CO deaths associated with use of generators versus 16 reports for all other engine-driven tools. The reporting of CO deaths to CPSC for recent years is not complete and so actual death counts can possibly increase.

Portable gasoline-powered generators account for an increasing majority of deaths reported for the small engine-driven tool category, and therefore, are the primary focus of the CPSC's "Small engine-driven tools" project. Recent project activities have included laboratory tests of generators in controlled settings, in order to characterize the CO poisoning hazard associated with exposure to CO-laden combustion emissions.

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[1] In 1992, to address outdoor pollution concerns, the U.S. Environmental Protection Agency (EPA) began to develop emissions standards applicable to new non-road spark-ignition nonhandheld engines, at or below 19 kW; these requirements apply to CO (completed), hydrocarbons and nitrogen oxides (still being phased in) (40 C.F.R part 90).

Common Scenarios Associated with Fatal, Generator-Related CO Poisonings

The previously mentioned Directorate for Epidemiology staff memorandum (Carlson, 2004) reports that 138 of the 228 total generator-related deaths have been the subject of 102 in-depth investigations (IDIs) conducted by CPSC staff. Data are not complete for all cases, but the anecdotal information obtained from analysis of the IDIs has identified some common features of fatal generator incident scenarios.

Most in-depth investigations of incidents that occurred at the home were associated with the use of generators in basements or crawlspaces, in garages or enclosed car-ports, or inside a living space. The generators were commonly used as an emergency power source for a fixed home, or as a power source for a temporary location such as a motor home, trailer, camper, or boat. In several of these reports, it was noted that a door or window had been left open, possibly to provide ventilation. In two unrelated deaths that were investigated, the generator had been placed outdoors; however, it was located too close to an open window, or to the home's air intake, which allowed lethal levels of CO in the exhaust to infiltrate the living space. Most fatal incidents reported only one fatality – typically an adult victim over 24 years of age, who was usually male. However, numerous fatal incidents involved simultaneous exposure of one or more additional victims, many of whom survived various degrees of CO poisoning severity (survivor symptoms ranged from headache to loss of consciousness). In a number of cases, several family members succumbed to CO poisoning associated with exposure to generator fumes; deaths were due to acute, high level, CO poisoning. Victims' blood carboxyhemoglobin (COHb) levels *(which can provide information on minimum CO exposure levels, as further explained in the next section)* were documented for 86 of the 138 generator-related deaths that were investigated. In the majority of cases where COHb levels were known (82/86 fatalities), victims had CO levels of at least 40%. Blood levels of 60% COHb or more were found in 62/86 victims, indicating that CO exposure levels most likely exceeded 1000 parts per million (ppm).

In the majority of fatal cases, the victims were found dead at the scene, although they were not necessarily in the room or enclosed space in which the generator had been operating. Health Sciences'(HS) review of the investigated incidents found in several cases, that generators were either found still running, or in a "switched on state" apparently having exhausted the fuel supply. There is a significant lack of data regarding the size of generators involved in the fatal incidents that have been subject to IDI; generator size was unknown for 56/138 of the investigated fatalities. In the 82 cases where size was known, all but one engine was rated below 7 kilowatts, and the most prevalent classes of generator engines were rated between 5.0-5.9 kilowatts (33 cases), and between 3.0-3.9 kilowatts (19 cases) (see Carlson, 2004).

Carbon Monoxide Poisoning Pathophysiology

Carbon monoxide is a colorless, odorless, poisonous gas formed during incomplete combustion of fossil fuels. Initial CO poisoning effects result primarily from oxygen (O_2) deprivation (hypoxia) due to compromised uptake, transport, and delivery to cells. Compared to O_2, CO has approximately a 250-fold higher affinity for hemoglobin. Thus, inhaled CO rapidly enters the bloodstream and effectively displaces O_2 from red blood cells, resulting in formation of carboxyhemoglobin (COHb). CO can also displace O_2 from the muscle protein myoglobin, but this usually does not occur until after COHb levels have been significantly elevated. The heart, brain, and exercising muscle are the tissues with the highest oxygen requirements;

consequently, they are most sensitive to CO-induced hypoxia. This is reflected in the non-specific flu-like symptoms of mild CO poisoning, and early symptoms of severe poisoning, e.g., headache, lightheadedness, nausea, and fatigue. More severe CO poisoning can result in progressively worsening symptoms of vomiting, confusion, loss of consciousness, coma, and ultimately, death. When CO levels rise steeply and suddenly, as is believed to be the case with generators, it is possible for exposed individuals to rapidly experience confusion, loss of muscular coordination, and loss of consciousness. This can occur without having first experienced milder CO poisoning symptoms associated with a low, or slowly rising, CO level.

Although the relationship is not absolute, the blood level of COHb (% COHb, i.e., percent of the total hemoglobin pool occupied by CO) serves as a useful approximation of CO poisoning severity, with increasing % COHb levels typically associated with progressively worsening symptoms (Table 1).

Table 1. Approximate Correlation Between % COHb Level and Symptoms in Healthy Adults

% COHb	Symptoms
<10%	No perceptible ill effects*
10-20	Mild headache, labored breathing, decreased exercise tolerance
20-30	Throbbing headache, mild nausea
30-40	Severe headache, dizziness, nausea, vomiting, cognitive impairment
40-50	Confusion, unconsciousness, coma, possible death
50-70	Coma, brain damage, seizures, death
>70	Typically fatal

(Source: Burton, 1996) * Some studies have reported adverse health effects in some cardiac patients at 2-5% COHb

The three primary factors that influence COHb formation (and elimination) from exogenous CO exposures are: (i) the concentration of CO in inspired air (ppm CO), (ii) the duration of exposure, and (iii) an individual's physical activity level. The highest COHb level that can be reached for any CO exposure is limited by the ppm level of CO in air. If CO is maintained at any given ppm level, COHb levels will progress to an equilibrium state where COHb formation and elimination are equal and the % COHb is limited by the CO concentration in air. Under sedentary conditions, more than 80% of the equilibrium value is reached within an 8 hour exposure, and equilibrium will usually be reached within 10 to 12 hours. The activity level of exposed individuals plays a key role in the rate at which COHb levels rise prior to attainment of equilibrium COHb levels. Individuals engaged in strenuous activities breathe rapidly; therefore, their CO intake is greater and COHb formation faster than in resting individuals. At higher activity levels and depending on the ppm level, more than 90% of the equilibrium COHb level can be reached within 4 hours. For most household activities, breathing rates or respiratory minute volumes (RMV) of residents typically range from about 6 liters per minute (L/min) at sleep or rest, to about 20 L/min for moderate activity. Higher RMVs (30 L/min or more) can be reached by individuals engaged in more strenuous activities and RMVs of about 40 to 50 L/min can be maintained for relatively short periods by those engaged in extremely heavy exercise. The relationships between CO ppm, duration of exposure, activity levels, and COHb formation are illustrated in Table 2.

Table 2. Relationships between CO level (ppm), Duration of Exposure, and Exposed Individuals' Activity Level on Carboxyhemoglobin (% COHb) Levels

Activity Level	CO	% COHb* at Different Duration Exposures and at Equilibrium			
(RMVs)	**(ppm)**	**1 hour**	**4 hours**	**8 hours**	**Equilibrium**
Resting/sleep	**100**	2.6	6.0	9.1	14.5
(6 L/min)	**200**	4.0	11.0	17.0	25.3
	300	5.5	15.8	24.3	33.7
	400	7.0	20.6	30.9	40.3
	500	8.4	25.2	36.9	45.7
	750	12.1	35.9	49.3	55.8
	1000	15.7	45.5	58.3	62.7
Low	**100**	3.6	8.6	11.9	14.4
(10 L/min)	**200**	6.2	16.2	21.9	25.2
	300	8.8	23.2	30.3	33.6
	400	11.3	29.7	37.4	40.2
	500	13.9	35.6	43.4	45.7
	750	20.1	48.0	54.5	55.8
	1000	26.3	57.3	62.0	62.7
Moderate	**100**	5.8	12.1	13.9	14.3
(20 L/min)	**200**	10.8	22.3	24.8	25.2
	300	15.6	30.7	33.2	33.5
	400	20.2	37.8	40.0	40.2
	500	24.8	43.7	45.5	45.7
	750	35.5	54.7	55.7	55.7
	1000	45.0	62.2	62.7	62.7
High	**100**	7.61	13.4	14.2	14.3
(30 L/min)	**200**	14.3	24.2	25.1	25.2
	300	20.6	32.7	33.5	33.5
	400	26.6	39.6	40.2	40.2
	500	32.2	45.2	45.6	45.6
	750	44.5	55.6	55.7	55.7
	1000	54.2	62.6	62.7	62.7

* % COHb estimated by CPSC Health Sciences staff using a customized computer model for the non-linear form of the *Coburn Forster Kane* equation with modifications of *Peterson and Stewart.* The following input parameters were used: 70 kg male; blood volume = 5,500 ml; baseline % COHb = 1.2% (urban non-smoker); Haldane constant = 218; barometric pressure = 760 torr (sea level)

While it is convenient to use discrete COHb levels to categorize symptom severity, clearly, the severity of symptoms associated with CO poisoning cannot be explained simply in terms of the maximum % COHb reached (or a maximum CO ppm level of exposure). Symptom severity is also influenced by the length of time that the individual's % COHb has been elevated, and by an individual's susceptibility to CO. Thus, symptom severity is a function of the level and duration of tissue hypoxia and is primarily determined by the rate at which the CO level increases, the maximum CO level reached (ppm), the duration of exposure, the exposed individual's activity level, and their general health status. The CO poisoning symptoms listed in Table 1 should therefore be regarded as part of a continuum of effects with overlapping transitions. Below 10% COHb, no perceptible effects of CO exposure are likely in healthy adults. Mild headaches and fatigue become evident between 10 to 20% COHb. At 20 to 30% COHb, throbbing headaches and nausea are likely initially, and severe headache, nausea, vomiting, cognitive impairment, and possible loss of consciousness can result if levels are sustained for a long time, or rise above 30% COHb. Such symptoms can seriously compromise the ability of exposed individuals to remove themselves from the hazardous environment. In healthy individuals, attaining a COHb level above 60% presents a significant risk of a fatal outcome and levels exceeding 70% COHb typically result in death. Fatalities can, and do, occur in healthy individuals at COHb elevations around 40-50%, generally in situations where the elevation has been sustained for several hours. Fatalities can also occur at much lower COHb levels in certain populations who are particularly susceptible to oxygen deprivation due to pre-exisiting conditions that compromise oxygen uptake and/or delivery to tissues (e.g., compromised heart or lung function, certain anemias), or due to particularly high metabolic demands for oxygen (e.g., fetuses, young children).

For some individuals who survive serious prolonged COHb elevations (usually above 20% COHb), the resulting brain hypoxia, and any consequent associated brain damage, may ultimately result in the phenomenon of delayed neurological sequelae (DNS). DNS is typically manifested within a few days or weeks after the apparent recovery from the initial CO exposure. Symptoms can include emotional instability, memory loss, dementia, psychosis, Parkinsonism, incontinence, blindness, paralysis, and peripheral neuropathy. Symptoms of DNS may respond to hyperbaric oxygen therapy and/or may resolve spontaneously over a two-year period, but victims exhibiting the most severe symptoms such as Parkinsonism, blindness, and paralysis are often permanently affected (US EPA, 2000). While loss of consciousness is typically associated with more serious outcomes, it is not necessary to have lost consciousness to sustain DNS from CO exposures.

Recent CPSC Laboratory Activities

The increasing number of generator-related CO poisoning fatalities reported to CPSC provides strong evidence regarding the lethal CO hazard presented by a generator when it is operated within an enclosed or poorly ventilated environment. In order to gain a greater understanding of factors that influence how rapidly a CO exposure from generator emissions can progress to a likely fatal outcome, CPSC staff has undertaken some experimental studies. The most recent of these activities are focused on a laboratory test program to measure CO emission rates of representative generators. In order to derive CO source strengths for sample test generators under different load conditions, CPSC staff in the Directorate for Laboratory Sciences (LS), is conducting a series of ongoing tests of generators inside a controlled, 339 ft^3

environmental test chamber (see J. Buyer, 2004). In late March 2004, preliminary CO source strengths, derived by LS staff for a sample 5.5 kilowatt generator operating under different load conditions, were used to model time-course profiles for CO (ppm) buildup and decay in different regions of a hypothetical model home (see Table 3).

Table 3. Preliminary Source Strengths Derived for a 5.5 Kilowatt, Gasoline-Powered Generator*

Load	CO emissions in cc/hr
No Load	676,604
Partial Load	1,017,576
Full Load	1,182,518

(*preliminary data provided to S. Inkster, (HS) by W. Porter, (LS), March 25, 2004)

For these modeling studies, LS staff assumed that the generator was operating in the enclosed basement (750 ft^2, [6,000 ft^3]) of a representative 4-bedroom, single-family home (total area and volume including basement = 2,250 ft^2 and 18,000 ft^3, respectively). For each of the source strengths listed in Table 3, a general assumption was made that the generator had run continuously for 6 hours before running out of fuel. The EPA's computer-based RISK 1.9.22 Indoor Air Modeling program was used to model the buildup and decay of CO ppm in different areas of the home, over an 18 hour period. Modeling of the source strength data was performed for two different scenarios considered appropriate to the generator hazard pattern. In the first scenario, the heating and ventilating air conditioning (HVAC) system was considered inoperative. For the second scenario, the generator was considered to supply sufficient power to run the air circulation fan of a typical HVAC system, but not enough power to run the compressor of an air conditioning system, or a heat pump. The HVAC air circulation fan was assumed to operate at an airflow rate of 2,500 ft^3/minute. The values for air exchange rates (AER) used in modeling by LS staff, fell within the range of values for these parameters that is documented in the literature (see EPA Exposure Factors Handbook, 1997). The following values were used by LS staff:

AER within the house:	(a) 0.75 air changes per hour [ACH] between floors
	(b) 3.0 ACH between adjacent rooms,
AER with the outdoors:	(c) 0.3 ACH for the basement
	(d) 0.5 ACH for the "above ground" house levels
	(personal communication to S. Inkster from W. Porter, 03/25/04).

For convenience, HS staff has incorporated LS staff's preliminary modeled data for CO time course profiles throughout the home model, into the summary tables A1 to A6 in the Appendix section of this memorandum.

Health Sciences Modeling of Carboxyhemoglobin Levels

In order to characterize and assess the CO poisoning risk associated with a consumer product, HS staff typically estimates the % COHb profile and/or peak % COHb level expected in exposed individuals. This is based on the source product's CO emissions, and/or the peak environmental CO level attained and the expected use scenarios for the specific product and user populations. A differential equation developed by Coburn-Forster and Kane (CFK equation) considers the major physical and physiological factors that affect COHb levels (1965). The non-linear form of the CFK, which corrects the available hemoglobin pool for the amount in the form of COHb, is widely regarded in the medical research community as the most physiologically accurate, predictive model for estimating COHb levels that has the broadest application for different CO exposure scenarios (U.S. EPA, 2000). HS staff developed a customized computer-based program for the non-linear form of the CFK equation, and routinely uses this for COHb modeling studies (Babich, 1993). The program has been validated against previously published human test data for CO exposures up to 1000 ppm. For safety and ethical reasons, controlled experimental data on prolonged human exposure to high levels of CO (> 1000 ppm) is not available. As such, HS staff cannot verify the validity of the computer CFK model for estimating COHb levels at such high level CO exposures associated with generator emissions. However, HS staff has no reason to believe that it is grossly inaccurate at higher levels. HS staff cautions that it should be clearly recognized that use of any model to predict COHb levels will give **approximate** estimates, the reliability of which will be dependent on how closely the input values represent the population characteristics and environmental exposure conditions.

To characterize the health hazard posed by operating a 5.5 kilowatt generator in a basement, HS staff used LS staff's derived CO profiles to model the corresponding % COHb profiles for hypothetical adult victims in different regions of the representative single family home. For each CO profile, HS staff modeled the COHb profiles using breathing rates representative of the range of most typical household activities i.e., RMVs of 6 L/min for sleeping/resting individuals, and 20 L/min for moderate activity.

Results

Staff notes that these preliminary modeled data are meant to apply to an average situation. Obviously, the size of a home and the rates of air exchange with the outdoor environment significantly impact the development of the potential CO hazard within the home. Larger homes and higher air exchange rates would reduce the hazard and smaller homes and lower air exchange rates would exacerbate the hazard.

The summary tables (Appendix A) present HS staff's data for the predicted % COHb profiles, together with LS staff's corresponding modeled CO ppm profiles. The modeled COHb profiles are also presented graphically in Appendix B of this memorandum. To facilitate comparison of the numerous COHb profiles generated, HS staff collated the data for the size and time of the approximate peak CO level predicted and the approximate peak % COHb levels reached and time attained for the resting and moderate activity exposure scenarios. These summary data are shown in Table 4. HS staff also derived from the modeled data, the approximate times at which the hypothetical victim would attain a COHb level of 20%, 40% and, if applicable, 60% (Table 5). The 20% COHb level is used by HS staff to represent the critical level at which the possibility exists that DNS could be manifested in surviving victims, and as a minimal level at which lucid decision making could be impaired by prolonged exposures. Attainment of 40% COHb is considered to reflect likely incapacitation due to severe cognitive impairment of victims and likely loss of consciousness; death is possible with prolonged elevations of 40% COHb. The 60% COHb level is considered to represent a level at which a fatal outcome is likely.

LS and HS staffs' modeling studies of LS staff's CO emissions data from generator tests show that a 5.5 kilowatt generator is capable of generating lethal CO exposures throughout a representative single family home. LS staff's data shows that in 33 of 36 cases, the maximum CO level estimated for all areas of a home exceeded 1200 ppm, a level defined by NIOSH as being Immediately Dangerous to Life and Health[2]. The corresponding peak COHb levels predicted by HS staff exceeded 60% in 69/72 cases and exceeded 70% in 54/72 modeled scenarios. The three predicted CO levels that did not reach 1200 ppm were all predicted for areas in the upper level of a home in which a generator was operating in the basement with no load, and in which the HVAC fan was inoperative. HS staff notes that the general 6 hour run time applied by LS staff is likely to underestimate the peak CO levels reached and duration of CO exposure. This is because the "lack of load" scenario would be expected to reduce the rate of consumption of fuel significantly, and consequently, would result in longer duration of operation and extended duration of CO production. The lack of load scenario is not considered to be representative of how most consumers would use a generator in their homes (personal communication from T. Smith, CPSC Human Factors staff, and J. Buyer, CPSC Engineering Staff).

The modeling data shows the influence of an HVAC fan in evenly distributing the CO emissions from the basement area to the rest of the home. While significantly higher levels were always found in the basement area for any modeled scenario, operation of the HVAC fan reduced the range of peak CO levels throughout the rest of the home; for each modeled scenario the range of peak CO levels in all areas except the basement, did not exceed 60 ppm. This resulted in virtually identical peak % COHb levels estimated within identical time frames for each scenario (see Table 4). In contrast, when the HVAC fan was not operating, a gradient of peak CO ppm levels and corresponding % COHb levels was evident from the basement to the upper level of the home. Peak CO levels ranging between 5,740 and 10,032 ppm, corresponding to COHb levels exceeding 85%, were predicted for the basement; minimum levels between 967 and 1,690 ppm, corresponding to peak COHb levels between 53% and 74%, were predicted for bedrooms 1 and 2, depending on an exposed individual's activity level.

The data demonstrate how the operation of the HVAC, the location of an exposed individual, and the exposed individual's relative activity level can influence the rate at which the CO exposure progresses to likely incapacitation (40% COHb) and likely lethal outcome (60% COHb). The status of the HVAC system modulates the developing CO hazard. By evenly distributing the CO throughout the home, an operating HVAC fan can increase the rate at which the hazard develops for victims in upper levels of the home and reduce the hazard in the lower levels, compared to situations in which the fan is off. Obviously, individuals with higher activity levels will accumulate CO more rapidly, and so will reach the 40% COHb level, at which incapacitation is assumed, much faster than resting individuals in identical locations. CPSC staff considers a generator operating at full load as a likely consumer use scenario. An individual in the basement is likely to be incapacitated within 40 and 29 minutes, and dead by 62 and 40 minutes (HVAC on/HVAC off, respectively) of operation of a generator at full load. For victims

[2] The Immediately Dangerous to Life or Health concentration (IDLH) is defined by NIOSH as *the concentration that could result in death or irreversible health effects, or prevent escape from the contaminated environment within 30 minutes";* the NIOSH IDLH recommended for CO is 1200 ppm (NIOSH ALERT, 1996)

in upper levels (e.g., bedrooms 1 and 2), 40% COHb will be reached after 146 minutes and 232 minutes, and lethal levels reached by 201 and 300 minutes (HVAC on/HVAC off, respectively). The rapid development of the lethal situation explains why HS staff's review of investigated incidents found that, in many cases, victims of generator-related CO poisoning were found dead within a few hours after family or friends had noticed that they were missing.

Conclusions

Authoritative sources have documented that use of small engines can cause CO levels to rise rapidly in the immediate vicinity in which they are used, reaching levels that can result in loss of consciousness, and ultimately death (see NIOSH Alert 1996, Publication No. 96-118). Frequently, the CO level rises so quickly that exposed individuals do not recognize they are in danger before their ability to think clearly and remove themselves from the hazardous environment is seriously compromised. One study reported in the NIOSH Alert tested a 5.5-horsepower, gasoline-powered pressure washer operated inside an 8,360-cubic-foot, double-car garage. The washer was found to be capable of elevating CO levels in the user's breathing zone to 200 ppm within 5 minutes, 1,200 ppm (IDLH value) within 15 minutes, and 1,500 ppm within 19 minutes, when all doors windows and vents were closed. When these ventilation routes were left open, CO measurements taken in the breathing zone were 200 ppm within 3 minutes, with a peak of 658 ppm within 12 minutes. Similar findings were reported with other engines, rated from 5 to 8 horsepower. The CPSC staff's data indicates how the CO hazard is expected to develop in other areas of a representative home and demonstrates that lethal outcome is the most likely if a 5.5 kilowatt generator is operated in a basement and no outside intervention occurs. The modeling studies found that, depending on generator load and HVAC fan status, moderately active individuals could be expected to attain lethal COHb levels (60% COHb) between 40 and 68 minutes if in the basement, and between 201 and 326 minutes if in the upper level bedrooms.

The CO hazard associated with use of any combustion product is related to the efficiency of combustion. For most combustion products routinely used by consumers (e.g., furnaces, ranges, space heaters), the efficiency of combustion is highly dependent on the available oxygen supply, and safety devices are in place to shut down modern appliances if efficiency is significantly impaired. Unlike these products, generators and other small engine-driven tools have much lower combustion efficiencies and so produce large amounts of CO during normal operation without serious depletion of the available oxygen. These small engine-driven tools will generally continue running until the fuel supply is exhausted, and they typically lack emissions controls or have any safety design features that shut off the products in the event of excess CO production.

Operation of gasoline-powered generators in enclosed spaces, such as a basement, can rapidly cause ambient CO to reach life-threatening levels in all areas of a home. This can seriously compromise an exposed individual's ability to escape from the hazardous environment, particularly if they are in the same room as the generator, whereby incapacitation can occur within 30 minutes. When used inside the confines of a basement, garage or crawlspace, the CO hazard created by generators is not obvious to all consumers and deaths are likely to continue occurring without intervention strategies.

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Table 4. MODELING OF CO EMISSIONS FROM A 5.5 KILOWATT GASOLINE-POWERED GENERATOR UNDER DIFFERENT LOAD CONDITIONS: ESTIMATED PEAK CO AND %COHb LEVELS, AND CORRESPONDING TIMES WHEN REACHED

ESTIMATES OF THE APPROXIMATE PEAK CO LEVEL (ppm) AND TIME REACHED (hours:minutes)

Generator Load	***NONE***				***PARTIAL***				***FULL***			
HVAC Fan Status	***OFF***		***ON***		***OFF***		***ON***		***OFF***		***ON***	
Room	**peak CO (ppm)**	**time reached**	**peak CO (ppm)**	**time reached**	**peak CO (ppm)**	**time reached**	**peak CO (ppm)**	**time reached**	**peak CO (ppm)**	**time reached**	**peak CO (ppm)**	**time reached**
Basement	5740	5:45	2232	5:45	8632	5:45	3273	5:45	10032	5:45	3803	5:45
Kitchen (Eat In)	2704	5:45	1246	6:15	4066	5:45	1860	6:15	4724	5:45	2162	6:15
Living and Dining Rooms	2297	6:15	1223	6:15	3455	6:15	1842	6:15	4015	6:15	2140	6:15
Bedroom 1 and 2	967	7:15	1228	6:15	1455	7:15	1824	6:15	1690	7:15	2120	6:15
Bedroom 3 and 4	979	7:15	1210	6:15	1473	7:15	1821	6:15	1711	7:15	2116	6:15
Hall (Upstairs)	1136	6:45	1227	6:15	1709	6:45	1830	6:15	1986	6:45	2127	6:15

ESTIMATES OF THE APPROXIMATE PEAK % COHb AND TIME REACHED (hours:minutes) FOR A RESTING INDIVIDUAL (RMV 6 L/min)

Generator Load	***NONE***				***PARTIAL***				***FULL***			
HVAC Fan Status	***OFF***		***ON***		***OFF***		***ON***		***OFF***		***ON***	
Room	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**
Basement	84*	2:45*	76	7:45	88*	2:15*	83*	5:15	82*	1:45*	87*	4:15
Kitchen (Eat In)	81	6:45	62	9:45	87*	5:45*	73	8:45	79*	3:45*	77	7:45
Living and Dining Rooms	77	7:15	62	9:45	83*	5:45*	73	8:45	84*	5:15*	76	7:45
Bedroom 1 and 2	53	10:45	62	9:45	66	9:45	73	8:45	71	9:15	76	7:45
Bedroom 3 and 4	53	10:15	62	9:45	66	9:45	73	8:45	71	9:15	76	7:45
Hall (Upstairs)	58	9:45	62	9:45	71	8:45	73	8:45	75	8:45	76	7:45

ESTIMATES OF THE APPROXIMATE PEAK % COHb AND TIME REACHED (hours:minutes) FOR A MODERATELY ACTIVE INDIVIDUAL (RMV 20 L/min)

Generator Load	***NONE***				***PARTIAL***				***FULL***			
HVAC Fan Status	***OFF***		***ON***		***OFF***		***ON***		***OFF***		***ON***	
Room	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**	**Peak %COHb**	**time reached**
Basement	85*	1:45*	79	5:45	62*	0:45*	84	5:15*	86*	1:15*	85*	4:15
Kitchen (Eat In)	82	6:15	67	6:45	87*	5:75*	75	6:45	85*	3:34*	78	6:45
Living and Dining Rooms	79	6:45	67	6:45	78*	3:15	75	6:45	85*	5:15*	78	6:45
Bedroom 1 and 2	61	8:15	67	6:45	71	7:45	75	6:45	74	7:45	78	6:45
Bedroom 3 and 4	62	7:45	67	6:45	71	7:45	75	6:45	74	7:45	78	6:45
Hall (Upstairs)	65	7:15	67	6:45	74	7:15	75	6:45	77	7:15	78	6:45

* Indicates that the projected % COHb exceeded 100% within 30 minutes of the time shown for the peak % COHb level

Table 5. MODELING OF CO EMISSIONS FROM A 5.5 KILOWATT GASOLINE-POWERED GENERATOR UNDER DIFFERENT LOAD CONDITIONS ESTIMATED TIMES (hours:minutes) INDIVIDUALS IN DIFFERENT HOME LOCATIONS ATTAIN 20%, 40% and 60% COHb : effect of activity level

NO LOAD	Time to 20% COHb (hours:mins)				Time to 40% COHb (hours:mins)				Time to 60% COHb (hours:mins)			
	6L/min		20L/min		6L/min		20L/min		6L/min		20L/min	
	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off
Basement	1:23	0:55	0:34	0:24	2:27	1:25	1:02	0:41	3:42	1:54	1:38	1:00
Kitchen	3:37	2:10	2:05	1:16	5:28	3:09	3:12	1:48	8:07	4:08	4:58	2:27
Living/Dining room	3:45	2:58	2:10	1:51	5:36	4:00	3:18	2:29	8:14	5:06	5:04	3:13
Bedroom 1+2	3:44	5:16	2:08	3:33	5:33	7:27	3:16	4:52	8:15	Max 53%	5:01	7:10
Bedroom 3+4	3:47	5:06	2:12	3:24	5:38	7:15	3:21	4:42	8:20	Max 53%	5:07	7:00
Upstairs Hall	3:58	4:25	2:24	2:48	5:50	6:17	3:38	4:00	8:21	Max 58%	5:16	5:45

PARTIAL LOAD	Time to 20% COHb (hours:mins)				Time to 40% COHb (hours:mins)				Time to 60% COHb (hours:mins)			
	6L/min		20L/min		6L/min		20L/min		6L/min		20L/min	
	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off
Basement	1:02	0:44	0:26	0:21	1:48	1:06	0:45	0:37	2:40	1:29	1:08	0:45
Kitchen	2:58	1:48	1:43	1:03	4:22	2:33	2:34	1:29	5:45	3:15	3:37	1:56
Living/Dining room	3:05	2:27	1:47	1:36	4:28	3:18	2:38	2:07	5:53	4:07	3:43	2:38
Bedroom 1+2	3:04	4:31	1:46	3:07	4:27	6:07	2:37	4:06	5:52	7:52	3:42	5:26
Bedroom 3+4	3:06	4:22	1:49	2:58	4:31	5:55	2:39	3:45**	5:54	7:38	3:44	4:28
Upstairs Hall	3:18	3:43	2:02	2:23	4:44	5:08	2.53	3:18	6:07	6:35	4:00	4:25

FULL LOAD	Time to 20% COHb (hours:mins)				Time to 40% COHb (hours:mins)				Time to 60% COHb (hours:mins)			
	6L/min		20L/min		6L/min		20L/min		6L/min		20L/min	
	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off	HVAC on	HVAC off
Basement	0:55	0:38	0:24	0:18	1:36	1:02	0:40	0:29	2:20	1:21	1:02	0:40
Kitchen	2:45	1:42	1:35	0:58	4:02	2:23	2:21	1:24	5:13	3:02	3:15	1:47
Living/Dining room	2:51	2:18	1:40	1:31	4:08	3:07	2:27	2:00	5:23	3:49	3:22	2:30
Bedroom 1+2	2:50	4:17	1:38	2:56	4:07	5:43	2:26	3:52	5:21	7:11	3:21	5:00
Bedroom 3+4	2:53	4:07	1:42	2:48	4:09	5:32	2:29	3:43	5:24	6:58	3:24	4:47
Upstairs Hall	3:05	3:30	1:54	2:16	4:23	4:48	2:41	3:05	5:37	6:04	3:38	4:04

APPENDIX A

SUMMARY TABLES (A1-A6) OF TIME COURSE DATA FOR MODELED CO (ppm) AND % COHb PROFILES

Appendix A1. LS and HS Modeling Results for Generic Generator 5.5 kW, No Load, No HVAC

Time	ppm CO	% COHb	% COHb	ppm CO	% COHb	% COHb	ppm CO	% COHb	% COHb	ppm CO	% COHb	% COHb	ppm CO	% COHb	% COHb	ppm CO	% COHb	% COHb
hours	Basement	20L/mn	6L/min	Kitchen	20L/mn	6L/min	LR & DR	20L/mn	6L/min	BR 1 & 2	20L/mn	6L/min	BR 3 & 4	20L/mn	6L/min	upstairs	20L/mn	6L/min
0		1.2	1.2		1.2	1.2		1.2	1.2		1.2	1.2	0	1.2	1.2	0	1.2	1.2
0.25	886.1	7.4	2.8	0.0	1.1	1.1	0.0	1.1	1.1	0.0	1.1	1.1	0.0	1.1	1.1	0.0	1.1	1.1
0.75	2139.8	44.5	14.0	354.8	5.8	2.4	65.1	1.8	1.4	0.0	0.9	1.1	0.0	0.9	1.1	27.4	1.3	1.2
1.25	3003.9	75.9	32.3	718.9	19.2	6.4	294.9	6.5	2.7	26.0	1.1	1.2	35.2	1.3	1.2	94.9	2.8	1.6
1.75	3632.9	84.2	53.6	1063.1	37.8	12.8	577.6	17.1	5.8	78.9	2.4	1.5	98.0	2.9	1.7	187.1	6.2	2.6
2.25	4112.5		72.8	1374.4	55.5	21.2	863.0	32.2	11.0	152.6	5.2	2.3	179.8	6.2	2.7	294.1	11.6	4.3
2.75	4491.7		83.8	1650.1	67.2	31.1	1129.2	48.2	17.9	240.4	9.7	3.7	273.3	11.3	4.3	408.4	18.9	6.8
3.25	4799.8			1891.5	73.3	41.9	1368.8	60.8	26.1	336.1	15.7	5.7	372.2	17.9	6.5	524.6	27.2	10.0
3.75	5055.0			2102.0	76.4	52.7	1580.4	68.4	35.3	434.8	22.8	8.4	472.3	25.4	9.4	638.8	35.9	13.8
4.25	5269.3			2285.1	78.3	62.5	1765.7	72.6	44.9	532.8	30.5	11.6	570.4	33.2	12.8	748.5	44.0	18.3
4.75	5451.0			2444.3	79.7	70.4	1927.3	75.1	54.2	627.7	38.1	15.4	664.3	40.6	16.8	852.0	50.8	23.2
5.25	5606.3			2582.9	80.7	75.9	2067.9	76.7	62.4	717.7	44.8	19.6	752.8	47.1	21.1	948.4	56.1	28.5
5.75	5739.8			2703.7	81.5	79.2	2190.4	77.9	69.1	802.0	50.4	24.1	835.1	52.3	25.8	1037.2	59.9	34.0
6.25	4280.0			2633.1	81.7	80.7	2297.1	78.9	73.8	880.0	54.8	28.9	910.8	56.3	30.7	1118.5	62.8	39.5
6.75	3345.9			2363.0	80.9	80.8	2221.9	79.1	76.6	941.5	58.1	33.8	965.6	59.2	35.6	1136.3	64.5	44.7
7.25	2700.0			2087.0	79.2	79.7	2037.8	78.3	77.4	967.1	60.2	38.4	979.1	60.9	40.2	1120.7	65.1	49.2
7.75	2228.9			1829.0	77.1	78.2	1820.8	76.7	76.9	962.1	61.2	42.6	962.7	61.6	44.2	1079.9	65.0	52.7
8.25	1869.8			1597.3	74.8	76.4	1605.6	74.7	75.7	933.6	61.3	46.2	925.3	61.4	47.5	1022.4	64.2	55.3
8.75	1586.3			1393.2	72.3	74.4	1406.8	72.4	74.1	889.0	60.8	48.9	874.3	60.7	50.0	954.8	63.1	57.0
9.25	1356.7			1215.3	69.7	72.3	1229.0	69.8	72.2	834.1	59.8	50.9	815.4	59.5	51.7	882.2	61.6	57.8
9.75	1167.2			1060.8	66.9	70.2	1072.8	67.2	70.1	773.7	58.5	52.2	752.5	58.0	52.7	808.4	59.9	58.0
10.25	1008.5			926.8	64.1	68.0	936.6	64.4	68.0	711.1	56.9	52.8	688.9	56.3	53.1	735.8	58.0	57.7
10.75	874.4			810.5	61.3	65.7	818.2	61.5	65.8	648.8	55.1	52.9	626.6	54.4	53.0	666.1	55.9	57.0
11.25	760.2			709.5	58.4	63.5	715.4	58.6	63.6	588.6	53.1	52.6	566.9	52.3	52.5	600.3	53.8	56.0
11.75	662.4			621.7	55.5	61.2	626.1	55.7	61.3	531.4	50.9	51.9	510.8	50.1	51.7	539.2	51.5	54.8
12.25	578.2			545.3	52.6	59.0	548.5	52.8	59.1	477.9	48.7	51.0	458.5	47.9	50.7	482.8	49.1	53.4
12.75	505.5			478.6	49.8	56.8	480.9	49.9	56.9	428.4	46.4	49.9	410.4	45.6	49.5	431.2	46.8	51.9
13.25	442.5			420.3	47.0	54.7	422.0	47.1	54.8	383.0	44.1	48.6	366.5	43.3	48.2	384.4	44.4	50.4
13.75	387.7			369.4	44.2	52.5	370.5	44.3	52.6	341.7	41.8	47.3	326.7	40.9	46.8	342.1	42.0	48.7
14.25	340.1			324.8	41.5	50.5	325.6	41.6	50.5	304.3	39.5	45.8	290.7	38.6	45.3	304.0	39.6	47.1
14.75	298.5			285.6	38.9	48.4	286.2	39.0	48.5	270.6	37.2	44.4	258.3	36.3	43.8	269.9	37.3	45.4
15.25	262.2			251.3	36.4	46.5	251.7	36.5	46.5	240.3	35.0	42.8	229.2	34.1	42.3	239.3	35.0	43.8
15.75	230.4			221.2	34.0	44.5	221.4	34.0	44.6	213.1	32.8	41.3	203.2	31.9	40.7	212.0	32.8	42.1
16.25	202.6			194.8	31.6	42.7	194.9	31.7	42.7	188.9	30.6	39.8	180.0	29.8	39.2	187.7	30.6	40.5
16.75	178.3			171.5	29.4	40.8	171.6	29.4	40.9	167.3	28.6	38.3	159.4	27.8	37.7	166.1	28.5	38.9
17.25	156.9			151.1	27.3	39.1	151.1	27.3	39.1	148.1	26.6	36.8	141.0	25.8	36.2	146.9	26.5	37.3
17.75	138.1			133.1	25.3	37.4	133.1	25.3	37.4	131.0	24.7	35.3	124.7	24.0	34.8	129.8	24.6	35.8
18.25	121.6			117.3	23.4	35.8	117.2	23.4	35.8	115.8	22.9	33.9	110.2	22.2	33.3	114.7	22.8	34.3
18.75	121.6			117.3	21.7	34.2	117.2	21.7	34.3	115.8	21.4	32.5	110.2	20.7	32.0	114.7	21.3	32.9

Appendix A2. LS and HS Modeling Results for Generic Generator 5.5 kW, No Load, with HVAC

Time hours	ppm CO Basement	%COHb 20L/min	%COHb 6L/min	ppm CO Kitchen	%COHb 20L/min	%COHb 6L/min	ppm CO LR&DR	%COHb 20L/min	%COHb 6L/min	ppm CO BR 1&2	%COHb 20L/min	%COHb 6L/min	ppm CO BR 3&4	%COHb 20L/min	%COHb 6L/min	ppm CO upstairs	%COHb 20L/min	%COHb 6L/min
0	0	1.2	1.2	0	1.2	1.2	0	1.2	1.2	0	1.2	1.2	0	1.2	1.2	0	1.2	1.2
0.25	664.1	5.9	2.4	0.0	1.1	1.1	0.0	1.1	1.1	0.0	1.1	1.1	0.0	1.1	1.1	0.0	1.1	1.1
0.75	1121.1	28.4	9.0	117.8	2.5	1.6	98.4	2.3	1.5	105.7	2.4	1.5	97.0	2.2	1.5	53.5	1.6	1.3
1.25	1296.0	50.4	17.6	244.4	7.1	2.9	221.0	6.3	2.6	228.1	6.6	2.7	216.5	6.2	2.6	165.5	4.4	2.1
1.75	1422.2	63.3	26.7	367.4	14.1	5.0	342.1	12.8	4.6	350.0	13.2	4.8	337.0	12.6	4.6	285.7	9.8	3.7
2.25	1537.1	69.2	35.9	486.3	22.7	8.0	459.4	21.1	7.4	468.4	21.6	7.6	454.1	20.8	7.3	404.4	17.3	6.1
2.75	1647.0	72.0	44.8	601.1	31.9	11.7	572.8	30.1	11.0	582.8	30.7	11.2	567.4	29.7	10.8	519.7	26.0	9.3
3.25	1753.0	73.6	53.1	712.0	40.7	16.0	682.4	38.8	15.1	693.3	39.5	15.4	676.9	38.5	14.9	631.3	34.9	13.2
3.75	1855.4	74.9	60.4	819.3	48.3	20.9	788.3	46.6	19.8	800.2	47.2	20.2	782.8	46.3	19.6	739.1	43.2	17.6
4.25	1954.4	76.0	66.4	922.9	54.3	26.1	890.6	52.9	24.9	903.5	53.4	25.3	885.0	52.6	24.7	843.4	50.2	22.5
4.75	2050.1	76.9	71.0	1023.1	58.9	31.7	989.6	57.7	30.3	1003.3	58.2	30.8	983.9	57.5	30.1	944.2	55.7	27.8
5.25	2142.6	77.7	74.2	1120.0	62.3	37.4	1085.2	61.3	36.0	1099.7	61.7	36.5	1079.4	61.1	35.7	1041.6	59.8	33.4
5.75	2232.0	78.5	76.4	1213.6	64.9	43.2	1177.6	64.1	41.7	1193.0	64.4	42.2	1171.8	63.9	41.4	1135.7	62.9	39.1
6.25	1353.3	75.7	75.8	1245.8	66.6	48.6	1223.4	66.0	47.1	1228.0	66.2	47.6	1210.1	65.8	46.8	1226.7	65.3	44.7
6.75	1180.9	70.2	73.0	1209.7	67.1	53.1	1192.8	66.7	51.7	1201.1	66.8	52.2	1188.3	66.5	51.4	1211.9	66.6	49.8
7.75	1080.1	66.2	69.2	1130.2	66.4	58.7	1115.9	66.1	57.7	1125.7	66.2	58.1	1114.8	66.0	57.4	1137.1	66.4	56.6
8.75	1008.4	64.1	66.7	1055.9	65.0	61.3	1042.5	64.7	60.6	1051.9	64.9	60.9	1041.7	64.7	60.4	1062.2	65.1	60.2
9.75	942.0	62.5	64.7	986.4	63.5	62.1	973.9	63.2	61.5	982.7	63.4	61.8	973.2	63.2	61.5	992.3	63.6	61.5
10.75	880.0	60.9	62.9	921.5	61.9	61.9	909.9	61.7	61.5	918.0	61.9	61.7	909.2	61.6	61.4	927.0	62.1	61.6
11.75	822.1	59.3	61.3	860.9	60.4	61.1	850.0	60.1	60.8	857.6	60.3	61.0	849.4	60.1	60.7	866.0	60.5	61.0
12.75	768.0	58.1	60.4	804.2	59.2	60.5	794.1	58.9	60.1	801.2	59.1	60.4	793.5	58.9	60.1	809.0	59.3	60.4
13.75	717.5	55.9	58.2	751.3	57.0	58.7	741.8	56.7	58.4	748.5	56.9	58.6	741.3	56.7	58.3	755.8	57.2	58.7
14.75	670.3	54.4	56.7	701.9	55.5	57.4	693.0	55.2	57.1	699.2	55.4	57.3	692.5	55.2	57.1	706.1	55.7	57.5
15.75	626.2	52.8	55.3	655.7	53.9	56.1	647.4	53.6	55.8	653.2	53.8	56.0	646.9	53.6	55.7	659.6	54.0	56.1
16.75	585.0	51.2	53.8	612.6	52.3	54.7	604.8	52.0	54.4	610.2	52.2	54.6	604.4	52.0	54.4	616.2	52.4	54.8
17.75	546.5	49.5	52.3	572.3	50.6	53.2	565.0	50.3	53.0	570.1	50.6	53.1	564.6	50.3	52.9	575.7	50.8	53.3
18.25	528.2	48.2	51.0	553.1	49.3	51.9	546.1	49.0	51.6	551.0	49.2	51.8	545.7	48.9	51.6	556.4	49.4	52.0

Appendix A3. LS and HS Modeling Results for Generic Generator 5.5 kW, Partial Load, No HVAC																		
Time	***ppm CO***	**% COHb**	**% COHb**	***ppm CO***	**% COHb**	**% COHb**	***ppm CO***	**% COHb**	**% COHb**	***ppm CO***	**% COHb**	**% COHb**	***ppm CO***	**% COHb**	**% COHb**	***ppm CO***	**% COHb**	**% COHb**
hours	***Basement***	20L/min	6L/min	***Kitchen***	20L/min	6L/min	***LR & DR***	20L/min	6L/min	***BR 1 & 2***	20L/min	6L/min	***BR 3 & 4***	20L/min	6L/min	***Hall***	20L/min	6L/min
0	***0***	1.2	1.2	***0***	1.2	1.2	***0***	1.2	1.2	***0***	1.2	1.2	***0***	1.2	1.2	***0***	1.2	1.2
0.25	***1332.7***	10.6	3.7	***0.0***	1.1	1.1	***0.0***	1.1	1.1	***0.0***	1.1	1.1	***0.0***	1.1	1.1	***0.0***	1.1	1.1
0.75	***3218.1***	61.6	20.5	***533.5***	8.2	3.1	***98.0***	2.3	1.5	***0.0***	0.9	1.1	***0.0***	0.9	1.1	***41.3***	1.5	1.3
1.25	***4517.7***		47.4	***1081.2***	28.0	9.0	***443.5***	9.3	3.5	***39.2***	1.3	1.2	***53.0***	1.5	1.3	***142.7***	3.8	1.9
1.75	***5463.7***		74.7	***1598.8***	52.8	18.6	***868.7***	25.0	8.2	***118.6***	3.3	1.8	***147.4***	4.0	2.0	***281.4***	8.9	3.4
2.25	***6185.0***		88.1	***2067.1***	70.3	31.1	***1297.8***	45.8	15.9	***229.6***	7.5	3.0	***270.5***	9.0	3.5	***442.3***	17.0	6.0
2.75	***6755.3***			***2481.6***	78.0	45.4	***1698.3***	63.7	26.2	***361.6***	14.2	5.1	***411.0***	16.6	5.9	***614.2***	27.5	9.7
3.25	***7218.6***			***2844.8***	81.4	59.9	***2058.6***	73.5	38.3	***505.5***	22.9	8.1	***559.8***	26.0	9.3	***789.0***	38.8	14.5
3.75	***7602.4***			***3161.3***	83.3	72.2	***2376.9***	78.1	51.2	***653.9***	32.9	12.1	***710.3***	36.4	13.6	***960.8***	49.5	20.2
4.25	***7924.7***			***3436.6***	84.6	80.1	***2655.6***		63.4	***801.3***	42.9	16.9	***857.8***	46.2	18.7	***1125.7***	57.9	26.8
4.75	***8198.0***			***3676.1***	85.6	84.0	***2898.5***		73.1	***944.0***	51.6	22.5	***999.1***	54.3	24.6	***1281.4***	63.9	34.0
5.25	***8431.6***			***3884.6***	86.4	85.8	***3110.1***		79.3	***1079.4***	58.3	28.7	***1132.2***	60.4	30.9	***1426.3***	67.8	41.5
5.75	***8632.3***			***4066.2***	87.0	86.7	***3294.3***		82.6	***1206.1***	63.1	35.2	***1255.9***	64.6	37.6	***1559.9***	70.6	48.9
6.25	***6436.9***			***3960.1***			***3454.8***			***1323.4***	66.5	41.9	***1369.8***	67.6	44.4	***1682.1***	72.6	56.0
6.75	***5032.1***			***3553.8***			***3341.6***			***1416.0***	68.8	48.5	***1452.2***	69.6	50.8	***1709.0***	73.7	61.9
7.25	***4060.6***			***3138.7***			***3064.7***			***1454.5***	70.2	54.4	***1472.5***	70.7	56.5	***1685.4***	74.0	66.3
7.75	***3352.1***			***2750.7***			***2738.4***			***1446.9***	70.7	59.2	***1447.8***	70.9	60.8	***1624.1***	73.6	69.0
8.25	***2812.1***			***2402.2***			***2414.8***			***1404.1***	70.6	62.7	***1391.6***	70.6	63.9	***1537.6***	72.9	70.4
8.75	***2385.8***			***2095.3***			***2115.7***			***1337.0***	70.0	64.9	***1315.0***	69.8	65.7	***1435.9***	71.8	70.8
9.25	***2040.4***			***1827.7***			***1848.4***			***1254.5***	68.9	66.1	***1226.2***	68.6	66.4	***1326.8***	70.4	70.5
9.75	***1755.4***			***1595.4***			***1613.4***			***1163.6***	67.6	66.4	***1131.8***	67.1	66.4	***1215.8***	68.8	69.7
10.25	***1516.8***			***1393.8***			***1408.6***			***1069.5***	66.0	66.0	***1036.1***	65.4	65.9	***1106.6***	67.0	68.6
10.75	***1315.1***			***1219.0***			***1230.5***			***975.8***	64.2	65.3	***942.4***	63.5	65.0	***1001.7***	65.0	67.2
11.25	***1143.4***			***1067.1***			***1075.9***			***885.2***	62.2	64.2	***852.6***	61.5	63.8	***902.9***	62.8	65.7
11.75	***996.2***			***935.1***			***941.7***			***799.2***	60.1	62.8	***768.1***	59.3	62.3	***810.9***	60.6	64.0
12.25	***869.6***			***820.1***			***824.9***			***718.7***	57.9	61.3	***689.6***	57.0	60.8	***726.1***	58.2	62.3
12.75	***760.2***			***719.8***			***723.3***			***644.3***	55.5	59.7	***617.3***	54.6	59.1	***648.6***	55.8	60.5
13.25	***665.4***			***632.1***			***634.7***			***576.0***	53.1	58.0	***551.3***	52.2	57.4	***578.2***	53.3	58.6
13.75	***583.1***			***555.5***			***557.3***			***513.9***	50.7	56.2	***491.3***	49.7	55.6	***514.5***	50.8	56.7
14.25	***511.4***			***488.4***			***489.6***			***457.6***	48.2	54.4	***437.1***	47.3	53.7	***457.2***	48.3	54.8
14.75	***448.9***			***429.6***			***430.4***			***406.9***	45.7	52.6	***388.4***	44.8	51.9	***405.8***	45.8	52.9
15.25	***394.3***			***378.0***			***378.5***			***361.4***	43.3	50.7	***344.7***	42.3	50.0	***359.9***	43.2	51.0
15.75	***346.6***			***332.7***			***333.0***			***320.5***	40.8	48.9	***305.6***	39.9	48.2	***318.8***	40.8	49.1
16.25	***304.8***			***293.0***			***293.1***			***284.1***	38.4	47.1	***270.8***	37.5	46.4	***282.3***	38.3	47.3
16.75	***268.1***			***258.0***			***258.0***			***251.6***	36.0	45.3	***239.7***	35.1	44.6	***249.8***	36.0	45.4
17.25	***235.9***			***227.2***			***227.2***			***222.7***	33.7	43.5	***212.1***	32.9	42.9	***220.9***	33.6	43.6
17.75	***207.7***			***200.2***			***200.1***			***197.0***	31.5	41.8	***187.5***	30.7	41.1	***195.3***	31.4	41.9
18.25	***182.9***			***176.4***			***176.3***			***174.1***	29.4	40.1	***165.8***	28.6	39.5	***172.5***	29.3	40.2
18.75	***182.9***			***176.4***			***176.3***			***174.1***	27.6	38.5	***165.8***	26.8	37.9	***172.5***	27.5	38.6

Appendix A4. LS and HS Modeling Results for Generic Generator 5.5 kW, Partial Load, with HVAC

Time hours	ppm CO Basement	%COHb 20L/min	%COHb 6L/min	ppm CO Kitchen	%COHb 20L/min	%COHb 6L/min	ppm CO LR & DR	%COHb 20L/min	%COHb 6L/min	ppm CO BR 1 & 2	%COHb 20L/min	%COHb 6L/min	ppm CO BR 3 & 4	%COHb 20L/min	%COHb 6L/min	ppm CO upstairs	%COHb 20L/min	%COHb 6L/min
0	***0***	1.2	1.2	***0***	1.2	1.2	***0***	1.2	1.2	***0***	1.2	1.16	***0***	1.2	1.2	***0***	1.2	1.2
0.25	***990.5771***	8.2	3.0	***0***	1.1	1.1	***0***	1.1	1.1	***0***	1.1	1.14	***0***	1.1	1.1	***0***	1.1	1.1
0.75	***1657.4***	40.6	12.8	***179.5***	3.4	1.8	***148.6***	2.9	1.7	***157.4***	3.1	1.70	***146.2***	2.9	1.7	***79.8***	2.0	1.4
1.25	***1910.0***	65.9	25.4	***369.4***	10.3	3.8	***333.7***	9.1	3.4	***339.5***	9.3	3.51	***326.3***	8.9	3.4	***247.0***	6.2	2.6
1.75	***2093.3***	75.1	38.5	***553.2***	20.7	7.1	***516.4***	18.8	6.5	***520.8***	19.2	6.59	***507.7***	18.5	6.4	***426.5***	14.2	5.0
2.25	***2260.6***	78.0	51.0	***730.5***	32.9	11.6	***693.1***	30.6	10.7	***696.7***	31.0	10.85	***684.1***	30.2	10.5	***603.7***	25.0	8.7
2.75	***2420.8***	79.5	62.2	***901.7***	44.8	17.1	***863.7***	42.6	16.0	***866.7***	42.9	16.15	***854.7***	42.1	15.8	***775.8***	37.0	13.4
3.25	***2575.2***	80.6	70.9	***1067.1***	54.7	23.5	***1028.6***	52.9	22.2	***1030.9***	53.1	22.34	***1019.5***	52.4	21.9	***942.2***	48.1	19.1
3.75	***2724.4***	81.6	76.8	***1226.9***	61.8	30.5	***1187.9***	60.5	29.1	***1189.6***	60.6	29.23	***1178.7***	60.1	28.7	***1103.1***	56.9	25.6
4.25	***2868.6***	82.4	80.2	***1381.4***	66.6	38.0	***1341.8***	65.6	36.5	***1342.9***	65.7	36.62	***1332.5***	65.4	36.1	***1258.7***	63.2	32.8
4.75	***3007.8***	83.1	82.1	***1530.6***	69.8	45.7	***1490.5***	69.1	44.1	***1491.0***	69.1	44.22	***1481.1***	68.9	43.7	***1408.9***	67.4	40.2
5.25	***3142.4***	83.7	83.2	***1674.8***	72.2	53.2	***1634.2***	71.6	51.6	***1634.1***	71.6	51.71	***1624.7***	71.5	51.2	***1554.1***	70.3	47.8
5.75	***3272.5***			***1814.1***	74.1	60.2	***1773.1***	73.6	58.6	***1772.4***	73.6	58.71	***1763.5***	73.5	58.3	***1694.5***	72.5	55.1
6.25	***1966.6***			***1860.1***	75.3	65.9	***1841.8***	74.9	64.6	***1824.0***	74.8	64.59	***1820.9***	74.8	64.2	***1830.0***	74.3	61.7
6.75	***1718.0***			***1803.4***	75.4	69.7	***1794.4***	75.3	68.8	***1783.1***	75.1	68.72	***1787.2***	75.1	68.5	***1807.9***	75.1	66.8
7.75	***1572.0***			***1683.3***	74.6	72.7	***1677.4***	74.5	72.2	***1670.3***	74.4	72.14	***1675.8***	74.5	72.1	***1695.4***	74.7	71.5
8.75	***1467.0***			***1571.6***	73.3	73.0	***1566.3***	73.3	72.8	***1560.0***	73.2	72.71	***1565.2***	73.2	72.7	***1582.9***	73.5	72.6
9.75	***1369.7***			***1467.4***	72.0	72.4	***1462.5***	71.9	72.2	***1456.6***	71.8	72.14	***1461.4***	71.9	72.2	***1477.8***	72.1	72.3
10.75	***1278.9***			***1370.1***	70.6	71.3	***1365.5***	70.5	71.2	***1360.0***	70.5	71.12	***1364.5***	70.5	71.2	***1379.8***	70.8	71.3
11.75	***1194.1***			***1279.2***	69.2	70.1	***1274.9***	69.1	70.0	***1269.8***	69.0	69.92	***1274.0***	69.1	70.0	***1288.3***	69.3	70.2
12.75	***1114.9***			***1194.4***	68.0	69.2	***1190.4***	67.9	69.2	***1185.6***	67.9	69.08	***1189.6***	67.9	69.1	***1202.9***	68.2	69.3
13.75	***1040.9***			***1115.2***	66.1	67.3	***1111.5***	66.1	67.2	***1107.0***	66.0	67.13	***1110.7***	66.1	67.2	***1123.1***	66.3	67.4
14.75	***971.9***			***1041.2***	64.7	66.0	***1037.7***	64.6	65.9	***1033.6***	64.5	65.82	***1037.0***	64.6	65.9	***1048.6***	64.9	66.1
15.75	***907.5***			***972.2***	63.2	64.6	***968.9***	63.1	64.5	***965.0***	63.0	64.44	***968.3***	63.1	64.5	***979.1***	63.3	64.7
16.75	***847.3***			***907.7***	61.6	63.2	***904.7***	61.5	63.1	***901.0***	61.4	63.04	***904.0***	61.5	63.1	***914.2***	61.8	63.3
17.75	***791.1***			***847.5***	60.0	61.8	***844.7***	59.9	61.7	***841.3***	59.8	61.60	***844.1***	59.9	61.7	***853.6***	60.2	61.9
18.25	***764.4***			***819.0***	58.7	60.5	***816.2***	58.6	60.4	***812.9***	58.5	60.30	***815.6***	58.6	60.4	***824.8***	58.9	60.6

Appendix A5. LS and HS Modeling Results for Generic Generator 5.5 kW, Full Load, No HVAC

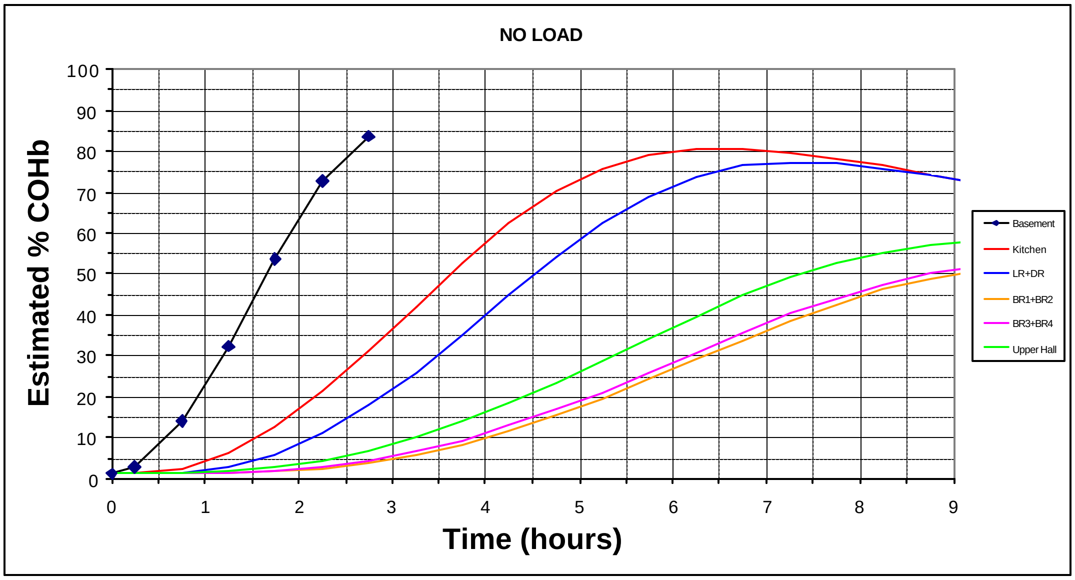
Time	*ppm CO*	% COHb	% COHb	*ppm CO*	% COHb	% COHb	*ppm CO*	% COHb	% COHb	*ppm CO*	% COHb	% COHb	*ppm CO*	% COHb	% COHb	*ppm CO*	% COHb	% COHb
hours	*Basement*	20L/min	6L/min	*Kitchen*	20L/min	6L/min	*LR & DR*	20L/min	6L/min	*BR1 & 2*	20L/min	6L/min	*BR 3 & 4*	20L/min	6L/min	*upstairs*	20L/min	6L/min
0	*0*	1.2	1.2	*0*	1.2	1.2	*0*	1.2	1.2	*0*	1.2	1.2	*0*	1.2	1.2	*0*	1.2	1.2
0.25	*1548.7*	12.2	4.1	*0.0*	1.1	1.1	*0.0*	1.1	1.1	*0.0*	1.1	1.1	*0.0*	1.1	1.1	*0.0*	1.1	1.1
0.75	*3739.8*	68.1	23.6	*620.0*	9.4	3.4	*113.8*	2.5	1.5	*0.0*	0.9	1.1	*0.0*	0.9	1.1	*47.9*	1.6	1.3
1.25	*5250.0*		54.3	*1256.5*	32.1	10.3	*515.4*	10.7	3.8	*45.5*	1.4	1.2	*61.6*	1.6	1.3	*165.8*	4.3	2.0
1.75	*6349.3*		81.8	*1857.9*	58.9	21.4	*1009.6*	28.7	9.4	*137.8*	3.7	1.9	*171.3*	4.6	2.1	*327.0*	10.2	3.8
2.25	*7187.5*			*2402.1*	74.8	35.8	*1508.2*	51.6	18.3	*266.8*	8.6	3.3	*314.3*	10.4	3.9	*514.0*	19.6	6.8
2.75	*7850.3*			*2883.9*	80.9	52.0	*1973.6*	68.9	30.2	*420.2*	16.3	5.8	*477.6*	19.1	6.7	*713.8*	31.4	11.1
3.25	*8388.7*			*3305.9*	83.7	67.4	*2392.3*	77.1	44.0	*587.5*	26.3	9.3	*650.5*	29.8	10.6	*916.8*	43.9	16.6
3.75	*8834.7*			*3673.7*	85.3	78.6	*2762.2*	80.8	58.2	*759.9*	37.4	13.9	*825.5*	41.2	15.6	*1116.5*	54.8	23.3
4.25	*9209.2*			*3993.7*			*3086.0*	82.9	70.7	*931.2*	48.1	19.5	*996.9*	51.5	21.5	*1308.2*	62.8	30.8
4.75	*9526.9*			*4272.0*			*3368.4*	84.3	79.1	*1097.0*	56.8	25.9	*1161.1*	59.4	28.3	*1489.1*	68.1	39.0
5.25	*9798.3*			*4514.3*			*3614.2*	85.4	83.5	*1254.4*	63.0	33.0	*1315.7*	64.9	35.6	*1657.5*	71.5	47.4
5.75	*10031.6*			*4725.4*			*3828.3*			*1401.6*	67.3	40.4	*1459.5*	68.6	43.1	*1812.8*	73.8	55.5
6.25	*7480.3*			*4602.0*			*4014.8*			*1537.9*	70.2	47.8	*1591.9*	71.1	50.5	*1954.8*	75.6	62.7
6.75	*5847.7*			*4129.8*			*3883.2*			*1645.6*	72.2	54.9	*1687.5*	72.9	57.4	*1986.0*	76.6	68.4
7.25	*4718.8*			*3647.5*			*3561.5*			*1690.3*	73.4	60.9	*1711.2*	73.8	63.0	*1958.6*	76.8	72.1
7.75	*3895.5*			*3196.6*			*3182.3*			*1681.4*	73.8	65.5	*1682.5*	74.0	67.0	*1887.4*	76.4	74.0
8.25	*3267.9*			*2791.6*			*2806.2*			*1631.7*	73.6	68.5	*1617.2*	73.6	69.5	*1786.8*	75.7	74.7
8.75	*2772.5*			*2435.0*			*2458.6*			*1553.7*	73.0	70.2	*1528.1*	72.8	70.7	*1668.7*	74.6	74.6
9.25	*2371.2*			*2124.0*			*2148.0*			*1457.8*	72.0	70.7	*1425.0*	71.6	70.9	*1541.9*	73.3	73.9
9.75	*2039.9*			*1853.9*			*1875.0*			*1352.2*	70.7	70.6	*1315.2*	70.2	70.5	*1412.8*	71.8	72.9
10.25	*1762.7*			*1619.7*			*1636.9*			*1242.8*	69.2	69.9	*1204.1*	68.6	69.6	*1285.9*	70.0	71.6
10.75	*1528.3*			*1416.5*			*1430.0*			*1134.0*	67.4	68.8	*1095.2*	66.8	68.5	*1164.1*	68.1	70.2
11.25	*1328.7*			*1240.1*			*1250.3*			*1028.7*	65.5	67.5	*990.9*	64.7	67.1	*1049.2*	66.1	68.6
11.75	*1157.7*			*1086.6*			*1094.3*			*928.7*	63.4	66.1	*892.7*	62.6	65.5	*942.3*	63.9	66.9
12.25	*1010.5*			*953.0*			*958.6*			*835.2*	61.2	64.5	*801.4*	60.3	63.9	*843.8*	61.5	65.1
12.75	*883.4*			*836.4*			*840.5*			*748.7*	58.9	62.7	*717.4*	58.0	62.1	*753.7*	59.1	63.3
13.25	*773.3*			*734.6*			*737.5*			*669.4*	56.5	61.0	*640.6*	55.6	60.3	*671.9*	56.7	61.4
13.75	*677.6*			*645.5*			*647.6*			*597.2*	54.0	59.1	*570.9*	53.1	58.4	*597.9*	54.1	59.4
14.25	*594.3*			*567.6*			*569.0*			*531.8*	51.5	57.2	*508.0*	50.5	56.5	*531.3*	51.6	57.5
14.75	*521.7*			*499.2*			*500.2*			*472.9*	49.0	55.3	*451.4*	48.0	54.6	*471.6*	49.0	55.5
15.25	*458.3*			*439.3*			*439.9*			*419.9*	46.5	53.4	*400.6*	45.5	52.7	*418.2*	46.4	53.6
15.75	*402.8*			*386.7*			*387.0*			*372.5*	44.0	51.5	*355.2*	43.0	50.8	*370.5*	43.9	51.7
16.25	*354.2*			*340.4*			*340.6*			*330.1*	41.5	49.7	*314.6*	40.5	48.9	*328.0*	41.4	49.7
16.75	*311.5*			*299.8*			*299.9*			*292.4*	39.0	47.8	*278.6*	38.1	47.1	*290.3*	38.9	47.8
17.25	*274.2*			*264.1*			*264.1*			*258.8*	36.6	45.9	*246.5*	35.7	45.2	*256.7*	36.5	46.0
17.75	*241.3*			*232.6*			*232.6*			*228.9*	34.3	44.1	*217.9*	33.4	43.4	*226.9*	34.2	44.2
18.25	*212.5*			*205.0*			*204.9*			*202.4*	32.1	42.4	*192.7*	31.2	41.7	*200.5*	31.9	42.4
18.75	*212.5*			*205.0*			*204.9*			*202.4*	30.2	40.7	*192.7*	29.3	40.1	*200.5*	30.0	40.7

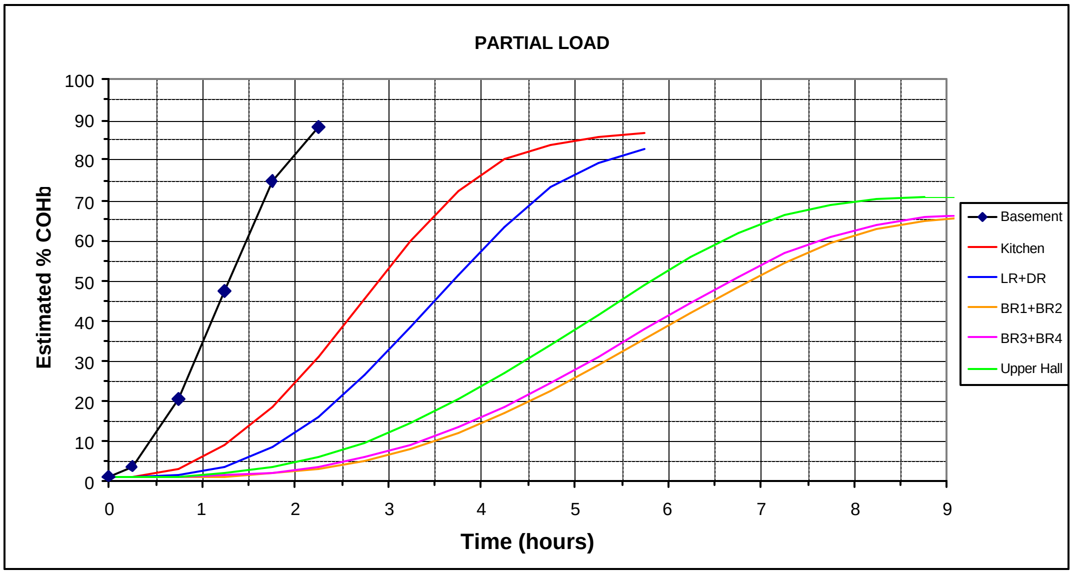
Appendix A6. LS and HS Modeling Results for Generic Generator 5.5 kW, Full Load with HVAC																		
Time	ppm CO	%COHb	%COHb	ppm CO	%COHb	%COHb	ppm CO	%COHb	%COHb	ppm CO	%COHb	%COHb	ppm CO	%COHb	%COHb	ppm CO	%COHb	%COHb
hours	Basement	20L/min	6L/min	Kitchen	20L/min	6L/min	LR & DR	20L/min	6L/min	BR1 & 2	20L/min	6L/min	BR3&4	20L/min	6L/min	upstairs	20L/min	6L/min
0	0	1.2	1.2	0	1.2	1.2	0	1.2	1.2	0	1.2	1.2	0	1.2	1.2	0	1.2	1.2
0.25	1151.1	9.3	3.3	0.0	1.1	1.1	0.0	1.1	1.1	0.0	1.1	1.1	0.0	1.1	1.1	0.0	1.1	1.1
0.75	1926.0	46.2	14.7	208.6	3.8	1.9	172.6	3.3	1.8	182.9	3.4	1.8	169.9	3.2	1.7	92.8	2.2	1.5
1.25	2219.6	71.3	29.3	429.3	11.8	4.2	387.8	10.4	3.8	394.6	10.7	3.9	379.2	10.2	3.7	287.0	7.0	2.8
1.75	2432.6	78.5	44.2	642.9	23.8	8.1	600.1	21.6	7.3	605.2	22.0	7.5	590.0	21.2	7.2	495.7	16.3	5.7
2.25	2627.1	80.7	58.1	848.9	37.5	13.3	805.4	35.0	12.3	809.6	35.4	12.4	795.0	34.5	12.1	701.6	28.7	9.9
2.75	2813.1	81.9	69.5	1047.9	50.2	19.6	1003.8	47.9	18.4	1007.2	48.2	18.6	993.3	47.4	18.1	901.5	41.9	15.4
3.25	2992.6	82.9	77.1	1240.1	59.9	27.0	1195.3	58.2	25.5	1198.0	58.4	25.7	1184.7	57.8	25.2	1095.0	53.5	22.0
3.75	3166.0	83.7	81.4	1425.8	66.3	35.1	1380.5	65.1	33.4	1382.4	65.2	33.6	1369.7	64.8	33.1	1282.0	62.0	29.5
4.25	3333.5	84.5	83.5	1605.3	70.4	43.6	1559.3	69.6	41.8	1560.6	69.6	42.0	1548.5	69.4	41.4	1462.7	67.5	37.6
4.75	3495.4			1778.7	73.2	52.1	1732.1	72.6	50.2	1732.7	72.6	50.4	1721.2	72.4	49.8	1637.3	71.1	46.0
5.25	3651.8			1946.2	75.3	60.0	1899.1	74.8	58.3	1899.0	74.8	58.4	1888.1	74.7	57.9	1806.1	73.6	54.3
5.75	3802.9			2108.1	77.0	66.8	2060.5	76.5	65.4	2059.7	76.5	65.4	2049.3	76.4	65.0	1969.1	75.6	61.8
6.25	2285.4			2161.6	78.0	71.9	2140.4	77.7	70.8	2119.6	77.6	70.8	2116.1	77.6	70.5	2126.7	77.2	68.2
6.75	1996.5			2095.7	78.1	74.9	2085.2	78.0	74.2	2072.2	77.8	74.1	2076.9	77.8	74.0	2101.0	77.9	72.7
7.75	1826.8			1956.1	77.3	76.5	1949.3	77.3	76.3	1941.1	77.2	76.2	1947.4	77.2	76.1	1970.2	77.4	75.8
8.75	1704.8			1826.4	76.1	76.2	1820.2	76.1	76.1	1812.8	76.0	76.0	1818.9	76.1	76.0	1839.4	76.3	76.1
9.75	1591.7			1705.2	74.9	75.3	1699.5	74.8	75.2	1692.7	74.7	75.2	1698.3	74.8	75.2	1717.4	75.0	75.4
10.75	1486.2			1592.2	73.6	74.2	1586.8	73.5	74.1	1580.4	73.4	74.0	1585.7	73.5	74.1	1603.5	73.7	74.3
11.75	1387.6			1486.6	72.3	73.0	1481.6	72.2	72.9	1475.6	72.1	72.8	1480.6	72.2	72.9	1497.2	72.4	73.1
12.75	1295.6			1388.0	71.1	72.1	1383.3	71.0	72.1	1377.8	71.0	72.0	1382.4	71.0	72.0	1397.9	71.2	72.2
13.75	1209.7			1296.0	69.4	70.3	1291.6	69.3	70.2	1286.4	69.2	70.1	1290.7	69.3	70.2	1305.2	69.5	70.4
14.75	1129.5			1210.0	68.0	69.0	1206.0	67.9	68.9	1201.1	67.8	68.9	1205.1	67.9	68.9	1218.6	68.2	69.1
15.75	1054.6			1129.8	66.5	67.7	1126.0	66.5	67.6	1121.5	66.4	67.5	1125.2	66.4	67.6	1137.8	66.7	67.8
16.75	984.6			1054.9	65.0	66.3	1051.3	64.9	66.2	1047.1	64.9	66.2	1050.6	64.9	66.2	1062.4	65.2	66.4
17.75	919.3			984.9	63.5	64.9	981.6	63.4	64.8	977.7	63.3	64.8	980.9	63.4	64.8	991.9	63.6	65.1
18.25	888.3			951.7	62.2	63.6	948.5	62.1	63.6	944.7	62.1	63.5	947.8	62.1	63.6	958.5	62.4	63.8

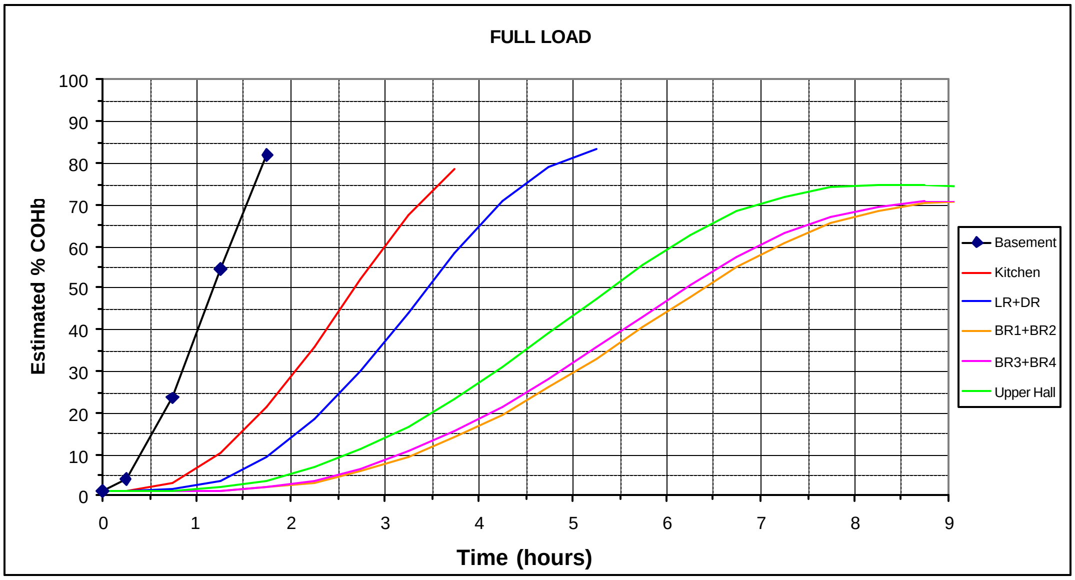
APPENDIX B

SUMMARY GRAPHS SHOWING % COHb TIME COURSE PROFILES FOR INDIVIDUALS ENGAGED IN RESTING/LOW OR MODERATE ACTIVITY LEVELS DURING THE FIRST 9 HOURS OF EXPOSURE TO GENERATOR EMISSIONS

Appendix B1
Predicted COHb profiles by home location during operation of a 5.5 Kw generator in a basement:
Assumptions: No HVAC fan running: resting/low activity (6L/min RMV)

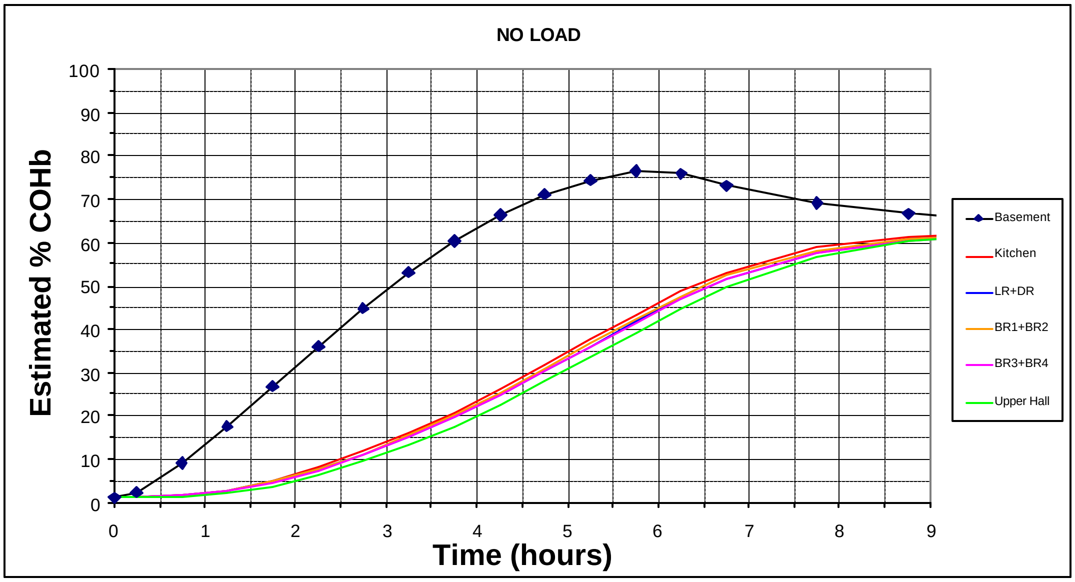


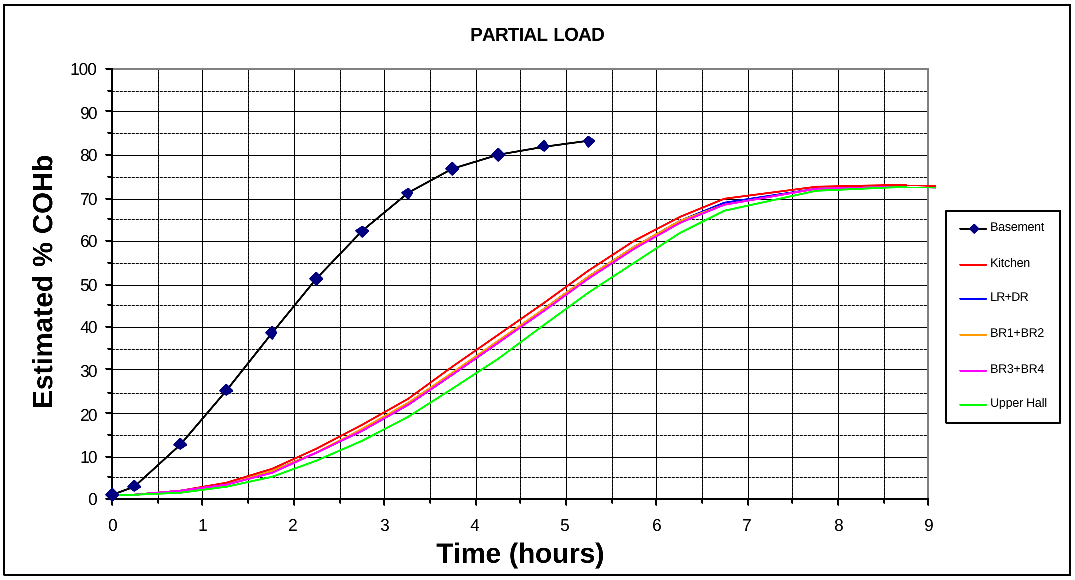


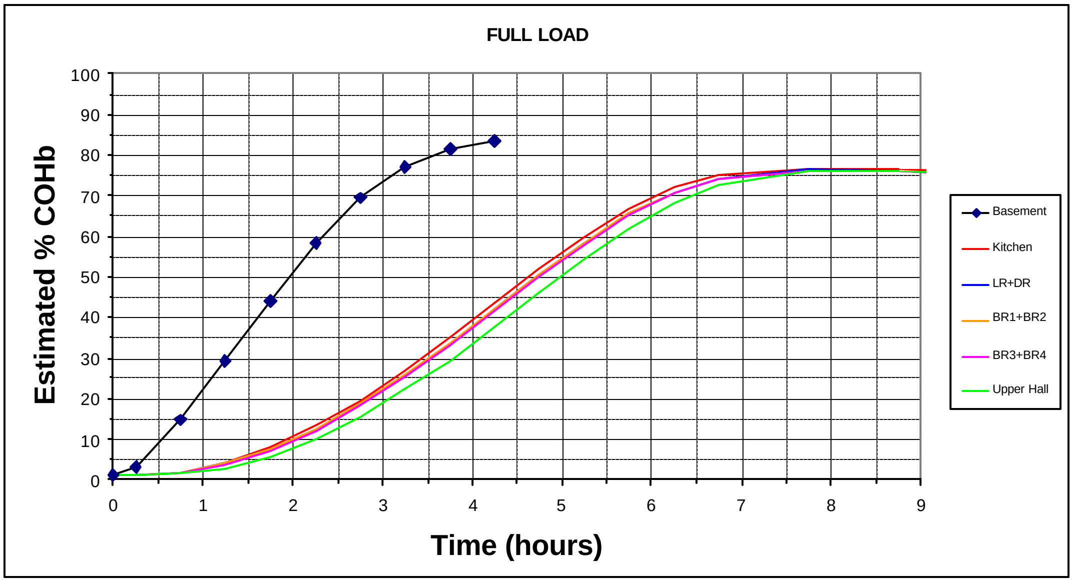


Appendix B2

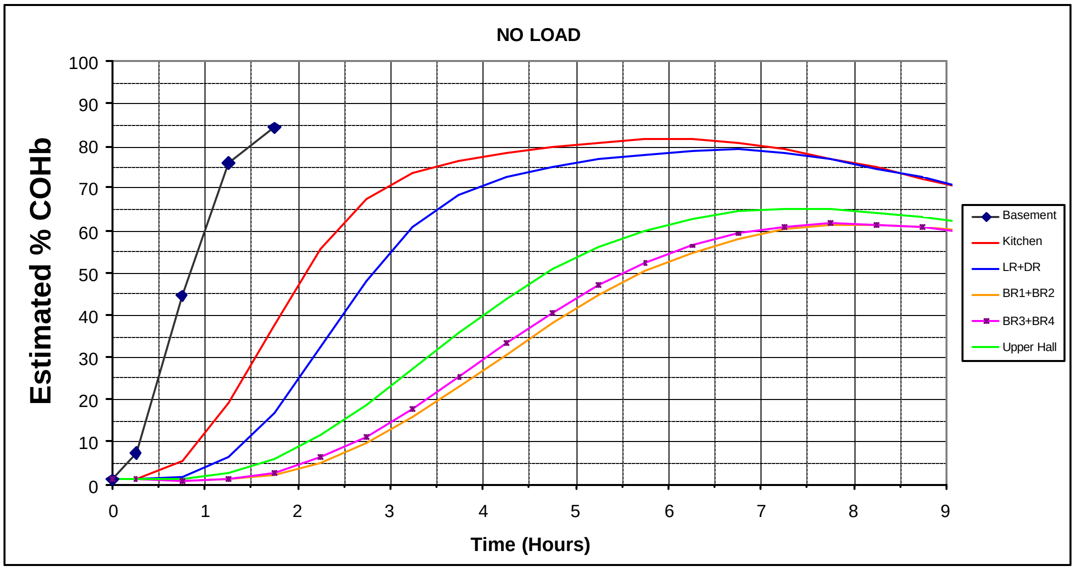
Predicted COHb profiles by home location during operation of a 5.5Kw generator in a basement:
Assumptions:with HVAC fan running: low/resting activity (6L/min RMV)

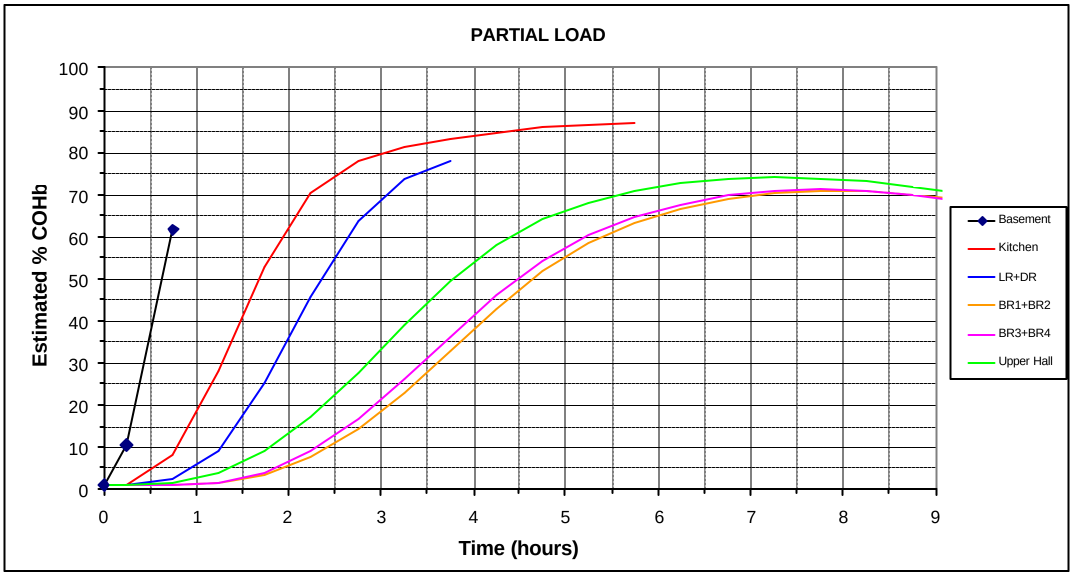


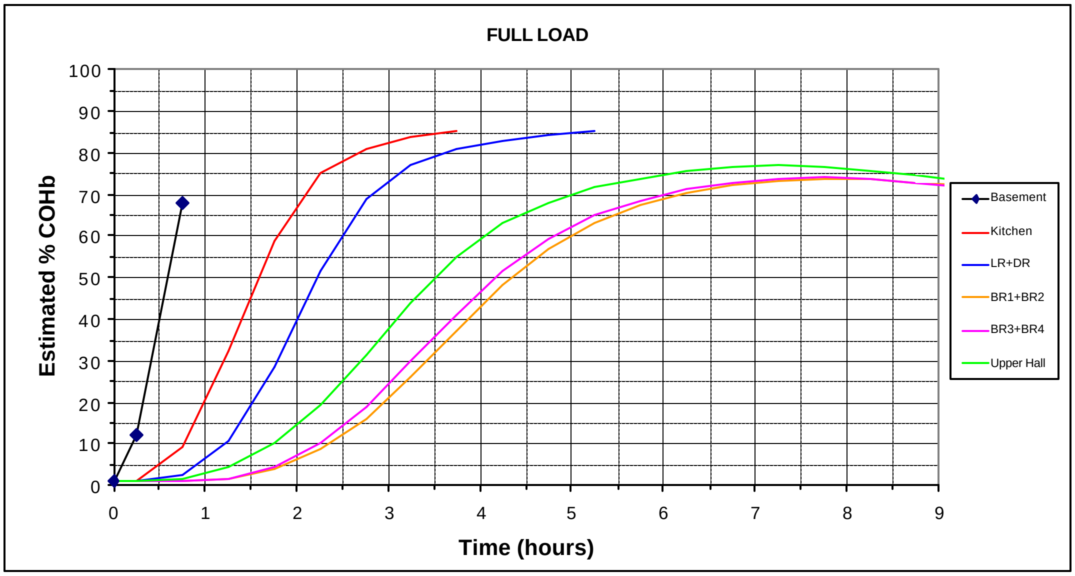




Appendix B3
Predicted COHb profiles by home location during operation of a 5.5 Kw generator in a basement:
Assumptions: No HVAC fan running: moderate activity (20L/min RMV)







Appendix B4
Predicted COHb profiles by home location during operation of a 5.5Kw generator in a basement: Assumptions:with HVAC fan running: moderate activity (20L/min RMV)