UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

MEMORANDUM

May 22, 2003

To: Janet L. Buyer
Project Manager, Small Engine-Driven Tools Project
Division of Combustion and Fire Sciences, Directorate for Engineering Sciences

Through: Hugh M. McLaurin
Associate Executive Director, Directorate for Engineering Sciences

Erlinda M. Edwards
Director, Division of Electrical Engineering
Directorate for Engineering Sciences

From: Andrew M. Trotta
Electrical Engineer, Division of Electrical Engineering
Directorate for Engineering Sciences

Subject: Weatherproof Portable Engine-Generators

This memorandum covers issues related to weatherproofing of portable engine-generator sets. For the purposes of this report, an engine-generator is defined as an electric power generator that employs a gasoline-fueled internal combustion engine as its mechanical rotational energy source. Generator output may include a variety of voltage configurations, including 120/240 volts, 60 Hz as it is typically configured in U.S. residential power systems. Applications of portable engine-generators include areas where electric power is unavailable or as backup electrical power when utility power is down. At the present time, there is no industry voluntary safety standard for portable engine-generators, but Underwriters Laboratories (UL) is in the process of publishing the first edition of a standard, UL 2201, *Standard for Portable Engine-Generator Assemblies*. The February 2003 draft version of UL 2201 was reviewed for this assessment. There is a standard for installed engine-generators, UL 2200, *Standard for Stationary Engine Generator Assemblies*, which was reviewed for applicability to the issue of weatherproofing.

Engine-generators that employ internal combustion engines produce a significant amount of carbon monoxide (CO), and therefore they must be used outdoors in a well-ventilated area, to prevent accumulation of dangerous levels of CO in enclosed spaces where people have access. Contrarily, most portable engine-generator sets are not suitable for use in rain because of the risk of electric shock. This situation is further complicated because severe weather conditions producing precipitation, such as thunderstorms, may result in the types of extended power outages in which people need to use their portable generators. A user could then be faced with a decision of prioritizing the risk of carbon monoxide poisoning versus electric shock. Part of the technical solution to address this problem would be to require portable generators to be weatherized to permit their use outdoors while precipitation is falling. The purpose of this memorandum is to discuss issues related to this option.

DISCUSSION

Portable engine-generators are available in a variety of sizes, ranging in output power from about 900 to 10,000 watts (W). The basic components are a gasoline engine, electric generator and power distribution panel (receptacle outlets and circuit breaker, if included), as shown in Figure 1. These components are assembled in a frame or enclosure. Figure 2 shows three examples of different-sized portable generators – 900 W, 1,500 W and 5,500 W. These sample generators were purchased as part of the Small Engine-Driven Tools Project.

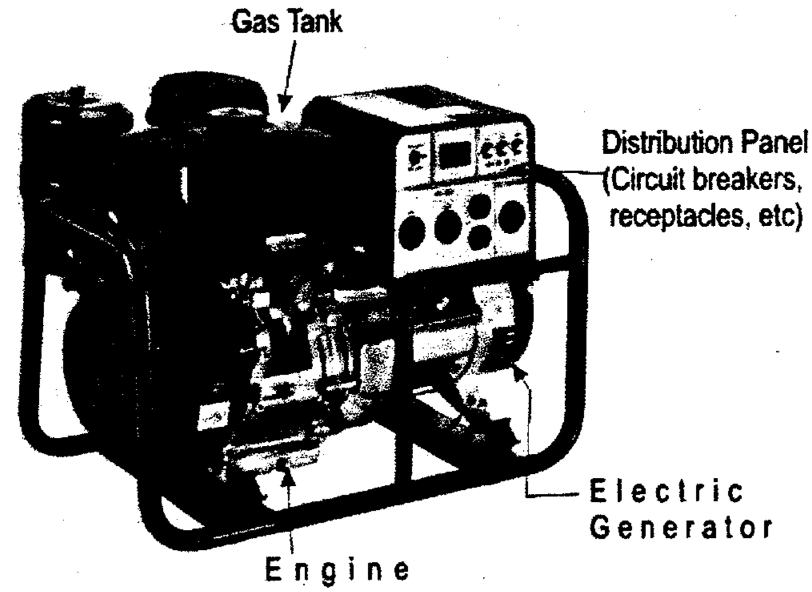

Figure 1. Typical engine-generator configuration.

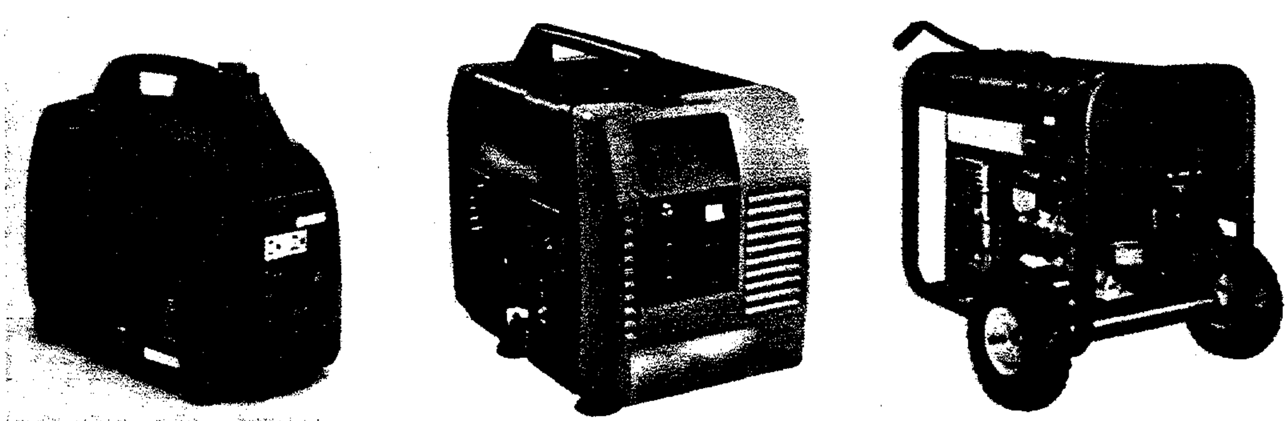

Figure 2. Portable Engine-Generators (L to R): 900 W unit (1.4 ft^3, 29 lbs.), 1500 W unit (2.0 ft^3, 68 lbs.) and 5500 W unit (7.5 ft^3, 148 lbs.); all weights exclude gasoline.

In general, the primary selection criterion for a generator is power capacity based on what appliances or electrical equipment (also generally referred to as loads) are expected to be supplied. Providing backup power to essential loads (e.g., a few lights, refrigerator, television, space heater, microwave, and a fan) in an average size house requires a generator in the range of 3,500 to 5,500 W. Powering a number of convenience items or a high wattage load (heat pump, central air or an electric oven) easily pushes the capacity requirement to 10,000 W. Small generators, in the 1,000 W range, are used for supplying power to a specific load, often where electric power is unavailable, e.g., a pitching machine used in the middle of a baseball field. However, provided the connected load does not exceed the capacity of the generator, any generator with the proper output voltage could be used in any application, particularly in an emergency situation.

Portable generators have receptacle outlets for connecting load equipment to the generator. This includes standard 15 ampere (A)/20 A, 120 volt (V) grounded duplex receptacles and circular four-socket 120/240 V grounded receptacles (if the generator supplies 240 V). Appliances and electrical equipment can be plugged directly into the generator, but often loads are connected via an extension cord. Another way of supplying loads, particularly for back-up power applications, is connecting the generator output to the household branch circuit wiring via power transfer equipment intended to segregate the house wiring from the utility. Also, custom power cords are available with male plugs on each end. This allows the user to connect the generator output into a branch circuit receptacle and backfeed the household wiring. This is an extremely inadvisable practice as it presents a shock risk to utility workers and bypasses some of the household circuit protection devices.

The primary hazard related to outdoor use of engine-generators is electric shock. Electric shock occurs when a person contacts a live electrical circuit and current flows through the parts of the body that complete the circuit. Contact between a line conductor and ground is called a ground fault. This is shown graphically in Figure 3.

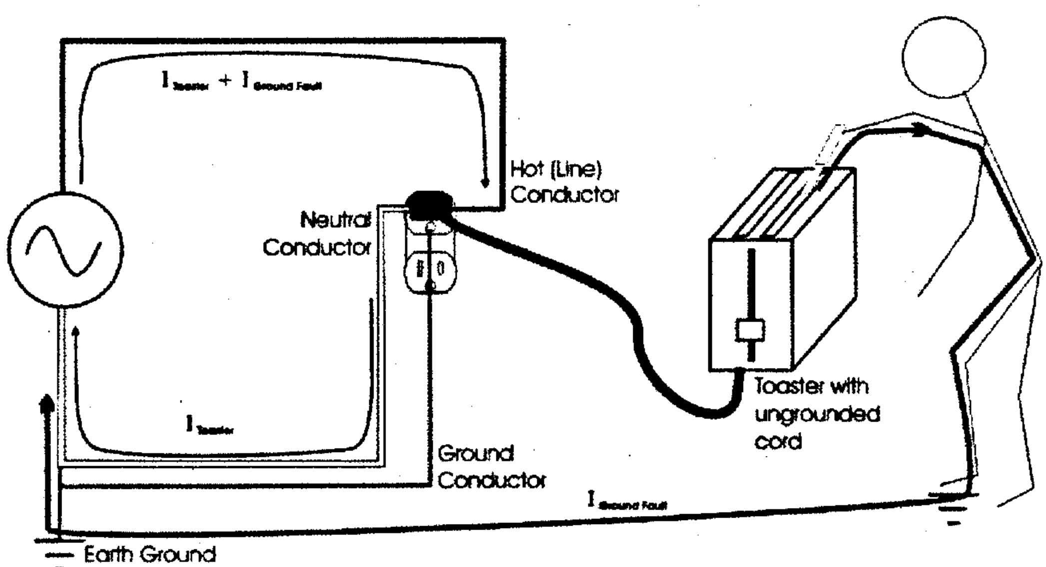

Figure 3. Schematic depiction of a ground fault in a grounded two-wire system supplying a two-wire ungrounded appliance.

The severity of electric shock ranges from minimal sensation to electrocution, depending on a number of factors, including the magnitude of the current (as a function of the applied voltage) and the part of the body through which the current flows.

According to UL 2200, for an outdoor-use unit where wet contact is likely, a live part is not a risk of shock if the voltage of the part is below 15 V_{rms} (21.2 V, peak).[1] For an indoor-use unit (wet contact not likely), the maximum voltage of live parts before a shock risk is defined is 30 V_{rms} (42.4 V, peak). A portable engine-generator for residential use produces voltages of 120 V/240 V and, as such, possesses a potentially lethal shock risk. Although this risk exists even in the absence of rain, it is amplified during inclement weather because rain water may compromise the insulation systems of components such as power cords, electrical equipment and human skin, and the abundance of water reduces ground resistance.

The risk of shock may exist whether the generator is grounded or not, as illustrated in the two fault current paths shown in Figure 4.

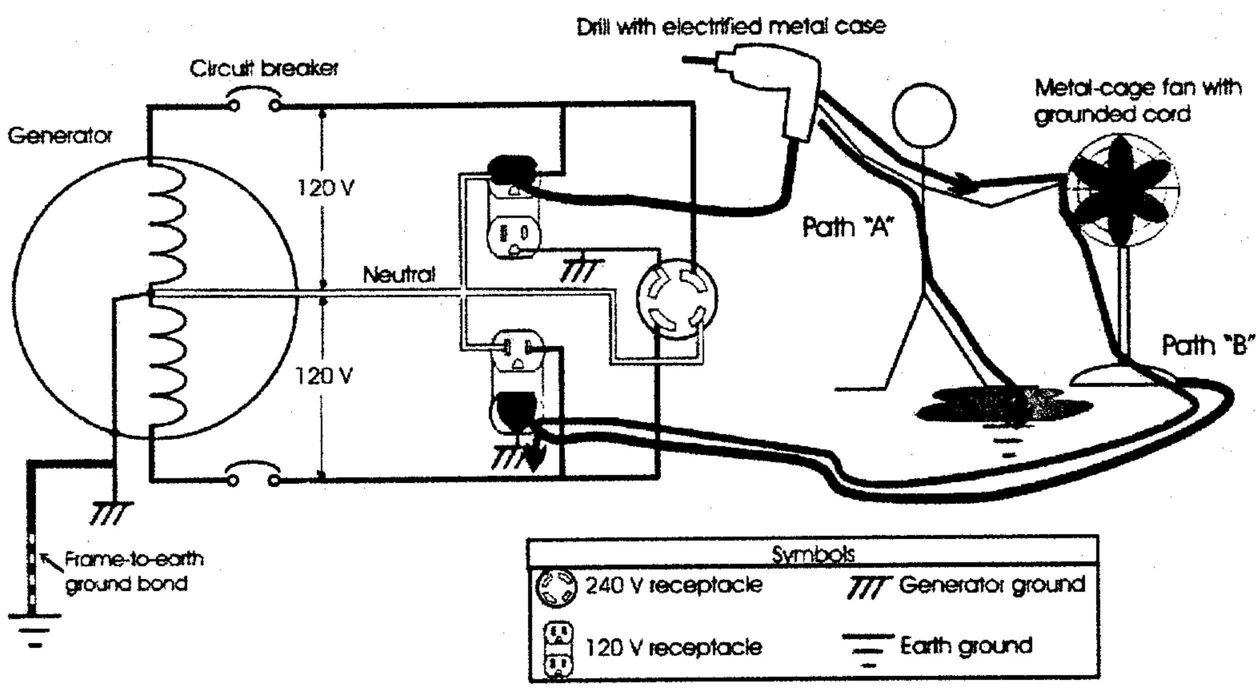

Figure 4. Graphical schematic of typical engine-generator set-up, showing alternate paths for electric shock. Path A depends on the user and generator being grounded, while Path B shows a leakage current path that does not require the generator to be grounded.

Path A shows the fault current flowing from a faulty drill through the user, who is grounded by a puddle of water, through earth ground and back to the grounded generator frame, which is tied to

[1] RMS is the root mean square value, which is used to describe the effective value of a sinusoidally-varying signal. For a pure sinusoidal waveform, the RMS value is the peak divided by the square root of 2. Unless otherwise noted, alternating current (AC) values are rms.

the neutral. This fault current path relies on both the generator and user being grounded. Path B shows the shock current flowing from the faulty drill through the user, through the metal case of the fan, through the power supply cord ground conductor to the receptacle ground, which is tied to the neutral conductor. Ground current path B does not rely on the generator being grounded to shock the user.

According to Article 100 of the 2002 *National Electrical Code*,[2] weatherproof is defined as equipment "constructed or protected so that exposure to the weather will not interfere with successful operation." The definition also indicates that, "rainproof, raintight or watertight equipment can fulfill the requirements of weatherproof where varying weather conditions other than wetness, such as snow, ice, dust or temperature extremes are not a factor." Requirements for outdoor use of portable generators are not included in the draft version of UL 2201. However, Sections 64 through 67 of UL 2200 include requirements for stationary generators intended for outdoor use. Basically, units listed for outdoor use must satisfy construction requirements to protect the unit against outdoor exposure and performance requirements to ensure the unit's exposure to rain does not result in conditions that could lead to a risk of electric shock. A stationary generator enclosure defined as raintight must prevent entrance of water during the rain test, while a rainproof enclosure must not permit live parts to get wet or permit entry of water above the lowest live part.

Using UL 2200 as a framework, development of outdoor-use requirements for portable generators should start with corrosion protection for vital parts and implementation of a raintight or rainproof enclosure for shock protection. As Figures 1 and 2 show, portable generator construction is very diverse – some are largely enclosed while others simply have an open frame on which the components are supported. Despite this diversity, it intuitively appears that a raintight or rainproof enclosure could be implemented, but it is not clear how this would impact other factors like size, cost and operability (e.g., a decreased ambient operating temperature range from a more airtight enclosure).

One major difference between portable and stationary generators is that output connections on portable engine-generators are made with plugs. Stationary generators have their output circuits hard-wired or permanently connected to the installed building wiring. Therefore, the output connections to a portable generator must be readily accessible by the user while the output connections of a stationary generator may be fully enclosed to prevent exposure from rain. This presents a particular problem for weatherproofing of portable generators.

There are some portable generator models that incorporate a cover for the power distribution panel to protect the outlets from water exposure. However, these covers are flat and do not provide coverage when a receptacle is in use. Since 1999, the *NEC* [410-57(b)(1) in 1999 and subsequently 406.8(B)(1) in 2002] has included requirements for receptacles installed outdoors in wet locations to have an enclosure that is weatherproof whether or not the attachment plug is inserted. Although this requirement is not applicable to a generator, these covers are now

[2] The *National Electrical Code* is a widely adopted code that establishes requirements for safe electrical installations. The *NEC* is revised every three years by a consensus committee process based on proposals from the public at large. Local jurisdictions adopt the NEC in part or in its entirety and local authorities, usually electrical inspectors, enforce these adopted provisions accordingly.

readily available in a number of different configurations and materials (e.g., polycarbonate and cast aluminum).

Figure 5 shows examples of the two basic types of weatherproof receptacle covers, one that is suitable for use whether or not a plug is inserted and the other that is weatherproof only when the cover is closed. Figure 5 also shows that an in-use weatherproof cover extends several inches beyond the face of the receptacle. This would extend the profile of some generators and could expose the cover to impact forces as the user transports the generator. There are impact resistance requirements for portable engine-generator enclosures in UL 2201 and plastic covers in UL 514C - *Nonmetallic Outlet Boxes, Flush-Device Boxes and Covers,* but they are different than those proposed in the draft version of UL 2201. The most appropriate requirements for application of these covers on portable generators would need to be selected.

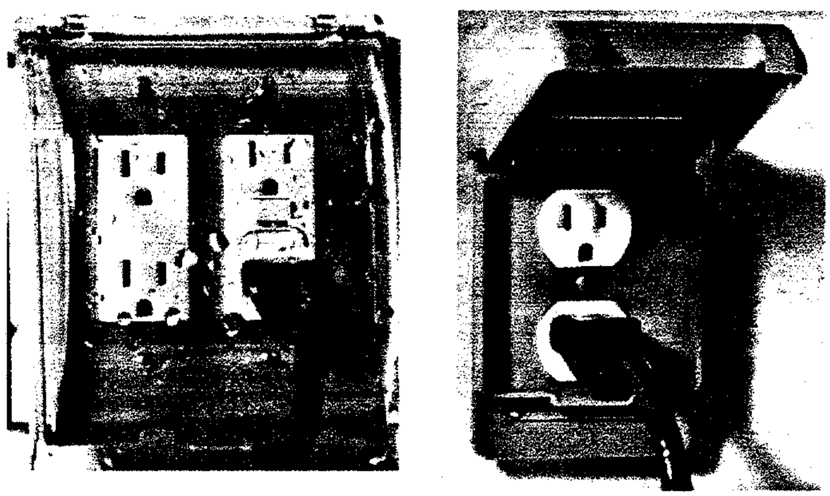

Figure 5. Examples of weatherproof covers. The cover on the left is weatherproof when in-use while the cover on the right is weatherproof only when closed.

An invaluable safety device to prevent electrocution is the ground fault circuit interrupter (GFCI). A GFCI looks for a differential between the line and neutral current, as would occur with a ground fault (as depicted in Figures 3 and 4). When the difference exceeds 0.005 amperes, the GFCI trips and opens the circuit. Ground fault circuit interrupters can be incorporated into receptacles, circuit breakers and power cords.

Recognizing the increased risk of electric shock from use of electrical equipment outdoors, the *NEC* has required GFCI protection for outdoor receptacles at dwelling units since 1973. Also, Section 15 of the draft version of UL 2201 proposes that all 120 volt and 120/240 volt outlets be ground-fault protected. However, a limited review of available generator models showed that very few portable engine-generator models have 120 V GFCI receptacles for shock protection. The review did not reveal any generators that included GFCI protection for their 240 V receptacles.

By itself, GFCI protection of all outlets does not constitute complete weatherization. The UL 2201 requirement for GFCI protection for all outlets only offers shock protection to users for loads that are plugged into the generator. Additional weatherproofing requirements to prevent wetting of live electrical parts and accumulation of water within the chassis are needed in addition to GFCI protection to provide complete shock protection for use of a generator in inclement weather.

One other issue related to portable engine-generators is the portability itself. While it appears that it may be possible (while not necessarily feasible) to weatherproof a portable generator through incorporation of a raintight or rainproof enclosure, in-use weatherproof receptacle covers and GFCIs, it is difficult to account for all possible locations in which a generator could be placed. For example, areas that are normally dry could be subject to significant puddling or channeling of water in heavy or prolonged rainfall. Some generators that are physically small (the first two generators in Figure 2 are only about 16" high) could become flooded from standing water (UL 2200 requirements do not address standing water).

CONCLUSIONS

Presently, portable gasoline-fueled engine generators are not constructed to permit their use outdoors during inclement weather. This creates confusion for users, who cannot place the units indoors because of the significant levels of carbon monoxide emitted by the gasoline engine. Weatherproofing portable-engine generators to permit their use outdoors during inclement weather appears to be an attractive strategy to eliminate this confusion and the potential risk of electric shock associated with their outdoor use.

There is no industry voluntary safety standard for portable engine-generators, but UL is in the processing of adopting a standard, UL 2201, *Standard for Portable Engine-Generator Assemblies.* However, the draft version of the standard does not include requirements for weatherproofing. The standard for stationary generators, UL 2200, includes requirements for outdoor use. Using UL 2200 as a framework for outdoor-use requirements for portable generators, it appears that weatherproofing portable generators would include a raintight or rainproof enclosure, in-use weatherproof receptacle covers and ground fault circuit protection for all receptacles.

A raintight or rainproof enclosure appears to be achievable except that the connection of equipment to the generator output is significantly different for portable generators. Portable generators have output receptacles that permit electrical equipment to be quickly and easily connected and disconnected. As such, a portable generator distribution panel requires ready access, which would require covers that weatherproof the receptacles even with a plug inserted. The draft version of UL 2201 already includes requirements for GFCI protection for all receptacles, so this is at least one weatherization requirement that is already being addressed by the draft standard.

Options to address this issue include:

- Conduct a follow-up study to assess feasibility of modifying portable generator designs to incorporate weatherproofing
- Propose revisions to UL 2201 to require all portable engine-generators to be weatherproof
- Present issue to the Standards Technical Panel for UL 2201 for resolution

REFERENCES

National Fire Protection Association (2002). *National Electrical Code (NFPA-70)*. Quincy, MA: National Electrical Manufacturers Association.

Standard for Portable Engine-Generator Assemblies - UL 2201, draft version of 1st Edition, February 2003 was available for review, Underwriters Laboratories, Northbrook, IL

Standard for Stationary Engine Generator Assemblies - UL 2200, 1st Edition, September 1, 1998, Underwriters Laboratories, Northbrook, IL

Overcurrents and Undercurrents Electrical Safety Advances through Electronics, 2000, Earl W. Roberts, Reptec, Mystic, CT

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: April 1, 2003

TO : Janet Buyer
Project Manager, Division of Combustion and Fire Sciences
Directorate for Engineering Sciences

THROUGH: Susan W. Ahmed
Associate Executive Director
Directorate for Epidemiology

Russell H. Roegner
Division Director, Division of Hazard Analysis
Directorate for Epidemiology

FROM : Susan Vagts
Mathematical Statistician, Division of Hazard Analysis
Directorate for Epidemiology

SUBJECT : Incidents, Deaths, and In-Depth Investigations Associated with Carbon Monoxide and Engine-Driven Tools, 1990-2002

This memorandum summarizes carbon monoxide (CO) incidents from the Consumer Product Safety Commission (CPSC) databases that were associated with engine-driven portable generators and other engine-driven tools for the years 1990 through 2002. Other engine-driven tools include tools such as power lawn mowers, garden tractors, portable pumps, power sprayers and washers, snowblowers, and floor buffers. This memorandum summarizes the characteristics of CO poisoning deaths reported to the CPSC associated with engine-driven tools. This memorandum also provides a more detailed summary of fatal CO poisoning incidents associated with engine-driven tools found in CPSC's In-depth Investigation (INDP) File.

See Appendix A for the codes and keywords used in the database searches. The following CPSC databases were searched: In-depth Investigation (INDP) File, Injury or Potential Injury Incident (IPII) File, and Death Certificate (DCRT) File. It should be noted that reporting may not be complete and this memorandum reflects only those incidents entered into the CPSC databases before March 13, 2003. All CO incidents found during the database search that were associated with at least one CO fatality or a non-fatal exposure to CO that resulted in one or more individuals attending a medical facility for treatment were included. Appendix B provides a listing of the incidents referenced within this memorandum.

Eleven incidents associated with both an engine-driven tool and a non-engine driven tool source of CO (such as a gas space heater or water heater) were considered out of scope for this memo since the exact source of the CO could not be determined. Incidents associated with multiple engine-driven tools (such as a generator and a lawn mower) were included within this memo. Incidents associated with generators that were specifically reported as integral parts of recreational vehicles (RVs), motor homes, or boats were not included within this memo. For example, generators that were reported as mounted to the bottom of an RV were not included nor were on-board boat generators that were installed by the boat manufacturer. Since incidents in recreational vehicles and boats can be associated with either a portable generator or an integral generator, only those incidênts that specifically stated that the generator was part of the RV, motor home, or boat were excluded. For one incident in a boat and two separate incidents in motor homes, it could not be specifically concluded that the generator was an integral part of the boat or motor home. Therefore these three incidents were included within this memo.

Table 1 shows the number of carbon monoxide exposure incidents and deaths in the CPSC files associated with generators and other engine-driven tools that occurred between January 1, 1990 and December 31, 2002. From 1990 through 2002, 205 incidents were found in the CPSC databases that were associated with engine-driven tools and a potential carbon monoxide exposure. The term potential is used to categorize these incidents since the CO exposure could not be confirmed for some of the non-fatal incidents. Incidents were associated with portable generators, garden tractors, lawn mowers, snowblowers, floor buffers, portable pumps, power washers and sprayers, other engine-driven power tools and multiple engine-driven tools. The category 'other engine-driven power tools' includes gas floor and concrete cutters. The category 'multiple engine-driven tools' includes an incident that involved both a generator and a power lawn mower.

One hundred and sixty-five of the 205 incidents reported to the CPSC were associated with generators. From 1990 through 2002, 210 deaths were associated with engine-driven tools and 179 of the 210 deaths (85%) were associated with a generator. Throughout the remainder of this memo, incidents associated with all engine-driven tools will be reported as a group. In addition, since the majority of incidents were associated with generators, characteristics of these incidents will be reported separately.

Table 1: Number of Non-fire CO Potential Exposure Incidents and Deaths Reported to the CPSC Associated with Engine-Driven Tools, 1990-2002.

Product	Number of Incidents	Number of Deaths
Total	**205**	**210**
Generator	165	179
Garden Tractor & Lawn Mower	22	20
Snowblower	5	5
Floor Buffer	3	0
Pumps	3	2
Power Washer & Sprayer	3	1
Other Engine-Driven Power Tools or Internal Combustion Engine (non-vehicular)	3	2
Multiple Engine-Driven Tools	1	1

The number of deaths occurring during each incident reported to the CPSC was examined (Table 2). Twenty-one percent of the CO exposure incidents reported to the CPSC and associated with an engine-driven tool were not associated with a CO poisoning fatality. Of those incidents that did involve at least one death (161 incidents), 79% of the total incidents involved a single fatality. Seventy-five percent of fatal generator incidents involved a single fatality. Of the 30 fatal incidents associated with 'all other engine-driven tools', all but one incident were associated with a single fatality. The one incident that was related to multiple CO fatalities associated with an 'all other engine-driven tool' was related to a sump pump.

Table 2: Number of Carbon Monoxide Poisoning Incidents reported to the CPSC By Number of Deaths per Incident, 1990-2002.

Number of Deaths Reported in Incident	Total		Generator		All Other Engine-Driven Tools	
Total Incidents	**205**	**(100)**	**165**	**(100)**	**40**	**(100)**
0	44	(21)	34	(21)	10	(25)
1	127	(62)	98	(59)	29	(73)
2	25	(12)	24	(15)	1	(3)
3	3	(1)	3	(2)	0	(0)
4	6	(3)	6	(4)	0	(0)

Note: Numbers in parenthesis represent percentages. Totals may not add up to 100% due to rounding.

Due to the difficulties in defining a CO poisoning injury or confirming a CO exposure, the remainder of this memorandum will focus only on CO poisoning incidents that were related to a death associated with an engine-driven tool. Throughout this memorandum, the number of deaths represents the actual number of deaths that have been entered into the CPSC databases by March 13, 2003. The count is the unweighted, actual number of CO poisoning deaths in the CPSC files associated with portable generators and other engine-driven tools.

The number of deaths associated with engine-driven tools and reported to the CPSC was looked at by year of the death (Table 3). It should be noted that since this table represents deaths reported to the CPSC, counts for more recent years may not be as complete as reporting for earlier years. It should also be noted that death certificates from the year 1999 and later are coded with the new revision of the International Classification of Disease (ICD-10). With the revision of the ICD-10 coding system, the types of death certificates purchased by the CPSC changed. These changes could affect the number of deaths associated with engine-driven tools that are reported to the CPSC. Prior to 1999, these deaths were normally coded with an ICD-9 e-code (868.2) that contained deaths associated mainly with motor vehicle exhaust and therefore these death certificates were not routinely purchased by the CPSC. Occasionally some death certificates that are related to these products are reported to the CPSC under other e-codes, usually under the unknown CO codes (E-codes 868.8 and 868.9). For death certificates from 1999 and later, CPSC began purchasing ICD-10 codes that contain all CO deaths associated with CO poisoning from all sources.

Table 3: Number of Non-fire CO Poisoning Deaths Reported to the CPSC Associated with Engine-Driven Tools By Year, 1990-2002.

Year	Total	Generators	All Other Engine-Driven Tools
Total	**210**	**179**	**31**
1990	18	18	0
1991	8	7	1
1992	7	7	0
1993	13	10	3
1994+	10	7	3
1995+	12	11	1
1996	20	17	3
1997	20	18	2
1998	14	13	1
1999*	11	6	5
2000	24	18	6
2001	22	17	5
2002	31	30	1

Note1: 1999 was the year the new ICD-10 system was implemented (*).
Note2: The number of deaths associated with engine-driven products in 1994 and 1995 differ from those reported in the annual estimate report[1,2]. This is due to the exclusion of products that were integral parts of boats (+).

[1] Ault K. "Estimates of Non-fire Carbon Monoxide Poisoning Deaths and Injuries," Washington, D.C.: U.S. Consumer Product Safety Commission. 1997.
[2] Mah J. "Non-Fire Carbon Monoxide Deaths Associated with the Use of Consumer Products, 1998 Annual Estimates." Washington, D.C.: U.S. Consumer Product Safety Commission. 2001.

Incidents involving deaths were further examined in Table 4 by the location where the death occurred. The majority of CO poisoning deaths (71%) reported to the CPSC and associated with engine-driven tools occurred at the home, which includes apartments, manufactured homes, and mobile homes. The location home also includes garages or sheds at the home or residence. Incidents associated with generators commonly took place when the generator was located in the garage or basement of the home. The temporary shelter category includes trailers, motor homes, recreational vehicles, cabins, and campers. The category 'other' involved incidents occurring in some of the following locations: bar, building, church, greenhouse, mineshaft, public place, and storage shed (offsite from home).

Table 4: Number of Non-fire CO Poisoning Deaths Reported to the CPSC and Associated with Engine-Driven Tools by Location, 1990-2002.

Location of Incident	Number of Deaths Reported to the CPSC					
	All Engine-Driven Tools		Generators		All Other Engine-Driven Tools	
Total	**210**	**(100)**	**179**	**(100)**	**31**	**(100)**
Home	149	(71)	119	(66)	30	(97)
Temporary Shelter	36	(17)	36	(20)	0	(0)
Boat	5	(2)	5	(3)	0	(0)
Other	10	(5)	10	(5)	0	(0)
Not Reported	10	(5)	9	(5)	1	(3)

Note: Numbers in parenthesis represent percentages. Totals may not add up to 100% due to rounding.

The age and sex of the deceased was examined in Tables 5 and 6. Table 5 shows that adults aged 25 years and older account for 81% of CO poisoning deaths reported to the CPSC and associated with all engine-driven tools. Adults age 25 years and older account for 78% of CO poisoning deaths associated with generators and accounted for all deaths associated with other engine-driven tools. Males account for 76% of the deaths associated with all engine-driven tools and 72% of the deaths associated with generators. Only one female death was associated with a product categorized as 'all other engine-driven tool', which was a sump pump.

Table 5: Non-Fire Carbon Monoxide Poisoning Deaths Associated with Engine-Driven Tool and Reported to the CPSC by Age of Victim, 1990-2002.

Age	Number of Deaths Reported to the CPSC					
	All Engine-Driven Tools		Generators		All Other Engine-Driven Tools	
Total	**210**	**(100)**	**179**	**(100)**	**31**	**(100)**
Under 5	4	(2)	4	(2)	0	(0)
5 – 14	16	(8)	16	(9)	0	(0)
15 – 24	13	(6)	13	(7)	0	(0)
25 – 44	62	(30)	54	(30)	8	(26)
45 – 64	74	(35)	59	(33)	15	(48)
65 and over	34	(16)	26	(15)	8	(26)
Unknown	7	(3)	7	(4)	0	(0)

Note: Numbers in parenthesis represent percentages. Totals may not add up to 100% due to rounding.

Table 6: Non-Fire Carbon Monoxide Poisoning Deaths Associated with Engine-Driven Tools and Reported to the CPSC by Sex of Victim, 1990-2002.

Sex	Number of Deaths Reported to the CPSC					
	All Engine-Driven Tools		Generators		All Other Engine-Driven Tools	
Total	**210**	**(100)**	**179**	**(100)**	**31**	**(100)**
Male	159	(76)	129	(72)	30	(97)
Female	51	(24)	50	(28)	1	(3)

Note: Numbers in parenthesis represent percentages. Totals may not add up to 100% due to rounding.

In-Depth Investigations Associated with Engine-Driven Tools

Data from the CPSC's In-depth Investigation File are not a statistical sample and national totals may not be derived from the number of incidents investigated. Data provide examples of actual incidents and anecdotal information. Incidents in the CPSC In-depth Investigation File were examined to obtain more detailed information about the scenario related to CO incidents associated with engine-driven tools. Not all information examined is available for each investigation.

CPSC staff further investigated 106 of the 205 incidents referenced within this memorandum. In-depth investigations associated with engine-driven tools were requested more frequently in recent years. For example, 83% of the incidents associated with engine-driven tools that were reported to the CPSC were investigated in the year 2001 and only 10% of the incidents were investigated in 1990. Of the 106 in-depth investigations, 82 involved at least one-fatality. These 82 in-depth investigations of fatal incidents associated with a CO poisoning death involved 109 deaths. Ninety-seven of these deaths were associated with a generator and 12 deaths were associated with other engine-driven tools.

Pre-existing health conditions affecting the heart, lungs, liver, and circulatory system can lower a victim's tolerance of carboxyhemoglobin (COHb) in the bloodstream, increasing the risk of a fatal CO exposure. Fifteen of the 109 CO deaths investigated and associated with engine-driven tools involved individuals who were noted as having secondary health conditions not related to CO poisoning at the time of death. Twenty-one of the 109 deaths investigated reported involvement of drugs or alcohol in the incident.

In-Depth Investigations Associated with a Fatal CO Poisoning and a Generator

The 97 fatalities, which involved 70 in-depth investigations of fatal generator incidents, will be explored more thoroughly. The characteristics of age and sex of victim, location of death, and number of fatalities per incident were similar in the total group of deaths reported to the CPSC associated with generators to those that were reported to the CPSC and further investigated. Seventy-eight percent of the deaths reported to the CPSC involved adults aged 25 years and older, 74% of the deaths investigated involved adults 25 years and older. Males accounted for 72% of the reported CO deaths associated with generators and 66% of deaths investigated. The location of the death was also similar for those cases that were investigated versus all CO poisoning deaths reported to the CPSC associated with a generator. The majority of deaths investigated (69%) occurred in the home while 66% of deaths reported to the CPSC occurred in the home. Twenty–two percent of the deaths investigated by the CPSC occurred in a temporary shelter while 20% of the total deaths that were associated with a generator and reported to the CPSC occurred in a temporary shelter. Fatal incidents investigated were also similar to all fatal generator incidents reported to the CPSC in that 75% of all incidents involved a single fatality while of those incidents investigated 73% of the investigated incidents involved a single fatality.

Information that was provided within an in-depth investigation that could not be obtained as regularly from an Injury or Potential Injury Incident (IPII) File and Death Certificate (DCRT) File source document included information about the location of the generator, the venting of the generator, the reason the generator was being used, whether the generator was owned by the deceased or a member of the deceased's household, the concentration of the CO at the location where the generator was used, and the carboxyhemoglobin (COHb) levels of the deceased.

The main reasons reported for using a portable generator were to provide electricity to a location that did not have electricity due to a temporary situation or to provide power to a temporary location. Twenty-eight of the investigated deaths were associated with generators used during a temporary power outage stemming from a weather problem or a problem with power distribution. Twenty-five of the investigated deaths were associated with generators being used to supply power to a temporary shelter, storage-shed (offsite from the home), or boat that did not have electricity. Fourteen of the investigated deaths were associated with generators being used in a situation where the utility company, often because of an overdue payment, turned off the power. Eleven of the investigated deaths were associated with locations where the electricity was off due to another reason, such as recent fire at the location, the home was abandoned, the home was a new home which did not have electricity at the time of the incident, the residents of the home requested that the electricity be turned off, or a home was undergoing a remodeling project. Ten of the deaths investigated were associated with a generator being used in a more permanent situation, such as supplying power to a home or mobile home that did not normally have electricity or to provide power to a shed or garage of a home. Nine of the deaths investigated were associated with incidents where the electricity was off at the location but the reason why was unknown.

Sixty-seven of the investigated deaths occurred at the home. Twenty-five of these deaths reported that the generator was in the basement or crawl space of the home. Twenty-two of these deaths reported that the generator was within the house, although the specific location was often not provided. One investigation specifically mentioned a bedroom and another mentioned the bathroom as the location of the generator. Seventeen deaths were associated with investigations where the generator was placed in the garage or enclosed carport of the home. One death that was investigated reported that the generator was located in the shed of the home. One investigation of a death that occurred in the home reported that the generator was placed on a screened in porch and another investigation stated that the generator was placed outside on the porch. All investigations of deaths that occurred in temporary shelters stated that the generator was inside the temporary shelter.

Many of the death investigations (49 of the 97 deaths investigated) did not contain information about the exact venting of the generator. In 37 of the deaths investigated, no type of venting of the generator was reported. There were eleven investigations that reported that some type of venting was employed. In one death investigation, the two-car garage door and back door of the garage that lead to the outside was open and the generator was placed in the back door doorway. In two separate investigations where the generator was located in the garage, one stated that the garage door was open and the second stated that the garage door was partially open. In another investigation where the generator was located in the garage, the garage car door was open until the generator was turned off. Then the garage door was closed. The deceased was found in the loft of the garage. In two separate investigations where the generator was located in the basement, one stated that a window in the basement adjacent to the generator was raised open and in the other investigation the door to the basement was open, the door from the house to the garage was open, and the main garage door was open in an attempt to vent the exhaust from the basement to the outside through the garage. In another three investigations, one in a trailer and two in a home, a window was open or partially open. In one investigation the generator was located in a screened porch with all of the windows opened. Finally, one investigation stated that the generator was placed outside the home on the back porch with the kitchen window slightly open and the deceased was found in a bedroom inside the home.

In many of the investigations (51 of the 97 fatalities), it could not be determined whether the generator was owned by the deceased or member of the deceased's household. In the investigations of 27 of the deaths, the deceased or a member of the deceased household owned the generator. In investigations of 13 of the deaths, it was determined that the generator was borrowed. In investigations of 6 of the deaths, the generator was rented.

Sixteen investigations (associated with 20 deaths) provided ambient levels of carbon monoxide at the location. Some values were measured only after the location had been vented and/or the generator had been shut down for some time prior to the measurement. Fourteen of the investigations had maximum CO levels that measured greater than 150 PPM. The two investigations that did not have maximum CO levels greater than 150 PPM were vented prior to the CO being measured. Twelve investigations had maximum CO levels that measured greater than 300 PPM. Ten investigations had maximum CO levels that measured greater than 450 PPM. Eight investigations had maximum CO levels that measured 600 PPM or greater.

Carboxyhemoglobin (COHb) levels were provided in the investigations for 55 of the 97 fatalities. Table 7 provides a breakdown of the COHb levels. In healthy adults, a COHb level of 40 to 50% approximately correlates with symptoms of 'confusion, unconsciousness, coma, possible death', a level of 50 to 70% approximately correlates with symptoms of 'coma, brain damage, seizures, death', and a level greater than 70% is 'typically fatal'[3]. The majority of individuals with reported COHb levels (51 of the 55) had levels greater than 50% COHb.

Table 7: Carboxyhemoglobin Levels Reported in In-Depth Investigations Associated with Generators and a CO Poisoning Death, 1990-2002.

COHb Level	Number of Deaths
Total	**97**
30-39.9%	1
40-49.9%	3
50-59.9%	8
60-69.9%	17
70-79.9%	22
80-89.9%	3
90-99.9%	1
Not Reported	42

[3] Burton LE. Toxicity from Low Level Human Exposure to Carbon Monoxide. Washington, D.C.: U.S. Consumer Product Safety Commission. 1996.

In-Depth Investigations Associated with a Fatal CO Poisoning and an 'All Other Engine-driven Tool'

Twelve of the 31 deaths associated with other engine-driven tools were investigated further. All 12 of the incidents investigated involved a single fatality and all were associated with a garden tractor or a power lawn mower, although one investigation involved both a generator and a power lawn mower. All the deceased associated with these investigations were male and the majority of the investigations (7 out of 12) involved individuals between the ages of 45-64. Two fatal investigations involved deaths of individuals in the 25-44 age group and three fatal investigations involved deaths of individuals in the 65 plus age group. For all 12 of the deceased, the carboxyhemoglobin level was provided (Table 8).

Table 8: Carboxyhemoglobin Levels Reported in In-Depth Investigations Associated with Other Engine-driven Tools and a CO Poisoning Death, 1990-2002.

COHb Level	Number of Deaths
Total	**12**
40-49.9%	3
50-59.9%	2
60-69.9%	3
70-79.9%	3
80-89.9%	1

All of these incidents occurred in an enclosed space at the home, with seven investigations occurring in the garage of the home and five in the shed of the home. Ten of these investigations provided details as to why the lawn mower or garden tractor was being used within an enclosed space. The majority of these investigations (9 out of 10) involved the victim working on or repairing a garden tractor or power lawn mower within an enclosed space.

Conclusion

Between 1990 and 2002 there have been 210 CO poisoning deaths reported to the CPSC that were associated with engine-driven tools. The majority of these deaths (179) were more specifically associated with portable generators. Other engine-driven tools that were associated with a much smaller number of deaths included garden tractors, lawn mowers, snow blowers, pumps, power washers or sprayers, and other engine-driven power tools. The majority of fatal incidents reported to the CPSC involved a single fatality and the majority of the reported deaths occurred while an individual was at home.

Adults aged 25 years and older accounted for 78% of CO poisoning deaths reported to the CPSC associated with a portable generator and the majority (72%) was male. Sixty-six percent of the deaths reported to the CPSC associated with a portable generator occurred at home. Generators were commonly placed in the basement or garage of the home. Generators were often used as alternative sources of electricity due to temporary power outages or power interruptions. Generators were often used in enclosed spaces with little or no ventilation.

Adults aged 25 years and older accounted for all of the CO poisoning deaths reported to the CPSC associated with engine-driven tools, excluding generators. Males accounted for all but one of the 31 deaths reported to the CPSC associated with other engine-driven tools. Deaths associated with garden tractors and lawn mowers were often associated with an individual repairing or working on the product within an enclosed space.

Reference:

Ault K. "Estimates of Non-fire Carbon Monoxide Poisoning Deaths and Injuries," Washington, D.C.: U.S. Consumer Product Safety Commission. 1997.

Burton LE. Toxicity from Low Level Human Exposure to Carbon Monoxide. Washington, D.C.: U.S. Consumer Product Safety Commission. 1996.

Mah J. "Non-Fire Carbon Monoxide Deaths Associated with the Use of Consumer Products, 1998 Annual Estimates." Washington, D.C.: U.S. Consumer Product Safety Commission. 2001.

APPENDIX A

The queries below were submitted through the EPIR application. Query results were manually reviewed to include only carbon monoxide poisoning hazards and to exclude duplicates and out-of-scope cases, which were cases that did not involve an incident that was associated with a non-fire carbon monoxide exposure and an engine-driven tool.

Date of Queries: 03/13/2003

Incident dates: 1/1/90 – 12/31/02
Product Codes: 113, 606, 809, 820, 887-888, 1062, 1400-1464
Narrative/Text contains: 'CO_' or 'CARB' or 'MONO'

APPENDIX B

Document Number	Investigation Task Number
0004000376	021031HCC3059
0005025284 0005027092	020228HCC2282
0012022297	021107HCC1123
0022034412	010628HCC2616
0023012228	021023HCC1078
0026039416	021121HCC2124
0032013569	
0037071040	011126HCC1143
0039010605	021227HCC2232
0039088650	021023HCC2060
0039100337	021227HCC2234
0042046788	021227HCC1229
0102000958	020529HCC3217
0118012182	020306HCC2308
0118044256	
0119024542	
0122008422	020426HCC2439
0122025070	020425HCC2431
0127533637	020814HCC2604
0127534843	
0128004205	021213HCC1207
0128006226	021213HCC1206
0129025962	020219HCC2228
0132003301	021213HCC3125
0147000577	011003HCC1019
0153030992	021025HCC3042
0153040464	021025HCC3041
0226024060	
0237011849	021203HCC1172
0240002682	021211HCC2193
9008005671	
9013006955	910410CCC2398
9017047646	
9042017400	
9042106564 9042106565	
9051043586	
9142077948	
9226020857	
9226038194	
9230007048	
9310002249	
9313014903	
9320007144	
9326022187	
9336032211	
9339053906	
9353000172	
9401016379	
9501032331	
9518040984	
9522020180	
9523009639	
9526018953	
9541018028 9541018025	
9566044258	970418HCC1135
9612049729	

Document Number	Investigation Task Number
9619023173	
9629013842	971107HCC2116
9633000571	
9647054126	970606CCC2246
9653009913	
9653039785	
9702002375 9702002376 9702002377 9702002378	
9706015619	971105HCC3396
9721022171	
9736029561 9736029562	
9739065894	
9745026498	
9748014763	970926HCC3355
9748094649	980302HCC3657
9806047463	990712HCC3396
9836001519 9836001520	
9836001865	
9836001881	
9842061749 9842061742	
9847053849	990804HCC2585
9854013955	
9912105076	010409HCC0469
9913038317	011001HCC1002
9918038664	010323HCC2334
9919012287	000426HCC2482
9920022797	
9921010087	000223HCC2319
9922031694	010319HCC2323
9926005556	020423HCC2423
9942009102	011001HCC1004
9951051013	010928HCC1895
F0115011A	010109HWE5011
F01C5005A	011206CWE5005
F02B5005A	021105HWE5005
F9010174A	
F9137015A	
F9185005A	910812CWE5005
F9545019A	950424CWE5019
F9620036D	
F9710085A	
G0070063A	
G00C0118A	010105CCC2174
G00C0129A	010214HCC2239
G0110387A	010122HCN0262
G0120404B	010226HCN0360
G0210353A	020221HCC2241
G0210480A	020131HCN0290
G0220010A	020204HCN0297
G0220010B	020305HCC2305
G0220072A	020207HCN0310
G0230092A	020328HCC2363
G0230161A	020319HCN0362
G0280199A	020919HCC2678

Document Number	Investigation Task Number
G02C0009A	021204HCN0159
G02C0035A	021209HCN0170
G02C0093A	
G9030027A	
G9160205A	
G9220139A	920212HCN1040
G92B0142A	
G9360164A	
G94C0106A	
G9660185A	
G9680002A	960802HCN1618
G9770020A	970708CCN0471
G97B0019A	
G97B0036A	971208CCC2153
G9810135A	980114CCN0133
G9870071A	
H9720123A	
H97C0250A	
H9990173A	991122HCC0120
N0090084A	010521HCC0603
N0090196A	
N0120381A	
N0150245A	010529HNE6411
N0240449A	020621HCC1645
N0270101A	020814HCC1771
N0280027A	020821HNE7444
N02B0021A	021112HNE7566
N02B0178A	021217HCC1216
N02C0009A	
N02C0050A	021217HNE7639
N02C0169A	021226HCC1227
N02C0170B	
N0310006A	030103HNE7660
N0310007A	030103CNE7661
N0310014A	030103HNE7668
N0310173A	
N9030054A	
N9350076A	930517HCC1130
N9390276A	
N9420206A	
N9470214A	
N9620364A	960228HNE5075
N9620388B	
N9620388C	
N9750084C	
N9750095A	
N9820032A	980313HCC0186
N9820033A	980313HCC0185
N9830006A	980309CNE5098
N9840138A	
NEISS	980901HEP5441

Document Number	Investigation Task Number
NEISS	981118HEP1681
NEISS	990903HEP1683
NEISS	010301HEP9009
NEISS	020724HEP9004
NEISS	020705HEP9005
NEISS	021219HEP9012
U9386709A	
X00C5791A	
X0131201A	021030HCC1111
X0141545A	011003HCC1018
X0210394A	020207HCC1281
X0210537A	020221HCC3126
X0220763A	020305HCC1371
X0273498A	020814HCC1772
X02A5320A	021203HCC2151
X02A5459A	021202HCC1166
X02A5506C	021203HCC2150
X02B6172A	021218HCC1218
X90A0170A	
X9252562A	920610HCC2178
X92A0491A	921204HCC1954
X9355499A	
X9432156A	
X9442652A	
X9453145A	
X9474928A	
X9520342A	
X9520452A	
X9520455A	
X9572156A	
X9582520A	
X9631637A	
X9652512A	
X9720336A	
X9720529A	970305CCC7400
X9741389A	
X9792993A	
X9793413A	
X9811540A	
X9811540B	
X9832418A	
X9842839A	
X9972395A	020415HCC1460
X9982981A	
X99B3684B	

Note:
Since the previous memo was written some incidents were further examined and determined to be out of scope. Reasons these incidents were considered out of scope include: (1) the generator was found to be an integral part of a recreational vehicle, motor home or boat, (2) the generator was used in a setting that could not be ruled out as work-related, (3) an incident was combined with another incident in database, and (4) another fuel-burning appliance was present and the source of the CO could not be concluded. The following incidents were removed: G9360034A, G9860200A, G0110470B, N9630078A, N9910094A, X0083784A, X0252604C, X9464072A, X9641935A, X9683351A, X9683393A, X9842662A, 9036000269, 9051047429, 9248115737, 9823005753, 9828014398, 9942110795, 9942110847, 910429HWE5018, 970521HCC1247, and 010920HCC2790.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

MEMORANDUM

June 18, 2002

To: Janet L. Buyer,
Project Manager, Small Engine-Driven Tools Project,
Division of Combustion and Fire Sciences, Directorate for Engineering Sciences

Through: Hugh McLaurin,
Associate Executive Director,
Directorate for Engineering Sciences

Robert B. Ochsman, Ph.D., CPE,
Division Director, Division of Human Factors,
Directorate for Engineering Sciences

From: Timothy P. Smith,
Engineering Psychologist, Division of Human Factors,
Directorate for Engineering Sciences

Subject: Human Factors Assessment for the Small Engine-Driven Tools Project

INTRODUCTION

When fuels such as gasoline burn, they produce various chemicals including carbon monoxide (CO), a potentially lethal gas (NIOSH, CDPHE, CPSC, OSHA, & EPA, 1996). As a consequence, many people who have used tools with small gasoline-powered engines, such as generators, have experienced CO poisonings. Staff from the U.S. Consumer Product Safety Commission's Division of Human Factors (ESHF) has been asked to determine the effectiveness of current warning labels in addressing this hazard, and to determine what could be done to improve the effectiveness of warning labels in this situation.

DISCUSSION

In general, warnings are only likely to be useful if the hazard, consequences, and appropriate safe behavior are previously unknown to those exposed to the hazard (Laughery & Wogalter, 1997). There have been many incidents of CO poisoning due to consumers not recognizing the danger of using small gasoline-powered engines indoors (NIOSH, et al., 1996). In addition, ESHF staff reviewed numerous in-depth investigations into incidents involving small engine-driven tools, and several are consistent with what one would expect if the consumer were not aware of the CO hazard posed by the tools.

Some incidents also appear to demonstrate consumer misunderstanding of CO, in general. For example, in one incident a consumer used a generator in the basement of his home due to a power outage. The consumer was not in the basement while it was in use, but later the consumer entered the basement, shut off the generator, and stayed inside the room. It is difficult to determine the extent to which the consumer was aware of the CO hazard associated with a running generator, but it is clear that the consumer failed to recognize the presence of a CO hazard after the generator had been shut off. This is not surprising since CO is colorless, odorless, and tasteless, and since the symptoms of CO overexposure—that is, headaches, dizziness, nausea, weakness, visual disturbances, changes in personality, or unconsciousness—could be easily mistaken for symptoms of other illnesses (NIOSH, et al., 1996). Therefore, consumers without prior knowledge of the hazard are unlikely to recognize overexposure when it occurs.

According to Earnest, Mickelsen, McCammon, and O'Brien (1997), some products that are equipped with small gasoline-powered engines have a warning stating that the product should be used only in well-ventilated areas. To better understand the warning information related to CO poisoning to which consumers are currently exposed, ESHF staff examined the on-product warnings present on different-model generators by visiting two large home-improvement stores. ESHF staff also examined three owner's manuals associated with different models of generators. Generators were the primary focus of these examinations since it appears that generators are involved with more CO poisonings than any other small engine-driven tool. While ESHF staff does not claim that the warning information examined encompasses all CO-related warnings present on small engine-driven tools and their manuals, the staff does believe they will provide a reasonable sample of the kind of information to which consumers may be exposed.

Warning Conspicuity

Most on-product warnings examined were on the top or side surface of the gas tank, which served as the top-most surface of each generator. Since the top surface of the tank is readily visible to the consumer, ESHF staff believes it is a good location for a warning label, in general. While most labels were consistent with ANSI Z535 (1998), some were of low contrast, used small type, and lacked a safety alert symbol, which made them less noticeable and more difficult to read. Sometimes this lack of contrast was due to the placement of a label with a black background onto a gas tank that was also colored black. Since all gas tanks examined were either red or black, labels with a white background for the message text would tend to be more conspicuous. The labels often included a great deal of safety information beyond warning about potential CO hazards, and the CO hazard was never the first message on any of the labels. As a consequence, some consumers may stop reading before getting to the CO-related information or may not read the label at all due to the amount of information presented. Some generators included a more concise label near the pull cord of the generator, but sometimes this label was not in plain view. The CO hazard is among the hazards described in this label, and its conciseness makes it more likely to be read by consumers if noticed. Label durability is also important for on-product warnings and directly affects conspicuity since a warning that does not withstand the elements may not be available to consumers when needed. For example, in one incident a consumer rented the generator involved, had no experience with its use, and was reportedly unaware of the need to ventilate the tool during use. An on-product label that warned of the generator's use in an enclosed area was essentially illegible because it was partially removed.

The owner's manuals examined by ESHF staff tended to include numerous warnings, many of which were grouped into a safety-like section. This can be useful for consumers who are looking for all safety information available on the product. However, consumers who use the manual may not necessarily be looking for safety information but may simply wish to know how to use the product. In addition, the number of warnings present in a safety section can be overwhelming, causing the consumer to simply bypass this information. One way to avoid this is to also embed warnings within the operating instructions where appropriate. Consumers—especially those who are unfamiliar with how generators operate—are very likely to check the operating instructions, yet only one of the reviewed generator manuals included a warning on the potential CO hazard within a section of this kind. Even that warning was placed after the final step rather than at the beginning of the sequence required for operation. Since a warning on the CO hazard tends to advise consumers on where or how to use the tool safely, it would be more appropriate to include this warning at the beginning of any operating instructions, possibly as the first step.

Warning Comprehension

The on-product warnings were often vague in describing the CO hazard and its consequences. Some identified the hazard as a "breathing hazard." This was sometimes reinforced through the use of a small pictorial of a person breathing gases or fumes. Some labels stated that the engine exhaust could "cause injury or death" or that "engines emit carbon monoxoide," but others only referred to the potential for "carbon monoxide poisoning" without further elaborating on the source of the CO. This lack of consistency makes it unclear exactly what information about the hazard consumers are eliciting from the on-product warnings. Consumers may understand that engine exhaust is dangerous but may not understand exactly what "carbon monoxide" is. Without an understanding of CO and its characteristics, consumers may believe they will be able to sense it if it approaches dangerous levels. This is somewhat reflected by some in-depth investigations that include statements about people "smelling" or not smelling CO, which is, in fact, odorless.

Information about the CO hazard and its consequences is often presented in greater detail within the owner's manuals. For example, according to one owner's manual the label placed on the generator itself described the CO hazard as, "Exhaust gas contains poisonous carbon monoxide." Within the manual, however, the potential CO hazard was described as "breathing exhaust" that "contains poisonous carbon monoxide, a colorless and odorless gas." This same manual also warned about running the generator "in an area that is confined, or even partially enclosed," which can cause the air being breathed to "contain a dangerous amount of exhaust gas." Other manuals provided additional details about CO in general, including the fact that it is odorless and invisible. ESHF staff believes it is important for warnings about the CO hazard, especially those within manuals, to identify the fact that CO is colorless, tasteless, odorless, and nonirritating, and that it can overcome a consumer without their perceiving it (NIOSH, et al., 1996). Advising consumers to look for the warning signs of CO overexposure may also be useful since the symptoms could be mistaken for symptoms of other illnesses such as colds, flu, or food poisoning (NIOSH, et al., 1996).

The warnings both on the generators and within the owner's manuals typically provided the same guidance on the steps consumers should take to avoid the CO hazard. In general, they instruct consumers to (1) provide proper ventilation and/or (2) not operate the generator in a confined or enclosed area. However, this advice is open to interpretation by the consumer. For example, does "confined" or "enclosed" mean *completely* confined or enclosed? The current language implies that using the generator indoors is acceptable as long as there is adequate ventilation or some other means of removing the exhaust fumes. Even if accurate, this begs the question of what constitutes proper or adequate ventilation. None of the on-product warnings examined by ESHF staff provided specific guidance, and only one of the manuals did: by piping exhaust gases "from enclosed areas." Would an open window or door also be sufficient? What if the consumer is running a fan? It is clear that some consumers believe opening a window or operating a fan provides sufficient ventilation (Earnest, et al., 1997; NIOSH, et al., 1996). Incidents involving generators provide further insight into consumers' perceptions of what constitutes good ventilation:

- The consumer used a generator in an attached garage with the door partially open.
- The consumer used a generator outside his trailer home.
- The consumer used a generator in an attached garage with the garage door open.
- The consumer used a generator in an attached garage with the garage door open and the generator just inside the door.
- A generator, blocked off with wood, was being used in the back partition of a trailer. The exhaust pipe of the generator was aimed towards a vent.
- The consumer used a generator inside a boat with the porthole open.
- The consumer used a generator inside his home after being warned by his friend not to use it inside. A fan was used to vent the fumes towards an open window.
- The consumer used a generator in the basement of his home for light.to connect vent pipes to the generator. The pipes were reportedly not sealed, which caused CO to leak from them.

In every one of these incidents, one could argue that the consumer's behavior was consistent with the recommended behavior on most CO-hazard warnings. The resulting CO poisonings, however, suggest this behavior is not appropriate. So the question becomes, how should consumers actually be responding?

A study by Earnest, Mickelsen, McCammon, and O'Brien (1997) indicates that hazardous CO concentrations can develop within minutes of using a small gasoline-powered engine, and that extremely high ventilation rates would be necessary to reduce this hazard. Their recommendation is that these engines not be operated inside buildings or semi-enclosed spaces at all, even if some ventilation is provided. This recommendation is consistent with an alert produced by several government agencies that states people should not use gasoline-powered engines or tools inside buildings or in partially enclosed areas unless the engines can be located outside and away from air intakes (NIOSH, et al., 1996). Earnest, et al. (1997) also recommend that people be informed that opening windows and doors or operating a fan does not provide sufficient ventilation. ESHF staff believes this is reasonable and believes that it would be possible to reword current warnings based on the above recommendations so they provide more clear and explicit guidance on proper avoidance behavior.

Consumer Motivation

Even a warning that provides accurate advice and is capable of being followed by consumers will be of no use if consumers do not actually choose to follow that advice. Research indicates that two of the most important factors in determining the extent to which people will be motivated to read and comply with warnings are the cost of compliance and the cost of noncompliance (Laughery & Wogalter, 1997; Sanders & McCormick, 1993). To motivate people to follow the advice of the warning, the consumers' perceived cost of compliance must be less than the perceived cost of noncompliance.

Complying with the CO warning on a small engine-driven tool would require consumers to keep the product outdoors and away from air intakes during use. There may be several factors that increase the perceived cost of carrying out this action. Some may seem rather trivial (e.g., keeping a generator outside would require the consumer to have a fairly lengthy extension cord), but will still have some impact on the likelihood of consumers following the warning's advice. Some factors are not trivial at all and are likely to have a significant impact. For example, generators often include electrocution warnings that instruct consumers to behave in a way that may conflict with the behavior necessary to avoid the CO hazard. One owner's manual states that the consumer should not expose the generator to moisture, rain, or snow, and should "not let the generator get wet." An on-product warning for that same generator warns the consumer that "using the generator in the rain, snow, or near water can lead to death from electrical shock," and that consumers should, "keep generator dry." Another manual also states that the generator should not be used in wet or damp conditions. Depending on the weather conditions at the time the generator is needed, consumers may find it difficult to abide by the instructions given in both the CO and electrocution warnings. For example, in one incident a generator was used in an attached garage; the consumer was aware of the need for ventilation, but left the garage door partially closed because it was raining out at the time. In fact, consumers are likely to borrow or rent generators during inclement weather conditions since those conditions are often the very cause of the power outage that precipitates the use of a generator. The only way to address this conflict may be to redesign generators to permit their exposure to rain or other poor weather conditions during use. But even if this were done, some consumers may still choose not to keep the generator outside during use simply so they can avoid exposing themselves to those same weather conditions. Other perceived costs of complying with the warning may include the generator being stolen—two incidents indicate this was a significant factor in the decision to bring the generator inside—or the embarrassment associated with having the power shut off due to nonpayment. It is unclear what, if anything, could be done to encourage consumer compliance with the warning in these cases. The only way to address this concern may be to increase the perceived cost of noncompliance (i.e., of not following the advice of the warning) so it outweighs this concern. This is discussed below.

The cost associated with not following the warning's advice typically corresponds to an increased exposure to the hazard. Therefore, influencing a consumer's behavior demands that use of the product in any way contrary to the advice in the warning be perceived as very hazardous.

Since consumers' risk perceptions associated with consumer products tend to be based almost entirely on the severity of potential injury rather than the likelihood of injury (Laughery & Wogalter, 1997), it is necessary for the potential consequences associated with the CO hazard to be very clear to consumers. This may be addressed through proper warning language, as discussed earlier in this memorandum.

CONCLUSIONS & RECOMMENDATIONS

Incidents involving CO overexposure and poisoning with small engine-driven tools indicate that some consumers do not recognize the CO hazard posed by the tool, and that some who do recognize the hazard may not understand the characteristics of CO. One way to improve consumer awareness of the hazard is to make the warning labels associated with the hazard more conspicuous. ESHF staff examined sample generators and generator owner's manuals. Based on these examinations, the staff recommends that on-product warning labels be consistent with ANSI Z535, and that warnings within owner's manuals be embedded within the operating instructions. In addition, warnings—especially on-product warnings—must be more explicit in describing the hazard (e.g., source, causes, characteristics of CO).

ESHF staff believes a great source of confusion with current generator warnings is the guidance offered on how to avoid the CO hazard. Current guidance on the product and within the owner's manuals is typically twofold: (1) do not use in a confined or enclosed space, and (2) provide proper ventilation. Both are open to interpretation by the consumer. In fact, some incidents indicate that the consumer knew ventilation was necessary when using generators, and that the consumer responded in ways that were consistent with what is currently recommended in the warning labels; yet CO overexposure still occurred. Since research suggests that the use of generators in even partially enclosed spaces is unsafe, ESHF staff believes warning labels must inform consumers that certain responses (e.g., opening a window, using a fan) do not provide adequate ventilation, and must instruct consumers to keep generators outdoors and away from air intakes during use. The latter recommendation, however, is in conflict with generator's electrocution warnings, which instruct consumers to keep the generator dry and out of damp conditions. Therefore, it would be necessary to resolve this conflict before specific language could be recommended regarding CO hazard avoidance behavior. In addition, some consumers may ignore the warnings' advice out of embarrassment (e.g., not wanting others to know that their power has been shut off) or to prevent the generator from being stolen.

REFERENCES

American National Standards Institute. (1998). *American National Standard: Product Safety Signs and Labels (ANSI Z535.4-1998)*. Rosslyn, VA: National Electrical Manufacturers Association.

Cushman, W.H. & Rosenburg, D.J. (1991). *Human Factors in Product Design*. Amsterdam: Elsevier. 301–303.

Earnest, G.S., Mickelsen, R.L., McCammon, J.B., & O'Brien, D.M. (November 1997). "Carbon Monoxide Poisonings From Small, Gasoline-Powered, Internal Combustion Engines: Just

What Is a 'Well-ventilated Area'?" American Industrial Hygiene Association Journal. 58: 787–791.

Laughery, K.R. & Wogalter, M.S. (1997). "Warnings and Risk Perception." In Salvendy, G., Ed. *Handbook of Human Factors and Ergonomics*. New York: John Wiley & Sons, Inc. 1175–1195.

National Institute for Occupational Safety and Health (NIOSH), Colorado Department of Public Health and Environment (CDPHE), U.S. Consumer Product Safety Commission (CPSC), Occupational Safety and Health Administration (OSHA), & U.S. Environmental Protection Agency (EPA). (November 1996). *Alert: Preventing Carbon Monoxide Poisoning from Small Gasoline-Powered Engines and Tools*. DHHS (NIOSH) Publication No. 96–118.

Sanders, M.S. & McCormick, E.J. (1993). *Human Factors in Engineering and Design*. New York: McGraw-Hill, Inc. 668–684.