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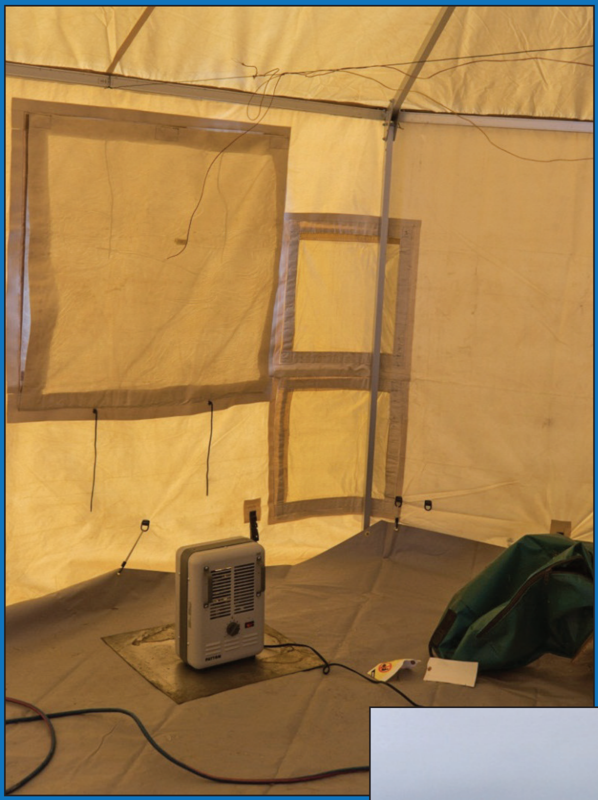
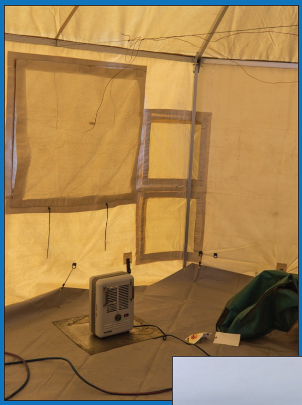
Portable Heaters for Firefighters in Enclosed Spaces



Cover figure—Photos showing an electric heater standing on a metal plate inside a canvas yurt and an outdoor propane heater connected to two canvas yurts through flexible ductwork.

Portable Heaters for Firefighters in Enclosed Spaces



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Contents

Introduction

Fire personnel often have to fight fires during cold months in locations where low temperatures become a factor that they must mitigate. They frequently hold operational briefings in temperatures below freezing in outdoor and indoor locations (e.g., walled tents, livable workspaces), using vent-free (unvented) propane heaters meant for outdoor locations.

In September 2011, the National Interagency Support Caches (NISC)—also referred to in this document as "fire cache" or "cache"—received reports that certain types of National Fire Equipment System (NFES) 006187 construction liquid propane (LP) heaters were suspected of causing headaches during use inside 14- by 16-foot wall tents. The Southwest Area Silver City Incident Support Cache tested several heaters in its inventory for carbon monoxide (CO) and observed that the round heaters from Scheu—the Scheu SPC-80VC (figure 1) and 250A—emitted 40 to 50 parts per million (p/m) of CO, while the other heater—the Mr. Heater MH125LP (figure 2)—emitted 0 to 2 p/m of CO. In response, NISC began supplying inserts with the NFES 006187 heaters, warning against their use indoors.

Figure 1—A Scheu SPC-80VC heater similar to one tested by the Southwest Area Silver City Incident Support Cache.

Figure 2—A Mr. Heater MH125LP Heater similar to one tested by the Southwest Area Silver City Incident Support Cache.

Background

Unvented propane radiant heaters fall into the following categories:

- Patio
- Recreational
- Construction
- Residential
- Commercial

The NFES 006187 radiant heaters (table 1) in the NISC system are construction-type heaters with high-heat outputs (30,000 to 275,000 British thermal units per hour [Btu/hr]) meant for outdoor use and in well-ventilated, unsealed rooms open to outside air. NISC also purchases and stocks NFES 006139 recreational tank-top radiant heaters (table 2) with smaller heat outputs (2,000 to 42,000 Btu/hr), also meant for outdoor use and in well-ventilated, unsealed rooms open to outside air. No one procured new radiant heaters through NISC from 2010 through 2013. However, NISC issued 1,411 NFES 006139 units during 2010, 811 during 2011, and 455 during 2013, and also issued 768 NFES 006187 units during 2010, 478 during 2011, and 188 during 2013 (table 3).

Table 1—Make and model of current National Fire Equipment System 006187 propane heaters in National Interagency Support Caches. Heat input, rather than heat output, more accurately defines the numerical range listed by the manufacturer. A heater's heat input is based on the heating value of the fuel consumed. To avoid confusion for the reader, the term "heat output" is used throughout this report.

Manufacturer and model number	Heat output British thermal units per hour (Btu/hr)	Manufacturer's venting requirements
Scheu Products SPC-80VC	60,000	Area must be well ventilated. Provide minimum openings of 2 square feet (ft^2) near the floor and 2 ft^2 near the ceiling.
Reddy Heater RCP-200V	200,000	Provide adequate ventilation. Before using heater, provide at least a 6 ft^2 opening of fresh outside air.
Mr. Heater MH125LP	125,000	Provide two openings directly to the outdoors: one low and one high (preferably on opposite sides of the heated area). Each of these openings must provide at least 3 square inches (in^2) of combustion air-intake and exhaust area for every 1,000 Btu/hr of heater output rate (about 1.6 ft^2 for this model) in order to complete the combustion/ventilation process.
Scheu Products 250A	250,000	Not applicable.
Master Heater TC275	275,000	Use only in well-vented areas. Before using heater, provide at least 3 ft^2 of fresh outside air openings for each 100,000 Btu/hr of rating.

Table 2—Make and model of current National Fire Equipment System 006139 propane heaters in National Interagency Support Caches. Heat input, rather than heat output, more accurately defines the numerical range listed by the manufacturer. A heater's heat input is based on the heating value of the fuel consumed. To avoid confusion for the reader, the term "heat output" is used throughout this report.

Manufacturer and model number	Heat output British thermal units per hour (Btu/hr)	Manufacturer's venting requirements
Mr. Heater MH12T	14,000	Provide two openings directly to the outdoors: one high and one low (preferably on opposite sides of the enclosure). Each opening shall have a minimum free area of 24 square inches (in^2) (6 by 4 inches). Structures of tight construction or tents using fire-retardant materials require larger openings. If any additional fuel-burning appliances are operating, increase the area of opening by at least 2 in^2 for each 1,000 Btu/hr of additional input rating.
Mr. Heater MH24T	28,000	Provide two openings directly to the outdoors: one high and one low (preferably on opposite sides of the enclosure). Each opening shall have a minimum free area of 36 in^2 (6 by 6 inches). Structures of tight construction or tents using fire-retardant materials require larger openings. If any additional fuel-burning appliances are operating, increase the area of opening by at least 2 in^2 for each 1,000 Btu/hr of additional input rating.
Mr. Heater MH42T	42,000	Provide two openings directly to the outdoors: one high and one low (preferably on opposite sides of the enclosure). Each opening shall have a minimum free area of 36 in^2 (6 by 6 inches). Structures of tight construction or tents using fire-retardant materials require larger openings. If any additional fuel-burning appliances are operating, increase the area of opening by at least 2 in^2 for each 1,000 Btu/hr of additional input rating.

Table 3—Number of National Fire Equipment System (NFES) heaters issued through the National Interagency Support Caches between 2010 and 2013.

Heater	2010	2011	2013
NFES 006139	1,411	811	455

Heater	2010	2011	2013
NFES 006187	768	478	188

In recent decades, State and local officials have developed standards to foster the safe use of propane heaters. Some are voluntary standards, such as those issued by the Canadian Standards Association (CSA), to which manufacturers can certify products, while others are State and local mandatory building code standards that limit the types of heaters installed in a region. See appendix A for a more indepth review of the standards and unvented gas-fired heater categories.

The inherent danger when using propane heaters in enclosed spaces is the production of CO during the combustion process. Propane burns quite cleanly, but still produces CO as a combustion byproduct. CO is an asphyxiant gas; it binds with hemoglobin in the blood and reduces the amount of oxygen-carrying hemoglobin, which causes hypoxia (shortage of oxygen). Incapacitation due to asphyxiant gases is well known; a short period of intoxication precedes a marked decline in cognitive function leading to incapacitation. In general, the victim is often unaware of approaching intoxication. However, deterioration is rapid once the victim reaches a certain threshold and can no longer maintain normal functions. The victim displays effects similar to that of severe alcohol intoxication—lethargy or euphoria followed by a quick slide into unconsciousness. Common symptoms at varying levels of CO poisoning include headaches, dizziness and drowsiness, nausea, vomiting, and tightness across the chest. Refer to the Occupational Safety and Health Administration (OSHA) Fact Sheet “Carbon Monoxide Poisoning” <https://www.osha.gov/OshDoc/data_General_Facts/carbonmonoxide-factsheet.pdf> for further information.

OSHA’s permissible exposure limit (PEL) for CO is 50 p/m of air as an 8-hour, time-weighted average (TWA) concentration. The National Institute for Occupational Safety and Health (NIOSH) assigned a recommended exposure limit of 35 p/m as a 10-hour TWA, with a not-to-exceed ceiling value of 200 p/m. The NIOSH limits are based on the risk of cardiovascular effects. The American Conference of Governmental Industrial Hygienists (ACGIH) established a threshold limit of 25 p/m as a TWA for an 8-hour workday and limits excursions in worker levels to 75 p/m for no more than 30 minutes during a workday, and never more than 125 p/m. ACGIH limits are based on the risk of elevated carboxyhemoglobin (COHb) levels.

The combustion process requires oxygen. In enclosed spaces with poor ventilation, hypoxia or low oxygen saturation levels can be an additional concern. Normal breathing air has 20.9 percent oxygen. OSHA defines an oxygen-deficient atmosphere as having less than 19.5 percent oxygen. The Society of Fire Protection Engineers “SFPE Handbook of Fire Protection Engineering” classifies hypoxia into four phases (table 4).

Table 4—Four phases of the effects of hypoxia (National Fire Protection Association; Society of Fire Protection Engineers "The SFPE Handbook of Fire Protection Engineering").

Phase	Oxygen concentration (percent)	Effect
Indifferent phase	14.4 to 20.9	Minor effects on visual adaptation to low-light conditions and beginnings of effects on tolerance to exercise when nearing 15 percent oxygen concentration.
Compensated phase	11.8 to 14.4	Slightly increased ventilation and heart rate, slight loss of efficiency in performance of complex psychomotor tasks and short-term memory, some effects on judgment. Reduced maximal exercise work capacity.
Manifest hypoxia	9.6 to 11.8	Degradation of higher mental processes and neuromuscular control, loss of critical judgment and volition, dulling of the senses. Emotional behavior may vary from lethargy and indifference to excitation with euphoria and hallucinations.
Critical hypoxia	7.8 to 9.6	Rapid deterioration of judgment and comprehension, leading to unconsciousness, followed by cessation of respiration and, finally, of circulation, leading to death.

The use of propane heaters in enclosed spaces is a concern for both military and commercial applications. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) issued a factsheet for guidance on the use of heaters inside tents and other enclosed shelters. It prohibits the use of propane heaters inside tents. "Personal (individually owned) heaters and commercial portable gas (e.g., propane, natural gas, etc.) heaters must not be used under any circumstances. Soldier deaths have been associated with their use in tents" (USACHPPM 55-007-1005). The Army Safety Center advises against the use of any unvented space heater where soldiers work or sleep. Army Regulation 420-96 prohibits use of any unvented space heaters in living quarters or enclosed locations where soldiers sleep (Mackoul 2003).

In commercial applications, the use of propane heaters is also a serious concern for camping, both in tents and in recreational vehicles. Between 1999 and 2000, 51 deaths (not related to fire or vehicular CO poisoning) were attributed to liquid propane gas heating systems, primarily in tents and other enclosed spaces (Vagts 2003).

Discussion of Potential Solutions

Fire camps often use NFES 006187 and NFES 006139 propane heaters supplied by NISC for outdoor space heating. When used as such, the heaters pose no danger to personnel. However, while no personnel reported using propane heaters in sleeping spaces, the size and portability of the heaters, particularly the NFES 006139 heaters, raise concerns about the potential for use in working and sleeping spaces.

All of the NISC propane heaters (refer to tables 1 and 2) are unvented heaters. NISC labels NFES 006187 heaters specifically for outdoor use, and labels 006139 heaters for mounting on a 20-pound tank. However, there is often confusion as to whether the 006187 heaters are really outdoor heaters. This confusion may be partially due to the environmental operating requirements of the heater itself. The operating manual for Master Heater model TC275 warns personnel to “[k]eep heater away from strong drafts, water spray, rain, or dripping water.” If the indoor space is large and there is an adequate exchange of fresh air, the heater is, in theory, safe to use. In practice, providing the necessary ventilation in cold weather seems counterproductive and is often ignored or not adequately followed.

Without adequate ventilation, propane will not burn as cleanly and the buildup of CO can quickly exceed safe limits. Even with Mr. Heater Model MH125LP, a heater with a fairly efficient combustion process (0 to 2 p/m of CO), personnel must provide adequate ventilation for any indoor use. A Mr. Heater representative confirmed that personnel should not use the MH125LP in any indoor setting, including large wall tents.

All construction and recreational propane heaters currently in production have warnings (both in the operating manuals and on warning labels on the heaters themselves) against indoor usage.

Refer to table 2 for the ventilation requirements for the current NFES 006139 heaters. The current models in the cache—MH12T, MH24T, and MH42T—have been superseded by MH15T, MH30T, and MH45T, respectively. While the heating outputs remain the same, the ventilation requirements in the operating manual have changed. Where the older models listed specific opening sizes for ventilation in enclosed spaces, the newer models state only that heaters are for nonresidential indoor and outdoor use, and should never be used inside “a house, camper, tent, or any type of unvented or tightly enclosed area.”

Despite the manufacturer’s recommendation, personnel use current NISC propane heaters in a way that is potentially hazardous. Any discussion concerning potential heating solutions must meet the heating needs of personnel, account for how they are likely to use the heaters, and have practical methods of implementation. To limit the scope, this report focuses on heating system outputs comparable to the current heaters supplied by NISC. **Note: personnel should NEVER use unvented propane heaters in personal tents** (see table 5 for tent designations, including personal tents).

Option 1: Adequate Ventilation

The size and configuration of tents used in fire camps vary according to the need and the method of procurement (table 5). Incident personnel also often order tents through agreements or contracts to serve as working spaces. The national solicitation templates for tent agreements specify four types of tents; regional contracts, such as for the Incident Base Unit (IBU, also known as "Camp-in-a-box") in the Pacific Southwest Region, use the same typing categories, although the specific terms and requirements may differ. Tents procured through agreements do not have language in the contract for heating or ventilation. While some contractors bring tents that have ceiling vents with passive turbine vents or attic fans, others do not.

NISC also stocks two smaller tents (10 by 12 feet and 14 by 16 feet) and a variety of sizes for octagon-shaped yurts. While these tents and yurts may come with some ventilation, no contract specifies this.

Table 5—Tents used on fire incidents. NISC is the National Interagency Support Caches. NFES is the National Fire Equipment System.

Method of procurement	Tent type	Tent size	Fire camp use
National agreement/regional contract	Type 1	40 by 40 feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
National agreement/regional contract	Type 1	40 by 60 feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
National agreement/regional contract	Type 1	40 by 80 feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
National agreement/regional contract	Type 2	20 by 40 feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
National agreement/regional contract	Type 2	20 by 60 feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
National agreement/regional contract	Type 3	501 to 700 square feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
National agreement/regional contract	Type 4	200 to 500 square feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
NISC NFES 000549	Octagon	20-foot diameter	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
NISC NFES 000540	Octagon	18-foot diameter	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
NISC NFES 000550	Octagon	16-foot diameter	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
NISC NFES 000430	Octagon	15 by 27 feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
NISC NFES 000223	Wall tent	10 by 12 feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
NISC NFES 000084	Wall tent	14 by 16 feet	Medical, operations, planning, briefing, safety, logistics, sleeping, etc.
NISC NFES 000077	Wall tent	7 by 8 feet	Personal tent

For the current set of NFES 006187 propane heaters NISC supplies (refer to table 1), the greatest ventilation needs can be summarized as two unimpeded openings to outside air, one low and one high. To provide adequate ventilation for all available NFES 006187 propane heaters, each tent opening would have a required minimum of 4.125 ft^2.

The problem, typically, is not that the tents lack adequate ventilation. There are windows, doors, and loose seals around the tent floor that personnel can open to ensure sufficient ventilation. However, during cold weather, these potential openings often go unused. The extreme case is in the use of smaller propane heaters inside personal tents. While virtually all personal tents have mesh-covered windows and openings to theoretically allow the safe use of gas-fired heaters, it is unreasonable to assume that all personnel will remember to create sufficiently sized openings, particularly on a cold night. Moreover, there is an increased fire risk when using such propane heaters inside personal tents, particularly if the tents are made of flammable materials. **Personnel should NEVER use unvented propane heaters inside a personal tent.**

To ensure adequate ventilation within tents (excluding personal tents), the first option is to modify existing tent agreements and NISC inventory to include two permanent ventilation openings, one on the ceiling and one at a lower position. These openings should each be 4.125 ft^2. Personnel could provide additional ventilation by using a wall fan or ceiling fan to increase air-changes-per-hour (ACH) rates. To provide further safety for tent occupants, the national solicitation template for tents, along with the NISC tents, could require CO monitors be installed according to the manufacturer guidelines. These monitors should be Underwriters Laboratories (UL)-listed and meet the requirements of UL 2034, "Single and Multiple Station Carbon Monoxide Alarms."

There are serious concerns with option 1. From a logistical standpoint, it is not clear how NISC would enforce permanent ventilation for tents purchased in off-the-shelf configurations. For tents that do not need heating, the first option would also leave in unnecessary large permanent vents. From a safety point of view, adequate ventilation would be difficult to ensure, especially on cold nights when it would be easy to block vents to retain heat. Furthermore, while CO monitors listed under the UL 2034 standard provide a measure of safety, the CO threshold limits set by UL 2034 may still be unacceptable for long-term exposures. UL 2034 requires detectors to sound within the following parameters:

- 70 p/m CO after 1 to 4 hours (not less than 1 hour)
- 150 p/m CO after 10 to 50 minutes
- 400 p/m after 4 to 15 minutes

When comparing the CO concentration parameters of UL 2034 with the recommended exposure limits, it is evident that a low-level CO exposure could occur that exceeds workshift limits while never triggering the CO alarm. While other forms of CO dosimeters could theoretically work with programmable alarm set points, there are significant logistical hurdles in ensuring that such models and individual units are calibrated to be functional and accurate over time.

Personnel should NEVER use unvented propane heaters inside a personal tent.

Option 2: Propane Heater With Oxygen Depletion System

Some heaters come equipped with an oxygen depletion system (ODS) sensor for consumer safety. The ODS shuts off the heater when oxygen concentrations dip below 18 percent. As shown in table 4, this is well within safety factors for concentrations. In the past decade, manufacturers have introduced many consumer heaters equipped with ODS to the market. Because none of the NISC heaters are currently equipped with ODS, the second option is to replace the current NFES 006139 heaters with systems equipped with ODS. Table 6 shows a list of ODS-equipped heaters. Large-output heaters are not available with ODS and are not an option for NFES 006187. A recent market search indicated no propane heaters equipped with ODS systems had heating outputs of more than 40,000 Btu/hr. This is likely because larger units generally are certified to a CSA construction standard that assumes use in unconfined spaces (a space with a volume of no less than 50 cubic feet per 1,000 Btu of aggregate appliances installed, according to American National Standards Institute [ANSI] Z223.1); indoor use of these larger units is strongly discouraged. As a result, multiple ODS-equipped heaters would be required to achieve the same amount of heating in the propane models currently available in the caches. For example, it would take approximately seven Mr. Heater Big Buddy units to match the heat output of one Mr. Heater propane unit from NISC.

In 2002, the U.S. Consumer Product Safety Commission (CPSC) published a report that evaluated eight different radiant heaters and documented CO and oxygen emissions tested to the ANSI Z21.63 standard (Tucholski 2002). The findings were encouraging. Of the eight heaters, only the two heaters equipped with ODS fell within the ANSI Z21.63 requirements (CO = 100 p/m maximum; oxygen = 16 percent minimum). Moreover, the oxygen concentration was the limiting factor, as the ODS shut off the units before the CO concentrations exceeded 100 p/m in the test chambers, thus validating the use of low-oxygen sensors to indicate and set thresholds for CO levels within the parameters of the standard.

Similar to concerns raised in option 1 over the appropriateness of UL 2034 CO thresholds, there are concerns about whether CO requirements in ANSI Z21.63 or CSA 4.98 are stringent enough for long exposure times in fire camps. Given that the ACGIH 8-hour TWA for CO is 25 p/m, propane heaters equipped with ODS could conceivably be out of compliance with the ACGIH or other occupational exposure standards and still not trigger the ODS. This is, in fact, what happened in the CPSC tests for two heaters equipped with ODS. The first heater's ODS system shut down the heater within 35 minutes; the CO concentration measured 46 p/m. The second heater's air change rate was raised to avoid triggering the ODS; at 4.64 ACH*, maximum CO concentrations reached 38 p/m after 50 minutes and did not trigger the ODS. CO concentrations were clearly below the 100 p/m maximum and would therefore allow the heater to be certified to the standard, but would not provide a workshift environment within ACGIH exposure limits. Regardless of permissible exposure levels or threshold limit values (TLVs), some personnel will experience adverse effects with exposure to low levels of CO because of preexisting conditions, exposure on the fireline, or for other reasons. The National Technology and Development Program (NTDP) tested a lightly used Mr. Heater Big Buddy at three different heat settings and 0 ACH to validate the CPSC study and to determine how quickly the ODS triggered (appendix B).

* To put the air change rate in context, public and private offices typically are designed for air change rates of 3 to 4 ACH.

It is important for firefighters to have low or no CO exposure away from the fireline to give them time for their COHb concentrations to drop. Occupational exposure limits, such as the OSHA PEL and ACGIH TLV, are based on COHb level as it rises during an 8-hour workshift. Time away from exposure allows the firefighter's COHb concentration to decline before exposure during another workshift. If heater exhaust in tents continues exposure, the firefighter's COHb will not have a chance to decline and will continue to rise until it reaches equilibrium.

Additionally, as the ODS is predicated on the concentration of oxygen in the air and oxygen concentrations decrease with higher elevations, propane heaters are subject to altitude limits for normal operation. Personnel can find maximum altitudes, such as those listed in table 6, in heater operation manuals.

Table 6—Propane heaters equipped with an oxygen depletion system (not comprehensive). Heat input, rather than heat output, more accurately defines the numerical range listed by the manufacturer. A heater's heat input is based on the heating value of the fuel consumed. To avoid confusion for the reader, the term "heat output" is used throughout this report.

Manufacturer and model number	Heat output British thermal units per hour (Btu/hr)	Type of heater	Maximum altitude (feet)
Mr. Heater: MH18 B–Big Buddy	18,000	Recreational	7,000
Mr. Heater: MHVFR30LPBT–Vent-Free Wall Mount	30,000	Residential (restricted in certain States and localities; see appendix A)	4,500
Dyna Glo: RA18LPDG	18,000	Cabinet heater	Not available; typically 4,500

Option 3: Electric Heater/Generator-Powered Heater

Electric space heaters (figure 3) can be categorized as radiant heaters, convective heaters, or fan heaters. Radiant heaters contain a heating element that emits infrared radiation. Convective heaters also contain heating elements, but the heating element heats the proximate air, causing a current of hot air to exit the appliance into the space. Fan heaters also use convection, but have an electric fan that helps speed the airflow. The major advantage of using an electric heater is that it produces no CO emissions. Electric heaters can be purchased as standalone units or paired with an air conditioning unit. The overall process, however, is less efficient than in similarly sized gas-fired heaters because electric heaters are dependent on a generator. In addition, heaters with larger heat outputs often demand higher voltages (table 7) supplied by generators capable of meeting those voltage requirements. Using electric heaters could potentially result in purchasing or contracting either more generators or generators with higher wattages.

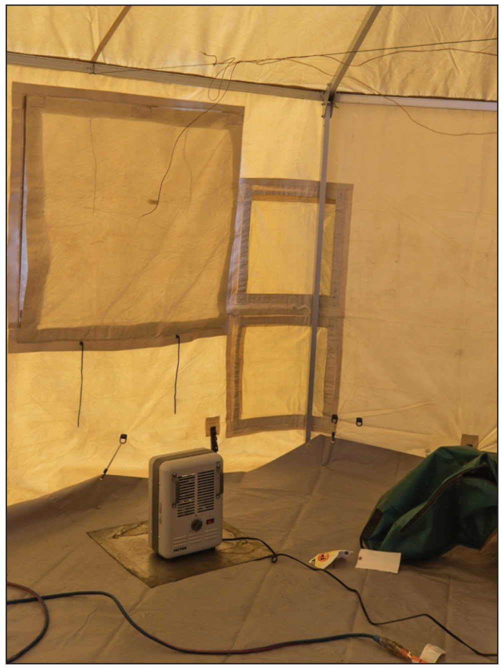

Figure 3—An electric heater standing on a metal plate inside a canvas yurt.

As option 1 indicates, many of the tents used for fire incidents are procured through a local or regional agreement using a national solicitation template. Because many different contractors supply tents, the tents come in various forms and configurations. Some tents come with generator-powered heating systems already included. However, cooling units (not heating) currently are the only options for conditioned air in the national solicitation template. For option 3, NTDP recommends mandatory cooling and electric heating on type 3 and 4 tents, with cooling and electrical heating as an option on type 1 and 2 tents. Additionally, option 3 would augment outdoor propane heaters in NISC with electric heaters with similar outputs.

Table 7—Electric heaters (not comprehensive). Heat output is approximate (converted from watts and rounded to the nearest hundred). NEMA is the National Electrical Manufacturers Association.

Manufacturer and model number	Heat output British thermal units per hour (Btu/hr)	Voltage requirement volt (V) ampere (A)
Optimus H-5210	2,700	120V–single phase
Honeywell HZ-725	5,100	120V–single phase
Lasko 5365	5,100	120V–single phase
TPI ICH-240C	13,600	240V–3 phase NEMA 6-20
Cadet RCP502S	17,000	240V–3 phase NEMA 6-30
Marley QMark BRH 562	19,100	240V–3 phase NEMA 6-30
King Electric PKB2415-3	51,200	240V–3 phase 36A
Heat Wagon P4000	136,500	480V–3 phase 50A

Option 4: Vented Heater

Personnel can also avoid high CO concentrations by using vented heaters. Vented heaters use carbon-based fuels (diesel, kerosene, wood, natural gas, etc.). These heaters have a flue that carries the exhaust to the outside. The market has many options for vented heaters, with a variety of heat outputs. Personnel must install vented heaters carefully to ensure that the exhaust does not recirculate in the heated space and vents to an open, unoccupied area. Additionally, the heater requires outside air to support the combustion process. Personnel must consider the following factors when procuring vented heaters:

- **Fuel type**—the type of heater personnel procure should be consistent with the fuel source available. Some heaters can accept a variety of fuel sources. The U.S. Army has developed a family of liquid and solid fuel space heaters (diesel, JP-8, JP-5, kerosene, wood, and coal) for use with tents (Mackoul 2003).
- **Integration with existing tents**—personnel would most effectively procure vented heaters as an option through the tent agreement. The contractor would then be responsible for integrating the vented heater with the supplied tent and for installing the heater correctly to reduce the risk of fire.
- **Portability**—personnel needs for easily transportable units may be met with a vented heater. Some vented heaters may be more portable than others.

Option 5: Outdoor Heater

Unlike vented indoor heaters, outdoor heaters sit outside the shelter and supply heated air to the interior space through ducts (figure 4). Outdoor heaters commonly include a forced air convection heating unit and an adapter that allows the supply side of the unit to push heated air directly into the ductwork. The intake for the heater and the adapter must prevent exhaust gases from mixing into the supply ductwork.

One advantage of using outdoor heaters is that personnel can use virtually any type of forced air convection heater, regardless of the fuel source. As long as the heater's air intake is far enough from its exhaust, there is little risk of combustion gases entering the shelter. Additionally, because the heater footprint is outside the shelter, personnel can maximize use of the interior space and can size the heater to be as large and powerful as needed.

Personnel should give careful consideration before using option 5. Forced air convection heaters that run off other fuel sources (diesel, JP-8, kerosene, propane, etc.) often require additional electrical power to operate the fan. Outdoor heaters also require the purchase and maintenance of ductwork and adapters and should have a remote thermostat so personnel can avoid going outside the shelter to change the heater settings. Finally, outdoor heaters require personnel to avoid opening windows near the heater exhaust to prevent the entrainment of combustion products into the shelter interior.

Figure 4—An outdoor propane heater connected to two canvas yurts through flexible ductwork.

Option 6: Combination

Similar to options 3, 4, and 5, option 6 would amend the national solicitation templates for tents to enable the selection of heating. Unlike either of the previous options, however, the template would not specify the type of heating. If the contractor uses electric heating, the power unit should be included. Contractors using vented heaters are responsible for safely installing the heater and ensuring that combustion products do not enter working spaces.

Option 6 would prohibit the use of unvented propane heaters in any enclosed tent. Like option 3, electric heaters would be added into the cache system for use with NISC tents. Vented heaters would not be allowed with NISC tents because incorrect installation with different models and sizes could potentially lead to combustion products leaking into interior spaces.

Option 6 would make it more likely for contractors to have tent systems with heating systems that are fully integrated and tested for the specific tent models. Furthermore, the contractor would have the responsibility and liability of ensuring the heating systems are installed and resourced correctly. For cache tents, electric heating (refer to option 3) would ensure that combustion products created by heaters would not compromise the interior working spaces.

Conclusion

Current NISC propane heaters are a source of potential health risk due to CO produced during the combustion process. Table 8 shows a summary of the different options for addressing this issue.

Recommendations

- NISC must stencil NFES 006187 and NFES 006139 propane heaters with language prohibiting the use of the heaters in indoor spaces; the stencil replaces previous tags or laminated warning sheets.
- NTDP recommends adopting option 6 for crafting agreements with contractors and ensuring that personnel only use electric heaters with NISC tents. This maintains maximum flexibility in contract agreements while simultaneously maintaining an interior working space free of heater combustion products.

Table 8—Summary of options for reducing the buildup of carbon monoxide in enclosed spaces. NFES is the National Fire Equipment System. NISC is the National Interagency Support Caches.

Options	Description	Pros	Cons
Option 1	Modifying tents to include permanent vents to ensure adequate ventilation. Possibly requiring carbon monoxide sensors in tents.	Continues use of current propane heaters. Allows heater operation within manufacturer-defined ventilation requirements.	Logistically difficult with number of different tents, vendors, and off-the-shelf items. Abuse of permanent ventilation possible. Still potentially unsafe.
Option 2	Replacing propane heaters with heaters equipped with an oxygen depletion sensor.	Prevents serious acute carbon monoxide poisoning. Heat outputs of off-the-shelf heaters with an oxygen depletion sensor match current NFES 006139 heaters.	Heat outputs of off-the-shelf heaters with an oxygen depletion sensor do not match current NFES 006187 heaters. Increased ventilation may keep the oxygen depletion sensor from triggering. An oxygen depletion sensor does not necessarily prevent exceeding workshift carbon monoxide exposure limits. Increased altitude may not allow heaters to work at all.
Option 3	Adding electric heaters into NISC and tent agreements based on tent solicitation templates.	Prevents emission of combustion products into enclosed spaces.	Requires a generator. Size of heat output limited by power requirements. Potential impact on NISC inventory of generators.
Option 4	Adding vented heaters into the tent agreements—based on tent solicitation templates—and NISC. Fuel type would be a major selection factor for vented heaters.	Removes accumulation of carbon monoxide by venting combustion products to the tent exterior. Available on the open market in many different forms and heat outputs.	Requires alternate fuel supplies. May be technically difficult to integrate with tents if purchased or procured separately from the tents. Logistically difficult with number of different tents, vendors, and off-the-shelf items. Requires ductwork.
Option 5	Adding outside heaters into the tent agreements —based on tent solicitation templates—and NISC. Fuel type would be a major selection factor for vented heaters.	Provides uncontaminated heated air to the tent interior while allowing heaters with any type of fuel source. Available on the open market in many different forms and heat outputs. Moves the heater footprint to the tent exterior.	May require alternate fuel supplies. May be technically difficult to integrate with tents if purchased or procured separately from the tents. Requires ductwork.
Option 6	Adding heating into national solicitation templates without specifying electric or vented heat. Electric heaters would be added into the cache for use with NISC tents.	Contractor-supplied heating systems likely to be fully integrated with contractor-supplied tents. Liability resides with the contractor. Ensures that heaters for NISC tents do not emit combustion products.	Potential impact on NISC inventory of generators.

Acronyms

ACGIH—American Conference of Governmental Industrial Hygienists

ACH—air changes per hour

ANSI—American National Standards Institute

Btu/hr—British thermal units per hour

CO—carbon monoxide

COHb—carboxyhemoglobin

CPSC—U.S. Consumer Product Safety Commission

CSA—Canadian Standards Association

ft^2—square foot

ft^3—cubic foot

IBU—Incident Base Unit

LP—liquid propane

NEMA—National Electrical Manufacturers Association

NFES—National Fire Equipment System

NFGC—National Fuel Gas Code

NFPA—National Fire Protection Association

NIOSH—National Institute for Occupational Safety and Health

NISC—National Interagency Support Caches

NTDP—National Technology and Development Program

ODS—oxygen depletion system sensor

OSHA—Occupational Safety and Health Administration

PEL—permissible exposure limit

p/m—parts per million

SFPE—Society of Fire Protection Engineers

TWA—time-weighted average

UL—Underwriters Laboratories

USACHPPM—U.S. Army Center for Health Promotion and Preventive Medicine

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Appendix A: Standards for Vent-Free Gas-Fired Heaters

Unvented propane radiant heaters are divided into several categories:

- Recreational
- Patio
- Construction
- Residential/commercial

Recreational

Canadian Standards Association (CSA) International Requirement 4.98 for "Gas-Fired Portable Heaters for Recreational and Commercial Use" serves radiant heaters designed for recreational use. CSA 4.98 applies to gas-fired portable heaters for recreational and commercial use, with energy-output rates up to and including 10,000 British thermal units per hour (Btu/hr). The standard requires gas-fired portable heaters to be equipped with an oxygen depletion system (ODS); the ODS must be programmed to shut the heater off when the oxygen concentration is depleted to less than 18 percent. Furthermore, in a 500 cubic foot (ft^3) room without air exchanges, the carbon monoxide (CO) concentration must not exceed 100 parts per million (p/m) when the oxygen concentration is depleted to 18 percent. Heaters certified to CSA 4.98 are designed for indoor use in enclosures that provide adequate combustion air and ventilation.

American National Standards Institute (ANSI) Z21.63, American National Standard/CSA "Standard for Portable Type Gas Camp Heaters," covers unvented gas-fired radiant heaters with outputs up to 12,000 Btu/hr intended for outdoor use. ANSI Z21.63 states that in small, 100 ft^3 spaces, the CO concentration in the room cannot exceed 100 p/m when tested with air exchange rates of 0.5, 1.0, and 1.5 air changes per hour. It also specifies that the oxygen concentration must remain 16 percent and above.

Patio

CSA 5.90, for "Gas-Fired Infrared Patio Heaters," contains the same requirements as CSA 4.98; however, the scope of the standard is limited to tabletop patio heaters rated at 15,000 Btu/hr and less.

Construction

Construction gas-fired space heaters are designed for large, well-ventilated, semi-open spaces, such as construction sites, barns, and loading docks. They are available in two configurations: radiant heat with 360-degree coverage and forced-air convective heat. There are no standards for construction space heaters because they are made only for outdoor/well-ventilated spaces.

Residential/Commercial

Unvented gas-fired heaters used in residential or commercial spaces often are permanently installed, wall-mounted heaters. Residential propane heaters are regulated by a variety of mandatory building codes that vary State by State and, in some instances, locality by locality. These building codes often incorporate voluntary standards National Fire Protection Association (NFPA) 54 and ANSI Z21.11.2.

NFPA 54/ANSI Z223.1, "National Fuel Gas Code (NFGC)" contains ventilation requirements for gas-fired unvented heaters. These heaters must receive and exhaust 4 ft^3 of air for every 1,000 Btu/hr of heating output. Furthermore, the NFGC stipulates that gas-fired unvented space heaters be listed under the Z21.11.2 standard. ANSI Z21.11.2 is a voluntary standard that permits the installation of vent-free gas heaters with output ranges up to 40,000 Btu/hr, with specific exceptions of 10,000 Btu/hr or less in bedrooms and 6,000 Btu/hr or less in bathrooms. ANSI Z21.11.2 requires that heaters be equipped with an ODS sensor. The sensor must shut off the gas supply to the pilot and main burners when the oxygen concentration is depleted to no less than 18 percent. Additionally, each certified heater design is tested for emissions of CO to 0.02 percent and nitrogen dioxide to 0.002 percent, and a heater cannot produce CO emissions of more than 0.025 percent in a room with no air exchanges.

California is the only State that has an outright ban on residential and commercial gas-fired heaters. California Health and Safety Code 19882 states that "[n]o person shall sell, or offer for sale, any new or used unvented heater that is designed to be used inside any dwelling house or unit, with the exception of an electric heater, or decorative gas logs for use in a vented fireplace." Some localities in other States also prohibit the use of unvented gas heaters in residential and commercial spaces.

Appendix B: Test Report—
Carbon Monoxide Generation from Mr. Heater Big Buddy Propane Heater

Sam Wu and Robert Manwaring

October 1 and 2, 2012

Objective

- To test the oxygen depletion system (ODS) on a lightly used Mr. Heater Big Buddy heater in a worst case scenario, measuring the time-to-shut-off and the carbon monoxide (CO) concentration at varying heights.
- To validate correlations drawn from previous tests about oxygen depletion, CO concentration, and ventilation.

Equipment

- Three CO dosimeters—MSA Altair Pro, Single Gas
- Test chamber—Environmental chamber (5.5 by 8.5 by 7 feet)
- Tape measure
- Vertical stand for attaching dosimeters
- Big Buddy Heater (MH18b)—CA Model MH18b, purchased May 9, 2011
- Full propane tanks
- Video camera and tripod

Test Procedure

1. Prepare for the test procedure.
   a. Calibrate the CO dosimeters. Configure to log:
      i. Peak CO per minute.
      ii. Average CO per minute.
   b. Time sync all dosimeters and video cameras.
   c. Prepare the environmental chamber by taping vents and openings.
   d. Ensure the batteries in the heater are fully charged and sufficient for testing.
   e. Ensure the fuel level is sufficient for the testing timeframe.
2. Set up the equipment per figure B–1. Place the heater flat on the ground.
3. Begin video recording. State:
   a. Date (e.g., Oct. 2, 2012).
   b. Test parameters (e.g., Measuring CO emissions with the Big Buddy heater set on high).
4. Turn on the heater fan.
5. Activate the heater at the high setting, making sure that the pilot light is lit and the heating element is on.
6. Close the door to prevent infiltration or exfiltration from the chamber.
7. Check the status of the heater within 1 hour. Do not enter the chamber for at least 45 minutes after the ODS has shut off.
8. Open the door wide to allow the rapid dispersal of CO from the chamber.
9. Turn off the video, dosimeters, and heater (fan and heat).
10. Upload the data onto a secure site.
11. Perform a functional “bump” test to ensure that the dosimeters are fully functional.
12. Repeat steps 3 through 11 (settings for medium heat and low heat, respectively) after reestablishing ambient conditions in the test chamber.

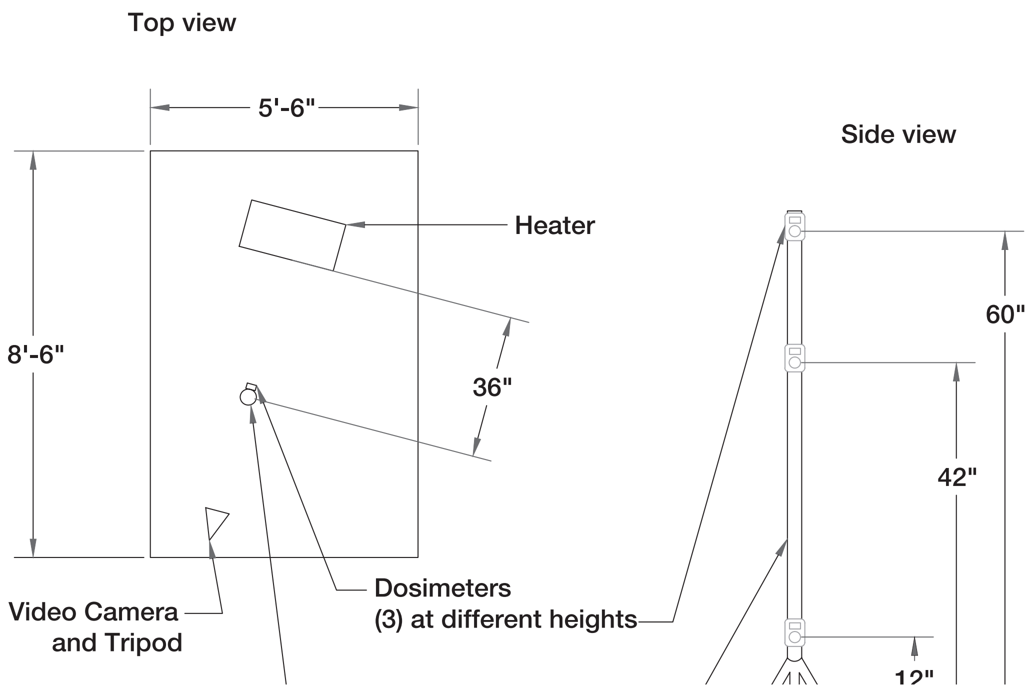

Figure B–1—Test schematic.

Results

In a test chamber with negligible air changes per hour (ACH), the Mr. Heater Big Buddy unit shut off its heating element in all three test cases. Because there was no makeup air to the unit, the oxygen depleted from its atmospheric concentration of 20.95 percent to between 18 percent and 19 percent, thereby triggering the ODS and cutting off the fuel supply to the heater. More ventilation would no doubt decrease the concentration of CO in the test chamber. However, more ventilation also allows the oxygen concentration to deplete more slowly, thus exposing individuals in the enclosed space to longer periods of sustained, elevated levels of CO. In fact, in tests performed by the U.S. Consumer Product Safety Commission (CPSC) on smaller heaters equipped with ODS, when ACH rates increased to a certain point, oxygen concentrations didn't deplete enough for the ODS to shut the units off. The inflection point for one of the units tested was a maximum concentration of 38 parts per million (p/m) CO at 4.64 ACH. Figures B–2 through B–4 illustrate that higher heat inputs directly related to the depletion of oxygen. The ODS triggered within about 30 minutes at the highest heat input of 18,000 Btu/hr versus 42 minutes at the middle heat input of 9,000 Btu/hr and 66 minutes at the lowest heat input of 4,000 Btu/hr. We expected this variance because of the higher rates of combustion and the lack of makeup air.

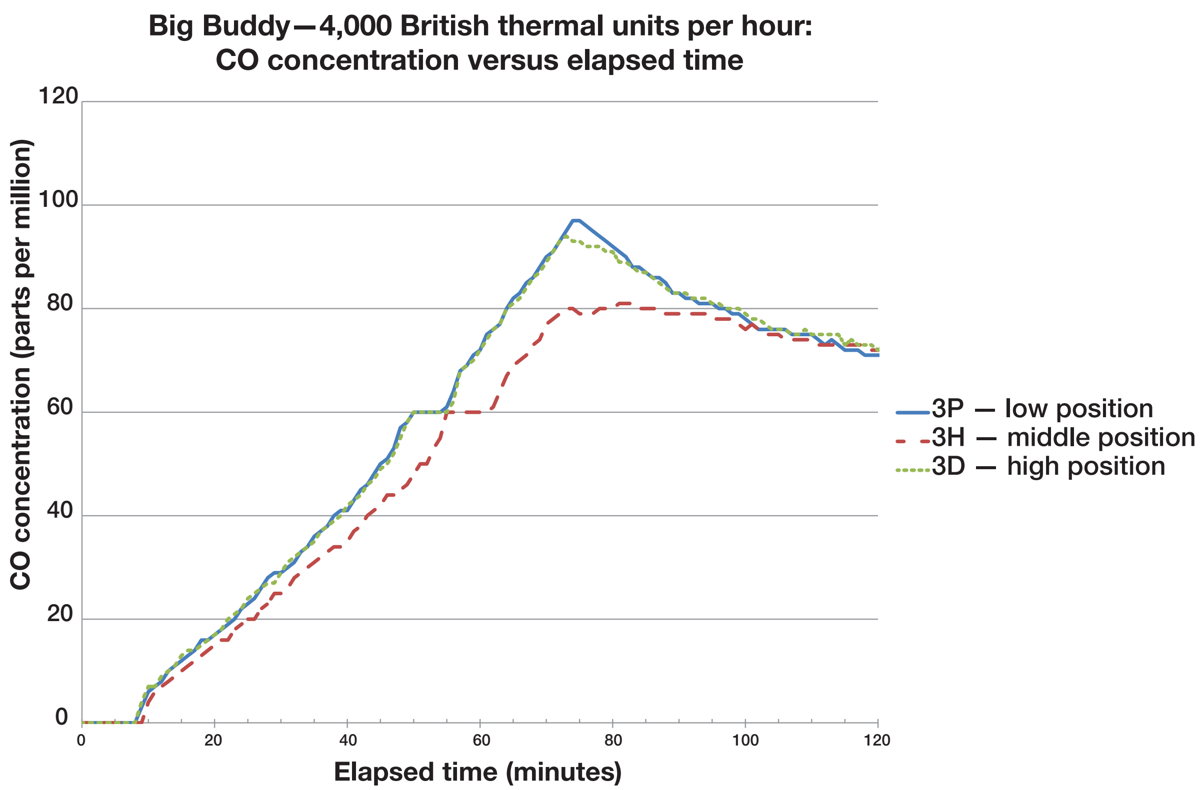

Figure B–2—Carbon monoxide concentration and elapsed time for the low heat setting.

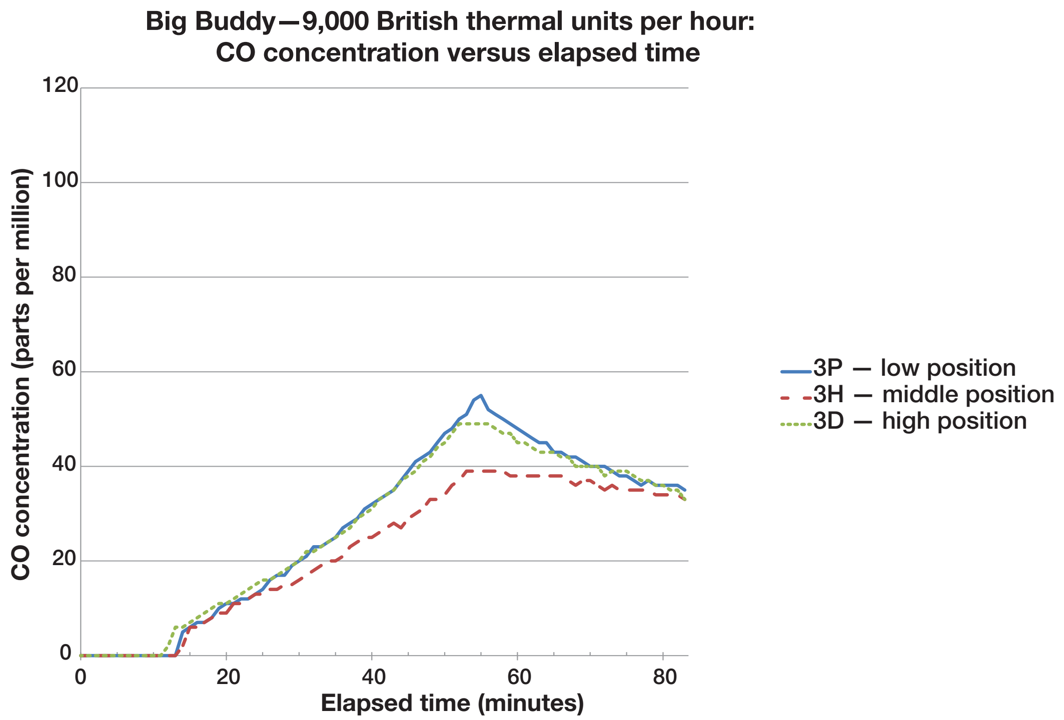

Figure B–3—Carbon monoxide concentration and elapsed time for the medium heat setting.

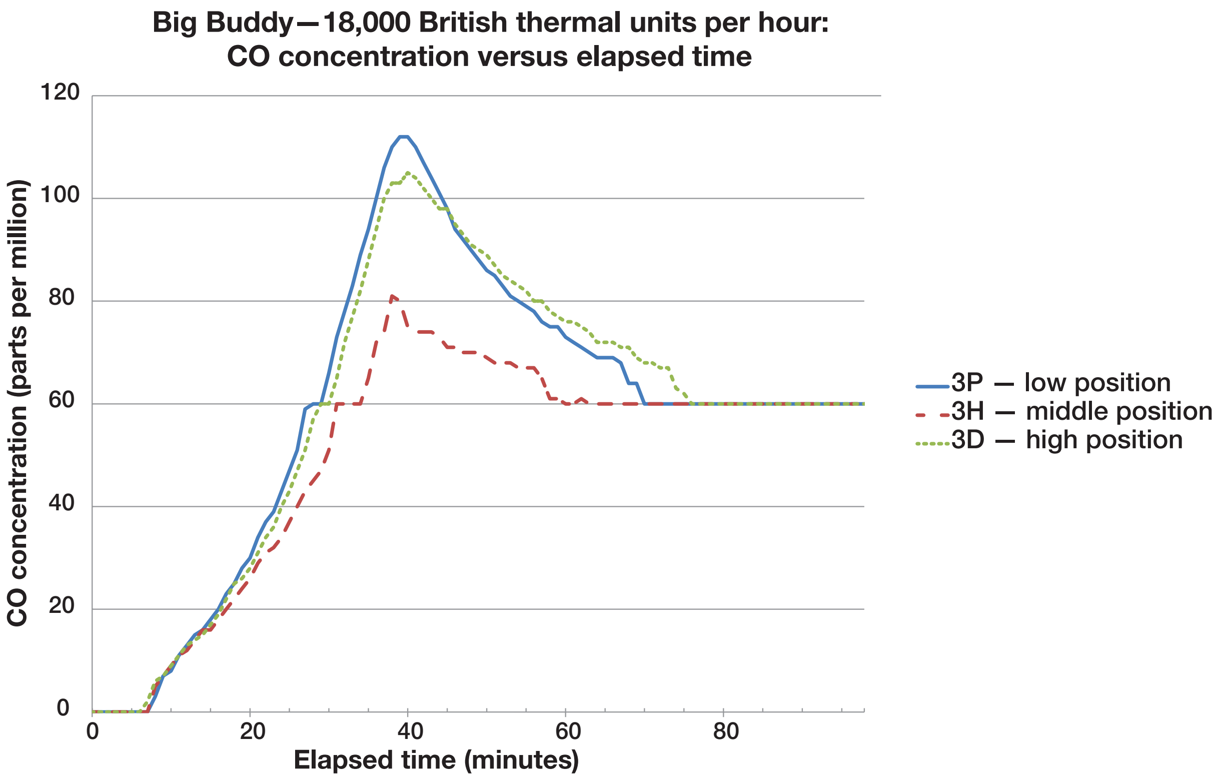

Figure B–4—Carbon monoxide concentration and elapsed time for the high heat setting.

The charts for all three heat settings also show that the CO concentrations are highest at the low position, followed closely by the high position; the middle position showed slightly lower concentrations at all heat levels. The high concentrations of CO at the low position likely resulted from the direct exposure to the heated air expelled from the heater. The higher concentrations at the high position relative to the middle position may be due to hot air rising and carrying combustion products, which may have caused a slight stratification in the room. After the ODS shut off the heater, however, the fan remained on and continued to mix the air in the room. Figure B–4 is an example of how the CO concentrations converged after a certain amount of time passed; we assumed the air was well mixed at that point. The rate of CO emissions was highest with the high heat setting. However, the rate of CO emissions was actually slightly higher in the low heat setting than in the medium heat setting. After 20 minutes, the CO concentration had risen to 26 p/m in the low setting versus 21 p/m in the middle setting (refer to figures B–2 and B–3). It may be that the medium heat setting allows for more complete combustion, resulting in slightly lower rates of CO emissions when compared with the low heat setting.

The Big Buddy Heater is certified to CSA 4.98—CSA International Requirement 4.98 for "Gas-Fired Portable Heaters for Recreational and Commercial Use"—and applies to gas-fired portable heaters for recreational and commercial use. The standard requires gas-fired portable heaters to be equipped with an ODS; the ODS must be programmed to shut the heater off when the oxygen concentration is depleted to less than 18 percent. Furthermore, in a 500-cubic-foot room without air exchanges, the CO concentration must not exceed 100 p/m when the oxygen concentration is depleted to 18 percent. Heaters certified to CSA 4.98 are designed for indoor use in enclosures that have the means to provide adequate combustion air and ventilation.

None of the three tests exceeded exposure limits for CO during the test timeframe due to the ODS automatic shutoff. However, the high setting exceeded the exposure parameters of CSA 4.98 (maximum allowed CO concentration of 100 p/m). Without additional ventilation, CO concentrations would likely exceed exposure limits for an 8- or 10-hour workshift. Moreover, the lack of ventilation allowed the CO concentrations to rapidly build up past 70 p/m—the level at which people may begin to experience short-term symptoms—in two out of the three heat settings.

More ventilation would likely decrease the concentration of CO in the test chamber. However, more ventilation would also allow the oxygen concentration to deplete more slowly, thus exposing personnel in the enclosed space to longer periods of sustained elevated levels of CO. In fact, in tests performed by CPSC on smaller heaters equipped with ODS, oxygen concentrations never depleted enough for the ODS to shut the units off when ACH rates increased to a certain point (Tucholski 2002). The inflection point for one of the units tested was a maximum concentration of 38 p/m CO at 4.64 ACH.

About NTDP

The U.S. Department of Agriculture, Forest Service, National Technology and Development Program provides Forest Service employees and partners with practical, science-based solutions to resource management challenges. We evaluate, design, and develop new technologies, products, and systems to solve problems and deliver solutions.

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Library Card

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Fire personnel often have to fight fires during cold weather months. Low temperatures can make walled tents used for operational briefings and livable workspaces uncomfortable. Personnel sometimes bring unvented propane heaters meant for outdoor use into the tents to provide heat, creating an unsafe and potentially unhealthy situation. During 2011, the National Interagency Support Caches received reports that personnel suspected certain types of National Fire Equipment System propane heaters of causing headaches when used inside 14- by 16-foot wall tents.

This report provides information about tests performed by the National Technology and Development Program (NTDP) on mitigating potential problems with unvented heaters in enclosed spaces. NTDP determined a number of potential solutions, including adequate ventilation, propane heaters with oxygen depletion system sensors, electric heaters/generator-powered heaters, and vented heaters.

Keywords: asphyxiant gas, carbon monoxide, CO, CO poisoning, hypoxia, National Interagency Support Caches, NISC, National Fire Equipment System, NFES, propane, propane heaters, safety at work, wildland fire, wildland firefighter, wildland fire fighter

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