Incident Summary #II-1032679-2020 (#18573) (FINAL)

SUPPORTING INFORMATION	Incident Date		June 27, 2020
	Location		Egmont
	Regulated industry sector		Gas - Propane system
	Impact – Injury	Qty injuries	2
		Injury description	One individual deceased and one individual taken to hospital in critical condition.
		Injury rating	Fatal
	Impact – Damage	Damage description	NA
		Damage rating	None
	Incident rating		Severe
	Incident overview		Two individuals were staying in a recreational cabin equipped with propane-fueled appliances. The occupants were exposed to high levels of carbon monoxide which were present in the cabin. The individuals were discovered inside unresponsive. One individual was deceased and the other was airlifted to hospital in critical condition.
INVESTIGATION CONCLUSIONS	Site, system and components		The lakefront cabin is accessible by boat or a rough dirt road. The cabin contains a wood stove for its main source of heat. There are no fixed gas or electrical utilities available in the area. Gas fuel is provided to the cabin by portable propane cylinders. Two propane cylinders are connected to a gas piping and tubing system which distributes the gas to appliances inside the cabin. Another propane cylinder is used to supply gas to an on-demand water heater installed on the outside of the cabin. Electricity is provided to the cabin either by a set of large low voltage batteries with a voltage inverter, or a gasoline fuelled portable generator. The inverter converts low voltage electricity from the batteries to 120 volts to power household lights and outlets in the cabin. The batteries are recharged by solar panels or the gasoline generator. The electrical system is effective for providing power for intermittent use of items that consume small to medium amounts of electricity, but ineffective at supplying power for constant or large electrical applications. For this reason, propane-fueled lamps, range, and refrigerator were installed in the cabin. A propane refrigerator has a sealed network of tubes and chambers which contain a solution of water, ammonia, and hydrogen. The refrigerator uses a small gas flame to heat a chamber holding the solution of water and ammonia. When the liquid ammonia vaporises it rises to the condenser where it condenses back to a liquid then flows to the evaporator where it mixes with the hydrogen. When the ammonia encounters the hydrogen it produces a chemical reaction which absorbs heat and produces a cooling effect which is used to cool the inside of the refrigerator. The ammonia returns to the water solution and the hydrogen returns to the evaporator and the cycle continues (Image 22). The propane refrigerator in the cabin was manufactured in 2010 by E-Z Freeze Refrigeration in Indiana and is model EZ-1050. This model does not require electricity to operate. Once the propane refrigerator burner is lit, it does not extinguish until the refrigerator is shut down. The gas flame operates on high (approx. 1500 btu/hr), when cooling, and transitions to low (approx. 700 btu/hr) when the demand

Incident Summary #II-1032679-2020 (#18573) (FINAL)

	for cooling has been satisfied. The refrigerator does not allow for an exhaust duct to attach to the flue pipe to vent the flue gases to the outdoors but they are instead distributed in the space the appliance is installed. The installation instructions and owner's manual ask for the installation of a carbon monoxide detector in the kitchen or dining room for safe operation of the refrigerator (Image 20). Carbon monoxide is a colourless, odourless, tasteless gas that is toxic to humans and animals (Chart 2). Exposure to carbon monoxide interferes with the body's ability to absorb oxygen, which can result in serious illness or death. Lower levels of carbon monoxide may result in serious health effects subject to the duration of exposure (Table 1). For example, exposure to carbon monoxide levels as low as 130 ppm can be lethal after exposure for eight hours. Symptoms of carbon monoxide poisoning can present similar to flu symptoms: headaches, nausea, dizziness, or vomiting. For more information on carbon monoxide, visit Carbon Monoxide Safety Tips. Carbon monoxide is produced from incomplete combustion of fossil fuels including natural gas and propane. Incomplete combustion can be caused by an inadequate air supply or flame impingement. Flame impingement occurs when a flame strikes an object and cannot extend far enough to complete the combustion process. Impingement disrupts the flame pattern, but may not produce a yellow, sooty flame. Common practice in the recreational community where the cabin is located is to open doors and windows while operating unvented propane appliances to allow for fresh air to enter, providing air for combustion and diluting flue gases inside the occupied space.
Failure scenario(s)	In March 2010, a new propane refrigerator was installed in the cabin. The refrigerator design did not allow for the flue gases to be vented to the outdoors and did not incorporate a carbon monoxide detector and safety valve interlocked to the operation of the gas burner. The refrigerator was installed by a person who was not a qualified gas fitter or a gas contractor. The refrigerator operated in the cabin for ten years without incident. Over time corrosion inside the steel flue pipe of the refrigerator produced scale and debris which fell around, inside, and on top of the gas burner tube. The flames from the gas burner were partially obstructed by the corrosion debris. This flame impingement resulted in incomplete combustion and the production of high levels of carbon monoxide while the fridge was operating. A carbon monoxide detector was not installed in the cabin. The individuals arrived to the family cabin midday June 25. Soon after their arrival, they began to feel ill. The two individuals remained inside the cabin with the doors and windows closed not allowing fresh air inside to dilute the increasing levels of carbon monoxide produced from the refrigerator. The couple were checked on multiple times by friends and neighbours from the community. At approximately 6:00 pm on June 27 both individuals were found inside the cabin unresponsive, emergency services were called.

Incident Summary #II-1032679-2020 (#18573) (FINAL)

Facts and evidence	**Interview statements** An owner stated that the cabin had been built in 1955 and has been in the family ever since. The cabin had been originally equipped with a woodstove, kerosene refrigerator, and propane lights. In 1997 an addition was constructed by a building contractor. In the early 2000's the existing propane range and propane pressure regulator were replaced. In 2010 the same individual also replaced the refrigerator with the unit that was installed in the cabin at the time of the incident. The individual was not a qualified gas fitter and did not install the components or appliances under a homeowner gas installation permit. The refrigerator was purchased from the USA and was shipped to BC with the assistance of a customs broker. The owner reported that at the time it was difficult to find gas refrigerators from suppliers in BC that met the size requirements they were looking for. They found the model they desired on the internet and purchased it online and had it shipped to BC. They were not aware of the requirement for gas equipment to bear a certification mark for use in Canada when they purchased the refrigerator. The gas oven and the propane lamps were very rarely used. The outdoor propane barbeque was used for the majority of the cooking and the electric indoor lights were typically used instead of the propane lamps to reduce gas usage. The portable gasoline generator was used occasionally and always operated outdoors. When the other owner arrived to the cabin on the evening of June 27, they observed that all the doors and windows were closed when the victims were found indoors. The victims had visited the cabin for many years and were aware of the procedures of opening and closing the cabin. They were familiar with and had practised in the past the procedure of opening the doors and windows in the cabin upon arrival and when operating the propane appliances. A neighbour who was in the area at the time of the incident stated that the two individuals arrived together midday Thursday June 25. They later complained to others that they were sick and had been vomiting. They believed they had food poisoning from a meal they had eaten earlier. People had been checking up on them periodically in the cabin. A witness went in the cabin and checked on them Saturday June 27 about 12:30 pm. The witness reported that the two individuals were both sleeping and were observed breathing. Another witness arrived Saturday evening at approximately 6:00 pm and found the two individuals both unresponsive inside the cabin. Emergency services were called and the propane supply was shut off and the doors and windows opened to ventilate the cabin. Another neighbor who was in the area at the time of the incident did not recall hearing a gasoline-fueled generator operating at the cabin while the two individuals were staying there. They stated that most of the residents in the area don't hire contractors to do gas or electrical work, they are mostly self-sufficient, have mechanical knowledge and do their own work. **Site examination** Technical Safety BC investigators conducted a site examination and testing of the propane-fueled equipment at the cabin after the incident. It was observed that two portable propane cylinders were installed on the outside wall of the cabin (Image 5) connected to a gas distribution system that supplied propane to a range, a double wall lamp, and a refrigerator. A separate propane-fueled on-demand water heater was found installed on the outside wall on the opposite side of the cabin. The water heater was connected to a separate propane cylinder via the appliances supplied hose and regulator.

Incident Summary #II-1032679-2020 (#18573) (FINAL)

Testing and analysis

There was no evidence that the gasoline-fueled generator was being used at the time of the incident. It was locked in a shed during the site investigation and the neighbor did not recall hearing it running during the time the couple were in the cabin. The gasoline generator was determined not to be a source of carbon monoxide in the cabin.

The gas barbeque was installed outside with the barbeque cover still on at the time of the investigation. It was placed approximately three feet away from an opening window which was determined to be closed at the time of the incident. The barbeque was determined not be a source of carbon monoxide in the cabin.

The wood stove installed in the cabin was a freestanding airtight design. No evidence was observed with the fireplace or vent that would suggest it would leak carbon monoxide into the cabin when operating. The wood stove was determined not to be a significant source of carbon monoxide in the cabin.

Testing the flue gas of the gas range cooktop burners did not produce any measurable carbon monoxide. Testing of the flue gas of the oven produced a measurement of 180 ppm of carbon monoxide. The gas range was installed in the kitchen without a ventilating hood fan (Image 8). The oven on the gas range was said to be rarely used and the outdoor barbeque was mainly used to cook food. It is not believed the individuals were using the oven during their time in the cabin. The gas range was determined not to be a significant source of carbon monoxide in the cabin.

Testing the flue gas of the gas lamps produced a measurement of 87-113 ppm of carbon monoxide. The lamps were installed on the wall above the kitchen sink (Image 7). They were said to be rarely used and they most likely would not have been used during the daytime. There were electric lights powered by the battery and inverter system that most likely would have been used instead of the gas lamps, to conserve the limited propane supply. The time of year the incident occurred, daylight typically lasts until 8 to 9 pm. Although long-term exposure to carbon monoxide levels of 113 ppm can be hazardous, in this incident the gas lamps were determined not to be a significant source of carbon monoxide in the cabin.

Testing the flue gas of the water heater produced a measurement of 150 ppm of carbon monoxide. The water heater was used to supply hot water to the kitchen sink and an outdoor shower. The heater only operates when water is flowing through a hot water tap for the sink or shower. The appliance was installed outdoors and vents over 4.5 feet away from opening windows (Image 3). The amount of dilution in the outdoor environment would reduce the risk of high levels of carbon monoxide from entering the occupied space inside the cabin. At the time of the site examination, the water heater was connected to an empty propane cylinder and the service valve was found in the closed position. The water heater was determined not to be a significant source of carbon monoxide in the cabin.

Testing the flue gas of the refrigerator produced a measurement of 1306 ppm of carbon monoxide within ten seconds of the burner's initial start-up (Image 12). The gas-fueled refrigerator was installed in the kitchen (Image 10). The refrigerator design did not allow for the flue gases to be vented to the outdoors or incorporate a carbon monoxide detector and safety valve interlocked with the operation of the gas burner. The flame was examined while in operation and debris was observed lying

Incident Summary #II-1032679-2020 (#18573) (FINAL)

on top of the gas burner. The burner flame was partially obstructed by the debris, identified as corrosion debris from the flue pipe (Image 13). The burner was shut off and the burner assembly was removed for closer examination. Corrosion scale debris from the burner flue was found on top, around, and inside the gas burner, and a larger flat piece of debris was found lying flat on top of the burner (Image 14).

The refrigerator flue gas measured high levels of carbon monoxide and were exhausted directly into the cabin. The refrigerator operates with a constant flame that does not extinguish but transitions from high to low when the cooling temperature of the set point is satisfied. Therefore, the refrigerator was constantly exhausting high levels of carbon monoxide into the cabin while the refrigerator was in operation. The refrigerator was verified as being the most likely source of carbon monoxide and very likely created a hazardous environment inside the cabin.

During testing, the debris was cleaned off the burner tube and burner assembly. The burner flame was relit and it produced a clean and stable flame (Images 15-16). Removal of debris lying on top of the burner had allowed the burner flame to return to the clean, stable flame pattern. The flue was observed to be clear with solid light passing through it. A flue brush was passed through the flue and fine particles were observed coming out the bottom. The burner box was reinstalled in its original location. Testing of the gas burner after it was cleaned produced a measurement of 15-28 ppm of carbon monoxide (Image 17). The carbon monoxide output of the propane refrigerator had reduced from a recorded 1306 ppm to 15-28 ppm after the debris was removed from the burner and the vent was cleaned out. The larger piece or debris can be seen laying off to the side but still touching the top of the burner (Image 14). It is suspected as this was the piece that was witnessed on top of the burner during its earlier operation when carbon monoxide levels were measured in the fridge flue in excess of 1300 ppm. It is suspected that this piece and possibly others shifted off the top of the burner during the manipulation of the burner housing away from the vent tube for closer examination. The corrosion debris on the burner was determined to be the cause of the production of high levels of carbon monoxide.

Refer to (Chart 1) for a comparison of carbon monoxide produced by each appliance measured following the incident.

Maintenance

The owners stated that they would typically complete maintenance on the refrigerator at the beginning of every spring season. There was a painting style brush, labelled in felt marker ”For cleaning back of fridge”, along with a flue brush designed for cleaning the inside of the flue of a gas refrigerator, hanging beside the refrigerator on a wire rack. The installation instructions and owner’s manual for the refrigerator were in a document holder on the wall next to the refrigerator and had highlighted passages in the instructions for defrosting. The manuals instructions strongly recommend maintenance and cleaning be completed every three months assuming the appliance is used full time year round. The manual’s maintenance procedures includes pulling the fridge away from the wall, removing a single screw, moving the burner box away from the flue and using compressed air to blow away any dirt or debris from the flue passage and entire burner and gas orifice area. The owner stated they followed the maintenance instructions and every year in March during spring break they would use a vacuum cleaner, set to blow air, and blow air down the flue and removed the screw and pull the burner box out and clean the debris from the burner area with the labeled paint style brush. The owner was unable to make it to the cabin the spring before the incident and does not believe that the maintenance of the fridge took place. The amount of corrosion scale debris found in the flue and

Incident Summary #II-1032679-2020 (#18573) (FINAL)

burner area indicates the cleaning of the debris from the burner and orifice area had not been completed recently.

Weather

Weather records identified the weather in the area over the three days when the individuals where at the cabin as mild with no precipitation and highs of 22°C and lows of 14°C. The lower end of this temperature range indicates that it may have been required to have the doors and windows closed for the occupants to stay warm in absence of another heating source such as the wood stove.

Regulation and standards

The Gas Safety Regulation, which is passed under the authority of the *Safety Standards Act*, governs gas appliances and gas systems in BC. This regulation requires that gas appliances can only be installed in the province of BC if they bear either a certification mark of an approved certification agency or an approval mark issued by Technical Safety BC. Section 31 of the regulation states that a person must not install an appliance unless it displays a certification or approval mark.

Certification marks can be applied to gas equipment by certification bodies accredited with the Standards Council of Canada when a nationally recognized standard exists. The gas equipment must meet the requirements of the recognized standard to be eligible for certification. The nationally recognized standard in Canada for refrigerators using gas fuel is the CSA 1.4 standard. All Canadian certified refrigerators will have certification mark(s) on the rating label and on the Installation and Operating Instructions cover page.

Research into the certification of the refrigerator installed in the cabin at the time of the incident, identified that the E-Z Freeze Model EZ-1050 did not hold a Canadian certification allowing it to be installed in BC.

The *Safety Standards Act* – Gas Safety Regulation section 4 states that individuals who install gas appliance's either hold a certificate of qualification to do so or are the homeowner who installs the appliance under an appropriate installation permit.

Codes

At the time the refrigerator was installed in the cabin in spring of 2010 the current adopted gas code in the province was the CSA B149.1-05 (2005) "Natural gas and propane installation code". That edition of the code has code clause 7.33.2 which stated: *An unvented refrigerator may be installed in a dwelling unit if certified with a carbon monoxide detector interlocked to shut off the gas supply to the burner when exposed to carbon monoxide levels not exceeding those specified in the CSA 6.19.*

In August of 2011 the CSA B149.1-10 (2010) code was adopted. That code changed clause 7.33.2 to: *A refrigerator in a dwelling unit shall be of the direct vent type,* and added clause 7.33.3 which states: *An unvented refrigerator shall be installed in an area that is not normally occupied and does not directly communicate with occupied areas.*

The installation of all unvented refrigerators in dwellings was removed from the 2010 version of the code based on safety concerns identified with unvented refrigerators from a fatal carbon monoxide exposure incident that occurred in BC in 2007.

Incident Summary #II-1032679-2020 (#18573) (FINAL)

Causes and contributing factors	It's highly probable that toxic levels of carbon monoxide accumulated inside the cabin due to the installation of a refrigerator that: • could not be directly vented to the outdoors; • did not have an integrated carbon monoxide alarm; and • did not have a safety valve interlocked to the operation of the gas burner. Failure to clean out the corrosion scale debris from the refrigerator burner assembly along with the failure to install a carbon monoxide detector in the cabin were contributing factors to the incident.

Images, Charts and Tables

Image 1 - Exterior of cabin

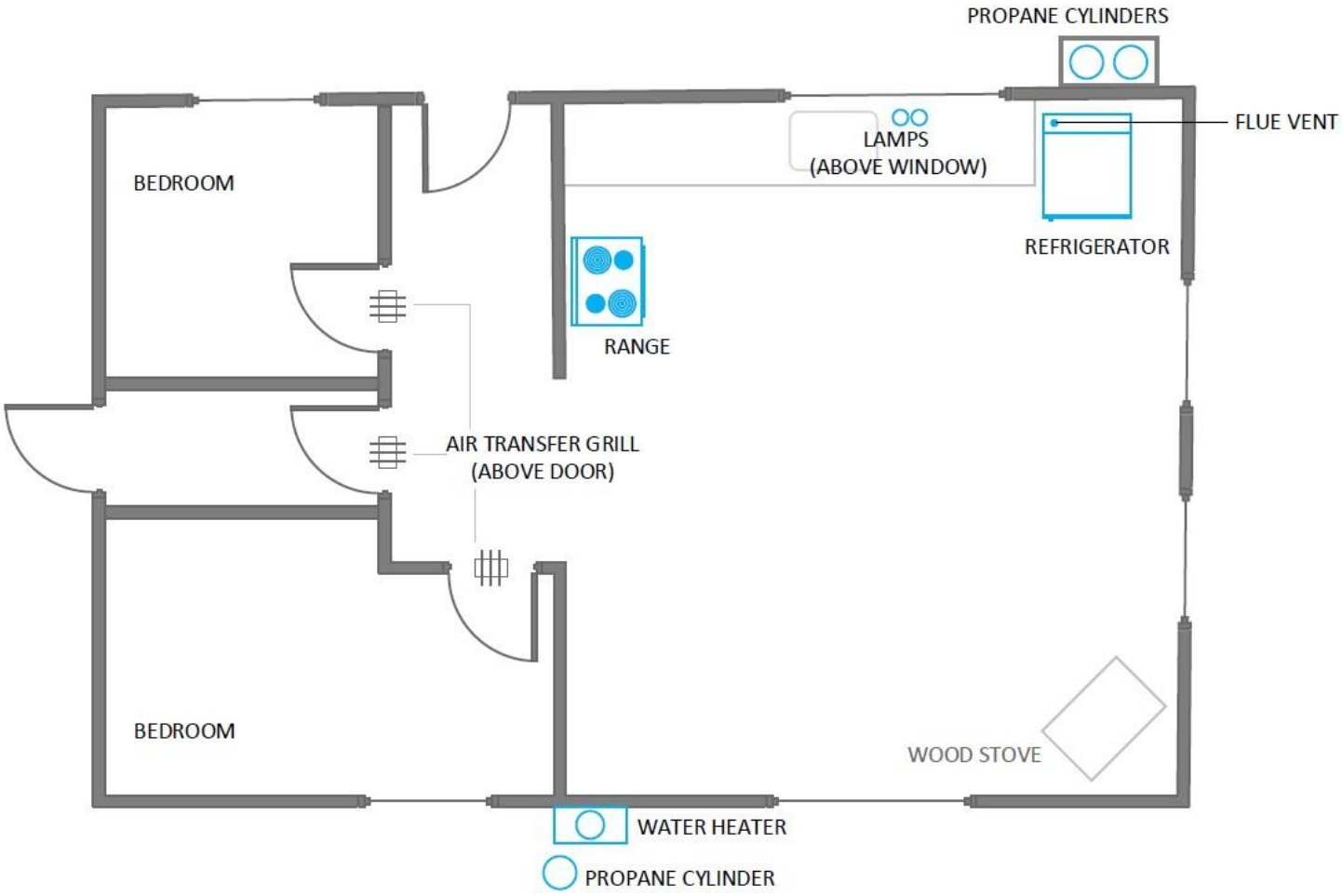


Image 2 – Cabin layout and appliance location

Image 3 – Water heater location on exterior of cabin away from opening windows

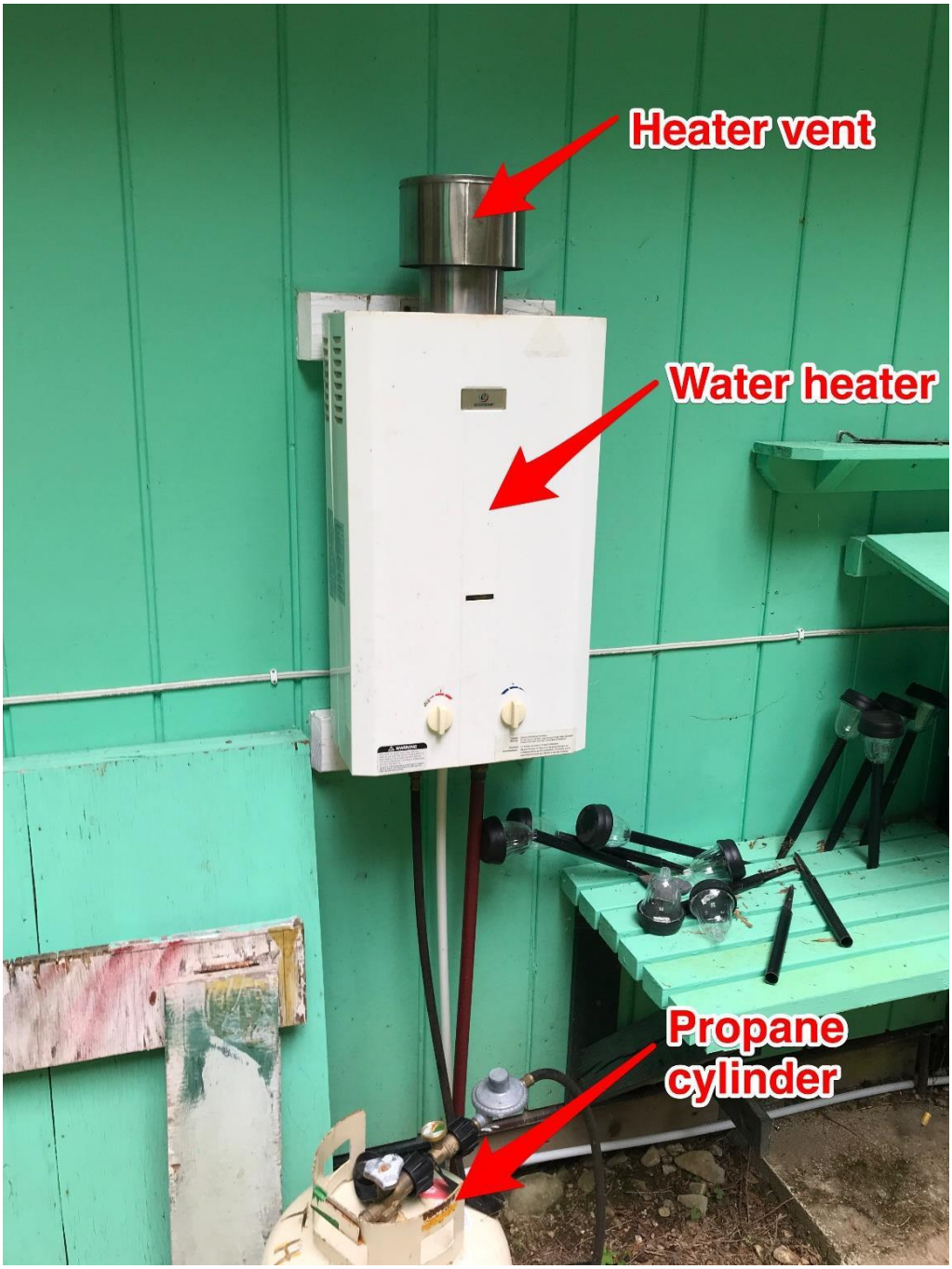


Image 4 – Water heater and propane cylinder installation

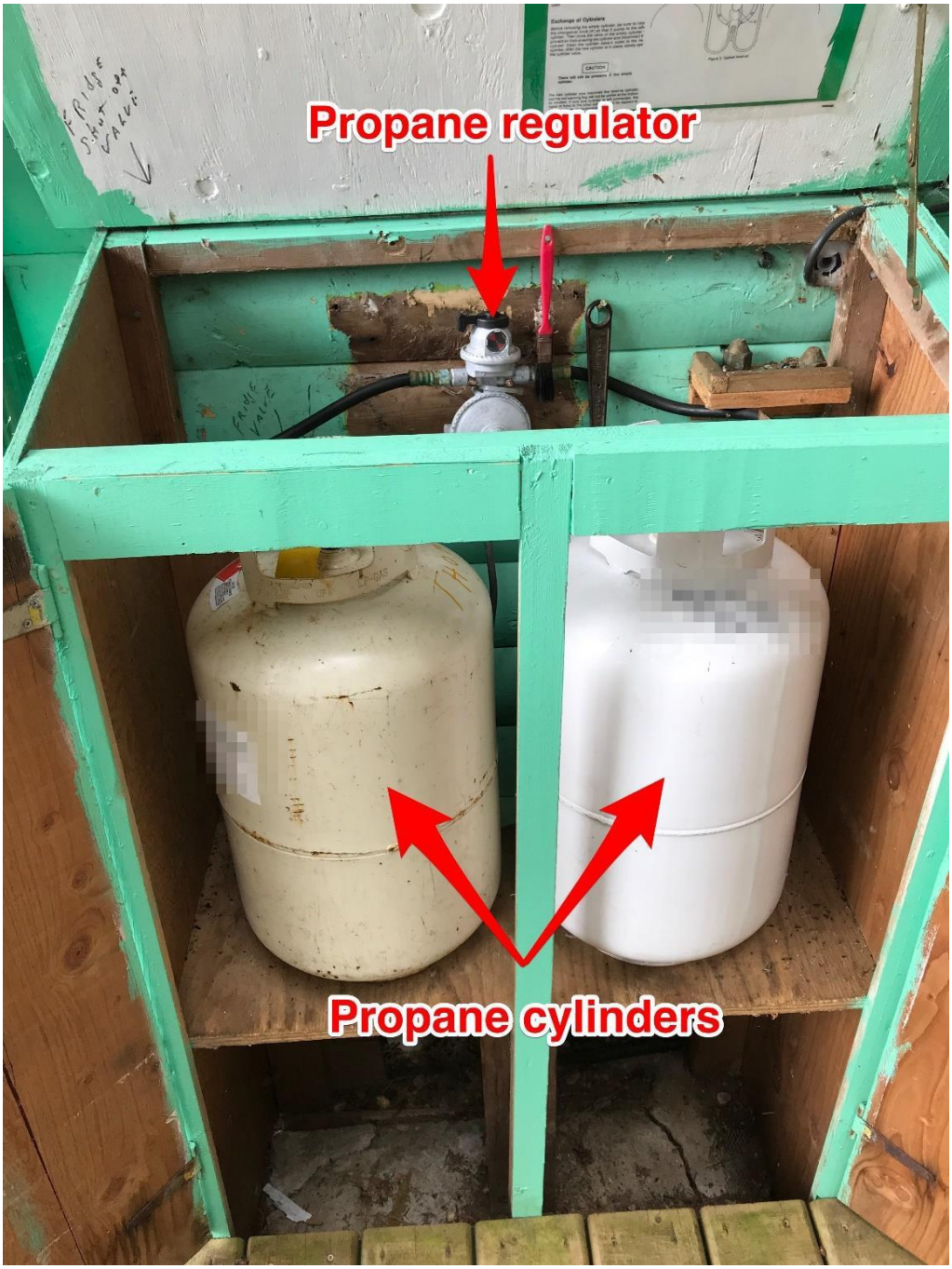


Image 5 – Propane cylinders and regulator installation on side of cabin

Image 6 – Gas shut off valve for refrigerator installed under propane cylinders

Image 7 – Propane lamps installed in kitchen above sink

Image 8 – Gas range installed in kitchen

Image 9 – Air transfer grills that are installed above all the interior doors allowing for air to circulate through the cabin

Image 10 – Propane gas refrigerator installed in kitchen

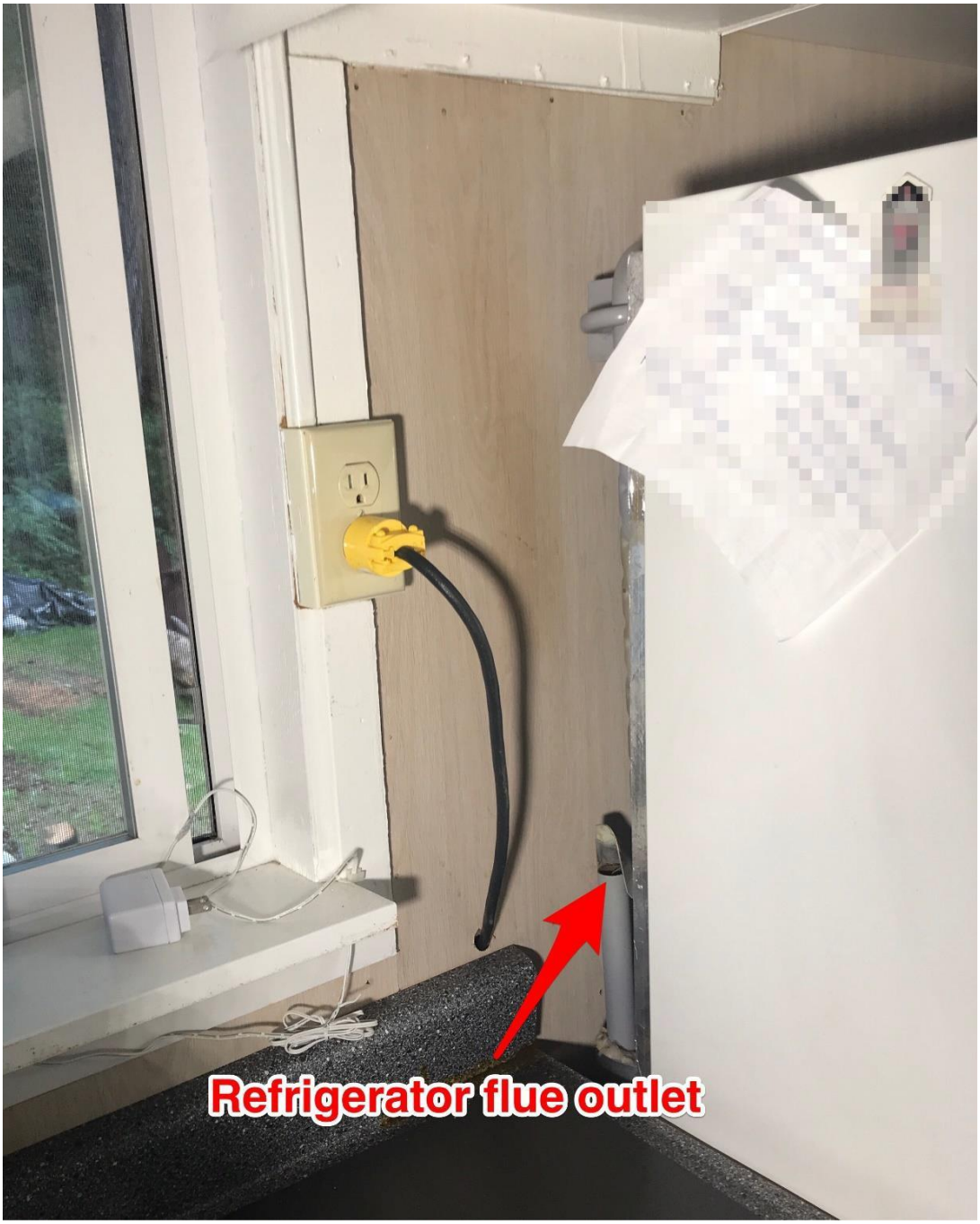


Image 11 –Location of refrigerator flue by kitchen window

Image 12 – Carbon monoxide reading of refrigerator flue gas

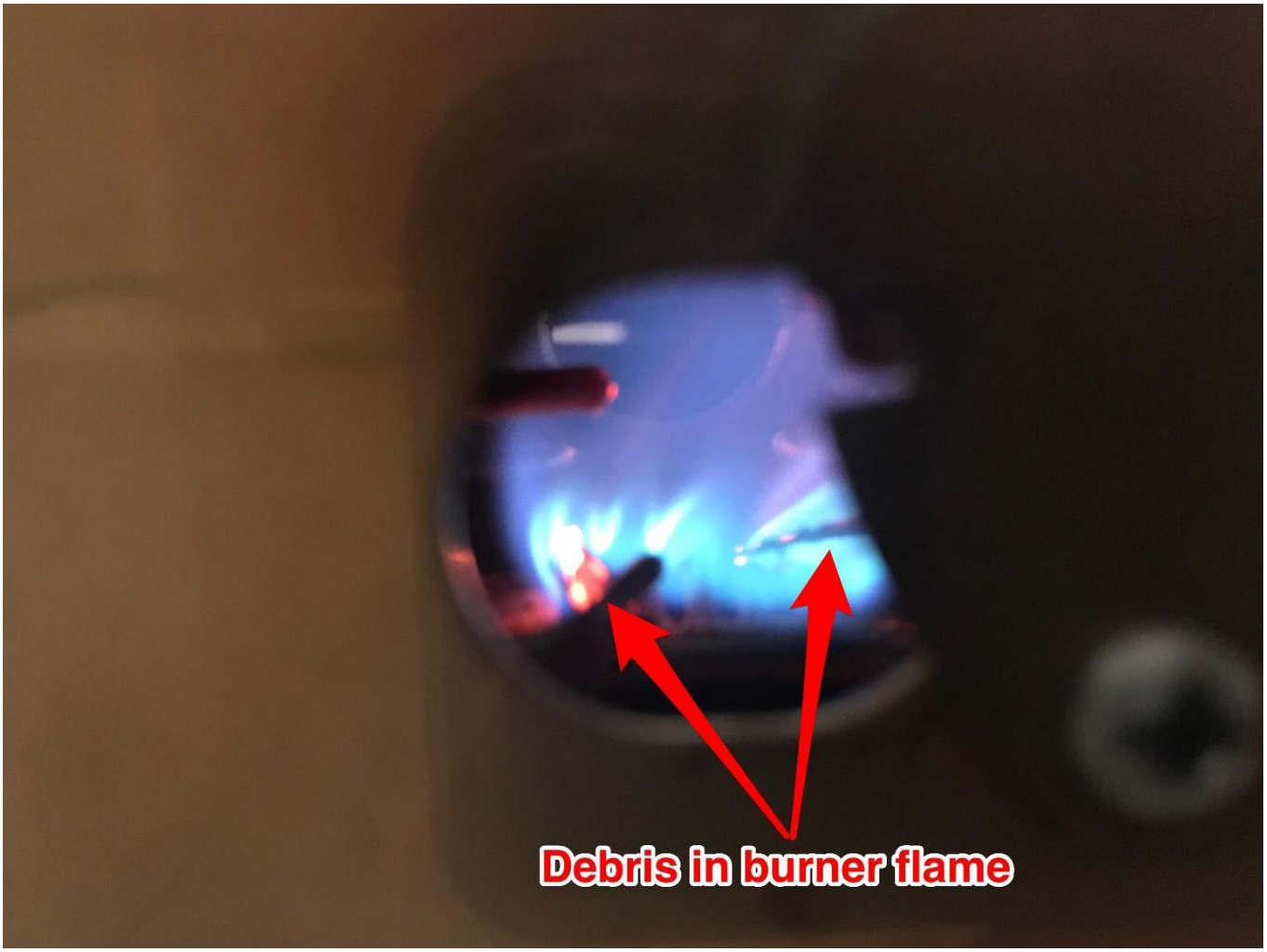


Image 13 – Refrigerator gas burner flame prior to disassembly

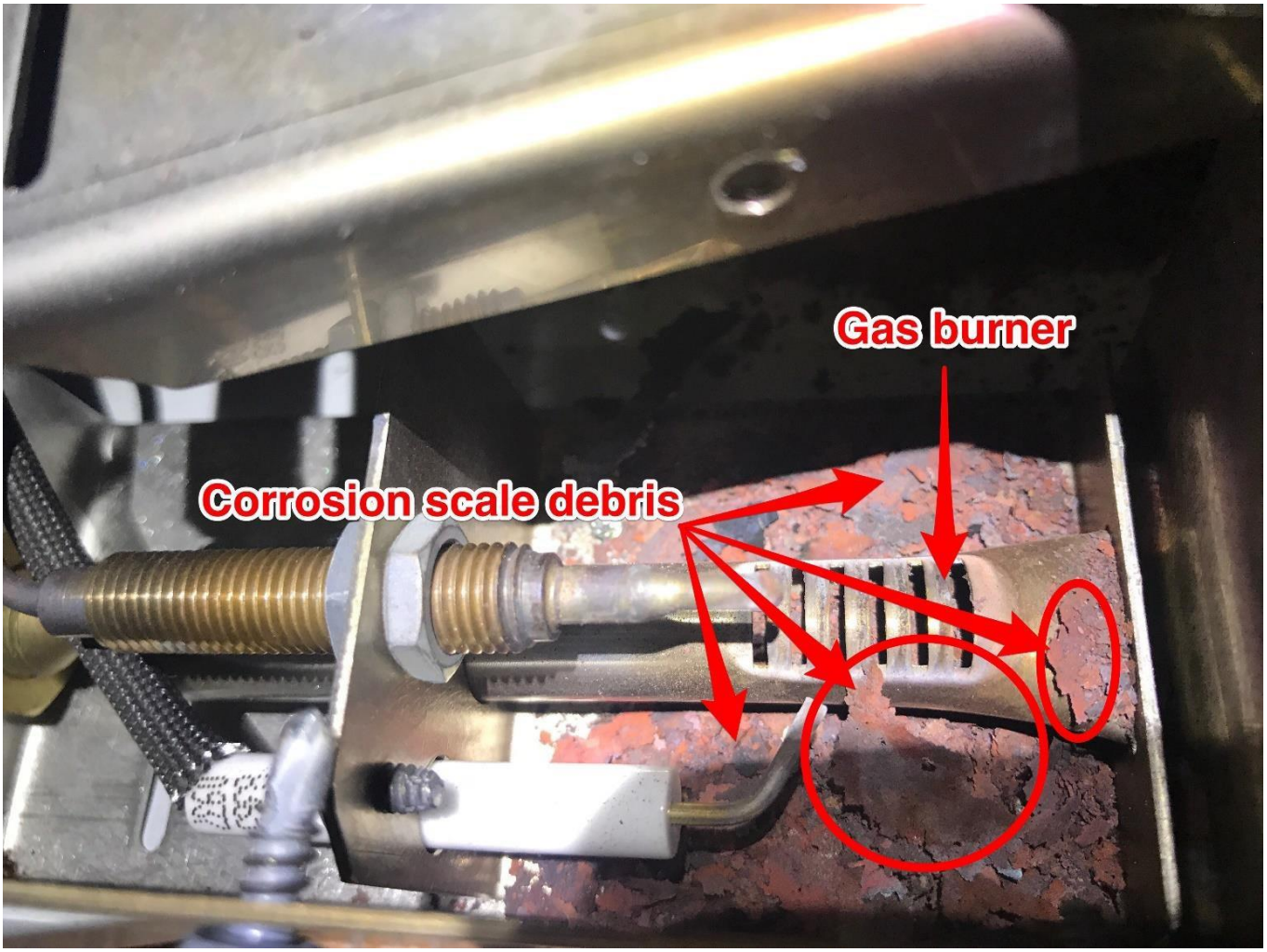


Image 14 – Refrigerator gas burner after disassembly. Circled large flat pieces of corrosion scale debris observed lying on top of the burner while operating prior to disassembly

Image 15 – Corrosion scale debris removed from burner box and flue

Image 16 – Refrigerator gas burner before and after debris removed

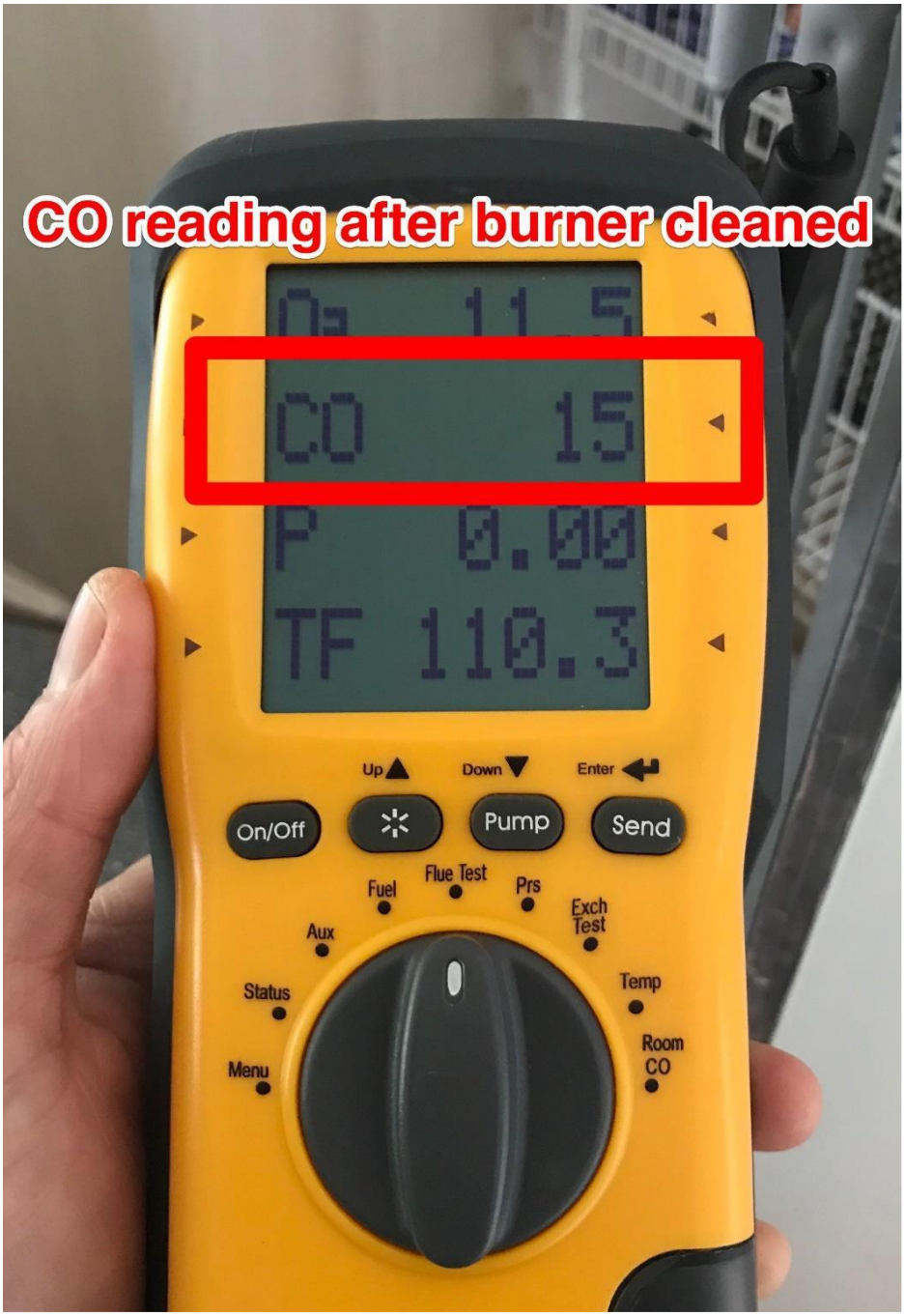


Image 17 – Carbon monoxide (CO) reading of refrigerator flue gas after debris removed from burner box and flue

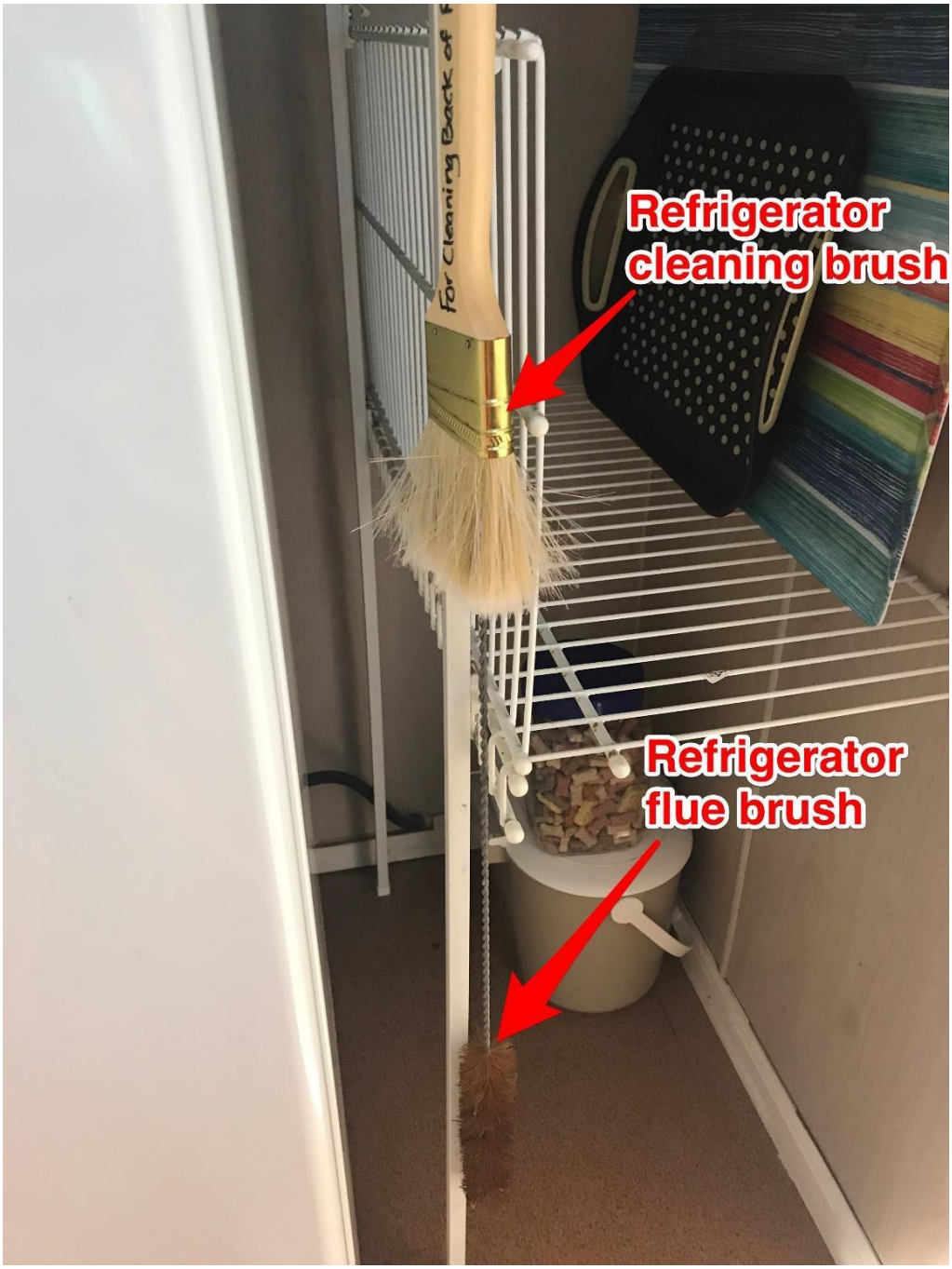
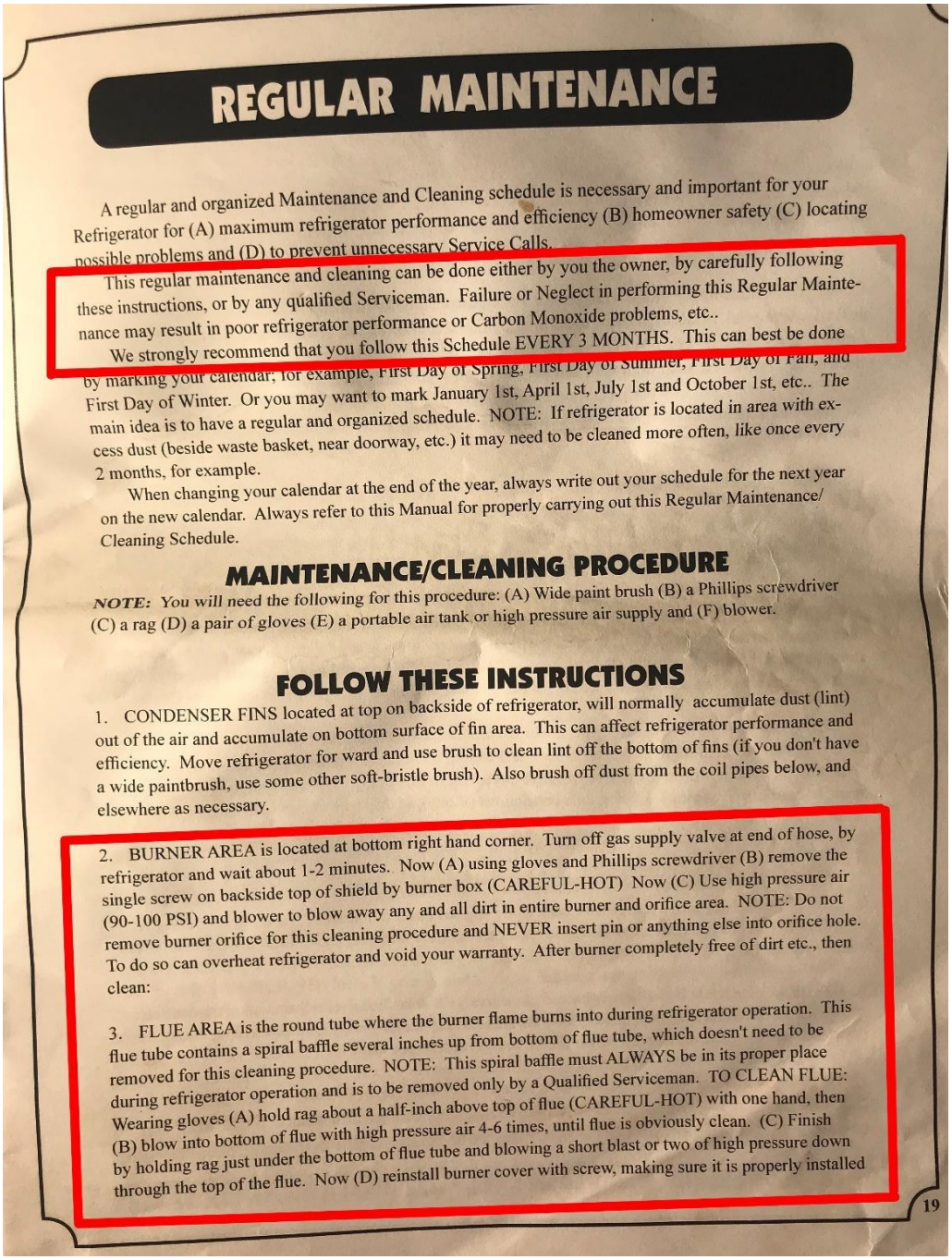


Image 18 – Brushes used for refrigerator maintenance cleaning hanging beside refrigerator in kitchen



REGULAR MAINTENANCE

A regular and organized Maintenance and Cleaning schedule is necessary and important for your Refrigerator for (A) maximum refrigerator performance and efficiency (B) homeowner safety (C) locating possible problems and (D) to prevent unnecessary Service Calls.

This regular maintenance and cleaning can be done either by you the owner, by carefully following these instructions, or by any qualified Serviceman. Failure or Neglect in performing this Regular Maintenance may result in poor refrigerator performance or Carbon Monoxide problems, etc..

We strongly recommend that you follow this Schedule EVERY 3 MONTHS. This can best be done by marking your calendar, for example, First Day of Spring, First Day of Summer, First Day of Fall, and First Day of Winter. Or you may want to mark January 1st, April 1st, July 1st and October 1st, etc.. The main idea is to have a regular and organized schedule. NOTE: If refrigerator is located in area with excess dust (beside waste basket, near doorway, etc.) it may need to be cleaned more often, like once every 2 months, for example.

When changing your calendar at the end of the year, always write out your schedule for the next year on the new calendar. Always refer to this Manual for properly carrying out this Regular Maintenance/ Cleaning Schedule.

MAINTENANCE/CLEANING PROCEDURE

NOTE: *You will need the following for this procedure:* (A) Wide paint brush (B) a Phillips screwdriver (C) a rag (D) a pair of gloves (E) a portable air tank or high pressure air supply and (F) blower.

FOLLOW THESE INSTRUCTIONS

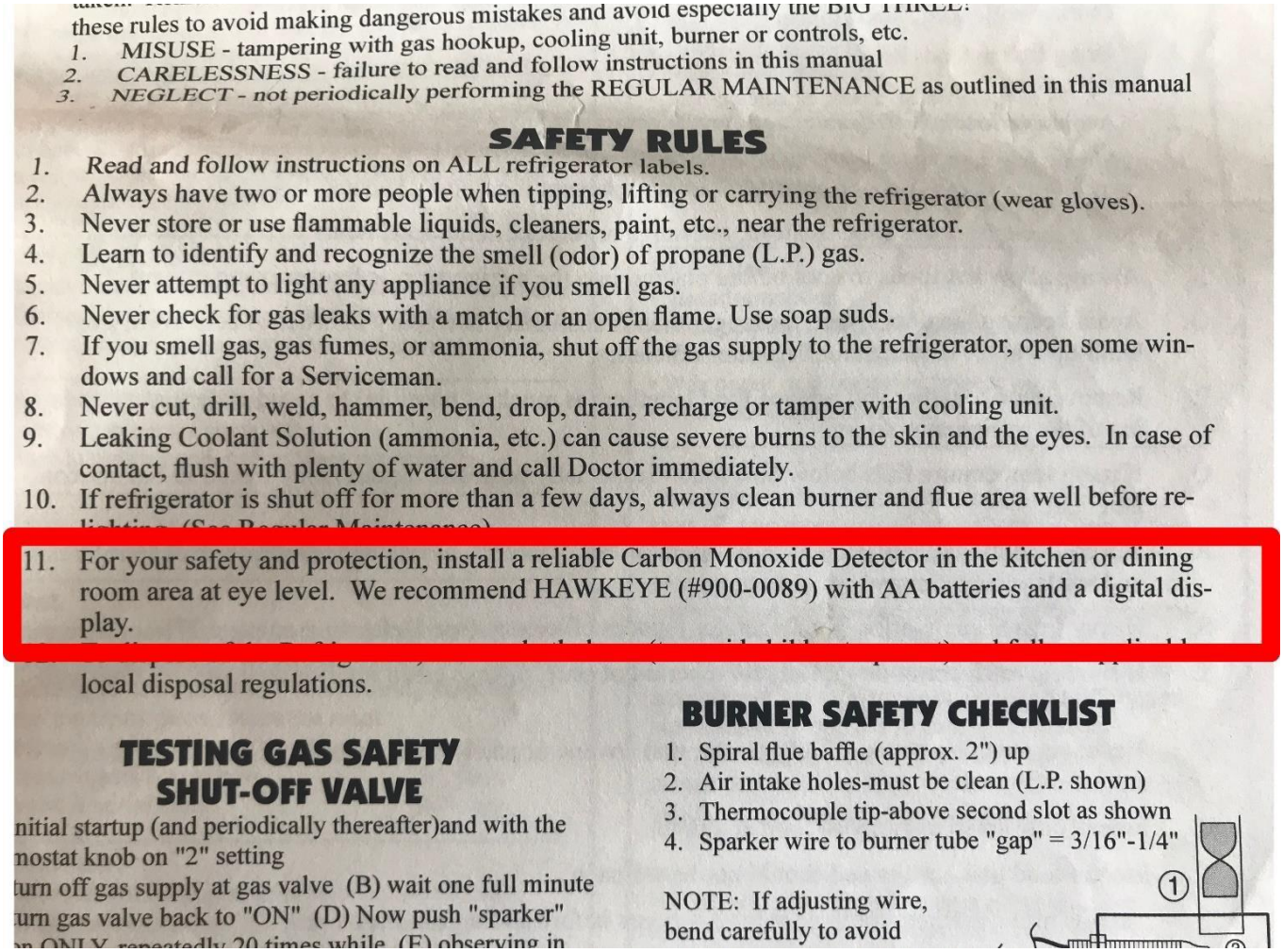
1. CONDENSER FINS located at top on backside of refrigerator, will normally accumulate dust (lint) out of the air and accumulate on bottom surface of fin area. This can affect refrigerator performance and efficiency. Move refrigerator for ward and use brush to clean lint off the bottom of fins (if you don't have a wide paintbrush, use some other soft-bristle brush). Also brush off dust from the coil pipes below, and elsewhere as necessary.

2. BURNER AREA is located at bottom right hand corner. Turn off gas supply valve at end of hose, by refrigerator and wait about 1-2 minutes. Now (A) using gloves and Phillips screwdriver (B) remove the single screw on backside top of shield by burner box (CAREFUL-HOT) Now (C) Use high pressure air (90-100 PSI) and blower to blow away any and all dirt in entire burner and orifice area. NOTE: Do not remove burner orifice for this cleaning procedure and NEVER insert pin or anything else into orifice hole. To do so can overheat refrigerator and void your warranty. After burner completely free of dirt etc., then clean:

3. FLUE AREA is the round tube where the burner flame burns into during refrigerator operation. This flue tube contains a spiral baffle several inches up from bottom of flue tube, which doesn't need to be removed for this cleaning procedure. NOTE: This spiral baffle must ALWAYS be in its proper place during refrigerator operation and is to be removed only by a Qualified Serviceman. TO CLEAN FLUE: Wearing gloves (A) hold rag about a half-inch above top of flue (CAREFUL-HOT) with one hand, then (B) blow into bottom of flue with high pressure air 4-6 times, until flue is obviously clean. (C) Finish by holding rag just under the bottom of flue tube and blowing a short blast or two of high pressure down through the top of the flue. Now (D) reinstall burner cover with screw, making sure it is properly installed

19

Image 19 – Recommended maintenance and cleaning procedures from the refrigerator manufacturers' owner's manual



these rules to avoid making dangerous mistakes and avoid especially the BIG THREE:

1. *MISUSE* - tampering with gas hookup, cooling unit, burner or controls, etc.
2. *CARELESSNESS* - failure to read and follow instructions in this manual
3. *NEGLECT* - not periodically performing the REGULAR MAINTENANCE as outlined in this manual

SAFETY RULES

1. Read and follow instructions on ALL refrigerator labels.
2. Always have two or more people when tipping, lifting or carrying the refrigerator (wear gloves).
3. Never store or use flammable liquids, cleaners, paint, etc., near the refrigerator.
4. Learn to identify and recognize the smell (odor) of propane (L.P.) gas.
5. Never attempt to light any appliance if you smell gas.
6. Never check for gas leaks with a match or an open flame. Use soap suds.
7. If you smell gas, gas fumes, or ammonia, shut off the gas supply to the refrigerator, open some windows and call for a Serviceman.
8. Never cut, drill, weld, hammer, bend, drop, drain, recharge or tamper with cooling unit.
9. Leaking Coolant Solution (ammonia, etc.) can cause severe burns to the skin and the eyes. In case of contact, flush with plenty of water and call Doctor immediately.
10. If refrigerator is shut off for more than a few days, always clean burner and flue area well before re-

11. For your safety and protection, install a reliable Carbon Monoxide Detector in the kitchen or dining room area at eye level. We recommend HAWKEYE (#900-0089) with AA batteries and a digital display.

local disposal regulations.

TESTING GAS SAFETY SHUT-OFF VALVE

nitial startup (and periodically thereafter)and with the
nostat knob on "2" setting
urn off gas supply at gas valve (B) wait one full minute
urn gas valve back to "ON" (D) Now push "sparker"

BURNER SAFETY CHECKLIST

1. Spiral flue baffle (approx. 2") up
2. Air intake holes-must be clean (L.P. shown)
3. Thermocouple tip-above second slot as shown
4. Sparker wire to burner tube "gap" = 3/16"-1/4"

NOTE: If adjusting wire, bend carefully to avoid

Image 20 – Recommendation for the installation of a carbon monoxide detector from the refrigerator manufacturers' owner's manual

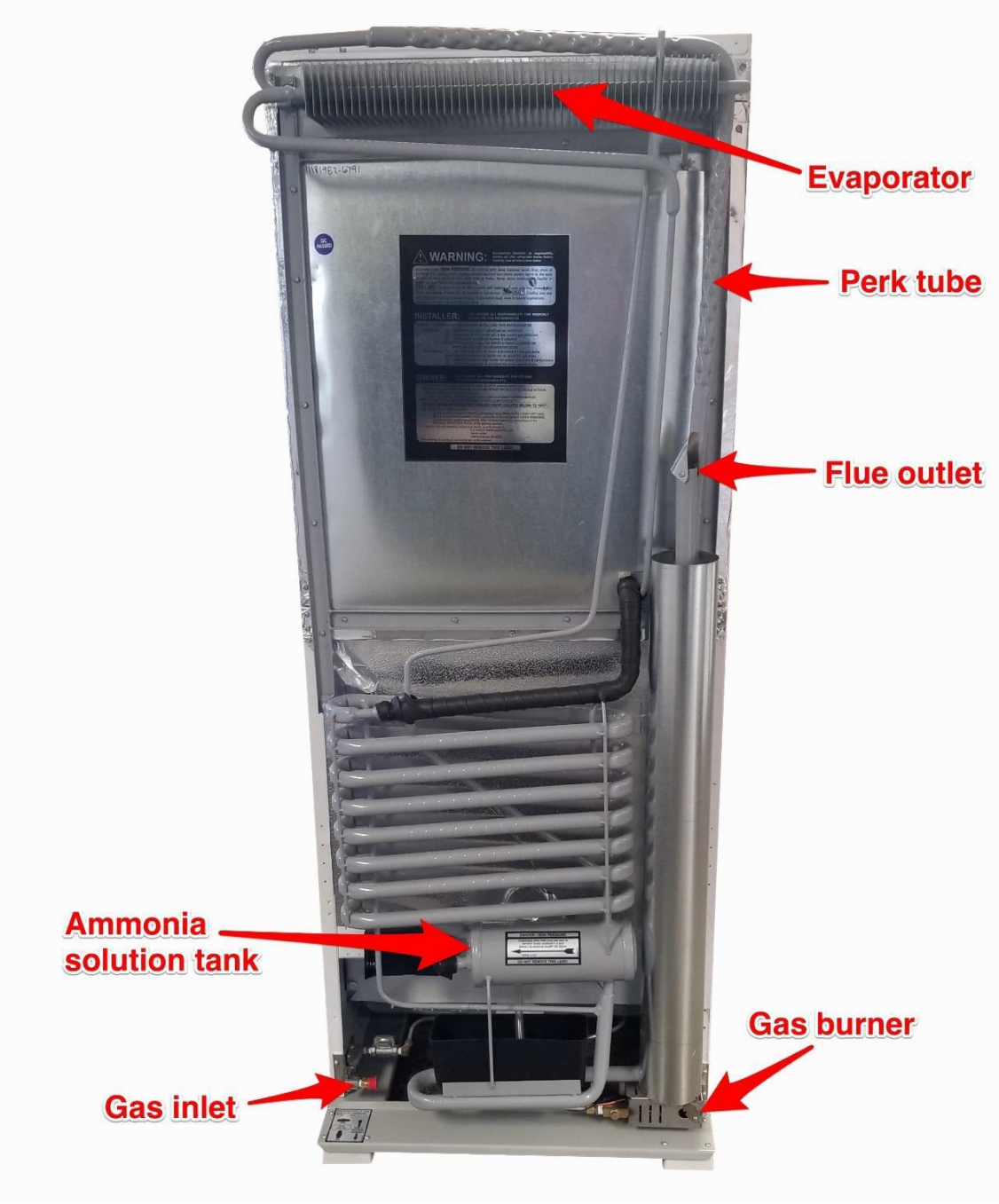


Image 22 – Example of same model of refrigerator showing location of gas burner, flue and refrigeration components

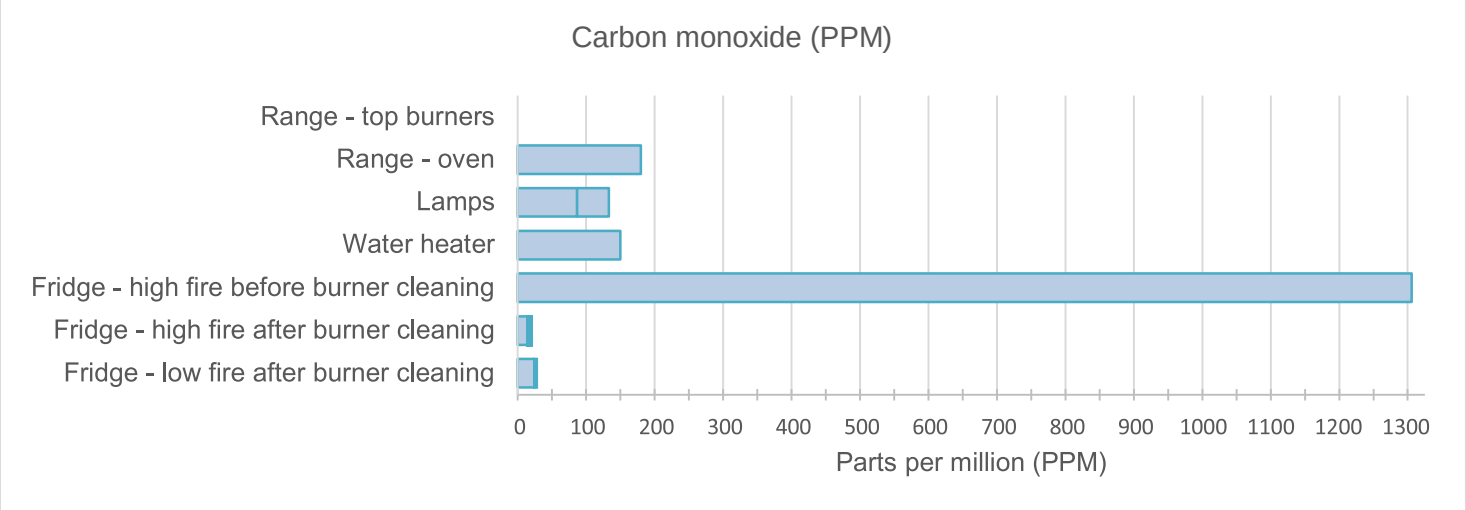


Chart 1 – Levels of carbon monoxide measured in the flue products of all fixed propane fueled appliances in the cabin. Lighter blue area show fluctuation of the measurements while adjusting the input of the lamps.

Properties of Carbon Monoxide

Colourless	Cannot be seen.
Tasteless	Cannot be detected through the sense of taste.
Odourless	Cannot be detected by sense of smell, However, CO can also be accompanied by aldehydes. Aldehydes' odour can somewhat resemble vinegar, which can be detected by the sense of smell, and may also result in a metallic taste in the mouth.
Non-irritating	Carbon Monoxide will not cause irritation. However, aldehydes usually present with higher levels of CO will irritate the eyes, nose, and mucous membranes.
Specific gravity	Slightly lighter than air (Sg 0.975). It may, but not always collect near the ceiling, and mixes freely with air.
Flammable (explosive) limits	CO is flammable between concentrations of 12.5% to 74% when mixed with air. Its ignition temperature is 609ºC (1128ºF).
Toxic	Can cause death if enough is absorbed into the bloodstream.

Chart 2 - Properties of Carbon Monoxide – From Technical Safety BC's "Carbon Monoxide Handbook"

Concentrations (*ppm)	Observations and Health Effects
1 to 3	Normal.
25	Occupational exposure limit averaged over 8 hour period.
30 to 60	Exercise tolerance reduced.
100	15-minute short-term exposure limit (STEL).
60 to 150	Frontal headache. Shortness of breath on exertion.
150 to 300	Throbbing headache, dizziness, nausea, and impaired manual dexterity.
300 to 650	Severe headache; nausea and vomiting; confusion and collapse.
700 to 1000	Coma and convulsions.
1200	Immediately dangerous to life and health (IDLH).
1000 to 2000	Heart and lungs depressed. Fatal if not treated.
Above 2000	Rapidly fatal.

*1 ppm = 1 part of gas per million parts air by volume

Chart 3 - Carbon Monoxide concentrations and health effects – From Technical Safety BC's "Carbon Monoxide Handbook"

Acute Exposure Guideline Levels for Carbon Monoxide

	Duration				
Classification (description)	10 min	30 min	1 hour	4 hours	8 hours
Disabling Irreversible or other serious, long-lasting adverse health effects, or an impaired ability to escape.	420 ppm*	150 ppm	83 ppm	33 ppm	27 ppm
Lethal Life-threatening health effects or death)	1700 ppm	600 ppm	330 ppm	150 ppm	130 ppm

*1 ppm = 1 part of gas per million parts air by volume

Table 1 - Acute Exposure Guideline Levels for Carbon Monoxide. Adapted from National Research Council (US) Committee on Acute Exposure Guideline Levels (AEGL) [1]

1. National Research Council (US) Committee on Acute Exposure Guideline Levels. Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8. Washington (DC): National Academies Press (US); 2010. 2, Carbon Monoxide Acute Exposure Guideline Levels. Available from: https://www.ncbi.nlm.nih.gov/books/NBK220007/ (Accessed August 11, 2020.)