Ozone Safe Work Practices

WorkSafe BC

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WorkSafeBC (the Workers' Compensation Board) is an independent provincial statutory agency governed by a Board of Directors. It is funded by insurance premiums paid by registered employers and by investment returns. In administering the *Workers Compensation Act*, WorkSafeBC remains separate and distinct from government; however, it is accountable to the public through government in its role of protecting and maintaining the overall well-being of the workers' compensation system.

WorkSafeBC was born out of a compromise between B.C.'s workers and employers in 1917 where workers gave up the right to sue their employers or fellow workers for injuries on the job in return for a no-fault insurance program fully paid for by employers. WorkSafeBC is committed to a safe and healthy workplace, and to providing return-to-work rehabilitation and legislated compensation benefits to workers injured as a result of their employment.

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The WorkSafeBC Prevention Information Line can answer your questions about workplace health and safety, worker and employer responsibilities, and reporting a workplace accident or incident. The Prevention Information Line accepts anonymous calls.

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Some publications are also available for purchase in print:

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Introduction

Ozone has been used as a chemical oxidant and disinfectant in Europe for many years. Even now in British Columbia, the use of similar technology is relatively recent. The production or use of ozone presents a number of health hazards that range from relatively minor, short-term effects to chronic health problems, or even death. In order to prevent injury due to ozone exposure, WorkSafeBC has developed requirements detailed in the Occupational Health and Safety Regulation.

This manual is mainly for two groups: companies or employers who generate and use ozone to oxidize contaminants or to disinfect water used by the public; and workers who work with or around ozone systems, including those who repair or maintain ozone systems. Companies and employers will find information on what they need to do to comply with the Occupational Health and Safety Regulation and to ensure a safe environment for workers. Workers will find information that will help them work safely around ozone systems.

Companies or employers whose business includes the use of ozone for purposes other than water treatment (for example, in medical treatment) will also find this manual useful.

The *Ozone system design* and *Ozone room design* sections of this manual outline criteria for the installation and operation of ozonation systems. This information should be useful to a variety of groups: companies and employers; designers, suppliers, and installers of ozone generating and handling equipment; and architects and engineers involved in the design of ozone facilities.

Health authorities in British Columbia have specific requirements related to the use of ozone to disinfect water used by the public. These requirements are highlighted in blue text throughout the manual.

Ozone systems installed in locations not under the inspectional jurisdiction of B.C. Health Authorities or WorkSafeBC should refer to the appropriate regulatory authority having jurisdiction for specific requirements.

This manual does not replace the Occupational Health and Safety Regulation. It complements the Regulation and is a tool to help industry work safely. The word *must* used in this manual means that a particular safety step is specified in the Occupational Health and Safety Regulation. The word *should* indicates that a particular action, although not specified in the Regulation, will improve safety in the workplace.

What is ozone?

Ozone (O_3) is a form of oxygen (O_2) generated using one of two methods: exposing normal oxygen to a high voltage electrical discharge; or exposing oxygen to ultraviolet (UV) radiation. Ozone is manufactured on-site for immediate use because it is unstable and decomposes quickly.

Pure ozone has a bluish colour, but ozone/air mixtures are invisible even at the normal concentration produced in any ozone generator. Ozone has a distinctive, pungent odour.

Although pure ozone gas is slightly heavier than air, at "ppm" concentrations it mixes completely with air and does not necessarily settle to the floor. Although the gas is only slightly soluble in water, concentrations up to 10 mg/L are possible.

Stability

Ozone is an unstable molecule that quickly changes back to normal oxygen. The time for half of the ozone in air to decompose (its *half-life*) is four to 12 hours, depending on the temperature and humidity of the surrounding air. Ozone's half-life in water is between three and 20 minutes, depending on the temperature and quality of the water. In high-quality water, such as water that has undergone double ozonation and filtration, ozone's half-life may be as long as 2.5 hours. Ozone decomposes faster in alkaline water.

Reactivity

Ozone is a very reactive gas. It will quickly corrode most metals, iron, and mild steel, and will damage most plastics. Rubber exposed to ozone will quickly harden and crack. Gaskets, sealing compounds, and piping must be chosen with great care before being used with ozone (see *Suitable materials*, page 33).

Uses

In British Columbia, ozone is used primarily for treating swimming pool water, preparing bottled water, and for handling perishable foods. Ozone is one of the most powerful disinfectants—it effectively and quickly kills more organisms than chlorine.

NOTE:

If ozone is marketed as a disinfectant, the regulation under the *Pest Control Products Act* (Pest Management Regulatory Agency—Health Canada) will apply.

Swimming pools

When used in swimming pools in combination with chlorine, ozone may provide an odourless environment and clearer water than a system that uses chlorine only. Ozone readily combines with some chemicals in solution and organisms in water to form oxidation products. While the chemicals are dissolved and the organisms alone are too small for filtration, these oxidation products are solids and large enough to be filtered out of the water. Ozone systems require more backwashing because the oxidation products tend to clog up the filters, but ozone systems may leave fewer contaminants in the water.

Ozone dissolved in water decomposes rapidly, so it leaves no residual disinfectant in the water. Because of this quality, it is still necessary to use a disinfectant, such as chlorine, to provide the required residual disinfection in the water. However, less chlorine is required when it is added to ozonated water than is the case for non-ozonated water.

Some swimming pools use a slipstream system (Figure 1) in which a portion of the main water stream (usually 10–25 percent) is directed into an ozonation loop. Continuous ozonation of a portion of the water flow reduces the amount of chlorine required for pool disinfection. Slipstream ozonation can provide clearer water and prevent the chlorine smell and eye irritation associated with normal chlorinated water.

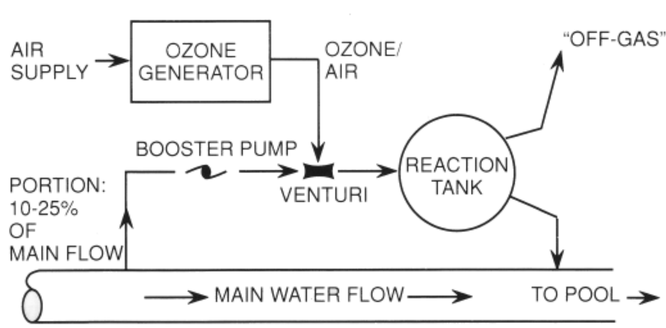

FIGURE 1—Slipstream ozonation

Food

Ozone can be used to disinfect bottled drinking water. There is no need to remove dissolved ozone, because it quickly decomposes to oxygen. Process and wash water disinfected by ozone does not need ozone removal either, because the ozone decomposes during the aeration part of the process, and by reaction with dissolved contaminants.

Large food outlets, such as supermarkets, may use a small ozone-generating system to ozonate water, which is then frozen. This ozonated ice is used to provide a more sterile environment in which to display perishable foods, such as fish. Ozonated water may also be sprayed on produce to prolong its shelf life.

Other uses

Ozone is also used for:
- Treatment of potable water supplies
- Waste water treatment
- Cooling tower water treatment
- Treating storage water in the fishing industry
- Purifying feed water in fish farming
- Disinfection in abattoirs, aquariums, and hospitals
- Pulp bleaching
- Medical treatment
- Perfume manufacturing
- Odour control and smoke elimination
- Air purifiers

Health hazards of ozone

Depending on the concentration, exposure to ozone can result in acute or chronic health problems, or, in high enough concentrations, even death.

Acute (immediate) effects

Ozone irritates the eyes, upper respiratory tract, and the lungs. Many people exposed to airborne concentrations of ozone above 0.1 ppm may develop a headache. The headache will often disappear after a few minutes in fresh air. The onset of pulmonary edema (fluid buildup in the lungs) may be delayed for a few hours after exposure to concentrations over 1.5 ppm.

Chronic (long-term) effects

Long-term exposure to ozone at concentrations above 0.1 ppm, or a single high exposure, may lead to some reduction in lung function. There is also some evidence that the oxidizing effect of ozone could lead to premature aging of the body as a whole. Medical studies show no evidence of ozone causing cancer or lung allergies, or harming a fetus.

Toxic effects of ozone		
Ozone concentration (parts per million)	**Duration of exposure**	**Effect**
0.01 ppm	—	Odour threshold
0.1 ppm	—	Minor eye, nose, and throat irritation
0.10–0.25 ppm	2–5 hours	Headache, dry cough and some reduction in lung function
0.3 ppm	2 hours	Reduction in lung function during moderate work for all persons
More than 0.6 ppm	2 hours	Chest pain
1 ppm	1–2 hours	Lung irritation (coughing); severe fatigue
More than 1.5 ppm	2 hours	Reduced ability to think clearly; continuing cough and extreme fatigue may last for two weeks; severe lung irritation and pulmonary edema (fluid buildup)
9 ppm	Intermittent	Severe pneumonia (arc welders)
11 ppm	15 minutes	Rapid unconsciousness
50 ppm	30 minutes	Expected to be fatal

Notes

1. All the details in this table are observations of actual exposures or experiments (as reported in the scientific literature), except for the last entry (50 ppm), which is an expected result based on observations of laboratory animals.
2. Information from *National Ambient Air Quality Objectives for Ground-Level Ozone*, section 8 of the Science Assessment Document published by Health Canada, 1999.

Exposure limits of ozone	
Exposure level (parts per million)	**Exposure limit**
0.05 ppm	Maximum allowable concentration averaged over an eight-hour period for heavy work
0.08 ppm	Maximum allowable concentration averaged over an eight-hour period for moderate work
0.1 ppm	Maximum allowable concentration averaged over an eight-hour period for light work
0.2 ppm	Maximum (short-term) exposure limit for light, moderate or heavy work, for less than or equal to 2 hours
10 ppm	Immediately Dangerous to Life and Health (IDLH)

Notes

1. The Immediately Dangerous to Life and Health (IDLH) exposure level is the point at which a person without appropriate respiratory protection could be fatally injured or could suffer irreversible or incapacitating health effects.
2. Ozone can be detected by its odour at concentrations of about 0.01 ppm. The nose, however, rapidly loses its ability to smell ozone. Do not rely on odour as a warning of high ozone concentrations.

Work load examples	
Light work	Sitting or standing to control machines, performing light hand or arm work; writing, knitting, typing
Moderate work	Walking around with moderate lifting or pushing; hammering nails, filing metal, planing wood, raking a garden, cleaning a floor
Heavy work	Pick and shovel work; laying railroad tracks

Note

Work load examples were obtained from the ACGIH TLV rationale document for ozone exposure, dated 2001.

Potential hazards

Ozone presents a number of hazards, including the following:

- When used to deodorize premises, precautions must be taken to prevent hazardous levels of ozone being produced, particularly near the generator, if there is a possibility of any persons being exposed.
- Through laboratory testing, WorkSafeBC has determined that ozone-generating air purifiers commonly used in many workplace settings may pose a health risk to workers because the airborne concentration of ozone may exceed the acceptable level for workplace exposure.
- Do not enter a room until the air purifier has been shut off, and the ozone has been vented out. Use remote testing equipment to verify that ozone levels have dropped to acceptable levels before returning to the work area.
- Some photocopiers and laser printers produce ozone as a result of the high voltage involved in the imaging process. The ozone levels are usually below 0.05 ppm, but may occasionally be as high as 0.5 ppm if the photocopier is operated in a small, unventilated room.

  Many photocopiers and laser printers are fitted with carbon filters to break down the ozone. These filters quickly become clogged with dust. Routine maintenance or filter replacement is necessary to help ensure that hazardous levels of ozone do not develop in the work area.
- Arc welding, particularly inert gas shielded welding, can produce ozone concentrations up to 10 ppm in the breathing zone of the welder.

Employer responsibilities

According to the Occupational Health and Safety Regulation, employers must develop and implement an effective health and safety program, which includes training workers and supervisors in relevant sections of the program.

Health and safety programs

A health and safety program helps ensure a safe, productive workplace by describing specific tasks and responsibilities for many different aspects of an employer's operation. An effective health and safety program for any workplace in which ozone is used must include:

- A written occupational health and safety policy that:
  - States the employer's commitment to health and safety
  - States the program's objectives
  - Defines the responsibilities and roles of the employer, supervisors, and workers
- Written safe work procedures and emergency response procedures
- Training for supervisors and workers
- Regular worksite inspections
- Regular health and safety meetings
- Accident investigation
- Records and statistics
- A joint health and safety committee or representative, if required

It is important to remember that every worksite is different. Although these general elements may be common to health and safety programs across the province, employers cannot expect to copy a program from another worksite. Instead, they must develop and implement a health and safety program specific to their own operation.

Written safe work procedures

A health and safety program is an overall program that includes a number of individual written safe work procedures and specific, smaller programs. Written safe work procedures and programs tell workers how to safely perform their duties. Management must ensure that all workers understand these procedures well enough to perform their duties competently. Management and workers must jointly review all written safe work and emergency procedures at least once each year to ensure that they are still valid.

WHMIS program

A Workplace Hazardous Materials Information System (WHMIS) program helps ensure that workers who work with or near an ozone installation are instructed in its safe use. This includes the use of labels or other means of identifying ozone systems. For more information, see Part 5 of the Occupational Health and Safety Regulation.

Because ozone is generated on-site in concentrations of one percent or more, the employer is considered a supplier and must produce a Material Safety Data Sheet (MSDS) that meets the requirements of the Controlled Products Regulations (Health Canada). This MSDS can be a basis for worker training and education, and will provide much of the information used in developing written safe work procedures.

In the Regulation

For more information about the elements of exposure control plans, see Section 5.54 of the Regulation.

Exposure control plan

An exposure control plan is required in any installation using ozone, as even a small leak will result in exposure of any persons in the ozone room well in excess of the action level (one half of the exposure limit). Written exposure control plans explain the work procedures and other controls that will be used to reduce workers' risk of exposure to ozone. Strict adherence to ozone exposure limits and the use of appropriate respiratory, eye, and skin protection are essential elements of such a plan. Employers must also ensure that qualified persons perform a formal risk assessment to determine which workers may be affected by exposure to ozone and the extent of any exposure.

In the Regulation

For more information on personal protective equipment and clothing, see Part 8 of the Regulation.

Respirator program (personal protective equipment)

Providing protective equipment and ensuring that workers use it are essential to any effective occupational health and safety program. Employers must develop and implement a written respiratory protection program that is acceptable to WorkSafeBC and that meets the requirements of the Regulation.

Employers must ensure that workers are trained in proper use and care of respirators. Employers must also provide fit-testing (using a WorkSafeBC-accepted protocol, such as described in the current version of *CSA Standard Z94.4*) when a worker is first fitted with a respirator, and once a year thereafter. (One type of test, the qualitative fit-test, determines if the worker can detect any amount of a test compound leaking through the respirator.) Employers must keep records of the fit-test program. Fit-test kits are available from respirator suppliers.

For more information on effective respiratory protection programs, refer to:

- WorkSafeBC safe practices guides, available through WorkSafeBC.com
- *CAN/CSA Standard Z94.4*, available from the Canadian Standards Association, 13799 Commerce Parkway, Richmond, BC V6V 2N9

Respiratory, eye, and skin protection are covered in more detail under *Personal protective equipment*, on page 18.

Written emergency procedures

Employers must conduct a risk assessment and prepare emergency procedures, including escape and evacuation, drills, and notification of emergency services. For more information on written emergency procedures, see *Preparing for emergencies*, page 14.

Written preventative maintenance procedures

Employers, in consultation with equipment manufacturers or suppliers, must ensure that all equipment is inspected regularly and replaced when necessary. Employers must ensure that written preventative maintenance procedures *and* written emergency procedures are readily available to and understood by all people required to work on the ozone system.

Employers must also include plans for testing and replacing, where required, all ancillary (secondary) safety equipment, such as monitors and alarm systems, detection equipment, radios, eye washes, respiratory and skin protection equipment, and first aid kits. To ensure that nothing is missed, employers may find it useful to develop checklists for inspecting and testing equipment. All use and maintenance of safety equipment must be recorded in a suitable log book.

Safe handling of ozone: Where to look in the Regulation

Employers can use several elements of their health and safety program to help ensure the safe handling of ozone. For the purposes of this manual, these key elements (and their location in the Regulation) include:

- Responsibilities (sections 115–120 of the *Workers Compensation Act*)
- Emergency preparedness (Parts 4, 5, and 6)
- Equipment preventative maintenance, critical parts inspections (Parts 4 and 6)
- WHMIS, exposure control programs (Part 5)
- Toxic process gases (Part 6)
- Respiratory protection programs (Part 8)
- First aid requirements (Part 3)

Checking on a worker working alone

Employers must establish a system with written procedures to ensure the continued well-being of workers working alone around an ozone system, or working in remote locations. Depending on the situation, a check system may consist of:

- A visual check made by another person—for example, a lifeguard at a swimming pool may be required to check on a maintenance person working alone
- A two-way radio or cellular phone
- A telephone call-in procedure

The check system must include:

- A set interval between checks
- A record of each check
- A check at the end of the work shift
- Procedures to follow if the worker cannot be contacted or is injured

Training, instruction, and supervision

Although workers may have special certification or other external training, employers are responsible for providing workers with thorough, site-specific training and continued instruction in the programs and procedures outlined above. Written safe work procedures form the basis of an employer's ongoing training program.

Employers must document training and instruction, and workers must be able to demonstrate competency in doing their work according to the work procedures.

All workers must clearly understand not only their responsibilities, but also the need to report all hazards, accidents, incidents, or injuries. Training must include worker responsibilities and responses in case of an emergency.

Designers, suppliers, and installers must provide initial training to the operator(s) on how to operate, maintain, service, calibrate, and repair equipment.

Designers, suppliers, or installers must also provide an operation and maintenance manual with technical information and manufacturer instructions, which must be available on site (see *System operation and maintenance*, page 42). The manual should prominently display the identification system (for example, the colour code) for piping at the particular worksite. In addition to this material, employers must include in the manual copies of all written safe work procedures and details of general programs, such as lockout requirements.

The operation and maintenance manual should include:

- System and component description and limitations
- System start-up and shutdown procedures
- Equipment servicing procedures
- Troubleshooting
- Metering and monitoring
- Safety equipment and procedures
- Written safe work procedures
- Emergency procedures

Preparing for emergencies

An ozone emergency will likely happen due to a leak or equipment malfunction. Preparing for emergencies includes planning for ozone leaks that may require procedures such as evacuation and notification of local emergency response units. The preparation required for these types of emergencies is detailed below under *Written emergency procedures*.

Preparing for emergencies also includes making appropriate emergency equipment available to workers and ensuring that they know how to use it. This equipment—eye wash and shower facilities and first aid kits—is discussed under *Emergency equipment*.

Written emergency procedures

Formal written emergency procedures provide workers with detailed directions in case of an emergency. A detailed emergency plan is not enough by itself, however. Employers must also conduct emergency drills to determine whether the procedures work in practice, and to thoroughly familiarize workers with their roles in an actual emergency. Employers must keep records of these drills to monitor efficiency.

The written emergency procedures must include specific details concerning the following:

- Notifying workers of the emergency location
- Personal protective equipment for use in an emergency, and its location
- Emergency lighting
- Evacuation procedure and a check system to ensure all personnel are evacuated
- Search and rescue procedures
- Notifying police, fire department, hospital, and other emergency response units

As soon as the written emergency procedures are created, the employer must:

- Provide each worker with a copy of the plan, and provide enough training to ensure that workers clearly understand the procedures
- Post the procedures and other relevant information (such as telephone numbers) in appropriate, conspicuous locations
- Hold regular tests of the procedures, including drills
- Notify the fire department and other emergency response units of any specialized information, such as specific health hazards, electrical hazards, emergency controls, or the use of oxygen if used as the feed gas

In addition to these general emergency procedures, employers must also have procedures specific to ozone systems, to cover concerns such as:

- Response to an alarm signal
- Response to an automatic generator shutdown
- Leak detection, control, and repair
- First aid response
- Accident investigation

Emergency equipment

Eye wash

As required by the Occupational Health and Safety Regulation, employers must conduct a risk assessment for each workplace hazard.

Use **Table 5-2: Risk assessment** (from the Regulation) to help determine risk levels relating to hazardous materials, including ozone.

Use **Table 5-3: Provision and location of emergency washing equipment** to help determine the type of eye wash equipment required, where it must be located, and whether or not a shower is required.

Employers must consider the following when conducting a risk assessment:

- The nature of the workplace chemical (corrosive or irritant). In pool facilities, many of the chemicals are corrosive—for example, chlorine gas, ozone, sodium hypochlorite, soda ash, and hydrochloric (muriatic) acid.
- The state of the substance (gas, liquid, or solid). Ozone is a gas.
- The potential for exposure to skin or eyes and the extent of any exposure.
- The number of potentially affected workers.
- The availability of first aid and professional medical help.

Employers must follow these requirements for eye wash facilities:

- Ensure that the facilities have a supply of tempered water—not running cold water. Ensure that workers cannot mistakenly turn on hot water alone.
- Determine the most appropriate location for emergency equipment. It is inappropriate, for example, to install emergency equipment inside the ozone room because a worker trying to use the emergency equipment during an ozone leak risks further exposure.

In the Regulation

Sections 5.85 to 5.96 of the Regulation describe requirements for emergency washing facilities.

- Take into account the geographical location of the facility when deciding whether or not an outdoor location will be practicable during the winter.
- Do not locate emergency equipment where the public may access and possibly damage it.

Shower

Since exposure to ozone gas has not been shown to present a hazard to the skin, a shower facility is not mandatory for the ozone part of the installation.

First aid services

Workers must have immediate access to an appropriate first aid kit, which is determined by the number of workers and the hazard classification. An ozone worksite will also have first aid attendants on site. To determine the appropriate first aid equipment and services required for a particular worksite, see Part 3 of the Occupational Health and Safety Regulation and the related guidelines accessible via WorkSafeBC.com (click on Occupational Health and Safety Regulation, and go to Part 3 and the respective Guidelines).

Investigating accidents

Investigating accidents is important for preventing future accidents, and for education of workers and employers. According to the Occupational Health and Safety Regulation, employers must immediately notify WorkSafeBC of any major release of a toxic substance. The *Workers Compensation Act* and the associated policy defines a major release as:

- A leak resulting in at least one person receiving professional medical attention, or
- A leak resulting in at least three people receiving first aid, or
- A leak that requires the assistance of an outside agency to control the situation

Any time enough ozone is released to set off the alarm, the employer must conduct a formal investigation to discover the cause(s) of the accident. This investigation must also examine measures that will prevent similar situations. Employers must forward copies of the investigation report to their occupational health and safety committee, and to WorkSafeBC.

Personal protective equipment

Personal protective equipment is vital in controlling exposure when an ozone leak has occurred or there is a possibility of such a leak. Personal protective equipment includes eye, skin, and respiratory protection. It also includes emergency equipment such as eye wash and shower facilities, and first aid kits.

To avoid exposure to ozone, workers should be familiar with and understand the requirements of their employer's written exposure control program.

Eye protection

Eye protection against ozone is not necessary under routine working conditions where airborne ozone concentrations are below 0.05 ppm. When the ozone concentration exceeds 0.1 ppm, eye irritation may occur. At 0.25 ppm, this effect will be significant. During emergencies, workers must wear full facepiece respirators to enter areas contaminated by hazardous concentrations of ozone (see *Choosing the right respirator*, page 20).

Workers required to use a respirator must be clean-shaven where the respirator seals with the face to ensure a proper fit.

Respiratory protection

This section outlines the types of respirators available to protect workers against exposure to ozone, and the limitations of each respirator. Choosing the right respirator must be based on both the needs of each individual worksite and the requirements of the employer's written safe work procedures.

Full facepiece respirators with cartridges

Workers may use full facepiece cartridge respirators for leak detection, or minor leak repair, in airborne ozone concentrations up to 2.5 ppm. Cartridge respirators intended for ozone must not be used for any other purpose. Cartridge respirators must never be stored in the ozone room.

Cartridges must be discarded after a single use in ozone-contaminated air. Organic vapour (OV) cartridges that have been used for removing organic vapours (solvents, paints, etc.) from air should not be used in ozone-contaminated air.

Full facepiece respirators with canister

Although cartridges are both sufficient and preferable, workers may use a full facepiece respirator fitted with an air-purifying canister for leak control and repair or maintenance procedures in ozone concentrations up to 2.5 ppm.

Half facepiece respirators with goggles

Workers may use half facepiece respirators with new cartridges in airborne ozone concentrations up to 0.5 ppm. Because of immediate eye irritation, workers must always use gas-rated, vapour-tight chemical goggles with half facepiece respirators. Half facepiece respirators and goggles must never be stored in the ozone room.

Half facepiece respirators with unused cartridges—no exposure of the cartridge to organic vapours—must be carried by all workers entering the ozone room, when the ozone generation system is operating. Should a leak develop while a worker is in the ozone room, this respirator will provide instantaneous protection to allow for immediate escape.

Supplied-air respirators (SARs)

Workers may use SARs—full facepiece respirators attached to an air compressor—to enter or work in airborne ozone concentrations up to 10 ppm. SARs must never be stored in the ozone room.

The compressor supplying the breathing air must be maintained in good working order, and the air intake must be properly located to provide clean, fresh air. The breathing air supply must be routinely tested (at least annually) to ensure that its quality meets current standards.

Self-contained breathing apparatus (SCBAs)

Workers must use SCBAs when the ozone concentration is unknown or is measured at 10 ppm or more. A worker wearing an SCBA must not enter a contaminated atmosphere until a second, qualified person is present, also equipped with an SCBA, and ready to perform a rescue.

SCBAs must never be stored in the ozone room. Air cylinders should be refilled every six months or after each use, whichever comes first. Cylinders must be inspected and hydrostatically tested according to Transport Canada requirements.

Check your respirator

During routine equipment inspections and immediately before use, respirators must be checked for deterioration of rubber parts, particularly hoses and valve flaps. The part must be replaced if there is any sign of hardening, cracking, or other deterioration. Maintain a stock of replacement parts.

Escape respirators

Workers may use half facepiece cartridge respirators fitted with organic vapour cartridges for escape purposes. In some circumstances (for example, in the sterile room of a bottling plant), workers may be required to carry an escape respirator at all times. Escape respirators must never be used to enter a contaminated atmosphere.

Choosing the right respirator

Situation	Ozone concentration	Respirator choice
Routine work in ozone room, leak occurs	Unknown; exit room immediately	Escape respirator
Working on ozone system, chance of leak	Unknown; exit room immediately if leak occurs	Full facepiece respirator
Leak occurs, enter to repair	Up to 0.5 ppm	Half facepiece respirator with OV cartridge and goggles
	Up to 2.5 ppm	Full facepiece respirator with OV canister or cartridge
	Up to 2.5 ppm	SAR: ½ facepiece
	Up to 10 ppm	SAR with escape bottle (full facepiece)
	10 ppm or more	SCBA
	Unknown; always assume to be IDLH level	SCBA: pressure demand mode

Check systems for workers working alone

Employers must establish a check system to ensure the continued well-being of workers who are working alone or at an isolated worksite. Where visual checks are not possible, the check system may require a radio or telephone. Workers who will need to use such a system must be trained in the appropriate written procedure.

Emergency equipment

Emergency equipment may include eye wash and shower facilities, and first aid kits. Workers must have immediate access to all required emergency equipment, and must know how to use them in case of emergency. Emergency equipment is covered in more detail on page 15. For first aid information, see page 47.

For more detailed information on personal protective equipment, contact:

- Ozone equipment manufacturers
- Safety equipment suppliers
- WorkSafeBC offices (listed at the end of this manual)

Ozone system design

Anyone involved in the design or set-up of ozone systems—designers, suppliers, installers, architects, and engineers—should find the following material useful.

This section describes how ozone systems work, system components (including two methods for generating ozone), and how to measure ozone production and concentration. This section also outlines the general requirements for ozone generators, and the requirements and suitable materials for ozone system piping.

Facilities that house ozone systems are covered in more detail in the section, *Ozone room design*.

How ozone systems work

Ozone generation consists of five basic steps:

1. Feed air (air fed into an ozonation system) passes through an air preparation system.
2. Air is drawn through the ozone generator—either pushed by a compressor or pulled through by the vacuum generated by a ***venturi***. As the air passes through the generator, some of the oxygen is converted to ozone.
3. The compressor pushes the ozonated air into an ***injector***, where the ozonated air mixes with water. A venturi pulls the air into the water stream, where it mixes. Only some of the ozone dissolves in the water less than 1g/L.
4. The ozone/water mix enters a ***reaction tank*** (sometimes called a ***contact tank***), where more ozone can dissolve in and disinfect the water.
5. The undissolved ozone/air mixture (***off-gas***) passes through an ***ozone destructor***, which destroys the remaining ozone before venting the off-gas to the atmosphere.

In a swimming pool setting, the water leaving the reaction tank may be passed through a ***de-ozonizing filter***, after which it is treated with the residual disinfectant (usually chlorine) and is ready for use.

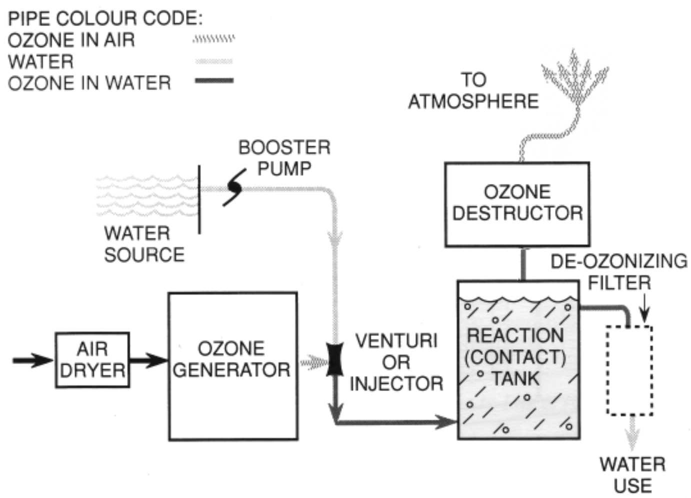

FIGURE 2—Ozone flow

System components

Air preparation system (air drier)

The air preparation system is part of the ozone generator itself. Before entering the generator, particulate material and moisture must be removed from the feed air. Particulate material can build up in the generator and affect the electrical discharge. Moisture in the feed air causes two serious problems. First, moisture can cause a significant drop in the production of ozone. Second, a small amount of the nitrogen in the feed air converts to oxides of nitrogen, which dissolve in moisture to form a corrosive acid. For this reason, a dew point detector must be installed between the air drier and the generator. The ***dew point*** must be kept below -50°C.

If drier columns are recharged by heating, a sign warning workers of the hot surfaces must be posted nearby.

Moisture can be removed by passing feed air through molecular sieves, activated alumina, silica gel, or by refrigeration.

Ozone generating assembly

Once properly prepared, air is fed into the generator using either:
- An air compressor that forces air through the generator, or
- A venturi, located downstream of the generator, that creates a vacuum and draws air through the generator (see *Injector/Venturi* on page 25)

The two common methods for generating ozone are ***corona discharge*** and ultraviolet (UV) light. Both types of generators include:

- An air preparation system
- A high-voltage electrical supply
- A generating assembly

Corona discharge generators

Corona discharge generators produce ozone by passing air through a high-voltage electrical discharge. The energy within the discharge converts some of the oxygen to ozone.

The voltage used to produce ozone usually ranges between 3000 and 25,000 volts. Adjusting the applied voltage or the air flow regulates ozone production. Reducing the air flow increases ozone concentration. The ozone/air mixture leaving the generator normally contains between three and five percent ozone (by weight).

Ozone production can be increased by using air with an enhanced oxygen concentration as the supply gas for the generator. However, greater oxygen content increases the risk of fire, in addition to the hazards posed by ozone. To prevent these adverse effects (such as fire), employers must implement additional controls. There is also the possibility of the air in the ozone room having an oxygen-enriched atmosphere—generally accepted to be greater than 23.5 percent. The employer will be expected to monitor the oxygen content of the air in the room and provide exhaust ventilation to reduce the enrichment.

Note:

Contact your local health authority to clarify requirements before considering UV generation as the method for producing ozone in a public pool.

UV generators

Ultraviolet (UV) generators produce ozone by irradiating ordinary air with UV light at wavelengths below 200 nanometres (nm). Longer wavelengths (around 250 nm) of UV light are more efficient at destroying ozone, rather than producing it. Commonly, a venturi creates a vacuum to draw the feed air through the generator.

UV generators produce less ozone than corona discharge generators—a maximum concentration of less than 0.1 percent by weight.

Injector/Venturi

Systems that use a compressor rather than a venturi will have an injector. The compressor pushes ozonated air out of the ozone generator and into the injector, where the ozonated air mixes with water flowing in from the booster pump. As ozone is injected into the water stream, some of the ozone dissolves in the water.

Instead of compressors, some systems may use a venturi to create a vacuum that will draw air from the air preparation system into the generator. The venturi then pulls the ozonated air from the generator into the water, where the ozone begins dissolving in the water.

Additional devices will increase the amount of ozone dissolved in the water. Some pool installations include an in-line mixer fitted into the pool water circulating line at the injector/venturi. Other systems feed the ozonated water and entrained (bubbles trapped in liquid) ozone/air mixture through a diffuser as they flow into the reaction tank. The diffuser is an assembly of multiple nozzles, perforated pipes, or porous ceramic tubing located near the bottom of the reaction tank.

Booster pump

The ***booster pump*** sends a steady flow of water past the injector/venturi and into the reaction tank. In systems that use a venturi, the water flow through the venturi creates the vacuum that pulls feed air through the ozone generator and into the water.

Reaction tank (contact tank)

The reaction tank serves two important purposes. First, it allows additional time for more ozone to dissolve in the water. Second, it allows time for the dissolved ozone to oxidize mineral and organic contaminants and disinfect the water. For these reasons, the tank should be designed with a diffuser to efficiently disperse fine gas bubbles in the water. Gas bubbles should flow in the opposite direction to the water flow, to provide more effective dissolving.

A *CT value* indicates the effectiveness of the disinfection process. To determine the CT value, multiply the concentration (C, in mg/L) of dissolved ozone by the time (T, in minutes) of contact between the dissolved ozone and the contaminants in the water. A minimum CT value of 1.6 provides adequate disinfection. For example, a dissolved ozone concentration of 0.4 mg/L in contact with water for four minutes provides a CT value of 1.6.

$$0.4\ mg/L \times 4\ min = 1.6$$

Adequate disinfection may not occur if:

- The amount of ozone gas injected into the water is too low to reach the minimum CT value
- The water temperature is too high (above 28°C), causing rapid ozone decomposition
- The microbiological and/or organic content of the water is too high for the available ozone
- The flow-through time allowed in the reaction tank is too short

The reaction tank should never provide less than four minutes contact time.

Health authorities in British Columbia monitor disinfection effectiveness using routine bacteriological analysis.

The undissolved ozone/air mixture (*off-gas*) that bubbles up through the reaction tank must be collected above the water level and fed safely through an exhaust line to the atmosphere. If not, the off-gas will entrain (mix) with the water flow and release in the work area (for example, at the pool water surface, or at the bottling machine). Instead of venting the off-gas, it can be collected and returned to the system using a venturi.

Ozone destructor

Before venting to the atmosphere, off-gas passes through an ozone destructor to destroy the remaining ozone in the gas. Off-gas can be fed into the ozone destructor using one of two methods: by allowing a slight pressure buildup at the head of the reaction tank to push the off-gas through the destructor; or by installing a fan downstream from the destructor to draw the off-gas through the system. The gases leaving the destructor must discharge well away from any air intakes or work areas.

Anyone designing and installing an ozone destructor must do so in accordance with good engineering practice, and must submit plans to WorkSafeBC.

The off-gas from the reaction tank must be vented to the atmosphere in a manner acceptable to both WorkSafeBC and the Air Resources Branch of the B.C. Ministry of Water, Land and Air Protection. The Ministry

requires the use of the "Best Available Control Technology" to limit discharge of contaminants to the environment.

An owner or contracted operator who proposes to use an ozone system must confirm with the local Ministry of Water, Land and Air Protection office that the proposed discharge method does not violate any regulation.

The pipe from the destructor must be approved for carrying ozone/air mixtures (see *Piping, Suitable materials*, page 33) and must have sealed joints. The pipe must be installed on a continuous upward grade, with a container at the low point for collecting any condensation. The line should be located outside the building, if possible, to minimize the risk of gases leaking into the building.

If the destructor does not work properly, it might discharge high levels of ozone. A pipeline blockage—moisture freezing in the pipe, for example—will result in a serious discharge of ozone into the ozone room.

Ozone destructors destroy ozone in the off-gas by:

1. Passing the off-gas through an oven, where it is heated to temperatures above 350°C for at least five seconds. This process (thermal decomposition) is simple, but power costs could be an important consideration.

2. Irradiating the off-gas with UV light that has a wavelength of 254 nm. This radiation is efficient for decomposing ozone, particularly when the temperature is below 0°C.

3. Passing the off-gas through a catalytic destructor unit. A catalyst, such as palladium/alumina or manganese dioxide, decomposes ozone to oxygen at about 50°C. The catalyst is not used up, so recharging is only necessary when reactions with impurities in the gas stream poison the catalyst.

4. Passing the off-gas through a bed of ***granular activated carbon*** (GAC). This will destroy the ozone and produce carbon dioxide and some carbon monoxide. Figure 3 shows the GAC bed suspended above a water reservoir. Incoming off-gas enters the air space between the water and the carbon. The off-gas passes through the carbon, which filters out ozone before piping the gas out of the tank to the atmosphere. Systems with a catalyst or GAC packed in an action chamber are currently the norm.

The water in the tank of a GAC system (as shown in the Figure 3) must be open to atmospheric pressure through an open trap tube extending up the side of the tank. The tank must be continually topped up with water, and must have a transparent trap tube to ensure it contains enough water. Water loss in the reservoir will cause the off-gas to pass directly into the ozone room, instead of going through the carbon layer.

The carbon is consumed in the destruction process and must be replaced. Regular inspections must take place—recommended monthly for systems in continuous use, or according to the manufacturer's guidelines—and carbon must be added as needed.

Manufacturers and design engineers must specify, for each installation, the suitability and safety of GAC destructors and their ozone removal capacity. The use of GAC destructors is prohibited when the feed gas supply contains an oxygen concentration of more than 21.5 percent.

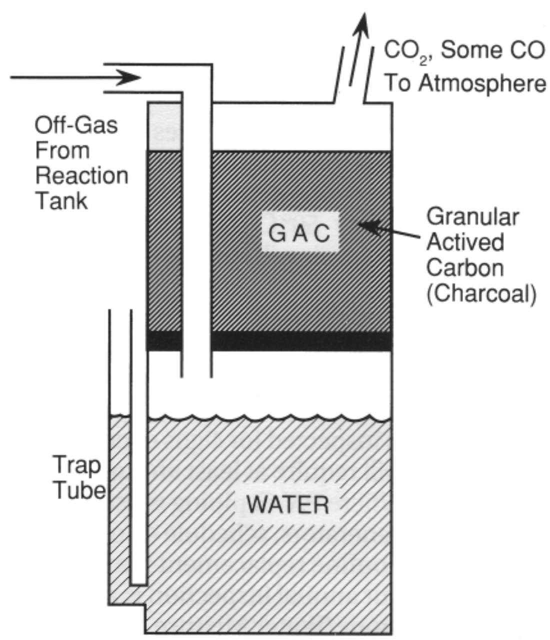

FIGURE 3—Ozone destructor

De-ozonizing filter

Water leaving the reaction tank may contain residual dissolved ozone, which may need to be removed. GAC filters may be used to remove excess ozone.

Dissolved chlorine will also remove residual dissolved ozone. This will result in increased use of chlorine to maintain the required residual chlorine content in the water.

Ozone production and concentration

One ppm of ozone equals two milligrams per cubic metre (mg/m^3).

Production and concentration are the two important parameters of ozone generation.

Ozone production refers to the amount of ozone gas that the generator discharges. Production is usually measured in grams per hour (g/h) for small systems, and kilograms per day (kg/d) for large systems.

Ozone concentration refers to the amount of ozone in the gas stream leaving the generator. Concentration is usually measured in parts per million (ppm), or sometimes in grams per cubic metre (g/m^3) and milligrams per cubic metre (mg/m^3).

Calculating ozone concentration—example

A generator produces 20 g/h of ozone with an air flow through the generator of 20 litres per minute (L/min). To calculate the ozone concentration in the air, follow these steps:

1. Calculate how much air flows through the generator in one hour. Multiply air flow (L/min) by time (minutes) to get air quantity (in litres). Multiply litres by 0.001 to get air flow in cubic metres.

   $$20\ L/min \times 60\ min = 1200\ L = 1.2\ m^3 \text{ of air}$$

2. Calculate how much ozone the generator produces in one hour.

   $$20\ g/h \times 1\ hour = 20\ g \text{ of ozone}$$

3. Calculate the ozone concentration by dividing the amount of ozone produced in one hour by the amount of air that flows through the generator in one hour.

   $$20\ g \div 1.2\ m^3 = 17\ g/m^3 \text{ (approx.)}$$

To calculate the ozone concentration in ppm, convert g/m^3 to mg/m^3 (multiply by 1000), then divide by two.

17 g/m^3 x 1000 = 17,000 mg/m^3 ÷ 2 = 8500 ppm (i.e., 0.85% ozone in air)

Ozone generator requirements

Manufacturers must ensure that ozone generators meet the requirements outlined in the following six headings: *Identification/marking, Generator protection, Automatic shutdown, Emergency shut-off, Electrical,* and *Air compressors*. An employer should specify necessary requirements when dealing with manufacturers because employers become responsible for the system once it has been installed.

The local health authority must approve plans before system installation may begin for the following:

- **Swimming pool systems, as defined under the B.C. Swimming Pool, Spray Pool and Wading Pool Regulations**
- **Water bottling plants**
- **Potable water treatment**

The detailed plans must be sealed by a B.C. Professional Engineer, submitted for approval, and must show—according to the guidelines of this manual—the piping arrangement and room design for the ozone system.

Identification/marking

Legible and permanent identification on ozone generators must indicate the:

- Manufacturer and/or supplier
- Type of ozone generation—corona discharge or UV
- Method of cooling
- Year of construction
- Serial number
- Type of supply gas
- Ozone production in g/h or kg/d (rated capacity)
- Ozone concentration in g/m^3 or ppm
- Maximum permissible pressure of the feed air to the ozone generator in kPa (negative pressure expressed in negative value)
- Electrical requirements

Employers must provide a WHMIS workplace label for ozone generators (or for ozone rooms).

Generator protection

In case of compressor or venturi failure, the gas delivery line from the generator must include one of the following: a water trap, an elevated loop, a back-flow preventer, or an anti-siphon device. These devices also prevent condensation from building up in the delivery pipe and dripping back into the generator.

Tubing made from non-ozone resistant material must not be used downstream from the generator to “detect” (by its deterioration) any corrosive acid.

Automatic shutdown

Ozone generators must be designed to shut down automatically when any one of the following occurs:

- Low intake air flow
- High or low generator current
- Loss of the flow of water to be treated
- Generator cabinet door open or cover panel removed
- High dew point in the intake air*
- High coolant water temperature*
- Loss of cooling water or air supply*

The manufacturer determines how the system shuts down under the above conditions. To alert users, an alarm must be activated if the generator shuts down for any of the above reasons.

Emergency shut-off

An emergency electrical shut-off switch must be located an appropriate distance from the ozone room. This allows for manual shut-off of the generator power during a leak or malfunction, and avoids a worker having to enter the room.

Electrical

All of the ozonation equipment’s electrical components must be CSA-approved, or be acceptable to the Electrical Section of the B.C. Safety Authority.

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* Applies only to corona discharge generators

In case moisture enters the generator, a ground fault circuit interrupter (GFCI, Class A type), or equivalent protection, must be installed to cut off the generator power supply. Equivalent protection for generators designed to have significant leakage current (more than enough to trip a GFCI) must include detailed written safe work procedures and training for workers. The building design may also require some necessary modifications, such as a generator platform to keep workers out of water while working on the generator.

Air compressors

Excess noise is likely when an air compressor is part of the system. Appropriate protective measures must be used, such as isolating the compressor away from routine work areas, and posting warning signs in accordance with the Occupational Health and Safety Regulation.

Piping

This section outlines general requirements for piping in ozone systems and suitable materials for pipes and related parts.

General requirements

Piping systems must be:

- Kept as short as possible to minimize leaks
- Mechanically supported (Teflon® must be continuously supported)
- Protected from shock or vibration
- Able to withstand system pressures
- Pressure-tested before entering into operation

Pipes carrying different materials (such as, ozone/air or ozone/water) must be identified (for example, by names, colour codes, coloured bands or arrows). All workers in the area must be able to immediately understand the system of identification. Tanks must also be identified in accordance with WHMIS requirements.

Suitable materials

The strong, oxidizing power of ozone must be considered when choosing materials for pipes, valves, gaskets, pump diaphragms, and sealants. Materials for piping, tanks, and other vessels must be resistant to electrolytic corrosion and chemical attack.

The selection of suitable materials depend on the ozone mixture and the system part. Materials for different mixtures and system parts are listed below.

Ozone/air mixtures

- Teflon® (Polytetrafluoroethylene, or PTFE)
- Stainless steel—grades 316L or 304L
  Stainless steel may be used only when the feed air for the ozone generator is dried to a dew point below -50°C. This is because corrosive acids formed in moist air will corrode stainless steel pipes from the inside.
- Black Tygon®, confirmed by the manufacturer to be ozone resistant
- PVC
  Corona discharge systems must not use PVC pipe, unless the owner can confirm, with a letter from the supplier, that the pipe is ozone-resistant. Schedule 80 PVC pipe in corona discharge systems has been found to crack open after only a few months of service.
  UV ozone generators may use Schedule 40 or 80 PVC pipe. To detect any signs of cracking, an annual inspection of the pipe interior is recommended.

Ozone/water mixtures

- Teflon® (Polytetrafluoroethylene, or PTFE)
- Stainless steel—grades 316L or 304L
- PVC—Schedule 80 or Schedule 40
- Ethylene-propylene terpolymer (EPDM)
- Polyvinylidene Fluoride (PVDF)
- Hypalon®
- Kynar® (Fluoropolymer)
- Ceramic
- Glass

Other materials proven to be ozone-resistant are acceptable for use.

Gaskets

Teflon® or "Red Polyurethane" are acceptable gasket materials. Viton® and Hypalon® do not provide enough resistance to deterioration at ozone concentrations above 1.5 percent to be acceptable gasket materials.

Joint sealers

Even though Teflon® tape may be used successfully for sealing joints, some leaks have occurred. Avoid threaded fittings. Hypalon® and silicone sealer, neither of which contain a rubber filler, have proven more successful at sealing joints.

Valves

Stainless steel or Teflon® valves are recommended throughout. Systems using PVC or Kynar® valves require regular inspection and valve replacement, when necessary. These systems also require routine maintenance to remove clogging.

Ozone room design

This section outlines specific requirements for ventilation, electrical systems, and exits, as well as general ozone room requirements. Anyone involved in the design or set-up of ozone system facilities—designers, suppliers, installers, architects, and engineers—should find this section useful.

Ozone generators and associated equipment must be housed in a separate building or in a separate enclosure within a building. For the purposes of this manual, this building or enclosure will be referred to as the *ozone room*, regardless of other equipment (such as boilers or ventilation equipment) that may also be present.

Ventilation requirements

Ozone room ventilation

Ozone rooms must be mechanically ventilated using either:

- A ventilation system that provides at least 10 air changes per hour, or
- A two-stage ventilation system that uses a general and an emergency system (see Figure 4). Under normal conditions, the general system should provide at least three air changes per hour. In the event of an ozone leak, the emergency system should provide at least 30 air changes per hour. An ozone monitor in the ozone room must automatically activate the emergency system when the ozone concentration exceeds 0.05 ppm.

  Because the ozone concentration that can be reached in the ozone room is limited to a few hundred ppm, and because the vented ozone will decompose rapidly, the monitor is allowed to automatically activate the exhaust, provided the exhaust vents are located well away from frequented areas.

Both these methods must discharge air well away from any air intakes and, in some cases, as high as 4.5 m above the roof, depending on the position on the roof.

The ventilation system must include an adequate supply of make-up air (air that replaces exhausted air). The make-up air supply must not be less than the volume of air exhausted.

When a vacuum ozone delivery system is used (venturi), any leak or break in the system after the generator allows the venturi to draw air into the system. This reduces or stops the flow of air through the generator, also reducing or stopping ozone production. Because the danger of overexposure to ozone with venturi systems is so much lower than with pressure-fed systems, the ozone room may contain other operating equipment (such as sand filters, furnaces, and pumps).

However, if the ozone room uses a two-stage ventilation system and there is other operating equipment in the room, the intake for the emergency ventilation system must be located behind the reaction tank and the destructor unit (see Figure 4).

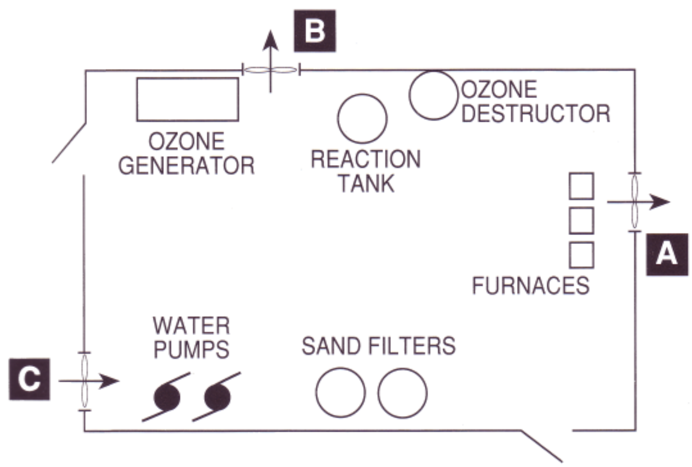


FIGURE 4—Two-stage ventilation system (Ozone room)

Workplace air contaminants must not be recirculated without written permission from WorkSafeBC.

Building ventilation

Heating, ventilation, and air conditioning (HVAC) systems in buildings with an ozone room must not normally draw air from the ozone room or any other area using ozone. However, this is allowed if the ozone room or area has an automatic shutdown control for the HVAC system that triggers when the room or area's ozone level exceeds 0.05 ppm.

Electrical requirements

- All electrical connections to and from ozone rooms must conform to the Canadian Electrical Code.
- Ozone generators must have an emergency electrical shut-off switch in a safe and readily accessible location away from the ozone room. This allows the operator to shut down and lock out the generator without having to enter the room.
- Electrical switches controlling lighting and exhaust ventilation must be mounted outside the ozone room.
- Ozone rooms must have emergency lighting.

Exit requirements

- Ozone rooms with floor area larger than 40 sq. m (430 sq. ft.), or longer than 10 m (33 ft.) on any side, must have two exit doors to ensure accessible escape routes.
- Ozone rooms must provide free and unrestricted access to exit doors.
- All exit doors must open outward, and must be fitted with panic hardware (such as, a crash bar) for easy exit.
- Doors should not be self-locking.

General requirements

- Ozone rooms must not house workstations or maintenance and repair benches.
- Ozone rooms must provide unobstructed access for maintenance staff to all pieces of equipment. There must be sufficient clearance to allow for repair or replacement of any equipment in the room.
- If the ozone room is a separate enclosure, all openings (walls, ceiling, electrical conduits, access ports, monitoring apparatus, etc.) must be tightly sealed.
- When a pressure-fed ozone delivery system (compressor) is used to feed air into the ozone generator, any leak or break in the system will immediately discharge ozone into the ozone room. Therefore, the ozone room should not contain any auxiliary equipment.
- Ozone rooms must not be used for storing chemicals, solvents, or any combustible materials.

- Ozone rooms should have two fire extinguishers: one inside the room and one immediately outside. Both fire extinguishers should be suitable for Class A, B, and C fires.
- Only authorized personnel are permitted to enter the ozone room.
- Signage, in the form of a workplace label (WHMIS), must clearly identify the ozone room.

If the workplace label is attached to the ozone generator, the room need only be identified by a warning sign.

Location of monitors

As shown in Figure 5, ozone concentrations must be monitored at:

- M-1 for room air
- M-2 for exhaust air

For swimming pool installations, the local health authority may require measurement of the ozone concentration in the water entering (M-3) and leaving (M-4) the reaction tank, and downstream from the de-ozonizing filter (M-5). Contact other regulatory authorities, such as the Canadian Coast Guard or Health Canada, for their requirements.

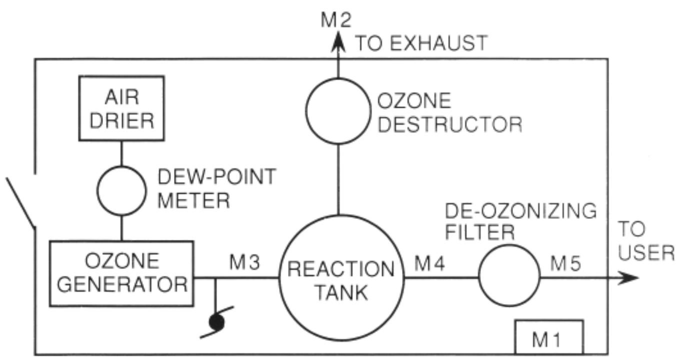


FIGURE 5—Location of monitors

Types of monitoring equipment

Various types of equipment are used to monitor ozone in air, ozone in water, and air flow and moisture.

Ozone in air

There are three methods of monitoring ozone in air: electronic meters, detector tubes, and test papers.

1. *Electronic meters*

   Ozone rooms require electronic meters for continuous monitoring. The meter at M-1 (Figure 5) monitors leaks; so, it should be able to measure ozone concentrations between 0.01 ppm and 10 ppm. The lower limit should be no higher than 0.025 ppm.

Note: If the upper limit of the monitor display is below 10 ppm, then that lower level becomes the effective IDLH concentration that triggers the requirement for SCBA.

A monitor outside the ozone room must display the ozone concentration in mg/m^3 or ppm. If possible, the monitor should attach to a probe that enters the room through a sealed conduit. The sampling head on the end of the probe must be beside the equipment and between the generator and the destructor. Reaction tanks or destructors further than 5 m (16 ft.) away from existing sampling heads must have their own, additional sampling head(s).

The exhaust air stream (M-2, Figure 5) should be monitored regularly to ensure the ozone destructor is operating effectively. A continuous monitor may be used, but detector tube measurements are also acceptable.

Continuous monitors must have:

- An audible and visible alarm that activates when the ozone concentration in the ozone room reaches 0.05 ppm
- An audible and visible signal output that automatically shuts off the ozone generator and activates the emergency air exhaust fan
- Signal outputs that activate an audible or visible alarm signal immediately outside the ozone room and at a separate location in the building
- The ability to operate continuously in fully automatic mode

The monitor must be calibrated and maintained in accordance with the manufacturer's instructions, or at least once a year.

2. *Detector tubes*

Detector tubes are not a substitute for continuous monitoring. They may be used for testing in unusual circumstances, such as a suspected leak.

Detector tubes provide "grab bag" samples, giving only an estimate of the ozone concentration at the time the measurement is made. Tubes cannot be re-used. Detector tubes have a shelf-life of about one or two years and must be replaced regularly (see the manufacturer's instructions).

Workers must be properly trained in detector tube use, maintenance, and limitations. Training includes how to check the operation of the hand pump before each use, using an unopened detector tube.

3. *Test papers*

Potassium iodide-impregnated test papers may be used for leak detection, but not for measuring ozone concentrations in air. These test papers are sensitive to many oxidizing agents, including chlorine, so caution is required when interpreting the results.

Ozone in water

Ozone concentration in water can be measured in various ways. There are two portable test kits currently available:

- The DPD (N,N-diethyl-p-phenylenediamine) method is not specific to ozone—it measures all oxidants, including chlorine.
- The INDIGO method is specific to ozone.

The effective concentration of ozone in water can also be monitored by measuring the Redox Potential (RP). RP meters are available in various types and configurations.

Air flow and moisture monitoring

Flow meters measure the air flow into or out of the generator.

All air flow meters in the system must be calibrated to read in the same measurement units. The air flow meter on the generator is normally adjustable, and contains the low intake air flow (interlock) sensor.

When more than one venturi is pulling the ozone/air mixture from the generator, an air flow meter should be installed at each venturi.

Flow meters made from "polysulfone" material are not compatible with the high concentrations of ozone in air produced by a corona discharge generator.

A dew point meter measures moisture in the feed air before the air enters the generator (dew point meter, Figure 5).

System operation and maintenance

This section includes information that should be useful to designers, suppliers, and installers; owners/operators; and maintenance workers.

Start-up procedures

Designers, suppliers, and installers of ozone-generating equipment and ozone-handling equipment share the responsibility of starting up the system and determining if it is working properly. Operation and maintenance manuals provided with equipment should outline procedures and maintenance requirements. A manual's maintenance section will normally include information regarding:

- Critical parts inventory
- Air preparation unit servicing
- Generator servicing
- Pump and venturi maintenance
- Ozone destructor maintenance
- Sensors and testing equipment inspection and maintenance
- Cleaning timetables and procedures
- System testing
- Operation and maintenance logs

Maintenance schedule

Once the system is operational, the owner or contracted operator becomes responsible for maintenance. Owners or operators must develop a maintenance schedule using the information in the operation and maintenance manual. The maintenance schedule will include:

- A list of equipment that requires daily, weekly, monthly, or annual inspection
- A troubleshooting guide
- Safety precautions (for example, lockout) that workers must follow during maintenance and repair

Owners or contracted operators must ensure that the regular maintenance outlined in the schedule takes place. Records of all replacements and repairs must be kept in a logbook, including the:

- Replacement date
- Reason for replacement

- Hours of service before replacement
- Specifications of any replacement part used, if different from the part specified in the maintenance section of the manual

Safety precautions

Qualified personnel must direct cleaning and repair of ozone systems. These workers must be properly instructed and trained, and know the precautions that must be taken to perform the work safely.

Any part of an ozone installation retaining ozone gas must be purged (for example, with air or nitrogen) before opening. All gases must be safely discharged to the outside atmosphere.

After maintenance work and before operation, the system must be pressure- or vacuum-tested, as appropriate, to detect leaks.

All parts in an ozone installation that are in contact with gases containing ozone must be kept free of oil and grease. This is particularly true when the system is fed with oxygen (or air with enhanced oxygen content) instead of normal air.

Safety equipment

The planned maintenance of all safety equipment is essential to worker safety:

- Alarm system and monitoring equipment must be tested and serviced according to the manufacturer's instructions.
- Eye wash equipment and showers must be serviced regularly to ensure clean water and proper operation.
- Respirators must be cleaned, repaired, and maintained.
- First aid kits must be kept fully stocked.

Definitions

Booster pump

A pump that provides water flow through an injector or venturi (see Figure 2, page 23). The flow through the venturi creates the vacuum that draws the ozone/air mixture through the ozone generator.

Contact tank

See *Reaction tank*.

Corona

A visible electric discharge. Oxygen in the air passing through this discharge is converted to ozone.

De-ozonizing filter

A vessel or series of vessels containing a suitable material that ozonated water passes through to destroy residual ozone. This treatment stage prevents water containing dissolved ozone from reaching a pool or water main.

Dew point

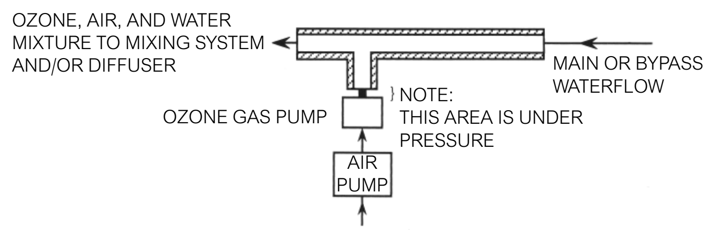
The temperature at which water vapour in the air begins to condense (dew, or moisture, begins to form).

Granular activated carbon (GAC)

Heat-treated charcoal used as a filter in ozone destructors. Off-gas passes through a GAC bed, which filters out the remaining ozone, also producing carbon dioxide and some carbon monoxide.

Injector

The ozone/air mixture passes from the ozone generator, through this device, and into the water. The injector mixes and dissolves the ozone in the water.



In-line mixer

An optional, static mixing device in the water line that helps mix and dissolve the ozone into the water.

Odour Threshold

The odour threshold is the lowest airborne concentration of a gas or vapour that can be detected by the human sense of smell. The odour threshold for ozone can be as low as 0.005 ppm.

Off-gas

The undissolved, ozonated air collected from the reaction tank(s) or de-ozonizing filter. Off-gas must be safely vented to the outside atmosphere.

Ozonation

The process of dissolving ozone in water.

Ozonated air

Air in which a portion of the normal oxygen (O_2) is converted to ozone (O_3).

Ozone destructor

A device that removes ozone from off-gas before discharging the off-gas into the atmosphere.

Ozone room

The room or building where the ozone generator and ozonation equipment are installed.

Reaction tank (contact tank)

A tank where dissolved ozone reacts with contaminants in the water. The reaction tank may have either a series of compartments or only one large chamber.

Redox potential (RP)

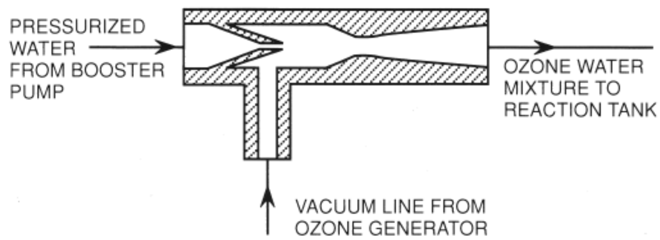
A measure of the strength of a solution as a disinfectant.

A more complete list of standard terms is published by:

International Ozone Association
Pan American Group
P.O. Box 28873
Scottsdale, AZ
85255   USA

Venturi (eductor)

A device in a water stream that creates a vacuum to draw feed air through the ozone generator and into the water. (Compare with *Injector*)



First aid

General	
First action	**Second action**
• If exposure to ozone causes headache or shortness of breath, immediately remove the patient to a fresh air environment.	• Workers who have been exposed to low concentrations of ozone should be given oxygen to breathe while under the observation of trained personnel.
	• If exposure is severe, send for medical assistance immediately.
Inhalation	
First action	**Second action**
• Assess patient's breathing.	• If breathing has ceased, start artificial respiration (mouth-to-mouth is the most effective method) until breathing has been restored.
• All unconscious patients must be placed in the drainage assistance position (on their sides), so that fluids can drain from the airways once breathing has been restored.	• Send for medical assistance immediately.
• Check the pulse.	• If absent, begin cardiopulmonary resuscitation (CPR).
Eye contact	
First action	**Second action**
• Effective irrigation should start immediately. Eyes should be irrigated for 30 minutes by the clock with running tap water or preferably normal saline.	• Effective irrigation must be continued while en route to the hospital.
Precautions	
Workers with a previous cardio-pulmonary (heart and lung) condition must consult their physician prior to working in an area in medical assistance which they may be exposed to ozone. Significant alterations in cardiopulmonary functions have been documented when such workers have been exposed to low concentrations of ozone.	

Notes

Notes

Notes

WorkSafeBC Offices

Visit our web site at WorkSafeBC.com.

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2774 Trethewey Street V2T 3R1
Phone 604 276-3100
1 800 292-2219
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Fax 604 232-1946

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Phone 604 273-2266
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Vancouver BC V6B 5L5

After Hours
Health & Safety Emergency
604 273-7711
1 866 922-4357 (WCB-HELP)

R06/06