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Capsule Report

Sources and Air Emission Control Technologies at Waste Management Facilities

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U.S. Environmental Protection Agency
Off ice of Research and Development
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Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading toacompatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data andtechnical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. Thegoal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

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Introduction

The chemicals processed during waste management operations can volatilize into the atmosphere and cause carcinogenic or other toxic effects or contribute to ozone formation. Regulations have been developed to control air emissions from these operations. The EPA has promulgated standards under the authority of Section 3004(n) of the Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA) that limit organic air emissions from waste management units at hazardous waste treatment, storage, and disposal facilities (TSDF); the rules also apply to 90-day accumulation units at hazardous waste generator facilities. In June 1990, EPA promulgated standards for process vents and equipment leaks; additional RCRA standards were promulgated on December 6, 1994, (effective December 6, 1996) and amended on November 25, 1996, to limit air emission from tanks, surface impoundments, and containers used in managing hazardous wastes. Implementation of air emission controls on many types of waste management operations are required by these RCRA air rules.

This capsule report focuses on the major sources and controls of air emissions at waste management facilities, how these emissions occur, and how they can be controlled. The major sources that are discussed in detail include surface impoundments, the very broad and diverse category of tanks and ancillary equipment, containers, and treatment devices. As each source is described, controls that are inherent to that source or commonly found on that particular source are presented. In addition, details are provided on the basic mechanisms by which emissions occur and the major factors that affect the emissions.

After the discussion of sources and their inherent controls, air pollution control devices that may be generally applicable to any enclosed or vented source (i.e., add-on controls) are described. The discussion of control devices focuses on their applicability, control performance, and the major factors affecting performance. Organic removal (i.e., pretreatment) and destruction processes are also discussed as a means of controlling air emissions and reducing or eliminating the emission potential. This discussion describes processes that remove or destroy the organics in the waste, which may eliminate the need to control subsequent waste processing steps.

Sources and Control Technologies

The types of sources found at waste management facilities, inherent controls that are typically part of the construction and operation of the sources, and emission mechanisms are discussed in this chapter. As each source is discussed, covers and enclosures that are specifically applicable to the source are described, as well as simple work practices that reduce emissions. Other emission controls that are broadly applicable to many of the individual sources are discussed collectively in the last part of the chapter. These controls include traditional air pollution control devices, processes that remove the organics before the waste is placed in units with a high emission potential, and waste incineration.

Sources of Air Emissions

The discussion of emission sources is divided into four categories: surface impoundments, the very broad and diverse group of tanks and ancillary equipment, containers, and treatment devices. The major focus is on the first three categories because they are the most directly impacted by the RCRA air emission regulations.

Surface Impoundments

A surface impoundment is defined under RCRA as "a natural topographical depression, man-made excavation, or diked area formed primarily of earthen materials (although it may be lined with man-made materials) which is designed to hold an accumulation of liquid wastes or wastes containing free liquids and which is not an injection well. Examples of surface impoundments are holding, storage, settling, and aeration pits, ponds, and lagoons."

Impoundments are simply ponds and lagoons that are used primarily for managing aqueous wastes and sludges. Specific uses include storage, equalization, neutralization, evaporation, solids settling, and biodegradation.

A surface impoundment is below grade, usually has berms with sloping sides to contain wastes, and has a liquid surface that is exposed to the atmosphere. It may be operated as a flowthrough system with liquid flowing in at one point and out at the same time at another point, or the liquid may be pumped out or evaporated, leaving behind a sludge. Figure 1 illustrates emissions from impoundments and other open liquid surfaces as caused by diffusion and wind flow across the surface.

Figure 2 lists several of the factors that affect emissions from impoundments. These same factors are applicable to emissions from open tanks. The constituent's volatility has a direct effect on emissions from impoundments and other sources with exposed liquid surfaces. Highly volatile compounds such as benzene are readily emitted from open sources, whereas relatively nonvolatile compounds such as phenol tend to stay in the water.

The residence time in the impoundment has an obvious effect on emissions: longer residence times result in higher emissions. If the waste is in the impoundment long enough, even relatively nonvolatile compounds are evaporated. For impoundments with relatively short residence times, a higher percentage of the organics may be removed with the effluent and emitted later in other units in the treatment sequence.

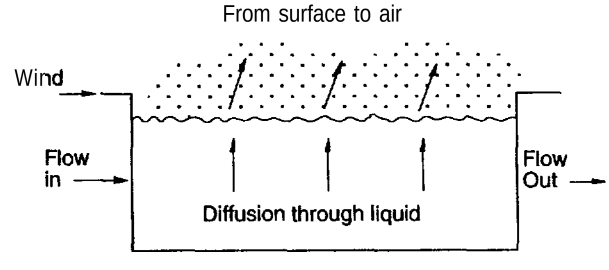


Figure 1. Emissions from impoundments and other open liquid surfaces.

- Constituent volatility
- Residence time
- Surface area
- Turbulence (aeration, agitation)
- Windspeed and temperature
- Extent of competing mechanisms (such as biodegradation)

Figure 2. Major factors affecting emissions.

Many impoundments and tanks are agitated for mixing, air stripping, or biodegradation. Agitation and aeration increase emissions by creating turbulent zones and increase contact between the waste and air. There are a highly turbulent area and water spray around the agitators used in mechanically aerated units. Essentially all of the highly volatile compounds can be emitted when the impoundment is mechanically agitated.

Approximately half of the impoundments used to treat hazardous waste are aerated or agitated.

As Figure 3 illustrates, organic removal from impoundments also occur from mechanisms other than air emissions resulting from wind blowing across the exposed surface of the waste. Organics can also be removed by biodegradation, adsorption onto sludge, or removed with the effluent. Emission models have been developed to estimate the extent of each of these different removal mechanisms.

The models developed for open liquid surfaces are applicable to impoundments and open tanks. These models can account for the emissions from relatively calm surfaces or from the turbulence created by aeration or agitation. The emissions are modeled as two mass transfer steps in series: (1) diffusion through the liquid, and (2) mass transfer from the surface of the liquid to the air. The approach can account for removal in flowthrough systems and removal in units designed for disposal or evaporation. The extent of biodegradation, if any, can also be estimated.

One of the controls demonstrated for impoundments is an air-supported structure, which uses fans to maintain a positive pressure to inflate the structure. For effective control, the air vented from the structure must be sent to a control device, such as a carbon adsorber. Air-supported structures have been used as enclosures for conveyors, open top tanks, and storage piles, as well as impoundments.

An air-supported structure and control device has been installed on a l-acre aerated lagoon that is used for biodegradation at a pharmaceutical manufacturing facility. The cover material is PVC-coated polyester with a Tedlar backing. An agitator system in the structure provides oxy gen and keeps carbon and biomass suspended. In this application, the exhaust from the structure is vented to a carbon adsorber. Very few leaks were found around the structure; consequently, the control efficiency is determined primarily by how well the control device works; it may exceed 95 percent. This plant's experience with the air-supported structure has found that corrosion can be accelerated inside the structure, condensation may occur, temperatures may be high, and special worker safety precautions are needed.

Floating membrane covers are another control option and have been demonstrated on various types of impoundments, including water reservoirs in the western parts of the United States. For proper operation as a control technique for organic compounds, the membrane must provide a seal at the edge of the impoundment and provisions made to remove rainwater. If gas is generated under the cover, vents and a control device may be needed. In addition, if sludge accumulates, some means for periodic sludge removal may be required, such as a sludge pump.

Emission control depends primarily on the type of membrane, its thickness, and the individual organic compounds in the waste. Theoretical estimates based on diffusion through the membrane indicate worst-case control efficiencies of 50 to over 95 percent. Laboratory studies indicate that the cover is an efficient control for some organic compounds, but, for specific compounds that permeate the membrane, the control efficiency is lower.

The floating membrane cover has been demonstrated on an impoundment that is used as an anaerobic digester. The impoundment is about 7 acres in size with a depth of approximately 14 feet. The membrane material is 100-mil high-density polyethylene. The cover is anchored over a concrete ring wall that extends above grade level around the perimeter of the impoundment. The membrane extends over the concrete wall and is covered with backfill to anchor and seal it. Punctures or tears in the membrane can be patched. This installation has been in operation for over 4 years, and the company supplying the membrane offered a 20-year warranty on the life of the material.

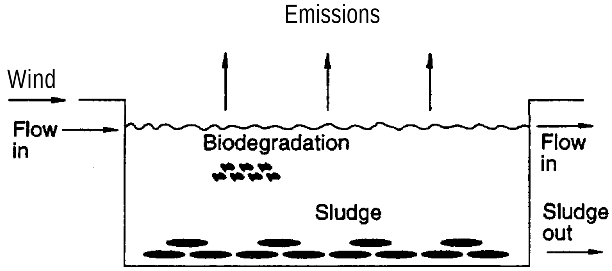


Figure 3. Fate of organics in a surface impoundment: emissions, effluent, biodegradation, sludge.

Tanks

The most diverse group of waste management sources falls into the category of tanks, which is broadly defined under RCRA. If the unit is not a land disposal source, it is probably a tank. A tank is defined as "a stationary device, designed to contain an accumulation of hazardous waste, which is constructed primarily of nonearthen materials (e.g., wood, concrete, steel, plastic) that provide structural support." A tank system is defined as a tank and its ancillary equipment, where ancillary equipment includes such devices as piping, fittings, flanges, pumps, and valves.

The category of tanks and tank systems includes two broad classes, open top tanks and covered tanks. The latter class is divided into fixed roof tanks, floating roof tanks, and pressure tanks. Fixed roof tanks are the most common type of storage tank found at hazardous waste facilities. Emissions occur through the tank's vent, which may be open to the atmosphere, equipped with a pressure-vacuum relief valve, or vented to a pollution control device.

Fixed Roof Tanks

The fixed roof may have several openings in addition to the vent, such as a manhole for tank entry, a hatch used for measuring the liquid level, or an overflow pipe (Figure 4). The pressure-vacuum relief valve is also called a conservation vent, which permits small changes in the liquid level without expelling the **tank's** vapors. If the tank has a conservation vent or is vented to a control device, it is important that the other openings on the tank be kept closed and sealed for the emission controls to be effective.

As an emission control option, fixed roofs can be retrofitted to open tanks, or a fixed roof tank can be used to replace an open tank or impoundment. Compared to an open tank, a fixed roof tank can provide additional control of 66 to 99 percent, depending on the waste volatility and the operating characteristics of the tank openings. If the fixed roof tank is constructed to withstand pressures of 2.5 psig, an additional control of 20 to 45 percent can be obtained. (Most tanks are not designed and constructed to withstand **this pressure.)**

Emissions from fixed roof tanks occur primarily from working! (loading) losses and, to a lesser extent, from breathing losses. The quantity emitted is most directly affected by the rate at which vapors are expelled from the tank and the volatility of the **tank's** contents. These emissions are increased by heating or aeration. Working losses occur when waste is pumped into the tank and vapors are expelled by the rising level of liquid (Figures 5 and 6). Breathing losses occur when the volume of vapor in the tank is increased because of changes in temperature or pressure (Figures 7 and 8).

Equations developed by the American Petroleum Institute (API) are used to estimate emissions for organic liquids. The basic form of the equation, which can be used for other types of wastes, estimates the volume of vapor

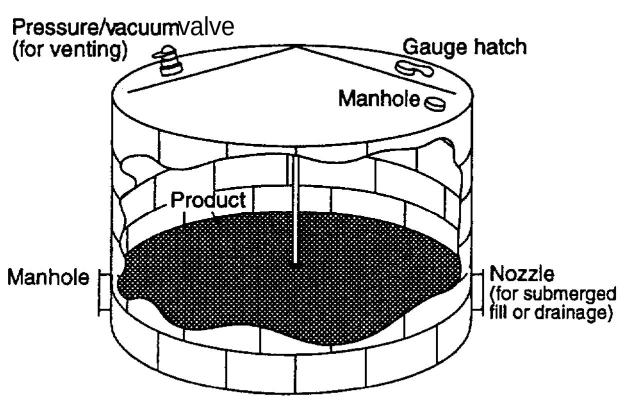


Figure 4. Typical fixed roof tank.

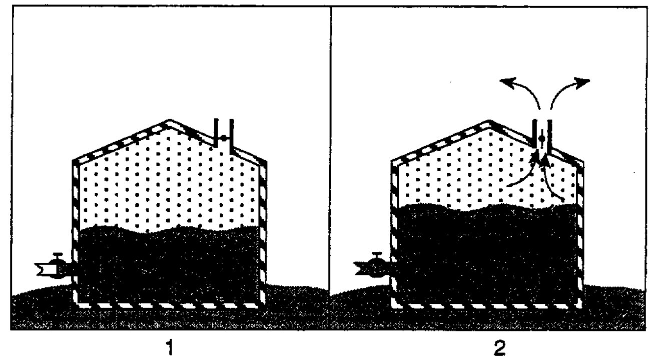


Figure 5. Tank working losses.

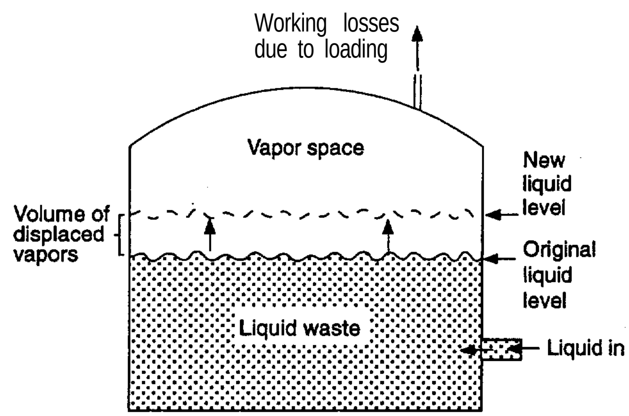


Figure 6. Covered tanks (working losses).

expelled from the tank based on the amount of liquid pumped in and on the vapor concentration. The concentration of constituents in the vapor can be measured or estimated from volatility data. **One** error in using the API tank equations for aqueous wastes is to estimate the concentration in the vapor from the mole fraction of the compound in the liquid, which significantly underestimates concentration. Henry's law constant should be used for dilute aqueous wastes. Breathing losses are usually very low compared to working losses. Note that if the tank is operated at a constant liquid level, as some separators and collection tanks are, very little vapor is displaced and working losses are small.

Two primary emission control approaches exist for fixed roof tanks. The vapor space above the liquid can be eliminated by keeping the liquid level at the roof line (or vice versa), or the vapor space can be vented to a control device. An alternative to keeping the tank at a constant liquid level is to install a floating roof, as discussed as follows. Figures 9 and 10 illustrate the **application** of a closed vent system with control device and two **arrangements** of floating roof tanks.

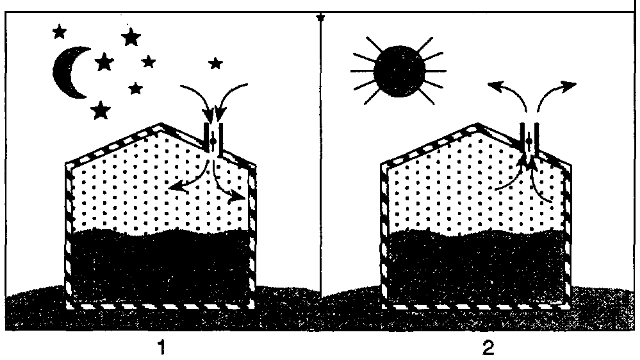


Figure 7. Tank breathing losses.

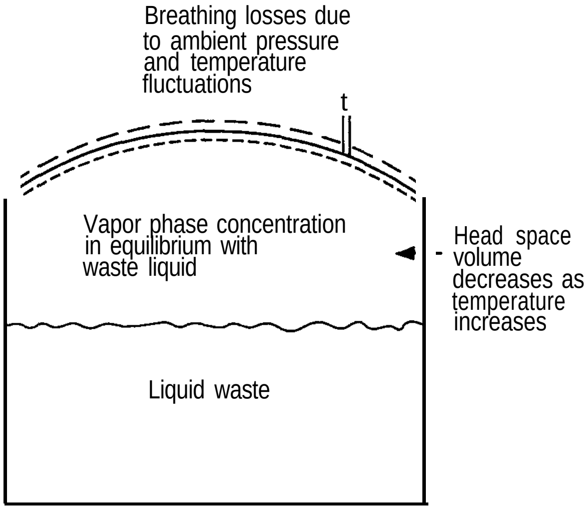


Figure 8. Covered tanks (breathing losses).

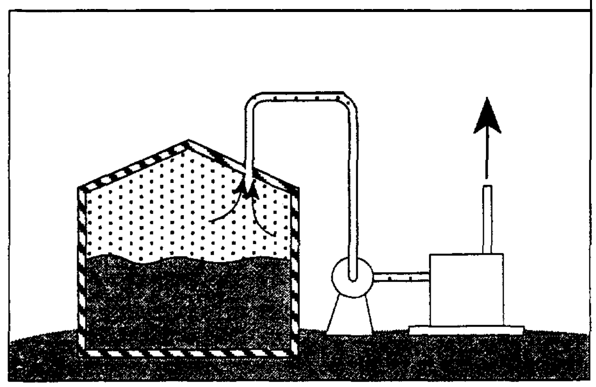


Figure 9. Closed-vent system and control device.

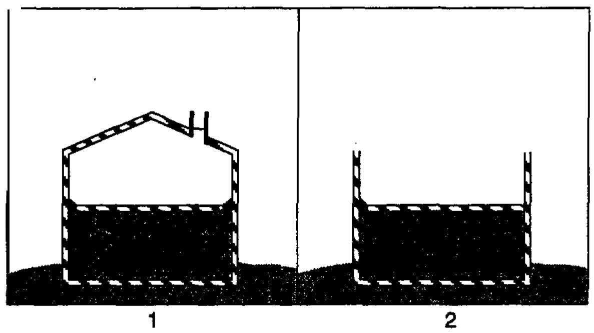


Figure 10. Floating roof.

Floating Roof Tanks

Floating roof tanks are common at petroleum refineries and gasoline marketing facilities for the storage of volatile liquids. The floating roof can be installed internally in a fixed roof tank or externally without a fixed roof. Figures 11 and 12 show internal floating roof and external floating roof tanks in cross-section. The roof floats on the liquid and moves with changes in the liquid level, thus reducing vapor displacement and controlling working losses. The major requirement for a floating roof is an effective seal between the roof and the tank walls. Emissions from a properly maintained floating roof are very low and occur from standing losses and withdrawal losses.

Figure 13 shows the equipment associated with an external floating roof. Standing losses occur at the deck seals and at openings for fittings in the floating roof.

If retrofitted to a hazardous waste tank, the floating roof materials must be compatible with the waste; also floating roofs cannot be used in hazardous waste treatment tanks with surface mixers or aeration equipment. The emission reductions achieved by a floating roof relative to a fixed roof have been evaluated for volatile organic liquids by using empirical models. Depending on the type of deck and seal system selected, emission reductions of 93 to 97 percent can be obtained. For the smaller size tanks and varieties of wastes found at hazardous waste facilities, reductions of 74 to 82 percent can be obtained relative to a fixed roof. Convening an open top tank to a floating roof tank is estimated to reduce emissions by 96 to 99 percent.

Internal and external floating roofs have different design and operating requirements. Typical EPA requirements relating to roof seals and fittings for floating roof tanks are discussed as follows.

An internal floating roof must be equipped with either a mechanical shoe seal, or a continuous liquid-mounted seal, or double-seal system. Figures 14, 15, and 16 illustrate the different kinds of seals. Mechanical shoe seals (Figure 14) operate through a scissors design with a weighted leg to maintain pressure between the seal and the tank wall. A flexible envelope covers the area between

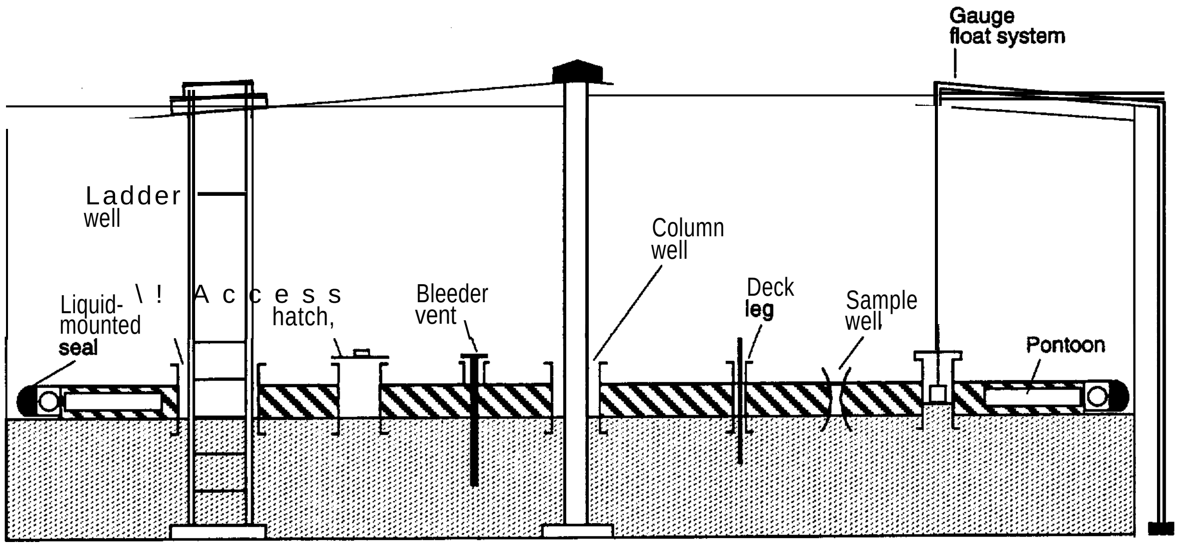


Fig. 11. Internal floating roof.

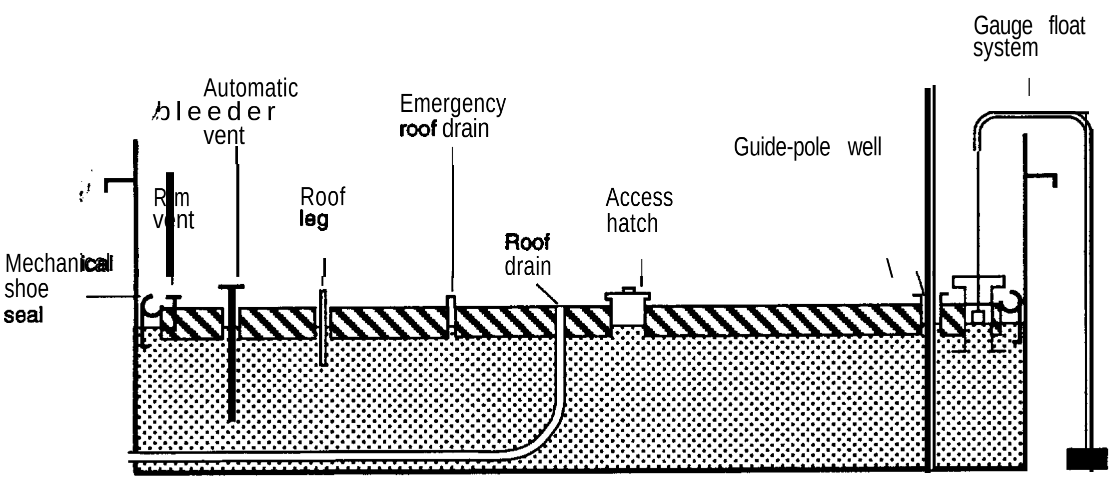


Figure 12. External floating roof.

the roof deck and the seal. Liquid-mounted seals (Figure 15) maintain pressure between the roof and the tank wall by means of a liquid-filled tube that rides between the two. The term "liquid-mounted" refers to the fact that the seal in this case contacts the liquid directly. A scuff band, sealed to the roof, protects the tube from abrasion against the wall. A variation of this seal uses a resilient foam ring instead of a liquid-filled tube. Double-seal systems are illustrated by a vapor-mounted seal with secondary seal (Figure 16). This seal is similar to the liquid-mounted seal with two exceptions. The liquid is replaced by foam and a flexible rim-mounted seal is added to the top of the floating deck. The term "vapor-mounted" refers to the fact that the seal does not come into direct contact with the liquid.

Fittings that typically require controls to achieve emission reductions are shown in Figure 17. A seal is required around each of these vents, wells, or hatches. Further, each opening must project below the liquid surface. Access openings and gauge wells must be equipped with gasketed covers equipped with bolts, and the cover must be closed and bolted except when in use. Ladder wells must have a gasketed sliding cover. Other requirements include a gasketed sliding cover or flexible fabric seal for column wells and slitted fabric covers that cover at least 90 percent of the opening for sample wells. Automatic bleeder vents must be gasketed and must be closed except when the internal floating roof is floated off or landed. Rim space vents must be gasketed, and open only

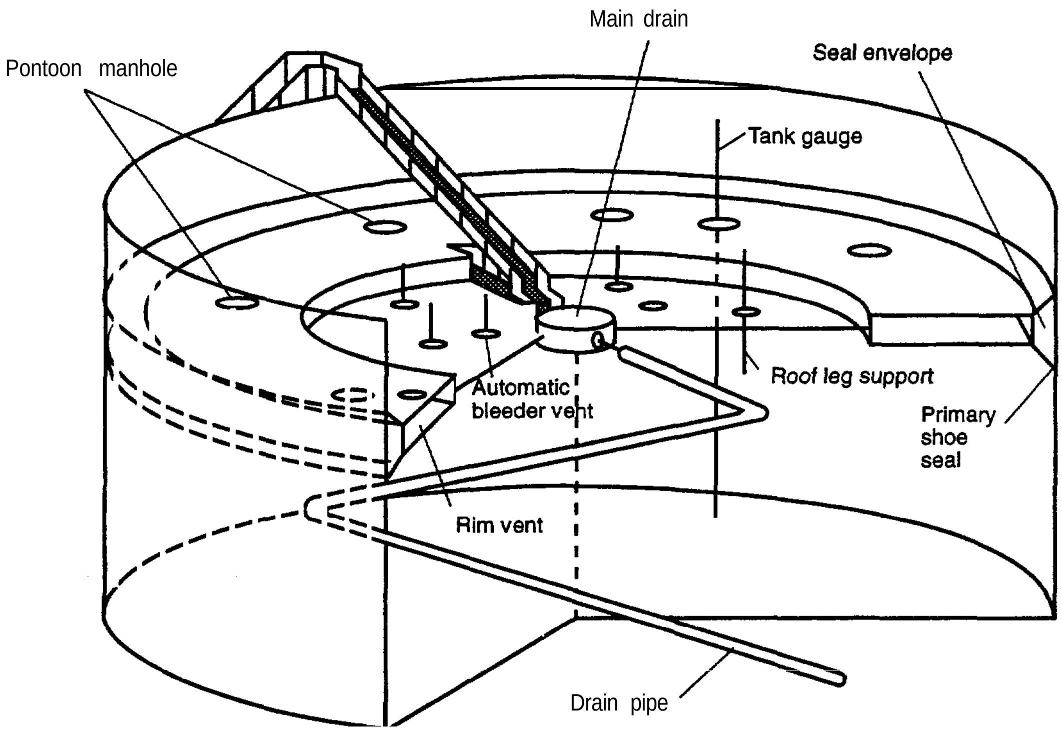


Figure 13. External floating roof tank

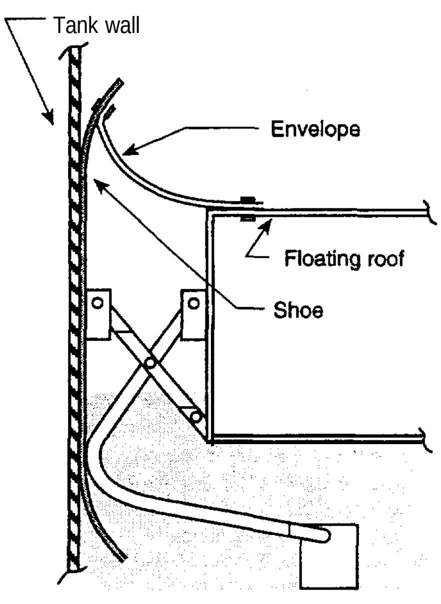


Figure 14. IFR mechanical shoe seal.

when the roof is floated off or as directed by the manufacturers for proper and safe operation.

External floating roof (EFR) requirements are similar in that the EFRs must use a primary seal with continuous, roof rim-mounted secondary seal. This specification means that the EFR must have a primary and a secondary seal. The primary seal can be either liquid-mounted or equipped with a mechanical shoe seal.

Figure 18 is an illustration of the EFR mechanical shoe seal with secondary seal. This seal is identical to the internal floating roof seal except for the addition of a flexible secondary seal mounted to the top of the deck rim. Figure 19 shows EFR liquid-mounted seals with added secondary seals at the deck rim. These seals also are identical to their internal floating roof counterparts except for the added secondary seals.

The EPA rules that apply to storage tanks have very specific requirements for the EFR fittings. The EFR fittings requiring controls are shown in Figure 20. Access openings, sampling wells, and gauge wells must project below the liquid surface, their covers must be gasketed, and the cover must be closed and sealed except when in use. Emergency roof drains, must be equipped with a slotted membrane fabric cover that covers at least 90 percent of the opening. Automatic bleeder vents must be gasketed and closed except when the EFR is floated off or landed. The rim space vents must be gasketed and may be open only when the roof is floated off.

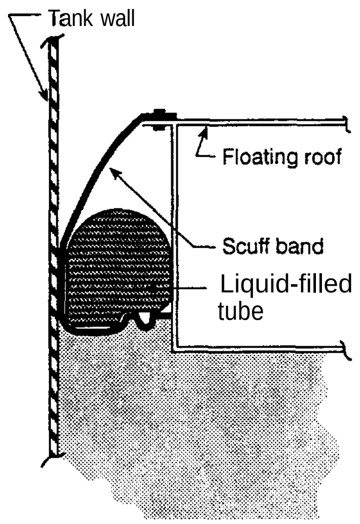
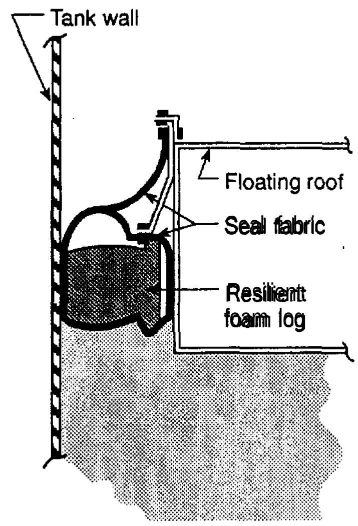


Figure 15. IFR liquid-mounted seal.



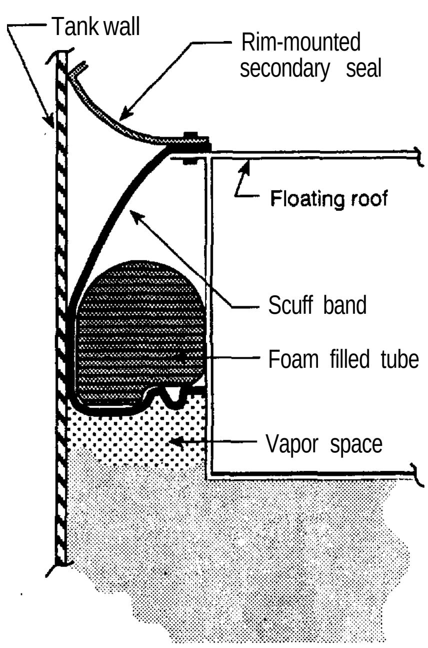


Figure 16. IFR vapor-mounted seal with secondary seal.

Pressure Tanks

Pressure tanks are designed to operate safely at internal pressures above atmospheric pressure. Consequently, these tanks can often be operated as closed systems and do not **have** emissions at normal storage conditions or during routine loading and withdrawal. Pressure-relief valves on the tanks open only in the event of improper operation or an emergency to relieve excess pressure. These tanks are most common for the storage of gases; however, they can also be used to store liquids.

Low pressure tanks can be defined as those operating at up to 2 atm, and high-pressure tanks are those operating at more than 2 atm. However, these values are not specified in the RCRA air rules; pressure tanks are defined in the rules as designed not to vent to the atmosphere as a result of compression of the vapor headspace in the tank during filling of the tank to its design capacity.

In summary, tank emissions primarily occur due to ambient temperature changes and tank filling operations. Control of tank emissions is accomplished by reducing vapor displacement or by venting vapors to closed systems. Tank controls include use of floating roofs with specific seal types and fittings or installation of leak-tight closed-vent systems and control devices that achieve 95 percent or more control.

Containers

Containers are defined under RCRA as, “any portable device in which a material is stored, transported, treated, disposed of, or otherwise handled.” Examples of typical containers are drums, dumpsters or roll-off bins, and tank trucks. Emissions occur from loading these containers, from uncovered containers during storage or transport, from treatment operation losses, and from spills.

Sources of emissions associated with drums include air emissions from the evaporation of leaks and spills; and poor housekeeping practices that can make spill detection and cleanup difficult. If the drums are well maintained on a diked pad, emissions from spills or ruptures can be identified by routine inspection procedures and promptly cleaned up. Dumpsters or roll-off bins can be a source of emis-

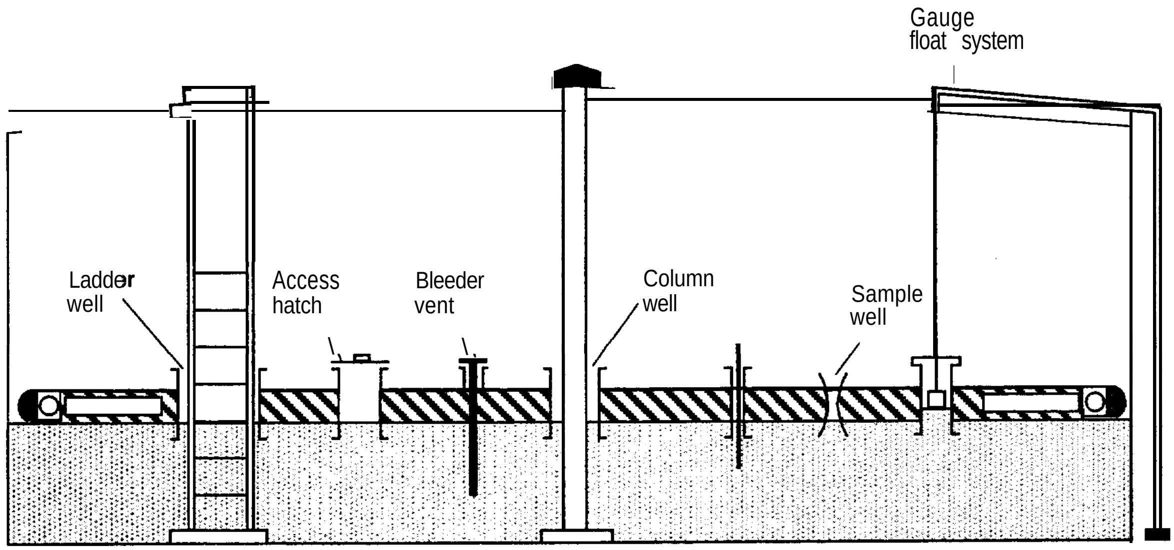


Figure 17. IFR fittings that require controls.

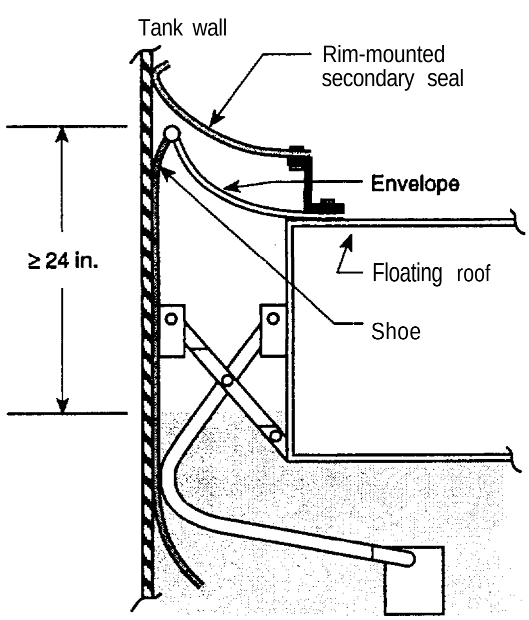


Figure 18. EFR mechanical shoe seal with secondary seal.

sions if they are left uncovered with the surface of the waste exposed to the atmosphere.

Emissions from containers also occur when they are loaded, and emissions are greatest when splash filling (shown in Figure 21) is used. When splash filling, the vapors displaced from the container by loading can quickly become saturated with volatiles caused by the splashing.

Submerged filling (shown in Figure 22) uses an influent pipe that is below the liquid surface, which reduces splashing and the degree of saturation of the displaced vapors. A study of submerged filling of tank trucks indicates that emissions are reduced by about 65 percent relative to splash filling.

A third method of filling containers, bottom loading, is shown in Figure 23. In this case, a tight connection is made between the fill pipe or hose and the container. Also, the container hatches remain closed and all vapors vented from the container can be routed to a control device. A typical bottom loading system with vapor collection is shown in Figure 24. Advantages for bottom loading include improved safety, faster loading, reduced labor costs, and lower emissions.

Other basic controls for containers include using simple covers during storage, placing containers used for treatment operations in an enclosure vented to a control device during treatment, or ensuring that appropriate transport and routine housekeeping practices are followed, with daily inspections and prompt cleanup of spills. For enclosures vented to a control device, EPA has provided criteria for design and operation of the enclosure (40 CFR 52.571, Appendix B). Efficiency of the system depends on the type and operation of both the control device and the enclosure.

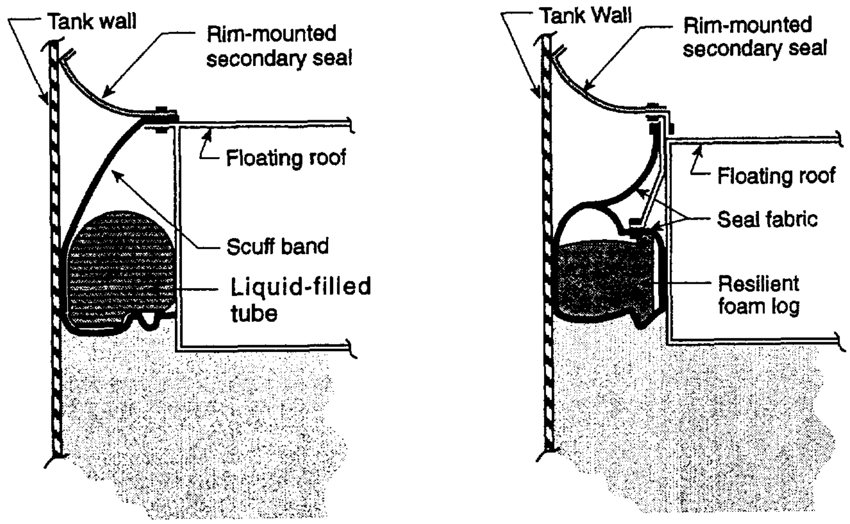


Figure 19. EFR liquid-mounted seal with secondary seal.

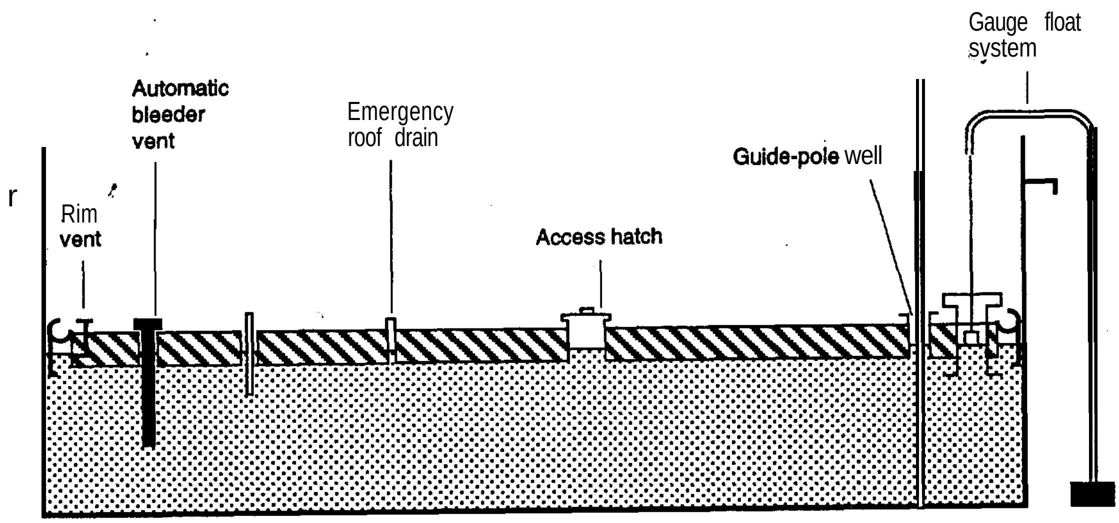


Figure 20. EFR **fittings** that require controls.

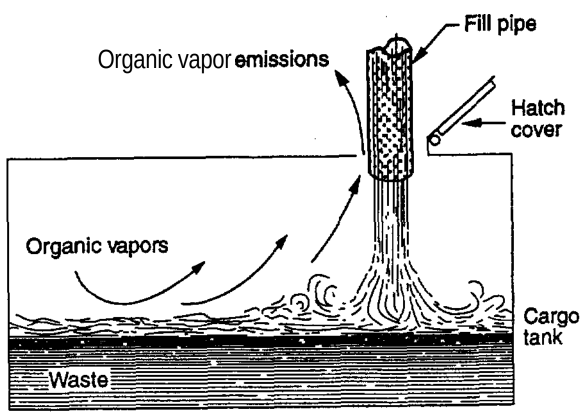


Figure **21.** Splash loading method.

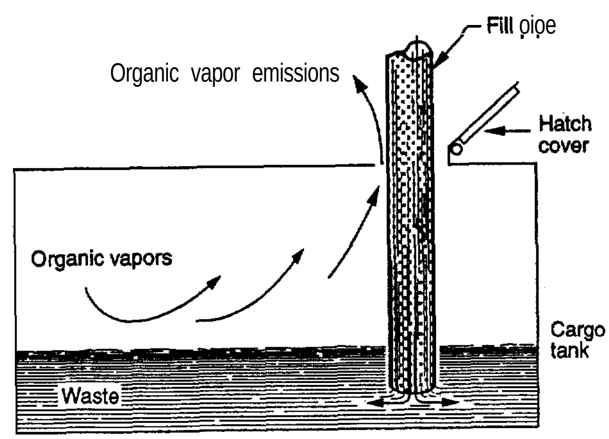


Figure 22. Submerged fill pipe.

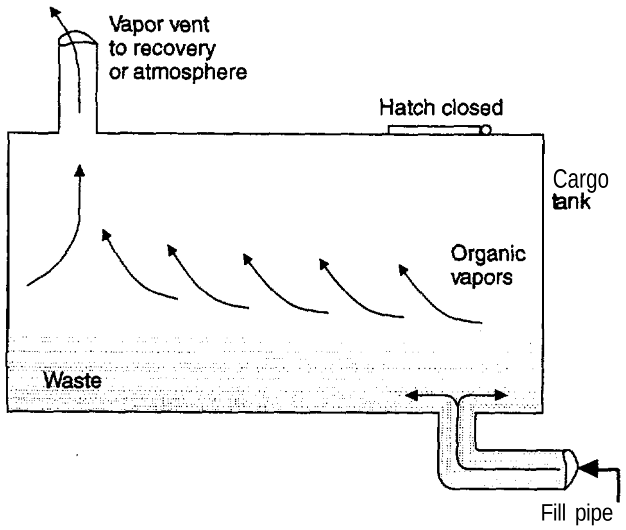


Figure 23. Bottom loading reduces liquid turbulence and vapor and/or liquid contact.

Treatment Devices

Several treatment technologies may be used to remove organic compounds from waste. The most common of these treatments include steam stripping, air stripping, thin-film evaporation, solvent extraction, distillation, and waste incineration.

Features common to all the technologies include avoiding the need for controls on subsequent processes (hence pretreatment), removal efficiency dependant on waste constituents and process design, removal of essentially 100 percent of highly volatile compounds, and applicability to many wastes and compounds.

The control efficiency achieved by waste treatment depends on several factors including the following: percent removed from waste and emissions from removal process, e.g., emissions from a steam stripping operation. Overall, a 98 to 99 percent removal efficiency can be obtained. For example, benzene being steam stripped from wastewater would typically achieve a 98 to 99 percent removal.

Distillation

One of the most commonly used treatment process for organic liquids is distillation. This separation process is based on the differences in volatility of components, and can be performed as continuous or batch operations at atmospheric pressure, under vacuum, or at greater than atmospheric pressure. Batch distillation is the most common of the three for TSDF sites. For each type of distilla-

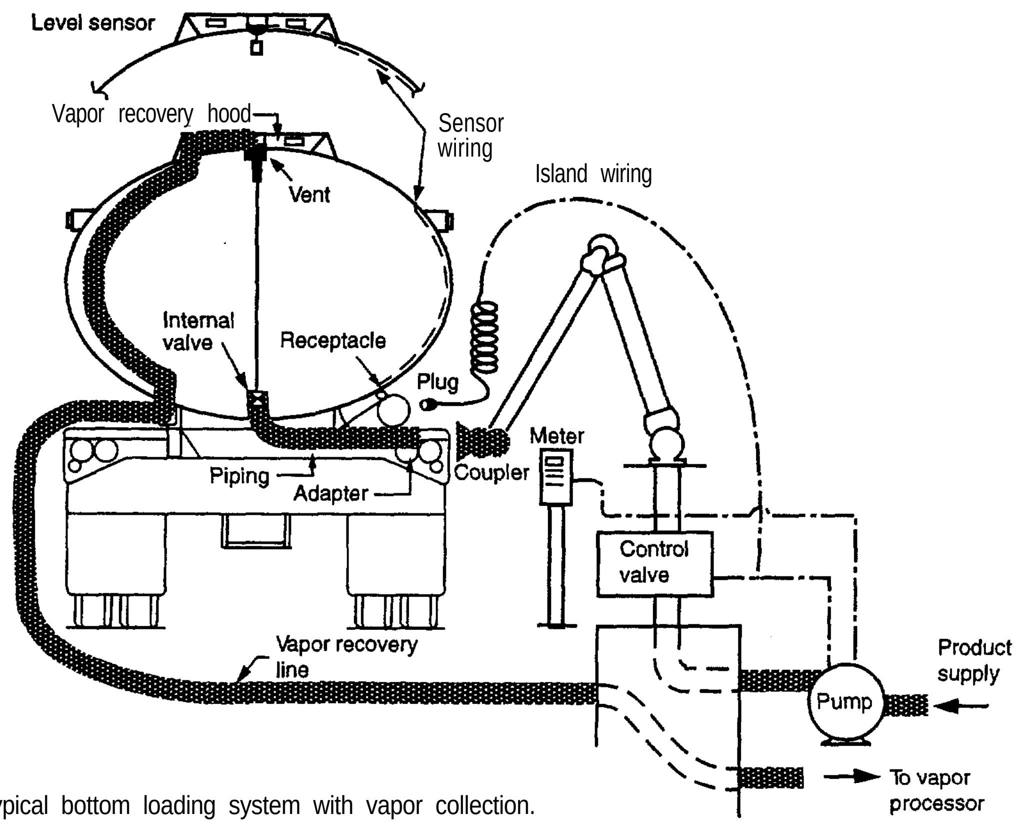


Figure 24. Typical bottom loading system with vapor collection.

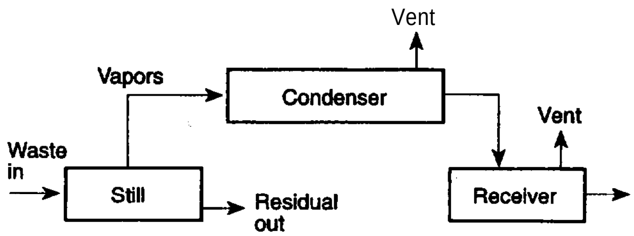


Figure 25. Emission sources for distillation.

tion operation, the organics are transferred from the liquid waste to the vapor phase, then condensed and collected as a separate liquid.

Emissions from distillation typically occur from the overhead venting system, the collection tank vents, or the vacuum system. The primary condenser is an inherent control for these emissions, but pollution control devices can be added to the still vents to provide additional control. Examples include a second condenser or an activated carbon canister. Figure 25 is a schematic showing emission sources for the distillation process.

Solvent Extraction

Solvent extraction is another type of separation process used for organic liquids. In this process, the constituent to be removed preferentially dissolves in a solvent chosen for its high capacity for dissolving the constituent combined with easy physical separation from the remainder of the treated waste. The solvent in the extract is typically recovered by distillation, while the still bottoms containing the constituent are decanted for reclamation or disposal. However, this solvent recovery stage is associated with emissions as shown in Figure 26 at the still vent. Any collection tanks associated with the unit may also have emission points. Although 80 to 100 percent of the target organics can be removed from the waste by the solvent, the overall control efficiency is probably less. Also, waste residuals usually require further treatment.

In common industrial applications, solvent extraction is used to remove phenols, acetic acid, hydroxy aromatic acids, and petroleum oils. Extraction is also applicable for organic sludges such as benzene from petroleum refinery sludge.

Air Stripping

Air stripping is a common treatment process used for aqueous wastes. The stripper may be a spray tower, a packed column, or simply an aerated tank used to provide contact between the waste and air. Strippers are most commonly used to remove parts per million or lower levels of **volatiles** from dilute aqueous wastes. Many strippers are simply vented directly to the atmosphere, while others are controlled by carbon adsorption or incineration. Condensers on air strippers are uncommon and are generally ineffective because of low vapor phase concentrations and high volumetric flow rates. Figure 27 is a schematic diagram of an air stripping system and shows the system elements and vents that are emission points.

Steam Stripping

Steam stripping is another method used to treat aqueous wastes with concentrations on the order of hundreds of parts per million or higher. Steam is injected directly into the wastewater, the overhead vapors are condensed, **organics** are separated from the condensed water, and the decanted water is returned to the feed stream. Emissions occur from the vent on the condenser/decanter and from collection tank vents. Continuous steam strippers operate with either trays or packing and require a low solids content in the feed to prevent plugging and fouling.

Figure 28 is a schematic of an actual steam stripping system and illustrates the use of a heat exchanger to preheat the feed (to recover energy) and to cool the bottoms stream from the stripper before additional wastewater treatment. This particular system has a high level of organic recovery because both a primary and much colder secondary condenser are used. Overall emission control should be excellent because noncondensibles are vented to an incinerator.

For continuous steam strippers, pretreatment as shown in Figure 29 may sometimes be required to adjust **pH** or to remove solids, which can foul the column packing or trays and cause plugging problems. Any separate organic phase that can be decanted from the wastewater is removed prior to stripping.

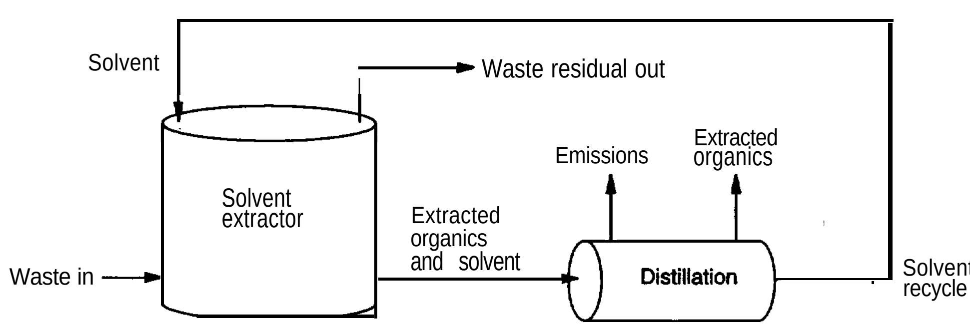


Figure 26. Emissions from solvent extraction.

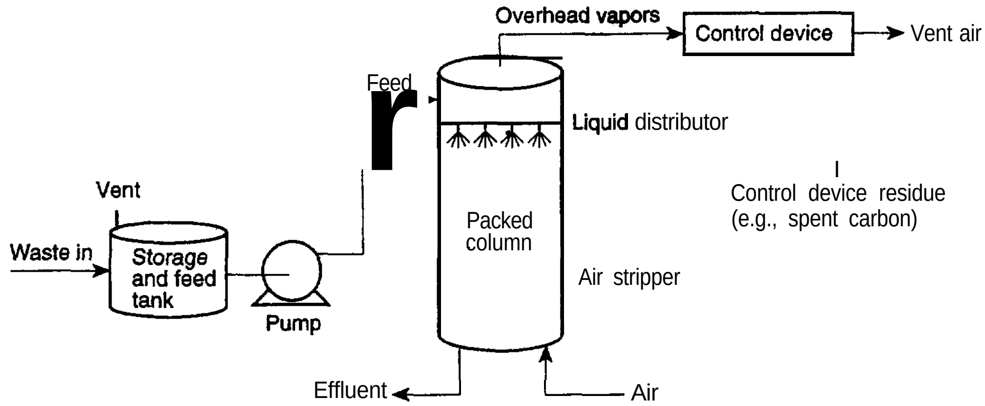


Figure 27. Schematic diagram of an air stripping system.

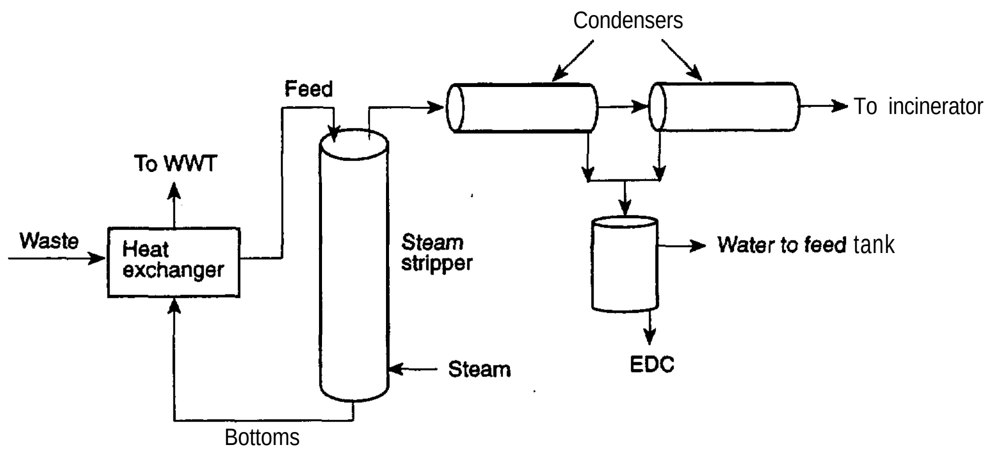


Figure 28. Steam stripper for ethylene dichloride (EDC)/vinyl chloride.

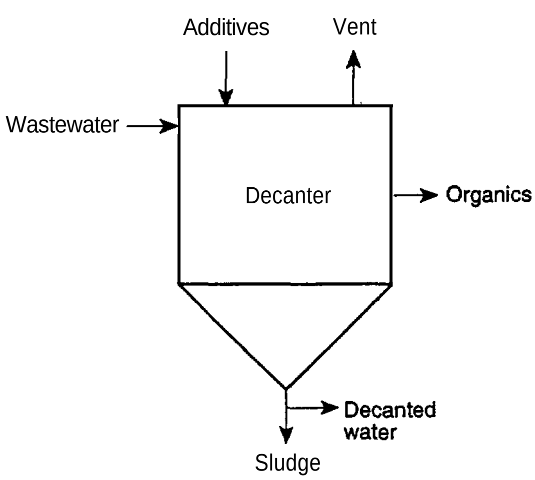


Figure 29. Preliminary treatment prior to stripping.

Emissions from steam stripping come from the condenser/decanter vent and collection tanks. The primary condenser provides an inherent control for this process, but additional control may be obtained by installing control devices on the equipment vents.

Thin-Film Evaporation

Thin-film evaporation typically is used for viscous liquids, sludges, and slurries that often cannot be treated with other technologies. A thin layer of waste is spread over a moving or wiped surface that is heated to volatilize organics. This configuration makes the technology adaptable to many physical forms and waste compositions.

The vertical thin-film evaporator (TFE) looks like a distillation column. In the TFE, the vapors with volatile organics are removed overhead to a condenser, and the treated waste is discharged from the bottom as shown in Figure 30. As with distillation units, emissions occur from vents on condensers, decanters, collection tanks, and vacuum systems if used. The primary condenser is an inherent control, but additional control may be obtained from control devices on the system vents.

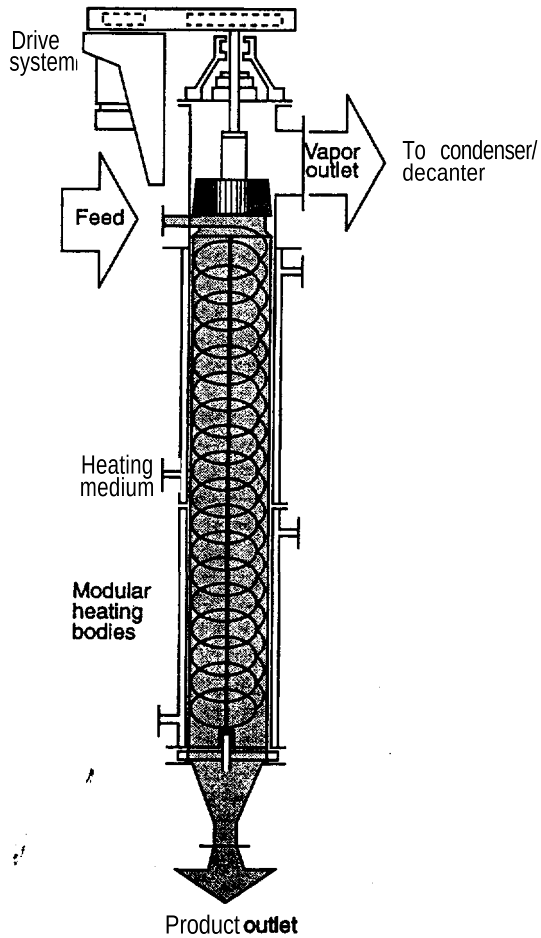


Figure 30. Flow path of thin-film evaporator.

Waste Incineration

Waste incineration is also an emission control option that can be used instead of processing the waste in units with a high emission potential. Waste incineration is commonly used for wastes that were previously land-disposed. The technology provides destruction of 99.9 percent or higher as demonstrated in many units and is applicable to organic wastes and sludges. This technology should not be confused with vapor incineration, which is discussed in a later section.

Control Devices

Conventional, or commonly used, air pollution control technologies applicable to waste management operations are discussed in this section. The conventional air pollution control devices are divided into two types: recovery devices, e.g., adsorption, condensation, and absorption; and combustion devices, e.g., flares, thermal incineration, catalytic incineration, and boilers or process heaters. The recovery devices recover organics for reuse when they are of value, while the combustion devices oxidize the organics to destroy them.

Adsorption

In the adsorption process, organics are selectively collected on the surface of a porous solid adsorbent (activated carbon, silica gels, molecular sieves). Activated carbon is the most commonly used adsorbent because it has high internal surface area, low cost, and insensitivity to water. One gram of activated carbon can have a surface area equal to that of a football field and typically can adsorb up to half its weight in organics. The adsorber will remove essentially all of the target volatiles from the vented vapors until breakthrough, which is when the volatiles are first detected in the cleaned vapor leaving the adsorption bed. Carbon adsorbers can achieve control efficiencies of at least 95 percent, and control levels of 97 to 99 percent have been demonstrated in many applications. The two common types of adsorbers are carbon canisters and regenerable fixed beds.

Carbon canisters, shown in Figure 31, are used for low vent flows, usually less than 100 ft^3/min, and are not regenerated onsite. They are usually discarded or returned to the supplier. The canisters are fairly compact units and can be removed easily and fresh canisters installed. However, their compact size implies limited capacity and a possible requirement for frequent changes.

Fixed-bed carbon adsorbers that can be regenerated (shown as a general process flow diagram in Figure 32 and in more detail in Figure 33) are used for controlling continuous vent streams, with flows exceeding 100,000 ft^3/min, and can handle a wide range of organic concentra-

- For vent flows less than 100 CFM
- Cannot be regenerated in canister

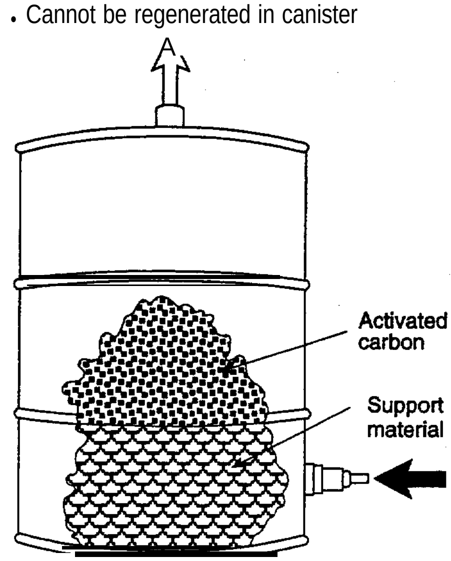


Figure 31. Carbon canisters.

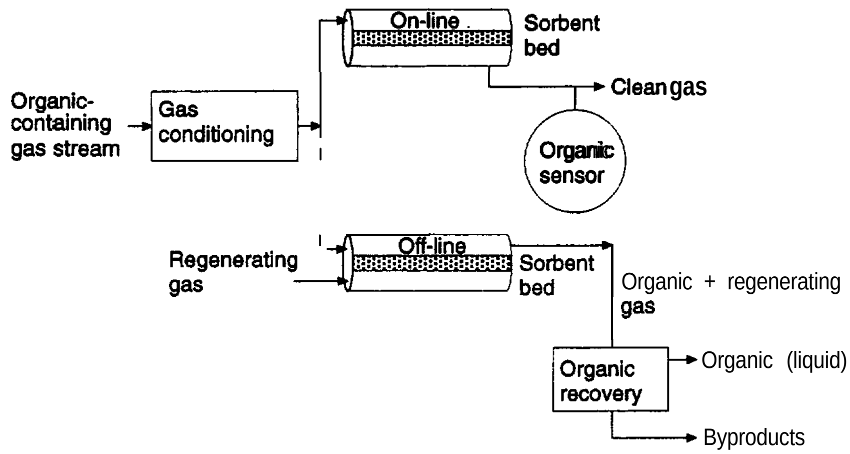


Figure 32. General process flow diagram of an adsorption process for organic recovery.

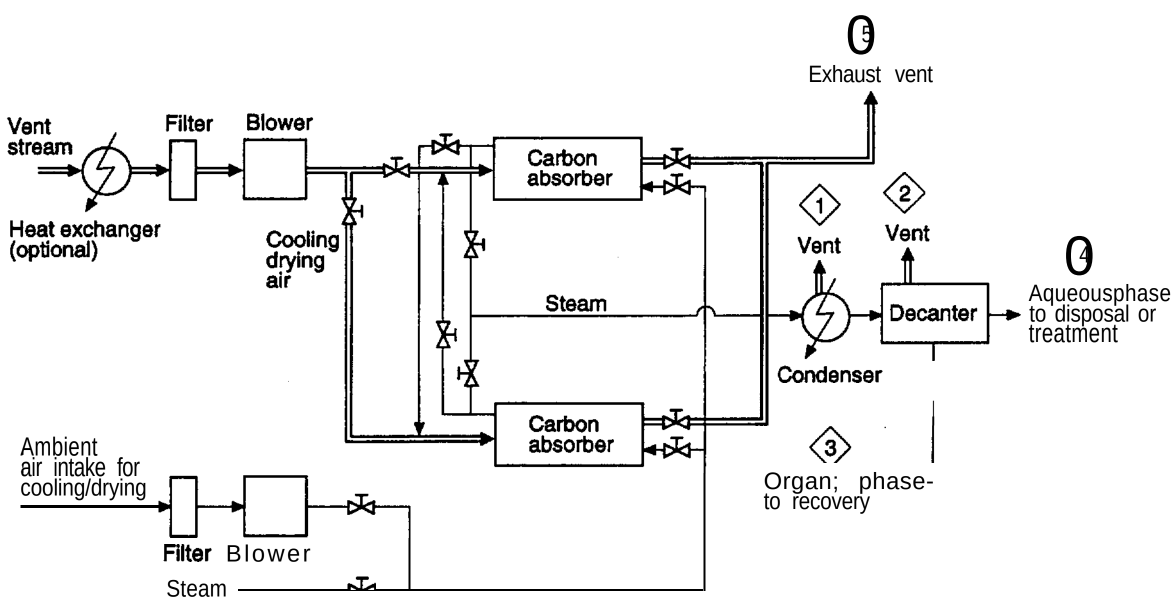


Figure 33. Fixed-bed regenerative carbon adsorption system process flow diagram and potential emission sources.

tions. A common procedure is to have dual beds with one desorbing while the other is adsorbing. The carbon capacity for organics is affected by the concentration of organics in the vapor. Carbon manufacturers generally have equilibrium data for specific compounds and specific carbons. The bed design is important and must be deep enough to prevent rapid breakthrough, yet not so deep as to cause excessive pressure drop. Flow rate is important in the bed design and in determining carbon capacity requirements. Humidity has an adverse effect when water occupies some of the adsorption sites. For a relative humidity of 50 percent or more, dehumidification or dilution may be necessary to lower the relative humidity of the inlet stream. The bed's operating temperature affects capacity, and some compounds such as aldehydes and ketones may generate heat in adsorbers. For these special cases, some means of removing the excess heat may be necessary.

For effective emission control by adsorption, it is necessary either to monitor for breakthrough or to replace the carbon periodically before breakthrough occurs (based on design and operating experience). In addition, any emissions from the disposal or regeneration of the carbon should be controlled. It is of little value to control emissions from a vent stream only to emit the collected organics later in the wastewater treatment associated with regeneration.

Condensation

One of the most common devices for organics recovery is the condenser. Condensers work by cooling the vented vapors to the dew point and removing the organics as a liquid. Typical coolants include cooling tower water, refrigerated water, brines, and glycols. The efficiency of a condenser is determined by the vapor phase concentration of the specific organics and the condenser temperature. Two common types of condensers are contact condensers and surface condensers (also called non-contact or shell and tube condensers).

The contact condenser (shown in Figure 34) is cheap and efficient. However, the cooling liquid that directly contacts the vented vapors can present a disposal problem. For example, if the coolant is water that is sent to wastewater treatment, the volatiles may be emitted in open tanks.

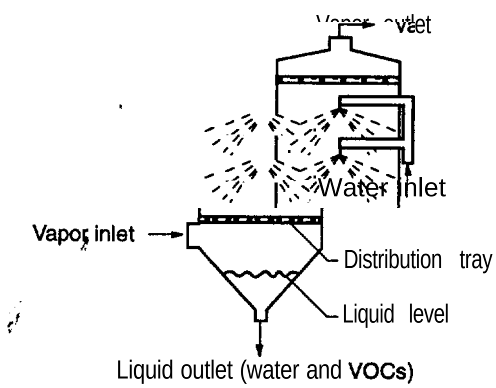


Figure 34. Schematic diagram of a contact condenser.

The shell and tube condenser (Figure 35) does not allow contact between the vented vapors and the cooling medium. In this type of condenser, a concentrated organic liquid can be recovered for recycle or other use.

Absorption

Absorption also is used as an air pollution control technology. In absorption, the organics in. the vent gas are dissolved in a liquid by direct contact as shown for the packed tower absorber in Figure 36. The contact between the absorbing liquid and the vent gas is accomplished in spray towers or packed or plate columns. Some common solvents that may be useful for volatile organics include water, mineral oils, or other nonvolatile petroleum oils. Absorption efficiency is affected by temperature of the gas and sorbent (higher temperatures give poorer absorption), pressure (higher pressures increase solubility), solubility of the constituent in the sorbent (higher solubilities require less sorbent and allow higher efficiencies at equilibrium), and reaction kinetics (for reactions that can effectively remove the constituent from the surface of the absorbing liquid). Absorption efficiencies of 60 to 96 percent have been reported for organics. For example, methylene chloride removal from vented vapors has been measured at 87 percent using water as the absorbing liquid. Commonly, absorbers also are used to remove inorganic gases such as SO_2, H_2S, HCl, and NH_3. When choosing a solvent, it must be compatible with the target constituent at the operating conditions of the absorber.

The material removed from the absorber may present a disposal or separation problem. For example, organics must be removed from the water or nonvolatile oil without losing them as emissions during the solvent recovery or treatment process.

Combustion Equipment

Vapor combustion is another control technique for vented vapors. The destruction of organics can be accomplished

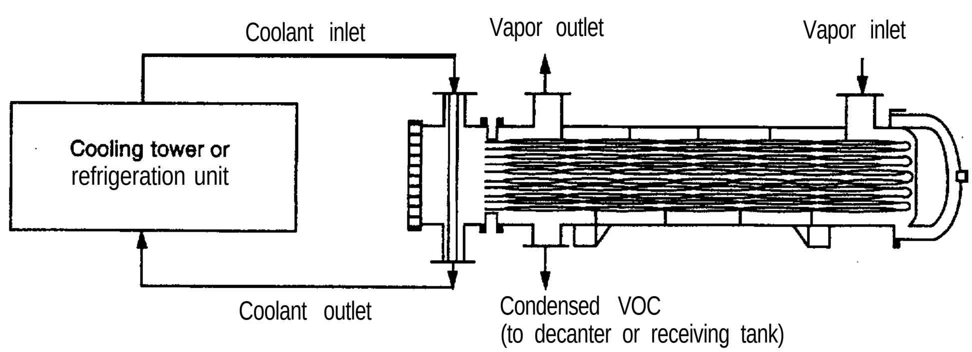


Figure 35. Schematic diagram of a shell-and-tube surface condenser.

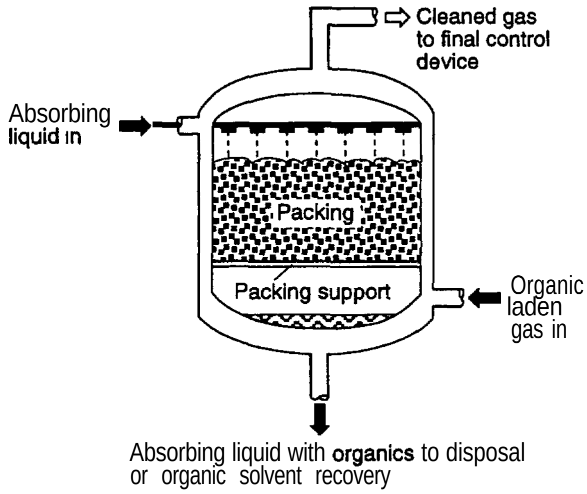


Figure 36. Packed tower for gas absorption.

in flares; thermal oxidizers, such as incinerators, boilers, or process heaters; and in catalytic oxidizers.

Flares are an open combustion process in which oxygen is supplied by the air surrounding the flame. Surrounding the flame with steam improves combustion. Flares are operated either at ground level (usually with enclosed multiple burner heads) or are elevated. Elevated flares often use steam injection to improve combustion by increasing mixing or turbulence and by pulling in additional combustion air. Properly operated flares can achieve destruction efficiencies of at least 98 percent. Figure 37 is a schematic of the basic components of a flare system. The EPA has developed regulations for the design and operation of flares that include tip exit velocities for different types of flares and different gas stream heating values (above 200 Btu/scf). These design and operating criteria were established because of the difficulty and cost associated with measuring flare emissions.

Thermal Incineration

Thermal incineration is a common air pollution control technology used to destroy organic vapors. Thermal incin-

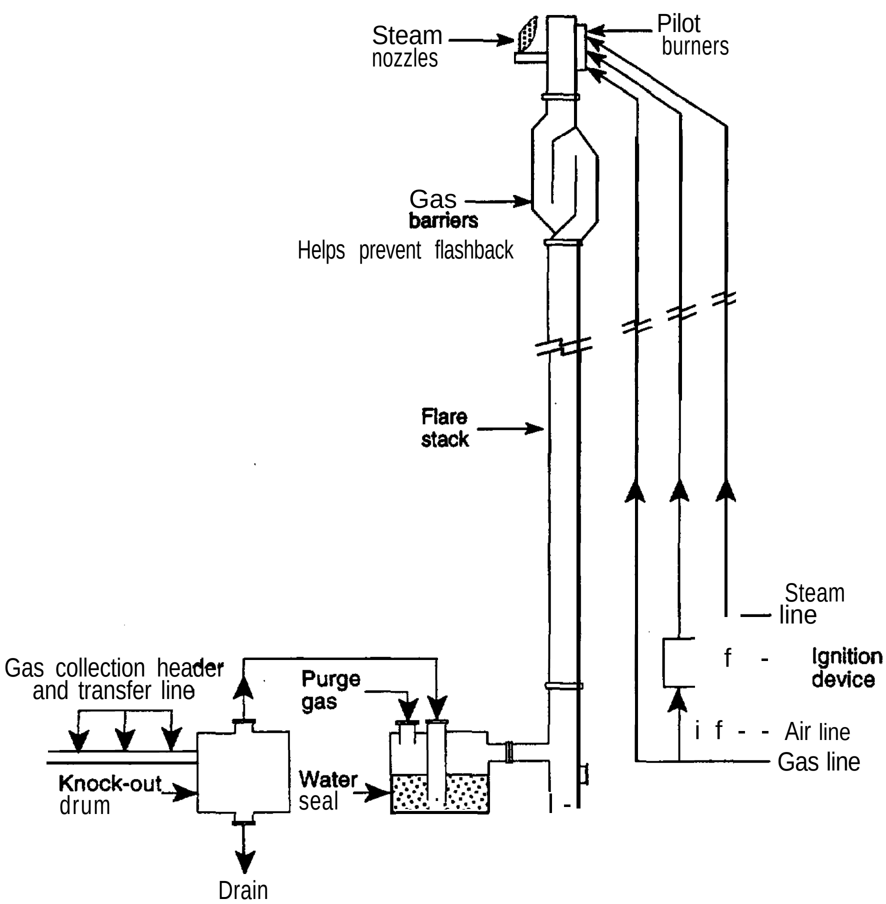


Figure 37. Steam-assisted elevated flare system.

eration requires high temperatures, good mixing, sufficient oxygen, and adequate resident time for proper operation and complete combustion of the organics. Auxiliary fuel is needed if the heating value of the waste gas is less than 50 Btu/scf. Thermal vapor incinerators are available in a wide range of sizes; capacity from 200 to 50,000 scfm are available. Destruction efficiency of at least 98 percent is achievable for an inlet concentration greater than 2,000 ppm. Below 2,000 ppm, EPA studies have found that combustion or destruction efficiency decreases as concentration decreases below 2,000 ppmv. A heat recovery unit, such as a steam generator, may be used to recover some of the energy from a thermal incinerator. Figure 38 is a depiction of the major components of a thermal vapor incinerator.

The two types of thermal incinerators are recuperative and regenerative. Recuperative incinerators have an exterior shell and tube type heat recovery system and process gases with heats of combustion sufficiently high to sustain high temperatures without auxiliary fuel. Regenerative incinerators have internal heat recovery by means of two or more, usually ceramic, gas paths through the incinerator. While gases are burned and heating one side, the previously heated side is used to heat the incoming gas. The two sides are switched to maintain an operating equilibrium. Regenerative incinerators are effective for waste gases with low concentrations of the constituent to be destroyed.

Catalytic Incineration

Catalytic incinerators provide oxidation at temperatures lower than those required by thermal incinerators (typically 350°C to 500°C versus 750°C to 1,000°C). Design considerations are important because the catalyst may be adversely affected by high temperatures, high concentrations of organics, fouling from particulate matter or polymers, and deactivation by halogens or certain metals. Destruction efficiencies in catalytic incinerators are on the order of 98 percent. The basic components of a catalytic oxidizer are shown in Figure 39 and are similar to those of a thermal unit except that a catalyst bed is used. Sizes of catalytic incinerators range from large, high-volume units to small, low-volume packaged units. A fluid-bed catalytic incinerator is shown in Figure 40. The energy requirements (and therefore, operating costs) of a catalytic oxidizer are lower than those of a thermal unit because of the lower operating temperatures. However, capital costs are higher.

Existing Boilers and Process Heaters

The organics in vented vapors can also be destroyed with a high level of efficiency in existing boilers or process heaters. In this case, no dedicated or new control equip ment is required. In these devices, vapors with halogens or sulfur are sometimes avoided because of potential corrosion problems when acid gases are formed. These devices recover the heating value of the vent stream and also offer the advantage of using existing equipment to control emissions. Vent streams are added as fuel, as secondary combustion air, or as diluent. Other advantages include recovery of the heating value of vent stream and destruction efficiencies of 98 percent or higher.

Unconventional Technologies

New, unconventional technologies are being used more frequently in the United States. One of these technologies, a modified two-stage system, combines adsorption with incineration or further adsorption. The first stage collects the target constituent and concentrates it in a regenerated gas from less than 100 ppm up to more than 2,000 ppm. The second stage involves more conventional treatment and depends on the concentration and chemical characteristics of the constituent. For example, if the constituent

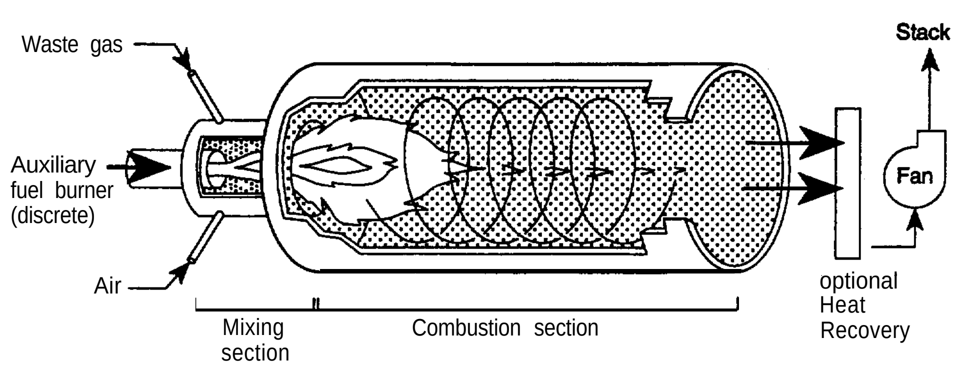


Figure 38. **Thermal** vapor incinerator.

can be reused, fixed bed adsorption would be used to collect it. Otherwise, the constituent would be thermally or catalytically incinerated. The most common of the two-stage systems with rotary carousels is shown in Figure 41. In this system either activated carbon or zeolite is used as the first-stage sorbent. While one segment of the wheel is adsorbing, another segment is being desorbed. While the second stage shows incineration or recovery in the figure, the specific process that is chosen depends on site conditions.

A carousel system in line with an incinerator is shown in Figure 42. In this configuration, combustion gas is used to produce hot desorption gas by means of a heat exchanger. Many of these units are in operation in Japan and Europe, and several have recently begun operation in the United States. Their use is driven by air standards and air toxics rules. These systems do not tolerate particulate loadings well and may require filtration of the incoming gas stream.

Another nonconventional device that is finding increased use for air pollution control is biofiltration. Vapors are vented through biologically active material where organics are digested to carbon dioxide and water by microorganisms. This technology, similar to compost in a garden, has been successfully applied in Europe to control odors, volatile organic compounds, and air toxic emissions. However, the process has not been used extensively in the United States. One of the properties of biofiltration is a general limitation to organic concentrations of 1,000 ppm or less, although new systems are reportedly treating higher concentrations. Control efficiencies greater than 90 percent are achieved in various applications, and the literature indicates low operating costs that provide an economic advantage over other technologies. Figure 43 is a schematic of an open single-bed biofilter system. In practice, industrial applications typically involve multiple closed or covered beds.

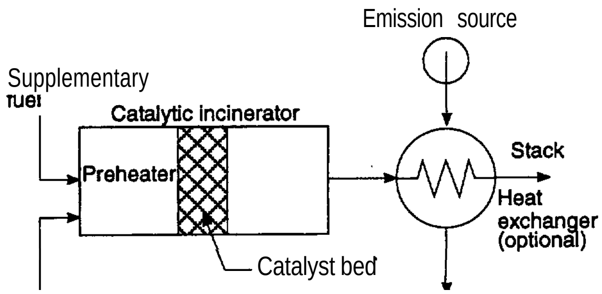


Figure 39. Schematic diagram of a catalytic incinerator system.

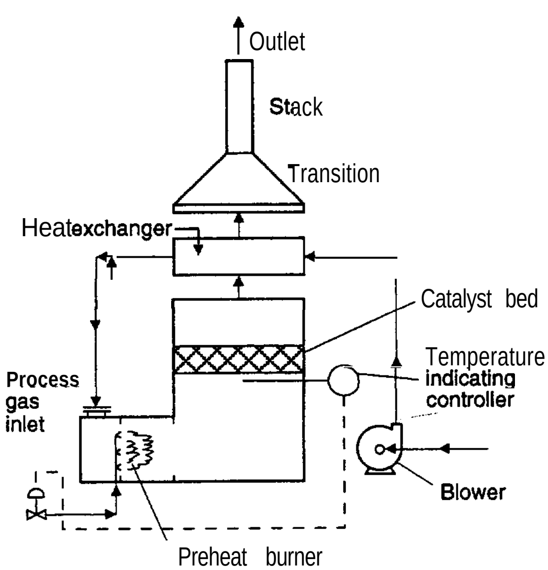


Figure 40. Fluid-bed catalytic incinerator.

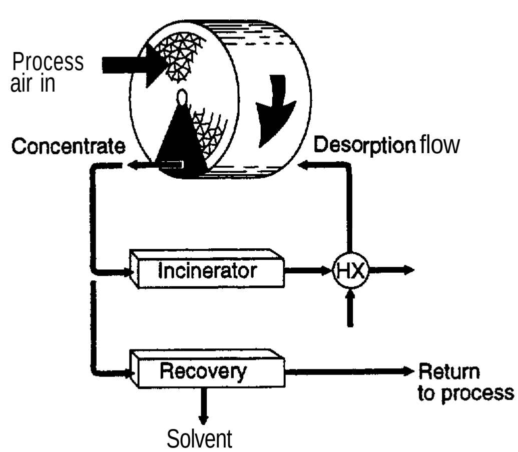


Figure 41. Typical rotary carousel system.

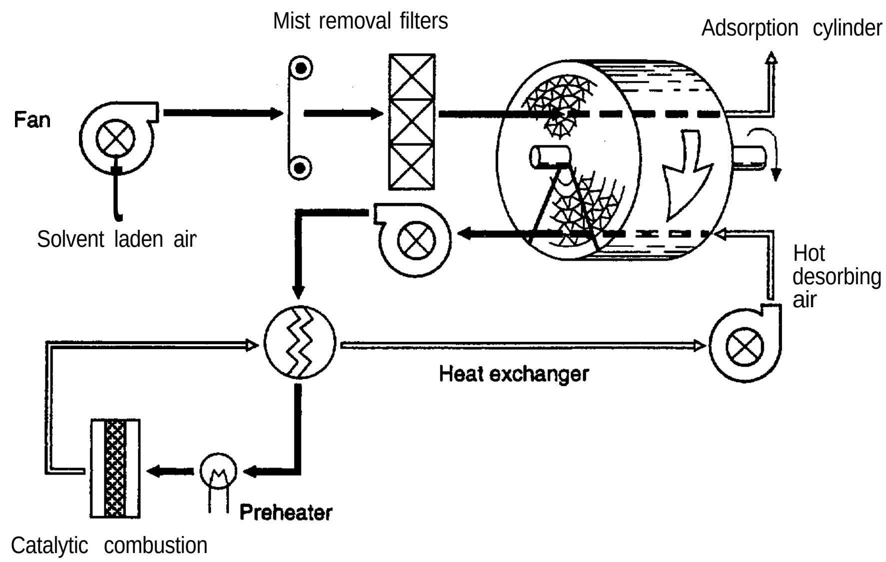


Figure 42. Carousel system with incinerator.

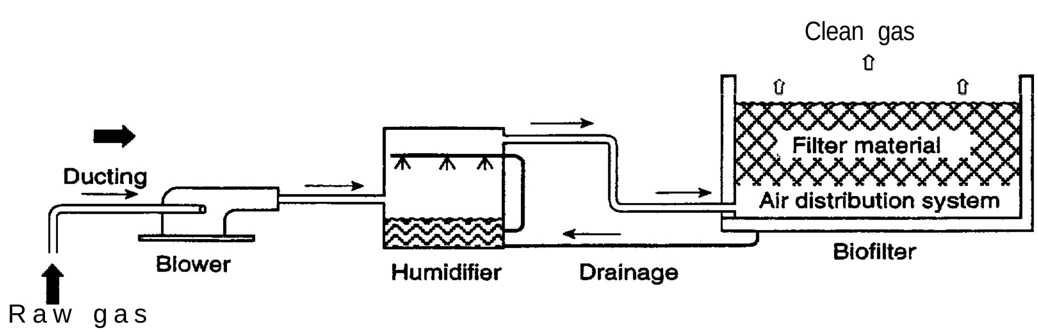


Figure 43. Schematic of an open single-bed biofilter system.

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