CHAPTER 10

SPECIAL WASTE DRAINAGE SYSTEMS

This chapter describes and discusses the collection and criteria necessary for the design of liquid effluent from various special waste drainage systems other than discharge from sanitary and storm water sources. Except for the neutralization of acid effluent, treatment methods are outside the scope of this chapter.

Each waste system discussed has unique properties that must be separately addressed. These systems are generally routed from fixtures and equipment into a local facility waste treatment system, with the treated effluent discharging directly into the public sanitary sewer system. Very often, untreated waste is stored on site and collected by approved waste removal contractors for disposal.

Unless specifically noted otherwise, all of the waste streams will be assumed to have the approximate flow characteristics of water. Pipe sizing criteria is based on this assumption.

CODES AND STANDARDS

There are two general jurisdictional bodies that regulate different aspects of special waste systems.

The first is the local and regional authorities that create and enforce plumbing and health codes. Included are the local authorities charged with review and approval of plumbing systems design. They are concerned primarily with regulating sizing and design of the piping systems within buildings. Their regulations generally mention special system piping material, treatment and system configuration. They do not mandate specific use of double-wall piping or leak detection. These requirements are mandated by federal, local and state agencies. Recommendations for piping material usually require that any pipe material be approved by the local authority and be capable of resisting degradation and the effects of the nature and concentration of any special waste. System design is concerned only with adequacy of the pipe to carry away the design flow. System configuration usually requires that traps be provided on fixtures and floor drains, and that the venting system conform to good plumbing design practice. The effect that the very general regulations have in terms of conformance with local and model plumbing codes is that all elements of the system design are left to the experience of the design engineer and are also to comply with the requirements of other regulating agencies.

The second jurisdictional body, and with far more stringent regulations, is the various agencies concerned with protecting workers, the public and the environment from the discharge of toxic substances. Included are federal, state and local authorities responsible for preventing discharge into the general environment, public sewers and public treatment systems of any substances considered harmful. Discharges can occur either lawfully or unlawfully, or as a result of spills and accidents. In order to prevent this discharge, it is common practice for these agencies to inspect facilities, mandate treatment systems, and require the use of specific piping systems such as double-wall piping and leak detection to advise of such leakage. The effect of some very specific regulations in terms of conformance with agency requirements is to rely on the experience of the design engineer to provide pipe materials and systems capable of complying with regulations and receiving approval from those agencies. Other regulations, such as cGMP and validation, are constantly being revised because of technological and design changes.

It is recommended that the services of an experienced environmental consultant, who is familiar with the latest applicable rules and regulations and their interpretations, be consulted for system compliance with the maze of regulations.

SYSTEM APPROVAL REQUIREMENTS

There are no applicable codes or standards relating directly to a chemical or acid drainage system. Any special drainage system effluent routed for treatment inside a facility or on the site does not require examination or approval by the local plumbing official. If any effluent is routed to the public sanitary sewer system for eventual treatment, maximum concentrations of any contaminant or pH levels will have been established by the local authorities having jurisdiction. The discharge then requires conformance with local regulations.

If the only required method of treatment is pH adjustment prior to discharging into the building sanitary drainage system or public sewer system, most authorities have requirements for acid drainage systems that must be followed. A generally accepted pH value of 4.0 is the lowest acceptable level for direct discharge into a public sewer system.

GENERAL MATERIAL, SIZING AND DESIGN CONSIDERATIONS

PIPE MATERIAL AND JOINT SELECTION CONSIDERATIONS

Selection of the most appropriate piping and jointing method is made by first establishing the composition and concentration of all chemicals that are to be expected and then establishing their expected flow rate and temperature range. All manufacturers of pipe have published chemical compatibility charts that give the effect various chemicals have on that particular pipe and recommendations for acceptance using these chemicals. For conditions that are not on these charts, direct contact with the manufacturer of the material giving the anticipated conditions will allow them to ask technical assistance from their organizations, which have the experience to provide answers.

When compatibility for various pipe systems is the same, total installed cost and possible ease of disassembly will be the deciding factors.

PIPE SIZING CONSIDERATIONS

System design is concerned only with adequacy of the pipe to carry away the design flow. System configuration usually requires that traps be provided on fixtures and floor drains, and that the venting system conform to good plumbing design practice, which limits the pressure inside the system. All elements of system design are left to the experience of the design engineer.

The various plumbing codes generally use only satisfactory performance as a sizing guide for special waste system pipe sizing, as compared to specific drainage requirements used for sizing sanitary drainage systems. A common exception is drainage and vent systems for laboratory fixtures, which may require sizing based on a fixture unit basis if mandated by the local code.

The reason for the lack of code requirements is that special drainage systems do not have a predictable or documented past usage history as do standard plumbing fixtures in sanitary drainage systems. Equipment drainage, spills, discharge from production facilities and discharge from fixtures within the facilities are not always planned. They occur mostly at random intervals dictated by cleaning, production and maintenance schedules and, often, accidents.

In addition, special drainage systems that are completely within the property of the facility do not fall under plumbing or other local code requirements for piping size or design. Because of these factors, the special drainage piping system is sized on the basis of ‘‘good engineering practice,’’ which uses pipe slope, composition of the effluent and the expected flow rates rather than fixture units.

From each point in the system, the flow rate and pitch of the piping must be known in order to size the pipe. Determine the pipe size based on the following criteria.

1. Effluent has the characteristics of water.

2. The drainage system is sized on the basis of gravity drainage and maintaining a minimum scouring velocity of between 2 and 2.5 ft per second (fps) or 0.6 to 0.75 meters per second (ms) using the anticipated average flow rate and pitch of the pipe at each point of design.

3. Gravity drainage pipe size is based on flow rate, slope and velocity. Refer to Table 10.1, which is an abridged table for finding the pipe size based on flow rate, velocity and slope. Depending on the system, piping should be sized to flow between ½ to ¾ full to allow for unexpected larger discharges, future changes and accidents.

PH DEFINITION

Any dissolved impurity in water separates to form negative and positive charged atoms called ions. Negative ions are called cations because they migrate to the cathode, and positive ions are called anions because they migrate to the anode.

All acid compounds consist of hydrogen combined with an acid radical. In a mixture of acid and water, hydrogen ions result. pH is a measurement of the hydrogen ion concentration of a solution. Since the balance of hydroxyl (cation) and hydrogen (anion) ions must be constant, changes in one ion concentration produces a corresponding change in the other. The pH value is calculated from the logarithmic reciprocal of the hydrogen-ion concentration in water. The pH scale ranges from 0 to 14, with 0 being acid and 14 being alkaline. 7.0 is neutral. A change of one unit represents a tenfold increase (or decrease) in strength. pH is not a measure of alkalinity.

GENERAL SYSTEM DESIGN CONSIDERATIONS

It is good practice to separate each of the different systems inside the facility or building to a point outside the building so that the individual services can be isolated and allowed to be tested and sampled as may be required in the future by any local or national authority. Also, the system may, at some point in the future, require separate treatment because of a new substance that may be discharged. For this reason, the effluent should be routed outside the building separately and discharged into a manhole. This manhole could receive sanitary effluent, further diluting the treated chemicals or acid. A typical manhole capable of receiving acid is illustrated in Fig. 10.1 The elbow on the outlet would be eliminated if there were no sanitary inflow to the manhole.

One of the most constant aspects of the special drainage systems are future changes. In time, the processes will change, equipment will be more efficient, facilities will become larger and technology will be improved so that the effluent will be different from the time that the systems were originally designed. This change must be allowed for. It is common practice to size the drain one size larger than the design figures indicate, or, by not sizing the drain line to the exact point on the sizing chart where the figures indicate, especially where there is a probability of future expansion.

TABLE 10.1 Slopes of Cast Iron Soil Pipe Sanitary Sewers Required to Obtain Self-cleansing Velocities of 2.0 and 2.5 ft/sec. (Based on Mannings Formula with $N = .012$)

Pipe size (in.)	Velocity (ft./sec.)	¼ Full		½ Full		¾ Full		Full	
		Slope (ft./ft.)	Flow (gal./min.)	Slope (ft./ft.)	Flow (gal./min.)	Slope (ft./ft.)	Flow (gal./min.)	Slope (ft./ft.)	Flow (gal./min.
2.0	2.0	0.0313	4.67	0.0186	9.34	0.0148	14.09	0.0186	18.76
	2.5	0.0489	5.84	0.0291	11.67	0.0231	17.62	0.0291	23.45
3.0	2.0	0.0178	10.11	0.0107	21.46	0.0085	32.23	0.0107	42.91
	2.5	0.0278	13.47	0.0167	26.82	0.0133	40.29	0.0167	53.64
4.0	2.0	0.0122	19.03	0.0073	38.06	0.0058	57.01	0.0073	76.04
	2.5	0.0191	23.79	0.0114	47.58	0.0091	71.26	0.0114	95.05
5.0	2.0	0.0090	29.89	0.0054	59.79	0.0043	89.59	0.0054	119.49
	2.5	0.0141	37.37	0.0085	74.74	0.0067	111.99	0.0085	149.36
6.0	2.0	0.0071	43.18	0.0042	86.36	0.0034	129.54	0.0042	172.72
	2.5	0.0111	53.98	0.0066	107.95	0.0053	161.93	0.0066	215.90
8.0	2.0	0.0048	77.20	0.0029	154.32	0.0023	231.52	0.0029	308.64
	2.5	0.0075	96.50	0.0045	192.90	0.0036	289.40	0.0045	385.79
10.0	2.0	0.0036	120.92	0.0021	241.85	0.0017	362.77	0.0021	483.69
	2.5	0.0056	151.15	0.0033	302.31	0.0026	453.66	0.0033	604.61
12.0	2.0	0.0028	174.52	0.0017	349.03	0.0013	523.55	0.0017	678.07
	2.5	0.0044	218.15	0.0026	436.29	0.0021	654.44	0.0026	872.58
15.0	2.0	0.0021	275.42	0.0012	550.84	0.0010	826.26	0.0012	1101.68
	2.5	0.0032	344.28	0.0019	688.55	0.0015	1032.83	0.0019	1377.10

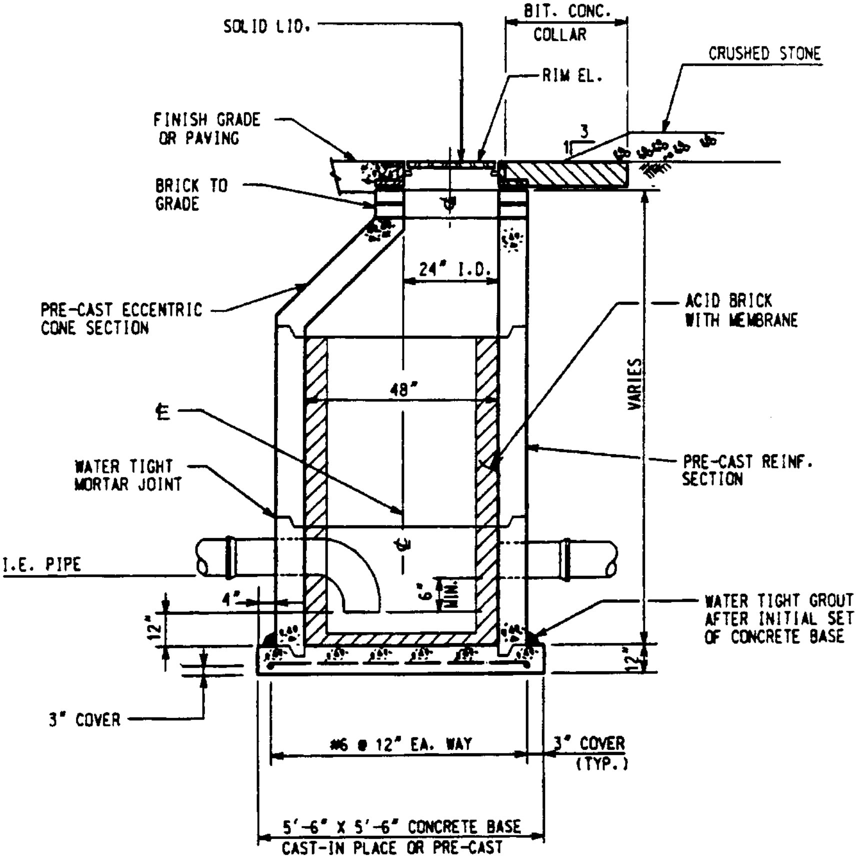

FIGURE 10.1 Typical acid manhole.

Selecting a pipe size slightly larger than required for the immediate flow rate or a material that is capable of resisting a greater selection of chemicals than necessary at the time of design should be considered. This, of course, must be verified with the client to assure that the extra cost is acceptable.

ACID WASTE AND VENT SYSTEMS

GENERAL

An acid waste drainage system collects and transports liquid wastes with a pH lower than 7.0 from laboratory fixtures, equipment and all areas of a facility for discharge into an appropriate treatment facility or the sanitary drainage system after local treatment. The acid vent system equalizes flow in the drainage system in the same manner as the sanitary drainage system. For purposes of this chapter, acid waste will be divided into two general categories: laboratory waste and industrial waste.

A laboratory could be considered as any room or area within a building where investigation, teaching, testing, experiments and research is conducted. Pharmaceutical facilities generally prepare, manufacture and package drugs of all kinds. Manufacturing is generally considered any facility where a product is the end result of having material or components packaged or assembled from parts obtained elsewhere or made within the facility. These facility definitions cover an extremely wide range of possible drainage categories discharging from various sources, each with different effluent characteristics and design requirements.

Laboratory waste consists primarily of diluted and concentrated mixtures of liquid chemical substances of mineral and organic origin, and water. Acids of many types are usually present. Laboratory waste is discharged from sinks, cup sinks, flume hoods, other similar fixtures and equipment. Discharge from floor drains, autoclaves, glass washers and condensed water from various sources are also included. All of these fixtures would require a separate vent, and should be considered a completely separate drainage system.

Acid waste drainage from industrial facilities will consist of accidental spills originating from tanks and piping and anticipated waste from equipment into drains. Very often, the drainage piping would have to carry many of the acids that are used as part of the process. Where spills are directed into holding tanks, the drainage piping, tanks, pumps and piping necessary to convey the effluent to treatment facilities will normally be part of the plumbing engineer's responsibility.

The most important considerations in the selection of piping, valves and tanks for acid are concentration and temperature of the acid. Acid wastewater from chemical and other facilities must be neutralized to a pH of 4.0 or higher prior to eventual disposal into the public sewer system.

Health and Safety Concerns

All grades and concentrations of acids can cause severe damage to eyes and tissues of the body. Contact with the skin will cause irritation and burns. Contact with the eyes could cause blindness. Inhaling the mist or vapors could cause lung irritation or burns. Ingestion will destroy tissue of the mouth, throat and stomach. Extreme care should be exercised in the handling and cleanup of all acids.

These concerns mandate that emergency drench equipment be provided immediately adjacent to all hazards and locations where spills and other accidents could occur. If several people are normally present at a hazardous location, multiple drench equipment should be provided. Where fumes may be given off, emergency breathing apparatus shall be provided. Refer to Chap. 17, Life Safety Systems, for a discussion of such emergency equipment.

For the laboratory environment, emergency showers shall be easily available to every room. Where rooms are adjacent, a single shower is acceptable. Floor drains for emergency drench equipment are not required but will prevent the surrounding floor from becoming wet and a hazard to helping individuals. Every room shall have an emergency eyewash inside the room usually mounted on a sink or free standing if sink mounting is not possible. In large rooms with more than one sink, it is good practice to install emergency eyewashes on each end.

Where the generation of acid vapor is possible, fog nozzles using water to suppress the vapor and foam systems to prevent vapor from rising should be considered to mitigate the effects of an accidental spill.

Common Types of Acids

Acids are widely used chemicals in the chemical processing industry. The most commonly used acids are as follows.

1. *Sulfuric acid* (H_2SO_4). Sulfuric acid, among the most used of the acids, is commercially available in many concentrations and as various percentages of oleum. Oleum is sulfuric acid containing sulfur trioxide dissolved in the acid, which are called ‘‘fuming’’ grades. Generally recommended piping materials for these acids at low temperatures (140°F [60°C] and lower) and up to 90% concentration could be PVC, CPVC, PP, PVDF, ETFE and HDPE plastic, glass, Alloy 20, Duriron and FRP piping with special resins. At 90% concentration and higher, carbon steel schedule 80 is often used. Stainless steel is generally unsuitable, except for oleum greater than 103% concentration. Vent lines should be of the same material as the drain line.

Valve types include ball, gate and diaphragm, with gate valves being the most commonly used. For low pressure and temperatures suitable for the specific plastic pipe, plastic is often used. For higher temperature and pressures, alloy 20 is preferred. In all cases, because of differences in manufacture, pipe vendors should be consulted as to the suitability of materials for specific acid piping service.

Centrifugal pumps constructed of SS alloy 320 with Teflon packing are in common use. Other manufacturers use FRP and plastic pumps. Also available are metallic pumps lined with plastic or glass. Temperature limits should be carefully checked for material suitability.

Spills of concentrated acids from tanks onto floors and on equipment should be washed off and flooded with water, which can then be routed to the acid drainage system for neutralization. Tanks that contain this spillage should be of a suitable plastic. Since water reacts rapidly with the acid and splatters, caution should be exercised. Heat and fumes are also given off. Breathing of the fumes will cause throat and lung injury. Where this situation is possible, suitable emergency breathing apparatus should be provided. An emergency shower should be provided in the immediate vicinity of acid storage and pipe routing.

Sulfuric acid is nonflammable, but it is highly reactive. Below a concentration of 75% it reacts with carbon steel and other metals to form hydrogen. It is particularly hazardous when in contact with carbides, chlorates, nitrates, fulminates, picrates and powdered metals. In higher concentrations it will ignite combustible materials such as oily rags and sawdust. Dry chemicals or carbon dioxide are the fire suppression methods of choice.

Oleum spills, because of the danger of fumes, should be contained by curbs and the liquid diverted away from the area of a spill to a containment area where the liquid will be neutralized. The resulting liquid should be absorbed with diatomiatus earth, expanded clay or other non-reactive material. This material will be carted away for suitable disposal.

2. *Phosphoric acid* (H_3PO_4). Phosphoric acid is available in concentrations of between 75 and 87%. Recommended pressure piping is SS type 316 Extra Low Carbon (FLC). Drainage and vent piping, valves and pumps are similar to those used for sulfuric acid. OSHA has limits for human exposure to this acid.

Spills, safety and health concerns are similar to those for sulfuric acid.

3. *Hydrochloric acid* (*HCL*). Hydrochloric acid, also known as Muriatic acid, is available in four strengths designated as degrees Baume (an equivalent notation of specific gravity).

Piping materials for drainage and vent piping, valves and pumps are similar to those used for sulfuric acid. Spills, safety and health concerns are similar to those for sulfuric acid, except that caustic soda should not be used because hydrochloric acid reacts with this chemical.

4. *Nitric acid* (HNO_3) Nitric acid is available in three grades, designated by percent of concentration by weight: 56–70, 70–84 and 97.5–100%.

Recommended pressure piping material for concentrations up to 95% is 304L SS. Above this concentration, aluminum piping is recommended. Pumps for concentrations up to 95% should be constructed of 304L SS. Above this concentration, titanium, aluminum type 3003 or silicon iron are commonly in use. Recommended materials for gate, ball, plug and globe valves are 347 SS or 304L SS. Drain lines should be glass.

Spills, safety and health concerns are similar to those for sulfuric acid, except that temperature and humidity has an effect on reaction of nitric acid on such metals as copper, brass and zinc. Nitric acid reacts violently with organic substances, occasionally causing explosions. Self-contained breathing apparatus is required when approaching spills because of the emission of nitrogen oxides, commonly called nitrous fumes, which are extremely hazardous.

5. *Hydrobromic acid* (*HBR*). Hydrobromic acid is commercially available in two concentrations: 70 and 99.95%.

Recommended pressure piping materials are glass and rubber lined steel pipe, PVC, PE and PTFE. Glass pipe could be used for drainage in addition to the pressure piping. Valve types are often ball and plug type with PVC, PE and PTFE lining. Rubber lined pinch valves are commonly used. Pumps are similar to those used for sulfuric acid, with the addition of Hasteloy B material.

Spills, safety and health concerns are similar to those of phosphoric acid, but, in addition, the vapors are much more hazardous. This acid reacts with metals and produces explosive hydrogen gas.

6. *Perchloric acid* ($HCLO_4$). Perchloric acid is available in a concentration of 69–72% strength and is the strongest of all the inorganic acids.

Recommended pressure piping materials are glass and PTFE. Drain lines could be glass or Duriron. Valve types are often ball and plug type manufactured from PTFE and Duriron. Pumps manufactured from PTFE are the most commonly used.

Spills, safety and health concerns are similar to those of phosphoric acid, except that when heated to 150°F (64°C), perchloric acid can cause objects not normally considered combustible, such as rubber gloves and human skin, to burst into flames.

SELECTION OF LABORATORY WASTE PIPING AND JOINT MATERIAL

The majority of the effluent from an ‘‘average’’ laboratory consists of primarily water and acid. Chemicals used for experiments are usually confined to fume hoods if toxic to the staff. Obtain from the end user the extent and concentration of all the chemicals expected to be used in the laboratory.

The most cost effective piping above the floor from laboratory fixtures is generally fire retardant polypropylene, either with heat fused socket or proprietary ‘‘screwed mechanical’’ type joints. Other acceptable materials are glass with compression joints and high silicon cast iron with caulked or compression gasket joints. Although PVC and CPVC have the least initial cost, they also have a limited range of chemical compatibility, with PVC having a low temperature rating. PTFE is the most resistant to the widest variety of chemicals and has the highest temperature rating and highest cost. The piping should be continuously supported on angle irons to prevent future saging resulting from hot effluent.

Piping underground could also be polypropylene with heat fused socket joints or high silicon cast iron with compression gasket joints. Glass piping should be encased in a sleeve of polyethylene for protection.

Vent pipe shall be the same material as the drain pipe. The vent shall be carried up to above the roof level. Vent piping penetrating the roof shall not be glass. Use an adapter and provide any other acceptable acid resistant pipe material through the penetration.

SYSTEM DESIGN CONSIDERATIONS

The laboratory drainage system shall have the same general system design considerations as the sanitary drainage system, including placement of cleanouts. Each fixture shall be individually trapped and vented. Clean water, such as that discharged from air compressors and other condensate drains, could also spill into the laboratory drainage system when convenient. Because of possible stoppages that could flood all the pipe, the entire laboratory waste system shall be of the same acid resistant piping material.

Where the only waste discharge is from laboratory fixtures, the use of fixture unit schedules for pipe sizing is acceptable, except that simultaneous use should be factored into the sizing process. When effluent is in gpm from a known discharge, base the size on gpm and the equivalent gpm from the fixtures. The pipe shall be sized using the required pitch and a ¾ full pipe.

The laboratory drainage and vent system shall be separate from all other systems until adequately treated and possibly combined on the site with other waste lines. If a manhole is required in the acid waste line, it should be acid resistant.

ACID WASTE TREATMENT

All acid waste requires neutralization to a pH of between 7.5 and 4.0 before it would be permitted to discharge into any public sewer for disposal. Commonly accepted practice permits local authorities to allow primary treated effluent to discharge directly into the public sanitary sewer system after only pH treatment. The most often used primary procedures are direct, continuous contact with limestone chips in an acid neutralizing basin or by means of continuous or batch treatment in an automated neutralization system utilizing chemical feces neutralizing.

An acid neutralizing basin operates on the principle of a chemical reaction between the acid and the limestone chips. Each basin shall be designed by the manufacturer to allow sufficient contact time for the chemical reaction to accomplish complete neutralization based on the maximum flow rate anticipated. Average figures have determined that 100 lbs of limestone chips treat 97 lbs of sulfuric acid and 75 lbs of hydrochloric acid. Effluent consisting mostly of sulfuric acid should be treated with dolomite limestone chips.

For general laboratory waste, several methods for treatment using limestone chips are available. For single isolated sinks, an acid neutralizing trap should be considered. For a small number of sinks in a cluster, a shelf mounted, small diameter basin could be used. It should be confined to treating the discharge of acids from a small number of fixtures and in remote locations or for individual sinks where timely maintenance needed to fill the basin may be questionable. A larger basin, illustrated in Fig. 3.10, is available to treat the effluent from a large number of laboratory sinks. If there is expected discharge of oil or grease in the laboratory waste stream, the installation of an interceptor basin is recommended before the acid sump. Some objectionable contaminants can coat individual chips and prevent proper chemical action to neutralize the acid.

For a larger number of fixtures or equipment and where treatment by limestone chips alone is not practical, a system consisting of single or multiple basins, and/or a mixing tank should be installed. If located at a low level, a pump will be required to discharge up to the level of the sewer. A sophisticated arrangement of probes, chemical feed pumps, level indicators and alarms will be required. An agitator or mixer may be installed in the basin to mix the acid with the caustic. The addition of a recorder may be desired. The acid neutralizing system operates on the principle of automatically adding proper amounts caustic to the incoming acid waste, thereby neutralizing the acid. The probe is connected to an automatic caustic feed pump that introduces the proper amount of neutralizing liquid into the basin or mixing tank. The most commonly used neutralizing chemical is caustic soda. Continuous treatment may also require additional downstream sensing probes and chemical additive locations to assure that the discharge is within acceptable limits. Refer to Fig. 3.11 for an illustration of a typical continuous waste treatment system. Various manufacturers have proven methods of acid treatment.

It is good engineering practice to have the discharge from the neutralizer separately routed into the sanitary house drain outside of a building for dilution prior to ultimate discharge into the public sewer. This may also be necessary for monitoring of the waste stream by local authorities without having to enter a building.

For preliminary determination of the number of sinks that will be required for average laboratories, allow one laboratory sink for each 200 sq. ft of laboratory area. Each sink will discharge one gpm. Cup sinks will discharge 0.5 gpm. For a maximum flow rate, assume that 10% of the cup sinks could discharge simultaneously. Add the two types of sinks together for the maximum discharge.

RADIOACTIVE WASTE DRAINAGE AND VENT SYSTEMS

General

Hospitals and laboratories are generally considered ‘‘institutional’’ facilities characterized by low quantities and levels of radioactive waste and are therefore subject to a less stringent set of regulatory requirements. Those types of facilities having higher quantities of radioactive material and levels of radiation fall under a different, much more stringent set of regulatory requirements. The principles of drainage system design are applicable to all kinds of projects, some of which may have significantly higher levels of radiation than most. The design philosophy is the same, but the submission of documentation for the protection of the public and workers in the event of any accident is considerably more complex. Because of the amount of radioactive material present at industrial facilities, larger storage and treatment systems are provided, as well as severe safety requirements that are not necessary at a site where lesser quantities of radioactive material are present.

With the exception of providing radiation shielding if necessary, the requirements for a radioisotope laboratory are essentially no different from requirements of other laboratories handling toxic chemicals or pathogens. The ultimate aim is to keep the exposure of workers, staff, and the general public to nothing. Since this is not realistic, it is required not only to prevent overexposure but to keep any exposure to radiation as low as reasonably achievable. The design shall implement criteria that will eliminate or reduce to allowable levels the radiation exposure of workers and maintenance personnel and prevent exposure of the general public to unacceptable amounts of radiation by waterborne radioactive waste (radwaste).

THE NATURE OF RADIATION

Radioactivity is the spontaneous emission of ‘‘harmful’’ particles from the unstable nucleus of an atom. *Nuclear radiation* is the propagation of these harmful emissions through space. In an effort to become stable, neutrons are spun out of the orbit of the atom, whereupon they collide with the nucleus of another atom, causing a *fission,* or splitting. This splitting forms a new element and at the same time releases heat, particles (including light), and new neutrons to fly out of orbit and split other atoms. There are many intermediate steps in the stabilization cycle that include the formation of other less complex radioactive by-products called *isotopes.* These by-products in turn decay to form other unstable isotopes as the cycle continues. The end result is an element that is highly stable. As an example, the end product of uranium is lead. One of the intermediate by-products of uranium is radon.

One of the most misunderstood concepts of radioactive materials is the potential for explosion. To clarify this, consider gunpowder. If the grains are spaced widely apart, one grain would ignite and possibly cause the ignition of the grain next to it. There could be not enough energy generated to push a bullet. But, when the same amount of gunpowder is placed in a confined case and ignited, it burns so quickly so as to virtually explode. In the same way, unless the atoms of a highly unstable (radioactive) element are closely packed together, or enriched, there is no possibility of an explosion. For example, the fuel in the cores of many nuclear power reactors is enriched only about 3 percent, which will allow only a self-sustaining reaction.

Radiation is a general term that encompasses any or all of the following: alpha rays, beta rays, gamma rays, neutrons, x-rays, and other atomic particles. There are three general classifications of radiation of concern, namely, alpha, beta, and gamma. *Alpha radiation* is actually a helium atom with a high velocity. *Beta radiation* is an electron with a high velocity. *Gamma radiation* is a particle similar to a photon, which is light. Alpha and beta radiation can generally be stopped by the skin or clothing, paper, or other similar light material. Alpha loses energy very quickly in air and is of no practical concern for distances greater than 12 in. High-energy beta radiation is commonly contained by only 1 in of solid, dense plastic. Beta is denser, carries more energy greater distances than alpha, and will burn bare skin and, in particular, damage the eye, but will generally not penetrate into the body to cause any internal damage. The greatest danger with beta radiation is to the eyes, particularly when the eye is directly exposed close to the source.

Gamma radiation is electromagnetic in nature. It carries the most energy and therefore is the most dangerous to humans. Its wavelength is shorter than light waves. When generated, it is similar to x-rays and behaves in a manner similar to light waves. When released from a source, gamma rays have a mass and velocity that has a measurable energy potential.

The best way to visualize the manner in which radiation harms cells in the body is to think of all the particles as bullets. These particles have velocity and energy. When stopped by the skin, these particles actually bounce off the skin, and the friction produces burns in the same way that sandblasting causes irritation. Sensitive tissue can also be killed by this friction. Gamma rays pass through the body and will change or damage any cell they touch on the way through. All three of the above radiation types are considered *ionizing radiation,* which means that the radioactive particles emitted from the source produce ionization. Ionization is the conversion of neutral particles to charged particles. Since cells are made mostly of water, the most common changes produce radicals that affect the bonds of cell molecules, causing breaks in DNA molecules and abnormalities in cells. Many cells are destroyed outright. Most affected cells die and are naturally replaced by the body. Some cells, particularly in the reproductive system, brain, and eyes, can’t be reproduced by the body and are gone forever. Some cells become mutant and reproduce so quickly that they multiply out of control. That is the start of a cancer.

RADIATION MEASUREMENT

Radioactivity is a general term used for the total release of radiation of all types from a source. It is measured in disintegrations per second (dps). This measurement is possible for gamma radiation because in most radioactive materials, disintegrations also produce a known amount of gamma radiation. However, the best manner of measuring gamma radiation is from the energy it produces per kilogram of air. Because the instruments needed to measure radiation in this way are very expensive, they are not widely used outside of the laboratory. The so-called Geiger-Müeller counter is the most common. This instrument measures penetration of the particles that enter into a tube where the particles react with a gas in the tube, creating an electric charge that can be measured. If an amplification device is used, the charge can be heard in the form of static. The more modern instruments have a digital readout.

UNITS OF RADIATION DOSE

Particulate radiation is measured by the number of disintegrations per unit of time. A curie (Ci) is equal to 3.7×10^{10} dps. One millicurie is equal to 0.001 curie, or 3.7×10^{7} dps. One *rad* (*r*adiation *a*bsorbed *d*ose) is defined as the dose corresponding to the absorption of 100 ergs per gram (erg/g) of tissue. A roentgen (R) measures ions carrying a total of 2.58×10^{4} coulombs (C) of electrical energy.

Since the term *radiation* is a general one, a more specific term must be used to indicate the effect of radiation on humans. That measurement is called a *dose.* A dose is defined as the total quantity of radiation absorbed by the body or any portion of the body. Much of the time, the dose will be modified by reference to a unit of time. This differs from radioactivity because all radiation is not absorbed by the body. A rad is a measure of the dose to body tissue in terms of energy absorbed per unit mass. Gamma radiation is the most common of this type.

The most important measurement is the *radiation equivalent to man,* or rem. A rem is the measure of ionizing radiation passing through or absorbed by the body in terms of the biological effect relative to a dose of one roentgen of x-rays. The relation of the rem to other dose units depends upon the actual biological effect to the particular part of the body being studied and the actual conditions and amount of time of the irradiation. One rem is the equivalent of one roentgen due to x or gamma radiation, and also one rad due to x, gamma, or beta radiation. One rem of high-flux neutrons is roughly equivalent to the 14 million neutrons per square centimeter incident to the body.

ALLOWABLE RADIATION LEVELS

There is no exact radiation level that is certain to cause permanent harm to the human body. On the other hand, many scientists believe there is no level below which it is certain that harm will *not* occur. A certain constant amount of naturally occurring radiation, called the *background level of radiation,* exists all over the world. The most common source is the sun, and its radiation is called *cosmic radiation.* In addition, there are many other sources of radiation such as fly ash from burning organic fuels (particularly coal), granite, and other natural substances that contain trace isotopes of elements. One of the most common of these trace elements is carbon 14, used by scientists to date many materials.

The Nuclear Regulatory Commission (NRC) is the government body that has the responsibility for establishing criteria for the field of radioactivity. These criteria appear in the federal government's Code of Federal Regulations. As an example, Title 10, Part 50 is commonly referred to as "10 CFR 50." The levels that have been established by the NRC are as follows (measured in rems for one calendar quarter for the exposure):

Individual in a restricted area:

Whole body (head, trunk, gonads, eye lens, marrow)	1¼ rem[*]
Hands, forearms, feet, ankles	18¼ rem
Skin of whole body	7½ rem

Individual in an unrestricted area:

Whole body dose for 1 h	2 mrem
Whole body dose for 7 days	100 mrem
Whole body dose for 1 year	0.5 rem

All personnel working at any site that has a possibility of exposure to radiation are required to wear some type of exposure detection device that will allow accurate determination of their actual exposure. The photographic badge is the most common and is used where sensitivity is required. A pen-shaped device called a *dosimeter* is commonly used where there is less need for accuracy. It is used where instant determination of dose is necessary.

An *unrestricted area* is any area within a facility that is not specifically controlled for the purpose of protecting any individual from radiation or radioactive materials. A *restricted area* is access controlled. Another term, *environs,* may also be used to describe areas adjacent to a restricted or high-radiation area. A *high-radiation area* is defined as any accessible area within a facility that is capable of allowing the body to receive 100 mrem of radiation in a 1-h period.

SHIELDING

The purpose of shielding is to reduce or eliminate radiation emanating from any source within the facility. The most effective material has the greatest density, and so lead has been universally used for this purpose. Another material that is commonly used is concrete. In terms of shielding thickness, 4 mm of lead is the equivalent of 12 in of concrete. If it is known that a building will need shielding, concrete is the most often chosen building material as it provides ample structural support as well as shielding from radiation. It is up to the radiation safety officer (RSO) to determine the type of shielding and its placement to lower radiation in specific areas. Radiation travels in a straight line; therefore, if a tank or a length of pipe has to be shielded, the proper manner is to form a labyrinth so that the shine from the tank cannot escape in a straight line.

The most common materials used for shielding purposes are concrete and sheet lead. Other materials that have proven effective are (a) lead-lined concrete blocks, (b) lead-lined lath for plaster, and (c) lead-lined panels and gypsum boards. The barriers set up to reduce radiation levels are primary barriers, which are the first

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[*] This can be increased to 3 rem to the whole body provided that no prior dose was received in the previous calendar quarter.

line of defense, and secondary barriers, which are used to eliminate leakage radiation and scattered radiation.

RADIOACTIVE MATERIALS

Radioactive materials are used for the following general types of activity:

1. Imaging sciences
2. Electrical power generation
3. Medical treatments and diagnostic tests
4. Manufacturing
5. Research

Almost all of the materials used are isotopes. An *isotope* is a form of an element with a different (or excess) number of neutrons in its nucleus. Because of this difference, the atom is unstable. These isotopes are identified by their atomic weight, which is the weight of the number of neutrons and protons in the nucleus.

There are a great number of isotopes in use today. Some of the more common are:

Iodine 131(8-day half-life)
Phosphorus 32
Technetium 99 (6-h half-life)
Calcium 45
Carbon 14
Strontium 90
Radium 226

Since any given amount of radioactive materials remains active for different periods of time, it is not possible to predict when any material will become completely stable. The most often used figure is the time required for a specific material to lose one-half of its radioactivity, which is called its *half-life*.

SYSTEM DESIGN CRITERIA

The Approval Process and Application Requirements

The use of any radioactive material requires the licensing of the site for a specific purpose and amount of radioactive material. Application for this license is made either to the NRC or a particular state. Those states that have elected to adopt the NRC regulations and provide their own staff for the purpose of issuing and approving licenses are called *agreement states.* In some cases these states make additional regulations of their own. Those states that rely on the NRC to review and issue licenses are *nonagreement states.* The application in those states is made to the appropriate department of the NRC.

For a hospital type of facility, the granting of the license mandates the presence of some form of a committee assembled for the express purpose of assuring compliance with the terms and conditions of the site license as well as reviewing all proposals for the actual use of the radioactive materials present at the site. This team may consist of a physician specialist in internal medicine, a physician specialist in nuclear medicine, and a radiation safety officer. A health physicist is also commonly included. For a research type of facility, the members of the team will include a member of the research team in lieu of a physician.

The administrative duties of the RSO include monitoring personnel exposure limits and controlling any release of radionuclides into the sewer system. In addition, the RSO works with engineers in the design phase of the facility to assure that the piping runs and all other mechanical work will result in a low exposure to people within the facility. For the most part, this work is directed to assuring that neither facility personnel nor nonstaff members are subjected to more than the maximum permissible radiation dose allowed under the applicable codes for any particular type of radioactive material present. The RSQ is also responsible for the following:

1. Teaching facility staff about the potential dangers
2. Keeping the necessary records for the facility
3. Keeping an inventory of material and records disposal
4. Concentrating materials at the facility
5. Assisting the engineer in design of mechanical systems
6. Designating areas within the facility to be restricted

GENERAL DESIGN CRITERIA

The prime consideration in the design of any facility is a concept controlling the exposure of personnel to radiation called ALARA, an acronym for ‘‘as low as reasonably achievable.’’ This requires that the design of the facility must consider every reasonable method to limit the possible exposure of personnel inside the facility and keep the presence of radioactivity in any unrestricted area to a figure as low as reasonably achievable. This must take into account the current state of technology, the economics of further improvements in relation to the benefits to public health and safety, and other aspects of socioeconomic considerations in relation to the utilization of radioactive material in the general public interest. The facility must also make a reasonable effort to eliminate residual radiation. One of the overriding concepts is the ‘‘worst-case’’ possibility, by which contingency plans are made for the worst possible combination of circumstances to determine the possible level and amount of time of radiation exposure. This concept should not be overdone, and a general rule is to have only one ‘‘accident’’ at a time. As an example, a serious spill and a fire would not be considered as occurring simultaneously.

PIPE MATERIAL SELECTION

The pipe selected for the radioactive drainage system depends upon the type of radiation and level of radioactivity, which in turn, depends upon the amount and type of radioactive material at the facility. In general, an ideal radwaste piping should have the following properties:

1. It must be nonporous.
2. It must be easy to clean and decontaminate.
3. It should be acid resistant.
4. It should be nonoxidizing.
5. The joints should not form a crud trap.
6. Joint materials must not be affected by radiation exposure.

It is possible in very high radiation areas to have a pipe affected by the radiation present. The oxides of the pipe can become radioactive, or the pipe itself can be weakened. Another factor is the weakening of elastomeric seals or gaskets because of high levels of radiation. For this reason, Teflon is never used where anything more than a very low level of radiation is present. Other materials should be investigated as to their suitability for use for the levels anticipated.

All the commonly used materials (cast iron, ductile iron, copper, steel, and glass) and the joints normally used to put the pipes together fall far short of the ideal. However, all of them are suitable for low-level waste and radioactive source materials found in conventional health institutions. Plastic piping is not acceptable for radwaste systems, due to the possibility that the plastic may be affected by the radiation. It is only when the radiation levels of the waste materials get into the high-radiation-level category that they fail one or more of these conditions. As a result, stainless steel with welded joints has emerged as the material of choice for all of the industrial types of waste products. Type 316L is the most common.

Welded joints are the only type of joint that meets the criteria for not allowing a crud trap.

GENERAL DESIGN CONSIDERATIONS

Human waste, even that contaminated with radioactivity, is exempt from all NRC regulations, requiring only compliance with local codes as far as disposal, sizing, and all other criteria applicable to standard drainage systems. There are also many isotopes that are exempt from regulations regarding disposal into the public sewer.

Another requirement is that the liquid radwaste to be discharged shall be diluted with the ordinary sanitary system effluent from the rest of the facility before being discharged to the public sanitary sewer system. This usually requires that the radwaste piping first be kept separate from the rest of the facility's piping, then joined to the main system before leaving the building for discharge into a public sewer. There are no restrictions regarding the combining of any radwaste together that are permitted to be discharged separately. A method should be provided for the RSO to take a grab sample of the radwaste stream if desired, such as a valved outlet from both the radwaste line and the combined discharge. Keep the pitch of the piping as steep as p05sible, in order to empty the pipe quickly and to provide a scouring action that will keep the radioactive solids in suspension.

It is common practice in laboratories to have high levels of radiation confined to glove boxes or protected fume hoods. The small amount of liquid waste produced from this equipment would be stored in shielded containers below the equipment that is removed periodically. If storage of larger quantities of low-level radwaste is required, it is piped to a holding tank. A common holding time is 10 half-lives of the effluent. Usually, radwaste is stored for disposal on the site, outside of a building where easy transfer of the liquid is possible. The removal must be done by licensed waste disposal contractors that remove the waste from the holding tank into a special truck that transports the liquid waste to a designated site suitable for disposal of low-level waste. The solid wastes, such as gloves and wipes, are stored in special containers that are removed to the disposal area with the liquid radwaste.

Floor drains are normally not desired in laboratories. If there is a spill of radioactive material, it is wiped up by hand using absorbent material, and the solid containing the spill is put in a special radwaste holding container within the lab. If a floor drain is called for in the design, it should be made of stainless steel, which is available from all the major manufacturers. For testing purposes and to close off a drain when it is not expected to be used, each drain should be supplied with a closure plug. If there are areas where there may be a spill, the floor must be pitched to a floor drain. A generally accepted value for pitch of the floor is 1 in 20 ft. The thickness of the slab must be closely coordinated because the slab is thinnest at the drain and made thicker at the ends of the area served to make up the pitch. It is not practical to cast the slab evenly and add a topping because there is a tendency to chip the topping and possibly have a radioactive spill get under the top coating. Since the slab depth is greater the longer the run to the drain, it is necessary to indicate the top of drain elevation at each drain. This also makes it easier for the shop fabricator to make up accurate pipe spools.

Drains also require special treatment in a high-radiation facility. Like the drains in a low-radiation facility, they should be manufactured of stainless steel. There will be different types of drains in different areas, and they may be installed at different elevations. Because of this and the probability that the piping will be made in spools, it is a good idea to number all of the individual drains on the design drawings. A box next to each drain can be used to provide information regarding type, number, and elevation.

Since fittings are a natural crud trap, avoid running piping in, under, over, or adjacent to unrestricted areas in a facility. If this is not possible, place the line where additional shielding can be added either at the time of construction or after the start of actual use, when the RSO may determine by survey that additional shielding is necessary. Much of the time, the ability to take apart the joint and flush out any crud is an advantage. Any of the popular joints for no-hub or grooved pipe are acceptable, as well as glass pipe if used in a laboratory for chemical resistance.

Be generous with cleanouts. They may be needed to flush out the line to reduce spot high radiation rather than to rod it out.

DECONTAMINATION

Decontamination of both personnel and equipment may also be required. Often, valves, small lengths of piping, or instruments must be taken out of service for repair or replacement. Personnel decontamination areas must be provided in the event that some radioactive contamination may accidentally spill on somebody.

There are three methods generally used to decontaminate equipment:

1. Ultrasonic decontamination
2. Electropolishing decontamination
3. Washing with water and/or brushes

The most commonly used decontamination method is washing equipment with a detergent solution and a stiff wire or bristle brush. This method can be used only if the part is lightly contaminated and the lack of close proximity any person must have to the part being cleaned. If the cleaning is on a system that is unrestricted, the crud relieved can simply be washed down any drain. The RSO must determine that the part is not radioactive enough to cause exposure problems. If the contamination is more than the allowed minimum, the part is placed in a container, and then a high-pressure stream of water is first used to remove the loose crud and then a brush is used to finish the job.

If the part is determined to have a significant amount of radiation and the crud cannot be removed by washing, ultrasonic cleaning is the next choice. Except for very large systems that are built in place, most of the ultrasonic cleaning systems are factory packaged. The cleaning system consists of a tank that contains a detergent cleaning solution with a wetting agent, water heater, ultrasonic generators, filters, and a water circulating system to remove the soil from the detergent solution in the tank. The part to be cleaned is put in the tank, whereupon the filters remove the loosened crud suspended in the water. The filters are in a cartridge that is removed periodically and disposed of along with the other low-level radwaste.

If ultrasonic cleaning is not effective, the final step is to use an electropolishing system. This cleaning system is similar to electroplating except that the part to be cleaned is the sacrificial anode, and a layer of nidal is deposited on the cathode of the system. This system also uses a liquid bath, and the removed crud is filtered out and contained in a filter cartridge.

All of these areas contain floor drains, discharging either to a public sewer if the radiation is from exempt material, or if a higher level, to a holding tank for disposal or to a radwaste treatment system.

Personnel decontamination consists of regular showers, with one exception: hot water cannot be used. Hot water opens the pores of the skin and may allow contaminated particles to enter the body. People go from a dirty area where they shed their protective clothing, then they get scanned, and then they go either to the clean area for a regular shower or to the decon area for a cold shower, during which they use a stiff brush with detergent for scrubbing the contamination off the skin. A rescan determines if it is safe for them to take a regular shower. Again, if the material used in the facility is exempt and the worst case determined by the RSO is acceptable, the effluent from the showers can all discharge into the public sewer system. If not, then it shall be routed to a holding tank or radwaste treatment equipment for disposal. It is highly unlikely that a decon facility will be necessary in any facility using only exempt products.

INFECTIOUS AND BIOLOGICAL WASTE DRAINAGE SYSTEMS

Waste generated in pharmaceutical facilities has the same basic characteristics as that of other laboratory and production facilities, but with the addition of biohazardous material. Biohazardous material consists of live organisms suspended in the waste stream that have the potential to cause infection, sickness, and other very serious diseases if not contained. This waste will be discharged by gravity and under pressure from many sources, including:

1. Fermentation tanks and equipment
2. Process centrifuges
3. Sinks, both hand washing and process
4. Containment area floor drains
5. Janitor closet drains
6. Necropsy table drains
7. Autoclave drains
8. Contaminated condensate drains

Containment is the method used to isolate and confine biohazardous material. The facility equipment and design shall conform to acceptable and appropriate containment practices based on the hazard potential. A containment category is used to describe an assembly of both primary and secondary preventive measures that provide personnel, environmental, and experimental protection. Primary barriers are specific pieces of equipment such as the biological safety cabinet (which is the biologist's equivalent of the chemist's fume hood) and glove boxes. Secondary containments are features of facility design surrounding and supporting the primary containment. These features are described and classified in many publications such as those of the National Institutes of Health in Bethesda, Maryland.

The classifications for biological containment in laboratories consist of four biosafety levels, BL1 through BL4. Publications describe the work practices, equipment, and BL selection criteria based on the activity of that particular laboratory. If the laboratory or production facility produces or uses greater than 10 L of any substance containing viable organisms, the facility may become large scale (LS). This is noted as BL2 LS. Manufacturing standards shall conform to good large-scale production (GLSP) standards. The same standards apply to both small- and large-scale facilities.

CODES AND STANDARDS

Mandated guidelines and regulations include the following:

1. OSHA Bloodborne Pathogen regulations
2. NIH guidelines for the use of recombinant microorganisms
3. FDA cGMP regulations
4. CDC/NIH Guidelines for Biosafety in Microbiological and Biomedical Laboratories

BIOLOGICAL SAFETY LEVELS

CDC/NIH Guidelines for Biosafety in Microbiological and Biomedical Laboratories are summarized in an abbreviated and simplified form for the following laboratory containment levels.

Biosafety Level 1 (BL1) Containment

This is the typical biological research facility classification for work with low-hazard agents. Viable microorganisms not known to cause disease in healthy adults are used at this level. Work activity is done on an open bench, and any hazard present can be controlled by using standard laboratory practice. Standard features consist of easily cleaned, impervious bench surfaces and hand washing sinks, and lab work is separated from general offices, animal rooms, and production areas. Contaminated liquid and solid waste shall be treated with a suitable disinfectant to remove biological hazards before disposal. Wastes containing DNA materials or potentially infectious microorganisms shall be decontaminated before disposal. Facilities to wash hands are required in each laboratory.

Biosafety Level 2 (BL2) Containment

This facility designation is similar to BL1 except that the microorganisms may pose some risk and safety cabinets are often present. Equipment and work surfaces shall be wiped down with a suitable disinfectant. Sinks shall be scrubbed daily with a chlorine-containing abrasive and flushed with a suitable disinfectant. All liquid waste generated shall be immediately decontaminated by mixing with a suitable disinfectant. Nearly all laboratories operate under level 1 or 2 containment. At these levels, the facility is engaged in research or diagnostic or production activities thought to pose little or minimal risk to workers.

Biosafety Level 3 (BL3) Containment

Level 3 activity involves organisms that pose a significant risk or represent a potentially serious threat to health and safety. Biosafety cabinets are required, and all penetrations to outside the facility must be sealed to prevent leakage. These seals must be capable of being cleaned. Liquid waste is kept within the laboratory or facility and steam-sterilized prior to discharge or disposal. Vacuum inlets must be protected by appropriate filters and/or disinfectant traps. Laboratory animals require special housing. Personnel must be appropriately protected with full suits and respirators. A handwashing sink shall be located adjacent to the facility exit and is routed to sterilization. Vents from plumbing fixtures must be filtered.

Biosafety Level 4 (BL4) Containment

This is a rarely used classification that applies to those facilities in which the activities require a very high level of containment. The organisms present lifethreatening potential and may initiate a serious epidemic disease. All of the BL3 requirements apply. In addition, showers shall be provided for personnel at the airlock where clothes are changed upon entry or exit. A biowaste treatment system shall be provided within the facility to sterilize liquid waste.

LIQUID WASTE DECONTAMINATION SYSTEM

A liquid waste decontamination system (LWDS) collects and sterilizes (decontaminates) liquid waste. Effluent containing potentially hazardous biomatter is collected in a dedicated drainage system, generally discharging by gravity into a sump below the floor level within the facility. From the sump, effluent is pumped into a ''kill tank'' where the actual sterilization occurs. A kill tank is a vessel into which steam or chemical disinfectant can be injected to kill any organism. The kill tank system should be qualified to the same biosafety level as the facility that it receives its discharge from. The kill tank system must be a batch process since time is needed to complete the sterilization and decontamination is based on the process used.

System Components

In addition to piping, the system consists of the sump or tank to receive contaminated discharge from the drains and equipment of the facility, a pump to remove the contaminated effluent from the sump and up into the kill tank(s), and the kill tanks that will decontaminate and sterilize the effluent to a point permitting disposal into the same system as the sanitary waste from the facility, generally into a public sanitary sewer.

Sump Pit

The sump pit into which the effluent drains shall have a gasketed, waterproof cover. The controls are similar to that provided on a plumbing sump pump and shall be capable of being chemically or steam sterilized. The pit is sized in conjunction with the sizing of the pump so that the pump stays on for a minimum of 1 mm to avoid too frequent starting. Other considerations, such as having the pit contain one batch of product if necessary, may be considered.

Kill Tank Assembly

The kill tank consists of a duplex tank arrangement, allowing one batch to be decontaminated while the other is filling. The size of the tanks will vary based on the individual facility, but common practice is to have each tank capable of containing 1 day's effluent plus the chemicals used for decontamination. Another consideration is to have sufficient size to hold a catastrophic spill. There is usually an agitator to mix the effluent with the deactivation chemicals. In addition to the kill tanks, tanks containing disinfectant chemicals to be injected are required. A fully automatic control system must be provided to ensure the timely addition of the required chemicals in the correct amounts and for the required duration of deactivation of the biomatter. Alarms and status should be displayed in an appropriate panel located in a facility control room or other area.

Drainage System and Components

The drainage system must be closed, which requires sealed floor drains and valved connections to equipment when not in use. Since the HVAC system maintains a negative pressure, it is important that the traps on all floor drains have a seal 2½ in deeper than the negative difference in air pressure. The traps of floor drains are filled with a disinfectant solution when not used to eliminate the possibility of spreading organisms between different areas served by the same connected sections of the piping system very often the floor drains are sealed.

The choice of drainage piping material is based on the suspected composition of effluent chemicals and the sterilization method. If the local authorities determine that the biowaste is hazardous, a double contained piping system with leak detection may be required. Stainless steel or PTFE pipe is usually chosen where higher-temperature effluent may be discharged or steam sterilization may be required. PVC, CPVC, PP, or lined FRP pipe could be used where effluent temperatures are lower and also where chemicals will provide the method of sterilization.

If waste from pressurized equipment is discharged into a gravity system, the system must be adequately sized to carry away the proposed flow rate with pipe flowing half full and adequate vents provided to equalize the internal pressure and assure that the pipe is always at atmospheric pressure.

Valves shall be of the diaphragm type, capable of being sterilized using the same method as the pipe. After appropriate decontamination, the kill tank effluent shall be discharged to drain. This effluent must be treated prior to discharge into a public sewer system for disposal.

Vents

Vents from pipe, fixtures, sealed sump pits, and kill tanks must be filter-sterilized prior to leaving the system using an HEPA or a 0.2-μm filter. In the event of an accident, OSHA has rules to aid personnel responding to emergencies involving any hazardous material.

SYSTEM DESIGN CONSIDERATIONS

The treated discharge from any containment treatment shall be separately routed to the sanitary system outside the building to allow for monitoring and sampling.

INDUSTRIAL WASTE SYSTEMS

GENERAL

Industrial waste drainage systems could contain an extremely wide variety of waterborne waste. Among them are chemicals, solvents, suspended solids, flammable liquids and wastewater, many of which are considered hazardous. The purpose of the industrial waste drainage system is to collect and transport these wastes from inside a facility to a point on-site where disposal or treatment is accomplished.

CODES AND STANDARDS

A great body of regulations affect the design of any industrial drainage system. Among them are the federal Clean Water Act (CWA) and Resource Conservation and Recovery Act (RCRA), which are administered by the federal Environmental Protection Agency (EPA) as well as state and other local agencies. The local authorities are also empowered to create regulations that are more strict than the federal regulations. Where production and manufacturing facilities discharge waste, it is a general practice to engage the services of professionals experienced in wastewater treatment and environmental issues to assure compliance with all of the latest applicable regulations and maintenance of an acceptable treatment system. The major regulatory factor to be considered is the determination of whether any particular waste stream is hazardous. If so, protective measures, such as double-contained piping systems and leak detection, may be required.

PIPE MATERIAL AND JOINT SELECTION

Because of the vast diversity of manufacturing processes, it is impossible to make any general characterization of industrial wastewater. It is common to have various areas within a plant or industrial complex discharging different types of effluent with greatly varying characteristics.

The largest quantity of effluent in an industrial facility originates from drains. Drains receive discharge from production equipment, floor washdown, process and production machines, and other equipment such as compressors and boilers. The floor drain and discharge pipe from the drain must be capable of resisting chemicals discharged from the production equipment. The selection of the most appropriate piping material can be accomplished only if the nature of the effluent, both present and future, is known and can be allowed for.

SYSTEM DESIGN CONSIDERATIONS

The design of the drainage system is dependent on the location, composition, and quantity of discharged effluent all sources. The layout and engineering of a piping network requires ingenuity and attention to detail.

The selection of the type and location of floor drains is a major aspect of drainage system design. The following are general guidelines for locating and selecting the drains:

1. Wet floors are to be avoided. Drains should be located next to equipment and be large enough to allow easy multiple discharges to spill over them without requiring a run of pipe over the floor or having to spill on the floor and run to the drain. If large flow rates are expected, select a large drain.
2. The use of long trench drains in areas where a number of pieces of equipment are placed will create an easy access to all of the various drains from the equipment. This arrangement is usually less costly than multiple drains.
3. In many cases the discharge from equipment may be under pressure because of the head of water in the piece of equipment such as a tank, being emptied. The drain should be large enough in physical size to accept the largest expected flow. The size of the discharge pipe must be large enough to accept the maximum quantity flowing full by gravity without overflowing. An air gap shall be provided to prevent pressurizing the gravity drainage system.
4. To accept the largest number of multiple, small-sized drainage lines from equipment, a funnel type of drain should be provided. The top of the funnel should be as close to the floor as reasonable in order for an air gap to be provided between the top of the floor drain and the end of the equipment drain. This air gap shall be twice the diameter of the drainage line.
5. Provide adequate cleanouts in drain lines. In lines that are at the ceiling of high floors, extend the cleanouts to the floor above to avoid the need for maintenance personnel to climb ladders in order to clean stoppages.
6. The minimum-size drain line under the slab or underground should be 2 in (50 mm). Floor drains should be a minimum size of 4 in (100 mm).
7. Adequate venting of the drainage line must be provided to allow for smooth flow. These vents shall be connected to the top of the drain line in order to allow air at the top of the pipe to be either vented out (when there is a slug of liquid) or admit air required by the flow of water or due to a partial vacuum created by the liquid flowing full. Vents shall be a minimum size of 2 in.
8. Local regulations may require the use of double-contained piping to prevent potential leakage from discharging into the environment. A leak detection system should be provided that will allow leakage to be annunciated.

FIRE SUPPRESSION WATER DRAINAGE

For industrial facilities, the water used to suppress a fire could become contaminated with the products and raw materials it comes in contact with. It is required that any water, such as sprinkler and fire hose discharge, that has the possibility of being contaminated in this manner, must be routed to holding basins for analysis and possible treatment before being discharged into the environment. If there is no material capable of causing contamination, no special consideration is necessary except to protect other areas of the facility from possible flooding.

SYSTEM DESCRIPTION

The drainage system consists of the drains located to intercept the flow of fire water, the drainage piping, a holding basin on-site to contain and treat the total volume of water, and the necessary treatment system that will neutralize the water prior to discharge into the environment.

The amount of water discharged from the fire suppression system is far greater than wastewater discharged from the facility under normal operating conditions. Overflow floor drains large enough to take the design flow rate shall be installed at points that will intercept the water before it flows out of doorways or drive bays and route it to holding basins. The placement of these overflow drains shall be selected to intercept all of the water discharged and prevent it from damaging other parts of the facility, escaping away from the property or into the ground.

The drainage piping is sized on flow rate and pitch from the facility to the detention basin. The effluent will be essentially clear water with few solids. The flow rate of water required to be disposed of is determined by first calculating the sprinkler water density over the area used for hydraulic calculations. Add to this the flow rate from the number of fire standpipe hose streams possible. Velocity in the drainage pipe is not a major consideration because the system is rarely used. A shallow pitch will give a low velocity that may result in deposit of some material that could be flushed out after the fire event. A high velocity will not affect the life of the piping system because of the short amount of time the system is in operation. Pipe size is selected based on the actual pitch of the pipe and the capacity flowing full. Refer to Table 6.26.

Venting of the system is required in order to allow free flow of the effluent. Each individual drain need not be vented, but each branch should have a loop vent of at least 2 in (50 mm) in size. The vent could be connected to the sanitary vent system or carried through the roof independently. The pipe material selected shall be compatible with the potential chemicals it might carry.

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FLAMMABLE AND VOLATILE LIQUIDS

Federal, state and local regulations have established standards for the discharge of volatile liquids, particularly oil, into stormwater and sanitary sewers. These standards vary, and the responsible enforcement and code authorities must be consulted to determine the level of treatment required.

The most common flammable liquid is oil. The hazard created is either one of safety, since the vapors could create an explosive condition, the oil will float on water and could be set on fire, or medical, where the breathing of the vapors is dangerous to health and toxic if ingested by humans. The common characteristic of all of these substances is that they are lighter than water. Their removal is similar to that of oil.

OIL IN WATER

Oil in water exists in several forms, and is considered immiscible since it cannot be mixed with water.

1. Free oil.
2. Mechanically dispersed oil is fine droplets ranging in size from microns to fractions of a millimeter. They are stable due to electrical charges and other forces but not due to the presence of surface active agents.
3. Chemically stabilized emulsions are fine droplets that are stable due to surface active agents.
4. Dissolved and dispersed oil is suspended in such a small size (typically 5 microns or smaller) that ordinary filtration is not possible.
5. Oil-wet solids, which are particulates to which oil adheres to their surface.

METHODS OF SEPARATION AND TREATMENT

Oil spills and leaks are best treated in their most concentrated state, which is at their source or as close as reasonable. The primary methods used to separate and remove free oil and oil wet solids are floatation and centrifugation. Secondary treatment, such as chemical treatment/coalescence and filtration, is then used to break up oil water emulsions and remove dispersed oil. Finally, tertiary treatment, such as ultrafiltration, biological treatment and carbon absorption will remove the oil to required levels prior to discharge. This chapter will discuss only the general principles of the primary and secondary separation methods and devices.

The American Petroleum Institute (API) has established criteria for the large scale removal of globules larger than 150 microns. In abbreviated form, they are as follows.

1. The horizontal velocity through the separator may be up to 15 times the rise velocity of the slowest rising globule, up to a maximum of 3 ft per second.
2. The depth of flow in the separator shall be within 3 to 8 in.

3. The width of the separator shall be between 6 and 20 in.
4. The depth to width ratio shall be between 0.3 and 0.5.
5. An oil retention baffle should be located no less than 12 in downstream from a skimming device.

GRAVITY SEPARATORS

Gravity separation is the primary and most often used separation method. It is based on the specific gravity difference between immiscible oil globules and water. Since all of these liquids are lighter than an equal volume of water, gravity separators operate on the principle of floatation. As the water and oil flow through the unit, the oil floats to the top and is trapped inside by a series of internal baffles. Since the oil remains liquid, it is easily drawn off.

FLOTATION DEVICES

For larger scale service, the flotation of oil and oil wet solids to the top of the floatation chamber can be increased by the attachment of small bubbles of air to the surface of the slow rising oil globules. This is done by adding compressed air to the bottom of the floatation chamber in a special manner that will create small bubbles that will mix with, and attach themselves to, the oil globules.

CENTRIFUGAL SEPARATORS

For larger scale service, the centrifugal separator is used. This device operates on the principle of inducing the combined oil and water mixture to flow around a circular separation chamber. The lighter oil globules will collect around the central vortex, which contains the oil removal mechanism, and the clear water will collect at the outer radial portion of the separation chamber. Methods have evolved that will produce effluent water with only 50–70 ppm of oil, and proprietary devices exist that will lower oil content to 10 ppm.

FILTRATION

Chemical methods used to break oil/water emulsions followed by depth-type filters to remove the destabilized mixture have proven effective in removing oil globules in a range of sizes between 1 and 50 microns. The velocity and the flow rate of the mixture must be carefully controlled to allow optimum effectiveness of the system.

SMALLER SYSTEMS

Oil separators for small flows usually take the form of a single unit consisting of a drain grating into which the effluent flows and inside which the oil remains to be drawn off manually. Another type of unit uses an overflow arrangement that sends the trapped oil to a remote oil storage tank.

Because there is the possibility that the vapor given off by the flammable liquid could also ignite, it is important to provide a separator vent that terminates in the open air at an approved location above the highest part of the structure. Some codes require that a flame arrestor be installed on the vent.

The most common material used for an oil interceptor is cast iron, although steel can be used for less severe service. Gratings must have the strength for the type of vehicle expected.

Refer to Fig. 3.6 for an illustration of a typical small oil interceptor. Fig. 3.7 illustrates the installation of a typical oil interceptor with gravity oil drawoff for multiple floor drain inlets.

ADDITIONAL REFERENCES

Grossel, S. F. ‘‘Safe Handing of Acids,’’ Chemical Engineering Magazine, July 1998.

Kaminsky, G, ‘‘Failsafe Neutralization of Wastewater Effluent,’’ Plant Services Magazine, May 1998.