MEDICAL WASTE INCINERATOR
EMISSIONS AND AIR POLLUTION CONTROL

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INTRODUCTION

Increased State regulations for the incineration of medical wastes are requiring new and existing medical waste incinerators to meet strict pollutant emission limitations. In most cases, air pollution control equipment is required to meet these new regulations. To evaluate the various alternatives for air pollution control equipment, it is first necessary to understand the nature of the emissions from medical waste incinerators. Emissions from medical waste incinerators, and air pollution control systems used to control those emissions are discussed within this paper. Air pollution control equipment is evaluated in terms of specific design criteria, operations and maintenance procedures, cost effectiveness and the ability to meet new regulatory emission requirements. Also presented in this paper is a general overview of air quality and health risk assessments which are often required by new state medical waste incineration regulations.

REGULATED EMISSIONS

The pollutants from medical waste incinerators either exist in the waste feed material or are formed in the combustion process. State regulations for medical waste incinerators may include pollutant emission limits for the following: particulate matter, toxic metals, toxic organics and carbon monoxide (CO), as well as the acid gases hydrogen chloride (HCl), sulfur dioxide (SO_2) and nitrogen oxides (NO_x).

Particulate emissions are solid and liquid particles suspended in the air, and are usually identified with visible effects such as smoke. Particulates consist of particles of varying sizes, and those particles may be combustibles or minerals (incombustibles). Combustibles consist of char and smoke (smoke is also called soot). Char is carbonated material (such as paper) that is carried up the stack before it is fully combusted. Char generally consists of larger particles. Smoke, or soot, consists of very fine particulates that are suspended in the gas stream. Minerals, or incombustibles, are inorganics, and consist mostly of salts and silicates which are not associated with environmental health impacts but contribute to particulate emissions.

Toxic metals are emissions which are formed from metals contained in the waste stream. The metals are changed into gases when exposed to the high temperatures of the incinerator. The majority of these metals condense onto fine particulates when the flue gases are cooled downstream of the incinerator. Examples of these trace metals are arsenic, beryllium, cadmium, chromium, lead, mercury and nickel.

Toxic organics, often referred to as products of incomplete combustion (PICs), are gaseous emissions and are formed from incomplete combustion which results in emissions of organics found in the waste feed, and in the generation of new organic species from complex chemical reactions occurring in the combustion process. When chlorine is present in the waste feed, such as in polyvinyl chlorinated (PVC) plastics which are common in medical waste, the organic emissions may include toxic chlorinated organics, such as dioxins and furans. There are organic emissions other than dioxins and furans that are generated by medical waste incineration, but their emission rates are usually not regulated. Combustion conditions that favor increased particulate emissions due to incomplete combustion also favor increased emissions of dioxins and furans when chlorine is present in the waste.

Carbon monoxide is an intermediate product of the reaction between carbonaceous fuels and oxygen, and therefore the concentration of CO in the incinerator exhaust gas stream is a good indicator of the combustion efficiency for an incinerator. Combustion conditions that result in incomplete combustion will produce CO as well as particulate matter and organics. Because carbon monoxide is such a good indicator of combustion efficiency, many state regulations for medical waste incinerators require that the level of carbon monoxide in the incinerator flue gas be continuously monitored. Continuous emissions monitoring systems, known as CEM systems, are often required for oxygen as well as carbon monoxide.

Hydrogen chloride (HCl) is the principal acid gas of concern for medical waste incinerators. This is because medical waste contains a high percentage of plastics, typically from 15% to 20% of the waste stream[1], and PVC plastics (which contain chlorine) make up approximately 10% of the total plastic waste stream. PVC plastics, in the presence of available hydrogen in the combustion chamber, convert mainly to HCl. Approximately one pound of HCl is generated from 2-3 pounds of PVC plastics. Sulfur dioxide generation is similar to HCl; most of the sulfur in the waste feed is converted to SO_2 during combustion. Since medical wastes typically contain less sulfur than chlorine, SO_2 generation is less of a problem. Many States do not regulate SO_2 because they realize that the amount of sulfur in the waste is low. Nitrogen enters the incinerator in the combustion air and as a component of the waste. It reacts to form NO_x in the combustion chamber. Although NO_x is a federally regulated pollutant, it is not typically an emission of concern for medical waste incinerators due to the low emission levels emitted.

Table 1 lists pollutant emission factors derived from tests conducted on a medical waste incinerator in California.

Regulatory Emission Requirements

Many states, including Pennsylvania, New York and Florida, have passed new regulations for medical waste incinerators, while many other states are in the process of adopting them. These regulations usually contain strict emission requirements for stack gas concentrations of particulates and acid gases. In addition to regulations controlling the concentration of specific pollutants in the stack gases, many states have established acceptable ambient air quality concentrations for toxic metals and toxic organics. These standards require that air quality modeling of the dispersion of the stack gases be conducted to ensure that pollutant concentrations at sensitive receptors (e.g. public areas) are within acceptable levels. This requirement is described further in the last section of this paper. To ensure that emissions are within standards, states usually require stack testing for regulated pollutants. Stack testing may be required only at start-up of the facility, on an annual basis, or at the discretion of the specific regulatory agency.

The trend in state regulations for new medical waste incinerators is to set emission limits for particulates at either 0.03 grains per dry standard cubic-foot (gr/DSCF) or 0.015 gr/DSCF. For example, Florida regulations set particulate emission limits for new medical waste incinerators with capacities between 500 and 2000 pounds per hour (lb/hr) at 0.03 gr/DSCF, while New York sets emission levels for all new medical waste incinerators at 0.015 gr/DSCF. State regulations for HCl emission limits usually require a 90% reduction in HCl by the air pollution control (APC) system, or a concentration of 30 parts per million in the stack gas. These emission limits are considered in the description of APC equipment described below. Regulations for existing medical waste incinerators, or for new small units (typically less than 200 pounds per hour), are usually more liberal and may have significantly higher emission limits, such as particulate emission requirements of 0.1 gr/DSCF.

DESCRIPTION OF AIR POLLUTION CONTROL SYSTEMS

Many different kinds of air pollution control systems are used. Systems include settling chambers, mechanical cyclones, electrostatic precipitators and a variety of wet and "dry scrubbers". Settling chambers reduce the velocity of the gases, thereby permitting the larger particles to settle out. Mechanical cyclones rely on centrifugal force to separate particles from the flue gas stream. Both these systems are unable to meet new emission regulations for medical waste incinerators, hence they are not addressed further in this paper. Electrostatic precipitators induce an electrical charge to particles in the flue gas which are then attracted to plates which have an opposite charge. The particles are then collected on the plates and removed from the incinerator flue gas. The high cost of electrostatic precipitators is one of the main reasons these systems are not found on medical waste incinerators, which are smaller in size than municipal solid waste (MSW) incinerators, where electrostatic precipitators have been used successfully. Additional reasons for electrostatic precipitators not being used on medical waste incinerators include problems with corrosion, fouling and the passing of large particles through the system. Wet scrubbers and "dry scrubbers," (baghouses with alkaline injection upstream), are the two APC systems that have been used successfully on medical waste incinerators to meet new state emission regulations. These two systems are described below.

Wet Scrubbers

Wet scrubbers are the most common APC on medical waste incinerators today. The main reason for this is that they have been the least costly and easiest to operate for this application. In addition, most older medical waste incinerators were only required to have acid gas removal and not high particulate removal efficiencies, so scrubbers did not have to be high energy venturi-type scrubbers. Wet scrubbers may be used for removal of acid gases, or for the removal of both acid gases and particulates.

Venturi, packed-bed, and spray towers are the most common types of wet scrubber systems used on medical waste incinerators. Venturi scrubbers are used primarily for particulate removal, and packed-bed scrubbers are used primarily for acid gas removal. The two may be used in conjunction for effective control of both acid gases and particulates. Spray towers may be used for both particulate and acid gas removal, but they are not effective enough to meet the new hospital incinerator regulations for particulates, hence they are primarily used in series with a venturi scrubber. Impingement tray scrubbers are another type of scrubber which may be used for particulate and acid gas removal, but like the spray tower scrubber, their particulate removal efficiencies cannot meet new regulations. Packed-bed and spray towers are more commonly used in conjunction with venturi scrubbers than impingement tray scrubbers.

Other types of scrubbers with potential applications for medical waste incinerators include (but are not limited to) the collision scrubber, ejector scrubber and the wet ionizing scrubber. These scrubbers all rely on either impaction for particulate capture or absorption for acid gas removal.

Wet scrubbers use large liquid droplets to capture relatively small dust particles. The droplets collect particles by using a process called impaction. Particles impact onto droplets whereby they can be removed from the system. Acid gases are removed in a scrubber by dissolving the gaseous pollutants in a liquid, which is known as absorption. To remove a gaseous pollutant by absorption, the exhaust stream must be passed through (brought in contact with) a liquid. To achieve good acid gas absorption, wet scrubbers must do the following: provide a large interfacial contact area between the gas and liquid phases, provide good mixing of the gas and liquid phases (turbulence), and allow sufficient contact time for the absorption to occur. The processes of impaction and absorption are described below for a venturi scrubber. This type of scrubber is the most common type of wet scrubber being installed on medical waste incinerators today.

Venturi scrubbers rely on impaction to achieve particulate removal, as opposed to filtration as in baghouse technology. A venturi scrubber consists of a liquid sprayed upstream from a vessel containing a converging and diverging cross-sectional area as illustrated in Figure 1. The portion of the venturi which has the minimal cross-sectional area and consequently the maximum gas velocity is commonly referred to as the throat. The throat can be circular or rectangular. As the gas stream approaches the venturi throat, the gas velocity and turbulence increases. Liquid droplets serve as the collection media and can be created by two different methods. The most common method is to allow the shearing action of the high gas velocity in the throat to atomize the liquid into droplets. The other method is to use spray nozzles to atomize the liquid by supplying high pressure liquid through small orifices.

To attain a high collection efficiency, venturi scrubbers need to achieve gas velocities in the throat in the range of 10,000 to 40,000 feet per minute. These high gas velocities atomize the water droplets and create the relative velocity differential between the gas and the droplets to effect particle-droplet collision. The effectiveness of a venturi scrubber is related to the square of the particle diameter and the difference in velocities of the liquid droplets and the particles.

From the venturi section the gas enters a large chamber for separation of particles and then passes through a packed tower or spray tower scrubber for removal of acid gases. A quench section is included in the scrubber system to bring the temperature of the incinerator flue gas to the saturation temperature. A waste heat recovery boiler may be located upstream of the quench section for heat recovery and to help reduce flue gas temperatures. A schematic for a venturi scrubber system with a packed tower is shown in Figure 2.

The design gas velocity in the venturi throat depends upon a variety of parameters, including the required particulate removal efficiency and the particulate matter size distribution. The removal efficiency falls off rapidly for small particulates. Venturi scrubber particulate collection efficiency is generally correlated with the pressure drop across the venturi as opposed to throat velocity. The pressure drop is easy to measure and has a direct impact on the size of the induced draft fan required. Fan size has a direct impact on the electrical operating costs for the system. The required pressure drop across a standard venturi scrubber increases exponentially as particulate removal requirements increase. The capture of large particulates is easily accomplished. Higher particulate collection requirements, such as those required to achieve 0.03 or 0.015 gr/DSCF, require collection of smaller particulates which are more difficult to capture.

Acid gas capture begins in the venturi scrubber and is completed in the absorption tower. The absorption tower may consist of either a packed bed or a spray tower configuration. A packed-bed system may either be vertical or horizontal (vertical is more common). The liquid is sprayed from the top and flows downward across the bed. The effectiveness of absorption in packed beds is related to the uniformity of the gas velocity distribution, the surface area of the packing material and the amount and uniform distribution of the scrubber liquid. Typically, sodium hydroxide (NaOH) is used with water to neutralize the absorbed acid gases in a packed-bed scrubber.

Particulate matter is captured by the caustic water solution injected into the venturi scrubber. This particulate filled water becomes the scrubber liquid at the base of the acid gas absorber and is mixed with the fluid sprayed into the scrubber for acid gas control. A significant part of the particulate loading from standard venturi scrubbers can be from insoluble material contained in water droplets which escape from the absorption tower. Much of this material consists of insoluble salts that have no adverse environmental impact but still contribute to outlet particulate loadings. In order to capture these smaller particulates without increasing the pressure drop across the system substantially, vendors may use special diffusion mist eliminators or other techniques for reduction of particulates in the absorption tower. They also introduce additional make-up water into the system so as to reduce particulates from escaping from the tower. A typical pressure drop for this type of venturi scrubber system is 45 in. W.G. Venturi scrubbers have had good success in the field and can easily meet the new regulatory requirements of 90% reduction for HCl emissions. Systems have been proven in the field to achieve particulate levels of 0.03 gr/DSCF on medical waste incinerators and vendors are installing them under guarantees to meet emission limits of 0.015 gr/DSCF. The major components of a commercial venturi packed-bed scrubber system are as follows:

- Venturi with variable throat section and spray nozzles;
- Integral quench system or chamber for quenching flue gases from the incinerator to the adiabatic saturation temperature upstream of the venturi scrubber throat;
- Packed tower section comprising packing media, a sub-cooler section and an outlet mist eliminator (demister) to remove entrained water droplets;
- Induced draft fan;
- Water circuitry including recirculation system with pumps, piping valves and fittings;
- A pH neutralization system with a caustic (sodium hydroxide) feed tank, pump set, piping and controllers; and
- System controls and instrumentation.

A schematic outlining the components of a venturi scrubbing system is shown in Figure 3.

"Dry Scrubbers"

"Dry scrubber" is a broad term that has been used to describe any APC equipment consisting of dry alkaline injection upstream of a particulate removal device. Hence dry scrubbers may consist of lime injected upstream of an electrostatic precipitator or a baghouse. As mentioned earlier, electrostatic precipitators are not commonly used on medical waste incinerator facilities, hence the discussion on dry scrubbers is limited to alkaline injection upstream of a fabric filter (baghouse).

Fabric filtration is one of the most common techniques used to collect particulate matter. A fabric filter is a collection of bags constructed of a fabric material (nylon, wool, or other) hung inside a housing. The combustion gases are drawn into the housing, pass through the bags, and are exhausted from the housing through a stack to the atmosphere. When the exhaust stream from the incinerator is drawn through the fabric, the particles are retained on the fabric material, while the cleaned gas passes through the material. The collected particles are then removed from the filter by a cleaning mechanism, typically by using blasts of air. The removed particles are stored in a collection hopper until they are disposed, and are referred to as flyash.

With a new filter, the open areas in the fabric are of sufficient size that particles easily penetrate the bag. Over time, a cake builds on the bag surface, and this cake acts as the primary collection medium. Generally, fabric filters are classified by the type of cleaning mechanism that is used to remove the dust from the bags. The three types of units are mechanical shakers, reverse air, and pulse jet. To date, the only medical waste incinerators that have been identified as having fabric filters use pulse jet units. Figure 4 shows a diagram of a pulse jet baghouse.

The operating temperature of the fabric filter is of critical importance. Since the exhaust gas from a hospital incinerator contains HCl, the unit should be operated at sufficiently high temperatures to assure that no surfaces drop below the acid dewpoint. Otherwise, condensation of HCl will result in corrosion of the housing or bags. The boiling point of HCl (aqueous hydrochloric acid) is 110°C (230°F); gas temperatures should be maintained at 150°C (300°F) to ensure that no surfaces are cooled below the dewpoint. Above a maximum temperature that is dependent on filter type, bags will degrade, or in some cases fail completely. Gas temperatures should be kept safely below the allowed maximum.

Fabric filters by themselves do not result in any removal of acid gases, hence they are not used on medical waste incinerators without additional processes for acid gas removal. To remove acid gases along with particulates, an alkaline absorbent may be injected upstream of a fabric filter. In addition to removing acid gases, the alkaline absorbent also helps prevent bags from corrosion by HCl (because it neutralizes the HCl). These systems generally are referred to as dry scrubbers.

Dry scrubber/fabric filter systems for acid gas and particulate removal are of two types: spray dryer/fabric filters and dry injection/fabric filters. Both systems introduce an alkaline absorbent into the flue gas upstream of a fabric filter. The fabric filter then removes the acid gases absorbed onto the alkaline particulates as well as other particulates. The main difference between a spray dryer and a dry injection system is the method of introducing the alkaline absorbent. Spray dryer systems utilize a lime slaker system whereby the lime is mixed with water to form a paste and then fed into a spray reactor. Since the lime is in a slurry form, this type of system is sometimes called a "wet/dry system", since the absorbent is introduced into the system in a wet state and removed from the system after it has been dried from the heat of the gases. Injection of lime slurry into the spray reactor can be through dual fluid nozzles where air is used to atomize the slurry, or through rotary atomizers. The acid gases react with the slaked lime in the slurry droplet and water is then evaporated by sensible heat from the gas stream until only the solid reaction products are left for collection at the baghouse.

In a dry injection system, the alkaline absorbent (i.e., lime) is injected directly into the gas stream where it absorbs acid gases. More alkaline absorbent per pound of HCl removal is required for a dry injection system than a spray dryer, and the reaction is not as efficient. Yet the effectiveness of these systems have been demonstrated. Since no lime slaker preparation and no spray reactor are needed, these systems are less expensive than a spray dryer. Spray dryers are found widespread in municipal solid waste (MSW) incinerators, but are generally too expensive for smaller applications such as medical waste incinerators. To date, no known installations of a spray dryer exist on a medical waste incinerator facility. Dry injection systems are becoming increasingly popular where very high particulate removal efficiencies are required along with acid gas scrubbing. These systems have been successfully installed at medical waste incineration facilities. A schematic for a dry injection/fabric filter system is shown in Figure 5. The major components of a dry injection/fabric filter system are listed below.

- Dry additive feed system comprising dry reagent, silo, and weighing system;
- Waste heat recovery boiler to reduce the temperature of the flue gases and for energy recovery (this is optional, gas temperatures may be reduced without a boiler);
- Heat exchanger for additional flue gas temperature control;
- Dry reactor for mixing of lime with flue gases (some systems just comprise a special nozzle with injection directly into the breeching);
- Fabric filter (baghouse) for high efficiency removal of particulates;
- Induced draft fan; and
- System controls and instrumentation.

OPERATIONS OF VENTURI SCRUBBERS AND DRY INJECTION/FABRIC FILTERS

Small Facilities

Venturi scrubbers are the APC system of choice for smaller size medical waste incinerators (less than 500 lb/hr), and are likely to continue to be so. There are many reasons for this. The primary reason a venturi scrubber is preferred is because the initial capital costs are much lower. Reasons other than economics account for the popularity of venturi scrubbers at smaller medical waste incinerators.

Small facilities, due to the smaller amount of waste produced, usually require one shift operating periods for their incinerators. This means that daily cold start-up of the APC system is required. Such start-up is a sensitive operation for a baghouse system because it requires careful preheating during start-up since it can only accept flue gases in a relatively narrow temperature range. Bags cannot accept gases too hot because of the limitations in the materials of construction for the bags. Gases below the dew point can cause blinding of the bags. To cool the gases before entering the baghouse, the gases from the incinerator must be cooled by a waste heat recovery boiler or some other method of cooling. The waste heat recovery boiler or other gas cooling mechanism adds to the cost of the system. Waste heat recovery boilers may not be economical for small incinerators due to the small amount of steam produced from the small waste streams incinerated. Because the start-up requirements for a baghouse system are more stringent, a sophisticated operating control system is required which is costly and generally not included in APC systems for small facilities.

Venturi scrubbers have a good track record in the field for small medical waste incinerators. They are able to accept the flue gas directly from the incinerator, and start-up is much easier than in a dry injection system. Under the new regulatory requirements, many existing small to medium size hospitals are being required to upgrade their incinerators with APC systems. Venturi scrubbers have an advantage over dry injection systems for these facilities because space is quite often restricted, and the space requirements for venturi scrubbers are less than those of a dry injection system.

Emissions

A dry injection system can achieve particulate emission levels below 0.01 gr/DSCF. Venturi scrubbers have demonstrated 0.03 gr/DSCF in the field, and vendors installing special diffusion mist eliminators while using additional make-up water to wash the gases in the tower are guaranteeing 0.015 gr/DSCF. However, no test results are available from these facilities.

In a venturi scrubber system the flue gas is reduced to the saturation temperature (approximately 150 degrees fahrenheit) before entering the system. This reduction in temperature causes most metals and organics to condense onto particulates for removal by the scrubber. To condense the majority of metals and organics onto particulates for removal in a baghouse, the temperature must be reduced to approximately 275 degrees fahrenheit (°F). This is close to the dew point of the gas, hence extreme care must be exercised in controlling the temperature. A temperature range significantly above 275 °F will result in metals and organics not being removed by the system. If operated correctly, both APC systems can meet regulatory requirements for all pollutant emissions.

Gases are reduced to below their saturation temperature in a venturi scrubber system, resulting in a visible steam plume emanating from the exhaust stack. This can be undesirable from an aesthetic point of view. A reheater may be included in the scrubbing system to eliminate this steam plume.

Ash and Liquid Effluent Disposal

The waste leftover from the APC system can affect costs and operations significantly, and hence affect the selection of the APC system itself. Wet scrubber systems produce a liquid effluent as waste which is usually discharged directly to the sewer system. Baghouse systems produce flyash, which is either classified as a solid waste, special handling waste or a hazardous waste. This waste is disposed of in an appropriate landfill according to its designation. The effluent from a venturi scrubber system from a medical waste incinerator may contain concentrations of heavy metals in excess of local sewer pretreatment standards (which can be very strict) or federal regulations. At hospitals the scrubber effluent is usually mixed with other liquid discharges from the hospital before being discharged to the hospital sewer, therefore providing a safe dilution factor for the effluent to ensure compliance with all regulatory requirements. In the case of direct discharge to the sewer system under strict sewer pretreatment standards, a specially designed spray evaporator may be employed in series with the wet scrubber to dry the liquid waste for disposal in a landfill. A more common dilemma is how to classify flyash from the baghouse. If this waste is categorized as hazardous then the annual cost of the system can increase significantly. This classification can be an important drawback for dry injection systems. The general trend seems to be to classify this flyash as a special handling waste - which puts it in between a solid waste and a hazardous waste in terms of disposal costs.

Another option is to use a dry injection/fabric filter system with a wet scrubber downstream. This type of system will capture trace metals in the baghouse flyash instead of in the scrubber effluent. The flyash must then be disposed of in a safe manner. Additional acid gas and particulate removal is achieved by the wet scrubber. These types of systems have been installed successfully on medical waste incinerators, but the redundancy of having a wet and dry scrubber generally is not required. These systems are more costly then venturi scrubbers or dry injection/fabric filter systems.

AIR QUALITY MODELING AND HEALTH RISK ASSESSMENTS

Many states require that an air quality modeling and health risk assessment be conducted as part of the permitting process for medical waste incinerators. Air quality modeling uses EPA approved computer models to estimate how the stack emissions, or stack plume, disperses from the incinerator stack. Commonly used EPA dispersion models include the Industrial Source Complex (ISC) model and the COMPLEX-1 model. The air quality modeler calculates how the plume from the incinerator stack affects pollutant concentrations at sensitive receptors. Data input requirements for an air quality model consist of meteorological conditions which simulate a wide range of weather conditions and provide a conservative estimate of worst case pollutant dispersion. Other inputs into the computer air quality model include stack parameters (velocity, temperature, height, etc.), and local terrain features which may affect dispersion (tall buildings, hills).

Estimated pollutant concentrations from the air quality modeling analysis are compared to state and federal standards for ambient air quality concentrations to show compliance with regulations.

In states where no established standards for pollutants exist, or where only guidelines exist, a health risk analysis may be required to show that estimated pollutant concentrations will not significantly increase the risk to public health.

A health risk analysis for a hospital incinerator includes an estimate of the incremental cancer risk due to the presence of the incinerator. The incremental cancer risk for an individual is the estimated excess probability of contracting cancer as the result of constant exposure over a 70-year lifetime to the ambient pollutant concentrations resulting from operation of the facility. An incremental cancer risk of less than one in a million is considered an acceptable risk[2]. Maximum concentrations estimated in the air quality modeling analysis for specific pollutants of concern are multiplied by their unit risk factor to give the estimated incremental cancer risk.

Unit risk factors are based on carcinogenic potency factors established by scientists in EPA's Cancer Assessment Group (CAG). The CAG recognizes numerous uncertainties in the process by which it has determined cancer potency factors. The CAG's policy has been, when faced with uncertainty, to error on the side of overestimating the carcinogenic potency, and therefore, the carcinogenic risk. Thus, the CAG's policy is a conservative approach. A health risk analysis is based on a conservative methodology. Risks are based upon maximum pollutant concentrations estimated in the air quality modeling analysis using conservative modeling assumptions. Also, people living near an incinerator facility are not usually exposed to the concentrations as assumed in the health risk analysis because: the incinerator will generally not operate for a 70-year period, and they are likely to spend significant parts of their time at other locations. The health risk assessment can be an important analysis in showing the public the comparative risks associated with a specific hospital incinerator. Generally speaking, most new medical waste incinerators pose an incremental cancer risk of less than one in a million.

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TABLE 1

UNCONTROLLED
EMISSION FACTORS
FOR
MEDICAL WASTE[1]

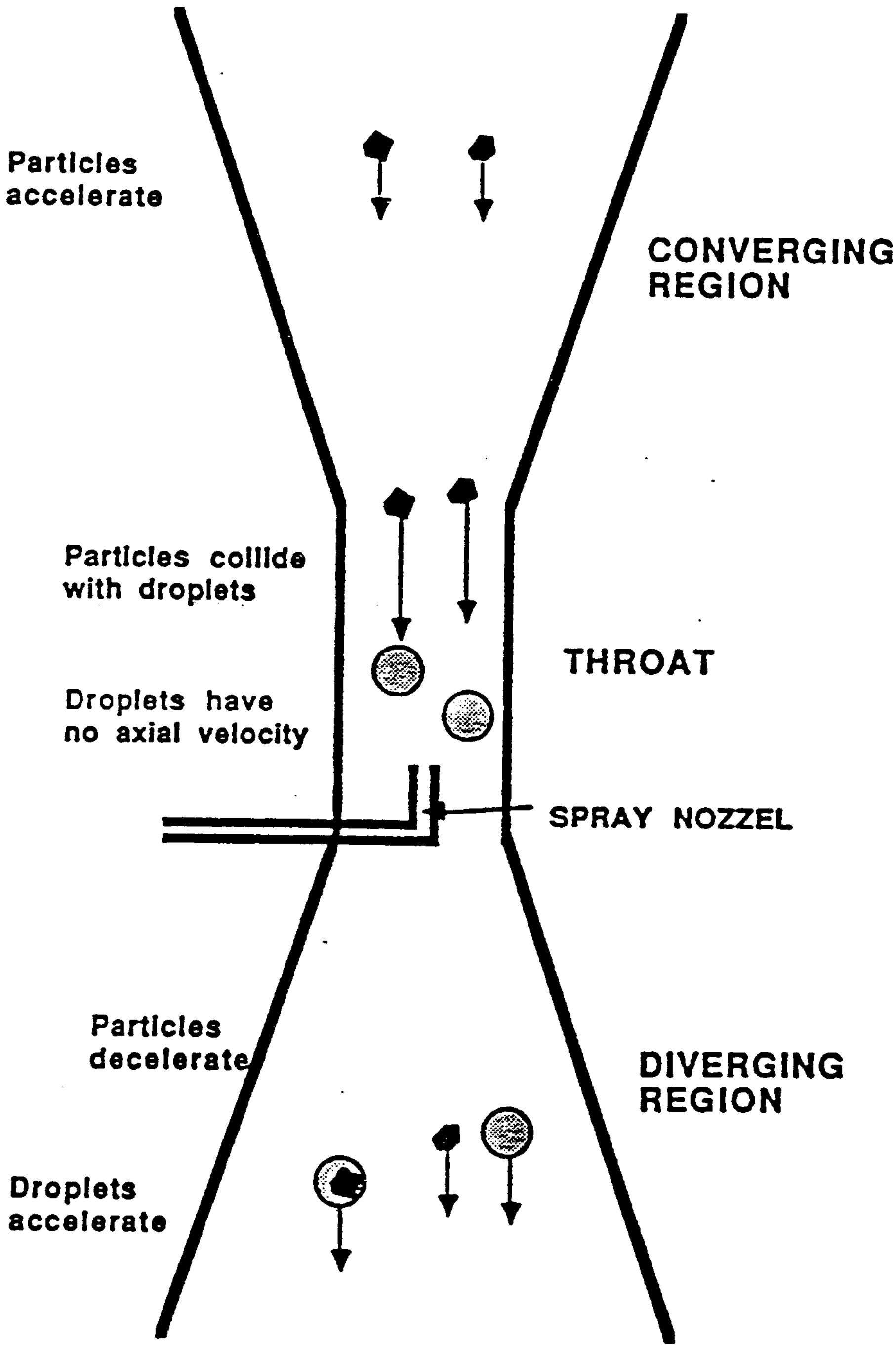
	Pounds per Ton of Waste		
	Max.	Min.	Avg.
Particulate	5.4	1.4	4.1
Hydrogen Chloride	66	7	9.4
Sulfur Dioxide	3	1.5	2.7
Nitrogen Oxides	7.8	4.6	6.2
Carbon Monoxide	1.7	1.3	1.5

	Pounds per Million Tons of Waste		
Metals	Max.	Min.	Avg.
Arsenic	300	70	180
Cadmium	7,000	2,000	4,500
Chromium	1,000	100	550
Nickel	500	100	300
Lead	60,000	30,000	40,000
Mercury	4,000	2,000	3,000
Trace Organics			
PCDD (Dioxins)	12.5	3.0	7.8
PCDF (Furans)	21.8	8.2	15.0

[1]Source: CARB tests of St. Agnes Medical Center, Fresno, CA (Ref. 3).

Figure 1

Ref: Energy and Environmental Research Corporation (Ref. 4)



The behavior of solid particles and liquid droplets in a venturi scrubber.

Figure 2

VENTURI SCRUBBER / PACKED TOWER

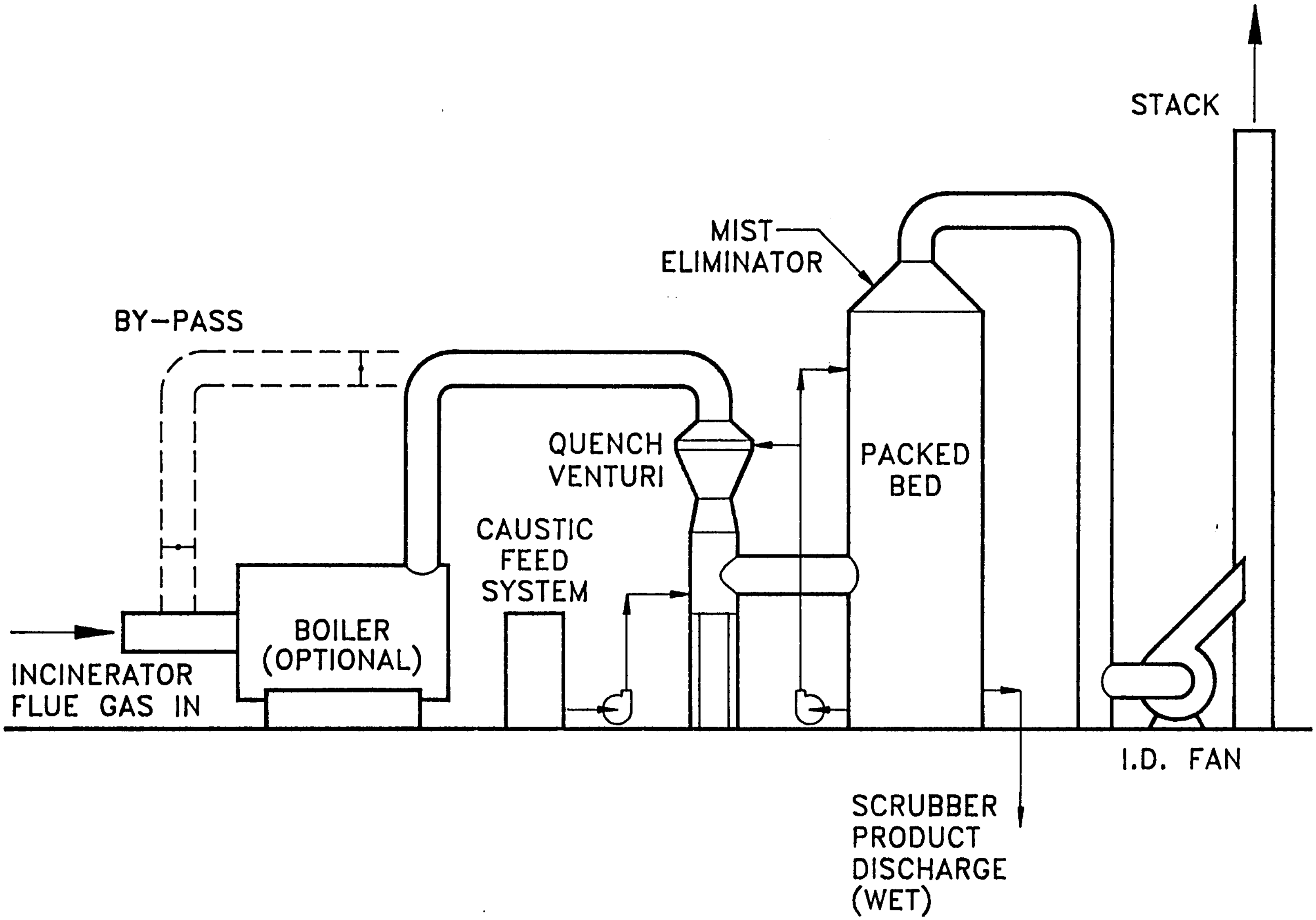
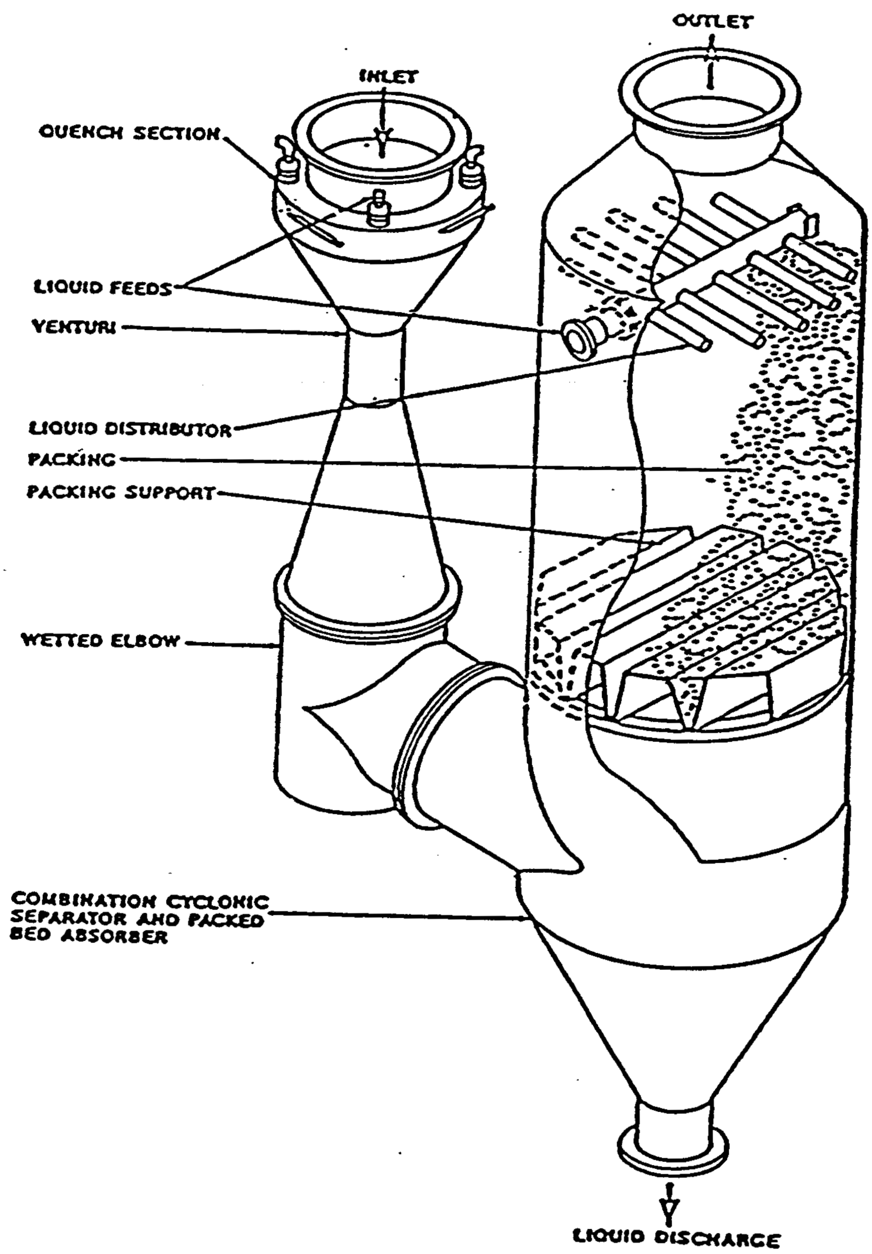


Figure 3

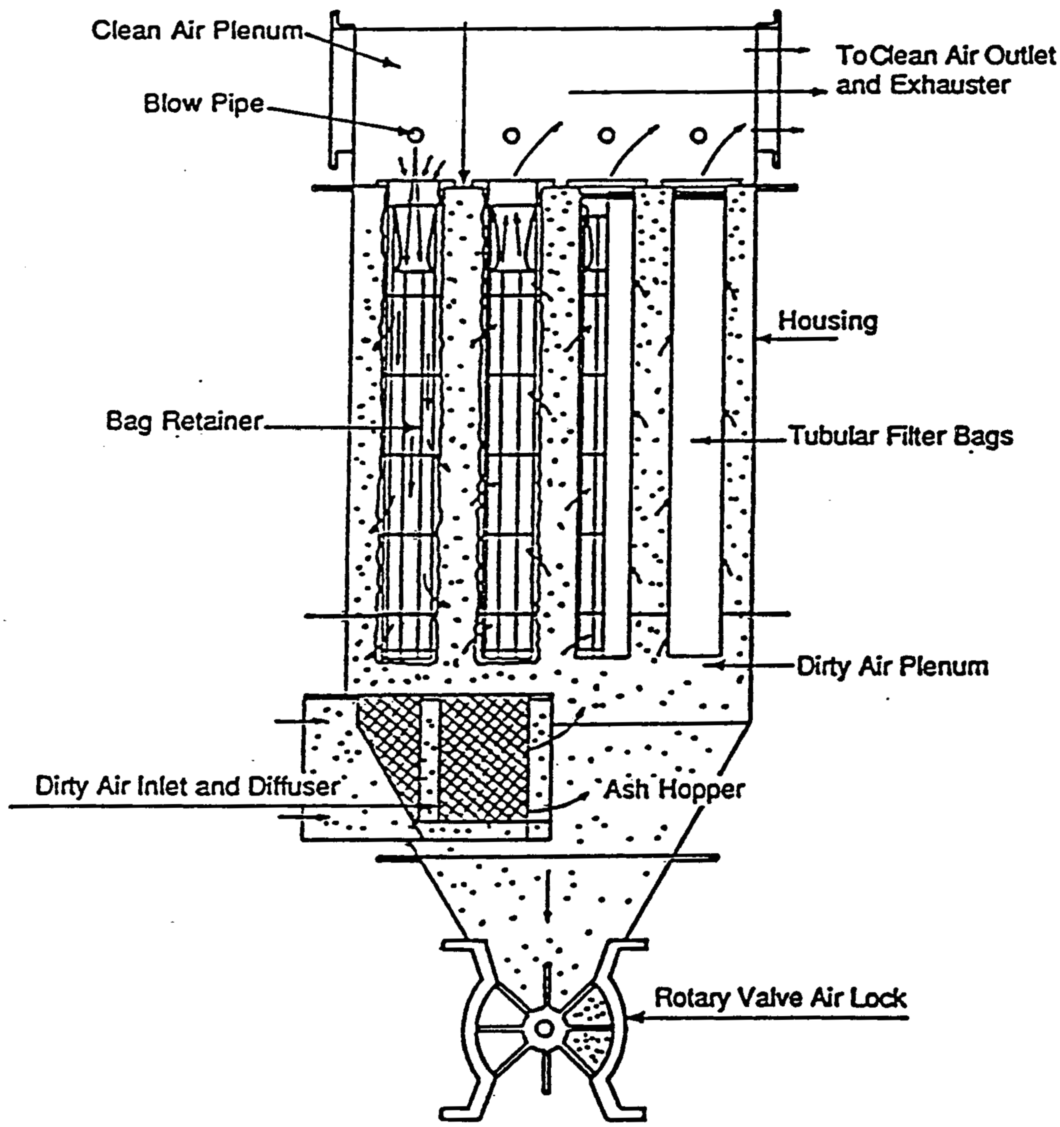
Ref: Andersen 2000, Inc. (Ref. 5)



VENTURI SCRUBBER SYSTEM

Figure 4

Ref. 6



PULSE JET TYPE BAGHOUSE FILTER

Ref: U.S. Environmental Protection Agency, "Controlled Techniques for Particulate Emissions from Stationary Sources," Volume 1. EPA-450/3-81-005a. (NTIS PB 83-127498) September 1982

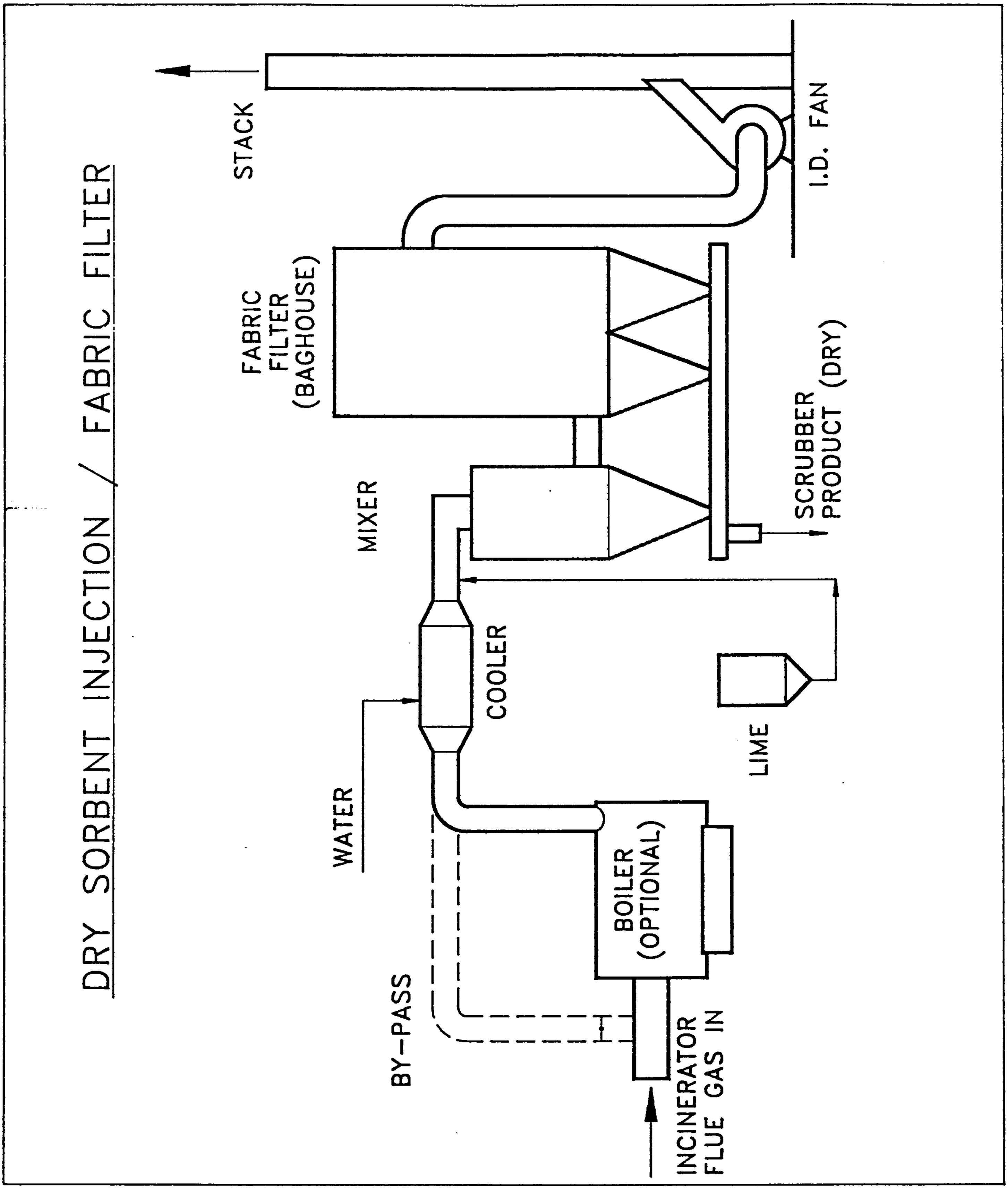

DRY SORBENT INJECTION / FABRIC FILTER
STACK
I.D. FAN
FABRIC FILTER (BAGHOUSE)
SCRUBBER PRODUCT (DRY)
MIXER
COOLER
LIME
WATER
BOILER (OPTIONAL)
BY-PASS
INCINERATOR FLUE GAS IN

FIGURE 5