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EVOLUTION OF THERMAL REMEDIATION

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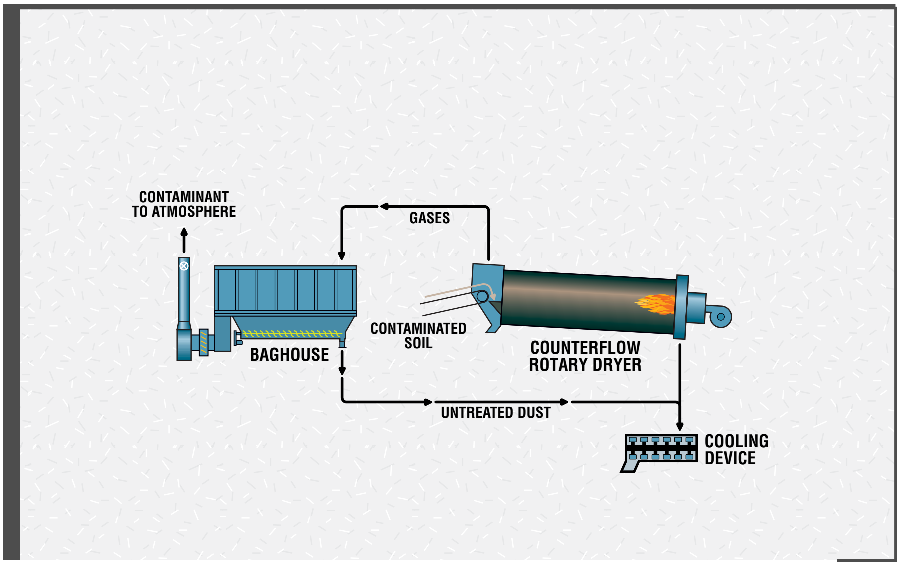
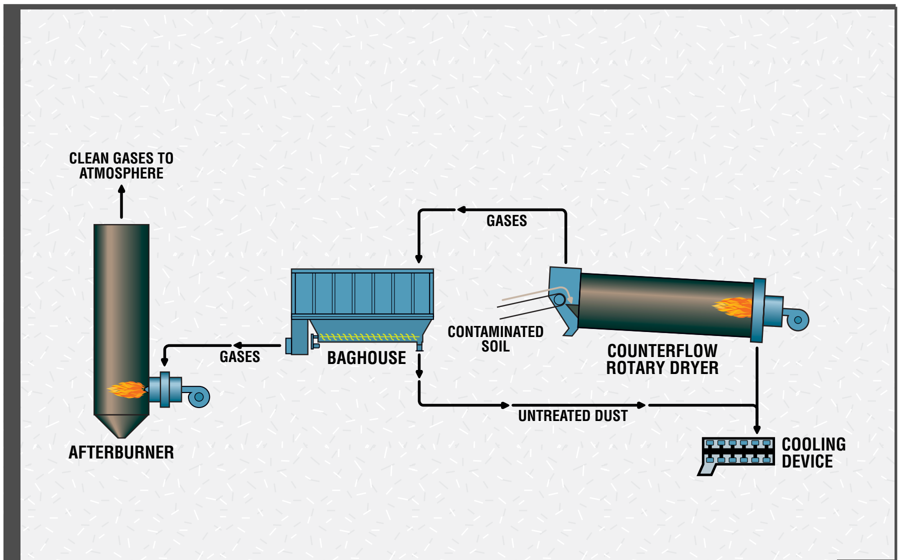
EVOLUTION OF THERMAL REMEDIATION

Treating petroleum contaminated soils with rotary kiln technology became popular several years ago, largely as a result of the Resource Conservation and Recovery Act. Among other things, this act provided requirements for the regulation of underground storage tanks (UST's) which became the driving force for remediation of UST sites containing petroleum contaminated soils. Asphalt plant and material drying equipment owners soon discovered that gasoline contaminated soils could be processed in their existing equipment by drying and heating the soils to temperatures of 400-500°F. This heating process would drive off the contaminants by forcing them to evaporate, leaving the soils remediated (see **Figure 1**). The gases were then discharged out of the exhaust stack with no further treatment. These evaporation operations were simply transferring the contaminants from the soils to the atmosphere. When regulatory agencies forced this type of operation into compliance with air emissions, afterburners were added to minimize hydrocarbon emissions from the baghouse stack gases. This soil cleaning method became popular because an alternative to landfilling (or bioremediation, aeration, etc.) was suddenly available to the contaminated soil generator, which could clean the soils quickly and effectively.



TYPICAL ASPHALT PLANT PROCESSING CONTAMINATED SOILS **F1**

Large quantities of hydrocarbon contaminated soils are in need of treatment or disposal throughout the world including soils contaminated with “light hydrocarbons” such as gasoline, diesel fuel and jet fuels as well as “heavier hydrocarbons” including fuel oils, motor oils, lubricating oils and coal tars. Many efforts have been undertaken in the US to thermally treat soils from underground storage tank closures typically containing the light petroleum products. The thermal remediation of maintenance yards, refineries and transfer stations that are predominately contaminated with the heavier hydrocarbons is not as widespread and is more complicated. These types of projects clearly mark the point at which thermal plant design becomes critical to the feasibility of the treatment process. There is a significant difference in the design and arrangement of components of a plant designed for heavy hydrocarbon contaminated soil treatment as compared to material drying systems that have been used on many gasoline station remediation projects. While there is a market for gasoline site remediation services, many contractors also have a need for fuel oil and heavier hydrocarbon cleanup capability. Many contaminated soil generators and environmental cleanup contractors understand that there is a need for extended retention times at higher processing temperatures for soil containing heavier hydrocarbon contaminants. This point is often overlooked in the design of a thermal process system. The condition of the gas stream leaving the rotary drum is most important. This gas stream, which contains the vaporized contaminants, is one of the determining factors in whether or not the system can meet the remediation objectives while operating under safe conditions. Equipment manufacturers differ in the design and application of equipment for this process which is known as Thermal Desorption. The two main process differences are: the arrangement of the rotary drum (parallel-flow or counterflow), and the location of the baghouse with respect to the afterburner gases.



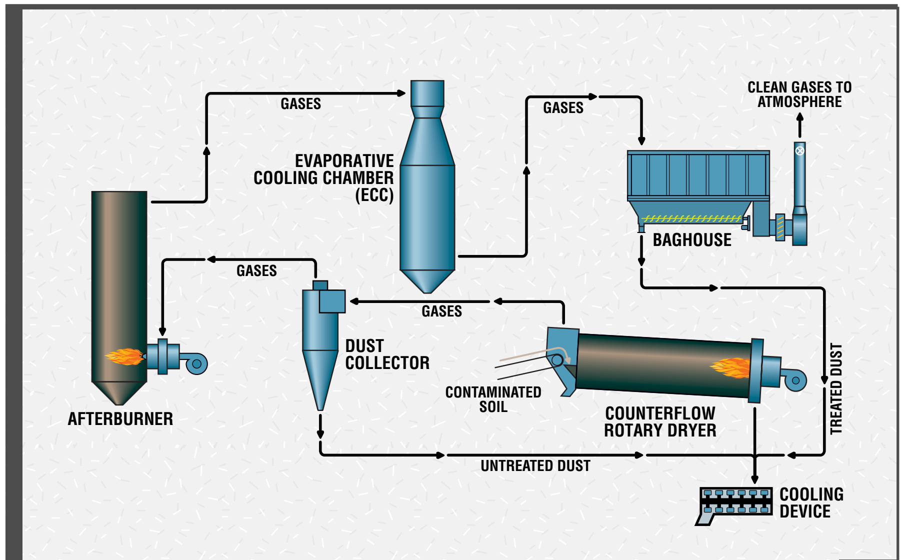
COUNTERFLOW ROTARY DRUM WITH AFTERBURNER AT END OF PROCESS F2

COUNTERFLOW

There are many soil remediation systems for gasoline contaminants available today that consist of a counterflow dryer and baghouse followed by an afterburner. As expected, these plants can be constructed for "the lowest initial costs" since there is less equipment involved. They also have limited capabilities. In a counterflow arrangement, the soils enter the drum at the opposite end of the burner and exit at the burner end (see **Figure 2**.) The drum gases exit at the end of the drum opposite of the burner, the feed inlet end. As hot gases travel from the burner toward the exit end, they contact cooler soils traveling in the opposite direction.

The end of the drum where the gases are exiting is the same end that the cold soil is entering. This allows the gas stream temperature leaving the drum to be much lower than the soil discharge temperature because the exiting gases are contacting cold incoming material. This arrangement allows these units to heat soils to 500-600°F and still maintain baghouse temperatures in the range of 350°F. Temperatures between 500 and 600°F are generally high enough to vaporize light to mid-range hydrocarbons. Heavier hydrocarbon contaminants require higher temperatures for vaporization from the soils but are not recommended in this type of configuration because the vapors will likely condense in the baghouse. This causes contaminated fines and hydrocarbon saturated bags, an undesirable and volatile situation. Additionally, the counterflow arrangement removes airborne dust particles from the drum with a gas stream that is much lower in temperature than the soil treatment temperature. Under these conditions, and at low initial concentrations, the majority of the light hydrocarbons that have been vaporized from the soils will stay in a vapor state while passing through the baghouse to the afterburner. The afterburner heats these gases with oxygen and provides pollution control of the volatile organic compounds (VOC's) that are contained in the gas stream.

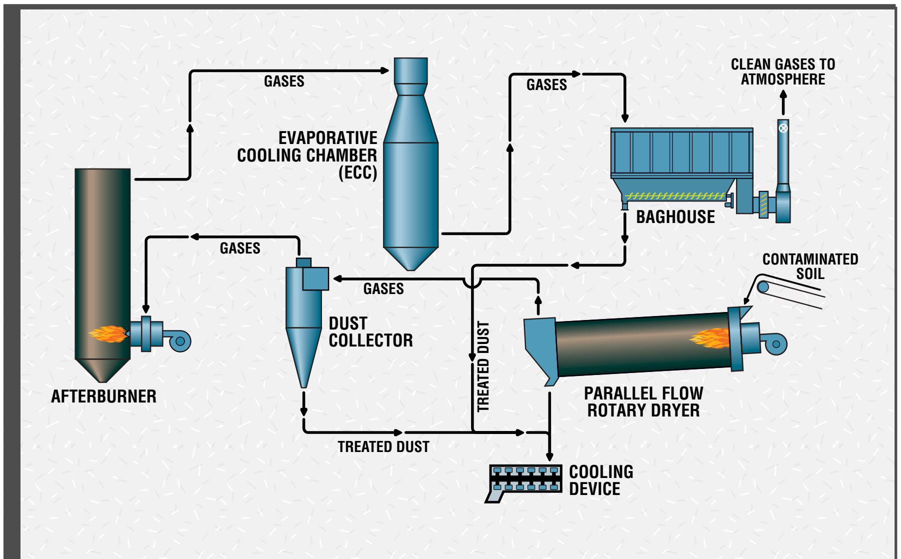
The limiting factor in a plant of this arrangement is the gas stream temperature that can be achieved in the baghouse. The maximum gas temperature for Nomex bags is 400°F. Higher temperature bags can be used in the baghouse to allow for somewhat higher baghouse gas temperatures. The baghouse can also be insulated to minimize the gas temperature drop as the gases pass through the baghouse, but the temperature limitation of the bag material and the temperature of the gas stream (which contains the vaporized hydrocarbons) remains a crucial limitation of performance capability. The potential for hydrocarbon condensation in the baghouse is maximized with this design.



COUNTERFLOW ROTARY DRUM WITH BAGHOUSE AT END OF PROCESS F3

If the counter-flow drum is not followed by a baghouse (in the case where the afterburner is placed between the drum and baghouse as shown in **Figure 3**), the potential for hydrocarbon condensation in the baghouse will be eliminated but the maximum achievable gas stream temperature will still be a limiting factor in performance capability for the process.

Heat transfer within a counterflow drum will still occur as described above and the gas stream temperature leaving the drum will be lower than the soil discharge temperature. This means that the lightest airborne particles will leave the drum at lower temperatures than the targeted operational temperature for treating the soils. Since these fine particles have a very low mass, they will become airborne easily. Fine particles have tremendous surface area and can therefore contain significant amounts of the hydrocarbon contaminant. If a primary dust collector is used following the rotary drum, the fines that are collected at this point in the process will likely contain contaminants that have not been adequately treated. The effect that the low gas stream temperature has on the fines removed by the primary dust collector is now the limiting factor of the process capability. With this arrangement, the fines must then be treated by recycling through the process, or the application of additional heating.



PARALLEL-FLOW ROTARY DRUM WITH BAGHOUSE AT END OF PROCESS F4

PARALLEL-FLOW

A parallel-flow, or co-current, system consists of a drum where the contaminated materials enter at the burner end and the gases and hot treated materials exit the opposite end (see **Figure 4**.) The gases and soil travel through the full length of the drum and in the same direction. The nature of heat transfer in this arrangement results in gas exit temperatures that are slightly higher than the soil discharge temperatures. If the unit is being operated with soil discharge temperatures of 650°F, the exit gases will be around 700°F in a properly designed rotary drum. The soil discharge and gas exit temperatures will be similar because both are exiting together at the same point in the process.

In this arrangement, all of the materials including the fine particles that become airborne are forced to travel through the entire length of the drum. Since the gas exit temperature is higher than the soil discharge temperature, the fine particles entrained in the air stream always leave the drum at or above the temperature targeted for treatment of a particular contaminant. These fine airborne particles will heat up quickly because they have a very low mass and are carried by a higher temperature gas stream. This means that all of the materials put into the drum for processing are heated to the operational temperature regardless of whether they become airborne.

In a parallel-flow configuration with the baghouse at the end of the process, higher processing temperatures are easily achievable. Since the gases leaving the rotary drum are routed to the afterburner, the only temperature limitation is the construction material of the ductwork and primary dust collector. Steel alloys can be selected for these components to coincide with the service temperatures necessary for heavy hydrocarbon contaminants. Refractory linings can also be installed in these components for increased thermal efficiency or for higher temperature applications.

SYSTEM EFFICIENCY

Efficiency is defined as a ratio of the amount of work or energy that comes out of a process compared to the amount of energy put into the process. With simple drying technology, the efficiency of heat transfer relates to how much heat can be put into the solid material compared to the exhaust gas stream. Efficiency of a rotary drum used for the remediation of contaminated soils (considering only heat transfer in the rotary drum) is highest with a counterflow arrangement because the counterflow arrangement will transfer more heat to the soils than to the gas stream. These cooler gases leaving the rotary drum will still have to be heated to the required operating temperature in the afterburner. This means that in a counterflow system the afterburner will have to handle a larger temperature differential. The afterburner will have to make up the difference in energy by burning more fuel to achieve the required operating temperature. From a standpoint of overall system efficiency, the heat transfer efficiency in the rotary drum alone is not representative of the entire system efficiency.

SAFETY

Systems with a baghouse located between the rotary drum and the afterburner can pose a safety problem because condensed hydrocarbons can accumulate in the baghouse and on the bags. Once this happens, the bags cannot remove the oil buildup through routine cleaning cycles. Depending on the contaminant being processed, and their concentrations, accumulation of condensed hydrocarbons may occur very gradually or surprisingly quickly. These condensed oils can build to a point that a fire can occur when a source of ignition is available. Baghouse fires have resulted from systems where the baghouse is located between the rotary drum and the afterburner. When processing heavy hydrocarbon contaminated soils, bags must be replaced periodically to avoid this hazard. Condensation is a function of vapor pressure of a given contaminant contained in the gas stream. The vapor pressure of the contaminant at the conditions of the gas stream is directly related to the contaminant concentration. As the concentration increases, so does the gas stream temperature necessary to keep the gases in the vapor state and prevent condensation.

The parallel flow plants which include the particulate filtration system as the final phase of the treatment process are the most effective in eliminating the danger of condensing and buildup of volatiles in the baghouse. This arrangement allows the vaporized contaminants to pass through the afterburner before the gases are filtered in the baghouse. Destroying the hydrocarbons before the gases enter the baghouse will increase the life of the bags while eliminating the potential for baghouse fires. This key feature allows for the processing of heavier hydrocarbons.

Another crucial parameter that is often overlooked in the application of thermal desorption involves the Lower Explosive Limit (LEL) of the gas stream containing the vaporized contaminants. The process of evaporating contaminants and transferring them to another chamber results in a gas stream containing some defined concentration of contaminants. For a given set of operating conditions, the higher the percentage of contaminants in the soils being processed, the higher the concentration of these vapors in the gas stream prior to the afterburner (regardless of its location). The design of a properly engineered thermal treatment system takes into consideration the concentration of these vapors and allows for no more than 25% of the LEL. This means that when operating with the maximum contaminant levels in the soils, the gas stream leaving the drum will contain a concentration of vapors that is no higher than 25% of the concentration that would be necessary for the gas stream to be combustible. The LEL calculations are based on the total gas volume leaving the rotary drum. As this volume increases, so does its capacity to safely carry vaporized contaminants. If a counterflow system limits the exit gas stream temperature and therefore limits the gas volume leaving the drum, it must also limit the amount of contaminant vapors that can be safely transported by this gas stream to subsequent components of the process.

APPLICABILITY

Counterflow designs for soil remediation can be advantageous in certain specific applications. Counterflow designs have been utilized in some special projects where a specific range of light hydrocarbon contaminants are treated. One such application involves a situation requiring partial and controlled oxidation of a specific contaminant within the rotary drum. These special applications should include the afterburner following the drum (upstream of the baghouse) since control of heat liberated from contaminant oxidation is the primary objective. When chlorinated hydrocarbons are processed, provisions for controlling HCl emissions should be included in the system. Dry scrubbing in the baghouse is one such scrubbing technique that is effective as long as the baghouse is in the appropriate location (i.e. HCl is not formed until a chlorinated hydrocarbon is oxidized in an afterburner, so a thermal system with the baghouse upstream of the afterburner could not utilize dry scrubbing methods). While counterflow designs have been appropriately applied in certain applications, they are not the best choice for a system that is intended to process a wide range of contaminants.

DIVERSE OPPORTUNITIES

SPI/Astec has designed and constructed many different thermal desorption and incineration systems which are in operation processing a variety of contaminants. The majority of these systems are designed for processing soils containing a wide range of contaminants including gasoline, diesel, jet fuel, fuel oils, motor oils, coal tars, Bunker-C, and other heavier hydrocarbons. Some of these low temperature systems have successfully treated pesticide and herbicide contaminated soils and other chlorinated hydrocarbon contaminated materials under the strict guidelines of RCRA and CERCLA regulated clean ups. Other thermal treatment plants have been designed for soils contaminated with specific hazardous compounds. High temperature thermal treatment plants include key design features such as high temperature rotary kilns operating in an oxidizing environment with acid gas scrubbers, additional control and monitoring equipment, ash discharge equipment, and other site specific special features. High temperature thermal treatment plants contain key mechanical features which make the system distinctly different from a typical low temperature desorption system. With enough foresight and planning in the design stage, a parallel flow desorption system with the baghouse at the end of the process can be easily retrofitted for more complicated projects. The modifications can involve provisions for high temperature operation, oxidation in the rotary drum, acid gas scrubbing, stabilization of treated materials and/or nutrient addition to the treated product.

SELECTING THE RIGHT EQUIPMENT

The key to selecting the right equipment for soil remediation includes identifying the intended materials, required cleanup level and type of contaminants that will be processed. This will dictate the operational parameters necessary for successful remediation. The size of the equipment components operating under these parameters will determine the rate at which the machine can operate and will qualify a contractor for the type and size of jobs that his company will be capable of handling. The next factor to consider is the ability of a given design to meet future regulatory requirements. This is an extremely important aspect to the long-term survival of a contracting company and will include future soil cleanup standards and air emission limitations. The past trends by regulatory agencies have been only to tighten these standards. The most versatile thermal system is one which can operate efficiently in treating a given range of contaminants without encountering problems due to condensation, cleanup levels, LEL and/or corrosion.

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