# 1.0 BACKGROUND

This report is a summary of testing activities conducted by BioSafe at its Woburn, Massachusetts Technology Center associated with contract BNL-725048. These activities were conducted by our personnel over the period of November 1995 through February 1996. While the requirement was to conduct bench-scale testing of the process, BioSafe actually fabricated a pilot-scale embodiment of the first phase of the process and conducted all tests using that unit.

This demonstration was an extension of the basic requirements of Phase I - bench-scale processing in that it was in reality a pilot-scale unit capable of processing material in excess of the minimum rate required by the contract. However, BioSafe's experience is that a minimum size is necessary to effectively demonstrate the most critical aspects of the process. This is especially true when dealing with processes that are required to process a complex feed such as the sediment. BioSafe's fundamental approach was to conduct this demonstration to provide data that was indicative of process operation at a size sufficient to identify the limitations of the process and any potential barriers to scale-up to commercial operation.

The Phase I pilot unit proved to be an effective demonstration of the basic operation of the process, and survives as a unit capable of being used as the first stage for subsequent demonstrations. Significant progress has been made in process development that will significantly reduce the "learning curve" for scale up. Specifically, the Phase I pilot unit demonstrated the ability of the FBT process to:

- Operate with a continuous feed;
- Process the sediment as received (without dewatering); and
- Producing a contaminant-free solid product in the first stage of the process.

BioSafe was successful in demonstrating all of these aspects at the pilot scale using commercially available systems and equipment. During a two continuous runs, 100 pounds of sediment were processed on a continuous basis producing a contaminant-free solid while vaporizing the organic constituents that could be processed in more conventional downstream systems.

The following report is a summary of the testing that occurred including the results and projected performance and costs associated with a pilot-scale demonstration of the full process.

## 1.1 FBT PROCESS DESCRIPTION

The BioSafe FBT process uses fluidized bed steam cracking to totally destroy any organic materials such as dioxins, PCB's and petroleum products present in a variety of materials including soils, sediments and sludges. It is a robust process, based on the application of fluid-bed technologies that have been in practice for more than 50 years, and can handle a wide range of materials and contaminants. The BioSafe process is not incineration or oxidation. It converts all organic materials to carbon monoxide, hydrogen and methane - a clean, fuel gas that is recycled in the process. The remaining solids are free of organic material, and (depending on the metal content) may be disposed of without restriction.

Key to the process is the use of fluidized beds as reaction vessels. While this particular application is new, the concept of using fluid beds for thermal processes began in the 1930's. Fluidized bed operation depends on the fact that when the velocity of a gas flowing upward through a bed of small particles is increased sufficiently, the particles begin to float. At the threshold velocity for fluidization, the bed of material expands upward and behaves as if it were a viscous fluid. Further increasing the velocity of the gas causes the bed to expand by about 30 percent as bubbles form, and the bed begins to behave like a turbulent boiling fluid. It does not have a sharply defined free upper surface, rather the as the solid fraction decreases in the upper regions of the bed, the gas velocity also decreases and the particles making up the bed are no longer lifted. However within this bubbling bed, the large gas bubbles that form move upward rapidly and in doing so displace bed material above it, and some circulates downward along the bubbles upward path. This turbulence provides a significant agitation within the bed which provides a uniform distribution of hot material and temperature within the bed.

The most significant advantage of a fluid bed for thermal applications is the mixing of a large mass of material that is held at a constant temperature. This mass of material provides not only a high thermal inertia, but a highly conductive heat transfer media. Each particle within the bed is hot (typically the entire bed is maintained within a 10 °F range), and acts as a source of heat that transfers via conduction to the material that is introduced. Studies have shown that within fluid beds heat transfer coefficients are typically 50 to 100 Btu/hr-ft$^2$-°F. This is 5 to 25 times that for the combustion gas alone. This inherent efficiency is the basis of selection of the fluid bed for the FBT process.

Figure 1.1-1 is a simplified process flow diagram. The FBT process uses two stages or fluid beds in series. The feed material is conveyed continuously into the first fluidized bed using a commercially available transport device. In the case of sludge, a progressive cavity pump would be used, while a screw conveyor is used for drier materials like soil. The FBT unit is an indirectly heated fluidized bed that heats the processed material to a temperature in the range of 1200 to 1400 degrees Fahrenheit (°F). Within the atmospheric vessel, a bed of sand or refractory grog is fluidized along with the feed using superheated steam with a temperature in the range of 1400 to 1500°F. The fluid bed is heated by tubes immersed in this bed of bubbling solids. Heat is supplied by burning a fuel such as natural gas (supplemented by the LoBTU gas that the process produces) and then passing the hot combustion gases through the tubes immersed in the bed. Combustion gases do not come into contact with the material being treated. In this bench-scale unit, the heat will be provided by electric heaters.

The volatile organic materials in the feed have boiling points in the range of 180 to 1200°F and volatilized ("steam stripped"). The organic vapor is then "cracked" at a temperature of about 2200°F in a second fluid bed to yield carbon monoxide, hydrogen, and methane. When treating simple wastes (e.g. sewage sludge), a single desorption/cracking stage at 1200 to 1400

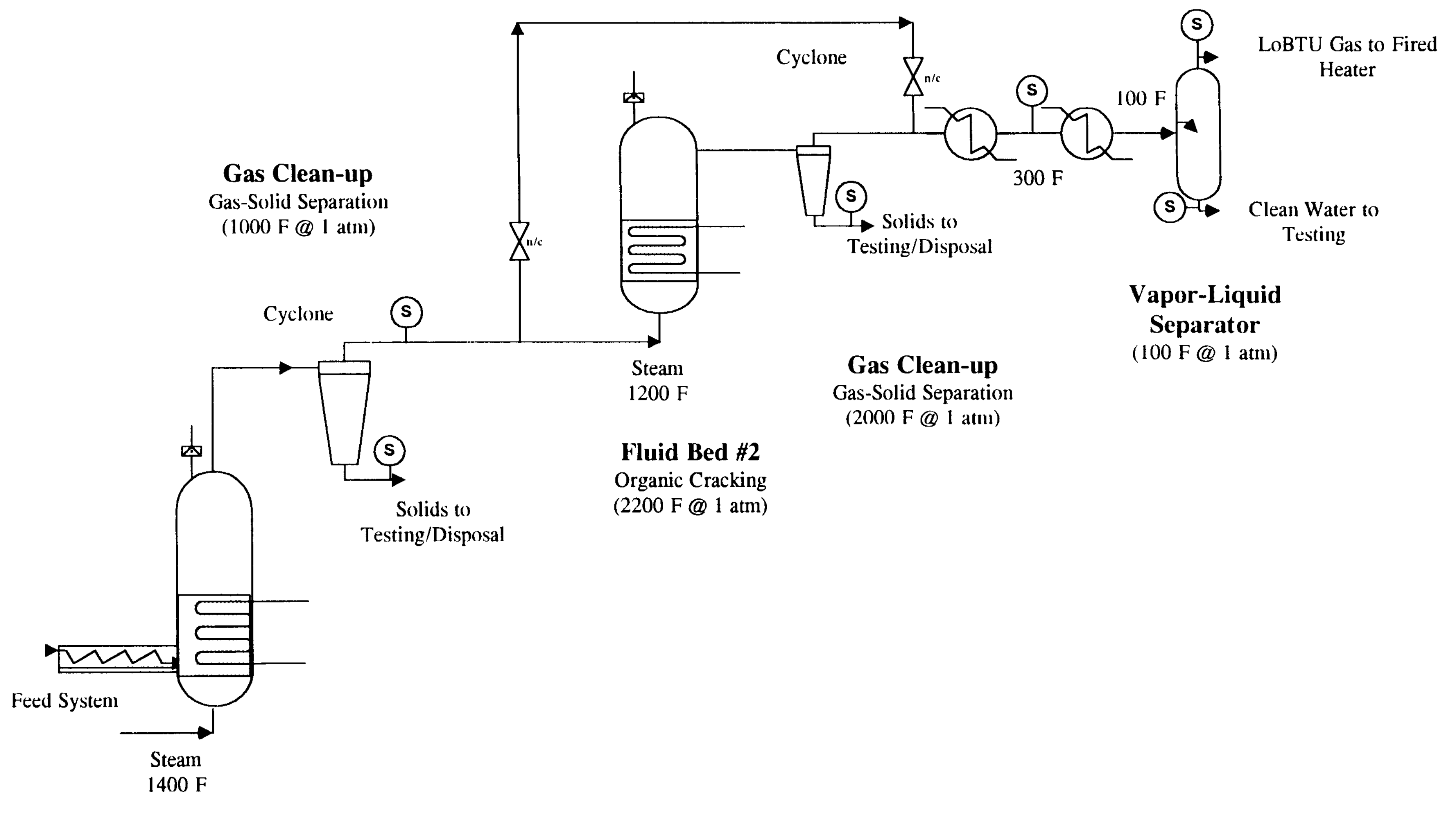


**FIGURE 1.1-1**
**BioSafe FBT Process**
**Basic Process Flow Diagram**

°F is adequate. These hot gases exit the fluidized bed with the steam and vaporized water. The ash/inerts are removed from the bottom of the fluidized bed and cooled with water to a temperature of 100°F with a moisture content of around 3% to reduce dusting. This material is disposed of as appropriate. Options for the ash/inerts include use as clean fill, concrete aggregate, cover material, agricultural material or beach nourishment.

The vapor from the outlet of the first fluidized bed (organic vapor, water and dust) enters a cyclonic separator where large particulates are collected. Following this separation, the hot gas passes through a baghouse/filter where small particulates less then one (1) micron are collected. These collected solids are mixed with the ash/inerts and disposed of. The gas then enters the second atmospheric fluid bed where they are "cracked" at about 2200°F to yield the components of the LoBTU gas. This stream is also processed to remove any entrained solids, cooled, and the water fraction condensed and collected. The organic portion which remains a vapor is the LoBTU gas (heating value of approximately 400 to 500 BTU/scf vs. 1,000 BTU/scf for natural gas) which can be recycled as fuel and burned along with natural gas in the combustion system which supplies heat to the tubes immersed in the fluidized bed.