

# I PRO 345

## Objective

The Purpose of I PRO 345 was to identify opportunities for innovation and developing an improved method for remediating soils contaminated with polychlorinated biphenyls (PCBs).

## THE DESIGN OF A NOVEL MOBILE PROCESS FOR THE REMEDIATION OF CONTAMINATED SOILS

## Contaminated Sites



**Waukegan Harbor** (Top Left)  
 Approximate Size: 0.5 square miles site plus harbor soil  
 Population Proximity: less than 1 mile  
 Industry Responsible: Outboard Marine Corporation  
 Clean Up Efforts: Started in 1992 & ongoing  
 Levels of Contamination:  
 Before Cleanup: 500,000 ppm  
 After Cleanup: 32 ppm

**Altgeld Gardens** (Top Right)  
 Approximate Size: 0.8 square miles  
 Population Proximity: On top of site  
 Industry Responsible: U.S. Steel, The Ford Company, Pullman Factory  
 Clean Up Efforts: None  
 Levels of Contamination: N/A

## Background

• PCBs were used as insulating fluids in electrical equipment in power plants, telecommunications and utility lines, and in large buildings across the country.

• Due to the unregulated disposal of PCB's, hundreds of millions of pounds of PCBs were improperly dispersed into the environment.

• Once in the air, PCBs can be carried long distances. They have been found in snow and seawater in the Antarctic.

• The United States Environmental Protection Agency classifies PCBs as carcinogens. Studies have shown that PCBs can also cause a variety of non-cancer related health effects including damage to the immune, reproductive, nervous, and endocrine systems.

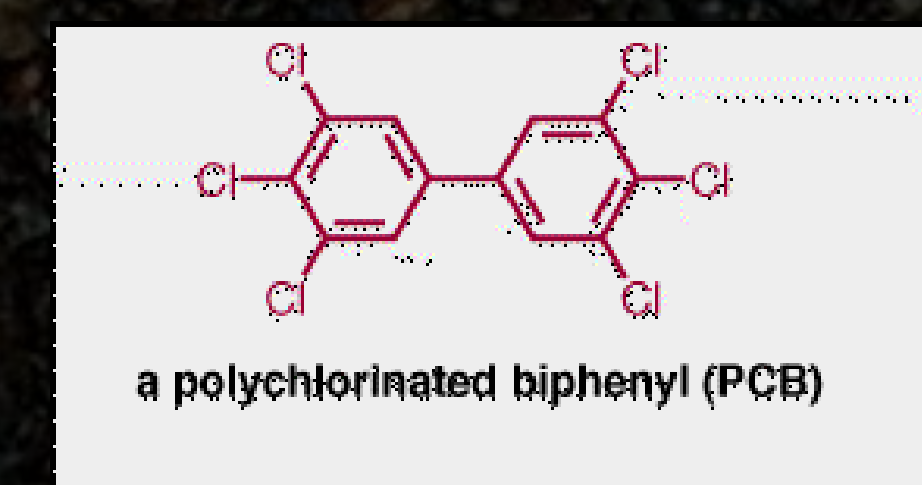
• Humans are exposed to PCBs through inhalation, skin contact or consuming fish from contaminated waters. Studies show that irritations such as rashes, burning eyes and skin can occur at work sites containing devices made with PCBs.

• Mothers who consume fish containing high levels of PCBs report higher incidences of birth defects such as birth weight, gestational age and neonatal behavior.

## Chemistry of PCBs

### Physical Properties

Appearance: light yellow viscous liquid  
 Melting point: 10 C  
 Boiling point: 370 C  
 Density (g cm<sup>-3</sup>): 1.51  
 Vapor Pressure: 0.000077mmHg at 25° C  
 Diffusion coefficient in air: 0.05571cm<sup>2</sup> /s  
 Water solubility: 0.031mg/L where 1mg/L is approximately equal to 1ppm (negligible)



• Polychlorinated biphenyls (PCBs) are synthetic chemical compounds consisting of chlorine, carbon and hydrogen. Our design will focus on the more common PCB: PCB 1254.

### Chemical Properties

- High degree of chemical stability
- Low solubility in water and low vapor pressure.
- Low flammability and electrical conductivity
- Favorable dielectric consistency.
- PCBs with a high degree of chlorination (Aroclor 1248, 1254, and 1260) are resistant to biodegradation and appear to be degraded very slowly in the environment.

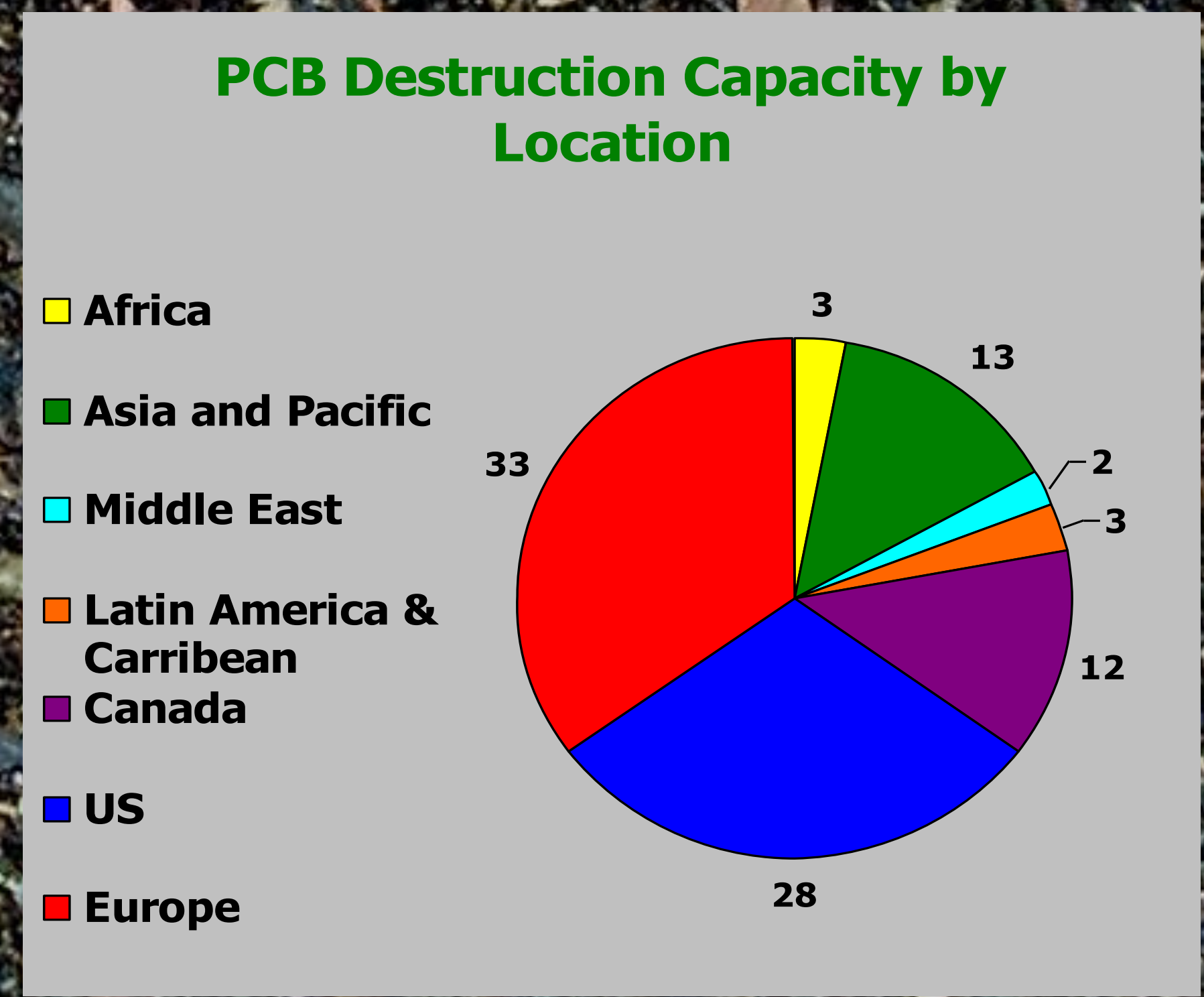
## Global Remediation Efforts

• According to Haz Waste Magazine, the global market for PCB clean-up is an estimated \$40 billion.

• Thermal desorption and chemical dechlorination are the most widely used methods while sonic and super critical fluid technologies are emerging.

• Legislation and international treaties provide the primary motivation for PCB remediation. Among these are the Basel and Stockholm Convention. The US and Europe have the toughest national legislations.

• China and India, like many underdeveloped countries, have limited legislation and often rely on international treaties for guidance. There is also a lack of facilities in these countries.



	U.S	Europe	China	India	Other
Total Number of Facilities	28	33	1	0	41
Relevant Legislation/Treaties	TSCA/Basel/Stock.	EFSA/Basel/Stock.	Basel	Basel	-
Types of Facilities	L/I/D	L/I/D	I	none	L/I/D
Cumulative PCB Production	625,000 tons	300,000 tons	-	-	70,000 tons

\*Landfill/Incinerators/Dechlorination = L/I/D Basel - Basel Convention Stock. - Stockholm Convention on POP's  
 TSCA - Toxic Substances Control Act EFSA - European Food Safety Authority  
 It is estimated that 1.2 million tons of PCBs were ever produced worldwide.

## Team Information



(Left to Right) Sotiel Sam Polena, Justin Kirk, LaShawna Taylor, Ahlam Hmadouch, Vito Bussmann, Charlotte Okwudi, Suman Bir, Dolapo Popoola, Robert Rivera, Katya Barragan-Perez, Dr. Lindahl (Not pictured Jonathan Witthoef)

## Consultants

- Dr. J. Abbasian – IIT Department of Chemical Engineering
- Dr. H. Lindahl – IIT Department of Chemical Engineering
- Dr. Pagilla – Environmental Engineering Faculty, IIT
- Ray Loach - IIT Graduate Student
- Dave Graham - City of Chicago DOE

# IPRO 345

## THE DESIGN OF A NOVEL MOBILE PROCESS FOR THE REMEDIATION OF CONTAMINATED SOILS

What are the different remediation options available?

1. Incineration: results in more toxic and unstable material
2. Excavation and land filling: Not acceptable by UNEP standards
3. Dechlorination: Only for 10% or less PCB contamination
4. Supercritical Fluid Extraction: Emerging technology not yet scaled up
5. Thermal Desorption: Widely accepted.. Novel design to include mobility

What is Thermal Desorption?

- Process of applying heat to the contaminated material to volatilize it into a gas stream
- The Gas stream is then treated prior to discharge to the environment

Thermal Desorption Methodology

- Combustion gas is the transfer medium for the vaporized components
- Fluidized bed is the contact chamber for the solid particles and the combustion gas

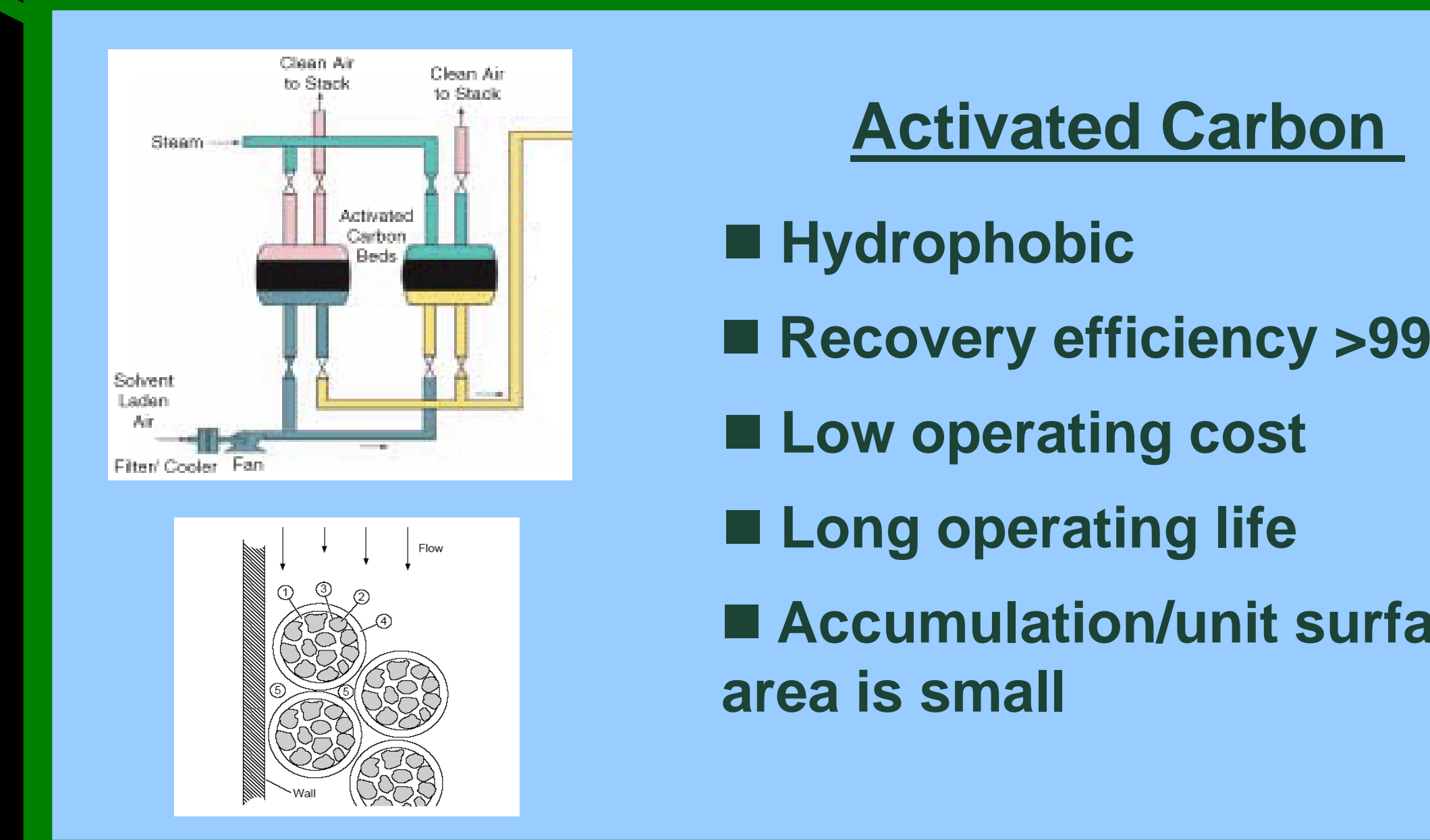
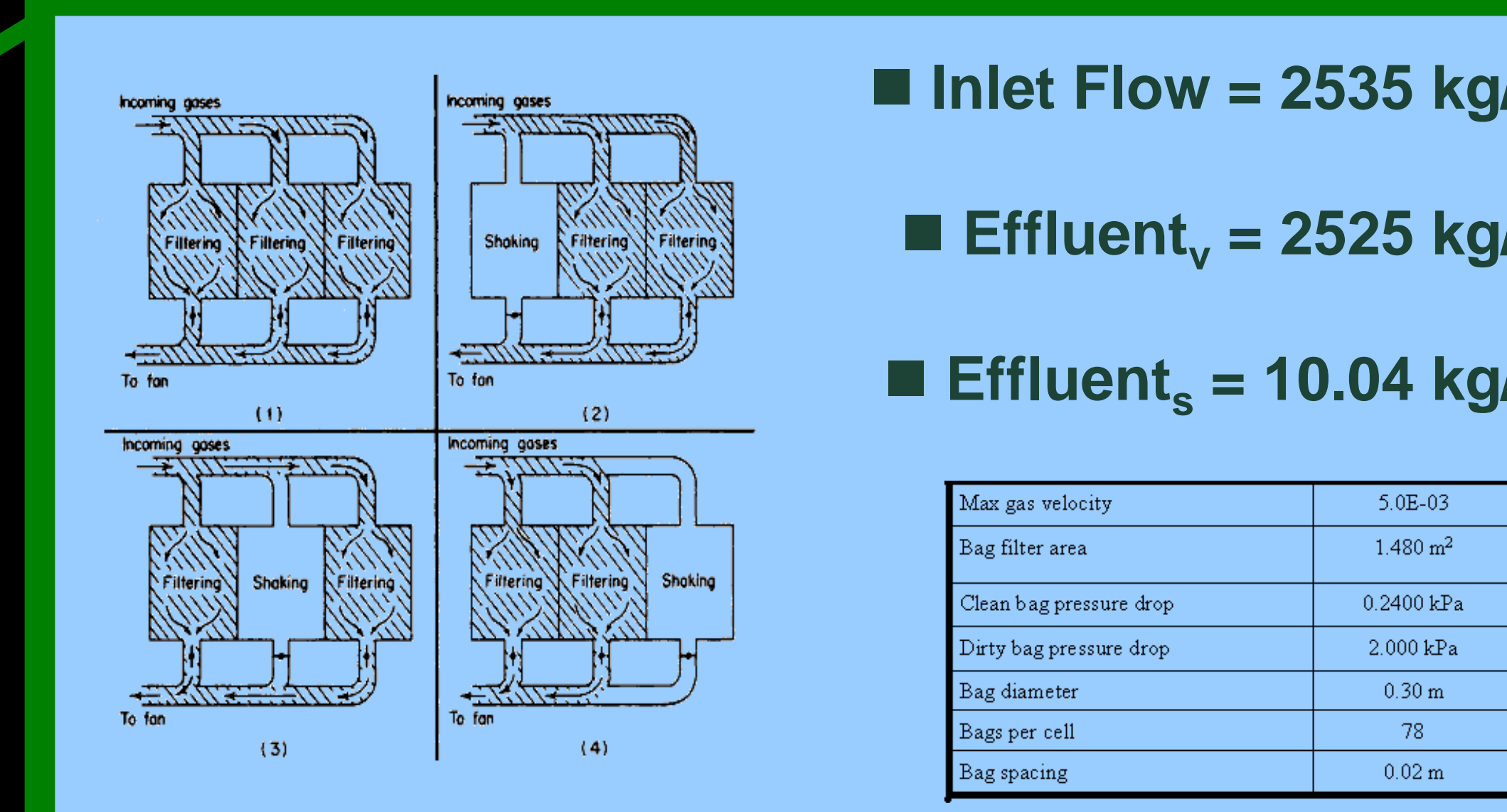
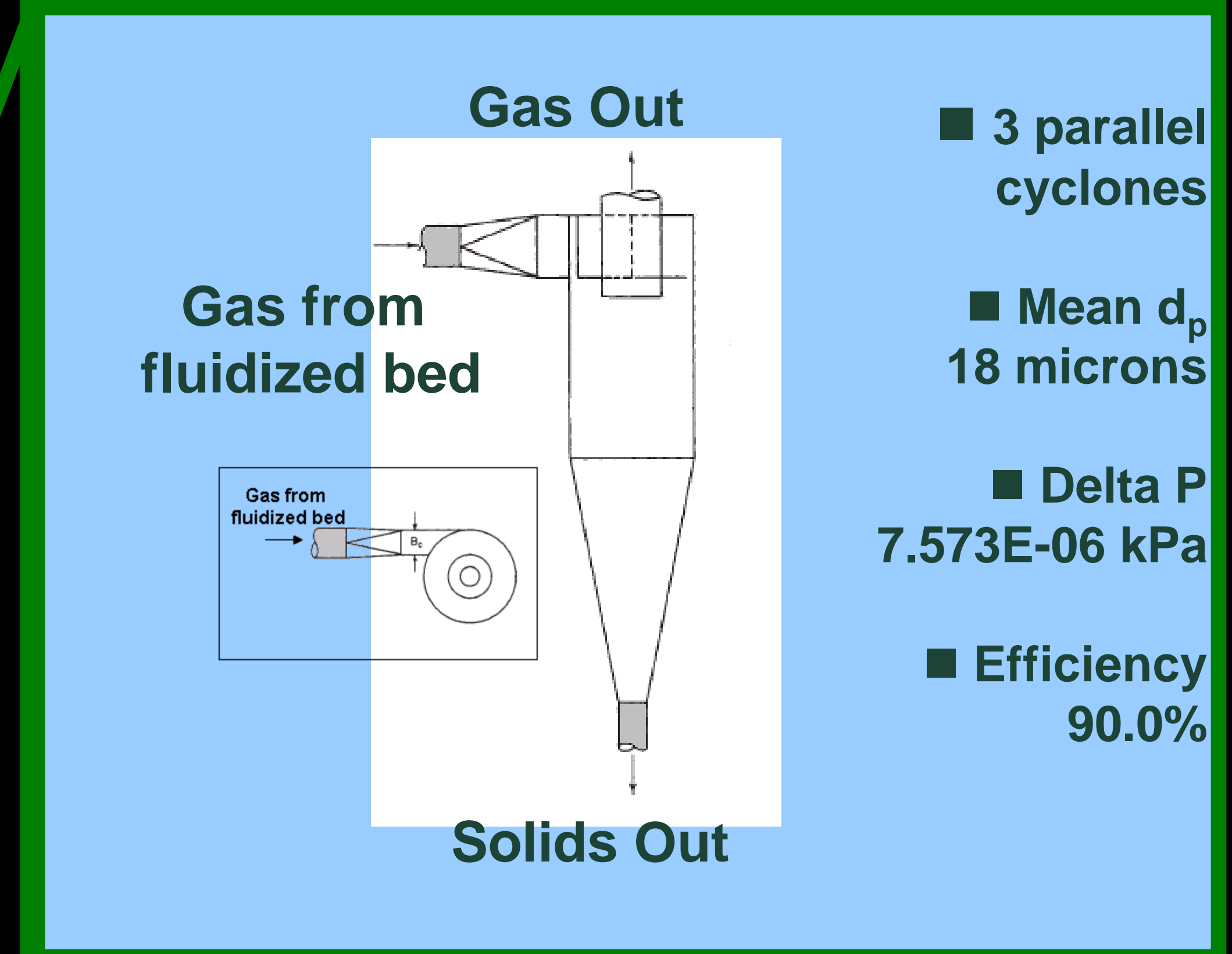
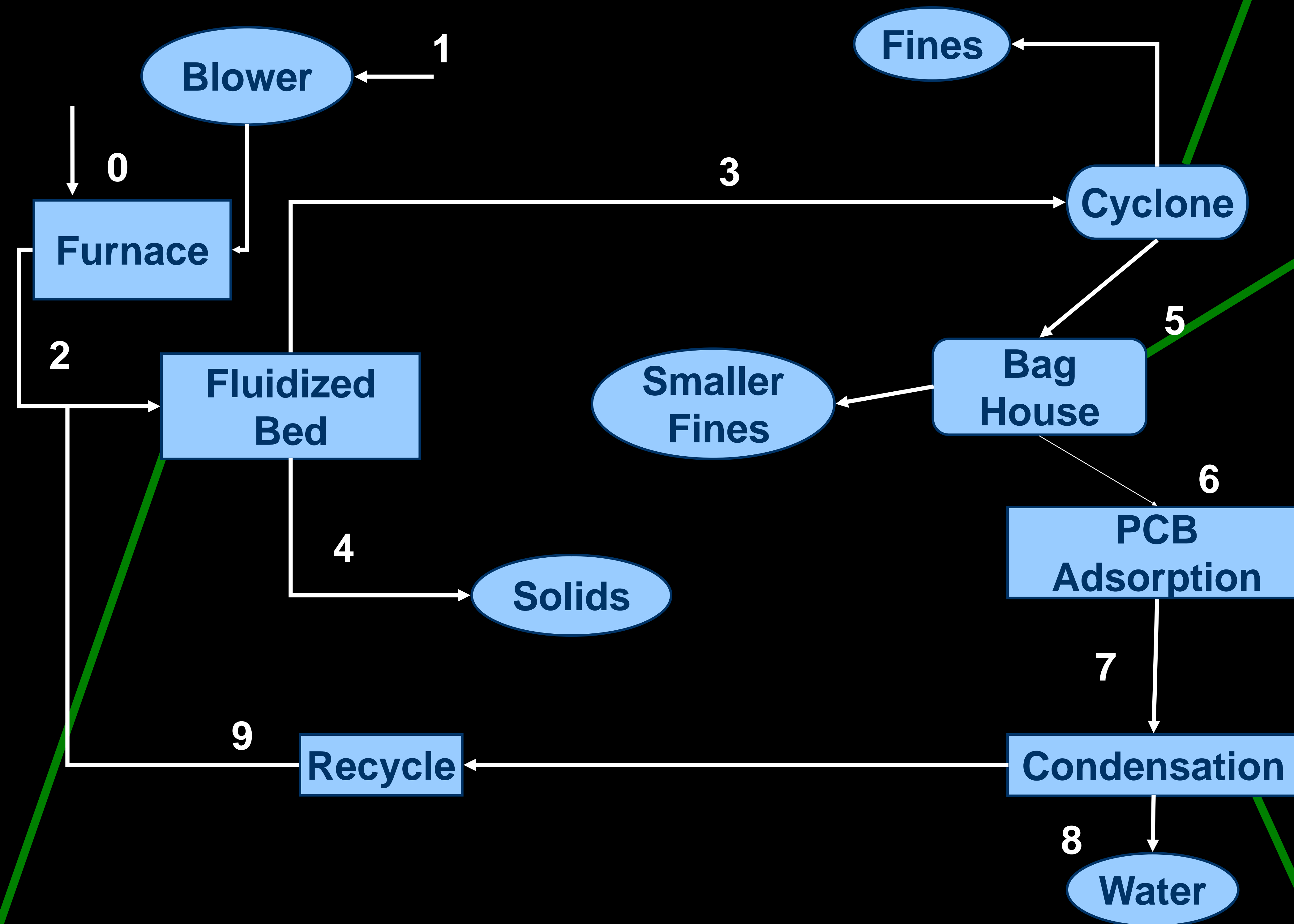
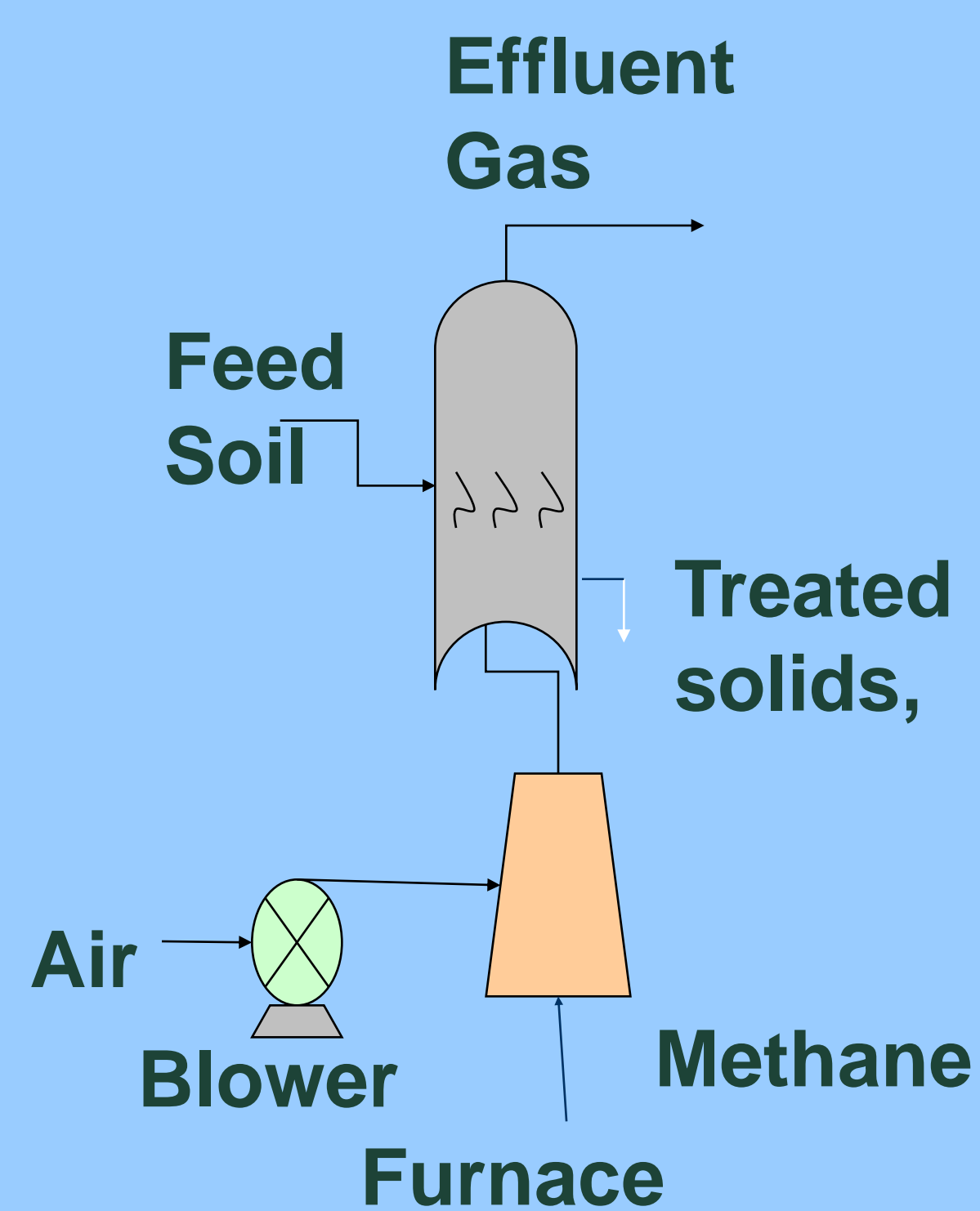
- 17,000lbs of soil per hour as feed to the bed

- Solid particles are suspended in upward rising gas

- Gas Velocity, V  
 $0.389m/s \leq V \leq 10m/s$

- Vessel diameter is 2.52m

Assumptions  
Adiabatic furnace  
Perfect sphericity of the sand particles



- Stream-0: Feed of Methane to the furnace
- Stream-1: Feed of Air to the furnace from the blower
- Stream-2: Combustion Gases (CO<sub>2</sub>, H<sub>2</sub>O, N<sub>2</sub> and O<sub>2</sub>)
- Stream-3: Flue Gas, water, PCB and solid Fines
- Stream-4: Water free Solids and trace of PCB
- Stream-5: Effluent of first separation unit
- Stream-6: Effluent from bag house with negligible fines
- Stream-7: Water and negligible PCB
- Stream-8: Water
- Stream-9: Recycle combustion gases and water back to the fluidized bed

According to the US EPA 1991 Engineering Bulletin, the Thermal desorption method has been proven successful in Remediating PCB contaminated soil

Rated 1 on a scale of 1-3 (1 being the best method)

### TOTAL ANNUAL TREATMENT COST

Capital Cost/yr	\$20,538,780
Fixed Cost	\$27,360,515
Variable Cost	\$2,582,045
<b>Annual Cost</b>	<b>\$50,481,340</b>

### CONCLUSION AND SUMMARY

After clean-up, only 1% of PCB remain

Novelty is in the Mobile design

- Plant can be transported to each site
- Flat bed trucks are used to achieve this purpose

