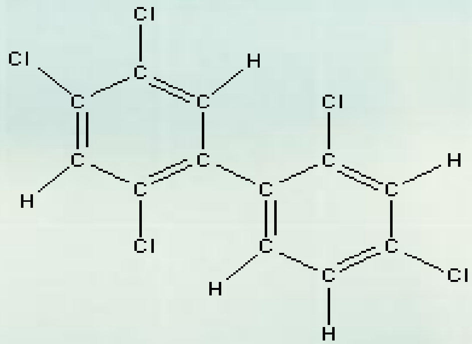
Process For Remediating PCB Contaminated Soils



2,2',4,4',5-Pentachlorobiphenyl

IPRO 345

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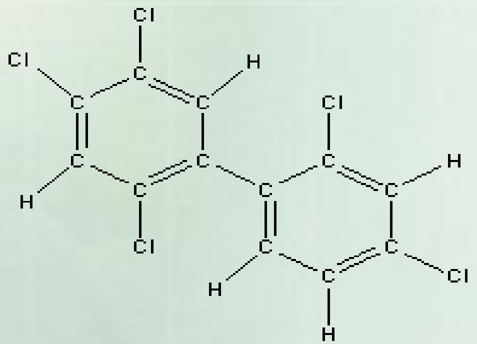
Objectives of IPRO 345

- Review research papers and articles on PCB
  - Define PCB chemistry
  - Document industrial usage of PCB
- Design a mobile fluidized bed operation to remediate the soil
- Use a computer-aided process simulation system (HYSIS) to model the design
- Determine equipment size, process capital and operating costs

Background on PCB

- Polychlorinated biphenyls (PCB) or Aroclor, are synthetic chemical compounds consisting of chlorine, carbon and hydrogen
- Used as an insulating fluid in electrical equipment until 1977
- Previously manufactured transformers and capacitors with lifetimes of 30+ years still contain fluids made with PCB's
- Due to previously unregulated disposal of PCB, a large quantity was improperly dispersed into the environment
- Upon exposure into the environment, PCB is not biodegradable



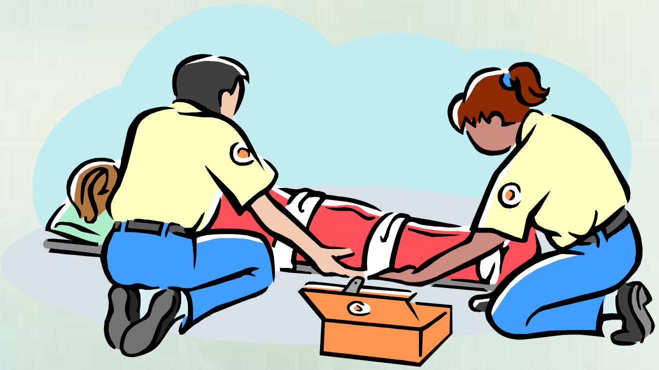
2,2',4,4',5-Pentachlorobiphenyl

The Danger of PCB

- The U.S. EPA classifies PCB as a carcinogen

- Other effects are to:
  - Various body systems such as the immune system
  - Birth Weight
  - Head circumference
  - Gestational age
  - Neonatal behavior

- Means of Exposure to PCB:
  - Inhalation
  - Skin contact
  - Consuming fish from contaminated waters



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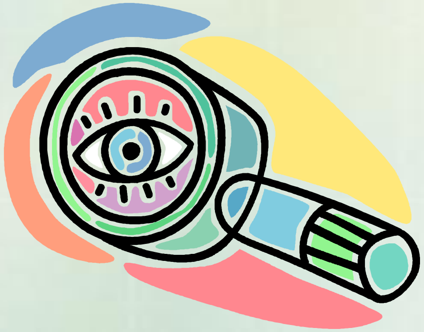
Regulations for the disposal of PCB in the U.S.



- Disposal of PCB materials that are still in service is controlled by federal regulations
- The Food and Drug Administration (FDA) has issued permissible levels of PCBs in food and packaging
- Releases > 1lb must be reported annually and entered into the Toxic Release Inventory (TRI)
- Companies must be granted an approval before performing their disposal activities

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Options for remediating PCB from soil

- Incineration
- Excavation and land filling
- Dechlorination
- Supercritical Fluid Extraction
- **Thermal Desorption**

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Thermal Desorption

What is Thermal Desorption?

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

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

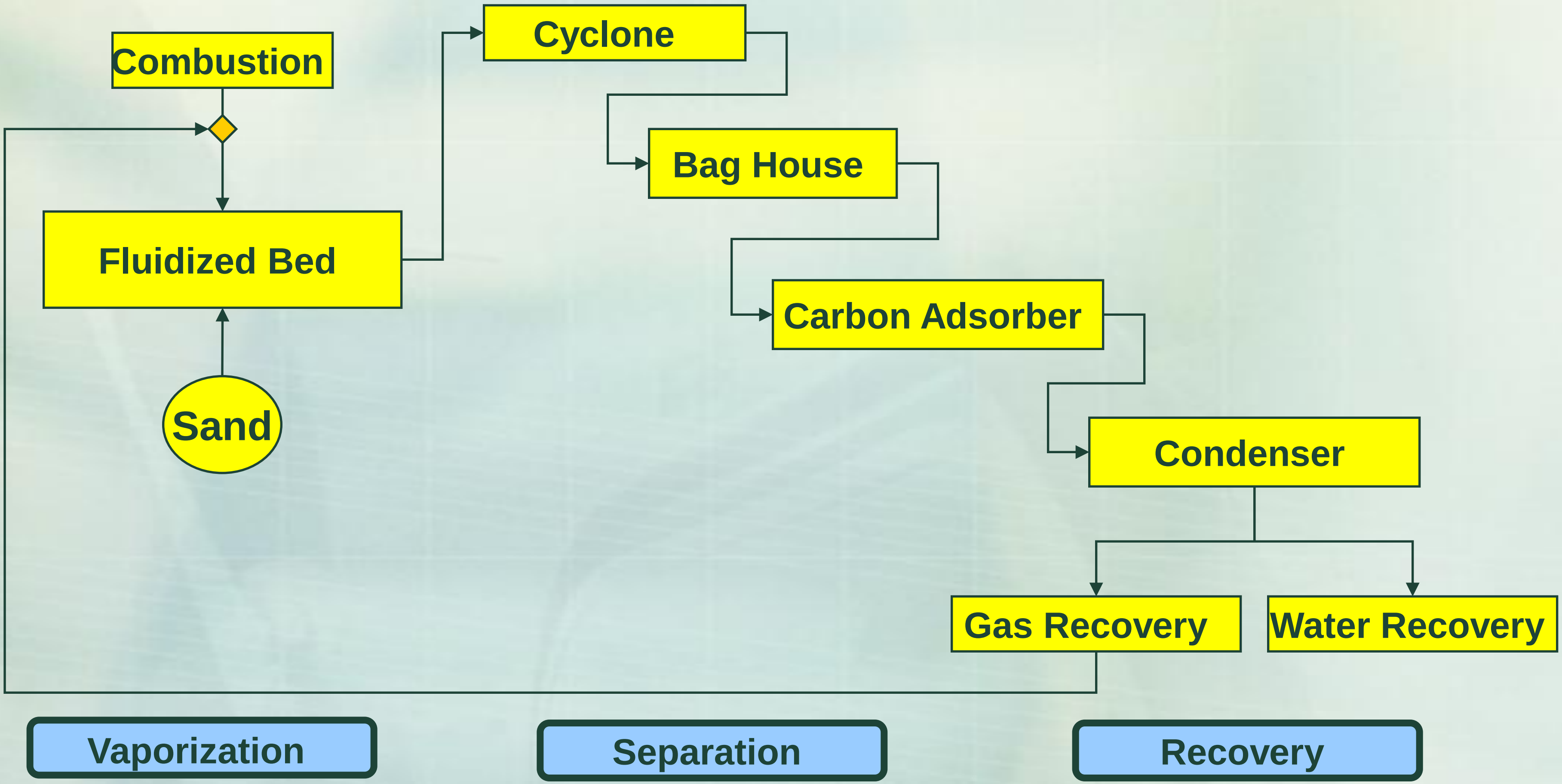
Effectiveness of Thermal Desorption

Contaminant Groups		Effectiveness			
		Soil	Sludge	Sediments	Filter Cakes
Organic	Halogenated volatiles	1	2	2	1
	Halogenated semivolatiles	1	1	2	1
	Nonhalogenated volatiles	1	2	2	1
	Nonhalogenated semivolatiles	1	2	2	1
	PCBs	1	2	1	2
	Pesticides	1	2	2	2
	Dioxins/Furans	1	2	2	2
	Organic Cyanides	2	2	2	2
	Organic Corrosives	3	3	3	3
Inorganic	Volatile metals	1	2	2	2
	Nonvolatile metals	3	3	3	3
	Asbestos	3	3	3	3
	Radioactive Materials	3	3	3	3
	Inorganic Corrosives	3	3	3	3
	Inorganic Cyanides	3	3	3	3
Reactive	Oxidizers	3	3	3	3
	Reducers	3	3	3	3

Key:
1 – Demonstrated Effectiveness: Successful treatability at some scale completed.
2 – Potential Effectiveness: Expert opinion that the technology will work.
3 – No Expected Effectiveness: Expert opinion that the technology will not work.

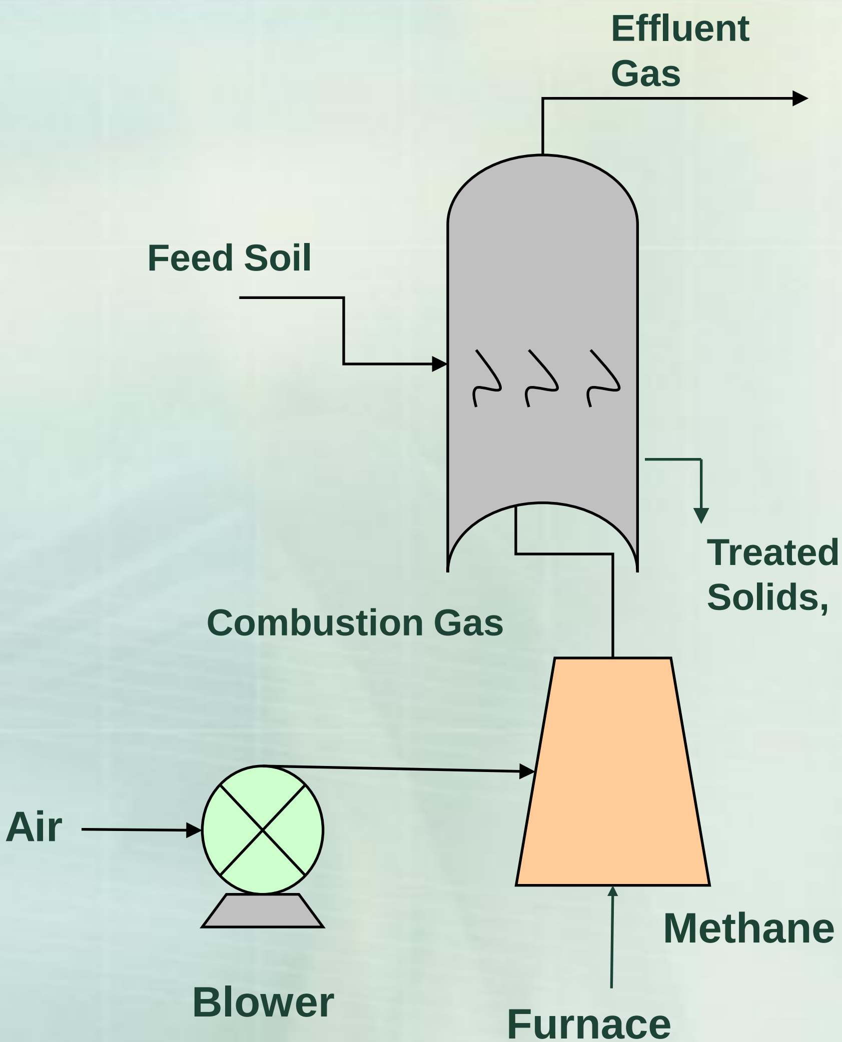
Source: U.S. EPA, 1991. Engineering Bulletin: Thermal Desorption Treatment. EPA/540/2-91/008.

Thermal Desorption Flow Diagram



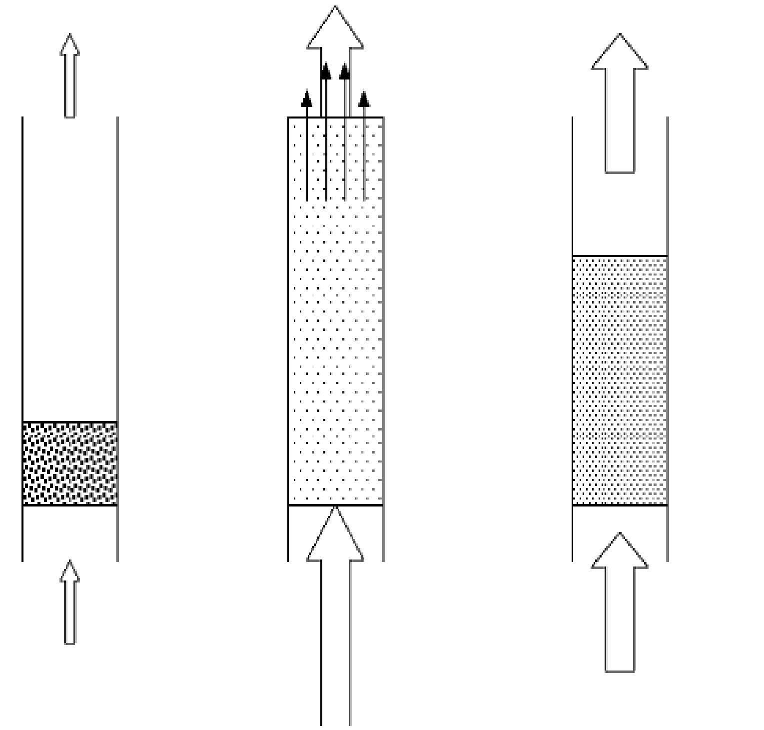
Vaporization

- Generate combustion gas to vaporize the contaminants
  - Furnace
  - Blower
- Maximize heat transfer between the solids and the gas
  - Fluidized Bed



Fluidized Bed

- Solid particles are suspended in upward rising gas
- Fluidization of the particles depends on the velocity of the incoming combustion gas
  - Minimum fluidization velocity
  - Terminal velocity



(a) Slow Flow Rate, Fixed Bed, $V_{0m} > V_0$

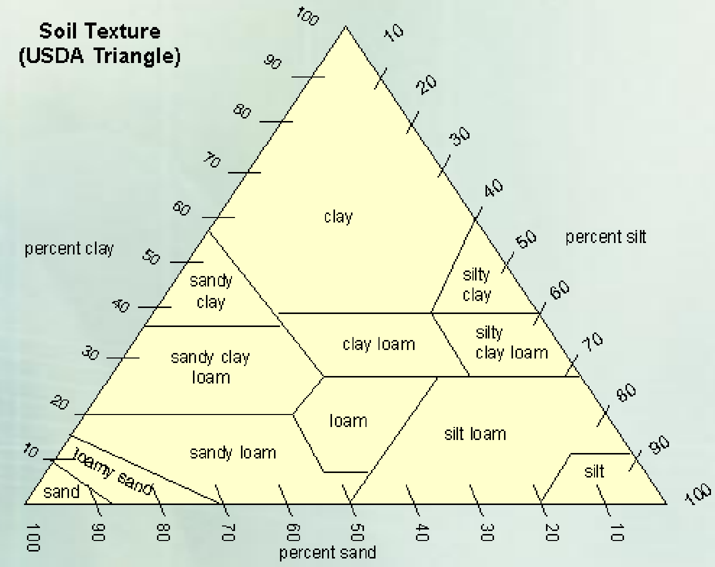
(b) High Flow Rate, Mobilized Bed, $u_t < V_0$

(c) Intermediate Flow Rate, Fixed Bed, $V_{0m} < V_0 < u_t$

Design Parameters

- Sand Distribution:
  - Bulk Density = 1.3g/cm3
  - Variable Size: 10% clay; 5% Silt; 85% Sand
  - Porosity = 0.35
- Fluidized Bed
  - T= 400F, P=20psig
  - Gas Velocity, V

$$0.389 m/s \leq V \leq 10 m/s$$



- Assumptions
  - Adiabatic furnace
  - Perfect sphericity of the sand particles

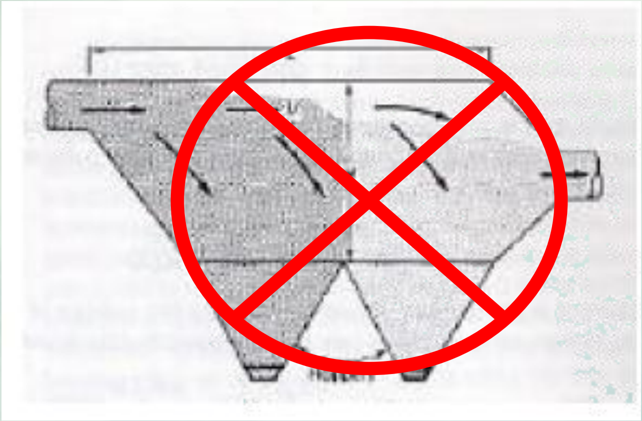
Design Calculations

- Furnace:
  - Design combustion reaction to supply the required heat and gas loads

- Fluidized Bed
  - The minimum Fluidization Velocity, V_m = 0.389m/s
  - The Particle Diameter, d_p=32.7μm
  - The Gas density, ρ= 4.59.E-4
  - The vessel Diameter, D=2.52m
  - The heat required to vaporize PCB, Q=2.7.E6 KJ/hr

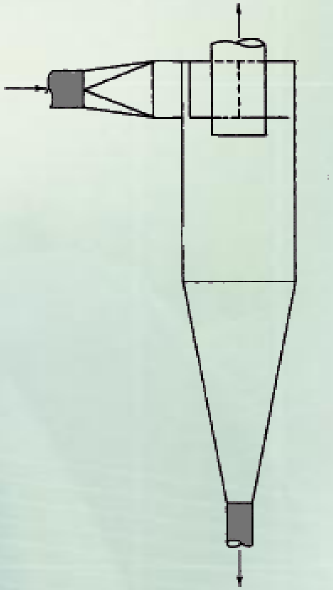
Types of Dust-Collection Equipment

Gravity Settling Chamber



- Low power consumption
- Large and Bulky
- Particle range 40-100 um

Cyclone



- Uses centrifugal force
- More efficient under heavy loads
- Particle range 15-50 um

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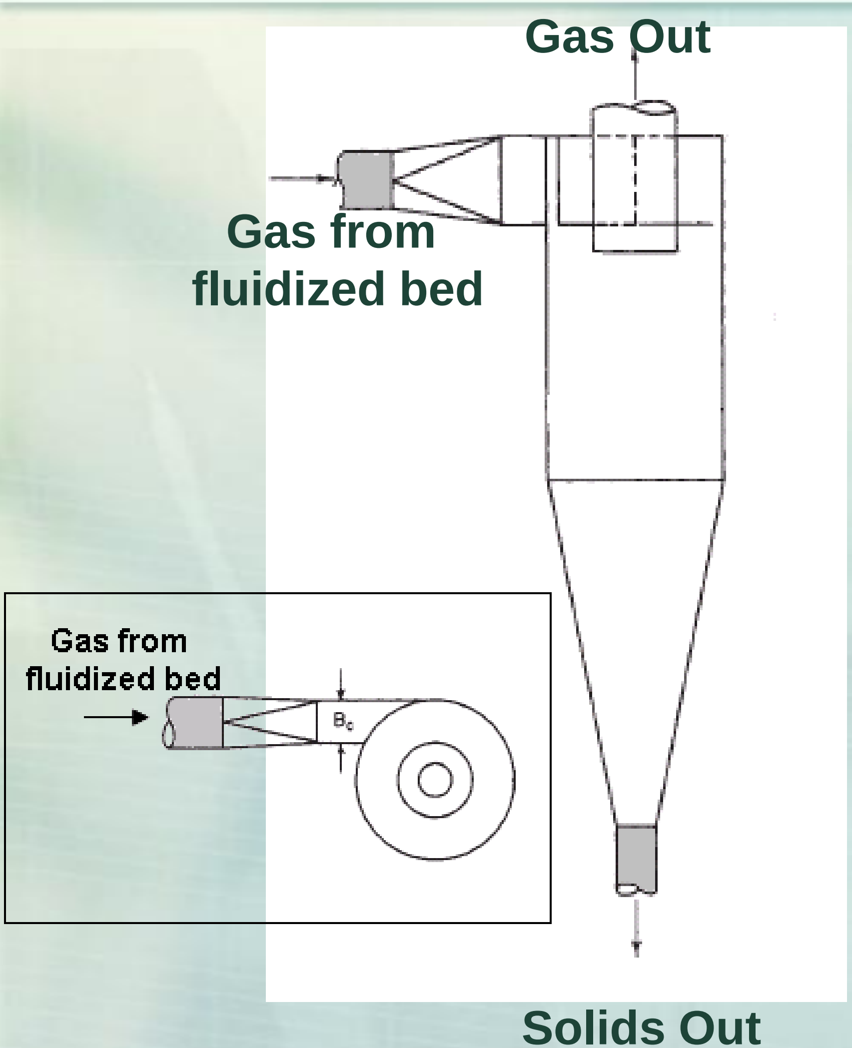
Physical Separations
Stage 1: Cyclone

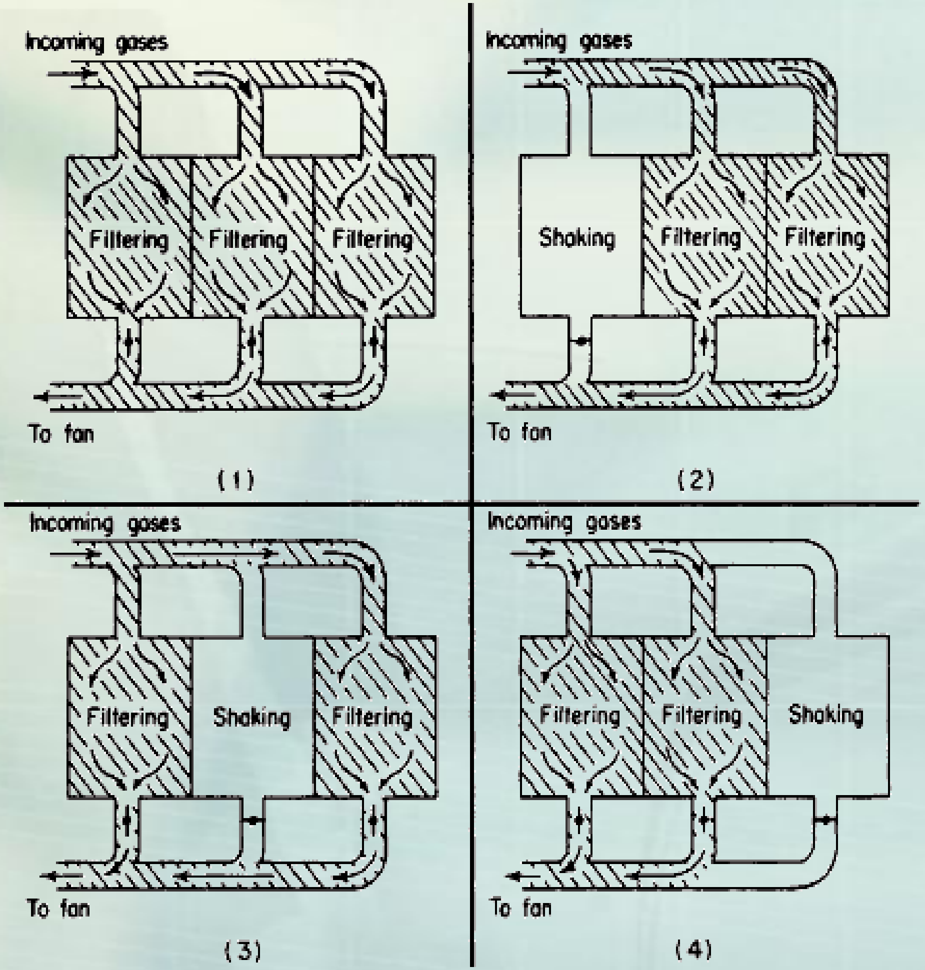


- Three parallel cyclones
- Mean particle diameter: 18 microns
- Pressure drop was 7.573E-06 kPa
- Efficiency was 90.0%.

$$D_{pth} = \sqrt{\frac{9\mu_g B_c}{\pi N_s v_{in}(\rho_p - \rho_g)}}$$

Inlet Width Ratio	0.2000
Inlet Height Ratio	0.5000
Cyclone Height Ratio	1.500
Gas Outlet Length Ratio	0.5000
Gas Outlet Diameter Ratio	0.5000
Solid Outlet Diameter Ratio	0.3750
Body Diameter	4.803 m
Total Height Ratio	4.000

Physical Separations
Stage 2: Bag House



Inlet Mass Flow: 2535 kg/hr

Vapor Effluent: 2525 kg/hr

Solid Effluent: 10.04 kg/hr

Material
Nextel (454-482)

Max gas velocity	5.0E-03
Bag filter area	1.480 m^2
Clean bag pressure drop	0.2400 kPa
Dirty bag pressure drop	2.000 kPa
Bag diameter	0.30 m
Bags per cell	78
Bag spacing	0.02 m

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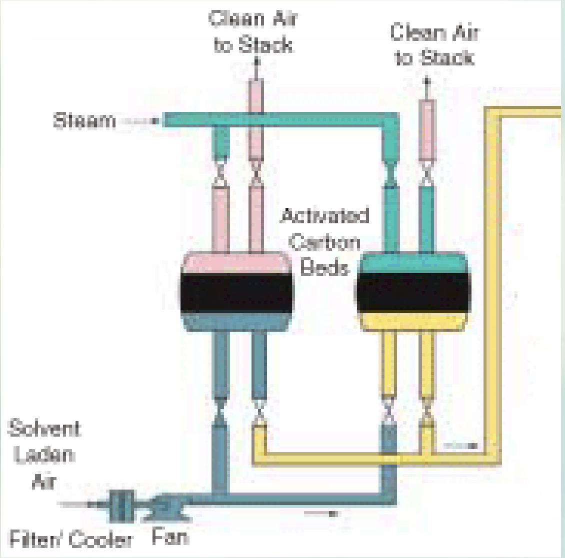
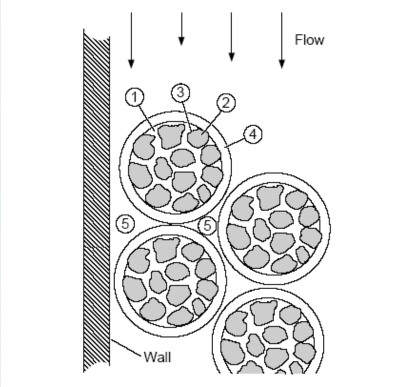
Adsorber





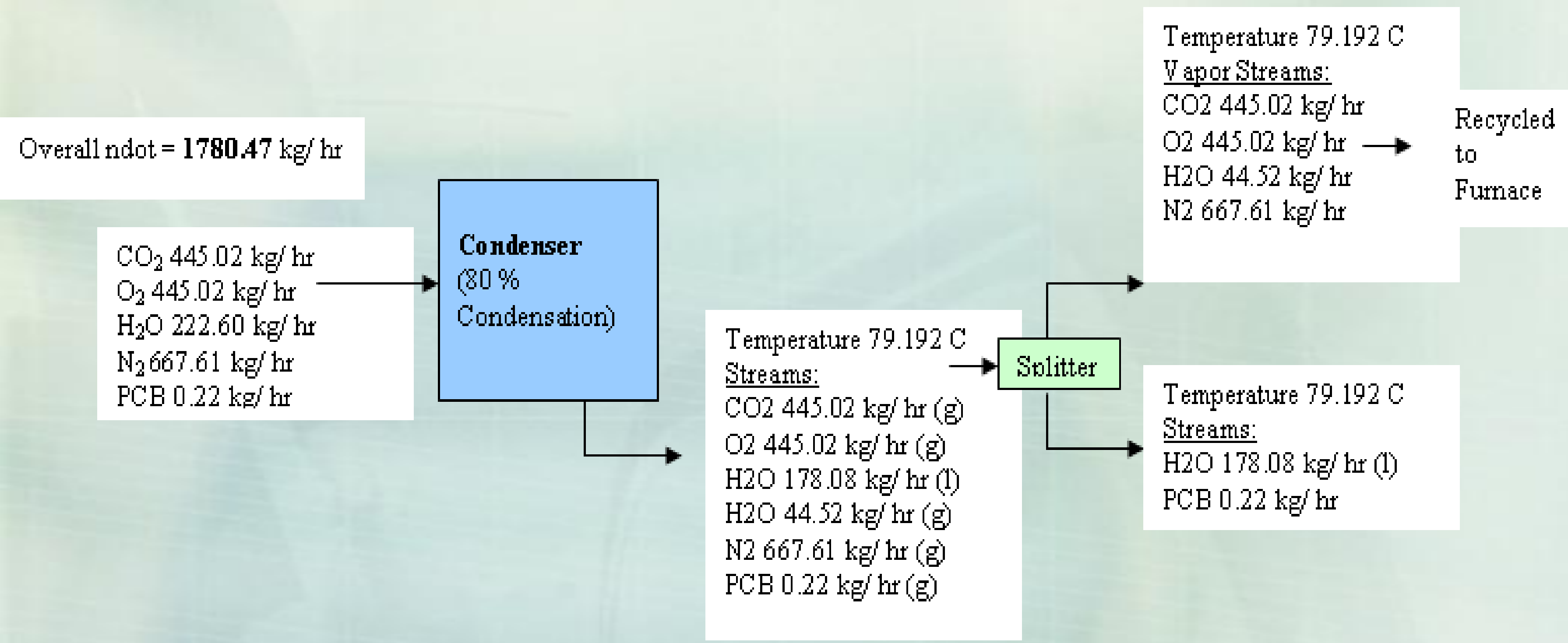
- Activated Carbon
  - Hydrophobic
  - Recovery efficiency greater than 99 %
  - Low operating cost
  - Long operating life
  - Accumulation per unit surface area is small
- Design
  - Langmuir Isotherm
  - Adsorbed phase is a unimolecular layer
  - At equilibrium, rate of adsorption equals rate of desorption from surface

Internal porosity	60%
Void fraction	0.4
Bulk density	20 lbm/Ft^3
Pore diameter	1.4 nm
Total Volume of Cilinder	56.55 ft^3
Volume of solute in cilinder	7.6 ft^3
Surface area	14.96 ft^2

Condenser

Temperature 350 C

Constant Pressure 403.3 kPa



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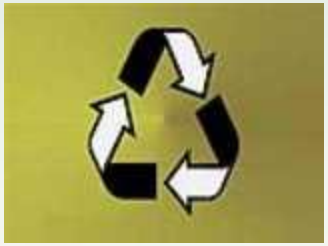
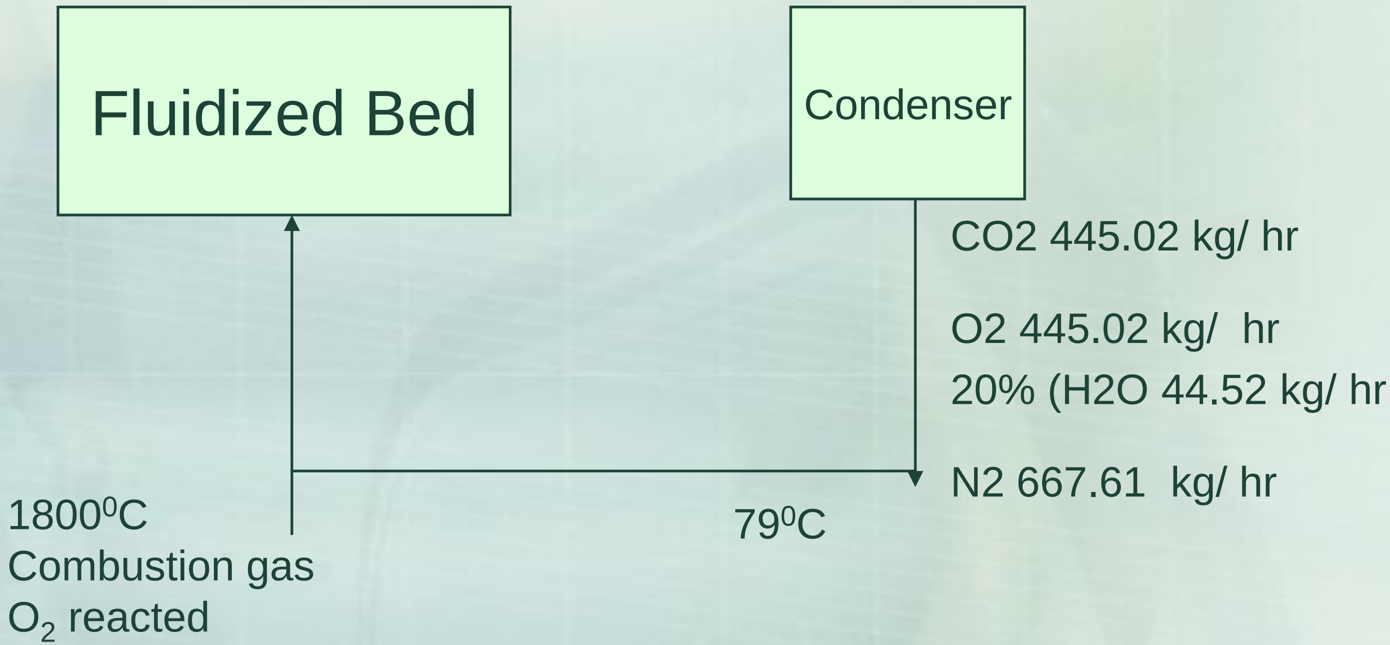


Recycle

- CO_2, 445.02 kg/ hr
- O_2, 445.02 kg/ hr
- H_2O, 44.52 kg/ hr
- N_2, 667.61 kg/ hr

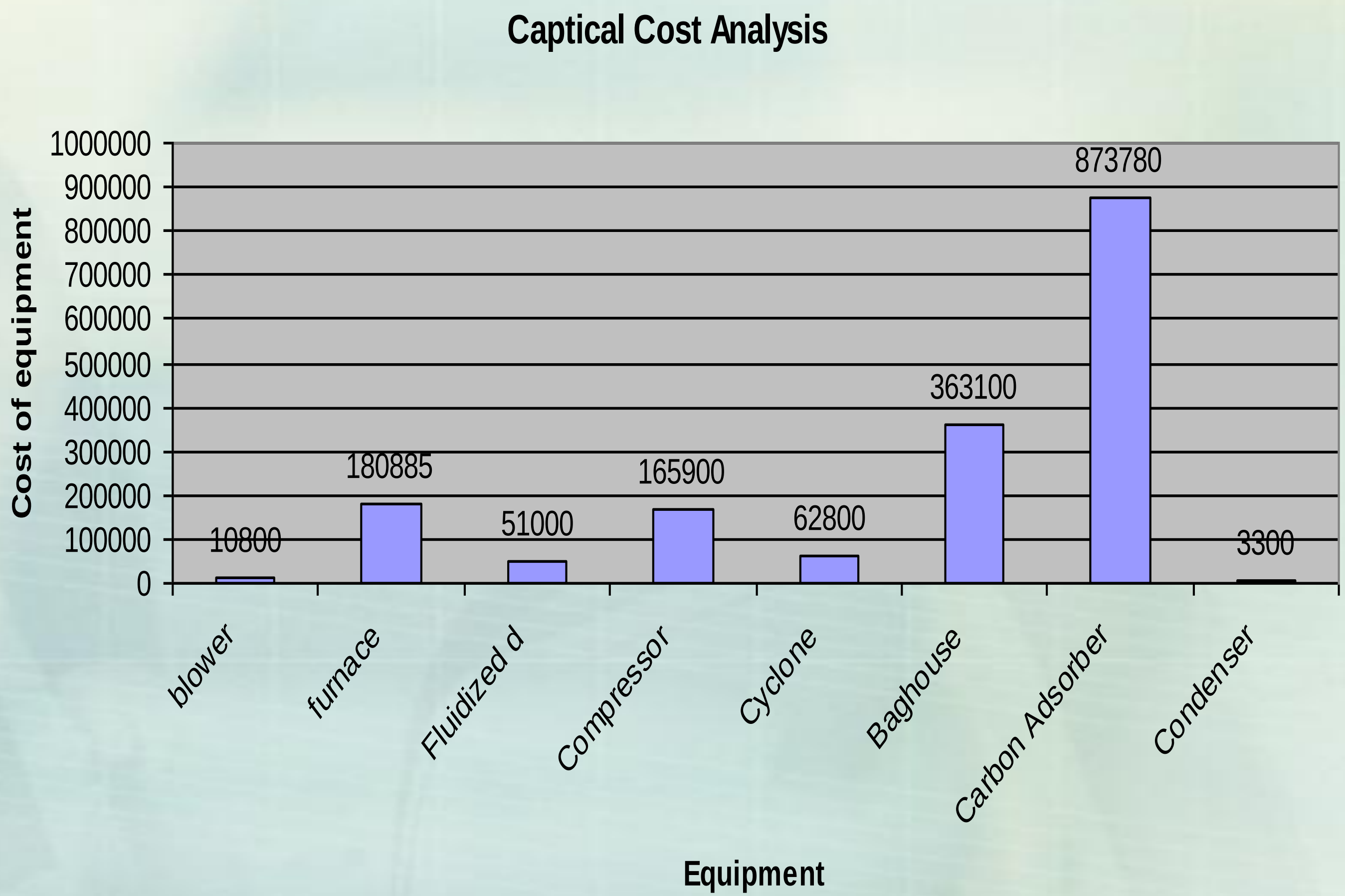


Cost Analysis

Capital Cost (Monthly)

Equipment	Unit Cost	Number required	Total cost including Installation ($)
Blower	3600	1	10,800
Furnace	60,285	1	180,885
Fluidized bed	17,000	1	51,000
Compressor	55,300	1	165,900
Cyclone	10,400	2	62,800
Baghouse	12,100	1	363,100
Carbon Adsorber	291,260	1	873,780
Condenser	1,100	1	3,300
TOTAL			**$1,711,565**

Capital Cost Comparison



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Fixed Cost

Waste Water Treatment (lb/yr)		250,000
Landfill (sand) (lb/yr)		0
Unit Cost (bed truck)	50,450	
▪ 2 flat bed trucks		100,900

<u>Purchased Components</u>

Methane	$2.12/lb
Air	$.06/lb
Carbon	$2.06/lb

Utility Cost

Electricity $0.06/Kwh

Source: Department of Energy Fact Sheets

		Utility Cost($)/hr
Splitter	44Kw	2.64
Cooler	223Kw	13.38
Cyclone	200kw	12
Baghouse	208KW	12.84

Total Annual Treatment Cost

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

Hazard Analysis

- Physical hazards
  - Elevated noise levels
  - Control: PPE
- Chemical hazards
  - PCB waste
  - Dust
  - Control:
    - Enclosed disposal unit
    - Wetting the sand

Safety Issues

- Process Chemicals
- Dust
- Fire and Explosion
  - Leaking of fuel from damaged storage containers or pipelines

Control:Forbid smoking and open flames in the area

- **Noise**
  - Working near air blowers and pumps

Control : Identify and mark areas requiring hearing protection

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Conclusion and Summary

- After clean-up, only 1% of PCB remain

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

Acknowledgments

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Questions

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