AmbientPro Educational

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Educational Proposal

Environmental protection has required the creation of the ISO14000. This certification is very important socially and economically to several industries, since it make their products more acceptable by the society.

The reduction of effluents emission can be done employing clean technologies and pollution control equipment. So, it is very important to all engineers to be prepared to deal with the equipments used in effluent treatment and pollution control.

This software was developed in order to help in teaching and training with these unit operations and its applications.

Exercises

Cyclone

❖ Detergent

In this exercise a cyclone should be designed in order to remove fine particles of detergent from an air stream that exists a spray-dryer.

Problem

Particles of Detergent	
density	2100 kg/m^3
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{49.5}\right)^{1.5}\right]$
Air	
temperature	292 °C
pressure	3.4 atm
flow rate	308 m^3/h
Requirements	
Global Efficiency	90%

Two cyclones should be designed: Lapple and Stairmand types.

Expected Results

Lapple Cyclone	
number of cyclones in parallel	8
air flow rate	38.5 m^3/h
diameter	6.6 cm
inlet velocity	19.37 m/s
cut diameter	5.35 μm
Stairmand Cyclone	
number of cyclones in parallel	1
air flow rate	308 m^3/h
diameter	23.3 cm
inlet velocity	15.77 m/s
cut diameter	5.35 μm

❖ Polyethylene

In this exercise a cyclone should be designed to recover fine particles of catalyst from a gas stream that exists a fluidized bed reactor used in polyethylene production.

Problem

Particles of Catalyst	
density	2850 kg/m^3
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{45.0}\right)^{1.2}\right]$
Gas	
temperature	60 °C
pressure	25 atm
flow rate	2125 m^3/h
Requirements	
Global Efficiency	98%

Two cyclones should be designed: Lapple and Stairmand types.

Expected Results

Lapple Cyclone	
number of cyclones in parallel	135
gas flow rate	19.7 m^3/h
diameter	4.2 cm
inlet velocity	15.7 m/s
cut diameter	0.99 μm
Stairmand Cyclone	
number of cyclones in parallel	3
gas flow rate	708.3 m^3/h
diameter	26.3 cm
inlet velocity	28.5 m/s
cut diameter	0.99 μm

The Stairmand cyclone is recommend for the process, since the Lapple set containing 135 cyclones would not be viable for the process.

❖ Sugar Cane

In this exercise, the cyclones are used to remove particles of ash from an air stream that exits the furnace that burn cane sugar bagasse. The performance of the cyclones should be analyzed and the minimum and maximum processing capacity of 5 Lapple cyclones should be found.

Problem

Particle of Ashes

density	1850 kg/m^3
particle size distribution	unknown

Air

temperature	300 °C
pressure	1.0 atm
flow rate	unknown

Cyclone

configuration	Lapple
number of cyclones in parallel	5
diameter	30 cm

Requirements

removal of particles greater than 20 μm with 90% of efficiency

Expected Result

Cyclone

air flow rate	640 m^3/h
air flow rate (total – all cyclones)	3200 m^3/h
inlet velocity	15.8 m/s
cut diameter	13.5 μm

❖ Petrochemical

In this exercise a cyclone should be designed to remove particles of ash from a gas stream that exists a coke reactor.

Problem

Particles of Ash

density	2300 kg/m^3
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{20.0}\right)^{1.4}\right]$

Carbon Dioxide

temperature	250 °C
pressure	2.0 atm
flow rate	100 m^3/h

Cyclone

configuration	Lapple

Requirements

removal of particles greater than 40 μm with 90% of efficiency

Expected Results

Lapple Cyclone

number of cyclones in parallel	1
diameter	32.0 cm
inlet velocity	2.2 m/s
cut diameter	13.3 μm

❖ Fertilizer

In this exercise the cyclones are used to remove particles of fertilizer from an air stream that is vacuumed from the factory. The performance of the cyclones should be analyzed and the minimum and maximum processing capacity of a set of 2 Stairmand cyclones should be found.

Problem

Particles of Fertilizer	
density	3100 kg/m^3
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{108.0}\right)^{1.5}\right]$
Air	
temperature	25 °C
pressure	1.0 atm
flow rate	unknown
fraction of solids	3% (volume)
Cyclone	
configuration	Stairmand
number of cyclones in parallel	2
diameter	20 cm
Requirements	
maximum concentration of solids released to the atmosphere	80 μg/m^3 de ar

Expected Result

Cyclone	
air flow rate	2450 m^3/h
air flow rate (total – all cyclones)	4900 m^3/h
efficiency	~100%

Hydrocyclones

❖ Manganese

In this exercise the maximum processing capacity of a hydrocyclone should be found. The hydrocyclone is used in the removal of particles of clay from an aqueous mixture of crushed rock (manganese + clay).

Problem

Particles of Manganese	
density	2700 kg/m^3
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{25}\right)^{1.5}\right]$
Particles of Clay	
density	2100 kg/m^3
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{2.7}\right)^{1.35}\right]$
Aqueous Solution	
temperature	25 °C
flow rate	unknown
fraction of solids	150 g/L Manganese 45 g/L Clay
Hydrocyclone	
configuration	Rietema
diameter	7 cm
Requirement	
maximum pressure drop	4 atm

Expected Results

Hydrocyclone	
flow rate	11.7 m^3/h
Manganese	
removal efficiency	51.8 %
recovered manganese (underflow)	77.8 g/L fed
lost manganese (overflow)	72.2 g/L fed
Clay	
removal efficiency	14.5 %
remaining clay (underflow)	6.5 g/L fed
removed clay (overflow)	38.5 g/L fed

❖ Gold

In this exercise a hydrocyclone should be designed to recover 98% of the gold particles present in an aqueous mixture of crushed rock containing gold, rock and clay.

Problem

Particles of Gold	
density	19320 kg/m^3
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{120}\right)^{1.32}\right]$
Particles of Rock	
density	2700 kg/m^3
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{120}\right)^{1.32}\right]$
Particle of Clay	
density	2100 kg/m^3
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{4.5}\right)^{1.32}\right]$
Aqueous Solution	
temperature	25 °C
flow rate	unknown
solid concentration	5% (volume)
Brittle	
Gold	1 %
Rock	55 %
Clay	remaining
Hydrocyclone	
design	Rietema and Bradley
Requirements	
maximum pressure drop	2.5 atm

Expected Results – Rietema Hydrocyclone

Rietema Hydrocyclone	
flow rate	15.3 m^3/h
diameter	9.0 cm
Gold	
removal efficiency	98.0 %
cut diameter	4.9 μm
gold recovered	135 kg/h (11.2 %)
Rock	
removal efficiency	89.0 %
remaining rock	945 kg/h (78.6 %)
Clay	
removal efficiency	18.5 %
remaining clay	122 kg/h (10.1 %)

Expected Results – Bradley Hydrocyclone

Bradley Hydrocyclone	
flow rate	14.3 m^3/h
diameter	13.7 cm
Gold	
removal efficiency	98.0 %
cut diameter	4.9 μm
gold recovered	135 kg/h (10.4 %)
Rock	
removal efficiency	90.7 %
remaining rock	963 kg/h (73.9 %)
Clay	
removal efficiency	31.1 %
remaining clay	205 kg/h (15.7 %)

❖ Water Purification

In this exercise a hydrocyclone should be designed to remove micro particles from water with an efficiency of 90%. The number of hydrocyclones needed to process a total of 100 m^3/h of water should also be determined.

Problem

Suspended Particles

density	$1700\ kg/m^3$
particle size distribution	$X = 1 - \exp\left[-\left(\frac{D}{12}\right)^{1,5}\right]$

Water

temperature	20 ºC
flow rate	$100\ m^3/h$ (total)
fraction of solids	0.1%

Hydrocyclone

configuration	Bradley
diameter	unknown
number of hydrocyclones	to be calculated

Requirement

maximum pressure drop	1 atm

Expected Results

Hydrocyclone

flow rate	$0.4\ m^3/h$
diameter	11 mm

Set of Hydrocyclones

250 hydrocyclones displayed in parallel

Separation Chamber

❖ Glass Spheres

In this exercise the student should verify the performance of a separation chamber should be analyzed and the particle size distribution of each of its 3 chambers should be found.

Problem

Glass Spheres

density	$2460\ kg/m^3$
sphericity	1.0

Air

temperature	20 ºC
pressure	1 atm
flow rate	$10800\ m^3/h$

Separation Chamber

height	0.5 m
width	3.0 m
total length	6.0 m
chamber lengths	2.0 m

To Determine

the particle size distribution of each chamber

which would be the maximum flow rate in order to retain particles bigger than 50 μm

Expected Results

Separation Chamber

velocity	2 m/s

Particle Size Distribution

chamber 1 (0 to 2 m)	> 231 μm
chamber 2 (2 to 4 m)	> 166 μm
chamber 3 (4 to 6 m)	> 130 μm

Maximum Flow Rate to Retain Particles Bigger than 50 mm

flow rate	$1044\ m^3/h$
velocity	0.29 m/s
chamber 1 (0 to 2 m)	> 85 μm
chamber 2 (2 to 4 m)	> 60 μm
chamber 3 (4 to 6 m)	> 50 μm

❖ Air Purification

In this exercise a separation chamber should be designed in order to process 5000 m^3/h of air containing suspended particles (particles are bigger than 60 μm) with an efficiency of 100%.

Problem

Suspended Particles	
density	3200 kg/m^3
sphericity	0.65
smaller particle	60 μm
Air	
temperature	30 ºC
pressure	1 atm
flow rate	5000 m^3/h
Separation Chamber	
height, width and length	design

This is an exercise with no unique solution. Several solutions can be obtained depending of the sectional area and height chosen.

Valid Results

Result 1	
dimensions	18.5 x 2.0 x 0.5
velocity	1.39 m/s
Result 2	
dimensions	9.2 x 4.0 x 0.5
velocity	0.695 m/s
Result 3	
dimensions	9.2 x 4.0 x 0.25
velocity	1.39 m/s
Result 4	
dimensions	9.2 x 4.0 x 0.125
velocity	2.78 m/s

Dimensions: length x width x height

Tickener

❖ Wastewater

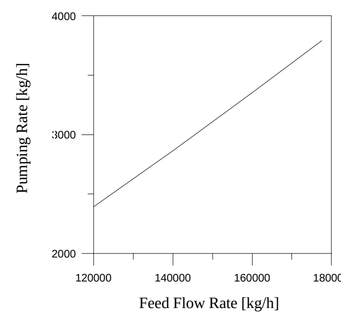
In this exercise, a thickener should be designed to treat wastewater, based on the result of a batch flux test. A spreadsheet or chart should be made to show how the changes in the feed flow rate affects the pumping rate and the underflow solids concentration.

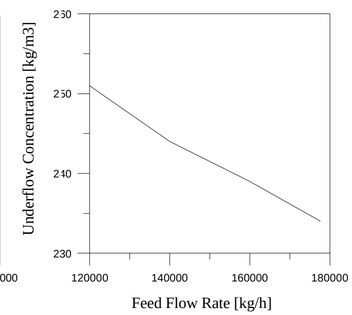
Problem

Operating Conditions	
feed flow rate	177600 kg/h
feed solids concentration	5 kg/m^3
density	1000 kg/m^3

Expected Results

Settling Velocity Function	
a	-0.0142
b	0.37
Area	191.4 m^2





❖ Metallurgic Industry

In this exercise, a thickener should be designed to treat the effluent of a metallurgic industry, based on the result of a batch flux test. The performance of the system when using a pump of 13 m^3/h should be analyzed for different feed flow rates.

Problem

Operating Conditions

feed flow rate	120000 kg/h
feed solids concentration	200 kg/m^3
density	1000 kg/m^3

Pump of 13 m^3/h

How is the performance of the system for a feed flow rate of 150000 kg/h
How is the performance of the system for a feed flow rate of 100000 kg/h

Expected Results

Settling Velocity Function

a	-0.0018
b	0.6237

Area 365.4 m^2

Pump of 13 m^3/h

How is the performance of the system for a feed flow rate of 150000 kg/h

- underflow flow rate	1350 kg/h
- effluent flow rate	0 kg/h

How is the performance of the system for a feed flow rate of 100000 kg/h

- underflow flow rate	1100 kg/h
- effluent flow rate	120 kg/h

❖ Pulp and Paper

In this exercise, the performance of a thickener used to treat the effluent of a pulp and paper should be analyzed. The system has a pump of 0.6 m^3/h, and the maximum solids concentration in the effluent, according to the local laws is 0.4 kg/m^3.

The allowed maximum feed solids concentration that still maintain the effluent solids concentration lower than 0.4 kg/m^3 should be found. In a second step the maximum feed flow rate that maintains the effluent solids concentration lower than 0.4 kg/m^3, when the feed solids concentration is 1.1 kg/m^3, should be found

Problem

Operating Conditions

feed flow rate	50000 kg/h
feed solids concentration	0.8 kg/m^3
density	1000 kg/m^3

Settling Velocity Function

a	-0.045
b	0.08

Area 53.6 m^2

Pump 0.6 m^3/h

Expected Results

What is the maximum feed solids concentration for a feed flow rate of 50000 kg/h?

- feed solids concentration 0.98 kg/m^3

What is the maximum feed flow rate for a feed solids concentration of 1.1 kg/m^3?

- feed flow rate 42500 kg/h

❖ Petrochemical Industry

In this exercise, the performance of a thickener used to treat the effluent of a petrochemical industry should be analyzed. The system processes 100000 kg/h of effluent containing 30 kg/m^3 of solids.

It should be decided if the effluent is to be diluted and split into 1 to 6 thickeners (120 m^2 each).

Problem

Operating Conditions

feed flow rate	100000 kg/h
feed solids concentration	30 kg/m^3
density	1000 kg/m^3

Settling Velocity Function

a	-0.008
b	0.25

Area	120 m^2
Dilution	1:1, 1:2, 1:5

Expected Result

Dilution	Feed Solids Conc. [kg/m^3]	Underflow Conc. [kg/m^3]	Underflow Flow Rate [kg/h]	Underflow Total Flow Rate [kg/h]
—	30	301	9959	9959
1:1	15	361	4153	8306
1:2	10	393	2542	7626
1:5	5	446	1121	6726

The dilution of the effluent can be economically viable since the underflow flow rate that needs to be processed is 6726 kg/h using 6 thickeners while 9959 kg/h should be processed with one thickener.

Dust Collector

❖ Textile Industry

In this exercise, a dust collector should be selected to filter 6200 m^3/h of air. A list of 5 dust collectors is given.

Problem

Operating Conditions

air flow rate	6200 m^3/h

Dust Collectors List

1	0.6 x 0.7 m	with 9 bags
2	0.7 x 0.8 m	with 9 bags
3	0.9 x 1.1 m	with 16 bags
4	1.2 x 1.5 m	with 36 bags
5	1.5 x 1.5 m	with 64 bags

valves	5
diaphragm	19.0 mm
blow-pipe	6.4 mm
bags diameter	0.114 m

Expected Results

Dust Collector	Maximum Flow Rate [m^3/h]	Can Velocity [m/h]
1	1300	3961
2	1300	2776
3	2310	2795
4	5198	3629
5	6467	4069

Analysis

Dust collectors 1 and 5 exceed the recommended can velocity for the system (3655 m/h)

Viable sets of dust collectors that is capable to filter 6200 m^3/h are:

1 Dust collector **5** + 1 Dust collector **1**

7 Dust collector **1**

❖ Sandblast

In this exercise, the performance of a dust collector should be analyzed to determine how many bags should be closed so the equipment will be within the recommended can velocity for the system.

Problem

Filter

Dimension	1.016 x 1.219 m
valves	5
bags	35
diaphragm	19.0 mm
blow-pipe	6.4 mm
bags diameter	0.114 m

Recommended Can Velocity

6403 m^3/h

Expected Results

Analysis

The operation should be done with 29 bags.

The flow rate should be reduced from 6497 m^3/h (35 bags) to 6403 m^3/h (29 bags)

Information

Required System

Pentium or higher

16 Mb Ram

Windows 95 or higher

CD-Rom (for installation)

Support

Contact

EFFTech Engineering Software

e-mail: efftech@efftech.eng.br

http://www.efftech.eng.br