UNIVERSITY OF UTAH

DEPARTMENT OF METALLURGICAL ENGINEERING

METE 6010 MODELING AND SIMULATION OF MINERAL PROCESSING PLANTS

EXERCISES FOR MODULE 6

1 Limestone

1.1 Simulation using Austin model.

Unit parameters:

Mill model GMIL. Average residence time in mill 7 minutes.

Selection function parameters:

$S_1 = 1.56\ \text{min}^{-1}$
$\alpha = 0.768$
$\mu = 1.567$
$\Lambda = 2.81$

Breakage function parameters:

$\beta = 0.441$
$\gamma = 1.714$
$\delta = 0$
$\Phi = 0.720$

The above are the default values for limestone.

Figure 1 Austin selection function for limestone.

Cyclone model CYCL (Plitt model).
Diameter 38 cm in cluster of 10

Results of the simulation:

Mill
D_{80}^{F} = 3606.3 µm
D_{80}^{P} = 309.7 µm.
Power required using Rowland’s open circuit factor = 80.8×11.1×1.20 = 1.07 MW.

Cyclone
D_{50c} in cyclone = 83.6 µm
Pressure drop across cyclone = 80.5 kPa.

Circuit
Recirculating load 200%
Cyclone underflow 70.7% solids.
D_{80}^{F} = 3700 µm
D_{80}^{P} = 37µm.

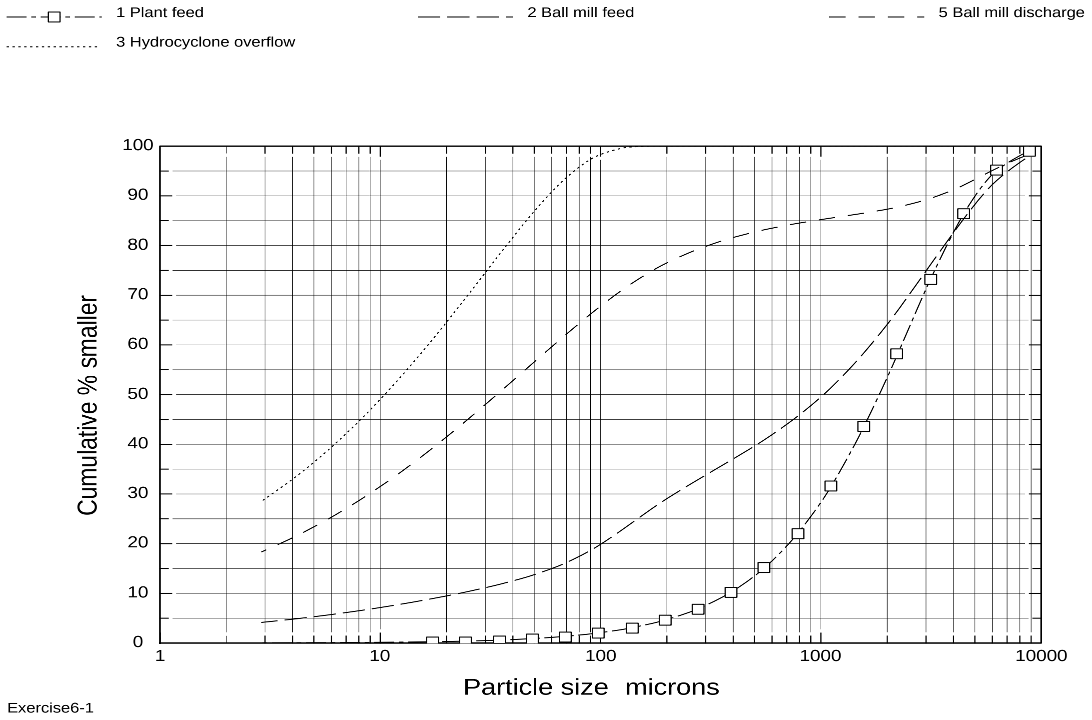

Figure 2 Size distributions in the circuit streams when processing limestone.

This is a typical pattern for a well set up closed milling circuit for an easy-to-grind material. Note the nice balance between the size reduction in the mill and the size reduction that is achieved by the circulating load. Note however the crossing of the feed size distributions at about 4mm which is a symptom of too small a ball size since >4mm particles are accumulating in the circulating load.

1.2 Simulation using Herbst-Fuertenau model

Unit parameters:

Mill model HFMI.

Power input to mill 1.07 MW.

Selection function parameters: S_1^E = 1.150 tonnes/kWhr. ζ_1 = 0.185. ζ_2 = -0.100

Breakage function parameters: β = 3.723, γ = 0.748, δ = 0.0, Φ_5 = 0.720

Cyclone model used: CYCL Plitt model. Diameter 38 cm in cluster of 10

Results:

Mill

D_{80}^F = 2650 µm

D_{80}^P = 291 µm.

Specific power input = 5.22 kWhr/tonne

Calculated operating work index = 13.3 kWhr/tonne.

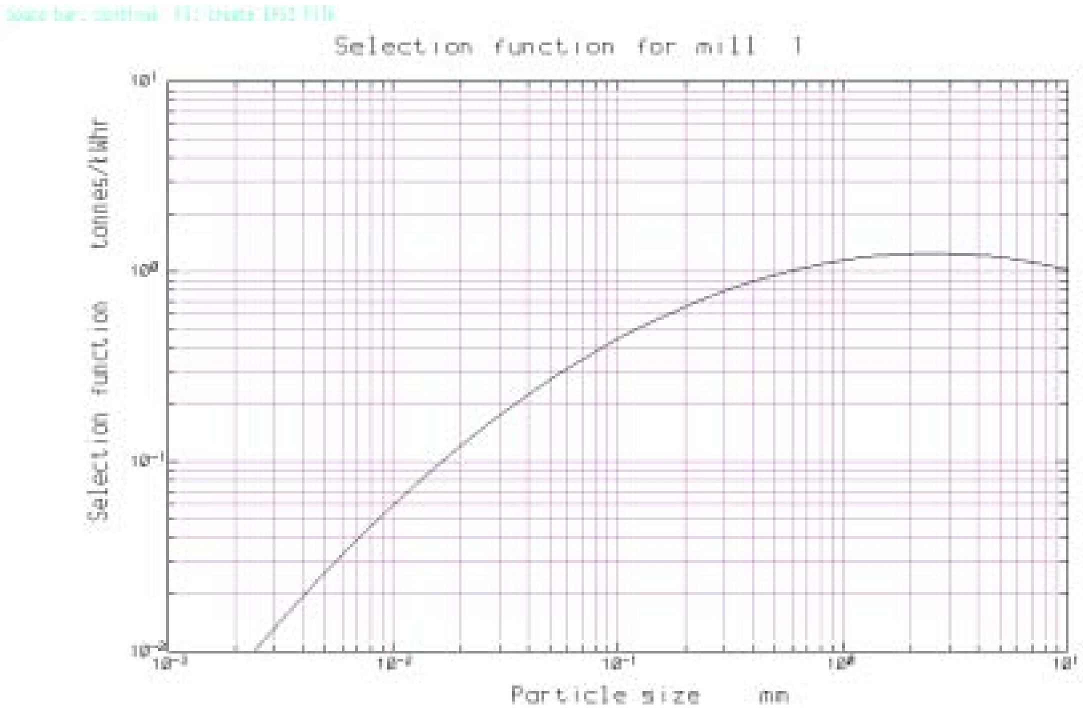

Figure 3 Selection function for limestone using Herbst-Fuerstenau energy specific model.

Cyclone

D_{50c} in cyclone = 83.2 µm

Pressure drop across cyclone = 82.4 kPa.

Circuit
Recirculating load 204%
Cyclone underflow 71.0% solids.
D_{80}^{F} = 3700 µm
D_{80}^{P} = 38µm.

The two models produce similar results for this material.

2 Taconite

2.1 Simulation using the Austin Model

Unit parameters:

Mill model GMIL. Average residence time in mill 7 minutes.

Selection function parameters:

S_1 = 1.441 min^{-1}
α = 1.213
μ = 5.46 mm
Λ = 5.06

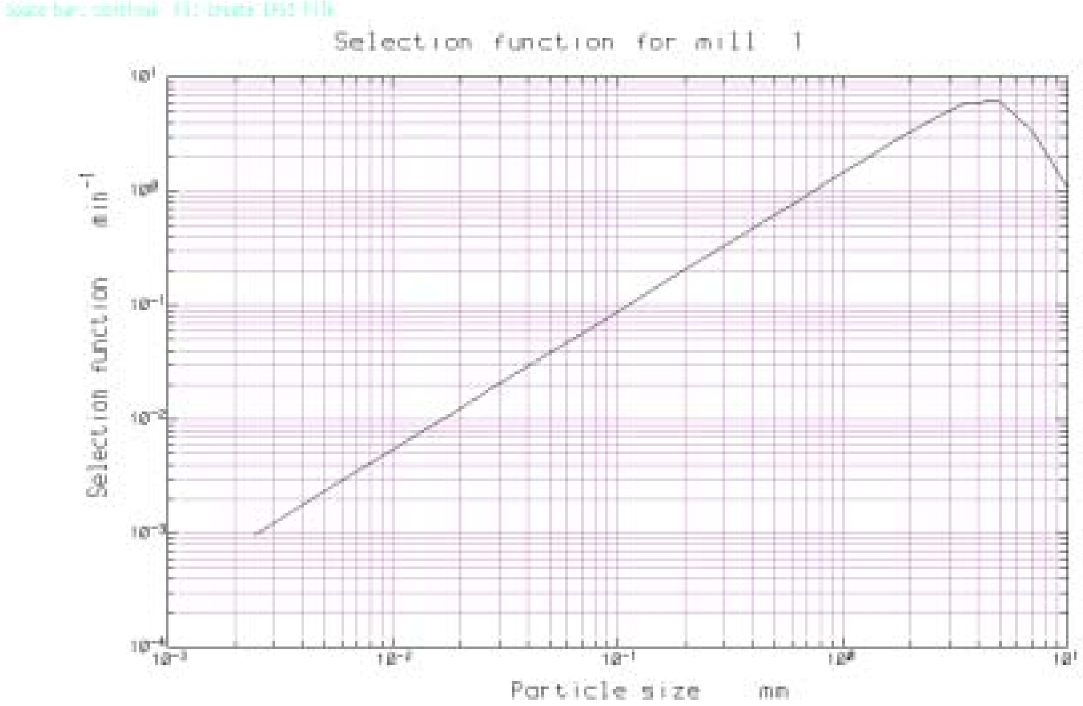

Figure 4 Austin selection function for taconite.

Breakage function parameters:

β = 0.5
γ = 1.329

$\delta = 0$

$\Phi_5 = 0.599$

These are default values for taconite.

Cyclone model used: CYCL Plitt model. Diameter 38 cm in cluster of 10

Results:

Mill

$D_{80}^F = 1497$ µm

$D_{80}^P = 130.4$ µm.

Power required using Rowland's open circuit factor = 181.5×14.9×1.20 = 3.24 MW.

Cyclone

D_{50c} in cyclone = 80.6 µm

D_{50} in cyclone = 41.3 µm

Pressure drop across cyclone = 119 kPa.

Circuit

Recirculating load 294%

Cyclone underflow 73.3% solids.

$D_{80}^F = 3700$ µm

$D_{80}^P = 42.8$µm.

2.2 Simulation using Herbst-Fuerstenau model

Unit parameters:

Mill model HFMI.

Power input to mill 2.34 MW.

Selection function parameters: $S_1^E = 0.75$ tonnes/kWhr. $\zeta_1 = 0.23$. $\zeta_2 = -0.200$

Breakage function parameters: $\beta = 3.723$, $\gamma = 0.0.624$, $\delta = 0.0$, $\Phi_5 = 0.65$

Cyclone model used: CYCL Plitt model. Diameter 38 cm in cluster of 10

Results:

Mill

$D_{80}^F = 2300$ µm

$D_{80}^P = 175$ µm.

Specific power input = 9.66 kWhr/tonne

Calculated operating work index = 17.6 kWhr/tonne.

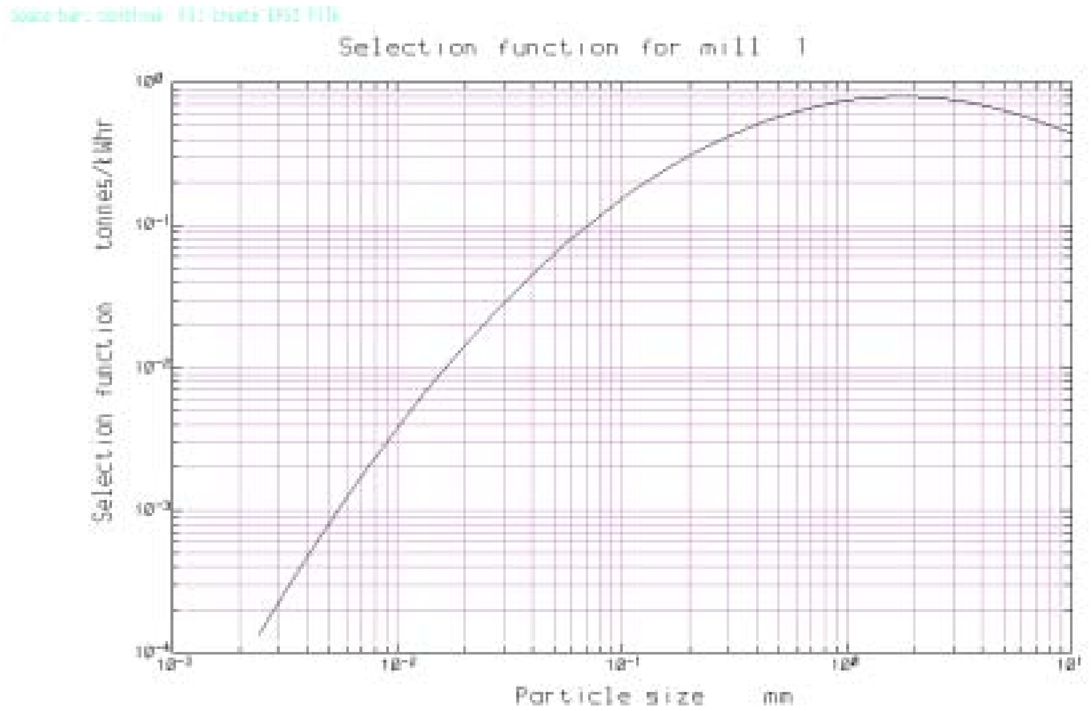

Figure 5 Selection function for taconite using Herbst-Fuerstenau energy specific model.

Cyclone
D_{50c} in cyclone = 53.3 µm
D_{50} in cyclone = 43.4 µm
Pressure drop across cyclone = 92.5 kPa.

Circuit
Recirculating load 242%
Cyclone underflow 71.4% solids.
D_{80}^F = 3700 µm
D_{80}^P = 36.5µm.

The two models produce similar results for taconite although the operating WI calculated from the Herbst-Fuerstenau model indicates that the mill is probably oversized for the duty.

3 Porphyry

3.1 Simulation using the Austin model.

Unit parameters:

Mill model GMIL. Average residence time in mill 15 minutes.
Parameters for selection function:
S_1 = 0.148 min^{-1}

$\alpha = 2.167$
$\mu = 0.626$ mm
$\Lambda = 2.167$

Breakage function parameters:

$\beta = 0.606$
$\gamma = 0.542$
$\delta = 0$
$\Phi_5 = 0.719$

These are default values for the porphyry ore.

Cyclone model used: CYCL Plitt model. Diameter 76 cm in cluster of 20

Results:

Mill
$D_{80}^{F} = 1902$ µm
$D_{80}^{P} = 1088$ µm.
Power required using Rowland's open circuit factor = 43.3×28.5×1.20 = 1.48 MW.

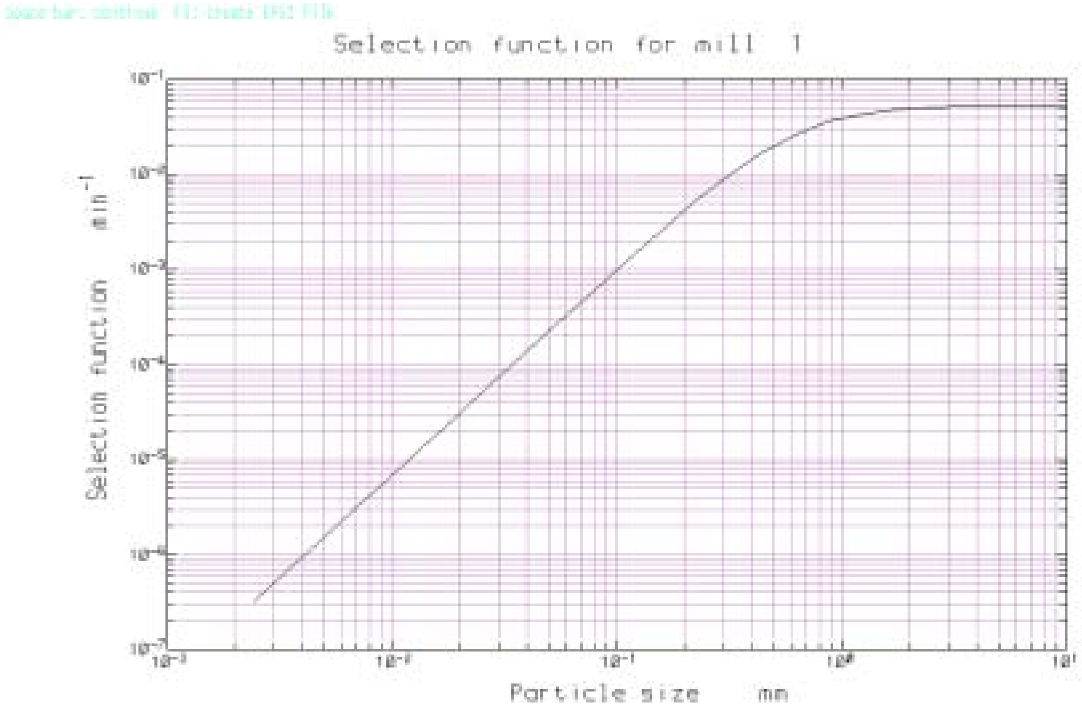

Figure 6 Austin selection function for porphyry ore.

Cyclone
D_{50c} in cyclone = 178.5 µm
Pressure drop across cyclone = 10.2 kPa.

Circuit
Recirculating load 587%
Cyclone underflow 77.7% solids.
D_{80}^{F} = 3700 µm
D_{80}^{P} = 160µm.

3.2 Simulation using Herbst-Fuertenau model

Unit parameters:

Mill model HFMI.
Power input to mill 1.48 MW.
Selection function parameters: S_1^E = 0.3 tonnes/kWhr. $\zeta_1 = 0.3$. $\zeta_2 = -0.25$
Breakage function parameters: $\beta = 3.723$, $\gamma = 0.748$, $\delta = 0.0$, $\Phi_5 = 0.720$

Cyclone model used: CYCL Plitt model. Diameter 76 cm in cluster of 20

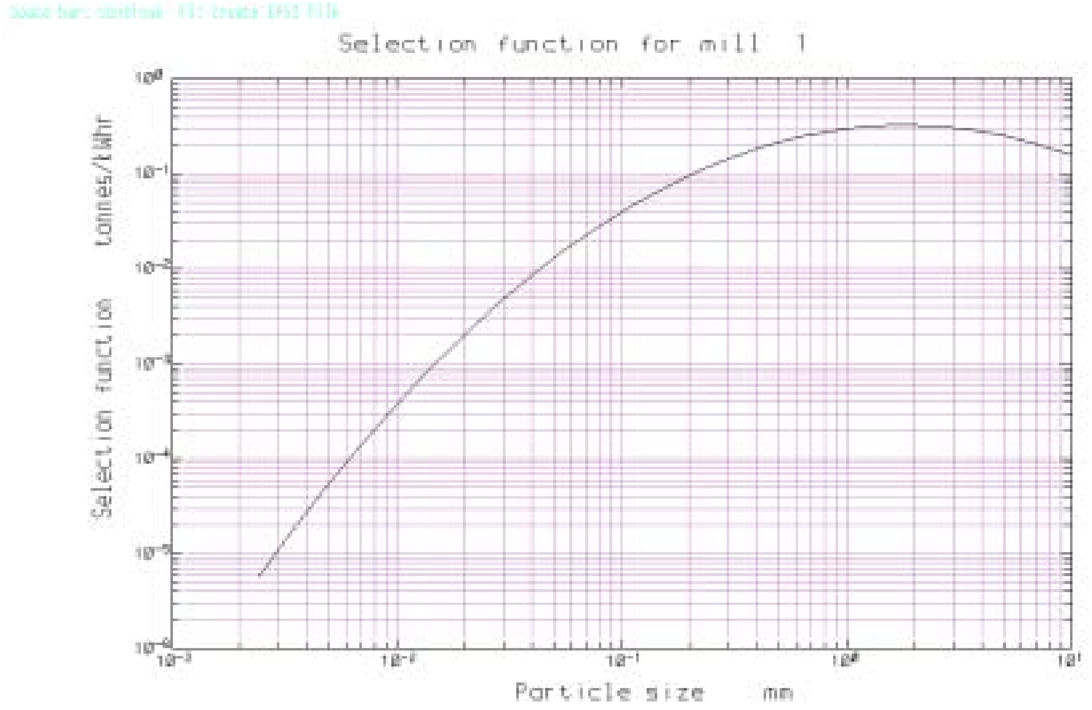

Figure 7 Selection function for porphyry using Herbst-Fuerstenau energy specific model.

Results:

Mill
D_{80}^{F} = 2590 µm
D_{80}^{P} = 1540 µm.
Specific power input = 3.61 kWhr/tonne

Calculated operating work index = 61.9 kWhr/tonne.

Cyclone
D_{50c} in cyclone = 205 µm
Pressure drop across cyclone = 5.9 kPa.

Circuit
Recirculating load 418%
Cyclone underflow 75.5% solids.
D_{80}^{F} = 3700 µm
D_{80}^{P} = 165µm.

ADDITIONAL EXERCISES.

Exercise 6-6 is rather an extreme example of grinding circuit simulation. The ore is very tough and the circuit is difficult to set up to operate satisfactorily. It therefore makes a good trial case for you to explore. The following simple set of simulations can be done in a short time and they will give you a feel for the benefits of having a good simulator available to help set up troublesome plants effectively. In reality we have adjusted the parameters for this ore slightly to make it a little more difficult to handle than in actual practice.

Use the job from exercise 6-6 and run the circuit at a sequence of power inputs from 3000 kW down to 1300 kW. You should start the simulations at 3000 kW and work down steadily. As the mill power gets below 1400kW the circuit starts to become unstable because the mill is not delivering enough size reduction to satisfy the demands of the classifier. This shows up in MODSIM as an increasing sensitivity in the recycle calculation. Convergence can be a problem. Doing the simulation starting at the easy conditions (3000kW) and working down, allows MODSIM to start each recycle calculation from the converged results of the previous case and this gives it the best chance of finding a converged solution.

The results of this exercise should look something like the data in the table below

Mill power kW	Circulating load %	Circuit d_{80} µm
3000	194	133
2500	211	144
2000	251	157
1700	310	163
1500	395	165
1480	418	165
1400	493	165
1350	592	163
1300	840	155

The results are shown graphically below together with three size distribution graphs - one from each operating extreme and one from the nominal or normal condition.

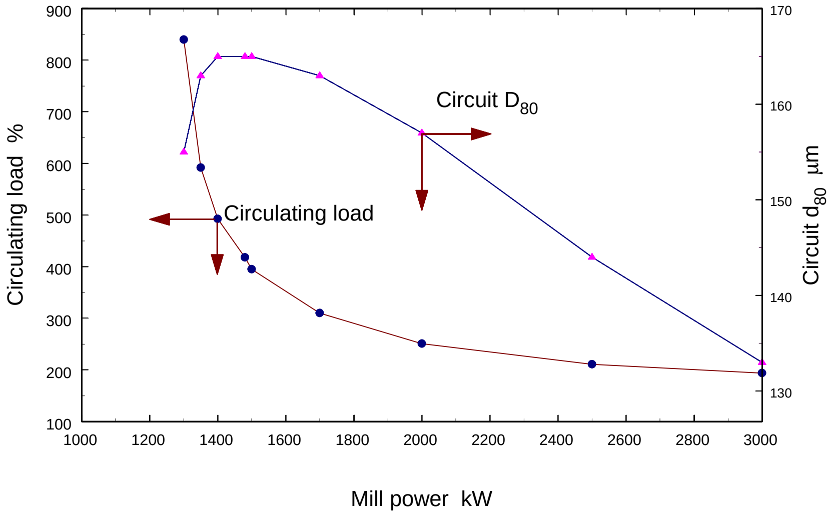

Figure 8 Circulating load and circuit D_{80} as a function of mill power.

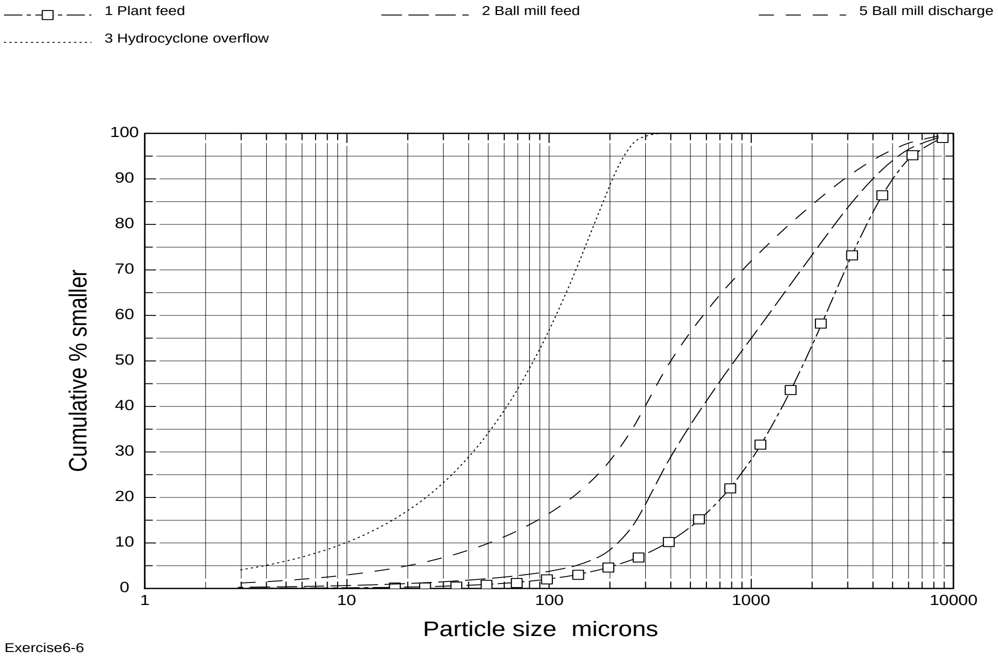

Figure 9 Size distributions in the key process streams when the mill draws 1480 kW.

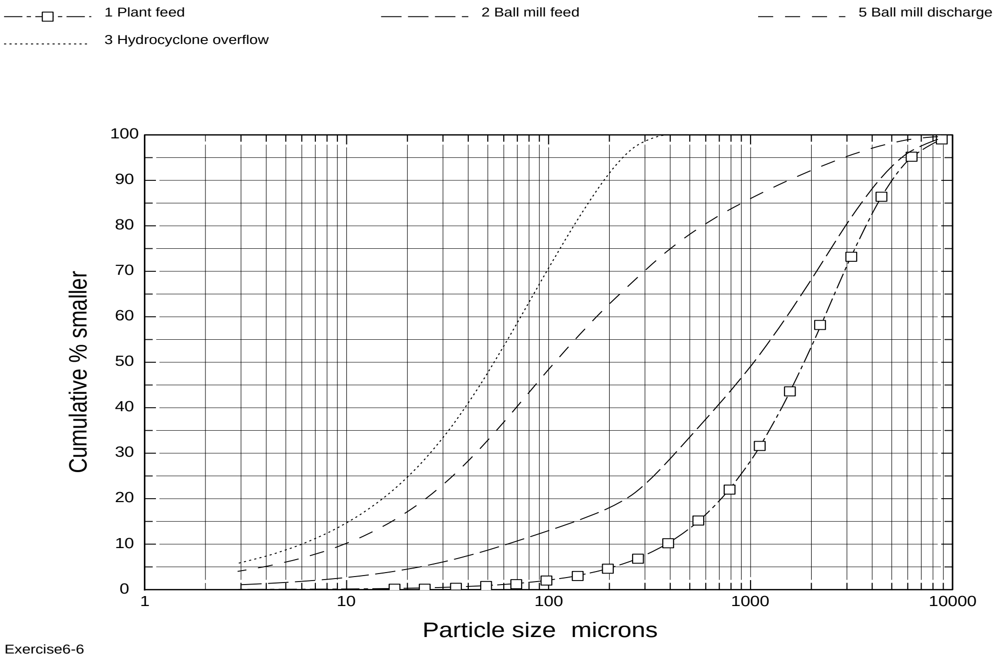

Figure 10 Size distributions in the three key process streams when the mill draws 3000 kW.

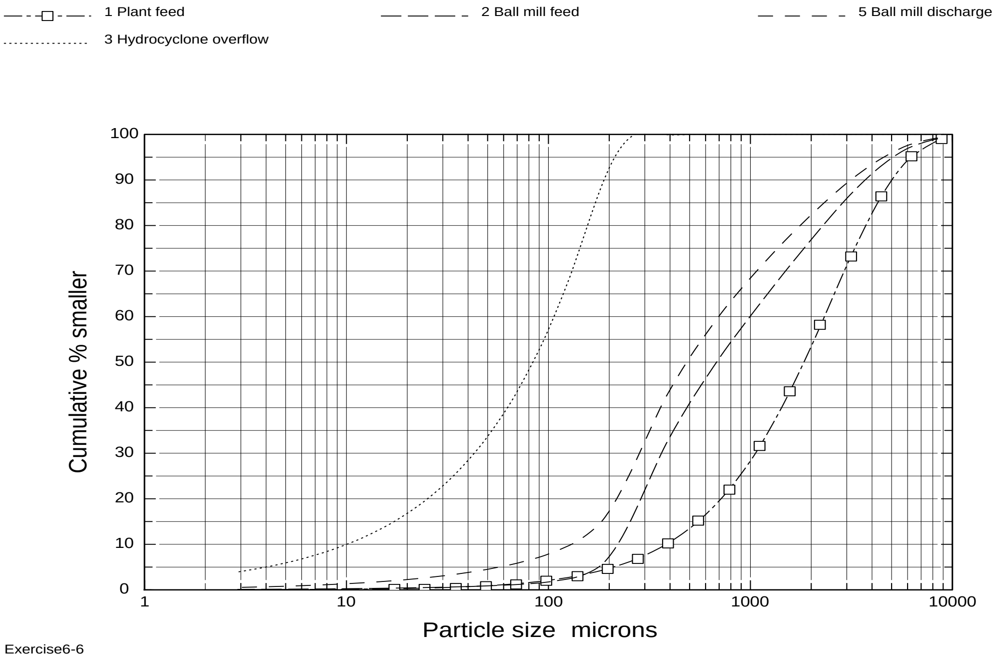

Figure 11 Size distributions in the four key process streams when the mill draws 1300kW