WASTEWATER PURIFICATION ENHANCED BY ELECTROCHEMISTRY

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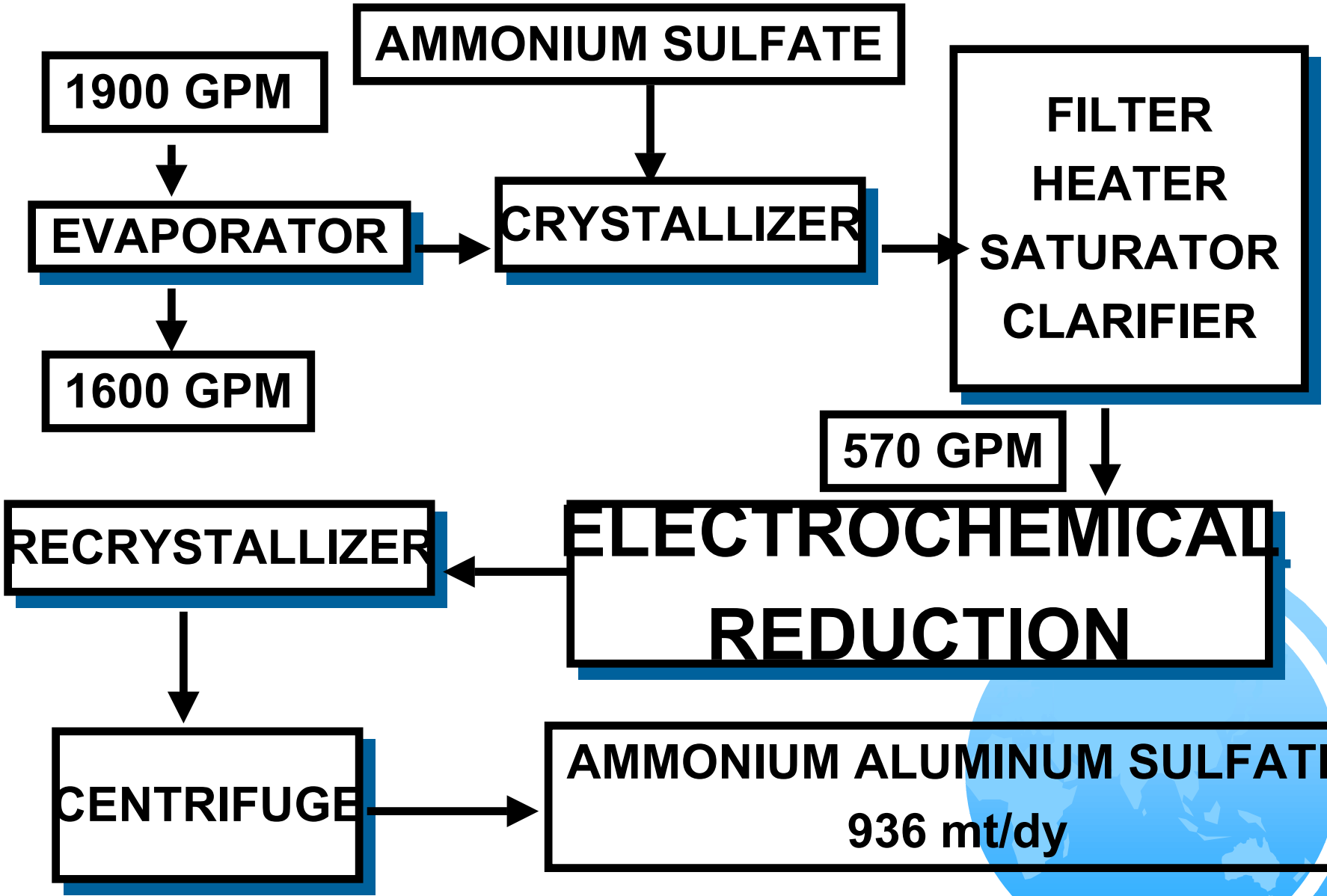

AMMONIUM SULFATE
1900 GPM
EVAPORATOR
CRYSTALLIZER
FILTER
HEATER
SATURATOR
CLARIFIER
1600 GPM
570 GPM
RECRYSTALLIZER
ELECTROCHEMICAL
REDUCTION
CENTRIFUGE
AMMONIUM ALUMINUM SULFATE
936 mt/dy

Evaporator & Electrolyzer Feed

ppm

Component	Evap	Elect
SO_4	49,500	166,300
free H_2SO_4	14,800	1,830
Al	6,000	20,800
NH_4	1,060	14,930
Fe_{total}	1,040 total	3,765
Fe^{+3}	NA	1,285

Main Objective: Reduce Fe^{+3} from 1285 to 285 ppm

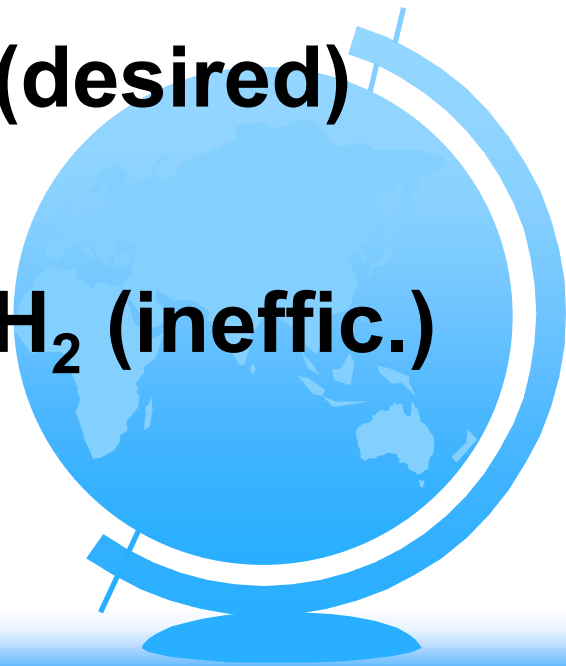
$$Fe^{+3} + 1e^{-} = Fe^{+2}$$

Anticipated Reactions

Anode: $H_2O = 2H^+ + 2\ e^- + 1/2\ O_2$

Cathode: $2\ Fe^{+3} + 2\ e^- = 2\ Fe^{+2}$ **(desired)**

$2\ H_2O + 2\ e^- = 2\ OH^- + H_2$ **(ineffic.)**



Limiting Current Density

$I_{limiting} = zFDAC_b/ó$

Where:

$I_{limiting}$ = limiting current density

z = number of electrons per equivalent, 1

F = Faradays constant, 9.65 x10^4 amp seconds

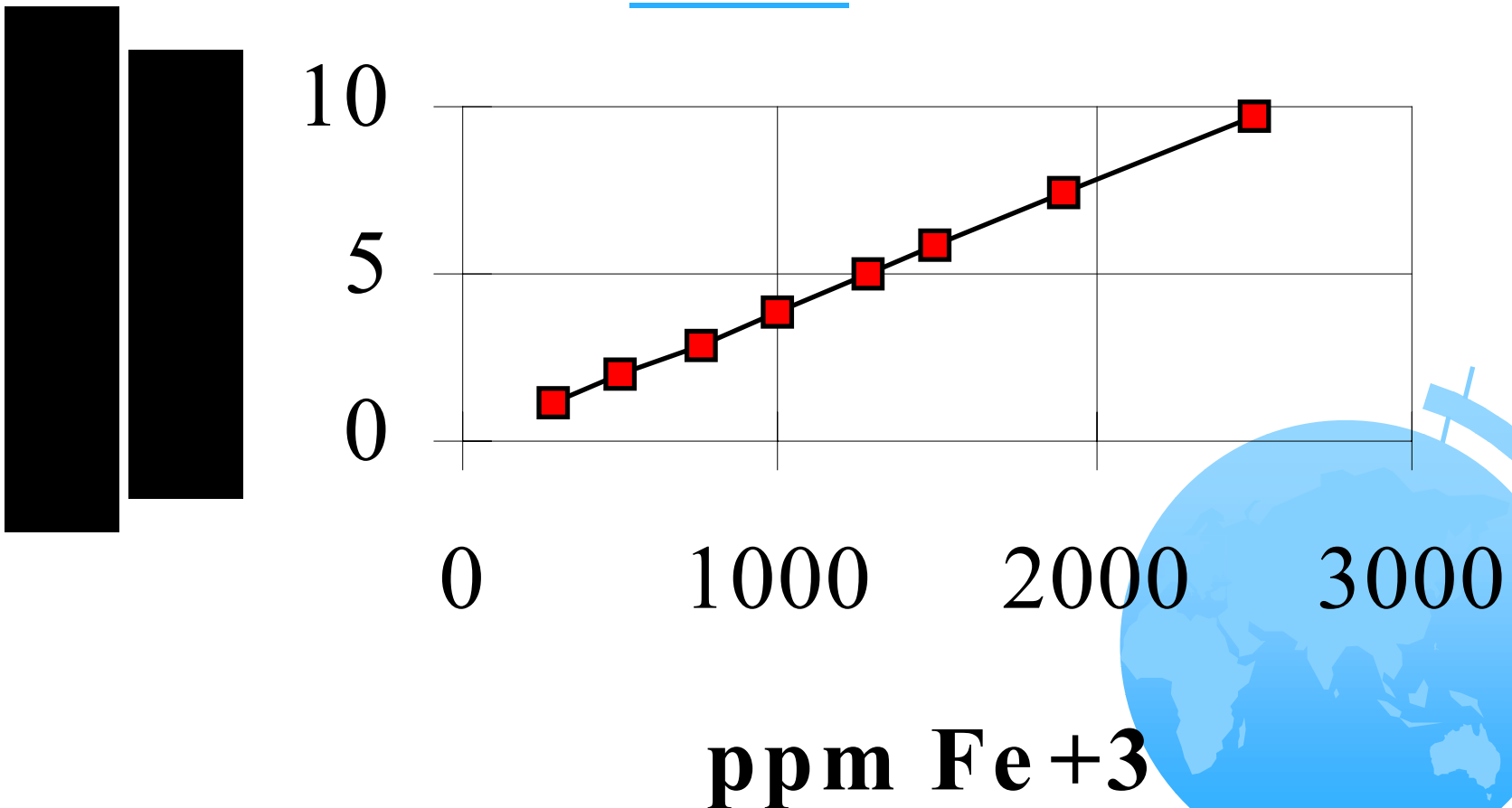
D = Diffusion Coef, ~2x10^{-6} cm/sec Fe^{+3}

A = Electrode Area, basis 1 sq cm

C_b = Fe^{+3} concentration, moles/cc

ó = diffusion layer thickness, ~1x10^{-3} cm

Estimated Limiting CD vs Fe+3



Current Density Selection

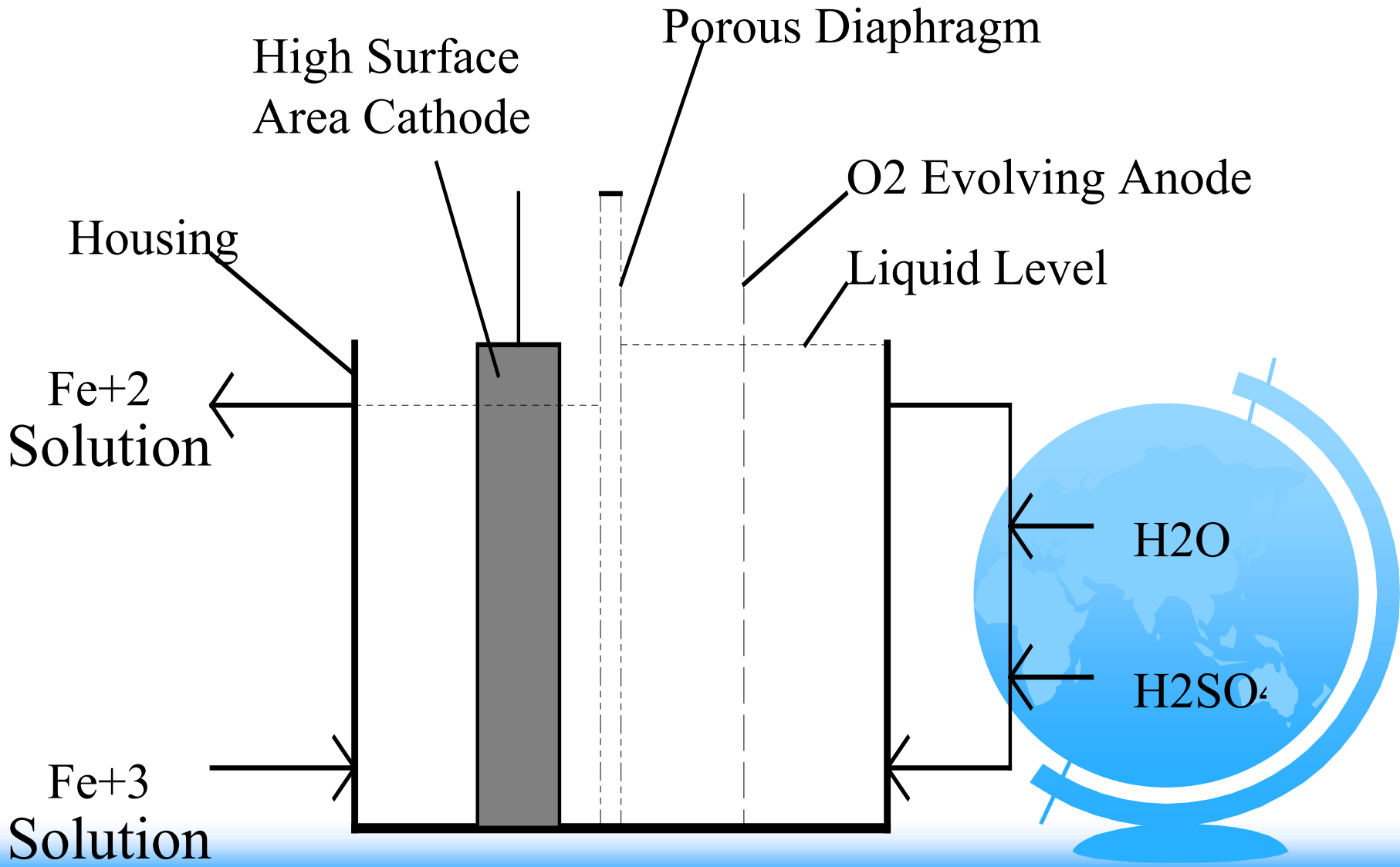
Desired CD 35 ASF (37.7 mA/sq cm)

- 1285 to ~750 ppm Fe^{+3}
- limiting CD ~3 mA/sq cm
- Actual/Projected Area ~12.6
- ~95% Current Efficiency

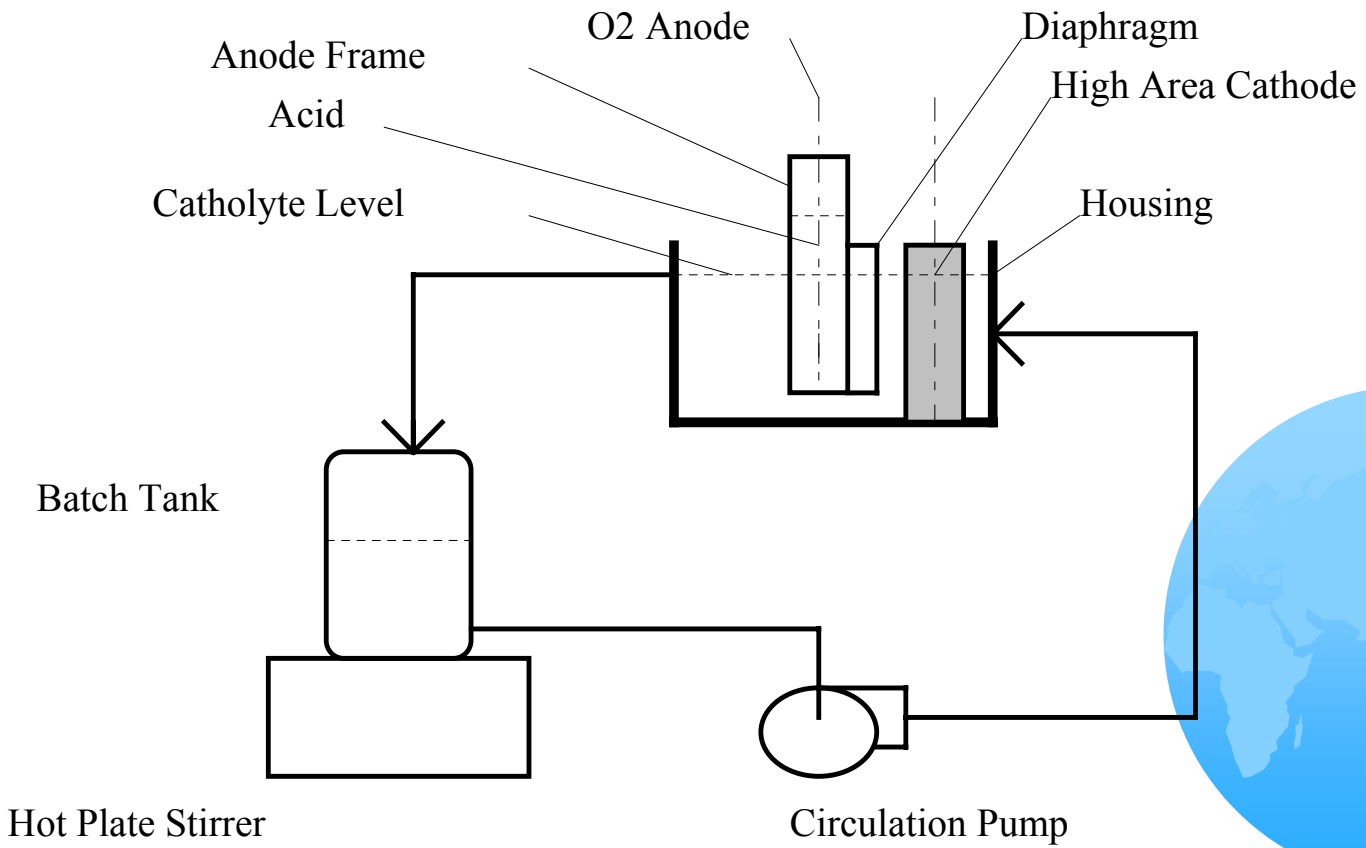
Desired CD 20 ASF (21.5 mA/sq cm)

- ~750 to 285 ppm Fe^{+3}
- limiting CD ~1 mA/sq cm
- Actual/Projected Area ~21.5
- ~80% Current Efficiency

Conceptual Flow Diagram

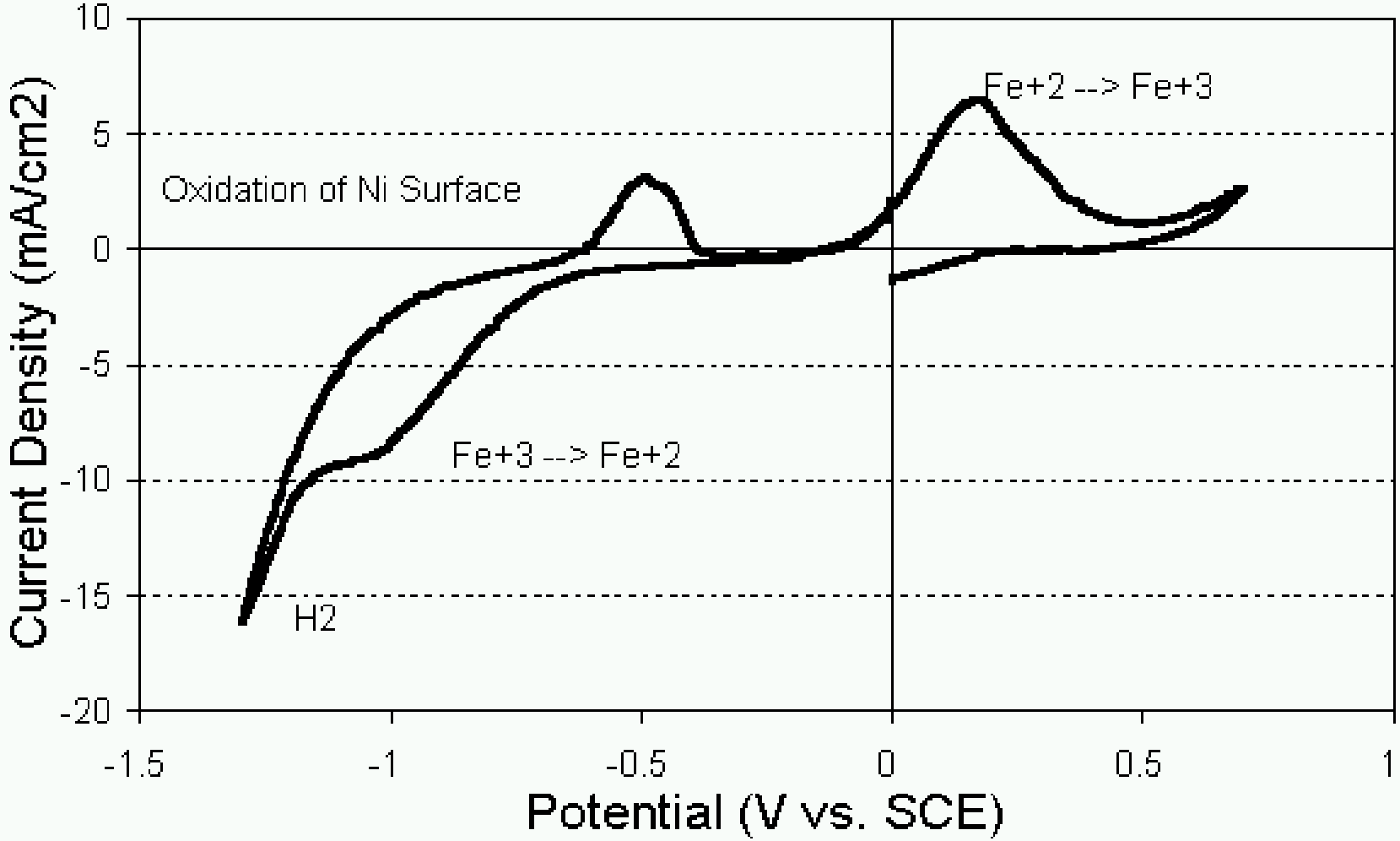


Bench Test System



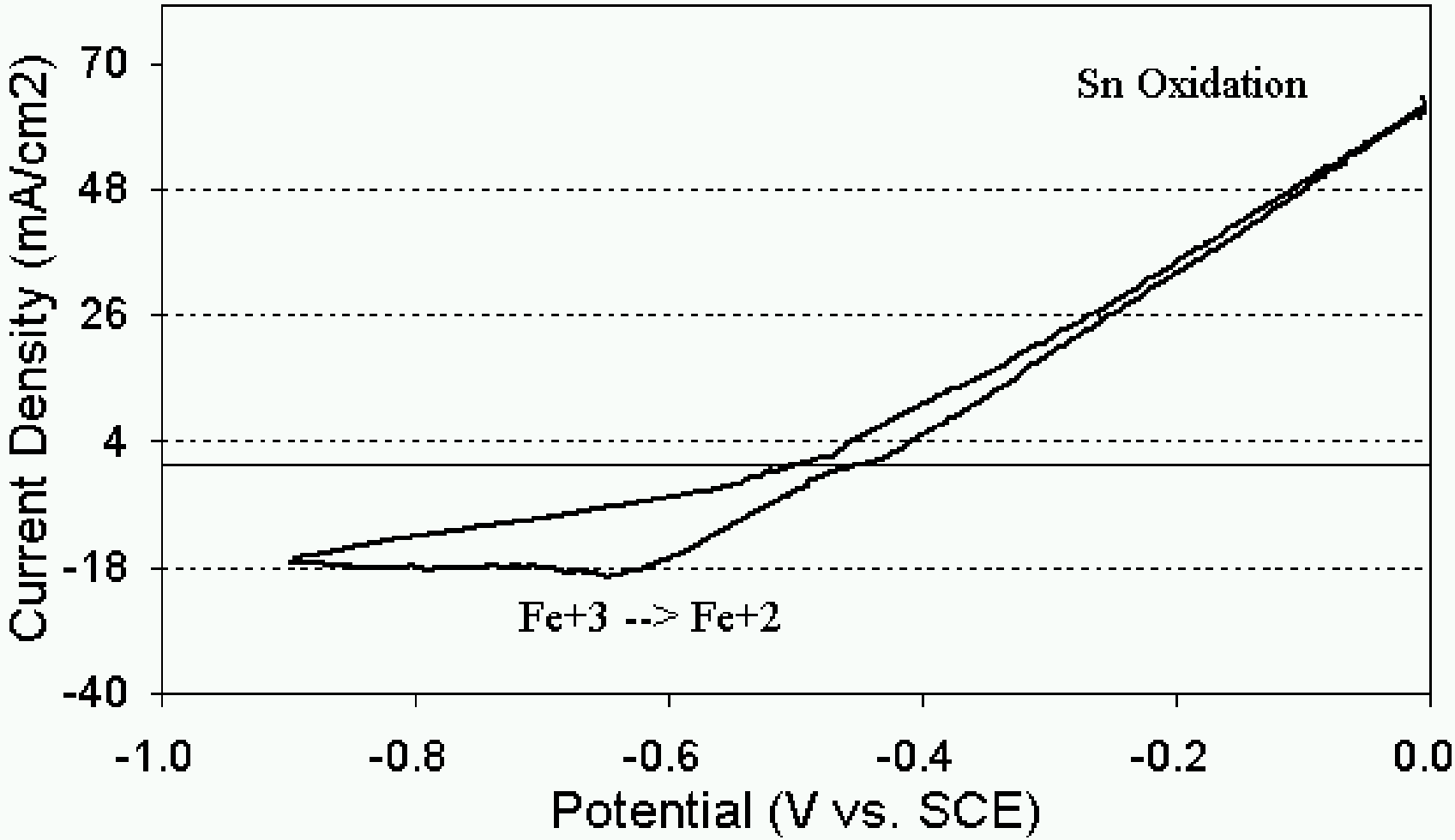
Ni Electrode for IONICS Fe Reduction

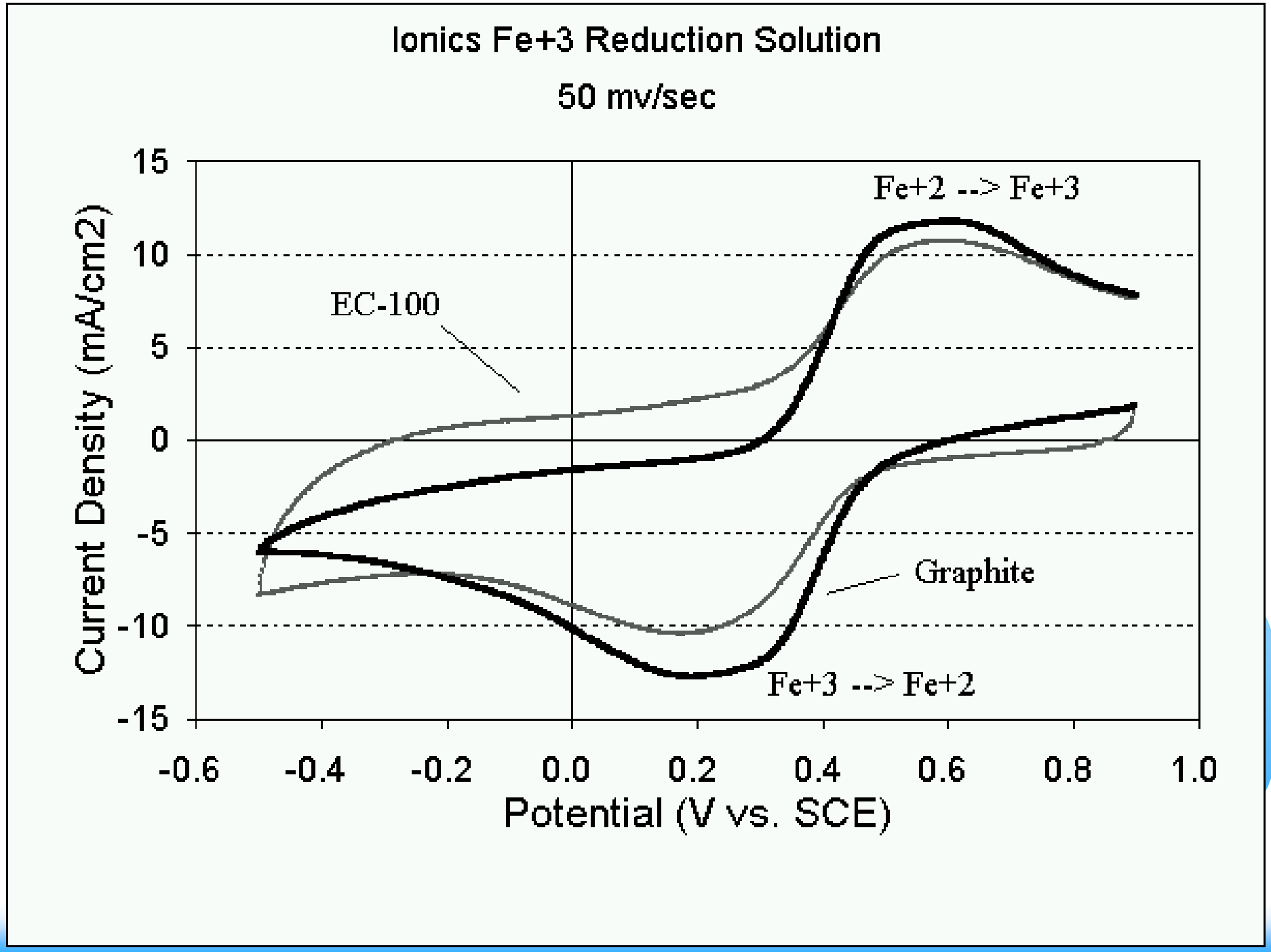
Cyclic Voltammogram, 50 mV/sec



Cyclic Voltammetry of Sn in Ionics Fe

50 mv/sec

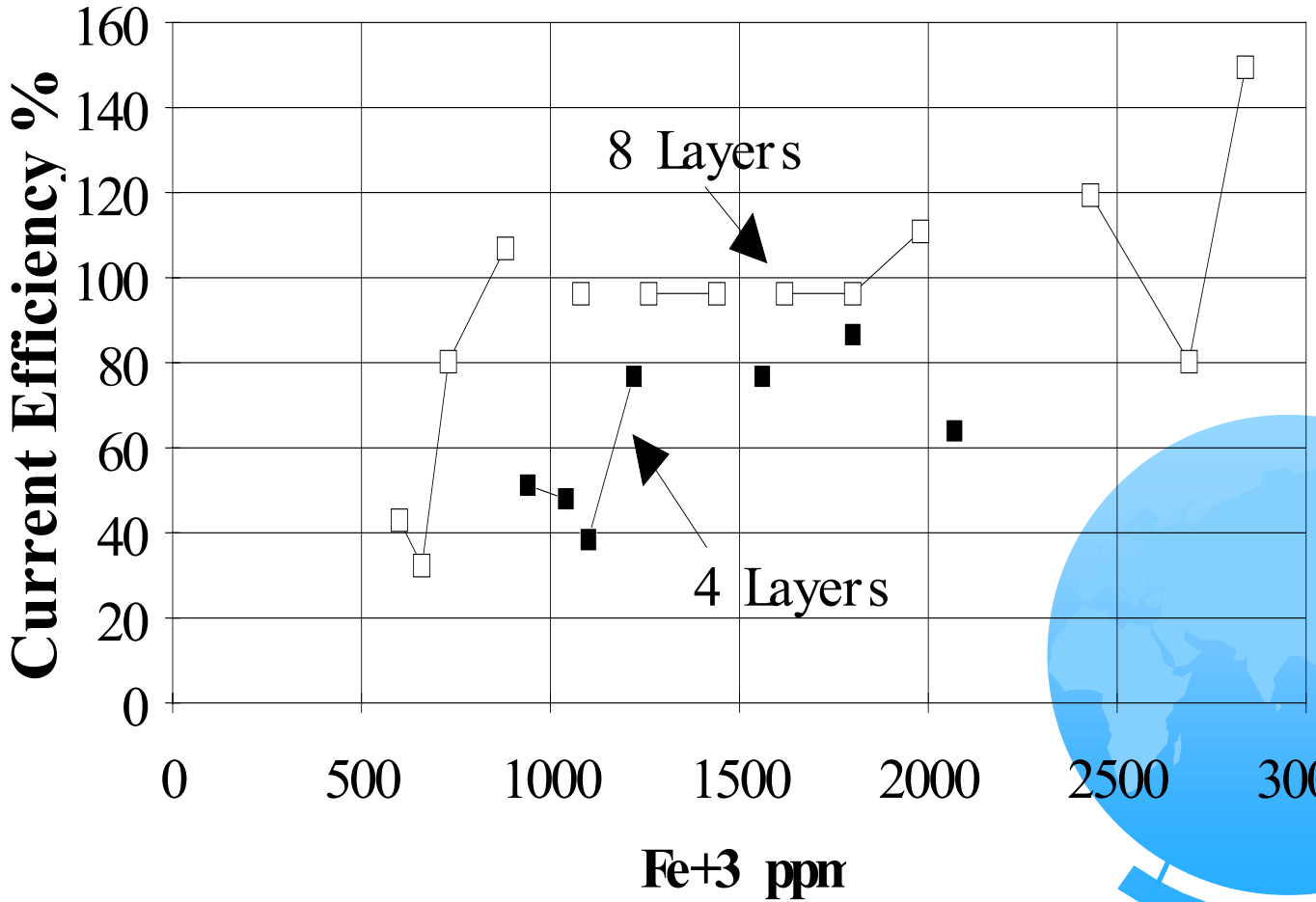



Ionics Fe+3 Reduction Solution
50 mv/sec
Current Density (mA/cm2)
15
10
5
0
-5
-10
-15
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Potential (V vs. SCE)
Fe+2 --> Fe+3
EC-100
Graphite
Fe+3 --> Fe+2

Cathode Materials Tested

Nickel	-	Corroded
Tin/Nickel	-	Corroded
Silver/Nickel	-	Corroded
Graphite Sheet	-	Low Current Efficiency
Retic. Graphite	-	Low Current Efficiency
	-	High Voltage
Graphite Felt	-	Low Current Efficiency
	-	High Voltage
DSA Coated Ti	-	High Current Efficiency

Bench Efficiency vs Fe+3
4 and 8 Layer Demister



Current Efficiency vs Cathode Area

(Avg CE between 600 and 1300 mg/l Fe^{+3})

Actual/Projected Area %	Current Efficiency
21.7	84.3
21.7	86.4
16.3	70.1
13.9	65.0
11.7	62.7
10.8	63.0

Commercial Electrolyzer