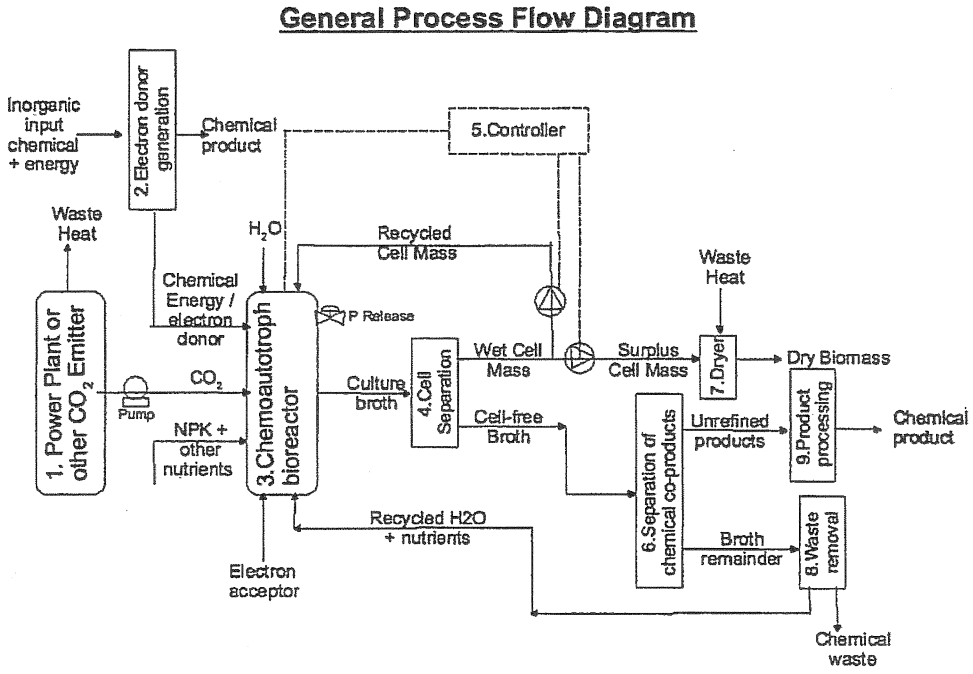

General Process Flow Diagram
Inorganic input chemical + energy
2.Electron donor generation
Chemical product
5.Controller
Waste Heat
H_2O
Recycled Cell Mass
Waste Heat
Chemical Energy / electron donor
P Release
1. Power Plant or other CO_2 Emitter
CO_2
Pump
NPK + other nutrients
3.Chemoautotroph bioreactor
Culture broth
4.Cell Separation
Wet Cell Mass
Surplus Cell Mass
7.Dryer
Dry Biomass
Cell-free Broth
Unrefined products
9.Product processing
Chemical product
6.Separation of chemical co-products
Broth remainder
8.Waste removal
Recycled H2O + nutrients
Electron acceptor
Chemical waste

FIG. 1

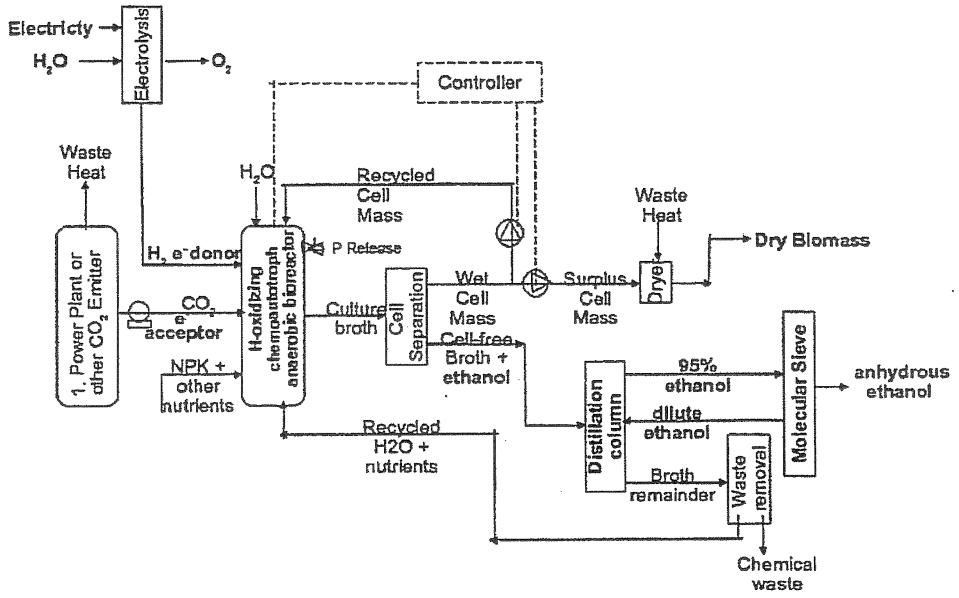
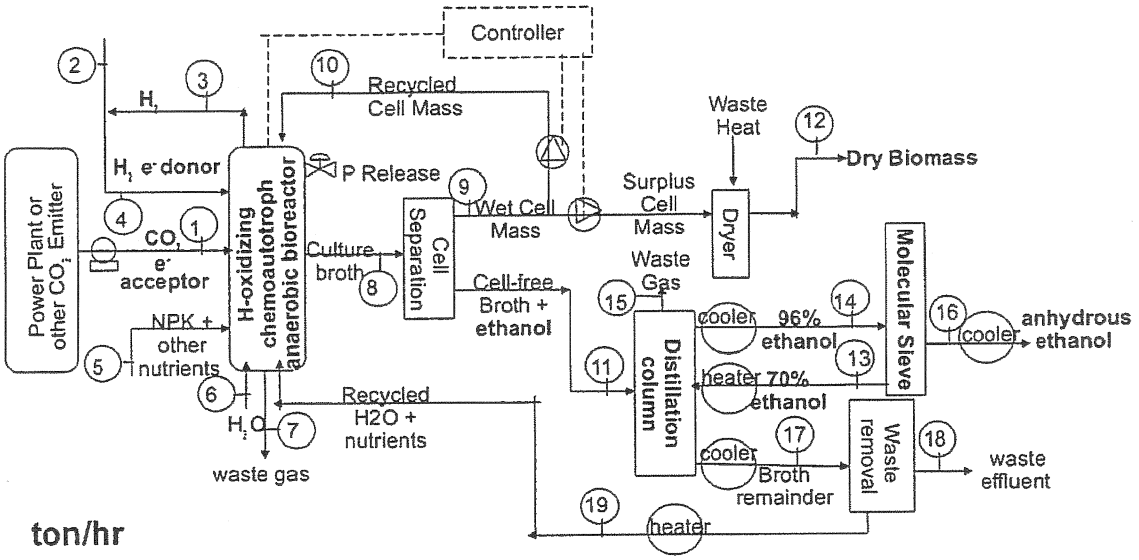

Electricty
H_2O
Electrolysis
O_2
Controller
Waste Heat
H_2O
Recycled Cell Mass
Waste Heat
Dry Biomass
H_2 e⁻donor
P Release
1. Power Plant or other CO_2 Emitter
CO_2
e⁻ acceptor
Oxidizing chemoautotroph anaerobic bioreactor
Culture broth
Cell Separation
Wet Cell Mass
Surplus Cell Mass
Dryer
Cell-free Broth + ethanol
NPK + other nutrients
95% ethanol
anhydrous ethanol
Molecular Sieve
Distillation column
dilute ethanol
Recycled H2O + nutrients
Broth remainder
Waste removal
Chemical waste

FIG. 2

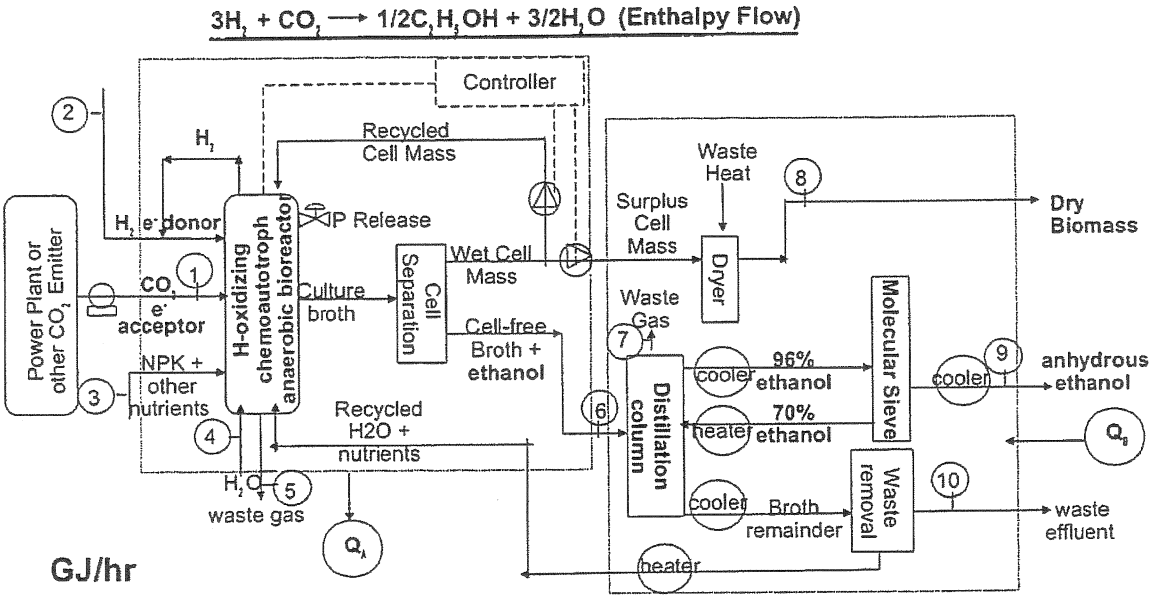
$3H_2 + CO_2 \longrightarrow 1/2C_2H_5OH + 3/2H_2O$ (Mass Balance)



Line number	1	2	3	4	5	6	7	8	9
stream	CO2 feed	H2 new	H2 recycle	H2 feed	nutrient feed	H2O feed	waste gas	medium	Cell mass
CO2	7.73	-	1.13	1.13	-	-	0.01	0.38	-
N2	19.64	-	-	-	-	-	19.64	-	-
H2	-	1.00	0.20	1.20	-	-	-	5.36E-04	-
Nutrients	-	-	-	-	9.45E-04	-	-	1.25	-
H2O	-	-	-	-	-	trace	-	382.87	4.20
ethanol	-	-	-	-	-	-	-	3.83	-
acetic acid	-	-	-	-	-	-	-	0.76	-
biomass	-	-	-	-	-	-	-	1.80	1.80
T (degrees C)	150.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00

Line number	10	11	12	13	14	15	16	17	18	19
stream	Cell recycle	Cell-free	Dry	Reflux	Top	Waste Gas	C2H6O	Bottom	Effluent	Recycle
CO2	-	0.38	-	-	-	0.38	-	-	-	-
N2	-	-	-	-	-	-	-	-	-	-
H2	-	5.36E-04	-	-	-	5.36E-04	-	-	-	-
Nutrients	-	1.25	-	-	-	-	-	1.25	9.45E-04	1.25
H2O	4.20	378.67	trace	0.17	0.18	-	0.01	378.66	2.89E-01	378.37
ethanol	-	3.83	-	0.39	4.22	-	3.83	trace	-	-
acetic acid	-	0.76	-	-	-	-	-	0.76	5.79E-04	0.76
biomass	1.80	-	trace	-	-	-	-	1.80	-	-
T (degrees C)	37.00	37.00	37.00	37.00	37.00	78.20	37.00	37.00	37.00	37.00

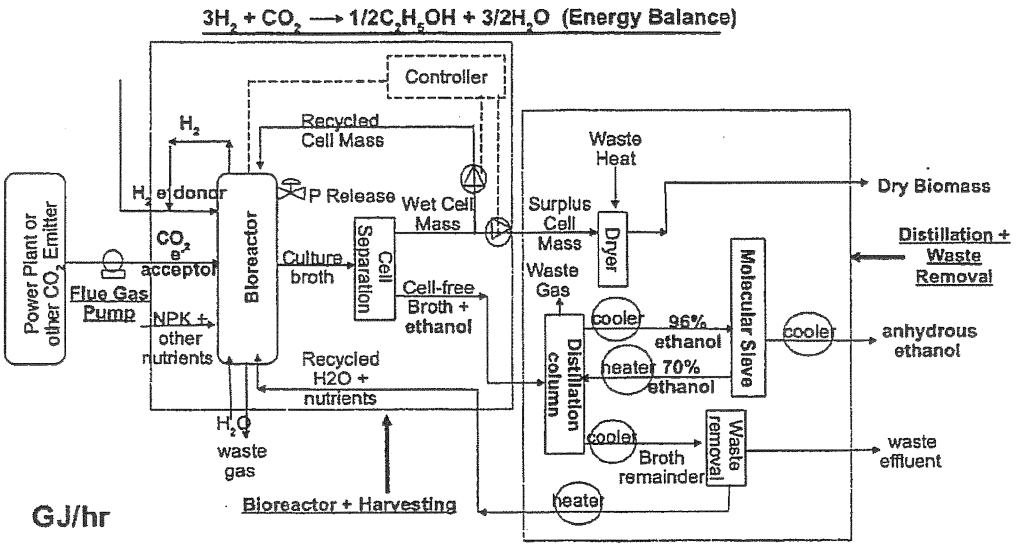
FIG. 3



Line number	1	2	3	4	5	6	7
stream	CO2 feed	H2 new	nutrient feed	H2O feed	waste gas	Cell-free	waste gas
CO2	0.80	-	-	-	1.13E-04	3.66E-03	1.65E-02
N2	2.32	-	-	-	0.22	-	-
H2	-	0.16	-	-	-	8.40E-05	3.74E-04
Nutrients	-	-	trace	-	-	trace	-
H2O	-	-	-	trace	-	17.47	-
ethanol	-	-	-	-	-	0.10	-
acetic acid	-	-	-	-	-	trace	-
biomass	-	-	-	-	-	-	-
Q (heat)	-	-	-	-	-	-	-
T (degrees C)	150.00	37.00	37.00	37.00	37.00	37.00	78.20

Line number	8	9	10	11	A	B
stream	Dry	Anhydrous	Effluent	Recycle	Chemosynthesis	Distillation
CO2	-	-	-	-	-	
N2	-	-	-	-	-	
H2	-	-	-	-	-	
Nutrients	-	-	trace	trace	-	
H2O	trace	trace	trace	17.26	-	
ethanol	-	0.10	-	-	-	
acetic acid	-	-	trace	trace	-	
biomass	trace	-	-	-	-	
Q (heat)	-	-	-	-	-29.97	42.94
T (degrees C)	37.00	37.00	37.00	37.00	37	78.2

FIG. 4



Energy Input					
input point	Process Heat	Waste Heat	Chemical Energy	Electricity	Total energy
Flue Gas Pump	0	0	0	7	7
Bioreactor + harvesting	0	3	130	13	146
Distillation + waste removal	43	0	0	5	48
Total Input	43	3	130	25	201

Energy Output					
Output point	Process Heat	Waste Heat	Chemical Energy	Electricity	Total energy
Flue Gas Pump	0	7	0	0	7
Bioreactor + harvesting	0	43	103	0	147
Distillation + waste removal	0	48	0	0	48
Total Output	0	98	103	0	201

FIG. 5

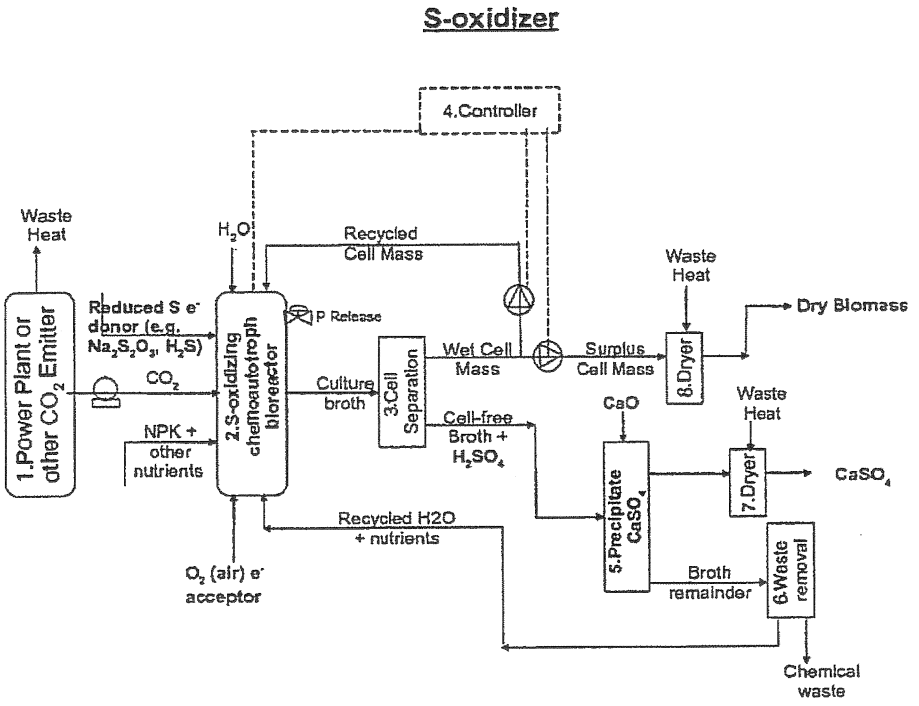

S-oxidizer
4.Controller
Waste Heat
1.Power Plant or other CO_2 Emitter
H_2O
Recycled Cell Mass
Reduced S e⁻ donor (e.g. $Na_2S_2O_3$, H_2S)
CO_2
NPK + other nutrients
2.S-oxidizing chemoautotroph bioreactor
P Release
Culture broth
3.Cell Separation
Wet Cell Mass
Surplus Cell Mass
8.Dryer
Waste Heat
Dry Biomass
Cell-free Broth + H_2SO_4
CaO
5.Precipitate $CaSO_4$
7.Dryer
Waste Heat
$CaSO_4$
Recycled H2O + nutrients
O_2 (air) e⁻ acceptor
Broth remainder
6.Waste removal
Chemical waste

FIG. 6

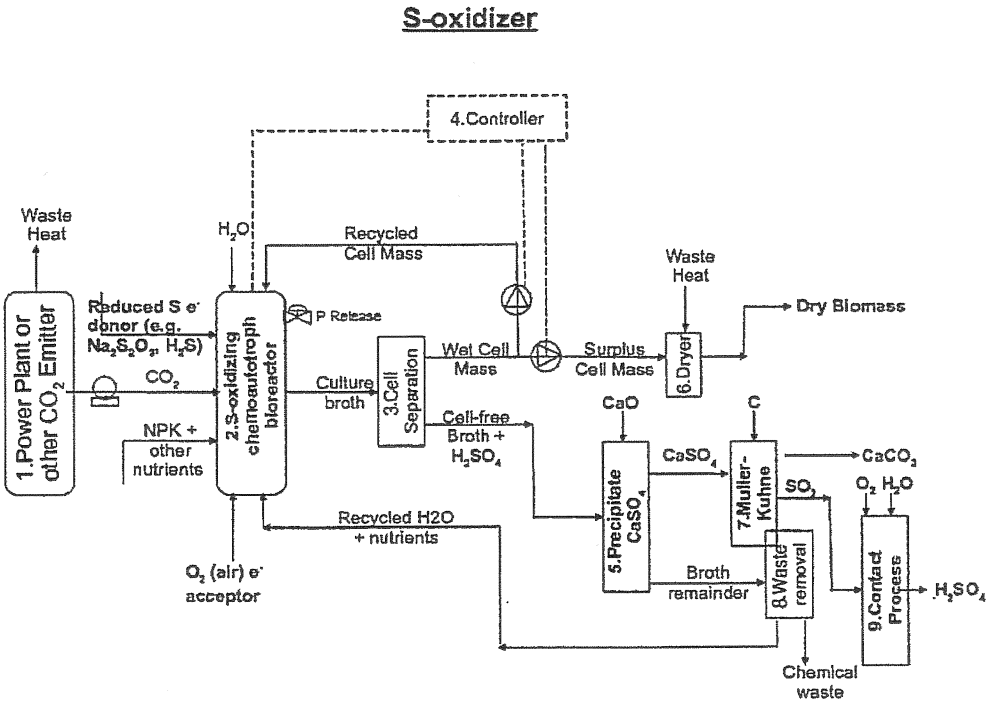

S-oxidizer
4.Controller
Waste Heat
1.Power Plant or other CO_2 Emitter
Reduced S e⁻ donor (e.g. $Na_2S_2O_3$, H_2S)
CO_2
NPK + other nutrients
H_2O
2.S-oxidizing chemoautotroph bioreactor
O_2 (air) e⁻ acceptor
Recycled Cell Mass
P Release
Culture broth
3.Cell Separation
Wet Cell Mass
Cell-free Broth + H_2SO_4
Recycled H2O + nutrients
Surplus Cell Mass
Waste Heat
6.Dryer
Dry Biomass
CaO
5.Precipitate $CaSO_4$
$CaSO_4$
C
7.Muller-Kuhne
$CaCO_3$
SO_2
O_2 H_2O
Broth remainder
8.Waste removal
9.Contact Process
H_2SO_4
Chemical waste

FIG. 7

S-oxidizer

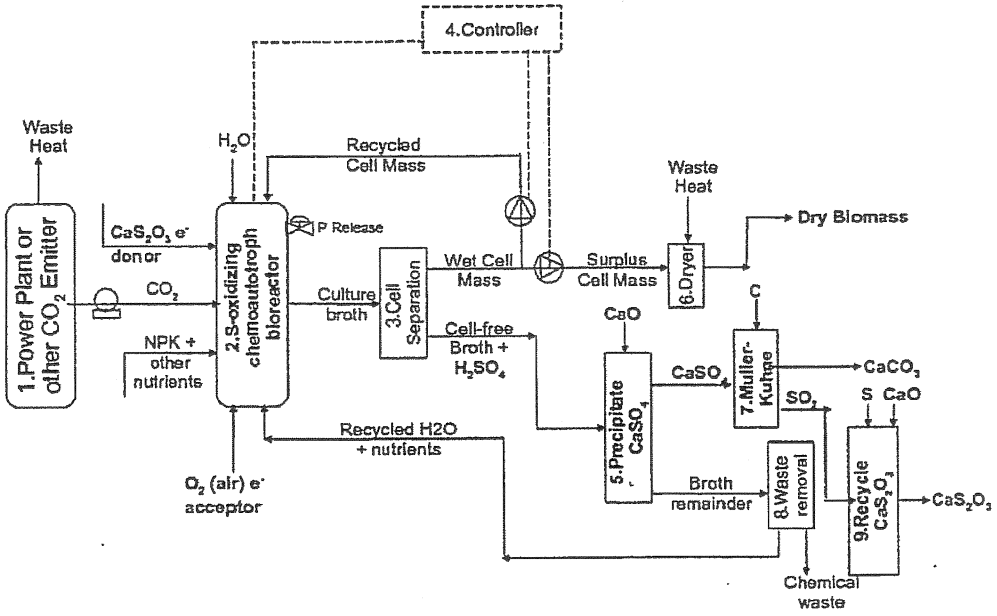


FIG. 8

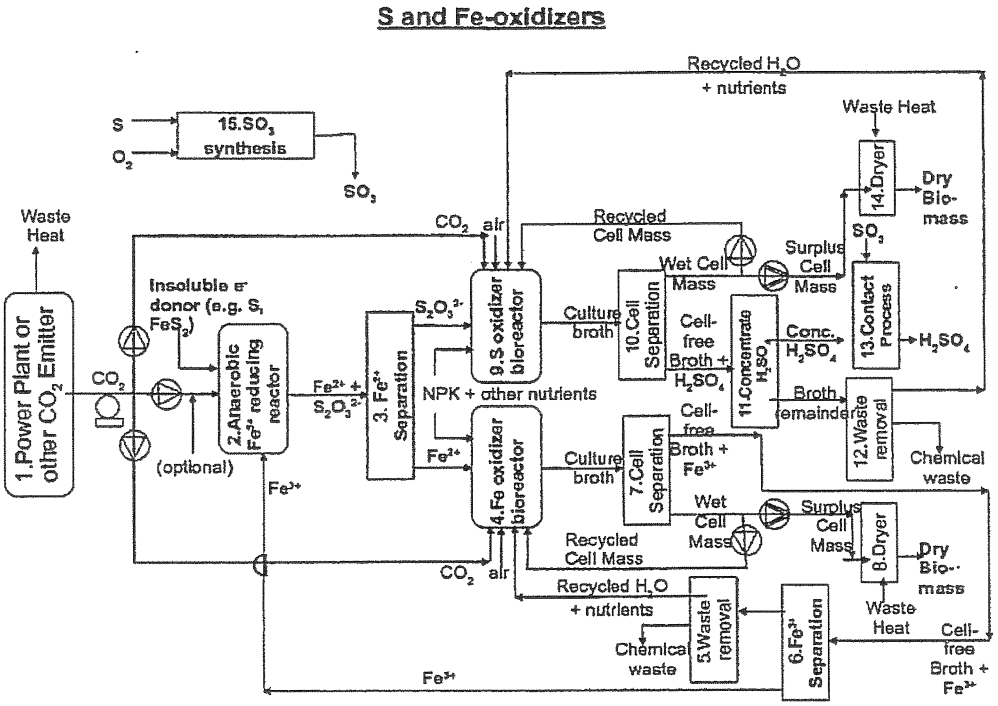

S and Fe-oxidizers
Recycled H_2O + nutrients
Waste Heat
S
O_2
15.SO_3 synthesis
SO_3
14.Dryer
Dry Bio-mass
Waste Heat
CO_2
air
Recycled Cell Mass
Wet Cell Mass
Surplus Cell Mass
SO_2
Insoluble e⁻ donor (e.g. S, FeS_2)
$S_2O_3^{2-}$
9.S oxidizer bioreactor
Culture broth
10.Cell Separation
Cell-free Broth + H_2SO_4
11.Concentrate H_2SO_4
Conc. H_2SO_4
13.Contact Process
H_2SO_4
1.Power Plant or other CO_2 Emitter
CO_2
2.Anaerobic Fe^{3+} reducing reactor
Fe^{2+} + $S_2O_3^{2-}$
3. Fe^{2+} Separation
NPK + other nutrients
Broth remainder
12.Waste removal
Chemical waste
(optional)
Fe^{3+}
Fe^{2+}
4.Fe oxidizer bioreactor
Culture broth
7.Cell Separation
Cell-free Broth + Fe^{3+}
Wet Cell Mass
Surplus Cell Mass
8.Dryer
Dry Bio-mass
Recycled Cell Mass
CO_2
air
Recycled H_2O + nutrients
Waste Heat
Chemical waste
5.Waste removal
6.Fe^{3+} Separation
Cell-free Broth + Fe^{3+}
Fe^{3+}

FIG. 9

S and H-oxidizers

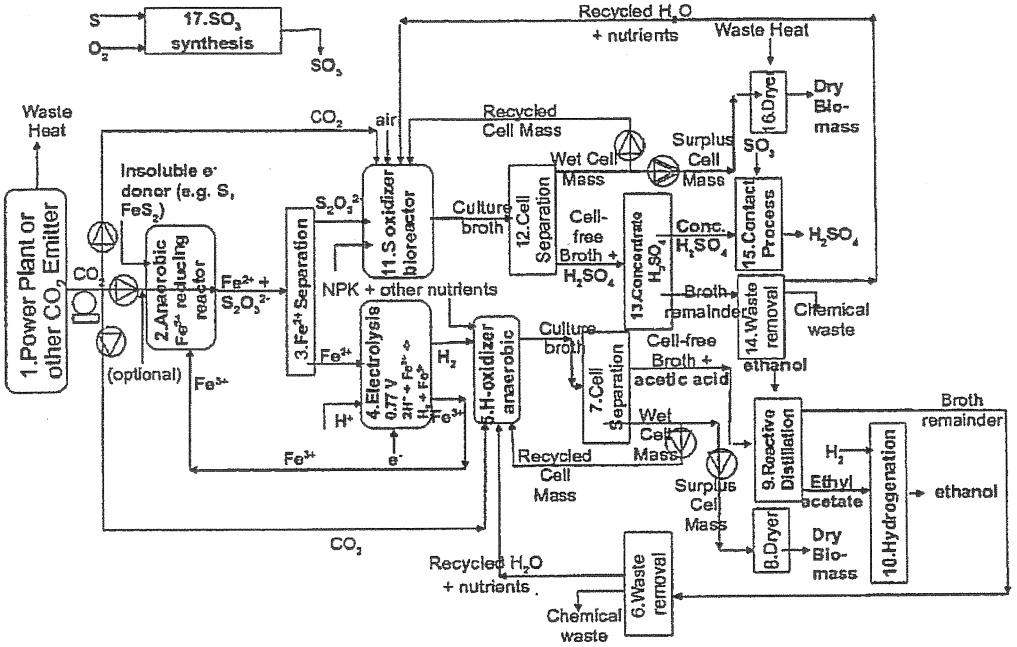


FIG. 10

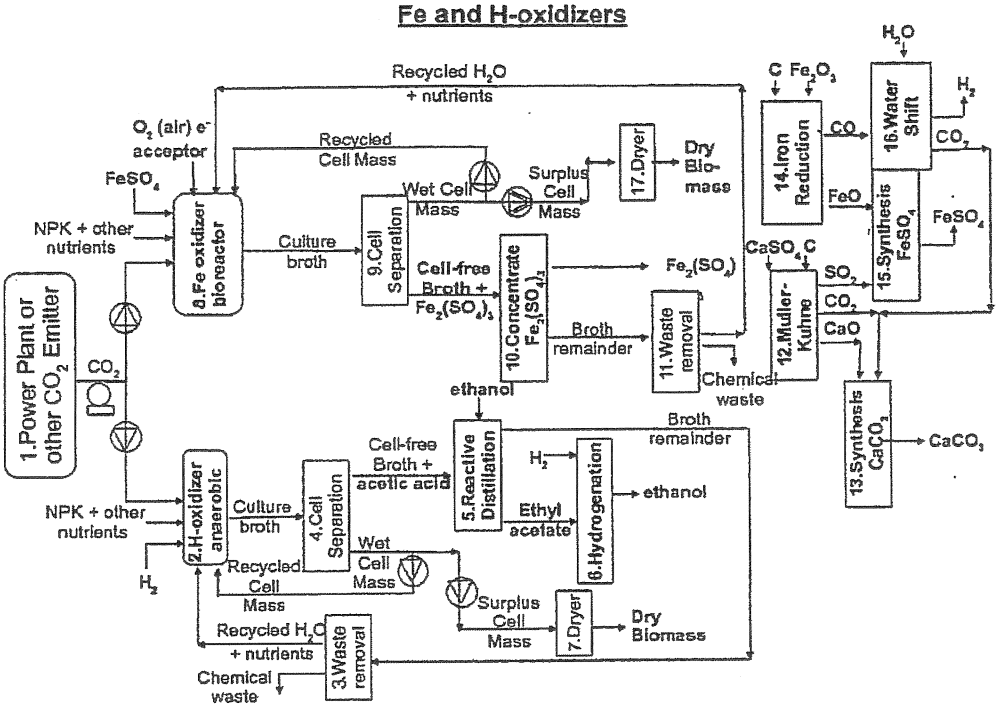

Fe and H-oxidizers
Recycled H_2O + nutrients
O_2 (air) e^- acceptor
Recycled Cell Mass
$FeSO_4$
NPK + other nutrients
8.Fe oxidizer bioreactor
Culture broth
9.Cell Separation
Wet Cell Mass
Surplus Cell Mass
17.Dryer
Dry Bio-mass
Cell-free Broth + $Fe_2(SO_4)_3$
10.Concentrate $Fe_2(SO_4)_3$
$Fe_2(SO_4)$
Broth remainder
11.Waste removal
Chemical waste
ethanol
1.Power Plant or other CO_2 Emitter
CO_2
2.H-oxidizer anaerobic
NPK + other nutrients
H_2
Culture broth
4.Cell Separation
Cell-free Broth + acetic acid
5.Reactive Distillation
Ethyl acetate
H_2
6.Hydrogenation
ethanol
Broth remainder
Wet Cell Mass
Recycled Cell Mass
Surplus Cell Mass
7.Dryer
Dry Biomass
Recycled H_2O + nutrients
3.Waste removal
Chemical waste
C Fe_2O_3
14.Iron Reduction
CO
FeO
16.Water Shift
H_2
CO_2
15.Synthesis $FeSO_4$
$FeSO_4$
H_2O
$CaSO_4$ C
12.Muller-Kuhne
SO_2
CO_2
CaO
13.Synthesis $CaCO_3$
$CaCO_3$

FIG. 11