Process design, simulation, and techno-economic analysis of integrated production of furfural and glucose derived from palm oil empty fruit bunches

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Appendix A: PFD, Mass and Energy Balance Table and ASPEN Simulation Flow Diagram

DRAWING CONTINUATIONS

CONTINUATION OF LINES AND SIGNALS:

FROM/TO
PFD NUMBER

DRAWING CONTINUATION ARROW WITHIN UNIT

- NUMBERING OF CONNECTOR:
  PFD NUMBER
  XX-YYZZ
  - NUMERICAL NUMBER
  - SYSTEM CODE
  - GROUP NUMBER

PIPING SYMBOLS/ INSTRUMENTAL SIGNALS

- MAIN PROCESS STREAM
- HOT UTILITY STREAM
- COLD UTILITY STREAM
- ELECTRICAL SIGNAL
- FLOW DIRECTION

MECHANICAL AND PROCESS EQUIPMENT

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	HEAT EXCHANGER (HEATER)		HEAT EXCHANGER (COOLER)
	CENTRIFUGAL PUMP		POSITIVE DISPLACEMENT PUMP
	GRINDER		MIXER
	INSULATED CONTINUOUS STIRRED TANK REACTOR (CSTR)		DECANTER CENTRIFUGE
	DISTILLATION COLUMN		ROTARY DRYER
	VIBRATING SCREEN		LIQUID-LIQUID EXTRACTION COLUMN
	BELT CONVEYOR		SCREW CONVEYOR

PROCESS SYSTEM IDENTIFIER

PROCESS/UTILITY SYSTEM	SYSTEM CODE
FEED PREPARATION UNIT	10
EFB PRETREATMENT UNIT	11
DEHYDRATION UNIT	12
FURFURAL PURIFICATION UNIT	13
PRETREATED SOLID NEUTRALIZING UNIT	14
SACCHARIFICATION UNIT	15
GLUCOSE SEPARATION UNIT	16
EMPTY FRUIT BUNCH STORAGE	20
SULPHURIC ACID STORAGE	21
PROCESS WATER STORAGE	22
BUTYL CHOLRIDE STORAGE	23
SODIUM HYDROXIDE STORAGE	24
CELLULASE ENZYME STORAGE	25
LOW PRESSURE STEAM GENERATION UNIT	30
HIGH PRESSURE STEAM GENERATION UNIT	31
COOLING WATER GENERATION UNIT	32
HOT WATER GENERATION UNIT	33
HOT AIR GENERATION UNIT	34
WASTE TREATMENT SYSTEM	40
BOILER FEED UNIT	50
FURFURAL STORAGE	60
GLUCOSE STORAGE	70

NOTE:

REV.	DESCRIPTION	DATE
1	COMPLETE MASTER LEGEND	05/05/2021

CO-PRODUCTION OF GLUCOSE(G) AND FURFURAL (F) FROM EFB IN MALAYSIA
CAPACITY – 10 KTPY (G) AND 4.96 KTPY (F)

PROCESS FLOW DIAGRAM MASTER LEGEND

DWR NO	LOCATION	CODE	REV
1	MALAYSIA	LEGEND	02

SCALE: 1 | 0 of 6

Fig. A.1. *Legend of process flow diagram.*

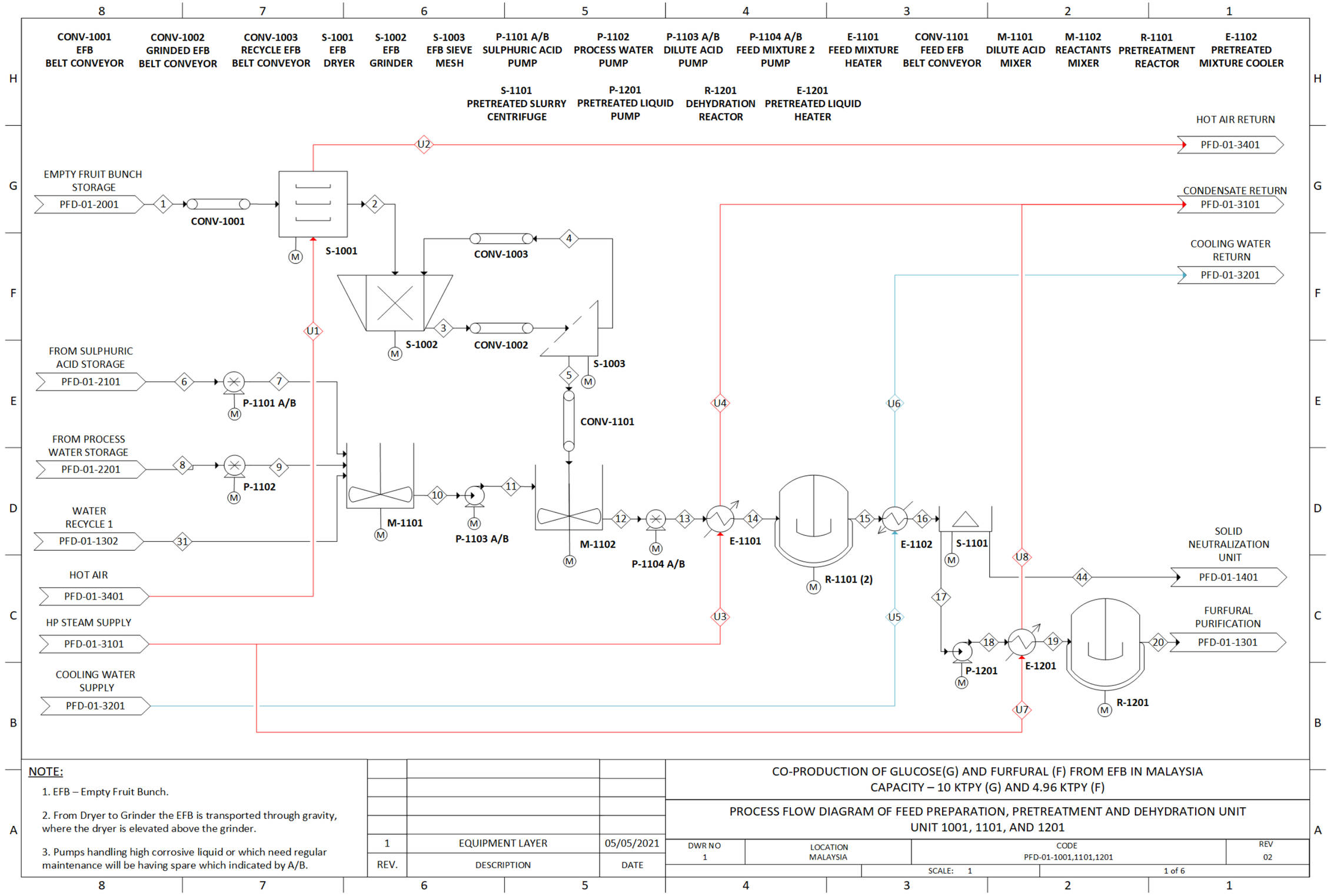


Fig. A.2. *Process flow diagram of feed preparation, pretreatment, and dehydration unit (Unit 1001, 1101 and 1201).*

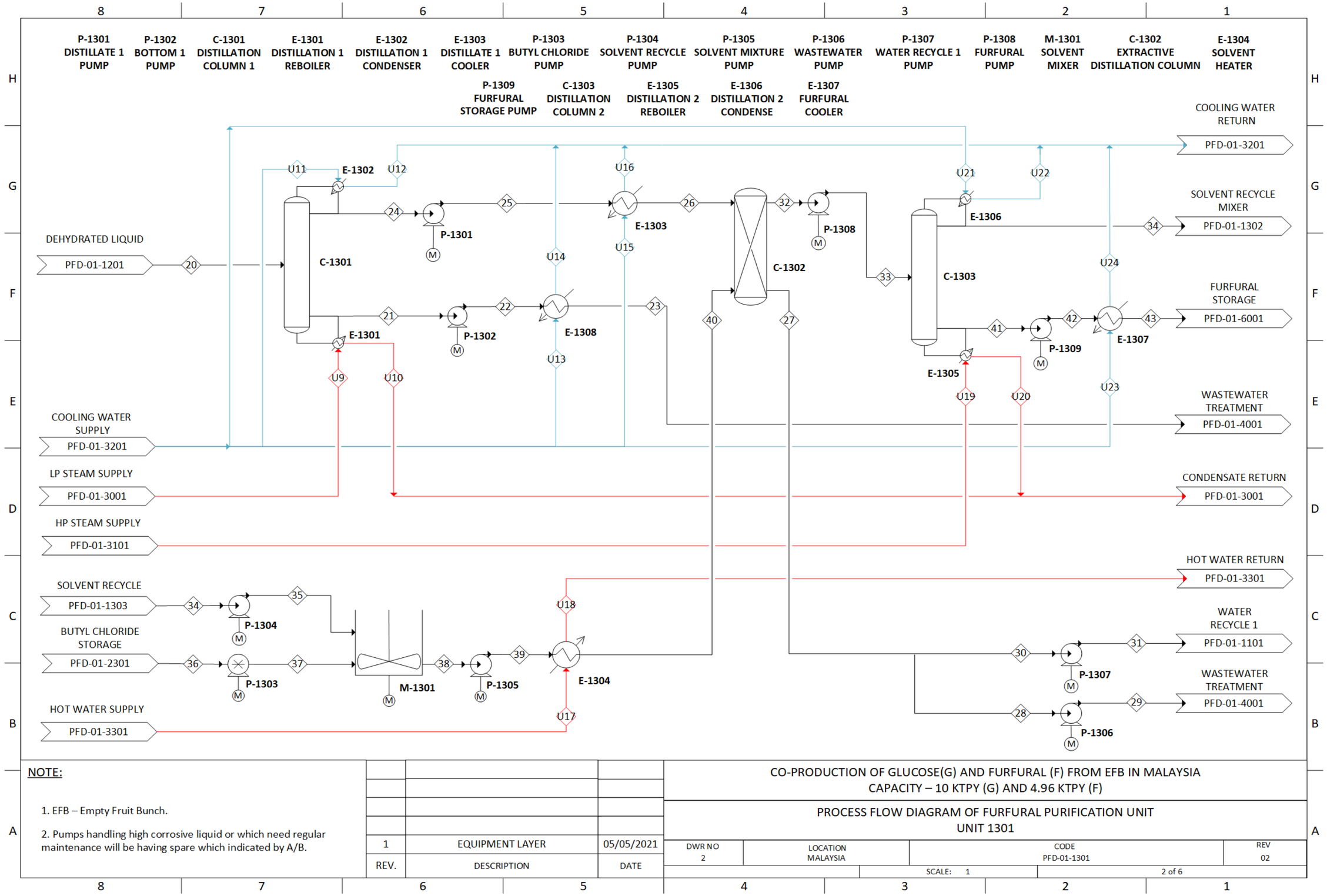


Fig. A.3. *Process flow diagram of furfural purification unit (Unit 1301).*

P-1401 SODIUM HYDROXIDE PUMP
P-1402 PROCESS WATER PUMP
P-1403 NEUTRALIZER PUMP
P-1404 PRETREATED SLURRY PUMP
CONV-1401 PRETREATED SOLID SCREW CONVEYOR
M-1401 NEUTRALIZER MIXER
M-1402 PRETREATED SOLID MIXER
E-1401 PRETREATED SOLID HEATER
P-1501 CELLULASE ENZYME PUMP
P-1502 GLUCOSE SLURRY PUMP
CONV-1501 RESIDUAL SOLID SCREW CONVEYOR
R-1501 SACCHARIFICATION REACTOR

S-1501 GLUCOSE SLURRY CENTRIFUGE
P-1601 GLUCOSE FEED PUMP
P-1602 DISTILLATE 3 PUMP
P-1603 WASTEWATER PUMP
P-1604 RECYCLE WATER 2 PUMP
P-1605 BOTTOM 3 PUMP
C-1601 DISTILLATION COLUMN 3
E-1601 DISTILLATION 3 REBOILER
E-1602 DISTILLATION 3 CONDENSER
E-1603 DISTILLATE 3 COOLER
E-1603 BOTTOM 3 COOLER

SODIUM HYDROXIDE STORAGE
PFD-01-2401
FROM PROCESS WATER STORAGE
PFD-01-2201
WATER RECYCLE 2
PFD-01-1601
HP STEAM SUPPLY
PFD-01-3101
COOLING WATER SUPPLY
PFD-01-3201
CELLULASE ENZYME STORAGE
PFD-01-2501
HOT WATER SUPPLY
PFD-01-3301
PRETREATED SOLID MIXTURE
PFD-01-1102

COOLING WATER RETURN
PFD-01-3201
WATER RECYCLE 2
PFD-01-1401
WASTEWATER TREATMENT
PFD-01-4001
GLUCOSE STORAGE
PFD-01-7001
CONDENSATE RETURN
PFD-01-3201
BOILER FEED UNIT
PFD-01-5001
HOT WATER RETURN
PFD-01-3301

NOTE:

1. EFB – Empty Fruit Bunch.
2. Pumps handling high corrosive liquid or which need regular maintenance will be having spare which indicated by A/B.

REV.	DESCRIPTION	DATE
1	EQUIPMENT LAYER	05/05/2021

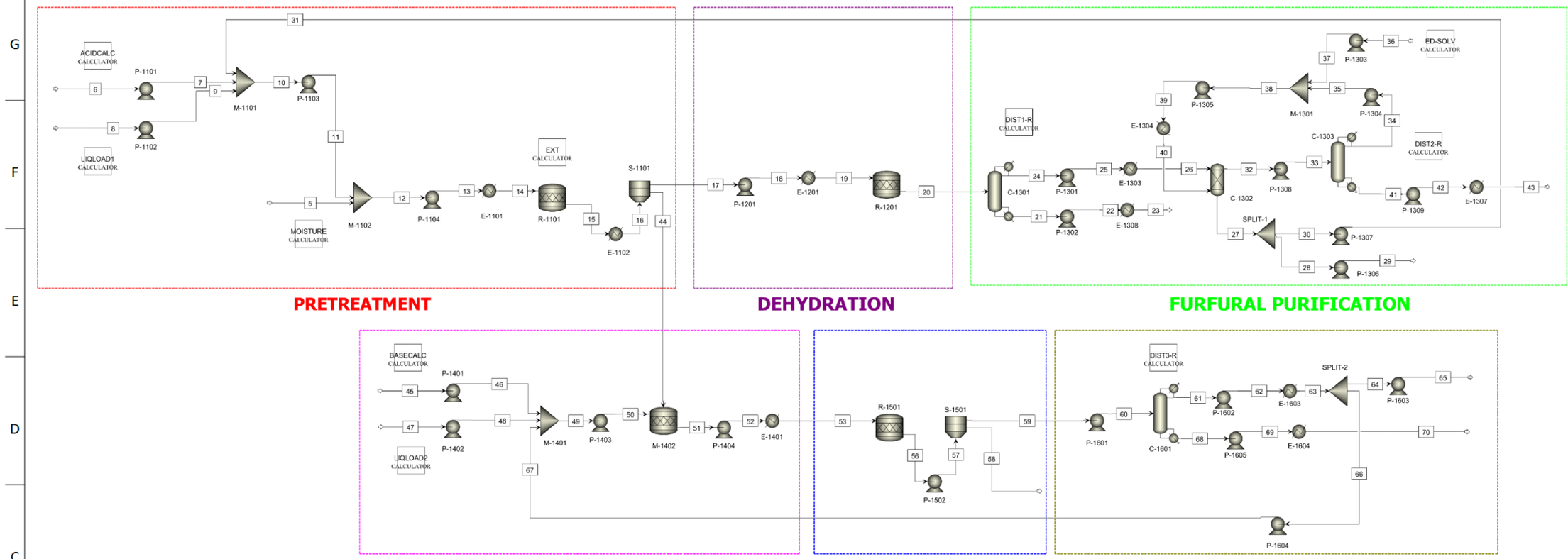
CO-PRODUCTION OF GLUCOSE(G) AND FURFURAL (F) FROM EFB IN MALAYSIA
CAPACITY – 10 KTPY (G) AND 4.96 KTPY (F)

PROCESS FLOW DIAGRAM OF NEUTRALIZATION, SACCHARIFICATION AND GLUCOSE PURIFICATION UNIT
UNIT 1401,1501, AND 1601

DWR NO	LOCATION	CODE	REV
2	MALAYSIA	PFD-01-1401,1501,1601	02

SCALE: 1 — 3 of 6

Fig. A.4. *Process flow diagram of neutralization, saccharification and glucose purification unit (Unit 1401, 1501 and 1601).*



NOTE:

1. The image has high resolution, therefore can be zoomed for better clarity

REV.	DESCRIPTION	DATE
1	SIMULATION FLOW DIAGRAM	10/05/2021

CO-PRODUCTION OF GLUCOSE(G) AND FURFURAL (F) FROM EFB IN MALAYSIA
CAPACITY – 10 KTPY (G) AND 4.96 KTPY (F)

ASPEN SIMULATION FLOW DIAGRAM

DWR NO	LOCATION	CODE	REV
2	MALAYSIA	ASFD-01	02

SCALE: 1 | 4 of 6

Fig. A.5. *Aspen simulation flow diagram.*

Steam Number	-	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Temperature	C	30.00	49.97	30.00	30.00	30.00	30.00	30.01	30.00	30.01	38.75	38.75	36.90	37.28	158.00	158.00	50.00	30.00	30.68	170.00	170.00	101.59	101.60	45.00	86.99
Pressure	bar	1.0133	1.0133	1.0133	1.0133	1.0133	1.0133	1.1146	1.0133	1.1146	1.1146	1.1146	1.0133	6.5861	6.0795	6.0795	6.5861	1.0133	9.1193	8.6126	8.9166	1.0133	1.1146	1.0133	1.0133
Enthalpy Flow	kW	-18136.6	-18136.6	-18136.6	-18136.6	-18136.6	-264.5	-264.5	-2270.8	-2270.8	-34457.5	-34457.5	-52594.1	-52590.8	-51020.1	-50889.3	-52327.4	-37569.6	-37564.6	-36011.5	-36005.4	-3484.8	-3484.8	-3540.6	-33504.6
Volume Flow	cum/hr	4.2648	4.2648	4.2648	4.2648	4.2648	0.0731	0.0731	0.5216	0.5216	8.0480	8.0480	12.3007	12.3031	25.1840	20.4798	12.3941	8.9937	8.9982	10.8739	10.8604	0.9756	0.9751	0.9160	8.7999
Mass Flowrate																									
GLUCAN	kg/hr	1312.79	1312.79	1312.79	1312.79	1312.79	0.00	0.00	0.00	0.00	0.00	0.00	1312.79	1312.79	1312.79	1177.57	1177.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XYLAN	kg/hr	922.50	922.50	922.50	922.50	922.50	0.00	0.00	0.00	0.00	0.00	0.00	922.50	922.50	922.50	23.99	23.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIGNIN	kg/hr	1015.64	1015.64	1015.64	1015.64	1015.64	0.00	0.00	0.00	0.00	0.00	0.00	1015.64	1015.64	1015.64	1015.64	1015.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ASH	kg/hr	239.50	239.50	239.50	239.50	239.50	0.00	0.00	0.00	0.00	0.00	0.00	239.50	239.50	239.50	239.50	239.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETYL	kg/hr	66.53	66.53	66.53	66.53	66.53	0.00	0.00	0.00	0.00	0.00	0.00	66.53	66.53	66.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLUCOSE	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	150.24	150.24	148.28	148.28	148.28	148.28	148.28	148.28	148.28	TRACE
XYLOSE	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	950.84	950.84	938.42	938.42	938.42	32.84	32.84	32.84	32.84	TRACE
FURFURAL	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.63	6.63	6.63	6.63	6.63	51.55	51.55	50.88	50.88	50.88	630.45	TRACE	TRACE	TRACE	630.45
WATER	kg/hr	878.15	395.22	395.22	395.22	395.22	27.44	27.44	515.97	515.97	7801.55	7801.55	8196.77	8196.77	8196.77	8084.50	8084.50	7978.85	7978.85	7978.85	8304.85	664.69	664.69	664.69	7640.16
SULPHURIC ACID	kg/hr	0.00	0.00	0.00	0.00	0.00	64.03	64.03	0.00	0.00	64.03	64.03	64.03	64.03	64.03	64.03	64.03	63.19	63.19	63.19	63.19	63.19	63.19	63.19	TRACE
SODIUM HYDROXIDE	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETIC ACID	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.50	23.50	23.50	23.50	23.50	90.06	90.06	88.89	88.89	88.89	88.89	63.16	63.16	63.16	25.72
SODIUM SULPHATE	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SODIUM ACETATE	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BUTYL CHLORIDE	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.62	8.62	8.62	8.62	8.62	8.62	8.62	8.51	8.51	8.51	8.51	TRACE	TRACE	TRACE	8.51
CELLULASE ENZYME	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Mass Flow	kg/hr	**4435.10**	**3952.16**	**3952.16**	**3952.16**	**3952.16**	**91.46**	**91.46**	**515.97**	**515.97**	**7904.33**	**7904.33**	**11856.49**	**11856.49**	**11856.49**	**11856.53**	**11856.53**	**9277.01**	**9277.01**	**9277.01**	**9277.01**	**972.16**	**972.16**	**972.16**	**8304.85**

Steam Number	-	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Temperature	C	87.00	40.00	39.41	39.41	39.42	39.41	39.42	39.62	39.79	34.20	34.22	30.00	30.02	34.21	34.21	40.00	180.80	180.81	35.00	30.00	30.00	30.02	30.00	30.01
Pressure	bar	1.1146	1.0133	1.0133	1.0133	1.1146	1.0133	1.1146	1.0133	1.8239	1.7225	1.8239	1.0133	1.1146	1.1146	1.1146	1.0133	1.7225	1.8239	1.0133	1.0133	1.0133	1.1146	1.0133	1.1146
Enthalpy Flow	kW	-33504.6	-33960.7	-33602.3	-1680.1	-1680.1	-31922.2	-31922.2	-935.4	-935.2	-579.5	-579.4	-1.4	-1.4	-580.8	-580.8	-577.0	-315.3	-315.3	-360.2	-14995.4	-10.2	-98.7	-4595.3	-4595.2
Volume Flow	cum/hr	8.8000	8.3669	7.8394	0.3920	0.3920	7.4474	7.4474	1.7275	1.7279	1.1734	1.1734	0.0028	0.0028	1.1762	1.1762	3.6490	0.6394	0.6394	0.5481	3.2126	0.0029	0.0029	1.0556	1.0556
Mass Flowrate																									
GLUCAN	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1177.57	0.00	0.00	0.00	0.00
XYLAN	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.99	0.00	0.00	0.00	0.00
LIGNIN	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1015.64	0.00	0.00	0.00	0.00
ASH	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	239.50	0.00	0.00	0.00	0.00
ACETYL	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLUCOSE	kg/hr	TRACE	TRACE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.96	0.00	0.00	0.00	0.00
XYLOSE	kg/hr	TRACE	TRACE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.43	0.00	0.00	0.00	0.00
FURFURAL	kg/hr	630.45	630.45	6.98	0.35	0.35	6.63	6.63	623.48	623.48	TRACE	TRACE	0.00	0.00	TRACE	TRACE	TRACE	623.48	623.48	623.48	0.67	0.00	0.00	0.00	0.00
WATER	kg/hr	7640.16	7640.16	7640.16	382.01	382.01	7258.15	7258.15	1.82	1.82	1.82	1.82	0.00	0.00	1.82	1.82	1.82	TRACE	TRACE	TRACE	105.65	1.61	1.61	1044.13	1044.13
SULPHURIC ACID	kg/hr	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.00	0.00
SODIUM HYDROXIDE	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.61	1.61	0.00	0.00
ACETIC ACID	kg/hr	25.72	25.72	24.74	1.24	1.24	23.50	23.50	1.05	1.05	0.06	0.06	0.00	0.00	0.06	0.06	0.06	0.99	0.99	0.99	1.18	0.00	0.00	0.00	0.00
SODIUM SULPHATE	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SODIUM ACETATE	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BUTYL CHLORIDE	kg/hr	8.51	8.51	9.08	0.45	0.45	8.62	8.62	1022.41	1022.41	1020.53	1020.53	2.44	2.44	1022.98	1022.98	1022.98	1.88	1.88	1.88	0.11	0.00	0.00	0.00	0.00
CELLULASE ENZYME	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Mass Flow	kg/hr	**8304.85**	**8304.84**	**7680.94**	**384.05**	**384.05**	**7296.90**	**7296.90**	**1648.75**	**1648.75**	**1022.41**	**1022.41**	**2.44**	**2.44**	**1024.85**	**1024.85**	**1024.85**	**626.34**	**626.34**	**626.34**	**2579.52**	**3.23**	**3.23**	**1044.13**	**1044.13**

NOTE:

1. TRACE denotes for mass flow lower than 10E-2 kg/hr

REV.	DESCRIPTION	DATE
1	STREAM TABLE INSERTION	10/05/2021

CO-PRODUCTION OF GLUCOSE(G) AND FURFURAL (F) FROM EFB IN MALAYSIA
CAPACITY – 10 KTPY (G) AND 4.96 KTPY (F)

MASS AND ENERGY BALANCE TABLE 1

DWR NO	LOCATION	CODE	REV
2	MALAYSIA	MEBT-01	02

SCALE: 1 — 5 of 6

Table A.1. *Mass and energy balance table 1.*

Stream Number	-	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
Temperature	C	34.47	34.47	30.00	30.01	48.00	30.00	30.00	48.00	48.01	48.00	48.00	48.01	110.18	110.18	35.00	35.00	35.01	35.00	35.01	208.12	208.13	35.00
Pressure	bar	1.1146	1.1146	1.0133	1.1146	1.0133	1.0133	1.0133	1.0133	1.1146	1.0133	1.0133	1.1146	1.0133	1.1146	1.0133	1.0133	1.1146	1.0133	1.1146	1.0133	1.1146	1.0133
Enthalpy Flow	kW	-42628.0	-42628.0	-57676.3	-57676.2	-57442.1	-98.7	-98.7	-57458.6	-57458.5	-12875.9	-44582.7	-44582.6	-41516.7	-41516.6	-42247.2	-4224.7	-4224.7	-38022.5	-38022.5	-2316.1	-2316.1	-2493.3
Volume Flow	cum/hr	9.8521	9.8521	13.0233	13.0233	13.2036	0.0196	0.0196	13.1454	13.1455	2.4264	10.7191	10.7191	10.4513	10.4514	9.7712	0.9771	0.9771	8.7941	8.7941	1.2016	1.2009	1.0526
Mass Flowrate																							
GLUCAN	kg/hr	0.00	0.00	1177.57	1177.57	1177.57	0.00	0.00	56.52	56.52	56.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XYLAN	kg/hr	0.00	0.00	23.99	23.99	23.99	0.00	0.00	23.99	23.99	23.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIGNIN	kg/hr	0.00	0.00	1015.64	1015.64	1015.64	0.00	0.00	1015.64	1015.64	1015.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ASH	kg/hr	0.00	0.00	239.50	239.50	239.50	0.00	0.00	239.50	239.50	239.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETYL	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLUCOSE	kg/hr	TRACE	TRACE	1.96	1.96	1.96	0.00	0.00	1247.57	1247.57	7.61	1239.96	1239.96	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	1239.96	1239.96	1239.96
XYLOSE	kg/hr	TRACE	TRACE	12.43	12.43	12.43	0.00	0.00	12.43	12.43	0.08	12.35	12.35	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	12.35	12.35	12.35
FURFURAL	kg/hr	5.67	5.67	6.35	6.35	6.35	0.00	0.00	6.35	6.35	0.04	6.31	6.31	6.31	6.31	6.31	0.63	0.63	5.67	5.67	TRACE	TRACE	TRACE
WATER	kg/hr	9695.69	9695.69	9801.99	9801.99	9801.99	0.00	0.00	9677.44	9677.44	59.03	9618.40	9618.40	9611.04	9611.04	9611.04	961.10	961.10	8649.93	8649.93	7.37	7.37	7.37
SULPHURIC ACID	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SODIUM HYDROXIDE	kg/hr	1.61	1.61	0.15	0.15	0.15	0.00	0.00	0.15	0.15	TRACE	0.15	0.15	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	0.15	0.15	0.15
ACETIC ACID	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SODIUM SULPHATE	kg/hr	TRACE	TRACE	1.21	1.21	1.21	0.00	0.00	1.21	1.21	TRACE	1.20	1.20	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	1.20	1.20	1.20
SODIUM ACETATE	kg/hr	TRACE	TRACE	1.61	1.61	1.61	0.00	0.00	1.61	1.61	TRACE	1.60	1.60	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	1.60	1.60	1.60
BUTYL CHLORIDE	kg/hr	0.95	0.95	1.07	1.07	1.07	0.00	0.00	1.07	1.07	TRACE	1.06	1.06	1.06	1.06	1.06	0.11	0.11	0.95	0.95	TRACE	TRACE	TRACE
CELLULASE ENZYME	kg/hr	0.00	0.00	0.00	0.00	0.00	23.55	23.55	23.55	23.55	3.47	20.08	20.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.08	20.08	20.08
Total Mass Flow	kg/hr	9703.93	9703.93	12283.45	12283.45	12283.45	23.55	23.55	12283.45	12283.45	1402.42	10881.03	10881.03	9618.40	9618.40	9618.40	961.84	961.84	8656.56	8656.56	1262.63	1262.63	1262.63

Utility Stream	-	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
Description	-	Hot Air	Hot Air	HP	HP	CW	CW	HP	HP	LP	LP	CW	CW
Temperature	C	105.00	49.00	212.39	212.39	30.00	45.00	212.39	212.39	133.53	133.53	30.00	45.00
Pressure	bar	1.01	1.01	20.00	20.00	1.01	1.01	20.00	20.00	3.00	3.00	1.01	1.01
Phase	-	Gas	Gas	Vapour	Liquid	Liquid	Liquid	Vapour	Liquid	Vapour	Liquid	Liquid	Liquid
Mass Flow	kg/hr	19762.24	20245.17	2992.11	2992.11	82372.51	82372.51	3189.45	3189.45	15001.77	15001.77	572757.80	572757.80

Utility Stream	-	U13	U14	U15	U16	U17	U18	U19	U20	U21	U22	U23	U24
Description	-	CW	CW	CW	CW	HW	HW	HP	HP	CW	CW	CW	CW
Temperature	C	30.00	45.00	30.00	45.00	80.00	45.00	212.39	212.39	30.00	45.00	30.00	45.00
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01	20.00	20.00	1.01	1.01	1.01	1.01
Phase	-	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Vapour	Liquid	Liquid	Liquid	Liquid	Liquid
Mass Flow	kg/hr	3195.71	3195.71	26128.57	26128.57	94.60	94.60	552.91	552.91	14308.10	14308.10	2567.90	2567.90

Utility Stream	-	U24	U25	U26	U27	U28	U29	U30	U31	U32	U33	U34
Description	-	CW	HW	HW	HP	HP	CW	CW	CW	CW	CW	CW
Temperature	C	45.00	80.00	45.00	212.39	212.39	30.00	45.00	30.00	45.00	30.00	45.00
Pressure	bar	1.01	1.01	1.01	20.00	20.00	1.01	1.01	1.01	1.01	1.01	1.01
Phase	-	Liquid	Liquid	Liquid	Vapour	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Mass Flow	kg/hr	2567.90	5746.38	5746.38	24496.44	24496.44	693607.44	693607.44	41848.06	41848.06	10147.48	10147.48

NOTE:

1. TRACE denotes for mass flow lower than 10E-2 kg/hr
2. CW- COOLING WATER; HW- HOT WATER; HP- HIGH PRESSURE STEAM; LP- LOW PRESSURE STEAM

REV.	DESCRIPTION	DATE
1	STREAM TABLE INSERTION	10/05/2021

CO-PRODUCTION OF GLUCOSE(G) AND FURFURAL (F) FROM EFB IN MALAYSIA
CAPACITY – 10 KTPY (G) AND 4.96 KTPY (F)

MASS AND ENERGY BALANCE TABLE 2

DWR NO	LOCATION	CODE	REV
2	MALAYSIA	MEBT-02	02

SCALE: 1 | 6 of 6

Table A.2. *Mass and energy balance table 2.*

Appendix B: ASPEN Simulation Description

Solid components can be created manually with the following parameters as the property obtained from the literature review. As the acetyl group is the derivative of xylan, the property of the acetyl group is similar to the xylan property.

Table B.1. *Solid components definition in ASPEN Plus* ***(Wooley & Putsche 1996)****.*

Component	Molecular weight (kg/kmol)	Heat of Formation (J/kmol)	Solid Molar Volume (CPSPO1-1) (m3/kmol)	Solid Heat Capacity (VSPOLY-1) (J/kmol.K)
Glucan	162.1436	-976.362E+6	0.106	-11704
			0	672.07
			0	0
			0	0
			0	0
			298.15	298.15
			1000	1000
Xylan	132.11	-762.416E+6	0.0864	-9529.9
			0	547.25
			0	0
			0	0
			0	0
			298.15	298.15
			1000	1000
Lignin	122.493	-1592.659E+6	0.0817	31431.7
			0	394.427
			0	0
			0	0
			0	0
			298.15	298.15
			1000	1000
Ash	162.1436	-976.362E+6	0.106	-11704
			0	672.07
			0	0
			0	0
			0	0
			298.15	298.15
			1000	1000
Acetyl Group	132.11	-762.416E+6	0.0864	-9529.9
			0	547.25
			0	0
			0	0
			0	0
			298.15	298.15
			1000	1000

B.1 Equipment Block Selection

For the equipment selection, **RSTOIC** is chosen as a reactor since the process involves chemical reactions. It requires inputs such as stoichiometric reaction and conversion rate or extent of reaction while the product mixture goes through a series of separations directly after the reaction. For solid-liquid separation, **CFUGE** is used as a decanter centrifuge with its given separation ratio and moisture content. The **RADFRAC** is used as a distillation column for the VLE mixture separation, where it requires input for a number of stages, reflux ratio, and distillate rate. For the LLE mixture separation, **EXTRACT** is used as an extraction column with its defined feed, solvent, and number of stages. Other equipment such as a mixer, heat exchanger, and pump (i.e., **MIXER, HEATER**, and **PUMP**) is used for mixing purposes, altering the temperature, and operating pressure of each main equipment, respectively. For ease of calculation and to minimize repetition, a few calculator blocks are included to automatically modify the parameters of specific equipment blocks by changing the flowrate of the feed.

B.2 Calculator Block

The equation and calculation used in each calculator block for each unit is shown below,

Table B.2.*Calculator block definition in ASPEN Plus.*

Unit	Calculator	Description	Equation
Pretreatment	ACIDCAL	Used to calculate the amount of required acid using the process condition and solid loading.	ACID=(18*SOLID/1000)/0.7
	LIQLOAD1	Used to calculate the amount of required freshwater using the process condition and recycle water.	WATER=(((1-0.3) *SOLID)-(0.3*(ACID+MOISTURE+RECYCLE)))/0.3
	MOISTURE	Used to calculate the required moisture in EFB with appropriate dry EFB.	MOISTURE=0.1*SOLID/0.9
	EXT	Used to calculate the extent of the reaction for the secondary reaction using mole flow of xylan, conversion rate and molecular weight of furfural.	E3=(XYLAN*0.974*0.05)/96.08556
Furfural Purification	DIST1-R	Used to calculate the distillate rate of the column using the feedwater flowrate.	DIST=WATER
	DIST2-R	Used to calculate the distillate rate of the column using the feed solvent flowrate.	DIST=SOLV
	ED-SOLV	Used to calculate the amount of fresh solvent required using the furfural to solvent ratio and recycled solvent flow.	EXSOLV = ((DILFUR-SOLV)/8.11) - SOLVDIST

Neutralization	BASECAL	Used to calculate the amount of required base using the process condition, solid loading and 10 mol% excess.	NAOH=(((H2SO4*2)+(ACETIC))/MOLEFRAC)*1.1
	LIQLOAD2	Used to calculate the amount of required freshwater using the process condition and recycle water with solid loading,	WATER=(((1-0.2)*SOLID)-(0.2*(BASE+MOISTURE+RECYCLE)))/0.2
Glucose Purification	DIST3-R	Used to calculate the distillate rate of column using the feedwater flowrate.	DIST=WATER

Appendix C: Fixed Capital Investment

C.1 Inside Battery Limit

The total cost required to purchase and install all the process equipment inside the process boundary is defined as the Inside battery limit (IBL). These costs are adjusted with installation, material, electrical system, erection, instrumental control system and piping cost within the process boundary.

The cost of equipment can be determined from Chemical Engineering Design by Gavin and Sinnott and Plant Design and Economics for Chemical Engineers by Peters. Plant Design and Economics for Chemical Engineers by Peters is used for equipment with complex internal structures. These costs are adjusted with the location factor and cost indices. Gavin's Chemical Engineering Design uses the cost of equipment obtained at the U.S. Gulf in 2006. Peter's Plant Design and Economics for Chemical Engineers applied graphical correlation to determine the cost of the equipment with motor and internal tray in the USA in 2002. The location factor and the cost indices are adapted to Malaysia and the year 2020, respectively. It can be converted into MYR, as in May 2021, the exchange rate of USD to MYR is 4.12 MYR **(XE currency 2021)**. The final equipment cost with the inside battery limit cost is shown below. The following shows the Chemical Engineering Plant Cost Index (CEPCI) and location.

Table C.1. *Adjusted equipment cost with lang factor in Malaysia in 2020 from Sinnott* ***(Sinnott & Towler 2020)****.*

Equipment tag	Material of constr.	No. of unit	Ce, Cost US 2006 (USD)	Ce, Cost MY 2020 (USD)	Lang Factor	Phase	C, Cost including installation	Final Cost MY 2020 (mil. MYR)
P-1103	CI	2	3426.04	3414.30	2.56	Fluid	8740.61	0.04
P-1201	CI	1	3444.01	3432.21	2.56	Fluid	8786.46	0.04
P-1301	CI	1	3440.30	3428.51	2.56	Fluid	8776.98	0.04
P-1302	CI	1	3310.02	3298.68	2.56	Fluid	8444.61	0.03
P-1304	CI	1	3312.50	3301.15	2.56	Fluid	8450.95	0.03
P-1305	CI	1	3312.54	3301.19	2.56	Fluid	8451.04	0.03
P-1306	CI	1	3303.35	3292.03	2.56	Fluid	8427.61	0.03

P-1307	CI	1	3414.84	3403.14	2.56	Fluid	8712.03	0.04
P-1308	CI	1	3319.89	3308.51	2.56	Fluid	8469.79	0.03
P-1309	CI	1	3306.03	3294.71	2.56	Fluid	8434.45	0.03
P-1403	CI	1	3460.66	3448.80	2.56	Fluid	8828.94	0.04
P-1601	CI	1	3477.77	3465.86	2.56	Fluid	8872.59	0.04
P-1602	CI	1	3472.46	3460.56	2.56	Fluid	8859.03	0.04
P-1604	CI	1	3440.19	3428.40	2.56	Fluid	8776.70	0.04
P-1603	CI	1	3310.04	3298.69	2.56	Fluid	8444.66	0.03
P-1605	CI	1	3312.86	3301.51	2.56	Fluid	8451.87	0.03
E-1101	CS	1	13346.94	13301.21	2.60	Fluid-Solid	34583.14	0.14
E-1102	CS	1	18415.66	18352.56	2.60	Fluid-Solid	47716.65	0.20
E-1201	CS	1	13569.78	13523.28	2.60	Fluid	35160.52	0.15
E-1301	CS	1	35575.21	35453.30	2.60	Fluid	92178.59	0.38
E-1302	CS	1	29367.63	29267.00	2.60	Fluid	76094.19	0.31
E-1303	CS	1	16429.13	16372.84	2.60	Fluid	42569.38	0.18
E-1304	CS	1	10038.03	10003.63	2.60	Fluid	26009.44	0.11
E-1305	CS	1	10384.50	10348.91	2.60	Fluid	26907.18	0.11
E-1306	CS	1	10726.02	10689.27	2.60	Fluid	27792.10	0.11
E-1307	CS	1	10355.64	10320.15	2.60	Fluid	26832.40	0.11
E-1308	CS	1	10391.82	10356.21	2.60	Fluid	26926.14	0.11
E-1401	CS	1	12295.63	12253.50	2.60	Fluid-Solid	31859.10	0.13
E-1601	CS	1	42258.82	42114.01	2.60	Fluid	109496.42	0.45
E-1602	CS	1	22239.32	22163.11	2.60	Fluid	57624.09	0.24
E-1603	CS	1	21266.99	21194.12	2.60	Fluid	55104.71	0.23
E-1604	CS	1	10429.49	10393.75	2.60	Fluid	27023.75	0.11
S-1001	CS	1	545212.02	543343.76	2.60	Fluid-Solid	1412693.78	5.83
S-1002	CS	1	27517.83	27423.54	2.15	Solid	58960.61	0.24
CONV-1001	CS	1	40250.00	40112.08	2.15	Solid	86240.97	0.36
CONV-1002	CS	1	28750.00	28651.48	2.15	Solid	61600.69	0.25
CONV-1003	CS	1	28750.00	28651.48	2.15	Solid	61600.69	0.25
CONV-1101	CS	1	34500.00	34381.78	2.15	Solid	73920.83	0.31
CONV-1401	CS	1	31625.00	31516.63	2.15	Solid	67760.76	0.28
CONV-1502	CS	1	40250.00	40112.08	2.15	Solid	86240.97	0.36
Total							**2790825.39**	**11.52**

According to Peter's Plant Design and Economics for Chemical Engineers that is used to calculate the cost of equipment, the graph of purchase cost with their respective unit size or capacity is used to find the cost at U.S.A in 2002 **(Peters et al. 2003)**.

Table C.2. *Adjusted equipment cost with lang factor at Malaysia in 2020* ***(Peters et al. 2003)****.*

Equipment tag	Material of constr.	No. of unit	Ce, Cost US 2002 (USD)	Ce, Cost MY 2020 (USD)	Lang Factor	Phase	Cost including installation	Final Cost MY 2020 (Mil. MYR)
P-1101	CI	2	550	672.46	2.56	Fluid	3443.01	0.01
P-1102	CI	1	600	733.60	2.56	Fluid	1878.01	0.01
P-1104	CI	2	1600	1956.26	2.57	Fluid-Solid	10055.16	0.04
P-1303	CI	1	550	672.46	2.56	Fluid	1721.51	0.01

P-1401	CI	1	550	672.46	2.56	Fluid	1721.51	0.01
P-1402	CI	1	680	831.41	2.56	Fluid	2128.41	0.01
P-1404	CI	2	1650	2017.39	2.57	Fluid-Solid	10369.39	0.04
P-1501	CI	1	550	672.46	2.56	Fluid	1721.51	0.01
P-1502	CI	1	1700	2078.52	2.57	Fluid-Solid	5341.81	0.02
S-1003	CS	1	33000	40347.81	2.15	Solid	86747.79	0.36
M-1101	CS	1	10080	12324.42	2.60	Fluid	32043.50	0.13
M-1102	CS	1	11700	14305.13	2.60	Fluid-Solid	37193.34	0.15
M-1301	CS	1	4280	5232.99	2.60	Fluid	13605.77	0.06
M-1401	CS	1	10780	13180.28	2.60	Fluid	34268.74	0.14
M-1402	CS	1	11780	14402.94	2.60	Fluid-Solid	37447.66	0.15
R-1101	CS	2	13820	16897.17	2.60	Fluid-Solid	87865.30	0.36
R-1201	CS	1	130500	159557.24	2.60	Fluid	414848.83	1.71
R-1501	CS	8	141000	172395.18	2.60	Fluid-Solid	3585819.76	14.80
S-1101	SS 316	1	85000	103926.17	2.78	Fluid-Solid	288914.76	1.19
S-1501	SS 316	1	85000	103926.17	2.78	Fluid-Solid	288914.76	1.19
C-1302	CS	1	137100	167626.80	2.60	Fluid	435829.69	1.80
C-1301	CS	1	192000	234750.88	2.60	Fluid	610352.30	2.52
C-1303	CS	1	116000	141828.66	2.60	Fluid	368754.51	1.52
C-1601	CS	1	107200	131069.24	2.60	Fluid	340780.03	1.41
Total							**6701767.04**	**27.66**

Therefore, the total equipment cost is calculated as **MYR 39.17 million.**

C.2 Outside Battery Limit

Table C.3. *OBL cost of each facility.*

Facilities	Percentage of FCI (%) (Peters et al. 2003)	Cost (Million MYR)
Building	7.00	5.71
Yard Improvements	2.50	2.04
Steam Generation	3.00	2.45
Steam Distribution	1.00	0.82
Air Compression and Distribution	0.20	0.16
Water Supply, Cooling, and Pumping	1.80	1.47
Water and Effluent Treatment	1.30	1.06
Water Distribution	0.80	0.65
Process Waste Disposal	0.50	0.41
Raw Material Storage	0.50	0.41
Finished-Product Storage	1.50	1.22
Electric Substation	1.30	1.06
Electric Distribution	1.00	0.82

Sanitary Waste Disposal	0.40	0.33
Communications	0.20	0.16
Fire Protection System	0.30	0.24
Safety Installations	0.20	0.16
Total	**24.00**	**19.18**

C.3 Indirect Cost

Legal expenses, construction cost, contractor fee, etc. are some examples of Indirect costs. The cost estimation is similar to OBL cost, where it is calculated using a percentage of FCI. The typical value is determined from Peter's Plant Design and Economics for Chemical Engineers **(Peters et al. 2003)**. Since the FCI is yet to be known, using the circular referencing method, FCI can be iterated accordingly. The total cost of OBL is calculated as **MYR 23.26 million,** which is shown below.

Table C.4. *Indirect cost using the percentage of FCI.*

Parameter	Percentage of FCI (Peters et al. 2003)	Cost (million MYR)
Engineering and Supervision	8.00	6.53
Legal Expenses	1.50	1.22
Construction Expenses	8.00	6.53
Contractor Fee	3.00	2.45
Contingencies	8.00	6.53
Total indirect cost (million (MYR)		**23.26**

Appendix D: Operating Cost

Product 1 (glucose) is chosen as the basis of calculation because the production rate of product 2 (furfural) follows the ratio of glucose to furfural produced in the process plant.

Table D.1. *Operating cost table.*

Product 1		Glucose		
Product 2		Furfural		
Capacity of Product 1 (tonne/year)		10000		
Capacity of Product 2 (tonne/year)		4960.64		
Total Fixed Capital (FCI) (million MYR)		81.60719615		
Product 1 Selling Price (MYR/tonne)		2140.453189		
Product 2 Selling Price (MYR/tonne)		8879.5		
Manufacturing Cost				
Raw Material	Unit Usage (Unit/ tonne Product 1)	Unit Cost (MYR/Unit)	Cost (MYR/tonne Product 1)	Annual Cost (Million MYR/year)
Empty Fruit Bunch (EFB)	3.513	50.00 **((Lo et al. 2020)**	175.63	1.76
Sulphuric Acid (70 wt%)	0.072	264.32 **(ECHEMI 2021)**	19.15	0.19
Sodium Hydroxide (50 wt%)	0.003	552.51 **(MERCK 2021)**	1.41	0.01
Butyl Chloride	0.002	333.26 **(Thermo Fisher Scientific 2021)**	0.64	0.01
Cellulase Enzyme	0.019	61600.00 **(Indiamart 2021)**	1149.01	11.49

Water	0.827	1.50 **(MIDA 2021)**	1.24	0.01
Total Raw Material Cost			**1347.08**	**13.47**
Utilities (20% Allowance)	Unit Usage (Unit/ tonne Product 1)	Unit Cost (MYR/Unit)	Cost (MYR/tonne Product 1)	Annual Cost (Million MYR/year)
Electricity	168.24	0.34 **(Nasional 2021)**	56.70	0.57
Low Pressure Steam	0.71	73.50	52.40	0.52
Medium Pressure Steam	1.48	75.58	112.17	1.12
Hot Water	0.28	3.73	1.04	0.01
Cooling Water	68.76	1.50 **(MIDA 2021)**	103.14	1.03
Total Utilities Cost			**325.43**	**3.25**
Total Variable Cost			**1672.52**	**16.73**
Process Labor	Number	Salary/year (MYR)	Cost (MYR/tonne Product 1)	Annual Cost (Million MYR/year)
Operators	10	20090 **(Malaysia Indeed 2021)**	2.01	0.02
Shifts per day	4	-	-	-
Total Shift Operators (SO)	40	803600	80.36	0.80
Supervisory & Clerical Labor	15% SO Salary		12.05	0.12
Total Process Labor Wage (PL)			**92.41**	**0.92**
Maintenance Cost (MC)	7% of FCI		571.25	5.71
Operating Supplies	15% of MC		85.69	0.86
Plant Overheads	10% of TMC		449.63	4.50
Property Insurance	1% FCI		81.61	0.82
Financing Interest	5% of FCI		408.04	4.08
Book Depreciation	13.91% of FCI		1135.16	11.35
Total Capital Related Cost (CR) (Peters et al. 2003)			2733.37	2731.37
Total Fixed Cost (PL + CR)			2825.78	2823.78
Total Manufacturing Cost (TMC)		Fixed	2823.78	28.24
		Variable	1672.52	16.73
		Total	**4496.30**	**44.96**
Non-Manufacturing Cost **(Peters et al. 2003)**				
Administration	20% of SO		16.07	0.16
Research and Development	2% of TMC		89.93	0.90
Distributing and Marketing	2% of TMC		89.93	0.90
Total Non-Manufacturing Cost (TNMC)			**195.92**	**1.96**
Total Operating Cost (TNMC + TMC)			**4692.22**	**46.92**

Appendix E: Working Capital

Table E.1. *Working capital table.*

Product 1	Glucose			
Product 2	Furfural			
Process Routes	Enzymatic Hydrolysis of cellulose (1) and Dehydration of xylose (2)			
Capacity of Product 1 (tonne/year)	10000			
Capacity of Product 2 (tonne/year)	4960.642			
Capacity Utilization (%)	100			
Raw Material Inventory				
Item	Inventory (weeks)	Amount	Unit Cost	Value (MYR)

Empty Fruit Bunch (EFB)	3	2235.29	tonnes	50.00 **(Lo et al. 2020)**	MYR/tonne	111764.46
Sulphuric Acid (70 wt%)	3	46.10	tonnes	264.32 **(ECHEMI 2021)**	MYR/tonne	12184.63
Sodium Hydroxide (50 wt%)	3	1.63	tonnes	552.51 **(MERCK 2021)**	MYR/tonne	898.26
Butyl Chloride	3	1.23	tonnes	333.26 **(Thermo Fisher Scientific 2021)**	MYR/tonne	410.42
Cellulase Enzyme	3	11.87	tonnes	61600.00 **(Indiamart 2021)**	MYR/tonne	731187.11
Water	1	175.41	tonnes	1.50 **(MIDA 2021)**	MYR/tonne	263.12
Total Raw Material Inventory Value (Million MYR)						**0.86**
Product Inventory						
Item	Inventory (weeks)	Amount		Unit Cost		Value (MYR)
Glucose (96.67 wt%)	3	636.36	tonnes	2140.45 **(UN Data 2018)**	MYR/tonne	1362106.57
Furfural (99.54 wt%)	3	315.68	tonnes	8879.50 **(Krishna et al. 2018)**	MYR/tonne	2803055.76
Total Finished Product Inventory Value (Million MYR)						**4.17**
Account Receivable						
Item	Inventory (weeks)	Amount		Unit Cost		Value (MYR)
Glucose (96.67 wt%)	6	1272.73	tonnes	2140.45 **(UN Data 2018)**	MYR/tonne	2724213.15
Furfural (99.54 wt%)	6	631.35	tonnes	8879.50 **(Krishna et al. 2018)**	MYR/tonne	5606111.51
Total Debtor Amount (Million MYR)						**8.33**
Account Payable						
Item	Inventory (weeks)	Amount		Unit Cost		Value (MYR)
Feedstock						
Empty Fruit Bunch (EFB)	6	4470.58	tonnes	50.00 **(Lo et al. 2020)**	MYR/tonne	223528.91
Sulphuric Acid (70 wt%)	6	92.20	tonnes	264.32 **(ECHEMI 2021)**	MYR/tonne	24369.27
Sodium Hydroxide (50 wt%)	6	3.25	tonnes	552.51 **(MERCK 2021)**	MYR/tonne	1796.52
Butyl Chloride	6	2.46	tonnes	333.26 **(Thermo Fisher Scientific 2021)**	MYR/tonne	820.85
Cellulase Enzyme	6	23.74	tonnes	61600.00 **(Indiamart 2021)**	MYR/tonne	1462374.21

Water	6	1052.49	tonnes	1.50 **(MIDA 2021)**	MYR/tonne	1578.73
Utilities						
Electricity	6	178432.76	kWh/h	0.34 **(Nasional 2021)**	MYR/kWh	60131.84
Low Pressure Steam	6	756.09	tonnes	73.50	MYR/tonne	55572.56
Medium Pressure Steam	6	1574.04	tonnes	75.58	MYR/tonne	118965.79
Hot Water	6	294.39	tonnes	3.73	MYR/tonne	1098.06
Cooling Water	6	72925.45	tonnes	1.50 **(MIDA 2021)**	MYR/tonne	109388.18
Total Creditor Amount (Million MYR)						**2.06**
Total Working Capital (Million MYR)						**11.29**

Appendix F: Cumulative Cash Flow

F.1 Tax Depreciation Allowance

The declining balance method is used to compute tax depreciation allowance, with a residual value equal to 5% of the initial investment that is returned at the end of this project. The tax depreciation rate can be calculated as **13.91%**

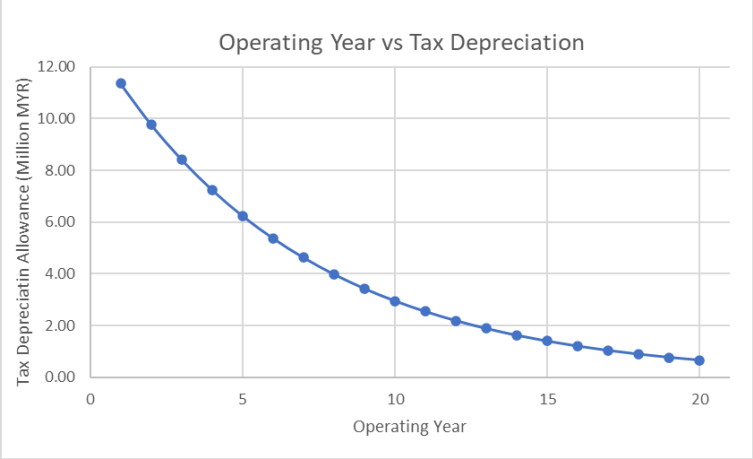


Fig. F.1. *Graph of the operating year against tax depreciation allowance.*

F.2 Cash Flow Table

For the first two years of construction, it is assumed that the fixed capital investment (FCI) is divided equally. In the first year, the plant is assumed to produce 70% of its nominal capacity, followed by 85% and 100% from the third operating year until its lifetime. As the plant runs at 70% of its capacity in the first operating year, it is assumed that 70% of the total working capital is used in that year, and 15% of total working capital is shared equally in the following years as the growth rate in production is linear. At the end of the project, it is anticipated that the total working capital will be recovered.

The declining balance method is used to compute tax depreciation allowance, with a 5% residual value that is recoverable at the end of this project. The fixed capital begins to depreciate at a rate of **13.91%.** Tax payment is not required in the operating year where the tax depreciation allowance exceeds the

cash flow before tax. So, the extra tax depreciation allowance can be pushed forward to the following year as a carried forward allowance from the previous year. In Malaysia, corporate tax is paid at the end of each year (final month). A company with a fixed capital of more than 2.5 million pays a corporate tax of 24%, which has remained consistent from 2016 to 2020 **(LHDN Malaysia 2020)**. Malaysia's inflation rate is forecasted to be at around 2% in 2022, but the minor impact of inflation during the lifetime of operation of the plant is estimated to be negligible **(Trading Economics 2021)**.

Table F.1. *Cumulative cash flow table of glucose and furfural production plant from EFB, operating for 20 years.*

Year		**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**
Year of Operation		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Fixed Capital Cost	Million MYR	0.00	-40.80	-40.80																					4.08
Working Capital Cost	Million MYR			-7.90	-1.69	-1.69																			11.29
Sales Volume 1	tonne/ year				7000	8500	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	
Sales Volume 2	tonne/ year				3472.4	4216.5	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	4960.6	
Sales Revenue 1	Million MYR				14.98	18.19	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	
Sales Revenue 2	Million MYR				30.83	37.44	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	44.05	
Total Variable Cost	Million MYR				-11.71	-14.22	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	-16.73	
Total Fixed Cost	Million MYR				-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	-28.24	
Cash Flow Before Tax	**Million MYR**	**0.00**	**-40.80**	**-48.71**	**5.87**	**13.18**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**20.49**	**15.37**
Tax Depreciation Allowance	Million MYR				11.35	9.77	8.41	7.24	6.24	5.37	4.62	3.98	3.43	2.95	2.54	2.19	1.88	1.62	1.39	1.20	1.03	0.89	0.77	0.66	
Carry forward Allowance	Million MYR				5.48	2.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Taxable Income	Million MYR				0.00	0.00	10.00	13.25	14.25	15.12	15.87	16.51	17.06	17.54	17.95	18.30	18.61	18.87	19.10	19.29	19.46	19.60	19.72	19.83	
Tax Payment	Million MYR				0.00	0.00	-2.40	-3.18	-3.42	-3.63	-3.81	-3.96	-4.10	-4.21	-4.31	-4.39	-4.47	-4.53	-4.58	-4.63	-4.67	-4.70	-4.73	-4.76	
Cash Flow After Tax	Million MYR		-40.80	-48.71	4.18	11.49	18.09	17.31	17.07	16.86	16.68	16.53	16.39	16.28	16.18	16.10	16.02	15.96	15.91	15.86	15.82	15.79	15.76	15.73	15.37
Cumulative Cash Flow After Tax	**Million MYR**	**0.00**	**-40.80**	**-89.51**	**-85.33**	**-73.85**	**-55.76**	**-38.45**	**-21.38**	**-4.52**	**12.16**	**28.69**	**45.08**	**61.36**	**77.54**	**93.64**	**109.66**	**125.62**	**141.53**	**157.39**	**173.21**	**189.00**	**204.75**	**220.48**	**235.86**

Appendix G: Net Present Value

As highlighted in green in Table G.1, the internal return rate (IRR) can be calculated by fixing the net present value (NPV) to the value of zero, which gives a discount rate of **14.25%**.

Table G.1. *Discounted cash flowrate after tax with a various discounted rates and IRR.*

Year	Year of operation	Discounted cash flow after tax at various discount rate (million MYR)					
		0	**0.05**	**0.10**	**0.1425**	**0.20**	**0.30**
0	-	0.00	0.00	0.00	0.00	0.00	0.00
1	-	-40.80	-40.80	-40.80	-40.80	-40.80	-40.80
2	-	-48.71	-46.39	-44.28	-42.64	-40.59	-37.47
3	1	4.18	3.79	3.45	3.20	2.90	2.47
4	2	11.49	9.92	8.63	7.70	6.65	5.23
5	3	18.09	14.88	12.36	10.62	8.72	6.33
6	4	17.31	13.56	10.75	8.89	6.96	4.66
7	5	17.07	12.74	9.63	7.68	5.72	3.54
8	6	16.86	11.98	8.65	6.64	4.71	2.69
9	7	16.68	11.29	7.78	5.75	3.88	2.04
10	8	16.53	10.65	7.01	4.98	3.20	1.56
11	9	16.39	10.06	6.32	4.33	2.65	1.19
12	10	16.28	9.52	5.71	3.76	2.19	0.91
13	11	16.18	9.01	5.16	3.27	1.81	0.69
14	12	16.10	8.54	4.66	2.85	1.50	0.53
15	13	16.02	8.09	4.22	2.48	1.25	0.41
16	14	15.96	7.68	3.82	2.17	1.04	0.31
17	15	15.91	7.29	3.46	1.89	0.86	0.24
18	16	15.86	6.92	3.14	1.65	0.71	0.18
19	17	15.82	6.57	2.85	1.44	0.59	0.14
20	18	15.79	6.25	2.58	1.26	0.49	0.11
21	19	15.76	5.94	2.34	1.10	0.41	0.08
22	20	15.73	5.65	2.13	0.96	0.34	0.06
23	-	15.37	5.26	1.89	0.82	0.28	0.05
Total	**-**	**235.86**	**98.39**	**31.45**	**0.00**	**-24.52**	**-44.84**

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