

Manufacture of Furfural from Sugarcane Bagasse

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ABSTRACT

Furfural is a renewable, non petroleum based and chemical feedstock. Furfural has been identified as one of most promising chemicals directly derived from biomass and a variety of agricultural by-products, such as bagasse, corn-cobs, wheat bran. Furfural has several applications such as antacids, fertilizers, plastics, fungicides, nematicides and adhesives. It could be a great alternative for organic compounds once petroleum resources start to dry up. Furfural may be obtained by acid catalysed dehydration of pentoses particularly xylose often found in hemicellulose fraction of biomass. This paper covers about the various technologies available for the industrial production of furfural and the manufacturing process used by us for furfural production from sugarcane bagasse with major emphasis on the yield of product, raw material inputs and their prices, plant size and capital investment, and product quality.

Keywords– xylose, catalytic dehydration, distillation, mass balance, cost estimation

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I. INTRODUCTION

The use of renewable sources for production of chemicals, biofuels, materials and energy has each time kept on becoming larger due to environmental, political and economical problems of non-renewable energies utilization. The renewability and abundance of lignocellulosic biomass such as bagasse, corncobs make it a viable resource for the production of platform chemicals such as furfural.

In this study, we have reviewed the various process technologies which have been utilized for producing furfural at industrial and laboratory scales and have selected the process technology which is the most efficient and developed a process as per modern world's requirements for the furfural production capacity of 900 MT/year by performing calculations for material and energy balance along with cost estimation of setting up the complete furfural plant and determining the payback period for the same. We have also cited the requirements for site selection and prepared a schematic plant layout.

II. FURFURAL- AN ORGANIC CHEMICAL

Furfural was first discovered in 1821 by the German chemist Johann Wolfgang Dobereiner, who produced a small sample as a by-product of formic acid synthesis by the distillation of dead ants. In 1840, the Scottish chemist John Stenhouse found that the same chemical could be produced by distilling a wide variety of crop materials, including corn, oats, bran, and sawdust, with aqueous sulphuric acid, etc.

2.1 Structure of Furfural

Furfural is an organic compound which consists of a furan ring with an aldehyde side group.

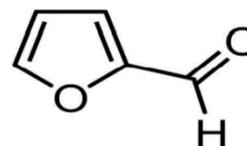


Figure 1: Schematic representation of furfural

2.2 Uses of Furfural

i. Furfural can undergo hydrogenation reaction to give furfuryl alcohol which is used in the manufacturing of adhesives, castings and coatings

- ii. Wetting agent in manufacture of abrasive wheels and brake linings.
- iii. Used in the refining of lubricating oils and vegetable oils as an extraction agent.
- iv. As a decolourizing agent to refine crude wood resin.
- v. Used as a preservative in foods and low calorie sweetener.
- vi. It is used to make various other furan chemicals like furan, tetrahydrofuran and furoic Acid.

2.3 Reactions of Furfural

Furfural undergoes a wide range of reactions such as hydrogenation, oxidation and decarboxylation to produce many chemicals which have a wide range of uses.

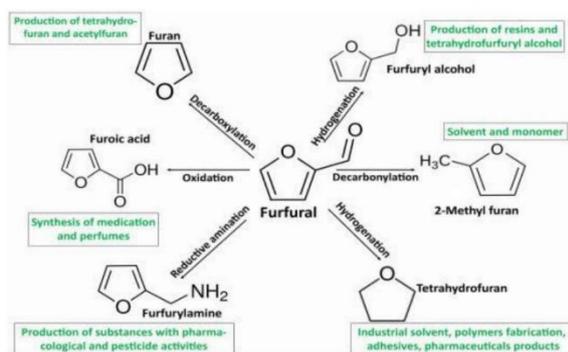


Figure 2: Schematic diagram of Furfural reactions to produce various chemicals

III. Literature Survey

1. Marlen Morales (Simulation of Furfural Production Process for Revamping with Ethanol Technology from Lignocellulosic Residuals - 2010) :The objective of this study was to carry out the simulation of the furfural production process for revamping ethanol technology of lignocellulosic residuals using the ASPENPLUS software

2. Grazielle Machado (Literature Review on Furfural Production from Lignocellulosic Biomass - 2016) : This article performs a review about mechanisms of furfural production from lignocellulosic biomass, highlighting its chemical properties which enable its utilization in different industrial applications of economic interest. This article performs a review about mechanisms of

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3. Bianca Barbosa (Preliminary Studies on Furfural Production From Lignocellulosics - 2014) :This study focused on the production of furfural from agricultural and industrial biomass residues by a hydro distillation process

4. Pedram Fatehi (Production of Furfural: Overview and Challenges - 2012): In this study, various processes developed for producing furfural at industrial and laboratory scales along with their advantages and disadvantages are to be reviewed

IV. Process Technology Selection for Furfural Production

4.1 Processing Technologies for Furfural Manufacture

Both batch and continuous processing methods are used for furfural, but batch processing is mostly used nowadays. Previous manufacturers of the plant for the continuous process include Defibrator and Rosenlew (Sweden and Finland), Societa Italiana Furfurola (Italy), and Escher Wyss (Germany), but these manufacturers now have either stopped production or scaled back. Batch plants are available from China and possibly South Africa. The option to engage in further processing of the lignocellulose residue or use it as an energy source for the initial furfural process is available in both methods. In each of the methods there is different emphasis on the yield and recovery of co-products, raw material inputs and their prices, plant size and capital investment, and product quality.

i) Quaker Oats Technology: The first furfural production plant was a batch process originally developed by Quaker Oats Technology in the 1920s in the United States. One of the earliest patents on furfural was that of Isenhour taken out in 1932 and assigned to The Quaker Oats Company (US Patent Office). In this process, biomass was treated with acid (2.2 wt.% (OD of biomass) aqueous sulphuric or phosphoric acid) and steam at 153°C in a hydrolysis step which could convert the pentosans in the biomass to pentoses. The generated pentoses were then converted (i.e., cyclo-dehydrated) into

furfural in a subsequent stage, and then furfural was recovered by steam stripping from solution.

ii) Huaxia Technology: A subsidiary of Westpro Company in California, is using a variation (continuous process) of the Quaker Oats technology to produce furfural in China. This method uses fixed-bed reactors and a continuous dynamic azeotropic distillation refining process, which led to 4%–12% production yield with respect to the initial weight of dry biomass used (i.e., corn cobs, rice hulls, ax dregs, cotton hulls, sugarcane bagasse, and wood).

iii) SupraYield Technology: This process is another modification of the Quaker Oats Technology process introduced in the late 1990s. SupraYield was developed from patented technology owned by Karl Zeitsch, a pioneer in furfural technology, and it has been taken up by a South African group. In this technology, sugarcane bagasse is hydrolysed in one stage, and then pentoses are converted into furfural in aqueous solution at its boiling point (with or without phosphoric acid). The solution containing furfural is then adiabatically flash distilled, which facilitates the transfer of the furfural formed from the aqueous phase to the vapour phase.

iv) Supratherm Process: The Supratherm process developed by KRUPP is a continuous hydrolysis where by using a high temperature between 200 and 240 °C the reactor is reduced to a simple pipe. Contrary to conventional processing, the furfural vapor obtained is entirely free of particles, so that encrustation problems, a well-known plague of orthodox furfural plants, are reliably avoided.

v) University of Melbourne's process for recovery of furfural and phenols: The University of Melbourne's patent (held jointly with B. Hermessec) for recovering low molecular weight phenols, furfural, Furfural alcohol and cellulose-rich residues involves less chemical input than the other technologies. Although similar intent exists in terms of producing chemicals and energy from renewable raw materials, this process is driven thermochemically under oxidative conditions. The fluidised bed pyrolysis reactor used here has smaller feedstock particle sizes and claims relatively low energy requirements. The process seems to make full

use of all residues. The main outputs are furfuryl alcohol and phenols.

4.2 Process selected in our project for Furfural manufacturing

We have used the Supratherm Process for furfural manufacturing. As compared to conventional furfural plants, the SUPRATHERM process has the following advantages:

- i) A truly continuous mode of operation devoid of gate problems.
- ii) A shorter residence time which permits an extremely small reactor volume.
- iii) A high reaction temperature which reduces both resinification and condensation losses, thereby increasing the yield.
- iv) A high concentration of furfural in the product vapor.
- v) A product vapor absolutely free of particles, thus avoiding encrustation problems.
- vi) Outstanding simplicity. Startup within seconds.

4.3 Reasons for not selecting other Processes

- i) Quaker Oats technology is not preferred because the draw-backs of this process were low yield (less than 50% based on mono-sugars), substantial steam requirement, high effluent production, (i.e., very acidic wastes), and high operating cost. This led to the closure of plants in developed countries in the 1990s. The rather low yield of this process was attributed to the fact that the first step (hydrolysis) was 50 times faster than the second step (dehydration).
- ii) There are other problems, including high steam costs producing valuable co-products such as bio-ethanol, and yield recovery limits of 55 per cent (often less than 35 per cent in practice) due to secondary reactions.
- ii) SupraYield technology is still at concept stage and the process has been tested only on a laboratory scale.

iii) The output of the Huaxia Technology which is a variation of Quaker Oats Technology is not quite as high as Supratherm, and further not enough information is available with regard to this technology

iv) The University of Melbourne’s technology however appears to be at a very early stage, little beyond research and facing investment in product development and a pilot plant for testing before it goes any further. The University of Melbourne’s technology is still at its concept stage.

IV. Process Description and Process Flow Diagram for Furfural Manufacture

The process preferred universally involves manufacture of Furfural from agricultural raw material rich in xylose. Chopped bagasse is fed into a mixing tank where it is mixed with highly diluted sulfuric acid to yield a flowable slurry. From this tank, the flowable slurry stream is withdrawn by an eccentric worm pump and delivered to a jacketed batch reactor. High pressure steam is passed through the jacket to heat the pulp to 2300C thus rapidly effecting the conversion of xylose to furfural. The reacted pulp is passed through a cooler and a pressure control valve before it enters a cyclone separator. In the cyclone separator, operated at reduced pressure, the reacted pulp is separated into a top fraction rich in furfural and an underflow representing the residual slurry. Due to the sudden decompression in the valve, furfural formed in the particles is released explosively by azeotropic cavitation. The high reaction temperature greatly reduces losses by both resinification and condensation, thus leading to a substantially increased concentration of furfural

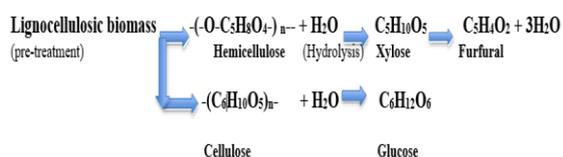


Figure 3: Process reaction indicating the synthesis of furfural from hemicellulose

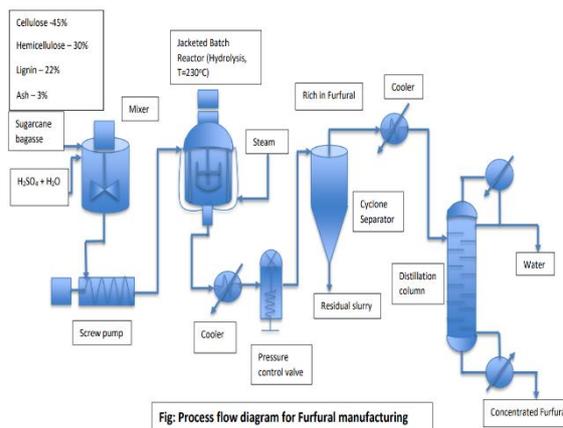


Figure 4: Simplified process flow block diagram for furfural manufacture

V. Material Balance For Furfural Production

Compositions of Feed Streams by mass

Table 1: Composition of bagasse

Cellulose	45%
Hemi-Cellulose	30%
Lignin	22%
Ash	3%

Basis, 180kg/h of furfural obtained as final product

% furfural lost in residual slurry = $(1/9) * 200 = 20\text{kg/h}$
 Composition of product stream: 90% furfural and 10% water
 Amount of water in final stream = $(10/100) * 180 = 18\text{kg/h}$

Conversion of Xylose to Furfural %
 conversion of xylose to furfural is considered to be 80%
 150.13g of xylose produces 96g of furfural & X kg of xylose produces 200kg/h kg of furfural

$$X = (150.13 * 200) / (96 * 0.8) = 391.53 \text{ kg/h}$$

Assume % Conversion of Hemicellulose to Xylose be 90%
 132g of hemicellulose produces 150.13g of xylose
 Y kg of hemicellulose produces 391.53 kg of xylose

$$Y = (132 * 391) / (150.13 * 0.9) = 382.5 \text{ kg/h}$$

Sugarcane bagasse has 30% content of hemicellulose
 Initial feed of bagasse required = $382.5 / 0.3 = 1275$
 kg/h Cellulose content in bagasse feed = $0.45 * 1275 =$
 573.75 kg/h Lignin content in bagasse feed =
 $0.22 * 1275 = 280.5$ kg/h

Ash content in bagasse feed = $1275 - (382.5 +$
 $573.75 + 280.5) = 38.25$ kg/h

Feed stream of 1000 kg/h of highly dilute sulphuric
 acid

Amount of water = $0.97 * 1000 = 970$ kg/hr

Inlet		Outlet	
Component	Mass(kg/h)	Component	Mass(kg/h)
Ash	38.25	Ash	38.25
lignin	280.50	lignin	280.50
Hemi-cellulose	382.50	hemicellulose	382.50
cellulose	573.75	cellulose	573.75
water	970	water	970
Sulphuric acid	30	Sulphuric acid	30

Amount of sulphuric acid = $0.03 * 1000 = 30$ kg/hr

Mixing tank

Bagasse stream & sulphuric acid stream mix and
 form a slurry without any reaction

Material balance around mixer

Total flow rate of outlet stream from mixer = $1000 +$
 $1275 = 2275$ kg/hr No chemical Reaction takes place
 here. Only Physical Mixing.

Table 2: Inlet and outlet composition in mixing tank

Reactor

Pressurized superheated steam is passed through
 slurry to obtain reaction temperature of 230°C

Assume % conversion of cellulose to glucose be
 90% 162.1406 g of cellulose produces 180.156 g of
 glucose ($0.9 * 573.75 = 516.375$) kg/h of cellulose
 produces 573.75 kg of glucose Amount of glucose
 produced = 573.75 kg/h

Amount of cellulose unreacted = 57.375 kg/h

382.5 kg/h of hemicellulose produces 391.53 kg/h of
 xylose Amount of xylose produced = 391.53 kg/h

Amount of hemicellulose unreacted = $0.1 * 382.5 =$
 38.25 kg/h Amount of xylose reacted to produce
 furfural = $0.8 * 391.5 = 312.8$ kg/h Amount of xylose
 unreacted = 78.33 kg/h

	Inlet	Outlet
Component	Mass(kg)	Mass(kg)
Ash	38.25	38.25
lignin	280.50	280.50
hemicellulose	382.50	38.25
cellulose	573.75	57.375
water	970	978.545
Sulphuric acid	30	30
xylose	0	78.33
furfural	0	200
glucose	0	573.75

56g of
 water is produced during 96g furfural formation
 Y kg of water is produced during 200kg furfural
 formation

$Y = 200 * (56/94) = 112.8$ kg/h of water

Table 3: Composition of inlet and outlet stream
 across reactor

Cyclone separator

Due to sudden compression in the valve, furfural
 particles are released explosively by azeotropic
 cavitation, due to which a sizeable portion of
 furfural is obtained as top product as particulate
 furfural and the separation is much better than other
 methods like conventional processes like transport
 by diffusion

Table 4: Composition of inlet and outlet stream

Component	Massflowrate (kg/h)	Cp(kJ/kgK)	ΔT(K)	Q=mCpΔT (kJ/h)
Hemicellulose	38.25	0.91	100	3480.75
Cellulose	57.375	1.5	100	8606.25
Water	978.54	4.19	100	410010.355
Xylose	78.33	1.1	100	8616.30
Furfural	200	1.68	100	33750
Glucose	573.75	1.24	100	71374.50
				Qout=535838

Distillation Column

Top Stream coming out of the cyclone separator enters and undergoes distillation producing two streams Top and bottom Bottom Stream Amount of furfural = 180 kg/h Amount of water = 20 kg/h Top Stream Amount of water vapour = 475.26 – 20 = 455.26 kg/h

Table 5: Composition of inlet and outlet stream across distillation column

	Inlet	Distillate	Residue
Component	Mass(kg)	Mass(kg)	Mass(kg)
water	475.26	20	455.26
furfural	180	180	0

VI. Energy Balance For Furfural Production

Component	Massflowrate	Cp (kJ/kg K)	DeltaT(K)	Q=mCpΔT (kJ/h)
Cellulose	573.75	1.5	205	176428.12
Hemicellulose	382.50	0.91	205	71355.375
Water	970	4.19	205	833181.50
				Qin=1080965 kJ

Flow Reactor

	Inlet	Particulate(TopOutlet)	residual slurry outlet
Component	Mass(kg)	Mass(kg)	Mass(kg)
Ash	38.25	0	38.25
lignin	280.50	0	280.50
hemicellulose	38.25	0	38.25
cellulose	57.375	0	57.375
water	978.545	475.26	523.285
Sulphuricacid	30	0	30
xylose	78.33	0	78.33
furfural	200	180	20
glucose	573.75	0	573.75

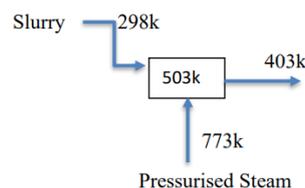


Figure : Temperature of slurry and pressurized steam across reactor

Reactor inlet at ΔT=205K

Reactor outlet at ΔT=100K

- ΔHf of hemicellulose = -1640 kJ/mol
- ΔHf of cellulose = -1640 kJ/mol = -265910 kJ/kg
- ΔHf of lignin = -21.13 MJ/kg
- ΔHf glucose = -1273.80 kJ/mol = -229392.6 kJ/kg
- ΔHf of water = -285.8 kJ/mol = -5144.4 kJ/kg
- ΔHf of xylose = -1054.5 kJ/mol = -158312.1 kJ/kg
- ΔHf of furfural = -200.2 kJ/mol = -19219.2 kJ/kg



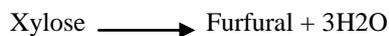
Heat of reaction (ΔHR)298°C
 = Σ ΔHf products - Σ ΔHf reactants
 = -229392.634 - (-265910-5144.4)
 = 41662.1 kJ/kg * 750 = 3124.6575 MJ/h



$$(\Delta HR_2) = \sum \Delta H_f \text{ products} - \sum \Delta H_f \text{ reactants}$$

$$= -158312.085 - (-213867.6 - 5144.4)$$

$$= 130699.915 \text{ kJ/kg} * 391 = 5110.367 \text{ MJ/h}$$



$$(\Delta HR_3) = \sum H_f \text{ products} - \sum H_f \text{ reactants}$$

$$= -19219.2 - 3 * 5144.4 - (-158312.085)$$

$$= 123659.655 \text{ kJ/kg} * 391 = 4835.09 \text{ MJ/h}$$

$$C_{p \text{ avg}} = \sum \Delta H_f x_i C_{p_i} = 0.0587 * 1.5 +$$

Component	Massflowrate	C _p	ΔT	Q=mC _p ΔT(kJ/h)
Water	473.2	4.2	65	128892.36
Furfural	180	1.7	65	19743.75
				Q _{in} =148636.1

$$0.048 * 0.048 * 0.91 + 0.893 * 4.19$$

$$X_1 = 0.0587,$$

$$\text{Cellulose} = 573.75 \text{ kg/h} = 3.538 \text{ kmol/h}$$

$$X_2 = 0.048,$$

$$\text{Hemicellulose} = 382.5 \text{ kg/h} = 2.8977 \text{ kmol/h}$$

$$X_3 = 0.893, \text{Water} = 970 \text{ kg/h} = 970/18 = 53.888 \text{ kmol/h}$$

$$\Delta H_2 = m C_{p \text{ avg}} \Delta T$$

$$= 1926 * 3.8734 * (298 - 503) = -1529533 \text{ kJ/h}$$

Mole fraction

$$0.048 \text{ Hemicellulose} = 38.25/132 = 0.289 \text{ kmol/h}$$

$$0.0058 \text{ Cellulose} = 57.375/162.1406 = 0.354 \text{ kmol/h}$$

$$0.8941 \text{ Water} = 978.545/18 = 54.36361 \text{ kmol/h}$$

$$0.0086 \text{ Xylose} = 78.33/150.18 = 0.521748 \text{ kmol/h}$$

$$0.0343 \text{ Furfural} = 200/96 = 2.0833 \text{ kmol/h}$$

$$0.0524 \text{ Glucose} = 573.75/180 = 3.1875 \text{ kmol/h}$$

$$C_{p \text{ avg}} = 3.78 \text{ kJ/kgK}$$

$$\Delta H_3 = 1926.25 * 3.78 * (573 - 298) =$$

$$1492631.753 \text{ kJ/kgK}$$

$$\Delta H \text{ (Heat of reaction)} = \Delta H_1 + \Delta H_2 + \Delta H_3 = -23833 \text{ kJ/h}$$

Heat

Balance

$$\text{Heat of reactant} + \text{Heat supplied} = \text{Heat of reaction}$$

$$+ \text{Heat products} - \text{Heat of reactants} = 1080965 \text{ kJ/h}$$

$$\text{Heat of products} = 535838.155 \text{ kJ/h}$$

$$\text{Heat of reaction} = -23833 \text{ kJ/h}$$

$$\text{Heat supplied} = \text{Heat of rxn} + \text{Heat of product} - \text{Heat of reactants} = -23833 + 535838.155$$

$$- 1080965 = 568960 \text{ kJ/h}$$

$$\text{Amount of steam required for providing heat, } Q = m C_p \Delta T$$

$$568960 = m * 1.996 * (773 - 523)$$

$$m = 1140 \text{ kg/h}$$

Amount of steam required

Distillation column

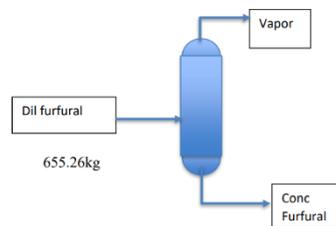


Figure 4: Separation across distillation column

Heat In

Heat Out

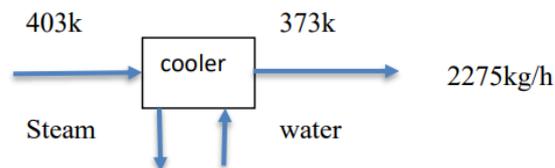
i) Distillate

Component	Massflowrate	C _p	ΔT	Q=mC _p ΔT(kJ/h)
Water	453.26	4.2	102	193714.25

ii) Residue

Component	Massflowrate	C _p	ΔT	Q=mC _p ΔT(kJ/h)
Water	20	4.2	105	799
Furfural	180	1.7	105	31893.75
				Q _{out} =234407

Cooler



$$Q = m C_p \Delta T = m \lambda$$

$$2275 * 3.87 * (403 - 373) = m * 2260 + m * 4.186 * 100 -$$

$$5) m = 99.383 = 100 \text{ kg/h}$$

$$\text{Mass flow rate of water required} = 100 \text{ kg/h}$$

Heat balance around reboiler

$$\text{Heat around reboiler} = \text{Heat removed in condenser} + \text{Heat with distillate} +$$

$$\text{Heat with residue} - \text{Heat with feed} = 3594404 +$$

$$193174 + 234407 - 148636.11$$

$$\text{Heat supplied using reboiler} = 4007119 \text{ kJ/h}$$

$$\text{Let the amount of coolant (chilled water) required in condenser be } m_{wqc} =$$

$mC_p\Delta T = 3594404 = m_w * 4.186 * (100 - 5) * 103$
 $m_w = (3594404 / (4.186 * 95 * 103)) = 9.0386 = 10$ kg/h
 Amount of heating media required in reboiler be $m_o C_p = 1.67$ kJ/kgK, $T_i = 200^\circ\text{C}$, $T_f = 130^\circ\text{C}$
 $Q = mC_p\Delta T = 4007119 = m_o * 1.67 * 103 * (200 - 130)$
 $m_o = 34.278$ kg/h = 35 kg/h
 Total amount of chilled water required = 110 kg/h
 Total amount of steam required = 1175 kg/h

VII. Cost Estimation

Cost of equipments involved in the plant:

Jackted Reactor	Rs 3,50,000
Mixing Tank	Rs 1,00,000
Pump	Rs 30,000
Steam Boiler	Rs 2,00,000
Cooler	Rs 70,000
Cyclone separator	Rs 75,000

Sr.No.	Capital Investment		Cost (in Rs.)
1	Delivery equipment cost	E	14,10,500
2	Installation	0.45E	6,34,725
3	Instrumentation and control	0.26E	3,66,730
4	Piping	0.45E	6,34,725
5	Electrical	0.2E	2,82,100
6	Insulation	0.05E	70,525
7	Building	0.4E	5,64,200
8	Yard improvement	0.1E	1,41,050
9	Service facilities	0.65E	9,16,825
10	Land	1.6E	22,56,800

Distillation Column	Rs 1,50,000
Condenser	Rs 60,000
Reboiler	Rs 50,000
Total	Rs 10,85,000

11	Total direct plant cost		7677880
12	Engineering & supervision	0.33E	4,65,465
13	Construction	0.80E	11,28,400
14	Total direct and indirect plant cost		92,71,745
15	Contractor's fee	0.7E	9,87,350
16	Contingency	0.38E	5,35,990
17	Fixed capital investment (FCI)		1,07,95,085
18	Working capital investment (20% FCI)		21,59,017
19	Total capital investment (TCI)		1,29,54,012

Delivered equipment cost is 1.3 times total equipment cost = $1.3 * 10,85,000 = 14,10,500$

Raw materials	Annual Requirement (in kg)	Cost (per kg)	Total cost per annum (in Rs)
Sugarcane bagasse	1,10,16,000	3.5	3,85,56,000
Dilute H ₂ SO ₄	2,59,200 kg H ₂ SO ₄	35	90,72,000
	83,80,800 kg H ₂ O	0.16	13,40,928
Total product cost (TPC)			4,89,68,928

i) Staff and labour charges (SLC) = 5% of TPC = Rs 24,48,447
 ii) Plant overhead cost = 20% of SLC = Rs 4,89,690
 iii) Maintenance and repair (M&R) = 5% of TCI = Rs 6,47,700
 iv) Operation and supply (OS) = 20% of M&R = Rs 1,29,541
 v) Laboratory and R&D charges = 25% of M&R = Rs 1,61,925
 vi) Patent royalties = 3% of TPC = Rs 14,69,068
 Patent royalties need to be provided for the use of Suprayield Technology used in our furfural manufacturing process which is developed by International Furan technology and now owned by PSM Biorefinery

vii)

Utilities	Consumption (in kg)	Cost(per kg)	Annualcost(Rs)
Coolingwater	110	0.016	13940
Steam	1175	0.12	14,88,960
Totalutilitycost			15,02,900

Direct production cost (DPC)
 = a + b + c + d + e + f + g = Rs 68,49,271

Local cost = 2% FCI = Rs 2,15,902

Insurance = 1% FCI = Rs 1,07,951 per year

Depreciation cost (Straight line depreciation) =
 10% of TEC= Rs 1,41,050

Total fixed charges
 = depreciation + local cost + insurance
 = 1,41,050 + 2,15,092 + 1,07,951
 = Rs. 4,64,093 per year

Total production cost = TPC + DPC + fixed charges
 = Rs 5,62,82,292

Sales

Product	Quantity/yr(kg)	Rate/ kg	Sales(inRs.)
Furfural	9,00,000	73	6,57,00,000

Gross Profit = total sales – total production cost =
 6,57,00,000 – 5,62,82,292 = Rs 94,17,708
 Income tax = 33% of gross profit = Rs 31,07,844
 Net Profit after tax reduction = 94,17,708 – 31,07,844 = Rs 63,09,864
 Payback period calculation = TCI / net profit = 2.053 years
Annual Production of Furfural = 900MT/year

VIII. Plant Site Selection & Layout

[1] The selection of ideal location for the plant site such that the overall cost of production is lowest and there is maximization of profits.

[2] Choice of the plant site should be made on basis of complete analysis of advantage and disadvantage of location chosen.

[3] The plant must be located somewhere near and be easily accessible to the sources of raw materials. The source of raw material is one of the most important factors affecting the choice of plant site.

[4] The climatic conditions in the area should be good for sugarcane growth. The furfural plant must be located in proximity to sugarcane fields and sugar mills for easy access to raw material- bagasse.

[5] The adequacy and availability of labour at the plant site. Also, the supply of various categories of labour, i.e., skilled and unskilled labours must be examined.

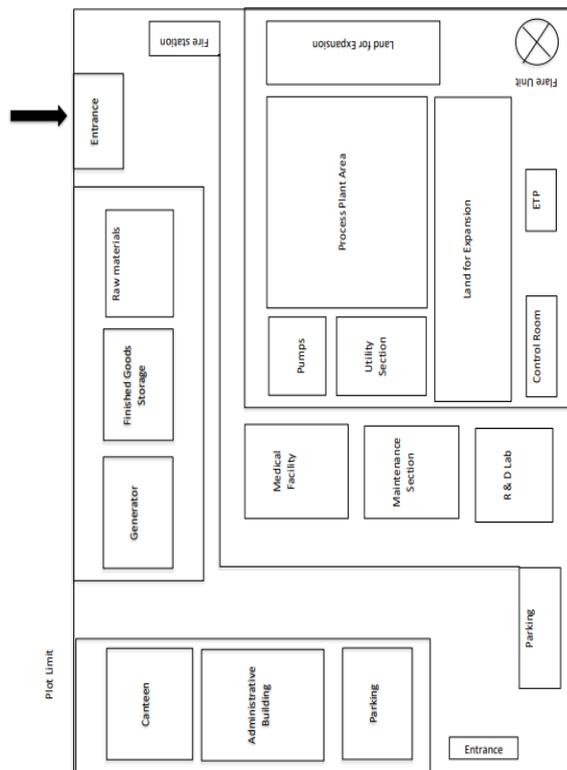
[6] There must be adequate supply of water available near the site location for the various processes occurring within the plant.

[7] The location of the plant should be such that it is accessible to the market location. It is an important criteria which affects the sales and product distribution costs as well as time required for transportation.

[8] There should be adequate amount of transportation available at reasonable cost. The area should have excellent rail and transport facilities.

[9] The regional taxes applicable should be reasonable and the relative cost of plant site should be optimum.

Figure 5: Schematic Layout of the plant



IX. Conclusion

Furfural is broadly used as a solvent or intermediate in several end-use industries, including foundry, agriculture, paints & coatings, pharmaceuticals, refineries, chemicals, automotive, and construction. The growing construction sector is projected to supplement the demand for the product in several refractory materials including ceramics, bricks, and fiberglass composites over the forecast period. In addition, surging demand for sustainable products due to the depletion of fossil fuel resources is estimated to drive the demand.

Furfuryl alcohol is a chemical, which is derived from furfural. Furfuryl alcohol plays a vital role in the production of foundry sand binders due to its high reactivity. This alcohol has been extensively used for producing cores and mould for metal for many decades. It is also used in the production of tetrahydrofurfuryl alcohol (THFA), which is widely used in the pharmaceutical industry. According to the World Foundry Organization, the foundry industry is expected to grow by 13.0-14.0% until 2025 in India, which is expected to be the second-

largest foundry market in the world, after China. Therefore, the growing foundry industry is leading to the demand for furfuryl alcohol, thereby boosting the market for Furfural.

The rising importance of bio-based solvents as a consequence of increasing environmental concerns is anticipated to boost the Furfural demand in solvent applications in the coming years. Due to high demand and growing market, we have selected this project. From this Project, the Material and Energy balance for the production of furfural were performed.

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