PROCESS DESCRIPTION

1. INTRODUCTION

Proposed Distillery shall be set-up based on latest Design, Engineering and Supply for Molasses handling, Fermentation, Distillation, Evaporation, Bio-composting, Bio-Methanation, Water treatment plant and Effluent Treatment Plant so as to have the Plant compliance to Zero Discharge. Latest Technology ensures incorporation of High efficiency Design, Higher fermentation efficiency and Effective heat integration in distillation and evaporation. The Process Technology adds value to overall plant engineering by incorporating global standards for Design, on safety norms and adherence to local design codes. The distillery process can be either with Continuous or Fed Batch Fermentation.

2. FED BATCH FERMENTATION

Series of fermenters of identical size capacity provided which are equipped with agitator for mixing of Fermenter mass & facilitate release of CO_2 produced. Molasses, diluted with water to the desired concentration is metered continuously into Fermenter I. Additives like urea (in the form of pellets or pills) and de-foaming oil are also introduced in the Fermenter I as required. There is an automatic foam level sensing and dosing system for de-foaming oil, in both the Fermenters.

A. CANE JUICE/SYRUP HANDLING AND DISTRIBUTION

Concentrated cane juice (i.e., Cane Syrup) transferred to Cane juice/Syrup receiving tank and the same is weighed through mass flow meter. Weighed cane juice/syrup is distributed to cell mass propagation, fermentation and yeast activation section.

B. MOLASSES HANDLING AND DISTRIBUTION

Screened molasses transferred to molasses receiving tank and molasses is weighed. Weighed molasses is distributed to cell mass propagation, fermentation and yeast activation section.

C. PROPAGATION

Yeast is grown in laboratory during plant startup. Yeast propagation section comprises of molasses diluter and hygienically engineered yeast vessels equipped with heating, cooling and air sparging facility.

Dilute molasses media are prepared in yeast vessel by re-circulating media through molasses diluter. Laboratory propagated cell mass is scaled up in series of yeast vessels. Filtered air is sparged in pasteurized and cooled dilute molasses medium for optimum growth of yeast. Temperature is maintained at 30-32°C by recirculation cooling water through jacket of yeast vessels. Cell mass from Yeast vessel is transferred to yeast activation vessel to build up cell mass required for fermentation by cell mass transfer pump.

D. FERMENTATION

Fermentation has been developed to further improve the operating parameters of the plant in terms of high fermentation efficiency, higher alcohol percent, and trouble free and higher consistency of the performance parameters over longer period. Most modern ethanol production plants adopt this fermentation technology. It is adaptable to fed batch process. The fermentation process employs a special yeast culture and yeast management system, which can withstand variations in the molasses quality, temperature and other shock loads.

Fermentation plant consists of four numbers Fermenter with all the accessories like, Plate Heat Exchangers for cooling, Air spargers, Broth mixers, and Air blowers etc. Hence it gives a tremendous advantage in maintaining the yeast population and in combating the bacterial infection. Molasses after weighing is diluted to an appropriate sugar concentration while pumping through Molasses Broth Mixer into the Fermenter. To help the fermentation sustain the assailable nitrogen are added in the medium in the form of Urea and DAP as required. Temperature in the Fermenter is maintained to an optimum level as required for efficient reaction with the help of Plate Heat Exchanger and recirculation pumping system. This recirculation also helps in proper mixing of fermented wash. Air blower is provided to supply the necessary oxygen required for the yeast. The CO_2, which is liberated, is scrubbed with water, in the CO_2 Scrubber. This CO_2 contains ethanol, which is recovered by collecting water from CO_2 Scrubber into Fermenter. The fermented wash collected in the Buffer Wash Tank is then pumped to Analyzer or Primary column for distillation. A closed loop cooling tower system with an induced draft-cooling tower with circulation pumps is also provided to ensure higher cooling efficiency and to minimize water wastages.

Fermentation is a bio-chemical reaction. This means both biological (related to living things) and chemical matters are involved in the process.

Living yeast cells participate on biological activity, while sugar ($C_{12}H_{22}O_{11}$) as chemical is involved in the fermentation process used for the manufacturing of alcohol.

In principle, glucose molecules are consumed by living yeast cells and in turn they excrete ethanol molecules and liberate carbon dioxide. This is an exothermic reaction, thus generates heat as the reaction proceeds in forward direction.

Following equation represents the fermentation reaction:

Yeast

$$C_6H_{12}O_6 = 2\ C_2H_5OH + 2\ CO_2 + \text{Heat}$$

Commercially, pure glucose is not economic choice. Thus sugars (disaccharides) are used for the industrial production of alcohol.

Living yeast cell generates an enzyme, called as invertase enzyme, at the cell wall surface. These enzymes hydrolyze one sugar molecule (disaccharide) into two mono-saccharide molecules, called as glucose and fructose. This mono-saccharide is involved in conversion to alcohol.

Following equation represents the hydrolysis of sugar to glucose & fructose at cell surface

$$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6$$

(Disaccharides) Invertase Enzyme (Mono-saccharide)

Fermentation is a complex process. It involves multiple reactions in parallel as well as in series. Though we require ethanol as product, but many other side products are formed involving multiple reactions. This reduces the conversion efficiency of glucose to ethanol. Optimum conditions of fermentation system favor glucose conversion to ethanol, while suppressing other reaction steps.

Living yeast cells are industrially used for the conversion of sugars to alcohol. These yeast cells generate invertase enzyme, which hydrolyses sugar molecules into glucose and fructose molecules.

Saccharomysis Cerevisea strains are used in the distillery plants for the production of alcohol from molasses.

Typical life cycle of yeast cells is divided into following four phases:

- Birth
- Growth
- Multiplication
- Death

All these four phases are considered while designing fermentation system.

Bacteria are the enemy of yeast cells. Basically it grows at faster rate and suppresses yeast activity.

Various process parameters are considered for best productivity of the yeast cells. These conditions also ensure higher production efficiency, good quality product and with minimum initial as well as operating cost involved.

The fermented wash collected in the Buffer Wash Tank & then pumped to Analyzer column for distillation. A closed loop & induced draft cooling tower with circulation pumps is also provided to ensure higher cooling efficiency and to minimize water wastages.

E. SCRUBBING & RECOVERY

The carbon-Di-oxide produced during fermentation is scrubbed with water in sieve tray scrubber to recover alcohol from vent gases. The vent gases from Fermenter mainly air and carbon dioxide are also scrubbed in sieve tray scrubber for alcohol recovery. The water from the scrubber is returned to respective Fermenters. About 1% of the total alcohol production is saved by scrubbing the Fermenter off gases.

The CO_2 produced from Fermenters after scrubbing will be bottled to avoid air pollution.

3. MULTI-PRESSURE DISTILLATION

Multi-Pressure distillation scheme has distillation columns operating under different pressures. Heat energy from columns operating under high pressure is recycled back to columns operating under low pressure to conserve energy.

DISTILLATION COLUMNS

The vacuum distillation has many advantages over conventional atmospheric distillation plants like lower energy requirement, better quality products and less scaling on the distillation trays due to sludge. The vacuum distillation produces ethanol of international quality standards and there is a lot of demand of ethanol from the vacuum distillation process. Alcohol quality, which is produced from this latest technology, meets to most of the international quality standards like US, British and Japanese standards.

The vacuum distillation approximately requires 50 % less steam as compared to conventional old distillation technologies. The vacuum distillation consists of distillation columns with high efficiency column trays, condensers, Reboilers, vacuum pumps and reflux pumps.

In this vacuum distillation, alcohol is separated and concentrated using principal of fractional distillation. This is based on difference in boiling points of involved compounds in mixture. There are eight distillation columns in the system. These are Primary column, Degasser column, Pre-Rectifier column, Hydro - extractive distillation column, Rectifier column, Refining column, De- Recovery Column and De-Aldehyde Column

➢ **WASH TO ETHANOL PLANT**

This scheme has total seven distillation columns.

The columns in order of flow are: -

1. Analyzer Cum Degasifying Column – vacuum.
2. Aldehyde Column – vacuum.
3. Pre-rectifier column – Pressure.
4. Recovery Column – pressure.
5. Dehydration System

1. **PRIMARY CUM DEGASSER COLUMN**

Primary column (Analyzer Column) is operated under vacuum and it is heated using the top vapours of the Primary Rectifier column. The vacuum operation of the Primary column decreases the overall energy requirement of column. Due to vacuum, scaling is also reduced in this column & plant can be operated for long time smoothly.

The fermented wash is preheated using a beer heater and followed by a plate heat exchanger, then it is fed at the top of Degasser column. The pre heating of mash in two stages recovers energy and saves steam required for the distillation.

Degasser column separates the impurities on the basis of boiling point. These impurities are sent to De-aldehyde column.

Alcohol and other volatile compounds are separated from the top of the Primary Column & fed to Pre- Rectifier Column.

The semi-solid waste in fermented wash is reached at the bottom of Primary column. This semi-solid waste is called as spent wash & sent to Effluent treatment plant for further separation.

2. **PRIMARY RECTIFIER COLUMN**

Primary Rectifier Column is derived on steam indirectly with the help of one reboiler. This column gets feed from Analyzer column & Dealdehyde Column. This column is operated under pressure condition to reduce the steam consumption & better quality. Heavy & Light Fusel Oils are separated from this column & fed to De - fusel Oil Column.

Impure spirit is also separated from the condenser of this column. Column top vapors are condensed in analyser reboiler & remaining in condensers.

Alcohol is concentrated in this column & spent water (spent lees) is separated from the bottom of the column.

Rectified spirit is separated from this column is fed Ethanol Recovery Column.

3. **ALDEHYDE COLUMN**

All fusel oil & esters impurities are fed to this column. Heavy Fusel Oil & Light Fusel Oil is drawn out from the column & concentrated in decanters. Water is also used for washing of fusel oil & to recover the alcohol. When fusel oil is get concentrate in decanter, fusel oil transferred to fusel oil storage.

***4*. RECOVERY COLUMN**

The main purpose of this column is to evaporate the 95% alcohol and feed the alcohol vapour to super heater for separation of water and alcohol molecules.

***5*. DEHYDRATION SYSTEM:-**

Molecular sieve technology works on the principle of pressure swing adsorption. Here water is removed by adsorbing on surface of `Molecular Sieves' and then cyclically removing it under different conditions (steaming).

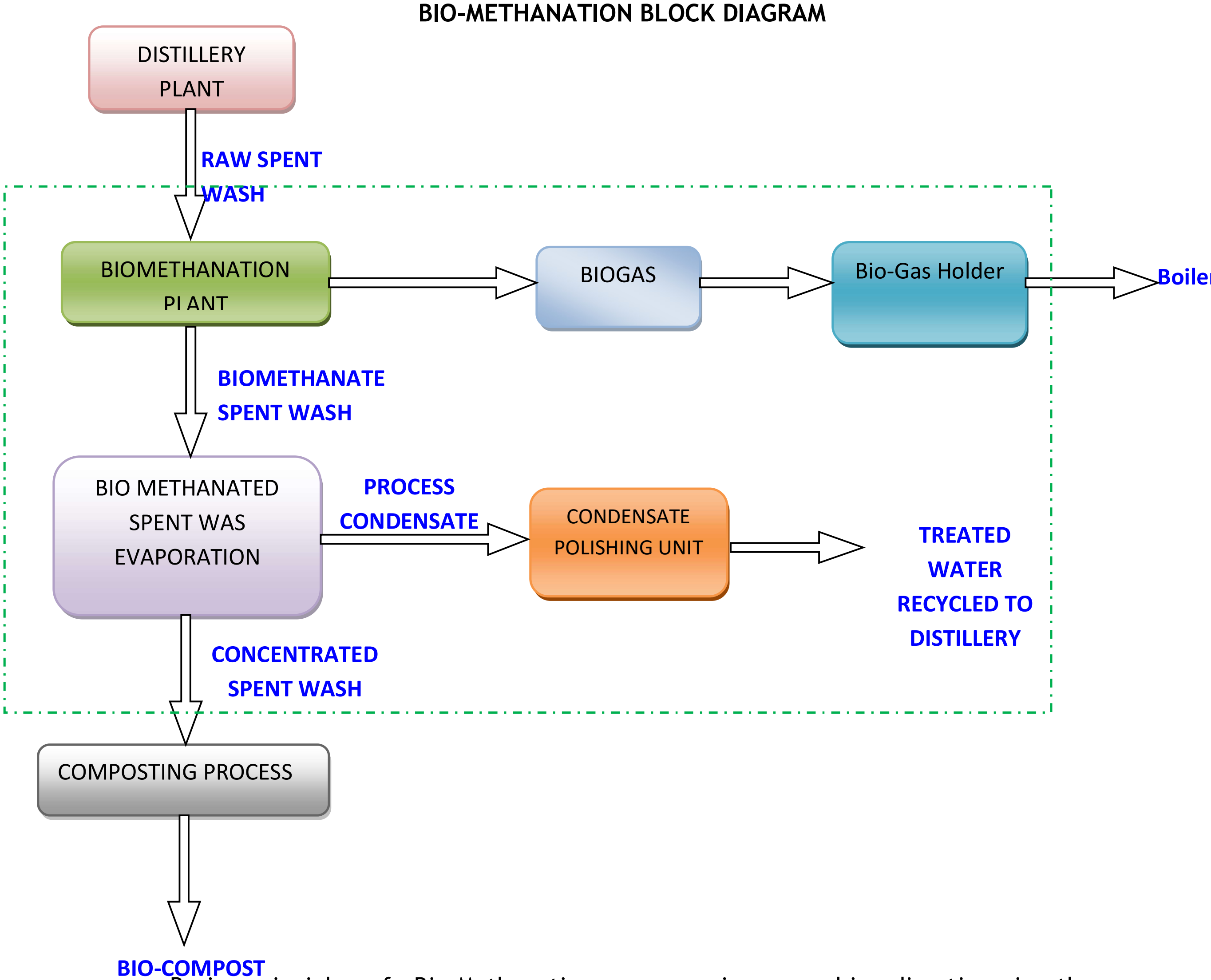
Molecular sieves are nothing but synthetic Zeolite typically 3A Zeolite. Zeolites are synthetic crystalline Aluminosilicates. This material has strong affinity for water. They adsorb the water when heated (and pressurized) and desorbs the water under vacuum. This principle is used to dehydrate ethanol. The crystalline structure of Zeolite is complex and gives this material the ability to adsorb or reject material based on molecular sizes. Water molecule can enter the sieve and be adsorbed, but larger alcohol molecule will not be retained and will go through the bed. There can be two beds in parallel. Once a particular bed is saturated with water, the anhydrous alcohol is re-circulated to remove water from the bed under vacuum. The operation is called regeneration of bed; so that adsorbed water is desorbed from the bed. Till that time, other bed is used for dehydration.

5. DISTILLERY EFFLUENT TREATMENT

A. Bio-Methanation

"CSTR" Continuous Stirred Tank Reactor process is used for Bio-methanation which convert organic matter into biogas. The process of conversion of organic matter into biogas occurs through group of bacteria.

BIO-METHANATION BLOCK DIAGRAM



Basic principle of Bio-Methanation process is anaerobic digestion in the MESOPHILLIC range of temperature wherein the pH inside the reactor is usually kept around 7.2 while proper ratio of volatile acid and alkalinity is maintained.

Distillery Spent wash is peculiar in nature characterized by very high organic matter concentration and extremely low pH. Anaerobic Digestion Process has established as most successful primary treatment, due to its advantages like: reduction of organic matter concentration with lower energy input, low sludge development, higher flexibility for variable loading and, above all, generation of Non– conventional energy in the form of biogas, which can substitute a substantial portion of fuel requirement for the captive power generation through Boiler /Turbo-Alternator arrangement

The spent wash coming out of Distillery is passed through heat exchanger to reduce the incoming temperature from 50°-60° C to 30°-40° C. This is necessary, as the major culture grouping is in mesophillic range. The initially neutralized spent wash is then taken to the 1st phase process of Acid Formation.

The basic operation is divided into two phases as it is necessary to have a two phase operation which gives greater stability in 2nd phase operation I.e. a Methane Phase.

The spent wash after acid formation enters the 2nd phase reactor, wherein it is conditioned with return sludge/supernatant. Multiple entry inlet and weir outlet combined with higher flow through jet mixers and sparger mechanism with high velocity gives the 'Up flow sludge blanket reactor with 'complete mix' facility.

The effluent after methane phase reactor is subjected to flash degasification to release entrapped gases. This is thereafter subjected to settling operation to avoid Carry-over of biomass/solids which is recycled back to the digester for maintenance of biomass. The supernatant is also partially recycled to maintain inlet conditions as per design. The biogas is collected in to a Bio-Gas holder with pressure maintenance facility and is used in the Boiler as Fuel for combustion.

B. EVAPORATION:-

In EVAPORATION consists of falling film evaporators. It gets heat from steam. There are five falling film evaporator. Vapours of last evaporator get condensed in a surface condenser. CIP connection for all evaporator is provided for cleaning purpose.

In EVAPORATION first evaporator get heat from the steam provided. Spent wash vaporized in first stage give energy to second stage. There are total five falling film evaporator. Evaporators are in forward feed arrangement. Vapours of Second evaporator are fed to third effect Evaporator. Vapours of Third evaporator are fed to fourth effect Evaporator. Then, Vapours of fourth evaporator are fed to fifth effect Evaporator. Falling film evaporators can be operated at very low temperature differences between the heating media and the boiling liquid, and they also have very short product contact times, typically just a few seconds per pass. These characteristics make the falling film evaporator particularly suitable for spent wash evaporation.

In EVAPORATION there is specifically designed Spent wash distributors for the proper distribution of Spent wash in tubes. Specific design of the liquid distribution system achieve full and even product wetting of the tubes. Because of the low liquid holding volume in this type of unit, the falling film Evaporator can be started up quickly and changed to cleaning mode easily.

In EVAPORATION Falling film evaporators are highly responsive to alterations of parameters such as energy supply, vacuum, feed rate, concentrations, etc. it will be equipped with a well designed automatic control system therefore it can produce a very consistent concentrated product.

In Evaporation is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid. It is thus a thermal separation, or thermal concentration, process. We define the evaporation process as one that starts with a liquid product and ends up with a more concentrated liquid as the main product from the process.

C. COMPOSTING PROCESS

Concentrated Spent wash as reject from Reverse Osmosis Plant is used for Composting process. This is first stored in Spent wash Storage Lagoon.

Construction of Impervious Spent wash Storage Lagoon

➢ **Details of Composting Cycle**

Composting process takes about 8 weeks (60 days) to complete one cycle and involves following activities.

WEEK 1

Collection & handling of press mud, formation of windrow of Dimension 3.5 X1.5 X 250 Meter and then first pass of Aero tiller to reduce the moisture content in windrow from 70% to 50%. It is inoculated with microbial culture (30% suspension in water) and Aero tilling for proper mixing of inoculants.

WEEKS 2-7

During this period, Effluent spraying is done and Aero tilling to maintain the moisture between 50 to 60 %. The above Effluent spraying is done thrice a week.

Aero tilling operation to enhance the composting reaction

Aero tiller is passed after every effluent spray. Trimming of windrow is required after every aero tilling to re-shape the windrow in triangular position.

WEEK 8

During this week the Curing, Aging & Drying takes place, wherein optimum moisture content is maintained. No effluent is applied during this stage. Leachate BOD & COD gets reduced. Aero tilling is continued twice a week till the compost is stabilized and finally dispatched to end user farmers.

Composted windrows ready for dispatch

Features of the Composting Process

- This is a zero pollution process.
- The BOD of effluent is destroyed.
- All the degradable organic material is oxidized to humus.
- There is no odour pollution.
- There is no air Pollution.
- The product is dry, Bagging is possible and has a high nutritional value for all crops, and is applicable on all types of soils.
- Compost is free from weed seeds and pathogens.
- The composting process is carried out on scientifically designed concrete yard and no ground water pollution/percolation is envisaged.

D. CONDENSATE POLISHING UNIT

PROCESS DESCRIPTION:

The scheme for Process Condensate and Spent Lees treatment shall be:

Storage Lagoon with pH dosing system

Equalization tank

Anaerobic filter

Aeration tank I

Clarifier I

Aeration tank II

Clarifier II

Multimedia filter

Activated carbon filter

Softener

It is found practical that to dampen the variations in the influent characteristics, particularly, the organic loading, an elongated period initial storage of about two days hydraulic retention can serve two purposes, one to equalize the characteristics and the other, this can be converted into Pre-Anaerobic Digestion also, reducing the loads on further units and also ensuring minimum chemical consumption for neutralization.

After this the effluent shall be stored in an equalization tank with adequate capacity to equalize the flow of spent lees and condensate from distillery. Auto pH adjustment system shall be provided to correct the pH of equalization tank. Equalized effluent shall be subjected to anaerobic digestion, in form of Anaerobic Filter, to reduce the organic matter concentration, and more particularly, Ammonical Nitrogen in the effluent.

The effluent after Anaerobic Digestion shall be subjected to Ist stage Extended Aeration System comprising of Aeration tank-I with Diffused air Aeration System and shall be equipped with blowers and micro bubble diffusers grid for aeration. Aerated water shall be subjected to clarifier-I for sludge separation.

The treated effluent after this stage still requires further organic matter reduction, before the same is subjected to Tertiary Treatment. One more treatment stage of 'High Rate Extended Aeration' is therefore planned as II stage treatment. The treated effluent after this stage shall be fit for subjecting it to Tertiary Treatment, which shall comprise of Chlorination, for disinfection, Coagulation for effective removal of suspended matter in the Multimedia Filter thereafter, followed by Activated Carbon Filter for removal of trace organics and colour. The treated effluent, devoid of organics and suspension, shall be subjected to softener to remove T.D.S. and Hardness, which will render it fit for reuse for the cooling tower make-up.