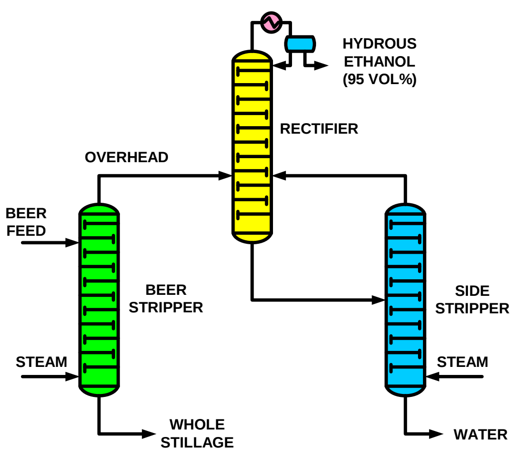
Low Energy Recovery of Dilute Alcohol from Fermentation Broths Produced from Cellulosic Biomass using ESep™

The Markets

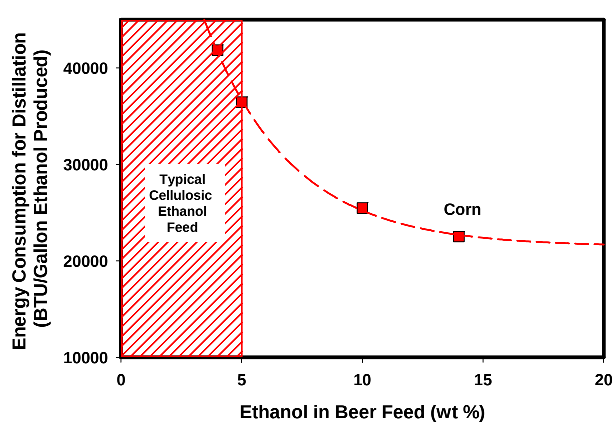
Ethanol for the U. S. transportation market is currently produced almost exclusively from corn, with production in 2008 of approximately 9 B gallons. At the present time, however, the U. S. ethanol industry is overbuilt with 13.1 BGPY nameplate capacity (of which 1.2 BGPY is idled) and another 1.4 BGPY under construction. Multiple producers are in bankruptcy; and the industry is undergoing consolidation. Though energy and corn prices have fallen from their record highs of mid-2008, margins are still tight. The price of ethanol is loosely correlated with the price of RBOB (reformulated gasoline blendstock for oxygen blending), although it seems to be less volatile. The current price for ethanol on the Chicago Spot Market of $2.10/gallon values the annual U. S. market for fuel-grade ethanol for 2008 at $18.9 B. This market is expected to grow due to a mandate for 36 BGPY of biofuels in the US gasoline supply by 2022 by the Energy Independence and Security Act of 2007, of which 21 BGPY must come from second generation cellulosic biomass processes.

The Problem with Existing Technology



The ethanol industry currently uses distillation (like the three column configuration shown here) to recover ethanol from beer feed. This system is comprised of a beer stripper, in which the feed is distilled into an overhead stream containing 40-45 vol % ethanol, and a rectifier/side stripper, which further enriches the ethanol to 95 vol% (hydrous ethanol). All columns are stainless steel, which has increased in cost significantly in recent years. Rigorous process simulations show that, for a feed containing 15.4 vol% ethanol, the overhead from the beer stripper is ~ 43.4 vol% ethanol; and the energy consumed by the entire distillation process is ~22,680 BTU/gallon ethanol produced.

Unfortunately, because the alcohol content in beer streams produced by fermentation of cellulosic biomass is much lower than that in those from corn, larger distillation columns are required (higher capital cost) and their energy consumption rises exponentially as the alcohol content of the feed decreases. For instance, it takes 41,660 BTU/gallon (or 84% more energy) to recover ethanol from a feed containing 4 wt% (5 vol%) ethanol than from a feed containing 14 wt% (17.7 vol%) ethanol.



ESep Overview

ESep is a technology that significantly reduces the capital and operating costs of recovering fuel-grade ethanol and butanol from dilute aqueous feeds by replacing all or part of the traditional distillation system with a low cost and energy efficient liquid-liquid extraction (LLE) system. Unlike membrane-based pervaporation systems, which can only process feeds containing > 50% ethanol, ESep works well on a wide range of ethanol feed compositions and has been demonstrated to work well with feed streams containing as little as 0.6 wt% butanol. Due to the nature of the proprietary final alcohol recovery step, the entire process operates at temperatures below 75 °C, thus reducing energy input by as much as 50% over distillation.

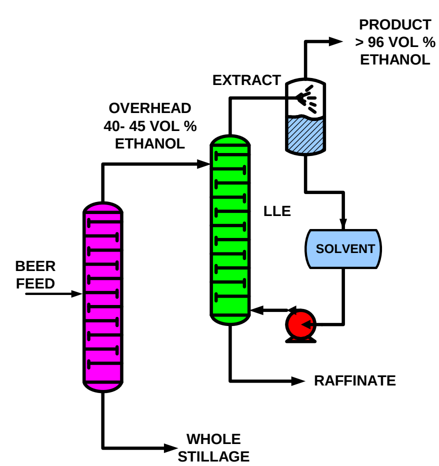
ESep Description

ESep is a very simple process. It involves the (1) contacting of an aqueous feed containing a dilute alcohol with an immiscible solvent that has a high affinity for alcohol but a much lower affinity for water (2) in a device that encourages the movement of alcohol from the water phase to the solvent phase more efficiently than in conventional LLE contactors.

While the concept of using LLE to recover ethanol from fermentation streams is not new, it has never been commercially applied - primarily because LLE systems generally require two distillation columns: (1) an extract/solvent recovery tower and (2) a raffinate/solvent recovery tower which together consume more energy than the LLE system saves. In ESep, solvent containing ethanol extract is fed to a proprietary recovery stage (which does not involve classical distillation) where the ethanol is recovered and the solvent is recycled back to the LLE system. Simulations have shown that the proprietary recovery system consumes only 16% of the energy required for a traditional distillation separation of ethanol from the ESep proprietary solvent.

Process Configurations

ESep may be used in one of two configurations: (1) Retrofit and (2) Grass-Roots. In a retrofit configuration, overhead from the beer stripper is condensed and contacted in an LLE column (designed to enhance mass transfer) with a selective solvent to extract the ethanol as shown here. The extract stream (solvent plus ethanol) is then treated in a second proprietary process to recover the ethanol. Purity of ethanol produced in this manner is higher than in distillation, since the concept of an azeotrope does not apply; and therefore, the amount of water removed downstream is significant reduced.



The grass-roots process is similar in that the beer stripper is replaced by a second LLE unit which may incorporate a different solvent and operate under different process conditions.

Commercialization Strategy

Trans Ionics is currently seeking strategic partners who are working in the cellulosic ethanol business with whom the ESep technology can be tested and scaled up. Testing can be done on corn based systems with extension to cellulosic systems when they are ready.

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