A new approach to an established product

Cost-efficient production of ethanolamines

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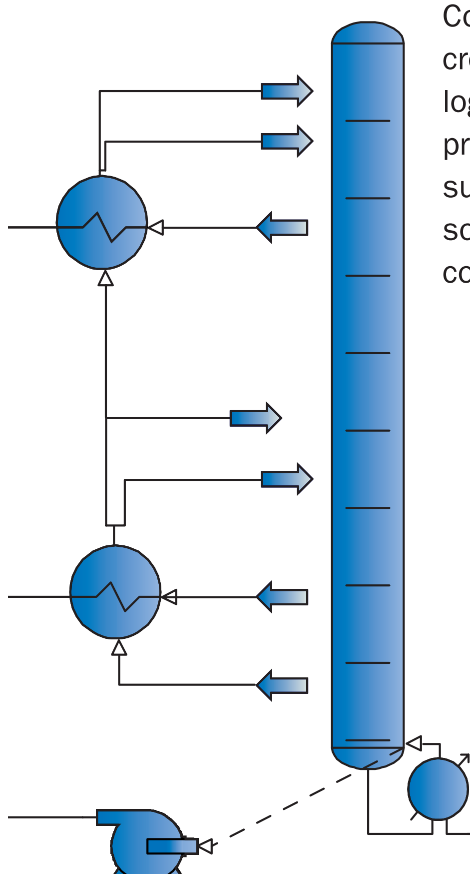
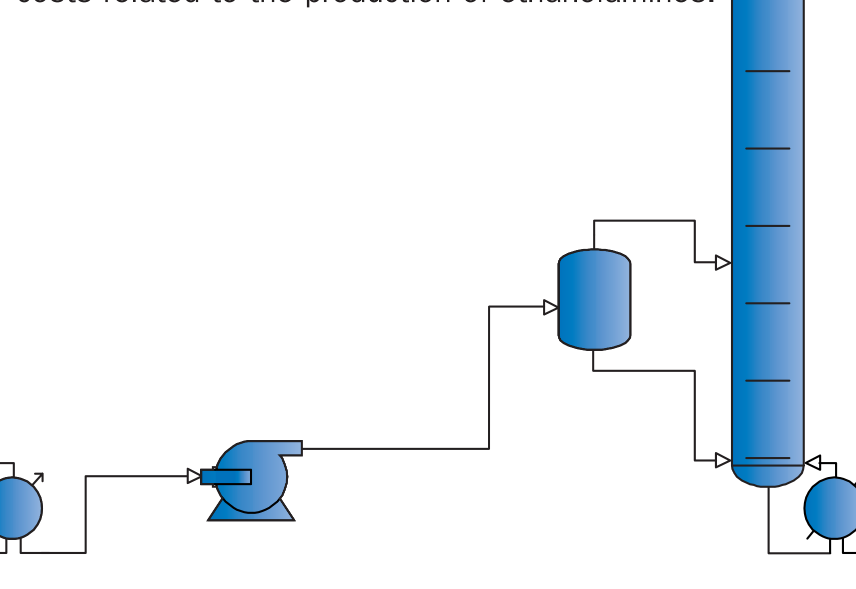
Sulzer Chemtech has over 30 years of experience in the field of ethanolamine technology. Its expertise includes the provision of comprehensive engineering services for the modernization of existing plants, as well as the manufacturing of key components for plants such as distillation column internals (Fig. 1). Sulzer Chemtech and Celeghin Consultants Corporation of Houston, TX, USA, teamed up to create an innovative new ethanolamine technology solution that optimizes product quality and process flexibility while lowering energy consumption during production. This complete solution reduces the investment and operating costs related to the production of ethanolamines.





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Ethanolamines are flammable, corrosive, colorless, viscous liquids that are produced by the reaction between ammonia (NH_3) and ethylene oxide (EO). Identified many years ago, ethanolamines are a key ingredient in a number of important product formulations such as cosmetics and personal hygiene applications, agricultural products, wood-preservation chemicals, soaps and detergents, gas treatments. They can also be used in the production of non-ionic detergents, emulsifiers, and soaps, as well as in emulsion paints, polishes, and cleansers.

Flexible ethanolamine production technology

There are 3 types of ethanolamines: monoethanolamines (MEA), diethanolamines (DEA), and triethanolamines (TEA). The formation of MEA, DEA, or TEA depends on whether an ammonia molecule reacts with 1, 2, or 3 ethylene oxide molecules (Fig. 2).
Unlike conventional ethanolamine production technology, which is often limited in terms of the ratio of ammonia to ethanolamine that can be handled, the flexible Sulzer Chemtech solution offers the option of altering the amounts of the final product generated. The composition of the resulting mixture is determined by the ratio between the raw materials, which can be varied in accordance with requirements. The higher the proportion of ammonia, the more monoethanolamine is formed (Fig. 3). The Sulzer Chemtech process can handle ammonia to ethanolamine ratios up to or exceeding 6:1 and offers the customer a high level of MEA or DEA distribution while minimizing the volume of TEA produced (Fig. 4).

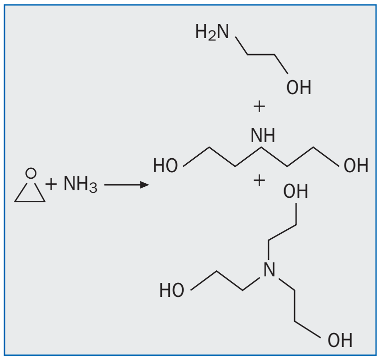
Lower costs

The volume of water used in ethanolamine production can vary: if the water content remains low during the process, it is necessary for the reaction to be conducted under high pressure—resulting in high investment costs. These reactions consume a low level of energy. In order to lower investment costs, a high water content may be used under low pressure, but the related energy consumption will consequently be higher. The new ethanolamine technology solution offered by Sulzer Chemtech combines the advantages of the high-pressure ammonia route with the benefits of the low-pressure process. The process allows the use of a relatively low-pressure reaction and incorporates very advanced heat integration, which saves costs across the board.
The Sulzer Chemtech water recovery system, which uses the energy integration concept, thermally ties the water evaporator to the ammonia stripper column and minimizes the size of the drying column. It thus enables the plant to operate economically even at ammonia to ethylene oxide ratios of 6:1 or above. Furthermore, the presence of water as a catalyst in the synthesis of ethanolamine ensures a rational and economical reactor setup. The use of water provides the greatest control over the temperature rise in the reactor system and allows a reduction in the volume of the reactor. The average reaction temperature can be lowered and adjusted to minimize secondary side reactions that could compromise the quality of the resulting ethanolamine.

Ammonia recovery

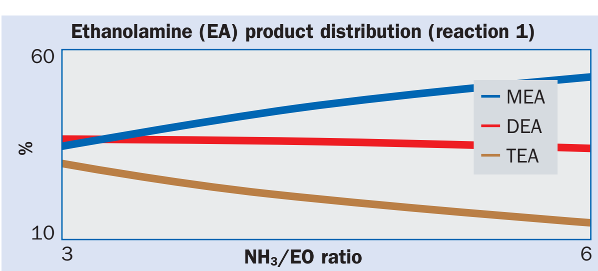
The key to saving energy in the production of ethanolamine lies in the design and operating pressure of the main ammonia absorber. The ammonia stripper is integrated directly with the absorber by feeding the stripper overhead vapors into the bottom of the ammonia stripper. In other words, there is a direct connection between the two columns. In addition, the overhead vapors from the main water distillation columns are used as a heat source for the ammonia stripper reboiler.
The pressure at the top of the main

1 Jilin ethanolamine production plant in China.

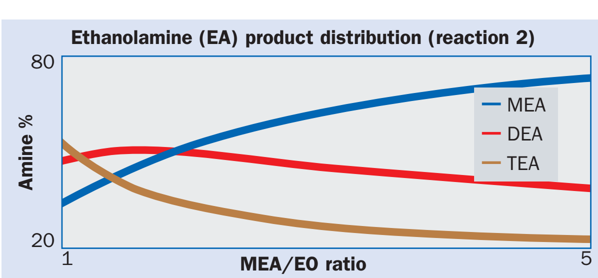


2 Mono-, di-, and triethanolamines are produced by reacting ethylene oxide with ammonia.

3 The ratio of MEA, DEA, and TEA produced can be varied by altering the ratio of the reactants.



4 The second reaction is required to produce a higher level of DEA.



water evaporation column is limited by the maximum permissible temperature at the bottom of the column. Hence, the boundary operating conditions of the ammonia absorber, ammonia stripper, and main water evaporation column are basically fixed. The only degree of flexibility in the design is in the selection of the column operating conditions, column internals, and the heat exchanger.

Sulzer Chemtech has added thermal and energy integration to the ammonia absorber, the ammonia stripper, and the water distillation column. As a direct consequence of this thermal and process heat integration, the energy required by the improved process is comparable to the high-pressure route (Fig. 5).

The increase in the ammonia concentration in the ammonia absorber is a direct result of the process heat integration and has a significant impact on overall energy consumption. The higher the operating pressure in the ammonia absorber, the higher the ammonia concentration. The higher the ammonia content, the less water has to be handled in the system. Since the water must be recycled back into the system by means of evaporation, each percentage point increase in the ammonia concentration leads to an approximate energy saving of between 1.5 and 2%—which represents a significant reduction in absolute terms.

The ammonia concentration can also be set to allow for the efficient and economical recovery of the residual ammonia from the reaction loop. This recovery occurs at a pressure that is sufficiently low to ensure that the ammonia stripping takes place at a low temperature, thus reducing the possible degradation of the product and minimizing the corrosion of equipment.

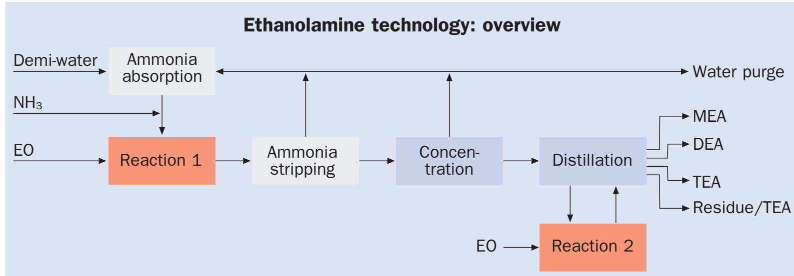
The high ammonia concentration allowed by the Sulzer Chemtech process further reduces the size of the ammonia stripper and ammonia scrubber and eliminates the need for an additional auxiliary reboiler heated by an external heating source. These features significantly reduce investment costs.

A clear advantage

Ethanolamines are sensitive to heat and therefore tend to degrade and must be separated with great care. The higher the temperature (respectively the pressure), the more colored the ethanolamines become. Color is, however, the most important characteristic determining their quality and value; the more colorless the substances are, the higher their market value. The use of high-efficiency packings from Sulzer Chemtech and the rational design of the distillation train minimizes the packing volume and enables the column to be operated at a lower temperature, with narrow residence time distribution and minimum permanent holdup. The separation of ethanolamines at these carefully maintained conditions improves the product color and reduces the corrosion at the bottom of the column.

Accelerated production without ethanolamine recycling

The ethanolamines produced are often recycled back into the main reactor system in order to adjust the desired MEA:DEA:TEA ratio. If the reaction is performed in the primary reactor, the recycling not only consumes more energy and requires a higher residence time but can also lower the product quality through the development of color and an increase in corrosion. The Sulzer Chemtech concept avoids the difficulties associated with recycling and eliminates repeated process steps, thus reducing the overall residence time in the plant and lowering energy consumption.



5 Sulzer Chemtech provides a complete and flexible solution for ethanolamine production.

Avoiding product stress

Product stress is defined as the tendency of the product to degrade and carbonize at the bottom of the column. Product stress can be minimized through the rational study of the temperature profile and the configuration at the bottom of the column, resulting in less product degradation. Side reactions, such as color precursors, can be suppressed to a certain extent through the smooth execution of the process at the lowest temperatures possible.

The level of product stress is directly related to the hot product residence time and is exponentially related to the temperature of the hot product (see box). The Sulzer Chemtech process for ethanolamine production makes effective use of the product stress concept to ensure the best handling of the hot product at the bottom of the column.

Product stress $\sim A \times (\text{residence time})^T$

where:

- Residence time = the time in minutes during which the average bottom product molecule stays in the bottom of the column.
- T = the absolute temperature of the hot stream at the bottom of the column.
- A = a proportionality factor.

Purification

The synthesis and purification of ethanolamines is a relatively complex process as the final product quality is determined by the presence of minor impurity streams in the feed, as well as by internal recycle streams, thermal process integration, and the reaction of individual components including side reactions.

Integrated approach

A fully integrated approach throughout the plant is a prerequisite for a successful design. Sulzer Chemtech and Celeghin have therefore adopted a single block for the entire process simulation. This module has been systematically improved not only by integrating the accumulated know-how but also by relying on real plant operating data and performance characteristics. This type of comprehensive simulation tool is sophisticated enough to provide a satisfactory description of plant details and serves as a powerful tool for the analysis of possible process improvements, for heat integration, and for new plant designs. Any adjustments that are required, e.g. relating to product capacity and product distribution, can be implemented relatively quickly and with a high degree of reliability.

In addition, the accumulation of unwanted byproducts or feed impurity products trapped in the process loops can be detected and eliminated through purging at specific locations.

Since such complex design approaches are very time consuming, they are only justified for selected process steps in ethanolamine production—an area in which Sulzer Chemtech has extensive experience, supported by a diversified range of market applications. ◀

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