REMOVAL OF ASH: POTENTIAL USE OF ELECTRODIALYSIS

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Introduction

It is well known that ash adversely affects the sugar industry. Ash has been shown to reduce sucrose recovery, decrease crystal growth and contribute to scale formation on evaporators. Over the past few decades various techniques have been employed to remove ash from sugar solutions. More recently, electrodialysis has been investigated.

Within an electrodialysis unit, the solutions are separated by alternately arranged anion exchange membranes (permeable only for anions) and cation exchange membranes (permeable only for cations). The membranes are arranged parallel to one another to form an electrodialysis stack. When a potential is applied across the selectively permeable membrane stack, anions selectively move through the anion exchange membrane and cations selectively move through the cation exchange membrane. The transport of ions across the membranes results in ion depletion in some cells (de-ionized, diluent or desalinated stream), and ion concentration (salt concentrate) in alternate cells. Further transport of the ions to the next cell is stopped by the next membrane (Figure 1). The electrodialysis process thus allows for the effective removal or concentration of ions (salts).

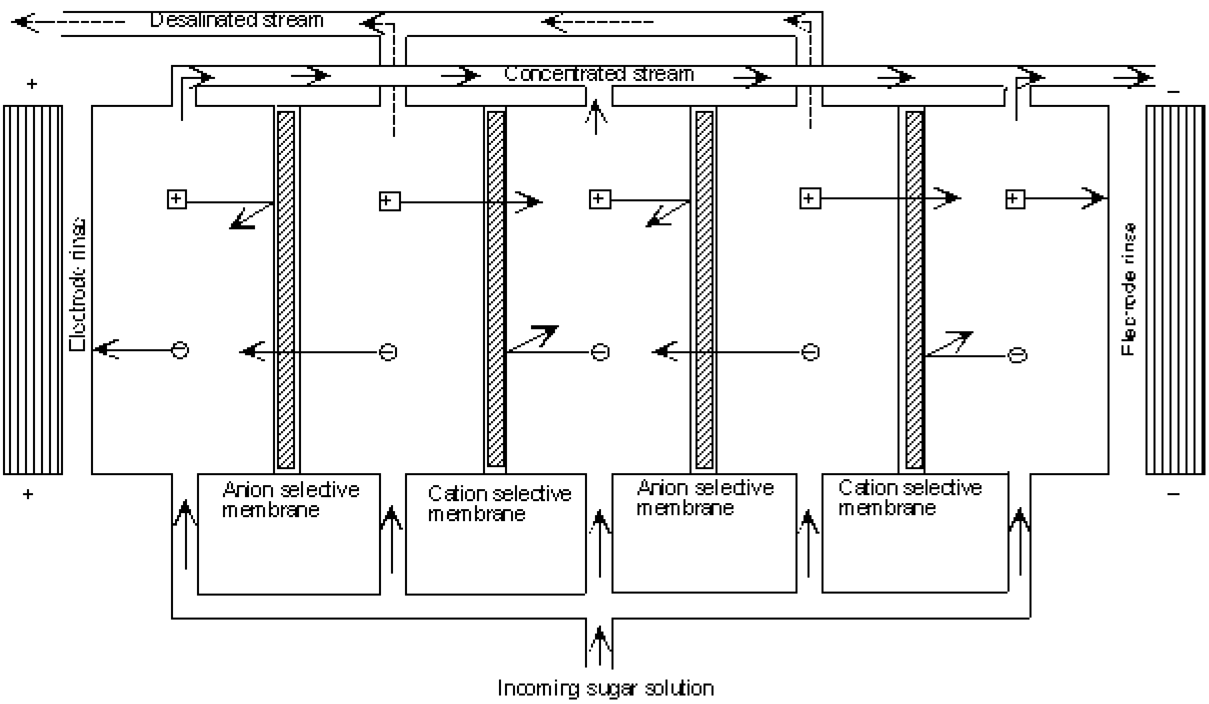

Figure 1. Movement of ions in electrodialysis (Lacey, 1979).

Use of electrodialysis within the sugar industry

The manufacture of raw sugar can be broadly categorised into juice extraction, juice clarification, evaporation and sucrose recovery. Electrodialysis requires a solution to be passed through an electrodialysis stack and can thus possibly be applied to clarified juice, low brix syrups and diluted molasses. However, as the product of each stage is different in structure, composition and form, the mode of treatment and the efficiency of the process is dictated by the nature of the material.

Effect of brix

All the papers cited suggest that demineralisation of sugar solutions is best in the region of 30-40°Bx. Suzuki and Mochizuki (1966) showed a parabolic relationship between specific resistance and the Brix of sugar solutions. At low and high Brix a high specific resistance was encountered. The specific resistance was lowest at 30°Bx, suggesting that electrodialysis would be most successfully employed at such levels. In a study conducted by Tako and Brahim (1991), B-molasses diluted to 30 and 40°Bx was subjected to electrodialysis. The molasses that was studied comprised various inorganic compounds, the most abundant being K_2O (5-10.1%). These authors reported that the K_2O concentration decreased more rapidly at the higher Brix concentration. Lutin (2001) likewise reported higher demineralisation capacities for concentrated solutions than dilute solutions. Crees and Schultz (1994) recently investigated the effect of Brix on the limiting current of syrups. There was a maximum in the limiting current density in the region of 35°Bx. Operating electrodialysis units with syrup above this maximum would introduce a considerable reduction in the current efficiency.

Effect of temperature

All research published suggests that the rate and efficiency of demineralisation is proportional to the temperature of the sugar solutions. However, ion exchange membranes have a specific thermal stability. At temperatures above the membrane's thermal stability, the membrane becomes de-activated and can no longer be used as a selectively permeable membrane. Research has focused on the temperature range of 30-60°C. Although the best demineralisation was achieved at 60°C, the membrane's longevity was considerably reduced. The possible energy saving afforded by higher temperature operations must be balanced with the shorter membrane life. Various commercial ventures have realised the benefits of high temperature operations and have directed research at the design of specialised thermally stable membranes. Most recently, the Tokuyama Corp. designed a membrane that can successfully operate at 60°C without compromising the lifespan of the membrane.

Effect of flow rate

Kumar *et al*. (1992) reported that the desalination of clarified juice was independent of the flow rate. However, the majority of work shows that there is an optimum flow rate, below and above which the rate of desalination is considerably reduced. A possible explanation for this phenomenon could be the residence time within the cell, i.e. at higher flow rates there may not be sufficient time for the selective diffusion of the inorganics through the membrane, and instead the inorganics remain within the incoming stream. The optimum flow rate would be membrane-specific and dependent on the permselectivity of the membranes.

Membrane fouling

Although in the past much research has focused on the optimisation of electrodialysis systems, the problems associated with the membranes have hindered commercial exploitation of electrodialysis technology. The membranes, particularly anion exchange membranes, are prone to fouling by large anionic organic ions. In a mill trial in Australia, Crees and Schultz (1994) noted that current efficiencies were lower and decreased steadily over time compared with those obtained in laboratory trials. The difference was attributed to the build-up of bagacillo in the electrodialysis stack and the high electrical resistance of the selectively permeable membranes.

For industry to reduce the effect of fouling of the membranes, various modifications have been documented.

These include:

- Changing from anion selective membranes to neutral membranes (as they are less prone to organic fouling).
- Properties of new membranes were explored (to reduce fouling and operate at higher temperatures).
- The direction of the current was changed and the current pulsed (to prevent foul build-up on the anion selective membrane).
- Pre-treatment of juice/syrup (chemical treatment, centrifuge, filtration).

The Daiicho Seito Co. Ltd. sugar mill in Japan uses non-selective ion permeable membranes successfully. Although neutral membranes are not prone to fouling and consequently exhibit longer life than anion selective membranes, neutral membranes are characterised by considerably lower current efficiencies (approximately 40%). The current efficiency of a membrane reflects the charge removed from the solutions compared with the charge supplied. A low current efficiency thus shows poorer de-ashing potential. It has been documented that the current efficiencies of neutral membranes are 50% lower than anion selective membranes. In recent years, Eurodia Corp. has developed improved anion selective membranes, which have higher current efficiencies, are less prone to organic fouling than traditional anion selective membranes and can be operated at higher temperatures.

Pre-treatment of sugar solutions prior to electrodialysis is obligatory. Various pre-treatment options have been considered, *viz.* screening/filtration through mesh prior to electrodialysis, centrifugation and chemical treatment. At Daiichi Seito Co. Ltd., a chemical pre-treament process is employed. With the addition of $CaCl_2$, polyvalent ions (Ca^{2+}, Mg^{2+}, SO_4^{2-}, PO_4^{3-}) are precipitated. $CaCl_2$ was introduced to concentrated cane sugar (>60°Bx) and heated; $CaSO_4$ formed by the reaction was precipitated. The process removed 64% ash from B-molasses and allowed a four-stage boiling process to be implemented.

Conclusions

Electrodialysis can undoubtedly be used as a technique for the removal of ash from sugar solutions, and is presently in use in three sugar mills globally. However, it appears that problems inherent in membrane processes (fouling, thermal stability) have prevented the technique from being commercially exploited within the sugar industry. With future advancements in membrane technology and/or technological developments for the removal of fouling matter, electrodialysis may prove to be a suitable de-ashing process for the sugar industry.

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