# THE FRACTAL SOFTENER

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## Abstract

Amalgamated Research Inc. has developed the concept of using fractal structure for control of fluid dynamics [1,2,3,4]. Primary uses include direct substitution of fluid turbulence and rapid transition of fluids to a specified geometry. A juice softener has been developed which has been designed using these concepts. Due to fractal related efficiencies, the softener cell size and resin quantity is only about 2% to 4% of that used for NRS or other strong cation softening systems and only 10% of that used for conventional weak cation softening. In addition, the fractal softener operates at very low internal pressure and with very low resin bed pressure drop. An industrial scale fractal softener treating thin juice at a maximum of 500 bed volumes per hour is in operation at an Amalgamated Sugar Company LLC plant in Paul, Idaho.

## Juice softening

Ion exchange softening of thin juice has become a commonplace procedure in beet sugar factories. A primary reason is that subsequent chromatography requires molasses or other syrups to be very low in divalent concentration. A variety of ion exchange thin juice softening methods are available. These variants use either weak or strong cation ion exchange resins. In all cases, the softening process must not produce a troublesome regenerant waste.

Weak cation juice softeners are regenerated with dilute sulfuric acid and produce a calcium sulfate byproduct. This material is used as a pulp pressing aid and therefore, rather than producing a regenerant waste, a useful product is formed. Weak cation softening is presently used in five U.S. beet factories. Conventional weak cation softeners operate at exhaustion flow rates of about 50 bed volumes per hour. The process is relatively small compared with strong cation softeners[5,6].

Strong cation juice softeners include the NRS process (also called Imacti or Akzo) and the Gryllus process. Strong cation softeners typically operate at about 10 to 20 bed volumes per hour. The NRS process uses NaOH alkalized softened juice as a regenerant[7]. The formation of a soluble lime-sucrose in used regenerant prevents the precipitation of insoluble $Ca(OH)_2$. The regenerant is returned to carbonation for calcium precipitation. Several U.S. plants use this method of juice softening.

The Gryllus process involves using the alkali ions in sugar syrups for regeneration[8]. For example, intermediate green can be used for this service. After regeneration the hard intermediate green is sent to the low raw pans so that the thin juice hardness eventually resides in molasses.

A thorough description of juice softening by ion exchange can be found in Dorfner[9].

Although we have determined that fractals can enable size reduction in both types of ion exchange, weak and strong cation, this paper will only discuss our results for weak cation juice softening.

## Fractals

Designing a juice softener to operate at flow rates 10 to 50 times greater than usual raises obvious concerns about pressure drop, cell structural design, resin kinetics etc. Conventionally, all these factors should be effected negatively. However, our reasoning was that fractal structure would allow for a system configuration where these factors would not be a problem. This reasoning was subsequently supported by pilot studies. Table 1 lists a qualitative comparison of expected versus observed pilot results for a 10 fold increase in exhaustion flow rate. The observed results include accompanying the flow rate increase with fractals for system fluid control.

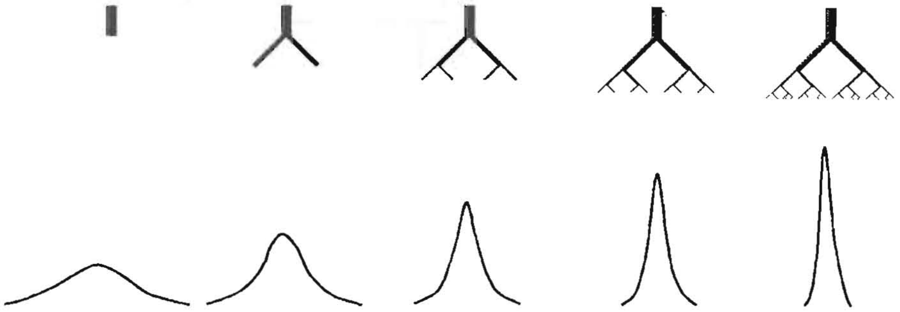
Table 1: Expected versus observed system characteristics with juice flow increased by 10x and resin volume constant.

| | expected (conventional) | observed (fractal) |
|---|---|---|
| bed pressure drop | very large increase | very large decrease |
| cell internal pressure | very large increase | very large decrease |
| cell construction | increased structural requirements | decreased structural requirements |
| turbulence | very large increase | very large decrease |
| energy consumption | increase | decrease |
| resin kinetics | increased hardness leakage | no increase in leakage |

Fluid transitions which occur in a softener, and many other processes, frequently involve a scaling requirement where fluid motion is scaled from large to small, or vice versa. Fluid scaling is necessary for operations such as mixing and for geometry alterations and is most often accomplished using turbulence. In the case of a softener, the fluid geometry entering a column should, assuming the most favorable result, quickly transition to a homogenous non-turbulent surface.

The scaling provided by engineered fractals can narrow the broad distribution of fluid properties ordinarily encountered when turbulent or inefficient scaling methods are used (Figure 1). A property of interest could be, for example, velocity, eddy size, particle/bubble size etc. Fractals can also scale fluids with reduced energy loss compared with turbulent scaling. In general, fractals can potentially benefit processes via reduction of energy use, decrease in equipment size, uniformity of flow and efficiency of mass and heat transfer.

Figure 1: Narrowing the distribution of a fluid property as a fractal is iterated to smaller and smaller scale.



## Industrial scale operation

For our weak cation thin juice softening application, cells and associated fractals were configured such that very rapid flowrates could be used without pressure drop or resin kinetic restrictions. One aspect of this configuration was the reduction of the resin bed depth to only a few inches while maintaining linear velocities appropriate for ion exchange. The fractals prevent turbulence from disturbing a bed with this shallow geometry. Pilot testing appeared favorable so for the 2000-2001 campaign an industrial scale fractal softener was installed at the Amalgamated Sugar Company LLC plant in Paul, Idaho (the Mini-Cassia factory). A simple outline of the process is illustrated in Figure 2. Exhaustion flowrate is a maximum of 500 BV/hour of thin juice. As is characteristic of weak cation systems, the used regenerant, $CaSO_4$, is a useful pulp pressing aid and is used in this service via return to the diffuser.

Table 2 lists a quantitative comparison of the fractal weak cation softener operation versus a conventional weak cation softener. The fractal softener clearly exhibits characteristics which are contrary to expectations at such high flow rate. The very large decrease in resin requirements and the very low pressure drop are particularly advantageous.

We note that energy consumption through the fractal softener decreases due to three factors: a decrease of required distributor pressure drop, a decrease of resin bed pressure drop and a reduction of turbulence in the cells (since turbulence is an energy dissipation phenomena).

Another unique characteristic of the Mini-Cassia installation is that the softener is gravity fed. This manner of feeding is possible because of the low system pressure drop.

Figure 2: Simple flow scheme for the Mini-Cassia fractal softener

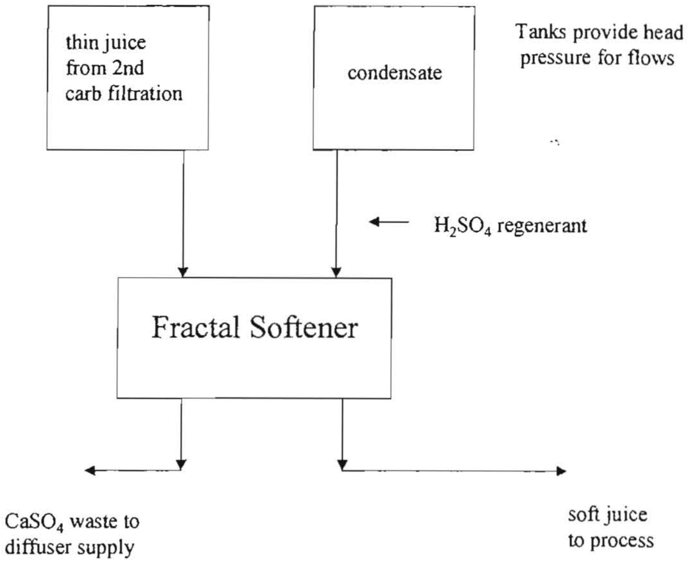


Table 2: Comparison of fractal versus conventional weak cation softening.

| | CONVENTIONAL WEAK CATION SOFTENER | FRACTAL WEAK CATION SOFTENER |
|---|---|---|
| RESIN BED DEPTH (ft) | 3.5 or more | 0.5 or less |
| EXHAUSTION FLOW RATE (bed volumes/hour) | 50 | 500 |
| MAXIMUM BED PRESSURE DROP EXHAUSTION (psi) | 50 - 70 | 1 or less |
| RELATIVE PROCESS SIZE | 1 | 1/10 |

## Conclusions

The benefits observed with the fractal softener include a relatively low capital cost, very small columns, a small amount of resin, a small amount of building space, a low pressure cell design, small peripheral equipment and relatively low energy consumption.

Fractal technology is applicable elsewhere in the factory as well. Benefits can be realized whenever a process can profit from precise control of fluid mixing, multi-fluid reactions, or fluid geometry transitions.

## Acknowledgement

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Note: ARi fractal technology is protected by patents issued and pending.