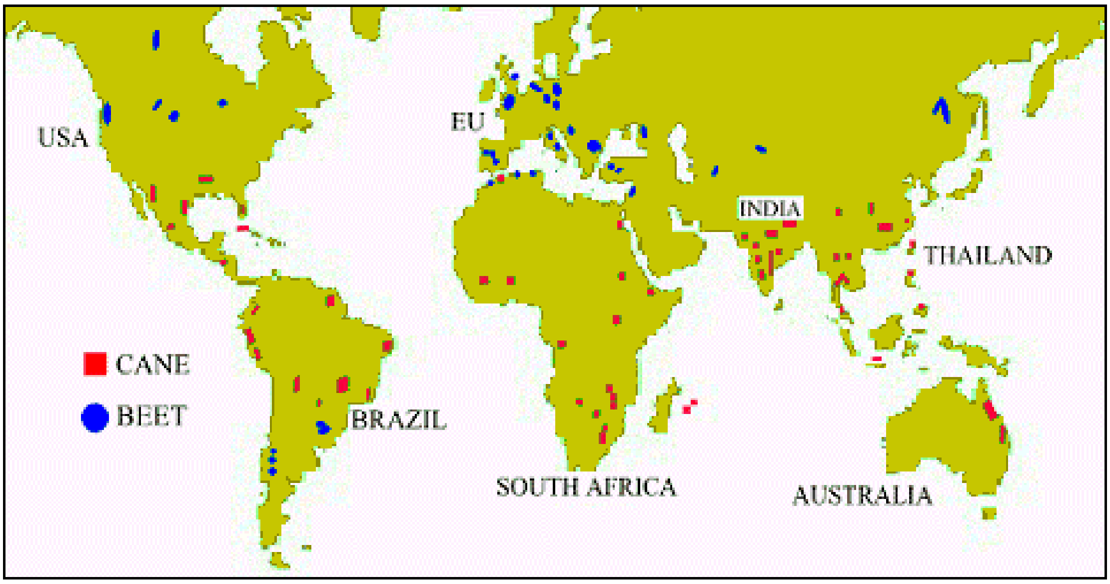
Improved sugar production
Utilising *Hydro*FLOW technology
By D. Stefanini February 2002

Sugar is made by some plants to store energy that they don't need straight away, rather like animals make fat. People like sugar for its sweetness and its energy so some of these plants are grown commercially to extract the sugar:

Sugar is produced in 121 Countries and global production now exceeds 120 Million tons a year. Approximately 70% is produced from sugar cane, a very tall grass with big stems that is largely grown in the tropical countries. The



remaining 30% is produced from sugar beet, a root crop resembling a large parsnip grown mostly in the temperate zones of the north.

What we call sugar, the chemist knows as sucrose, one of the family of sugars otherwise known as saccharides in the grouping called carbohydrates. Carbohydrates, as the name implies, contain carbon and hydrogen plus oxygen in the same ratio as in water. The saccharides are a large family with the general formula $C_nH_{2n}O_n$. The simplest of the sugars is glucose, $C_6H_{12}O_6$, although its physical chemistry is not that simple because it occurs in two distinct forms, which affect some of its properties. Sucrose, $C_{12}H_{22}O_{11}$, is a disaccharide, a condensation molecule made up of two glucose molecules [less a water molecule to make the chemistry work].

The process whereby plants make sugars is photosynthesis. The plant takes in carbon dioxide from the air though pores in its leaves and absorbs water through its roots. These are combined to make sugar-using energy from the sun and with the help of a substance called chlorophyll. Chlorophyll is green, which allows it to absorb the sun’s energy more readily, and which, of course, gives the plants' leaves their green colour. The reaction of photosynthesis can be written as the following chemical equation when sucrose is being made:

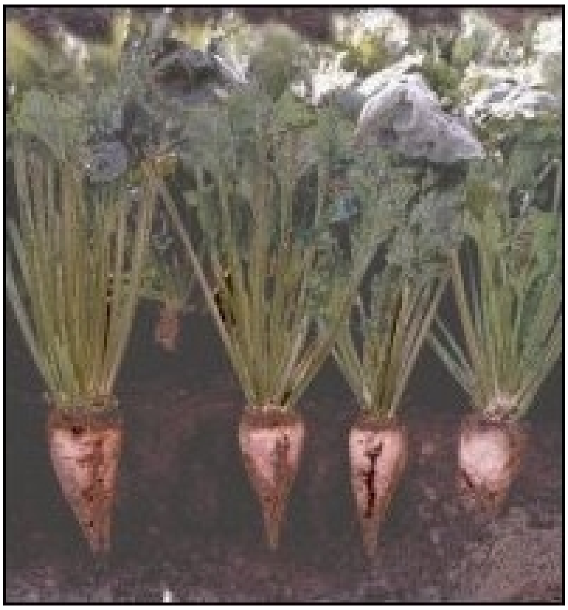
$$12\ CO_2 + 11\ H_2O = C_{12}H_{22}O_{11} + 12\ O_2$$

carbon dioxide + water = sucrose + oxygen

This shows that oxygen is given off during the process of photosynthesis.

Historically, sugar was only produced from sugar cane and then only in relatively small quantities. This resulted in it being considered a great luxury, particularly in Europe where cane could not be grown. The history of man and sugar is a subject in its own right but suffice to say that, even today, it isn't easy to ship food quality sugar across the world so a high proportion of cane sugar is made in two stages. Raw sugar is made where the sugar cane grows and white sugar is made from the raw sugar in the country where it is needed. Beet sugar is easier to purify and most is grown where it is needed so white sugar is made in only one stage.

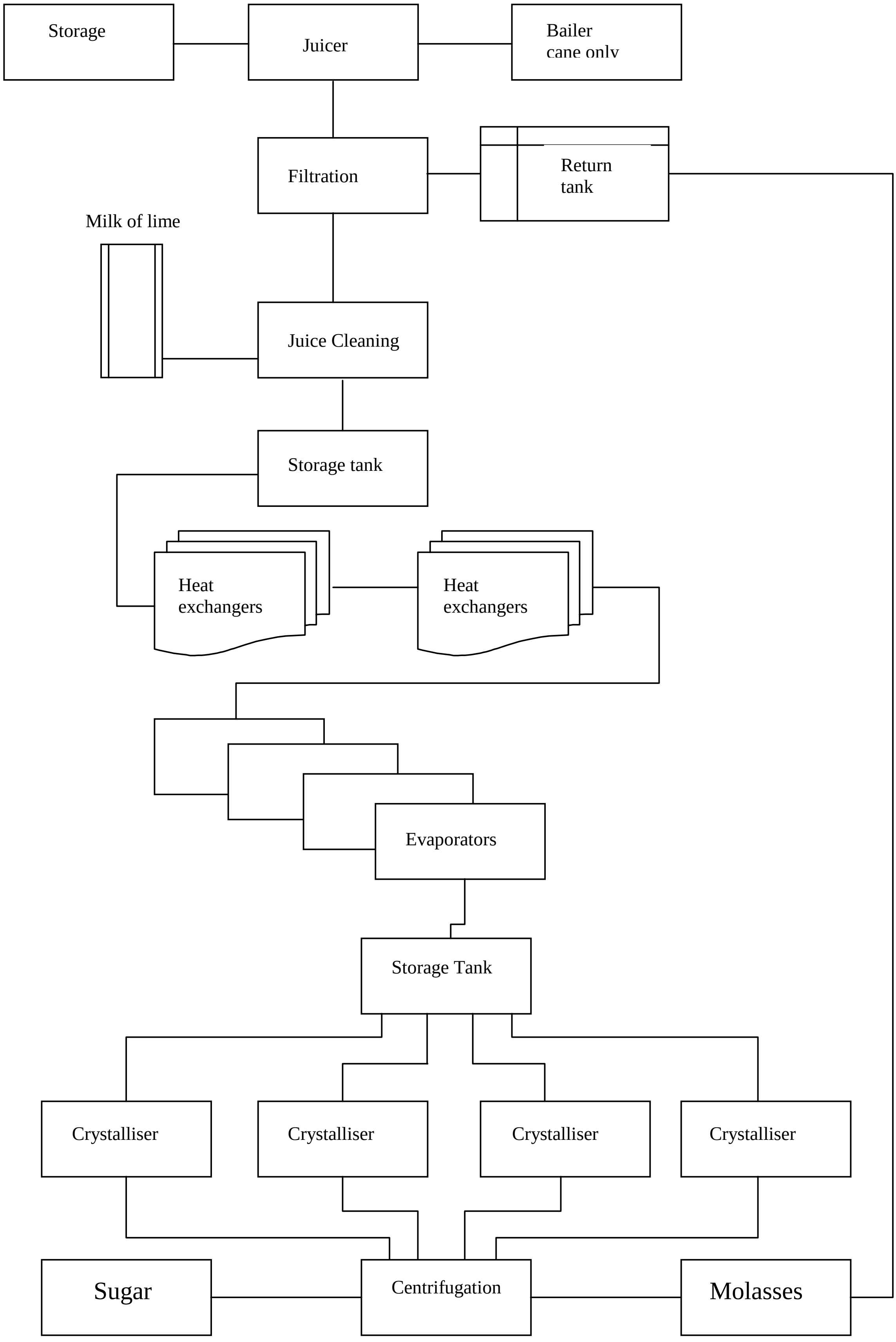
Sugar Beet



Sugar beet is a temperate climate biennial root crop. It produces sugar during the first year of growth in order to see it over the winter and then flowers and seeds in the second year. It is therefore sown in spring and harvested in the first autumn/early winter. As for sugar cane, there are many cultivars available to the beet farmer. The beet stores the sucrose in the bulbous root, which bears a strong resemblance to a fat parsnip. Typical sugar content for mature beets is 17% by weight but the value depends on the variety and it does vary from year to year and location to location. This is substantially more than the sucrose content of mature cane but the yields of beet per hectare are much lower than for cane so that the expected sugar production is only about 7 tons per hectare.

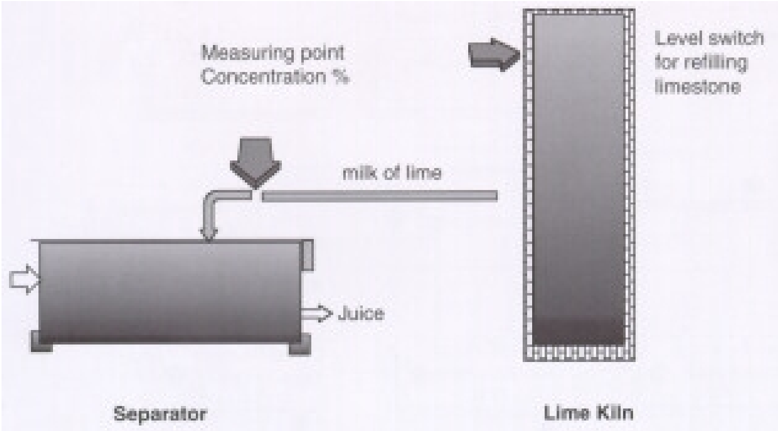
The World Sugar Production

Country	Total Production In million Tons	Total Export In million Tons	Total Population In millions	Consumption Per Capita In kilograms
Australia	5.5	4.7	19	45
Brazil	14.5	6	167	48
China	5.0	0	1300	3.8
E.U.	18	5.5	375	36
India	14	0.5	981	14
South Africa	2.5	1.1	45	30
Thailand	6	4	62	27
USA	6.5	0	269	30
World total	72			


Storage
Juicer
Bailer
cane only
Filtration
Return
tank
Milk of lime
Juice Cleaning
Storage tank
Heat
exchangers
Heat
exchangers
Evaporators
Storage Tank
Crystalliser
Crystalliser
Crystalliser
Crystalliser
Sugar
Centrifugation
Molasses

Juice Cleaning

Thin juice naturally contains a lot of impurities and many non-sugar substances, which are eliminated in the juice cleaning process. The juice is cleaned by adding milk of lime to the thin juice. This has two effects: Coagulation of the fine dirt particles; binding of organic fruit acids through neutralization with milk of lime and thus conversion into salts.



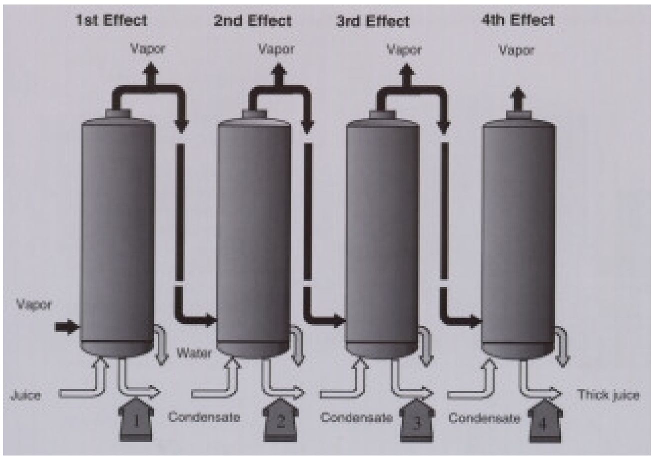
Concentrate of milk of lime

To produce milk of lime, limestone (CaCO3) is burned with coke in the limekiln. The burned lime is mixed with water and the result is called milk of lime.

Juice Thickening

Heating the juice in heat exchangers and then boiling the juice in vacuum chambers achieves juice thickening. The juice is then ready to begin the crystallisation process.

The multi pass heat exchanger used in the juice heating, use steam to heat the juice and are designed for easy access to the top and bottom, they are usually installed between floors for that purpose. This process is effected by precipitation of Calcium carbonate on the surfaces of the heat exchangers. A layer of scale .5mm thick will prevent the desired rise in juice temperature and will necessitate the introduction of a clean heat exchanger into the production line and the removal of the fouled exchanger in readiness for the cleaning process. As a result the overall production is restricted to half the heat exchangers. While the other half are being cleaned.



The process of cleaning involves the opening of the covers of the heat exchanger and the loss of large amount of juice; this process is wasteful; is time consuming and requires skilled labour not available within the sugar production plant. The covers weigh as mach as 500 Kg each. External contractors usually provide the cleaning service. The cleaning is done manually using long steel brushes or high power water jet equipment.

The introduction of ***Hydro*****FLOW** technology in strategic positions to apply an electrical field to the juice can eliminate the cleaning process thus enabling the use of all the heat exchanger and evaporators in the sugar plant, increasing production and reducing cost.

After the introduction of HydroFLOW in the system the heat exchangers and evaporators, remained free of deposits as illustrated in the photo above.

In order to understand the way this electrical field is applied, it is necessary to understand the basic theory of electromagnetic waves; their generation and effects and basic theory of transformers. It is also necessary to understand the fundamental principles of Crystallisation, scale-forming mechanisms, and hardness of water. This understanding will help to prevent some misconceptions held by many, including academics not involved directly in the field of electronics. These misconceptions can create total disbelief and can prevent a person taking this technology seriously.

FUNDAMENTAL PRINCIPLES.

CRYSTALLISATION.

Crystallisation normally occurs when a solution becomes supersaturated. A supersaturated solution is one that contains higher concentration of dissolved solute than its equilibrium concentration. However super saturation alone is not sufficient for a system to begin to crystallise. It is generally accepted that two steps are involved in the formation of microscopic crystals from supersaturated solutions: First, nuclei, minute crystalline entities of definite size must be formed (nucleation)

***Hydro*FLOW** technology can perform this step as described below; and second, these nuclei must grow (crystal growth). There are many other variables, which influence the nucleation and growth of crystals such as: The presence of the impurities; the turbulence within the system; the nature and state of the surfaces in contact with the solution etc.
There are two basic nucleation mechanisms:

- Homogeneous nucleation where the nucleus is formed spontaneously from the mother solution; and
- Heterogeneous nucleation where a foreign substance, (such as an impurity), a metal surface or another nucleus acts as a seed for precipitation to occur.

Any crystallising system is characterised by the generation of a spectrum of differently sized particles under conditions where new crystals, generated through nucleation, are being advanced in size by crystal growth and are interacting with existing crystals in a complex and unpredictable manner.

SCALE FORMING MECHANISMS.

Both homogeneous and heterogeneous nucleation are of interest in scale deposition mechanisms, although it is unlikely that homogeneous nucleation occurs very often in sugar production (except when ***Hydro*FLOW** is installed). In fact, homogeneous nucleation only occurs in bulk solution away from surfaces when super-super saturation has been reached (this condition doesn't exist in sugar production). There are many potential nucleation sites for heterogeneous precipitation: suspended particles in the solution, the walls of a pipe of the heat exchanger, welds and other stress points in metals, oxide films, fingerprints etc. Once nucleation has occurred, crystal growth on existing nuclei follows rapidly.

If nucleation occurs on the pipe or vessel wall, scale growth would continue and the observed deposit is a hard encrusted layer (eggshell; in sugar production .5mm scale is enough to disrupt production). This type of scale requires aggressive techniques (acid washing or scraping) to dislodge. If, on the other hand, nucleation occurs on suspended particles in the body of the solution, scale growth would continue within the solution until the crystals are large enough to settle as sludge in the bottom of the heat exchangers. This type of scale is not encrusting and can be dislodged easily either by brushing or hosing under moderate pressures. The amount of settled deposits in sugar production is small and it may be removed occasionally by opening the bottom of the heat exchangers. If ***Hydro*FLOW** is installed, most of the scale is formed in the form of suspended crystals 10-50 micron in size and will finish in the final sugar (> 0.0001%).

INDUCTION.

Induction is the creation of an electric current in a conductor moving across a magnetic field (hence the full name, electromagnetic induction).

ELECTRIC GENERATOR.

When a conductor, such as a wire, moves through the gap between the poles of a magnet, the negatively charged electrons in the wire will experience a force along the length of the wire and will accumulate at one end of it, leaving positively charged atomic nuclei, partially stripped of electrons, at the other end. This creates a potential difference, or voltage, between the ends of the wire. If a conductor connects the ends of the wire, a current will flow around the circuit. This is the principle behind the rotary electric power generator, in which a loop of wire is spun through a magnetic field so as to produce a voltage and generate a current in a closed circuit.

ELECTRIC TRANSFORMER.

Induction occurs only if the wire moves at right angles to the direction of the magnetic field. This motion is necessary for induction to occur, but it is a relative motion between the wire and the magnetic field. Thus, an expanding or collapsing magnetic field can induce a current in a stationary wire. Such a moving magnetic field can be created by a surge of current through a wire or electromagnet (the primary coil in the ***Hydro*FLOW** unit). As the current in the electromagnet rises and falls, its magnetic field grows and collapses (the coaxial magnetic lines. The lines of force move outwards, then inwards). The moving field can induce a current in a nearby stationary wire (the pipe and the juice in it). Such induction without mechanical motion is the basis of the electric transformer. A transformer usually consists of two adjacent coils of wire wound over a single core of magnetic material (the ferrite ring). It is used to couple two or more AC circuits by employing the induction between the coils.

When the current in a conductor varies, the resulting changing magnetic field cuts across the conductor itself (the Juice in the pipe) and induces a voltage in it. This self-induced voltage is opposite to the applied voltage and tends to limit or reverse the original current. Electric self-induction is thus analogous to mechanical inertia. An inductance coil, or choke, tends to smooth out a varying current, as a flywheel smoothes out the rotation of an engine.

HARDNESS.

Salts of calcium are dissolved in the Sugar Juice due to the clearing process. These take the form of bicarbonates of calcium.

TEMPORARY HARDNESS-ALKALINE HARDNESS.

Calcium decomposed by the action of heat, part of the carbon dioxide then being released:

$Ca(HCO_3)_2$ ------> $CaCO_3 + H_2O + CO_2$

Calcium bicarbonate Calcium carbonate.

Since the simple action of heating the juice will remove bicarbonates the term "temporary" has been used, although this could be called "Alkaline hardness" as a precise distinction.

DISSOLVED SOLIDS.

The mineral salts found in juice are present as a result of the milk of lime process. These substances do not exist in solution as definite compounds, but as "ions" - charged soluble particle of metal (known as cations) or as acid radicals (know as anions). The most commonly occurring cations are:

Calcium Ca++

The most commonly occurring anions are:

Bicarbonate HCO3-

The negative and positive signs indicate polarity of electron charge. The negative sign indicated electron gain, positive sign electron loss. Contaminants can be grouped according to polarity and magnitude of charge.

The ***Hydro*FLOW PATENTED TECHNOLOGY**

A unique and new approach to physical solute treatment

The most important feature of the ***Hydro*FLOW** technology that sets it apart from that of any competing technology is the efficient manner by which the electric field is directionally generated through the entire system.

This unique advantage protected by international patents singularly delivers consistently beneficial results in industrial, commercial, and domestic applications.

***Hydro*FLOW THEORY OF OPERATION**.

A sugar production plant must be regarded as an open circuit from the electrical point of view. It would be impractical and expensive to form a reliable circuit from a sugar production plant whereby an electrical current flows through every section of the plant.

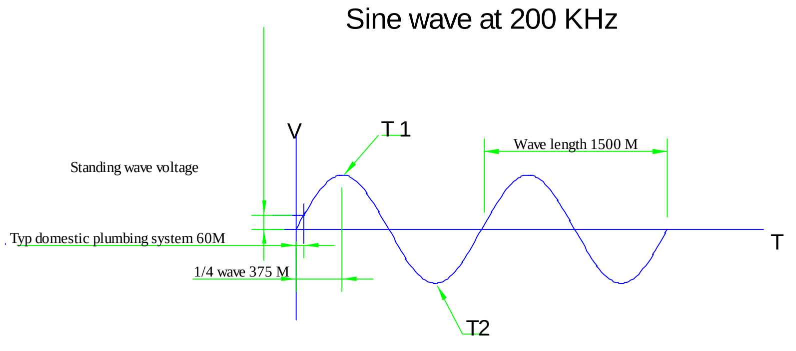


Fig. 5

To generate a reasonable flow of electrons in an open circuit conductor, it is necessary to provide a source of high frequency to a conductor that is long enough to generate a standing wave voltage over its length. Fig 5 shows a sign wave of 200 KHz. The wavelength is 1500 m; the ¼ wavelength is 375 m. A sugar production plant pip work in the relevant section is approximately 100 m. If the source is 29 V then the standing wave voltage will be [sin ((100/375)*90)]*29 = 11.79V between one end of the plant and the other. This voltage difference between the extremities of the pipes is caused by a substantial flow of electrons from one end to the other of the system. Fig 6 represents the position at T 1 on Fig 5 and Fig 7 represent the position at T 2 on Fig5.

To achieve this flow of electrons in the sugar plant, a voltage must be generated in the juice in the direction of the pipe. This is achieved by utilising a high frequency transformer. This transformer consists of a ferrite ring around the juice pipe. A primary coil is wound around the ferrite ring. Any conductor, the juice and the pipe (if it is a conductive material) will form parallel secondary windings of the transformer. The signal that is fed to the primary coil is a high frequency diminishing wave with random wait periods. This wave is designed to allow the formation of seed crystals for a variety of crystal forming ionised salts conditions that may be present in the juice.

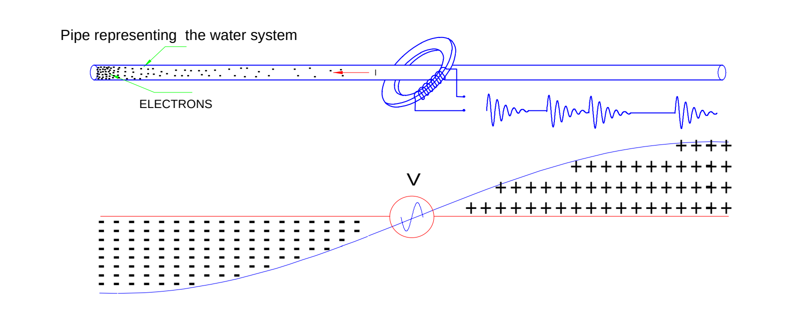


Fig. 6

Fig. 6 and Fig. 7 illustrate the diminishing wave and the voltage V over the sugar plant at specific times marked T1 and T2 in Fig. 5, as well as the position of the electrons, and the positively charged atoms in the conducting juice (and pipe), at maximum voltage position. [V] Is the voltage generated by the ferrite ring and. [I] is the accelerated charge generated

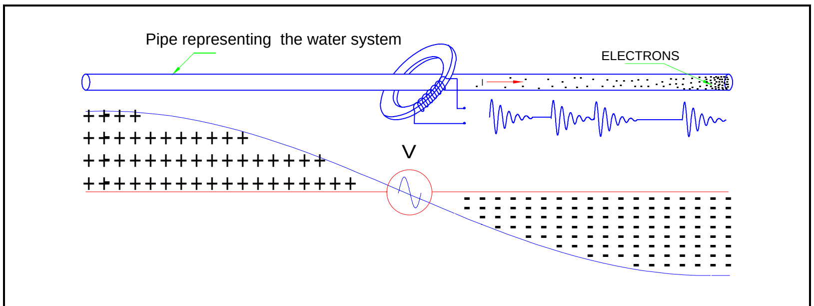


Fig. 7

due to the standing wave.

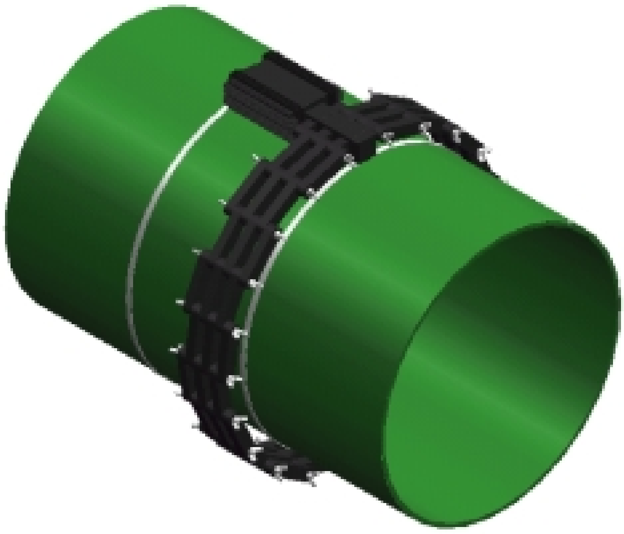
It is this acceleration that forms the electromagnetic field. The electric component is responsible for the generation of nuclear clusters that act as seed crystals to prevent the formation of encrusting scale.

SCALE REMOVAL.

In a scaling system there are three processes that are at work: Heterogeneous crystallisation, homogeneous crystallisation and the return to solution of the scale when the solute has become unsaturated. Heterogeneous crystallisation occurs mainly on surfaces that are subject to increasing temperatures. Homogeneous crystallisation occurs in large vessels containing a large volume of solute with relatively small surface area, as the solute is being heated, the solution becomes supersaturated. The surface area is not sufficient to provide all the nucleation necessary. The solute reaches a critical condition. At this point any source of energy, like turbulence in the solute will cause homogeneous nucleation. A large number of small crystals are formed. These crystals have a high surface charge that causes them to adhere to all the surfaces. The fine crystals adhere to the surfaces and will become the nuclei for heterogeneous crystallisation in subsequent heating cycles. This process explains the reason for scale deposits on surfaces other than the ones being heated. The third process is the return to solution of the scale deposits. After the solute has become unsaturated due to turbulence, a quantity of the deposits will be returned to solution. In addition some scale will return to solution when new unsaturated solute is introduced.

In every system containing solute, there is a balance of scale-formation and scale-solution. In a system where the balance is in favour of scale-formation, the system will experience scaling. In a system where the balance is in favour of scale-solution, the system will remain free of scale in a sugar heat exchanger both conditions exist due to turbulence.

***Hydro*FLOW** simply tips the balance in favour of the scale-solution, by providing a large quantity of unsaturated solution due to the increased pressure near the heat exchanger pipes walls, which dissolve the existing scale. ***Hydro*FLOW** provide seed crystals to precipitate the dissolved solids in suspension. This occurs when the solution become super-saturated due to the reduced pressure and increased heat. Since the heterogeneous crystallisation is replaced by homogeneous crystallisation. But in this case homogeneous crystallisation occurs in the middle of the heat exchanger pipes.



Sugar Crystallization

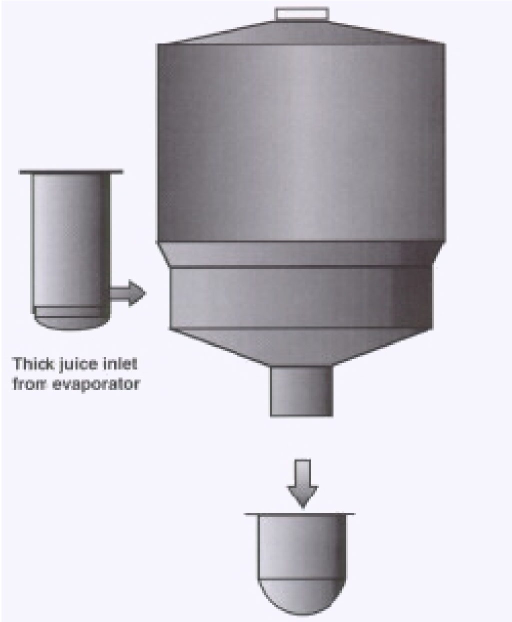
Crystallisation can occur in batch or continues vacuum Pans

Batch Vacuum Pans.

In a batch vacuum pans, the hot and thickened juice is stored in a insulated storage tank a quantity of thickened juice is introduced to the vacuum pans, vacuum is applied and seeding is started by introducing sugar crystals from the end of the line.

Continues vacuum pans

In continues vacuum pan system, the juice is feed directly from the evaporators to the vacuum pan in which the process of concentration continues. At the same time crystallisation of the white more voluble sugar is started by seeding the thick juice with brown sugar from the end of the line.



The brown sugar is produced in a similar continues vacuum pan. The remaining juice is returned to the beginning of the line.