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Date: November, 2013
Comparison between SRI and Rapi Dorr Clarifiers in Sugar Cane Juice


Ali Babiker Ali Attia

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Date of Examination: 6/11/2013
Dedication

To my father and mother who taught me the meaning

Of life may god bless them

To my wife son and daughters

To my brothers and sisters with sincere wishes to achieve their ambition

To all those who encouraged me to carry out this research work
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Sincere thanks to my colleague and Quality control lab staff in Kenana Sugar Factory and staff of Sugar Institute University of Gezira for their support and hospitality.

Finally, I shall be falling in duty if I do not say a word of appreciation to my small family for their enduring my absence, who helped me in every possible way and their encouragement. Sincere thanks are due to Lab of Agriculture Economic for formatting this thesis.
Comparison between SRI and Rapi Dorr Clarifier in Sugar Cane Juice Purification:
A Case Study of Kenana Sugar Factory (2004-2006)

Ali Babiker Ali Attia

ABSTRACT

The study was done in Kenana Sugar Factory in the period (2004-2006) and was concentrated on the performance of the SRI clarifiers, which are recently introduced. The SRI were compared to the Rapi Dorr which were installed since the start up of the factory in 1979. The importance of the topic raised from the fact that clarification is considered as the heart of sugar manufacturing process. The purpose of clarification is the precipitation and removal of all possible non-sugars, organic and non-organic, and the preservation of the maximum sucrose and reducing sugars possible in the clarified juice. Poor clarification of cane juice complicated the entire process of sugar manufacturing. The objective of this study is to evaluate and improve the performance of the new SRI clarifiers through a comparative study with the previous system (Rapi Dorr Clarifiers) at Kenana Sugar Factory. To achieve this objective, all parameters affecting clarification performance for both clarifiers were studied. The outcome of the study showed that the pH range of clarified juice from SRI clarifier is always slightly higher than the Rapi Dorr clarified juice. This due to less retention time in SRI clarifiers. On the other hand the SRI clarified juice purity is always higher and hence the sucrose loss is less for SRI clarifiers and the reducing sugars is more in Rapi Dorr clarifier due to the mentioned drop in pH and longer retention time in Rapi Dorr. Likewise the turbidity results in SRI clarified juice is always better than Rapi Dorr through the crop except in one case at very high flow rate. For the P$_2$O$_5$ content in clear juice there is no clear difference except at very high flow rate, where clear juice from SRI showed less P$_2$O$_5$ than the Rapi Dorr. This may be due to more drop in temperature in Rapi Dorr clarifier that retard the reaction where no such chance for temperature drop in SRI clarifier. Comparing between colour of clear juice for SRI and Rapi Dorr clarifiers, it is quite clear that the best performance of the SRI clarifier is in the mid season, where during early and late season with low purities, the performance of SRI clarifier
depends on juice flow rate. Only with the high flow rate and lower purity in early and late season, the old clarifiers showed better color results. Finally a number of recommendations were stated at the end of the study, to make best use of the SRI clarifiers as they are the simplest, lowest investment cost and maintenance cost.
دراسة مقارنة مرسبات Rapi Dor و SRI لتنقية عصير قصب السكر في مصنع سكر كنانه موسم 2006-2004
علي باكير علي عطية

ملخص الدراسة

هذه الدراسة تمثل في مصنع شركة سكر كنانه في موسم 2006/2004. تركزت الدراسة في المقارنة بين نوعين من المرسبات: Rapi Dor و SRI. أهمية الدراسة تكمن من أن محط التنقيح في مصنع السكر تمثل القلب من العمليات التحضيرية حيث أن كل ما بعدها يتعلق بها. عمليه التنقيح في الماشية التي فصلت في خلالها يتم ترسيب كل المواد الغير مرغوب فيها من العصير. بدون توحيد عمليه التنقيح لا يمكن الحصول على سكر ذو نوعية جيدة تتمتع بالكاملية الداخلية و خارجياً ولا الكمي الاقتصاديه المطلوبة. الهدف من الدراسة هو المقارنة بين المرسبات المختلفة وتقدير أدائها من خلال رصد نتائجها و الوقوف على نقاط لتحسين الأداء. للوصول لهذا الهدف تم تحليل العصير النقي الخارجي من كلها أذ أن العصير الداخل "المخلوط" واحد. أخذت العينات أول الموسم و منتصف الموسم آخر الموسم. التحاليل التي تم التركيز عليها لأبراز كفاءه المرسبات هي الرقم الهايدروجيني و معدل التدفق, النقاوه , العكاره و الفوسفات الذائب الحر في العصير النقي. أثبتت النتائج أن الرقم الهايدروجيني العصير الناتج من مرسب SRI أعلى قليلاً من الرقم الهايدروجيني الناتج من مرسب Rapi Dorr. كما أن النقاوة أعلى في العصير الناتج من مرسب Rapi Dorr في العصير الناتج من مرسبات Rapi Dorr و فتره مكوث العصير الأطول فيه من أهم أسباب الحصول على نقاوه أقل و سكريات مختزله أعلى بالنسبة للعكاره فكانت النتائج دائمًا أفضل في حالة المرسبات الجديدة في حالة واحدة كانت كمية العصير المتشفية العصير زائدة بصورة كبيرة. على نفس المنوال أظهرت النتائج أن كمية الفوسفات الحر في العصير الناتج من كل النوعين على درجة واحده الا في حالة الزيايده الكبيره للعثور، حيث كان أداء المرسب الجديد أفضل. يبدو أن الالليا و درجه الحراره في درجه الحراره في المرسب القديم لطول مكث العصير (2.5-3.00) ساعه و سعته الكبيرة مقارنه بالSRI و الفوسفات (CaO & P2O5) هذا العامل غير موجود في المرسبات الجديدة أذ لا وقت للنقطة لدرجة الحراره و لأن درجه الحراره عامل حاسم في التفاعل من قبل الزمن. في نهاية البحث أدرجت عدة توصيات معوله على استخدام المرسب الجديد و تحديد النقاط التي تحافظ على كفاءته و ترفعها أذ أنه الأسيب و الأقل ثمناً و الأقل تكلفه في الصيانه.
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LIST OF ABBREVIATIONS

Pol the apparent sucrose present in sugar containing materials.
Bx Brix (Dissolved solids in sugar bearing liquid)
ICUMSA International Commission for Uniform Method for Sugar Analysis
SRI Sugar Research Institute (Name of the Clarifier)
Rs Reducing Sugars, glucose or fructose.
EDTA Ethylenediaminetetraacetic acid $\text{C}_{10}\text{H}_{16}\text{N}_{2}\text{O}_{8}$
PH #1 PHASE # 1
pH $\text{pH}$ is a measure of $\text{hydrogen}$ ion concentration; a measure of the acidity or alkalinity of a solution
OH $\text{OH}$ is a measure of hydroxyl ion concentration; a measure of the acidity or alkalinity of a solution.
$\alpha$ Alpha
$\beta$ Beta
CHAPTER ONE
INTRODUCTION

This study was carried out in Kenana Sugar Factory. It may be mentioned here that Kenana Sugar Company operates one of the world's Largest Sugar Cane estate and sugar refinery ever established as a single integrated development project. The Factory has crushing capacity of 25,000 tonnes cane per day and is capable of producing up to ward of 400,000 tonnes of refined sugar per year. In Kenana Sugar factory the clarifier station divided in to two phases, phase one and phase two. The SRI (only tow clarifiers) were installed recently in phase one, the Rapi Dorr (five units) four of them were installed since the start up of the factory in 1979. The process block flow diagram of Kenana Sugar Factory is shown in Figure. 1.1.

The importance of the topic raised from the agreed upon fact that consider clarification as the heart of the sugar manufacturing. The main objective of mixed juice clarification to achieve the following goals according to (Kulkarni, 1996):

a) Removal of maximum non-sugar.

b) Elimination of suspended and colloidal impurities.

c) Removal of color forming compounds.

d) To obtain brilliant, light colored, transparent clear juice free from any suspended impurities.
As stated by Kulkarni (1996), removal of non-sugar impurities helps in the processing with respect to the following factor:-

a) Better crystallization of sugar.
b) Production of white sugar free from complications.
c) Low final molasses purity which means less sugar loss in final molasses

Clarification process in cane sugar manufacture is not a simple process. It is a combination of many reactions depending on the constituents, shown below according to (Kulkarni, 1996):

a) Protein in contact with heat for longer period form amino acid.
b) Gums and pectin's also form complex organic acids known as Uronic acids.
c) Colouring compounds and colour forming

These compounds are very dangerous and play vital role in clarification, and in the further process of manufacture of sugar.

As stated by Baikow (1982) every sugar technologist knows that, without good clarification of sugar cane juice, the production of good quality raw sugar is impossible. The purpose of clarification is the precipitation and removal of all possible non-sugars, organic and non-organic, and the preservation of the maximum sucrose and reducing sugars possible in the clarified juice. Poor clarification of cane juice complicates the entire process of sugar manufacturing.
A patent review of clarification, sedimentation and thickening equipment shows that clarifiers in the sugar industry have progressed from batch tanks, to continuous tanks, and since 1915 multi-tray designs were introduced.

These multi-tray designs were described in the review as significant advance, and to “since capacity is proportional to settling area, and since each compartment acts as an individual unit. Thus each added tray increases the original single compartment tank 100 percent. The economic advantages of these types of construction both head and operating costs which is really appreciated.

Recently in juice clarification it is very difficult to depend on one system to produce the best results for all types of juices. With development of mechanical harvesting and the introduction of impurities and extraneous matter to the process, the clarification station should be carefully studied to adapt to the new condition.

The objective of this study is to evaluate and improve the performance of the new SRI clarifiers through a comparative study with the previous system (Rabi Dorr Clarifiers).

To achieve this objective, a number of parameters influencing clarification were studied through off- line (laboratory experimental work) and on- line (production line), this in addition to discussion on flash tank design and its important role in clarifier performance.
FIG. 1.1 Kenana Sugar Factory Process Block Diagram
CHAPTER TWO
LITERATURE REVIEW

2.1 Chemical properties of sucrose

2.1.1-Structure of the sucrose molecule

Sucrose (Saccharose, cane sugar or Beet sugar) is a carbohydrate of the brutto formula $\text{C}_{12}\text{H}_{22}\text{O}_{11}$; consisting of two mono saccharidic components: D-glucose and D-fructose. The monosaccharidic components are condensed at their glycosidic groups. These two glycosidic groups, which in the free monosaccharides, show an equilibrium of $\alpha$- and $\beta$-configuration, are fixed in the sucrose molecule in $\alpha$-configuration at the glucose component, and in $\beta$-configuration at the fructose component. Whilst the glucose component is bound in its normal pyranosidic form, the fructose component shows, in the sucrose molecule an anomalous furanosidic form that is not observed in free fructose.

In agreement with these facts, the exact chemical name of sucrose is $\alpha$ -D-glucocyranosyl- $\beta$ -D- fructo-furanoside according to (Hirschmuller and Benson, 1949) as shown in Fig 2.1.

Sugar is formed in plant by the action of sun light, the presence of chlorophyll, by which CO$_2$ from the air combines with water forming sugar. Then the sugar travels from leaves to other parts and it stored in the stem as shown in the following equation:
$6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{Sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 - \Delta H$

$\Delta H = 2870 \text{ kg/m}$

**FIG 2.1 Sucrose Chemical Formula**

- **Glucose**
- **Fructose**
- **Sucrose**
2.1.2 Decomposition of sucrose

2.1.2.1 Hydrolysis

In the presence of hydrogen ions (or of certain ferments) a hydrolytic decomposition of dissolved sucrose takes place. A tautomeric mixture of the α – and β – cyclic, and the aliphatic forms of D-glucose and fructose is formed. As the furanoid cycle is not stable in free fructose, pyranoid fructose cycles are formed according to (Hirschmuller and Levi, 1950).

If purest sucrose (when rotation = 100° S in leaner scale is hydrolyzed, a rotation of the plane of polarized light corresponding to -33° S is observed. Because of this transformation of the dextrorotary sucrose to the levorotary mixture of monosaccharides, the process of hydrolysis is named inversion, and the equivalent mixture of D-glucose and D-fructose is named invert sugar. The rotation is not constant immediately after the inversion (multirotation), because the equilibrium between the different tautomers is obtained slowly as stated by (Hirschmuller and Bates, 1942).

Under normal circumstances when water is in great excess, the dimolecular reaction between sucrose and water may be regarded as a unimolecular (pseudounimolecular) reaction. Presuming this, the velocity of inversion is \( dc/dt = k*C \), where C is the actual concentration of sucrose, K the velocity constant, t the time. The velocity constant is to be measured. E.g. by change of rotation during the process.
It is

\[ K = \frac{1}{t} \ln \frac{R_\infty - R_t}{R_\infty - R_0} \]

Where \( R_0 \) and \( R_\infty \) are respectively the initial and final rotation and \( R_t \) is the rotation at the time \( t \) according to (Hirschmuller and Bates, 1942).

Experiments showed that \( R \) is not quite independent of the sucrose concentration but increase where the concentration is augmented.

The displacement of the constant \( K \) with the temperature follows the equation.

\[ \frac{d \log K}{dt} = \frac{Q}{RT^2} \]

as stated by Hirschmuller and Bates (1942)

In which \( Q \) represents the energy of activation, \( R \) is the gas constant, and \( T \) the absolute temperature. The energy of activation was found to be 25.9 k cal at \( 20^0 \text{C} \); it faintly decreases with increasing of temperature.

Furthermore \( K \) depends on the concentration of \( H^+ \)- ions (\( H_2O^+ \)-ions). In small \( H^+ \)-concentrations (not more than \( \{H^+\} = 0.01 \) mole per liter, respectively not less than \( \text{pH} 2 \)), \( K \) is proportional to \( \{H^+\} \); in greater concentration, \( K \) increases to more than proportional to the \( H^- \)-concentration or \( H^+ \)-activity as stated by Hirschmuller and Heidt (1940). The different inverting power of different dissociation of the arids, but exceptions to this rule was reported. The effect of neutral salts on the inversion also generally is indicated by their different buffering power
causing changes in pH. However, many exceptions to this rule were observed. Usually an increase of velocity by salts is observed, but also inhibiting effects, especially of heavy metal ion, were reported. Nevertheless, for most purposes a previous calculation of the inverted quantity of sucrose is possible by means of the constant found by (Hirschmuller and Natl. Bur. ,1942). (table 2.1)

Table 2.1: Velocity constant of the inversion of sucrose.

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>Velocity constant K At pH 2</th>
<th>Time for 99.99 percent Inversion, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.000 01899</td>
<td>3511</td>
</tr>
<tr>
<td>40</td>
<td>0.000 3186</td>
<td>209</td>
</tr>
<tr>
<td>60</td>
<td>0.00 3806</td>
<td>17.5</td>
</tr>
<tr>
<td>80</td>
<td>0.0 3303</td>
<td>2.02</td>
</tr>
<tr>
<td>90</td>
<td>0.08982</td>
<td>0.74</td>
</tr>
</tbody>
</table>

Reference Honig (1953)

2.1.2.2 Alkaline decomposition of sucrose solution

When sucrose solutions are heated in presence of OH- ions, decomposition takes place. The formation of furfural, 5-hydroxy-2-furfural, methyl-glyoxyl, glyceraledehyde, dioxyacetone, acetone, lactic acid, trioxyglutaric acid, acetic acid, formic acid, carbon dioxide, and other substances is observed by Hirschmuller and Bergdoll (1951). In first line lactic acid is formed, under certain circumstances up to 75 percent of the weight of decomposed sucrose (theoretical yield = 100
percent). Under normal circumstances of the evaporating or boiling process in sugar technology, about 3 g-equivalents of acids are formed per one mole of decomposed sucrose.

In a solution of sucrose with lime of pH value 12, the sugar loss in 1 hour boiling under normal pressure was found to be about 0.5 % according to (Hirschmuller and Spengler, 1936).

The sugar loss at other pH’s, temperature or periods of time may be calculated on an average; it is about three times higher per one unit rise in pH or per 10 degrees centigrade rise in temperature, and in the case of small losses, nearly proportional to the length of time. (It is exactly proportional to the length of time when the percent of sugar loss is not related to the total quantity of sucrose given into the solution but to the actual quantity of not yet decomposed sucrose in the actual quantity sucrose in the solution).

The decomposition of sucrose is accompanied by formation of undefined mixtures of substances in small quantity but of very intensive brown color. There is no strict relation between formation of acids, and formation of colored substances. But generally a higher decomposition of sucrose causes a higher coloration. Impurities can have color-inhibiting or color-promoting influence.

Because of the formed acids the alkalinity of solutions decreases during the alkaline decomposition. The minimal decomposition of sucrose takes place approximately at pH 9, where the H- concentration (causing
inversion), and the OH-concentration (causing formation of acids and color) are small according to (Hirschmuller and Spengler, 1936).

2.1.2.3 Thermal Decomposition of dry Sucrose

At temperature bellow the melting point, the decomposition of sucrose is slow. When molten sucrose is further heated, a rapid decomposition takes place.

Refined sugar, heated for a time to melting temperature, decomposes without loss in weight into D-glucose and D-fructosan (i.e. D-fructose-1-H₂O). When this mixture is dissolved in water, the D-frutosan is transformed to D-fructose and invert sugar is obtained (thermal hydrolysis of sucrose). When purest sucrose is heated to melting temperature, the decomposition is greater than that of commercial refined sugar.

The formation of colored substances remains slow at melting temperature but very intensive at higher temperature. At about 200°C a dark brown mass is resulting in a mixture of various brown–coloured substances which are soluble in water, not sweet and fermentable. Such mixture is named caramel. Many investigations were made in the older literature in order to determine the composition of caramel. But the old literature is extremely unreliable due to the individual approach of the old sugar research chemists in naming the different products. They talk about 'glucinic acid', 'apolgucinic acid', 'humic acid', "saccharic acid" and similar terms without proper identification of the formed products. As for
caramel, a 'caramelan,' 'caramelen' 'carmmelin', 'fuscaizinic acid', 'saccharan' etc, were prepared from caramelized sucrose, and brutto formulas were given, as e.g. C_{12}H_{18}O_9 for the 'saccharan', as stated by (Hirschmuller and Ambler, 1935).

2.1.2.4 Decomposition by strong mineral acids

Concentrated strong mineral acids, especially sulfuric, phosphoric, and hydrochloric acid have a dehydrating effect on sucrose according to H. Hirschmuller and Takahashi, (1944).

'Humic acids', and finally sugar char are formed, and volatile substances, e.g. formic acid, carbon dioxide, are developed besides reduction products of the applied acid (e.g. sulfur dioxide). Under mild conditions, in smaller acid, concentrations or in alcoholic hydrochloric acid, hydroxymethyl furfural and levulinic acid (CH_3–CO–CH_2–CH_2–COOH) are obtained in high yield as stated by (Hirschmuller and Wiggins, 1949).

2.1.2.5 Oxidation

At the combustion of sucrose, carbon dioxide and water formed. With potassium permanganate in neutral or acid solution, carbon dioxide, formic acid, acetic acid, and oxalic acid are obtained, while in alkaline solution sucrose is quantitatively changed to carbon dioxide and oxalic acid.

With hydrogen peroxide the observed reaction products are oxygen, hydrogen, carbon dioxide, formic acid, and other acids and aldehydes.
When ammonium vanadate or similar catalyzers catalyze the oxidation with nitric acid, oxalic acid is produced in 70 percent of the theoretical yield. It is possible, however, to arrest the oxidation before this stage is reached, and tartaric acid is obtained instead of oxalic acid as stated by (Hirschmuller and et al, 1945).

2.1.2.6 Reduction

Sucrose can be reduced by hydrogen in the presence of metallic acid catalyzers. The main products of the hydrogenation are D-mannitol, D-sorbitol, glycerol, propylene glycol, ethylene glycol, isopropyl alcohol, methyl alcohol, acetol, tetrahydrofuran derivatives etc according to (Hirschmuller and Wiggins, 1949).

2.1.2.6 Biochemical reaction

The hydrolysis of sucrose into D-glucose and fructose is catalyzed by certain ferments. The two monosaccharidic components being connected in the sucrose molecule at their glycosidic groups, two glycosidases are capable of hydrolyzing the sucrose molecule. Namely α-glycopyranosidase (α-glycosidase, maltase) present, e.g. in yeast. After hydrolysis the formed invert sugar can be fermented to alcohol, lactic butyric, acetic acid, etc. By means of suitable ferments, further degradation products of sucrose (e.g. citric acid, butanedioleetc) are available by biochemical reactions from sucrose.
Beside hydrolysis, biochemical reactions of alcoholytic, glycerolytic, phosphorylytic, and arsenolytic decomposition of sucrose are known.

During the enzymatic hydrolysis of sucrose, a trisaccharide, kestose, is formed in small amount.

Some polysaccharides are formed from sucrose by biochemical reactions. The most important of them in sugar technology is the dextran, which is produced by leuconostoc mesenteroides, dextranicum, Betacoccus arabinosaceus, and by some other bacteria from sucrose. Dextran is a polysaccharide consisting of D-glucose components. Branched chains were determined, with a cross linkage for every repeating unit of five D-glucose molecules and 1.6 – linkages within each repeating unit. Sucrose was found to be the only suitable carbohydrate substrate. pH8 and room temperature were found to be favorable for dextran production. Sulfure dioxide is used to control the growth of levconostoc, and lime to remove the dextran. However, traces of dextran still exist in practically all sugar products.

Other polysaccharides of the starch-glycogen type are produced (besides fructose) by bacteria of the Neisseria genus.

Other bacteria, e.g., Aerobacter levanicum, produce levan, a polysaccharide consisting of D-fructose components (D-fructofuranose molecules with linkages at the positions 2 and 6 of the D-fructose units) (Hirschmuller and Hehre et al, 1946).
2.2 Physical properties of sucrose

2.2.1 Sucrose molecule

The molecular weight of sucrose is 342.296. The calculation from grams of Sucrose to moles of sucrose, and vice versa, is facilitated by the multiples in Table 2.2

<table>
<thead>
<tr>
<th>Grams of sucrose</th>
<th>Moles of sucrose</th>
<th>Moles of sucrose</th>
<th>Grams of sucrose</th>
</tr>
</thead>
<tbody>
<tr>
<td>342.296</td>
<td>1</td>
<td>0.29214</td>
<td>100</td>
</tr>
<tr>
<td>684.592</td>
<td>2</td>
<td>0.584290</td>
<td>200</td>
</tr>
<tr>
<td>1026.89</td>
<td>3</td>
<td>0.876435</td>
<td>300</td>
</tr>
<tr>
<td>1369.18</td>
<td>4</td>
<td>1.16858</td>
<td>400</td>
</tr>
<tr>
<td>1711.48</td>
<td>5</td>
<td>1.46072</td>
<td>500</td>
</tr>
<tr>
<td>2053.78</td>
<td>6</td>
<td>1.75287</td>
<td>600</td>
</tr>
<tr>
<td>2396.07</td>
<td>7</td>
<td>2.04501</td>
<td>700</td>
</tr>
<tr>
<td>2738.37</td>
<td>8</td>
<td>2.33716</td>
<td>800</td>
</tr>
<tr>
<td>3080.66</td>
<td>9</td>
<td>2.62930</td>
<td>900</td>
</tr>
</tbody>
</table>

Reference (Honig, 1953)

The normal entropy (i.e. the entropy at 25°C and 760 mm press.) of sucrose is 86.1 Cl = (86.1 cal / absolute) per mole.

The entropy of formation (i.e. content of C_{12}H_{22}O_{11} crystal. minus content of heat of 12C graphite, 11H_{2} gas, and 5.5O_{2} gas) at 25°C and 760 mm pressure is -530.8 kcal per mol; accordingly the heat of formation
(i.e. the heat delivered from this hypothetical synthesis) is 530.8 kcal per mol.

The work of formation stated by H. Hirschmuller and Hufman (1932) amounts to – 317.6 kcal per mol at 25\(^0\)C and 760 mm pressure; accordingly the maximum available work from the mentioned hypothetical synthesis is 317.6 kcal per mol.

The enthalpy of combustion as stated by H. Hirschmuller and Henning (1921) (Content of heat of \(12\text{CO}_2\) gas and \(11\text{H}_2\text{O}_{\text{liq}}\), minus content of heat of \(\text{C}_{12}\text{H}_{22}\text{O}_{11}\) crystal. And \(12\text{O}_2\) gas) is -1351.3 kcal per mole; accordingly the heat of combustion is 1351.3 kcal per mol or 3.949 kcal per gram of sucrose.

2.2.2 Crystallized sucrose

Crystallographic, piezoelectric, and X-ray investigations prove that there are no different modifications of sucrose, as formerly suggested by (Hirschmuller, and Narry, 1940).

The sucrose crystallizes in monoclinic system, forming monoclinic hemimorphic (sphenoidal) crystals." The ratio of axis is \(a : b : c = 1.2595 : 1 : 0.8782\); the angle \(\beta = 103\;30'\). Usual forms are \{100\}, \{001\}, \{101\}, \{110\}, \{110\}, \{111\}, \{101\}. The crystals have a prismatic habit. Impurities have a remarkable influence on the form and habit of the crystals according to (Hirschmuller and Springer, 1947).
The optical axis are nearly perpendicular to the (100) and (101) faces. The angle between them is 48. The axis of intermediate refraction coincides with the b reference axis of the crystal.

2.2.2.1 Solubility

Sucrose is very soluble in water; the solubility increases with an increase of temperature. The solubility of sucrose in water is not quite certain, especially for temperature exceeding 600°C.

The solubility of sucrose in water is influenced by other solute substances, in the same manner as the solubility of other substances is influenced by soluted sucrose. Accordingly, the solubility of sucrose in solutions containing cane or beet juice impurities is determined not only by temperature but also by the purity quotient (100. sucrose/ nonsucrose in the dry substance), and by the nature of the impurities. The ratio:

\[
\text{Saturation coefficient} = \frac{\text{Sucrose/ water in saturated impure solution at } t \degree C}{\text{Sucrose/ water in saturated pure solution at } t \degree C}
\]

Is called saturation coefficient (Hirschmuller and Birkett, 1935).

2.2.2.2. Light refraction

Refractometry is the preferred method for determination of concentrations in sugar technology.

The refraction itself, hence, is an exact mean for determination of the concentration of sucrose solutions. Beet and cane juice impurities cause similar refraction to that caused by sucrose. Thus the concentration
determined by the refractometer in impure solutions is not concentration of sucrose but approximately that of the total dry substance.

2.2.2.3 Rotation of polarized light

In consequence of the asymmetric carbon atoms in the sucrose molecule, sucrose solutions rotate the plane of polarized light.

Sucrose and glucose rotate the plane of polarized light in a “clock-wise direction” or to the right and is called dextrorotatory. Fructose rotates in a "counter colock-wise" direction or to the left and is known as levo-rotatory.

A 'normal' sucrose solution, that is , a solution of 26.000 grams of pure sucrose weighed in air with brass weights, dissolved in 100 ml and polarized at 20°C in a 200-millimeter tube, has a rotation of 1000S (degrees sugar) according to the international sugar scale, and absolute rotation of 34.6170 in light of 598.25 m (sodium light). Since such solution contains 26.016g of sucrose weighed in vacuo per 100ml at 20°C the specific rotation Hirsiumller and Bates (1941), is

\[ [\alpha]_{20^\circ} = 66.5290. \]

589.25

The rotation depends on the wave length (rotary dispersion); the specific rotation for e.g., the mercury line 546.1 mμ
20°C

\[ \alpha \] = 78.3420.

546.1

2.2.2.4 Various solvents

Sucrose is fully insoluble in gasoline, petrol, chloroform, carbon tetrachloride, carbon disulfide, benzene, turpentine, etc. It is noticeable soluble in aniline, pyridine, ethyl acetate, an amyl acetate, melted phenol, liquid ammonia, and in mixtures of alcohol and water and mixtures of acetone and water (dilute alcohol and acetone) according to (Hirschmuller and Bates, 1942).
2.3 Physical Properties of the Reducing Sugars (Dextrose and Levulose):

The physical Properties of the Reducing Sugar as shown in table 2.3.

**Table 2.3 Physical Properties of the Reducing Sugar**

<table>
<thead>
<tr>
<th></th>
<th>Glucose (dextrose)</th>
<th>Fructose (levulose)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Occurrence</strong></td>
<td>In cane 0.5-2% and in grape 13%</td>
<td>Present in unripe cane but chiefly present in fruits</td>
</tr>
<tr>
<td><strong>Crystalline form</strong></td>
<td>transparent rhombic crystal</td>
<td>needle shaped crystal</td>
</tr>
<tr>
<td><strong>Solubility</strong></td>
<td>soluble in cold water,</td>
<td>More soluble in cold than glucose. Also soluble in alcohol and ether, thus differs from all sugar.</td>
</tr>
<tr>
<td></td>
<td>Insoluble in glycorine and acetone.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soluble in dilute alcohol and less</td>
<td></td>
</tr>
<tr>
<td></td>
<td>soluble in absolute alcohol</td>
<td></td>
</tr>
<tr>
<td><strong>Optical rotation</strong></td>
<td>Dextro-rotary i.e clockwise direction</td>
<td>Levo-rotatory i.e. anti-Clockwise direction</td>
</tr>
<tr>
<td></td>
<td>(Like sucrose).</td>
<td></td>
</tr>
<tr>
<td><strong>Specific rotary</strong></td>
<td>not influenced by temperature. It is 57.74 At 20°C</td>
<td>much in influenced by temperature. It is-53° at 90°C and -106° at 15°C</td>
</tr>
</tbody>
</table>

Reference (Mathur, 1986).
2.4 Chemical Properties of the Reducing Sugars (Dextrose and Levulose)

2.4.1 Action of heat

Glucose and fructose decompose on heating to a temperature of 160 – 170 °C, when one molecule of water is liberated, and turned to brown in color

\[ \text{C}_6\text{H}_2\text{O}_{16} \rightarrow \text{C}_6\text{H}_{10}\text{O}_5 + \text{H}_2\text{O} \]

(Or fructose) (Or fructosane)

On further heating from 190° – 200 °C the brown color changes into black caramel, and ultimately it turns completely into carbon dioxide.

Action of heat on aqueous solution:

Solution of glucose in water can be heated to its boiling point without undergoing any change but that of fructose decomposes with the formation of acids and dark colored products according to (Panda , 2011).

2.4.2 Action of dilute acids

Glucose and fructose require more acids for 'inversion' than sucrose at moderates’ temperatures. On prolonged heating the rotatory power of fructose changes without apparent decomposition stated by (Panda , 2011).
2.4.3 Action of concentrated acids

Fructose is more readily decomposed than glucose by the same concentration of acid and at the same temperature, forms both char and formic acid according to (Mathur, 1986).

2.4.4 Action of alkalies

This is very important when manufacturing white sugar for consumption.

Action of alkalies on reducing sugars is very important. Different products some of which are very harmful are formed under the influence of different temperatures. For instance as stated by (Mathur, 1986).

(a) At ordinary temperature, below 55°C decomposition of reducing sugars is comparatively small, the chief product formed is lactic acid which is a colorless and stable acid and causes no trouble in the process.

(b) At a temperature exceeding 55°C, spontaneous destruction of reducing sugars takes place forming many organic acids and colored compounds. These colored compounds cannot be separated by later treatment and, therefore remain in the juice to influence the color of sugar. It is obvious such product should be avoided.

(c) The temperature of 55°C, as mentioned, has to be considered an empirical limit found in carbonation practice, but this does not means that no reducing sugars are broken down below this temperature.
2.4.5 Action of yeast

Reducing sugars are directly decomposed by the action of yeast into alcohol and carbon dioxide according (Mathur, 1986).

2.4.6 Action of reducing agent

Solution amalgam reduces glucose to sorbitole, but reduces fructose to a mixture of sorbitole and mannitol stated by (Panda, 2011).

2.4.7 Action of oxidizing agent

Glucose and fructose are liable to oxidation by various reagents. Dilute nitric acid converts glucose into oxalic acid and fructose into formic, oxalic and tartaric acids. Free oxygen and ozone oxidize both the reducing sugars into formic and carbonic acids and water. The oxidation products of fructose and glucose are identical, but fructose is more readily oxidized than glucose according to (Panda, 2011).
2.5 Colour of the cane juice

Coloring matter in sugarcane juice and syrup is an undesirable impurities due to its adverse effects on crystallization process and on finished sugar products.

The organic non-sugars are coloring matters in sugarcane and raw juice. The color of the cane juice may have two origins (Matur, 1986)

2.5.1 Coloring matters from the cane itself

This may have four origins: (1) Chlorophyll, (2) anthocyanin, (3) saccharetin, and (4) tannins.

The rind cells of sugarcane stalks contain a mixture of two coloring matters, the chlorophyll and the anthocyanine. The fiber of the cane contains saccharretin, and the 'top' and 'cysts' of the plant contain 'taninins'. It contains several other coloring matter but very little is known about them. These pass with the juice on extraction according to (Mathur, 1986).

2.5.1.1 Chlorophyll

Chlorophyll is chramoprotein forming the green colouration in plants. It is a soft green mass insoluble in water and sugar solution, but soluble in solvents such as ether, alcohol and alkalies. When extracted from cane it remains in colloidal suspension and easily removed during clarification. Xanthophylls and carotene are yellow pigments closely associated with chlorophyll. Both are insoluble in water and have little effect on cane juice processing stated by (Mathur, 1986).
2.5.1.2 Anthocyanin

This is present in certain dark varieties of cane only. Unlike chlorophyll, it is readily soluble in water and cane juice and so during the process of milling, it passes almost completely into the cane juice giving a dark coloration to the juice. The purple color of the anthocyanin solution is changed into dark green by the addition of lime. The pigment, if present in a small amount is precipitated by small amount of lime used for defecation. But if the pigment is more as it is when dark varieties are crushed, then the quantity of lime used in defecation is insufficient for the elimination of the coloring bodies. More lime has to be added as in the case of Carbonation process to precipitate these pigments completely. Sulphurous acid is incapable of bleaching the entire pigment even temporarily, and the original color appears again when the solution treated is exposed to the atmospheric Oxygen (Mathur, 1986).

2.5.1.3 Saccharetin

Saccharetin is found impregnated in the fiber of the cane. This coloring matter cannot be extracted with water or sugar solution from the fiber but when these media are rendered alkaline with lime or with any other alkaline body, the hitherto colorless saccharetin becomes yellow and is extracted by the liquid. In the raw juice, there are fine particles of bagasse in suspension and when lime is added the yellow pigment is extracted. It is, therefore, important to be removed as much from the juice as possible, before the juice is limed so that saccharetin is prevented
from entering the clarified juice. Saccharetin is comparatively a harmless pigment, as it becomes colorless again in neutral or acidic media (below pH 7.0) according to (Matur, 1986).

2.5.1.4 Tannins

These bodies are located in the actively vegetative portion of the cells, especially of the (tops) and the buds (cysts). It is soluble in juice. It is green but when it reacts with ion salts present in the juice-it becomes dark in color. On heating it decomposes with formation of catechol and combines with alkalies, to form protocatechuic acid which is similar to saccharetin stated by (Mathur, 1986).

2.5.2 Chemical decomposition: This may have three origins:

(1) Coloration of the juice due to the decomposition of its combined; (2) coloration of the juice due to the presence of soluble iron salts (ferric) from equipment, because of reaction with polyphenols; and (3) colorations of the juice due to reaction of non-sugar with other substances stated by (Mathur, 1986).

2.5.2.1 Coloration of the juice due to decomposition of its constituents

At high temperature 200°C sucrose and the two reducing Sugars glucose and fructose caramelize and assume a dark coloration.

The decomposition of fructose takes place first, then comes the turn of glucose and finally of sucrose. In the interest of light colored juices high temperature should be avoided according to (Mathur, 1986).
The color of sucrose and reducing sugars in acid solution is not as strong as in the neutral solution. But acids cause 'inversion' of sucrose. In an alkaline medium there is no fear of 'inversion' of sucrose. Only the reducing sugars are decomposed at a temperature high than 55°C, forming harmful stable dark decomposition products affecting the color of sugar followed by an increase of lime salts stated by (Mathur, 1986).

2.5.2.2 Practical consideration

Any prolonged treatment of juices, syrups, massecuites, molasses, etc., at high temperature should be avoided as much as possible, in order to minimize the formation of color. The reasonable limit of temperature allowed is 70°C according to (Mathur, 1986).

2.5.2.3 Coloration of juice due to soluble iron salts

During treatment, juices constantly come in a contact with metallic iron surfaces, such as those of the defecting Pans, the eliminators, the subsiding tanks, the filter presses, juice heater, evaporators, etc. and tend to increase the intensity of the color further due to the absorption of iron salts, especially in the acid medium, because of possible reaction with the polyphenols. If the formation of iron compounds is the ferric state (Fe₂O₃), these are mostly dark in color. These have detrimental influences on the color of sugar because these color products crystallize with sugar. But if the formation of iron compounds is in the ferrous state (FeO) the products are colourless. Complete removal of iron from sugar solutions has a beneficial effect upon the quality of the resulting white or refined
sugar. In modern technology, a number of chemicals are used to remove the harm action of ion. Among these are Sulphorous acid, phosphours acid or phosphates and activated carbon or bone char. By treating the juice with sulphorous acid, the ferric iron is reduced to a ferrous state, which is colorless and imparts acid reaction to the juice as stated by (Kulkarni, 1996).

It has been shown that in acid solution, iron (ferric saccharate) does not crystallized with sugar and remains in molasses. The color of sugar does not get affected and this is to the advantage of the cane sugar industry. Phosphates have a specific effect by which the iron is chemically bound and removed by the filtration process. Bone char is an excellent absorbent of colour and largely used in the refinery sated by (Mathur, 1996).

2.5.3 Coloration of the juice due to reaction of non- sugars with other substances

The most important are classed into three, groups,

(a) Polyphenols, (b) amino compounds (nitrogenous bodies), and (c) products of superheating according to (Kulkarni, 1996).

2.5.3.1 Polyphenols

These include 'tannins' derived from protocatechuic acid, phenolic hydroxyls from anthocyanin in the cane rind, and saccharetin in the cane fiber. These polyphenols react with iron (ferric and oxygen particularly in alkaline solutions and form dark colored products).
2.5.3.2 Amino compounds

Cane juice contains nitrogenous bodies such as aluminous, ammonia, amino acids and amides varying from 0.5 to 1.0%, these compounds are of some importance because these react with reducing sugars and form colored compounds.

2.5.4 Product of superheating

True caramel is never formed under normal conditions of working in a vacuum pan factory. But in an open pan factory where juice is heated by naked fire, much caramel undoubtedly forms.

In a sugar mill, the source of caramel formation is sometimes due to the crystalline crust on the surface of coils or calandria tubes of the vacuum pan. Therefore, it is quite essential to clean the vacuum pan thoroughly with steam after every strike. Caramel can be bleached slightly by reducing agents. Thus, the nature and extent to which these colored compounds are formed depend upon the condition involved.

2.5.5 Precautions to reduce the formation of colors

Avoid excessive heat. The temperature above 55°C, and alkalinity above pH7.2 must be avoided to prevent excessive colour development. If excess of lime is used, neutralization is first necessary by the application of CO₂ or SO₂ before the temperature is raised to above 55°C so the precipitation formed may strongly absorb colors.

Excessive pH and temperature can form highly colored decomposition products as result of the destruction of reducing sugars. It
is, therefore, essential to maintain such conditions so that reducing sugars are neither formed nor destroyed during clarification process staed by (Kulkarni, 1996).

2.5.6 Removing of Coloring matters from cane

1. Chlorophyll (green substance) removed in the presscake.

2. Antocynin (red substance) removed by excess of lime.

3. Saccharetin (yellow pigment) extracted by the action of lime on fiber. Removed by SO₂.

4. Tannins (green pigment) located in the actively vegetative portion of the cell.
2.6 The influence of raw cane juice constituent's on juice clarification

2.6.1 Importance of \( P_2O_5 \) – in clarification

In the clarification of cane juices the presence of an adequate amount of phosphoric acid is very important. Insufficient available \( P_2O_5 \) in cane juice is one of the causes of poor clarification. The amount of \( P_2O_5 \) present in cane juice must not be range from (200-300) PPM. If the juice is deficient in \( P_2O_5 \), it must be made up to this minimum before liming. The G.S. shepherd shows that how phosphate added as phosphoric acid to a mixed juice initially low in phosphate influences the initial settling rate and turbidity of the juice obtained using three types of flocculants. The study shows that decreasing turbidity and increasing settling rate as \( P_2O_5 \) levels are raised according to (BAIKO, 1982).

The \( P_2O_5 \) added to the cane juice can be in the form of phosphoric acid (\( H_3PO_4 \). 85% syrup, mono-calcium phosphate (\( CaH_4(PO_4).H_2O \)) or tri-calcium phosphate \( Ca_3(PO_4)_2 \), which is of the fertilizer type. The latter two should be prepared in aqueous solution in small tank or wooden barrel. All of these phosphates contain Ca. 48% of available \( P_2O_5 \) the juices treated with phosphates should be limed to pH 8.0 – 8.5 as stated by E. BAIKO (1982). Formerly, this was presumed to form tri-calcium phosphate directly, but the reaction produces a mixture that seems to be octa-calcium phosphate pentahydrate and hydroxyapatite, with sometimes a little anhydrous dicalcium phosphate presents.
2.6.2 Calcium salts

Precipitation by lime to other calcium salts occurs during clarification. To the extent depending largely on the pH to which the juice is limed, Louisiana juices high in aconitic acid show little or no removed as calcium aconitate, but in Hawaii with high liming (pH 8.5 on mixed juice) filter calle has been found to contain more than 3% aconitic acid as aconitate according to (Meade and Chen, 1977).

Calcium sulphate removal is variable 20% removal of SO$_4$ is reported at normal pH levels (7.0 pH clarified juice) Meade and Chen (1977). So that the adjustment of juice pH with lime results in the addition to juice of a large amount of jonic calcium such that the precipitation of the phosphate is nearly complete. However it has been noted that addition of extra calcium to certain juices yields improved clarities (Shepherd, 1980).

As stated by shepherd (1980). Notice that as the amount of phosphate in mixed juices was held constant at 320 PPM P$_2$O$_5$ the increase in calcium concentration in juice (added as calcium chloride to mixed juice) led to increasing phosphate precipitation.

Since it is via the adsorbed Ca+2 ions that juice impurities are built into the primary flocculants and also that the flocculants attach themselves to these flocs, the above sensitivity of turbidity to Ca$^{+2}$ concentrations is to be expected according to (Shepherd, 1980).
2.7 Composition of Cane and Juice

2.7.1 Trash and Cane

When cane is cut and cleaned by hand, and delivered fresh, processors receive the best possible starting material for sugar production. Cane that is cut and loaded by machine invariably contains tops, leaves, stubble and roots, as well as soil, water and other extraneous matter according to (Meade and Chen, 1977).

Deduction for trash in the delivered cane is a worldwide practice, but methods of trash determination vary widely. To judge the effect of trash, one should consider each fraction of the cane plant and its contribution of sucrose and of undesirable components. Juice from tops including the stem tip, or soft, elongating, joints as well as leaf blades, sheaths, and rolls- contains less than 1% sucrose and is relatively rich in starch, soluble polysaccharides, and reducing sugars. When tops (and dead leaves) are milled, these undesirable constituents are extracted and adversely affect sucrose recovery. Milled cane trash mixes with the crushed stalks, sponges up the richer stalk juices, and leaves the mill train with 3% sucrose. So that the various parts of the cane top total 19% of the whole plant. Large, juice-rich cells store sucrose. Less extraction is the rule in other parts except that stubble, which, in plant cane at least, has both extraction and sucrose values of 70%-88%. Stubble is generally classified as trash, probably because of its close association with field soil as stated by (Meade and Chen, 1977).

The cane stalk (trash free) is composed of approximately 75% water and the remainder is divided between fibers and soluble solid. The amount of each of three components is genetically determined and varietals differences are well known. The
noble varieties are water-rich and relatively low in fiber and sugar. The inter specific hybrids, now wide spread, are higher in both fiber and sugars.

The constituents of the juice of the cane stalk are considered. In order of abundance, these are the sugars, sucrose, glucose, and fructose; mineral, waxes, fats and phosphatides.

And miscellaneous minor constituents, generally listed as percentage of juice solids.

2.7.2 Sugars and Other carbohydrates

Sucrose in the juice and cellulose in the fiber are the two main constituents of sugar cane, and both are made of simple sugars. The simple sugars glucose (dextrose) and fructose (laevulose), occurs free in sugarcane, usually in lesser amounts than sucrose. The production of sugar from sugar cane juice is based on the ability of sucrose to crystallize from thick syrup while glucose and fructose remain dissolved. Other sugars occur in cane but not in free State; these are constituents of gums or cell walls according to (Meade and Chen, 1977).

Sugar is classified as carbohydrates and, as the name suggests, are composed of the elements carbon, hydrogen, and oxygen; hydrogen and oxygen are usually present in the same ratio occurring in water. The simple sugars, glucose and fructose, are also classified as monosaccharide because they can not be reduced to smaller carbohydrate molecules when attacked by acids or enzymes. The arabinose in cane gum is a pentose, and glucose and fructose are hexose stated by (Meade and Chen, 1977).

Sucrose is disaccharide, as are maltose and lactose. When attacked by acids or enzymes, disaccharides hydrolyze into their various monosaccharides. Trisaccharides
give three monosaccharides on hydrolysis, and tetrasaccharides give four. Compounds composed of more than two monosaccharides may also be called oligosaccharides. The triesaccharides raffinose is a common deterioration product in sugar beets. Only one oligosaccharide has been reported in cane juice, and this was isolated from stale cane. Several (raffinose, 1- ketose, 6- ketose, planteose, and nystose) have been isolated from cane final molasses. Large numbers of monosaccharides may be condensed to from polysaccharides, which occur in sugarcane as starch, cellulose, gum, and dextran. One or more monosaccharides may condense with other organic molecule to form compound carbohydrates such as tannins and glycosides according to (Meade and Chen, 1977).

2.7.3 Sucrose (Saccharose)

Sugar in the ordinary sense, is sucrose. It is the sugar of house hold and industry and is the most common sugar in the plant kingdom. Sucrose occurs in all parts of the sugarcane plant and is most abundant in the stalk, where it is found in the watery vacuoles of storage cells (parenchyma). The sucrose content is lowest in the actively growing regions, especially the soft portions of the stem tip and the leaf roll stated by (Meade and Chen, 1977).

The monosaccharide sugars glucose and fructose condense to form sucrose and water. Sucrose thus has the empirical formula $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ and molecular weight of 342.3. Sucrose crystals are monoclinic prisms having a density of 1.588: A 26% solution has a density of 1.108175 at 20 °C. Sucrose is optically active with the specific rotation $[\alpha]_D^{20} + 66.53$ when a normal weight is used. Its melting point is 188°C (370 F), and it decomposes on melting. The refractive index is 1.3740 for 26% solution. Sucrose is
soluble in water and ethanol. Sucrose is only slightly soluble in methanol and is insoluble in ether or chloroform stated by (Meade and Chen, 1977).

When hydrolyzed, sucrose yields equimolar amounts of glucose and fructose, and the mixture is called invert stated by (Meade and Chen, 1977).

However these sugars do not always occur in equal amounts in raw juice. Sucrose is dextrorotatory, and this feature is used to measure amounts of sucrose in solution. The specific rotation of invert is $\alpha_{20}^D - 39.7$ because the levorotatory activity of fructose is greater than the dextrorotatory activity of glucose stated by (Meade and Chen, 1977).

2.7.4 Glucose (Dextrose)

Glucose is widespread in both the plant and animal kingdoms. It is found in corn sugar, grape sugar, and blood sugar. Only in the actively growing portion of the cane plant does the glucose content exceed that of sucrose. The glucose content of cane juice is high early in the harvest season, decreasing with maturation. Although equal amounts of glucose and fructose are involved in the hydrolysis and condensation of sucrose, the dextrose – laevulose (D/L) ratio seldom equals that in raw juice stated by (Meade and Chen, 1977).

The empirical formula for glucose is $\text{C}_6\text{H}_{12}\text{O}_6$ as shown in Fig. 2.2, and the molecular weight is 180.2. Anhydrous glucose crystals are rhombic, melt at 146°C (295 F), and have a density of 1.544, while a 26% solution has a density of 1.10643. Glucose monohydrate ($\text{C}_6\text{H}_{12}\text{O}_6\cdot\text{H}_2\text{O}$) produces a monoclinic sphenoidal crystal, where one end of dissolves much more quickly than the other; it melts at 83°C (181 F). Glucose is less soluble in water than sucrose; even at 30°C (86 F), a saturated solution contains only
57.6%. It is soluble in ethanol and insoluble in ether. Glucose molecules condense to form starch, dextran, and cellulose stated by (Meade and Chen, 1977).

Glucose occurs in solution in three forms and all forms may occur at once. The chain form has the aldehyde group free and can reduce on alkaline solution of cupric salts, giving a positive test for reducing sugars. The ring form exists in α and β configurations that are in equilibrium in solution. Glucose solutions exhibit mutarotation, which means that the specific rotation changes on standing. A fresh solution of α- D-glucose has a specific rotation \(\alpha_{20}^{20} + 112.2\) while β – D-glucose is \(\alpha_{20}^{20} + 18.7\). Because the α and β forms are interconvertible, these solutions have a specific rotation of \(\alpha_{20}^{20} + 52.7\) on reaching equilibrium stated by (Meade and Chen, 1977).

Glucose has been determined traditionally by several methods based on reducing reactions. More specific determinations of glucose in mixture with other sugars can be made by techniques using the enzyme glucose oxidase, or gas-liquid or high pressure liquid chromatography. The latter two methods offer high precision but require sophisticated equipment according to (Meade and Chen, 1977).
2.7.5 Fructose (laevulose)

Also called fruit sugar, fructose is sweeter than sucrose and glucose, but of the three, it is the least abundant in cane. Like glucose, it is most abundant in the growing parts of the plant and least abundant in the lower stalk and roots. Fructose decreases with maturity and may be undetectable in some high purity varieties at maturity. Fructose is usually present in lesser amounts than glucose. Fructose molecules condense to form inulin, a storage product of some plants stated by (Meade and Chen, 1977).

The empirical formula of fructose is the same as that for glucose, \((C_\text{6}H_{\text{12}}O_{\text{6}})\) as shown in Fig. 2.3, and the molecular weight is 180.2. The orthorhombic crystals of fructose have a density of 1.598 and a 26% solution has a density of 1.1088. Crystals melt at 105°C (221F), Fructose is very soluble in water, a saturated solution at 20°C is 78.94% and at 30°C (86 F) is 87.54% fructose. It is also soluble in acetone and methanol and slightly soluble in ethanol. Like glucose, fructose is a reducing sugar, but it has a ketone rather than an aldehyde group. Also like glucose, fructose has α and β forms, but it
also occurs as both five- and six-membered (fructose or pyranose) rings. Equilibrium is established between the four types in solution, and the initial specific rotation of \( \{\alpha\}^D_{20} = -132.2 \) changes to \( \{\alpha\}^D_{20} = -92.4 \) at equilibrium. Methods of detection of fructose in mixtures are similar to these for glucose stated by (Meade and Chen, 1977).

![Fructose Molecule](image)

**FIG2.3 Fructose (Laevulose) Molecule, C₆H₁₂O₆**

### 2.7.6 Inversion

In the chemical sense, "inversion" means the changing of dextrorotatory optical activity to levorotatory, or converse. The term was used to describe the rotation change following acid hydrolysis of a sucrose solution when the strong dextrorotation of sucrose inverted to the laevorotation of the resulting mixture of glucose and fructose. Usage in sugar technology has evolved a new meaning: The acidic or enzymetic hydrolysis of sucrose to invert sugar. "Inversion" is wrongly but widely used to refer to deterioration
following severe boring or freezing when the sucrose is metabolized by bacteria and the dextrorotation of the juice is increased by the formation of dextran \[ \{\alpha\}_{20}^{D} + 199 \].

Enzymatic (invertases) inversion occurs in harvested sugar cane and sucrose is hydrolyzed. Enzymatic activity depends on variety, temperature and pH. Rapid inversion occurs in immature cane in hot weather, resulting in lower purities. Experiments indicate that sodium melasillicate acts as an invertase inhibitor in cane juice. Enzymatic inversion stops when the enzyme is destroyed during clarification stated by (Meade and Chen, 1977).

Acid inversion begins during clarification and may continue throughout processing. It is well established that acid inversion depends on both heat and pH. When juice pH is 5.8 and the temperature is 120°C (248 F), inversion proceeds at a rate that reduces sucrose 2%/hr. This level of inversion is maintained as pH and temperature are lowered until pH reaches 4.6 at 90°C (194 F). Acid inversion is minimized by liming juices to maintain the pH at or slightly above 7. Processing at the lowest temperatures compatible with efficient production also reduces inversion (Meade and Chen, 1977).

### 2.7.7 Starch

The juice from sugarcane stalks contains small amounts (0.005 %,) of starch, determination of starch by the enthrone methods gives higher values than those obtained by the isometric method. Within the stalk, starch is usually limited to the intercalary meristem, the part of the stem just above the node that grows after cane lodges and aids in turning the tops upright. The starch that serves as a reserve food is indicated by its temporary disappearance after lodging and after sprouting of roots or buds. Starch in the
stalk increases as the cane matures and disappears after freezing. Varieties differ widely in starch content. Starch is absent from root stumps and dead leaves and is slightly higher in the leaf roll and immature internodes than in older parts of the stalk. The average starch content of green leaves is 10 times that of the base of the stalk, and it varies during the day because the products of photosynthesis are accumulated and stored temporarily in the leaves as starch. At night, starch is converted to sugars that move out of the leaf and into the rest of the plant. The lowest leaf starch content of leaves occurs several hours after sunrise, and the highest found at sunset (Meade and Chen, 1977).

According to Matic, all varieties of sugarcane grown in South Africa contain starch, and the variety of NCO 310 has the highest content, of the order of 300mg/L of juice. Vignes determined the purity and amylase (Meade and Chen, 1977).

2.7.8 Content of different starches

Starch is a long, branching chain of glucose molecules with a specific rotation of \( \alpha \)\(^{D}_{20} + 200 \). It is not soluble in water unless it is heated, as in clarification. Then it becomes partially soluble, and though some starch is removed in clarification, some remains in the syrups. If the amount remaining is high, starch can retard crystallization in the vacuum pans, impairing molasses exhaustion. Starch may become incorporated within the sucrose crystal, or absorbed on it, and these conditions retard filterability in refining. Even with vegetable carbon refining, 7% of the starch originally introduced is retained in granular sugar (Meade and Chen, 1977).

Starch problems can be avoided by variety selection and by minimizing the starch extracted from green leaves. When these options are not acceptable, starch may be
eliminated as particles in clarification by cold defecation, or air flotation, and (if dissolved), by natural or bacterial enzyme (Meade Chen, 1977).

2.7.9 Gum and Dextran

Sugar polymers are high molecular weight compounds formed by condensation of one or more kinds of sugar molecule into straight or branched chains. Natural gum and dextrans are soluble in water and insoluble in ethanol. Gum occurs in normal, undamaged sugarcane and is different from dextran, which is a bacterial metabolite formed in crushed, burned or frozen sugarcane cells. Sugarcane gum is composed of six different sugars, arabinose, galactose, glucose, mannose, rhamnose, and xylose, with arabinose and galactose predominant. Glucose may be present as hydrolysis product of small amounts of dextran or starch. The specific rotation of gum is \( \alpha_{20}^{20\text{c}} = -46 \). Varieties differ in amounts of natural gum, and gum is present in varying amounts in raw and refined sugar. Sugar cane gum is one of the chief constitutes of acid beverage flocculent according to (Meade and Chen, 1977).

Dextran is a polymer of only one sugar, glucose, and is produced by the bacterium Leuconostoc mesenteroides Van Tleghem. Its specific rotation is \( \alpha_{20}^{D} = +199 \). Dextran forms rapidly in sugar houses under conditions favoring growth of the bacterium and causes slow crystallization, needle-grain, and poor filterability in refining. Dextran is a refinery problem particularly in thin, high purity, sweet water. Dextran was identified as the cause of processing difficulties accompanying harvest. Dextran content was shown to be closely related to sugar yield. Frozen cane increases rapidly in dextran content, and this increases rather than the associated increase in acidity, causes processing losses. Varieties differ in their response to freezing and in dextran content, and the
concentrations of gum and dextran are the best indicators of deterioration in sugar cane. Gum, or gum and dextran together, can be determined by the sensitive phenol-sulfuric acid method stated by (Meade and Chen, 1977).

Dextran can be economically reduced in factory juices by the enzyme dextranase. Treatment costs are equivalent to a 10% loss in sugar production: loss from dextran can be 10% or more stated by (Meade and Chen, 1977).

2.7.10 Mineral constituents

The inorganic constituent of sugarcane consists of water and elements dissolved in it as ions, salts, or as parts of organic compounds. Although some minerals such as silica may occur in opallike solids, the inorganic constituents of greatest concern in processing are those dissolved in the juice (Phosphate, silica and magnesium) are partially removed by clarification, whereas potassium, chloride, sodium and low concentrations of sulfate are not. However these materials, tend to become concentrated with processing. When molasses has high concentrations of minerals, especially potassium, sucrose retention in molasses is increased, causing losses to the processor stated by (Meade and Chen, 1977).

The mineral content tends to increase with the plants age, or at least to remain constant. Potassium is the most abundant mineral in the juice (up to 60% of ash); unlike others, it is most abundant in the younger parts and decreases in the older parts of the stalk. This distribution may be reflected in the ash content of the different plant parts, with the greatest as content in the juice from tops and the lowest from the juice from the base of the stalk. The high ash content of tops, and the effect of potassium on sucrose
retention, gives processors incentive to avoid milling cane tops and associated green leaves stated by (Meade and Chen, 1977).

Mineral content varies, not only within parts of the sugarcane plant, but also with variety and with soil type. That the newer varieties had higher ash content than the older ones. This was the transition period from the noble and older varieties to the modern inter specific hydroids. As stated by (Meade and Chen, 1977).

The heavy metal in raw sugar is only iron that occurs in significant amounts in cane juice and syrup (0.006% solids). It is probable that many of the metals occurs contaminants acquired in processing. All the metals occur in mill fabrication as the metals and alloys used for mill rolls, vessels, tanks, lining, piping, bearings, plating, welds, and solder. The amounts of these metals in raw sugar are not troublesome in refining and present no problems to consumer health stated by (Meade and Chen, 1977).

It should be stressed that ash and salt content are not synonymous. Organic acids yield carbonate on incineration but not in amounts equal to the original content stated by (Meade and Chen, 1977).

2.7.11 pH and acidity

The hydrogen ion concentration (pH) of the juice of normal mature sugarcane ranges from 4.73 to 5.63, but the usual value is between 5.2 and 5.4. With precise measurement and many samples, small differences between varieties and locations can be established. Acidity values are only an indirect indicator of deterioration; soluble polysaccharide content, especially dextran, is a more direct indicator according to (Meade and Chen, 1977).
2.7.12 Organic acids

Nine carboxylic acids isolated from normal mature cane stalks, of these, the value for aconitic acid is almost three times that for all the others combined. Aconitate was commercially recovered from cane during favorable pricing periods. Tartaric acid has been detected in raw sugar, the acids that increase markedly when frozen cane sours are acetic and lactic, not the normal acid constituents of cane.

Two amides and 16 free amino acids are found in cane juice. Aspertic acid is the most abundant of the amino acids, and eight of these occur only in trace amounts in the free state.

The amino acid content of cane infected with ratoon stunting disease was reported as differing from that of healthy cane according to (Meade and Chen, 1977).

2.7.13 Protein

The free amino acids accumulate in molasses and contribute to sucrose loss; when linked together in peptide chains to forms proteins, however, the same amino acids become beneficial. In countries where sugar production is a cottage industry, milk or plant albumins may be added to enhance clarification. The protein in cane juice though present in small amounts, is coagulated by heat and lime and helps clarification. Mixed juices contain more protein than crusher juices because the crusher ruptures the sugar-rich cell vacuoles, whereas subsequent mills, with closer spacing and maceration water, free protein from the residue. Early estimates of sugarcane protein were high, later efforts using carefully dialyzed proteins showed that the dry solids of cane juice contained only 0.5% protein, with very little variation (Meade and Chen, 1977).
2.7.14 Colorants and minor constituent

The pigments typical of higher plants, chlorophylls A and B, carotene and xanthophyll, are readily extracted from the green parts of sugarcane. These pigments can easily be separated from each other on filter paper with benzene or petroleum ether. Where extracted during milling, these pigments are removed in clarification or destroyed during boiling, and are not usual constituents of raw or refined sugar. Saccharetin, a black pigment associated with sugarcane processing, has not been reported from the plant. It is not a single compound, but is a mixture formed during processing. Constituents that are retained and occur as colorants in raw and refined sugar are flavonoids, polyphenols, and related compounds. Even such compounds have been isolated from the leaves and rind. Seven additional compounds from raw sugar and 15 from refined sugar have been identified. Of these, chlorogenic acid and kaempferol are most abundant. Some colourants are natural products; same (hydroxymethyl-furfural decomposition products are degradation products of sucrose or other constituents according to (Meade and Chen, 1977).
2.8 Clarifying agents

The following clarifying agents are used in the chemical treatment of cane juice for the manufacture of plantation white sugar:

2.8.1 Lime and milk of lime

As far as the present knowledge goes, lime in the only most effective purifying agent of moderate cost and is readily obtainable as stated by (Mathur, 1986).

2.8.2 Quality of lime

Lime used for clarification should be fresh, of high degree of purity and reactivity and free from grits and stones which is considered as an desirable material that affect bearings, pump liner, piping and other equipment. The air slaked lime on or 'uncooked' lime stone should also be eliminated as far as possible due to its tendency to slow down the settling rate of the juice. Lime should give the flowing tests to be fit for good clarification stated by (Kulkarni, 1986).

(1) Good quality lime should contain above 95% calcium carbonate and not more than 2% insoluble matter. The effects of higher impurities.

(2) Higher percentage of silica in lime retards the settling of juices and will result in the formation of heavier scales inside the heating tube of the heaters and the evaporators.

(3) Higher iron content in lime affects the color of juices. Both iron and aluminum salts cause hard scales in the heater and the evaporator.

(4) Higher magnesia content retards filtration and rate of settlings.

(5) It should be come very hot in a few minutes when treated with half of its weight of water.
(6) It should form a soft cream after slaking when mixed with three or four times its weight of water.

(7) The cream should not contain more the 0.1% lumps of the original weight of lime which fail to pass through a lime cream fine sieve and most of these particles should soften in an hour’s time.

(8) The lime after being slaked should dissolve in hydrochloric acid without appreciable effervescence and should not leave more than 2% in soluble matter as stated by (Mathur, 1986).

2.8.3 Hydrated lime Ca(OH)$_2$.

Hydrated lime is a better grade sold in powder form, packed in heavy paper bags or polyethylene sakes and will keep indefinitely. Hydrated lime is easy to handle and transport according (Kulkarni, 1986).

2.8.4 Pulverized quick lime

Pulverized quicklime is another development in lime manufacture. This keeps in dry storage for several months according to (Kulkarni, 1986).

2.8.5 Phosphoric acid

\[
\text{Ca(OH)}_2 + 2\text{H}_3\text{PO}_4 \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 6\text{H}_2\text{O}
\]

Precipitate

This was formerly employed as principal clarifying agent. In its place less costly agent, slupher dioxide, has been substituted. Phosphoric acid is now used an auxiliary defecant either as a free acid or as a soluble neutral phosphate both for raw or and white sugar manufacture according to (Honig, 1953).
2.8.6 Form of phosphoric acid employed during clarification of cane juice

There are many forms of phosphoric acid preparation put on the market, and they have varying proportion of soluble $P_2O_5$. The single super phosphate normally used as manure contains 16 -18% of soluble $P_2O_5$. Trace the double super phosphate contains 25 - 30% and the triple phosphate about 40%; phosphoric acid paste about 45% and sumaphos about 50%. The composition of some samples of super phosphate is given below according to

The crude form of super phosphate, single or double cannot be used as such due to presence of large percentage of gypsum (Calcium sulphate) an impurity which promote heavy scaling in the heaters. These should first be purified before use according to (Rien , 1979).

2.8.7 Preparation of lime cream

The preparation of lime cream requires careful supervision. It should be prepared three or four hours before use to ensure proper slaking according to Mathur (1986).

In the case of defecation process, where the lime requirement is not much, slaking is done in shallow iron tanks. The procedure is that the fresh burnt quick lime is moistened with water and left for some time, some water to be added and left until ebullition is over. Afterwards, some more water is added to make a thick paste. It is then passed on into the mixing tanks and milk of lime is prepared of the required density. The milk of lime is then pumped through strainers to the liming station as stated by (Chen and Chi , 1993).
2.9 Juice flow

Juice flow control is an important issue. That is because of the effect it has on clarification and the range of topics it embraces as stated by P. Rien (1979).

Clarification is basically a continuous process and therefore needs a continuous flow; ideally it needs a constant flow to make best use of installed capacity. For example in designing clarifiers we would like be able to design for average conditions. This is not easy though because of the inherent variations in juice flow from the mills. These are due not only to natural variations in the cane which is being crushed but also from mill stops, variations in crushing rate, etc.

2.9.1 Mixed Juice flow control

These variations in juice flow affect the clarification properties of the juice as a whole and it is necessary to put in system which will give as steady a flow as possible. The system must be designed at least to eliminate any rapid changes in flow. Firstly a surge tank is needed, and to make maximum use of that surge tank we required a system which is going to give poor level control but good flow control. In other words we want the level to go up and down as much as possible without over flowing or running dry, thereby helping to stabilize flow rates (P. Rien 1979). Another important aspect is that the controller must be a proportional plus reset controller, So that it can automatically compensate for changes in crushing rate or juice flow rate. If there is no automatic reset in the controller it will tend to favour the upper limit when crushing fast and the lower limit when crushing slowly as stated by (Rien , 1979).
2.9.2 Control valve or variable speed pump

According to P. Rien (1979) there are two alternatives, one is to use a control valve and the other is to take the signal to a variable speed pumping device. The disadvantages of using a valve are increased pump maintenance due to the higher loads imposed on the pumps, and in comparison with a variable speed pump, wasteful use of power. Stainless steel butterfly valve is recommended which has been in operation for a couple of years with no problem. Obviously the use of a valve is wasteful as far as power is concerned according to P. Rien (1979). As a power used by a pump is proportional to both flow and head then it is obvious that less power is used in reducing flow by speed control than by valve control. Variable speed pumps are recommended generally in heads to pump against, when pumping with abrasive materials in the liquid, and when a wide range of flow is required. The disadvantage of variable speed pump is price according to (Rien, 1979).

2.9.3 Size of surge tank

The other important question to discuss is: how big must the mixed juiced tank should be. Obviously it should be as big as possible for effective surge capacity, but with high retention times there is concern regarding juice degradation as stated by P. Rien (1979).

2.9.4 Benefits of using flow control

Improve clarification. Reduce the degree of carry over considerably. An indirect benefits but the most important is the control of temperature & pH. Vapor and exhaust steam will be steadied out as stated by (Rien, 1979).
2.10 Juice weighing

The weight of juice entering the plant has to be determined accurately since this forms the basis of chemical and process control. It is important for the calculation of mill performance extraction, and boiling house efficiency.

2.10.1 Weighment system

Juice weighment system is done by automatic weighing scales. They are of two types.

According to karmarkar (1990) The principle is as below:

(a) Lever and counter weights (Maxwell Boulonge type).

(b) Penumatically operated.
2.11 Cane juice liming

The liming station is one of the most important stations in a raw-cane sugar factory. Without correct liming, good clarification cannot be expected. The importance of proper treatment of raw cane juice with milk of lime must be kept in mind when a sugar factory is designed or modified, and the requisite capacity of liming tanks should be provided according to (Mathur, 1986).

The gums, wax and albumin make the raw sugar cane juice rather viscous and it cannot, therefore, be readily filtered when cold. Liming and heating cause many impurities in the juice to coagulated and precipitated out. At the same time, the acids are neutralized and any phosphates present are flocculated, absorbing a large amount of colouring matters, colloids and other impurities. Usually, the lime is added to the raw sugar cane juice in the form of milk of lime, for better dispersion and quicker as following reactions

\[
\begin{align*}
\text{CaCO}_3 & \xrightarrow{\Delta T} \text{CaO} + \text{CO}_2 + \text{H}_2\text{O} \\
\text{CaO} + \text{H}_2\text{O} & \rightarrow \text{Ca(OH)}_2; \quad \Delta H = -62.8 \text{ kJ/gmol} \\
\text{Ca(OH)}_2 + 2\text{C}_{12}\text{H}_{22}\text{O}_{11} & \rightarrow \text{Ca(C}_{12}\text{H}_{22}\text{O}_{11}) + \text{H}_2\text{O}
\end{align*}
\]
as stated by (Mathur, 1986).

2.11.1 Different liming method

There are three possible procedures for liming: cold, hot, and fractional liming and double heating.
2.11.1.1 Cold liming

Appears to be the best method for treatment of raw sugar cane juice prior to the clarification process. The danger of sucrose inversion is reduced to a minimum, since the juices are neutralized before they are heated to boiling temperature. Besides, lime is more soluble in cold juice than in hot. With an increase in sucrose content of the cane juice, the solubility of lime also increases. Cold liming however, requires a special technique and will give the best result only when the liming station is properly installed and operated. As mentioned above, lime is the most effective material to combine with phosphate, acids and impurities in sugar cane juice and form mud which settles in clarifiers stated by (Arca , 1988).

As all chemical reaction requires a certain time to complete, especially in the cold, the contact of milk of lime with mixed raw cane juice before it is heated must be for a minimum of 15 min, and preferably 20 min. If the length of contact of milk of lime with cold mixed juice is insufficient, a certain amount of lime will remain free and will tend to precipitate upon heating, causing scaling of heaters and evaporators. When milk of lime is mixed with raw mixed juice, it forms a mechanical mixture, and desirable pH may be indicated, but the actual reaction doses not take place if the mixture is heated too soon. For this reason stirring for 15.20 min is necessary. If the correct amount of lime is added to the cold raw mixed juice and it is given sufficient time to neutralize the acids and to form compounds with non—sugars (which will be precipitated in the clarifier), There will not be any appreciable drop in pH of the clarified juice or, at a later stage, in the syrup. Contact of milk of lime with cold raw juice for 20 min. give very satisfactory results in purification and clarification of cane juice stated by (Arca , 1988).
Some sugar cane juices are deficient in available P$_2$O$_5$, and lack of phosphates affects the clarification process unfavorably according to (Hugot, 1986)

### 2.11.1.2 Mixing milk of lime with juice

During liming, the mixed cane juice must be stirred continuously to disperse milk of lime properly and evenly throughout the juice. After all the required milk of lime is added, the juice must be thoroughly mixed by means of a mechanical stirrer. The stirring must be gentle in order to reduce breaking of the nucleus of floc which is beginning to appear in the liming tank. However, a certain amount of floc will unavoidably broken by the centrifugal pump. The speed of the stirrer in liming tanks should not exceed 60 rpm, preferably slow if the stirring arms of the agitator are long and give a full sweep in the liming tank. The liming tank can be provided with vertical baffles which will assist mixing.

Any kind of air agitation must be avoided, because cane juice already contains a large amount of air, and excess air will cause problems in the clarifiers, and prevent proper settling of mud. When the cane juice is heated, the expanded air tends to escape from the juice into the atmosphere, and the bubbles rising through the juice will disturb settling of mud stated by (Honig, 1963)

### 2.11.1.3. Capacity of the liming tank

The capacity of the liming tank in delayed liming will depend on the amount of sugar cane ground per hour, calculated on a 20 min. retention time. A single tank can be used for liming, and if the juice is removed by overflow, then to prevent short-circuiting, the juice and milk of lime should be fed into the tank through pipes extending toward the bottom and center of the tank. The liming station may also be composed of two, three or
even four tanks in series, the juice flowing from one tank to another by overflow. The tanks must have dividing baffles which stop 4-5 ft from the bottom to leave a passage for the juice. Only the first tank need be equipped with stirrer, unless the juice has an excessive amount of sand or heavy inorganic suspended matter. In this case, a stirrer should be provided in each tank to maintain extraneous matter in suspension, and liming tanks should be cleaned and steamed periodically according to (Mathur, 1986).

2.11.1.4. Preliming and pH control

For more precise results, and in order to prevent strain on the automatic pH meter, the mixed juice should be prelimed with a predetermined amount of milk of lime. It is too much to expect of an automatic pH meter for it to correctly adjust and control the total amount of milk of lime to be added to mixed raw cane juice which has to be limed from pH 5.2 to pH 8.0. Since the pH of raw cane juice does not generally vary by more than 0.5 pH units, the work of the automatic pH meter should be confined only to this range. In order to establish the required amount of pre liming, 1 L of raw juice can be titrated with diluted milk of lime until the desired pH is reached. It may be within 0.5 pH of the final pH desired for juice leaving the liming tank Arca (1988). This established volume of pre liming can be easily calculated per ton of juice and added in a continuous stream when the rate of grinding has been established and dilute extraction is known, or it can be added by batch as with Maxwell-Boulonge juice scale where a certain amount of milk of lime with each discharge of scale. Therefore, the largest portion of milk of lime should be added continuously into a surge tank, and only a small portion should be added by the automatic pH regulator into the liming tank for exact pH control. The excess of milk of lime from the automatic controller must be continuously recirculated into the
liming storage tank contain 5° Baume milk of lime. For exact control of pH, a continuous sample of juice should be taken from the pipe line leading to the heaters, since it is of primary importance to know the pH of cane juice leaving the liming station stated by (Mathur, 1986).

2.11.1.5 Insufficient liming

If the juice is insufficiently limed, the pH meter will increase the flow of milk of lime into the tank to adjust it to the desired pH. If the juice is over limed, the pH meter will not add any additional milk of lime, and the excess of pH will shown on the recording chart, in such case manual pre-liming can be slightly modified. If the pH meter is in good operating condition and properly adjusted, it should not be difficult to maintain a constantly uniform pH of limed juice (Kulkarni, 1996).

2.11.1.6 Excess of lime

An excess of lime should be avoided. All the lime used in excess of the amount required to neutralize the acids and precipitate impurities has a destructive action upon reducing sugars, which are transformed into soluble lime salts which increase the colour and viscosity of cane juices. In other chemical reaction, excess lime upon heating attacks reducing substances to produce acids which may further invert sucrose according to (Kulkarni, 1996).

2.11.1.7. Leuconsotoc infection

Sometimes cane juices are infected with leuconostic bacteria, which produce a gummy substance called dextran \((C_6 H_{10} O_5)_n\). This gum is produced by the leuconostic fermentation and frequently occurs in sugar cane damaged by frost or insect’s leuconostoc bacteria develop very rapidly in cold alkaline juice and only very slowly in a
neutral or acid medium and they quickly become logod in pipes, elbows and valves. If this infection occurs, the bacteria can be destroyed by thoroughly steaming the tandem conveyors and receiving tanks, and pumping unlimed acid sugar cane juice through juice heater to clear the system. Heating juices to the boiling point or disinfection with a 1% ammonium fluoride solution also kills leuconostoc. Bussan 881 can be used for sanitation of a tandem. Formalin also used as anti bacteria but undesired due to his strong odor. Normal liming can be resumed after the system between tandem and clarifier has been cleaned according to (Mathur, 1986).

2.11.1.8. Liming hot juices

The liming of hot juices was introduced into the sugar factory for the purpose of destroying the leuconostoc bacteria by heat before liming, which creates and alkaline medium in which the bacteria develop rapidly. However, heating the raw sugar cane juices to a high temperature prior to liming is dangerous, since raw juice has a low pH, and substantial inversion of sucrose can occur. Proper sanitation of mill tandem and periodical steaming will prevent infection of juice with leuconsotoc bacteria, and therefore liming hot juices is not necessary at all stated by (Hugot, 1986).

2.11.1.9. Fractional liming and double heating 'FL and DH'

The 'FL and DH' method was considered very effective for treatment of refractory juices. In the FL and DH process, the raw sugar cane juice is limed to pH 6.1- 6.4 then heated to 100°C– 104°C (212 -220°F) and limed again to pH 7.4 -7.8. This method precipitates reversible colloids but heating acid juices to a high temperature produces inversion and losses of sucrose. In some cases, the loss in sucrose may be preferable to poor clarification of refractory juices and long retention of juices in clarifier’s at a high
temperature, which also results in unavoidable destruction of sugar according to (Arca, 1988).

With modern continuous clarifiers and varieties of sugar cane which rarely have refractory juices, the FL and DH have fallen into disuse.

In the diffusion process, in which residual juices are limed and clarified and recirculated through the continuous diffuser, the juices withdrawn from the diffuser have a pH of 6.5, and temperature about 70 °C (158 °F).

This so-called 'diffusion juice' is mixed with cold crusher juice. The mixture will have a little higher average temperature than that of ordinary raw cane juices and the cold liming technique can be used stated by (Arca, 1988).

2.11.1.10 Java method

In Sugar industry. Decolorizing power is most important in property. The determination of the decolorizing power, however, has to carry out by a carefully standardized method. In Java the following method is used (Honig, 1953)

1. Liming the juice up to 6.2-6.4 pH.

2. The limed juice divided into two portion 60% and 40%.

3. The 40% portion prelimed up to pH 9

4. The 60% portion should be heated up to boiling.

5. The 40% which prelimed up to pH 9 and 60% which heated up to boiling to be collected to give pH 7.6.
2.12 Juice temperature defective

In sugar manufacturing, heat and lime are the principal factors in juice clarification. There are a number of theories describing the temperature to which the juice should be heated. The best practice is to heat the juice to a temperature a few degrees above boiling. Approximately 215° - 250 °F (102 – 104 °C).

It should be remembered, the juice boiling point is higher than water, at the same pressure. Under atmospheric pressure the mixed juice boils at 213 °F (100.6 °C) while water boils at 212 °F (100 °C). This difference is called boiling point rise of sucrose solutions in sugar cane juice as stated by (Arca , 1988).

At lower temperatures, clarification would be incomplete and as a direct consequence sugar would be of inferior quality. It is obvious that it is impossible to produce high quality sugar with poor clarification. The temperature at which the juice is heated is very important to clarification. Therefore the needs to give temperature control the attention it deserves.

2.12.1 The effect of heating and temperature on clarification at low temperature

Many problems can appear when juice is heated to a temperature below boiling points (213 °F or 100.6 °C). They are:

2.12.1.1 Incomplete floc formation

Incomplete floc formation because the reaction of lime with the phosphates present in the juice depends on the limed juice temperature.

Phosphates flocculation absorbs large colloids quantities, color producing materials, bagacillo, and solids in suspension. When the limed juice temperature is below
boiling point (213 °F or 100 °C), clarified juice will be cloudy, with solid particles and bagacillo in suspension, etc according (Arca, 1988).

2.12.1.2 Incomplete coagulation

Gels coagulation, wax, albumin, etc., present in mixed juice require for coagulation, at pH 7.2 -7.4, a maximum temperature equal to the juice point (213°F or 106°C). When the temperature is lower, incomplete coagulation will occur. The results will be cloudy clarified juice, with no brightness and a very low clarify index. This will result in high massecuite viscosity, bigger volumes of higher purity molasses and low filterability sugars that affect yield and refining costs according to (Arca, 1988).

2.12.1.3 Incomplete elimination of gases

The reason why heating the juice slightly above its boiling point is recommended (215°F – 220°F) or (102 ° – 104 °C), is to insure the complete elimination of gases, air, and vapor accompanying the heated limed juice, prior to entering the clarifier. This elimination of gases, air, and vapor is obtained when the juice enters the flash tank. This tank is located between the heaters and the clarifiers. When entering the flash tank, the slightly superheated juice at (215 ° – 220 °F) or (102 ° – 104 °C) coming from the heater, flashes when brought to atmospheric pressure. The result is it frees the excess, heat, gasses, air, and vapor in the juice during flashing. In this manner, a uniform juice temperature into the clarifiers is assured. This prevents within the clarifiers temperature differences that tend to disturb and cloud the clarifiers according to (Arca, 1988).

The flash tank eliminates gases, air, and vapor trapped in the juice. These would create movement while ascending through the clarifier juice. It also precludes air, gas, or
vapor from ad hearing to fine bagacillo particles or to the flocs, making them float, rather than dropping to the bottom as sediment.

None of the above benefits would be obtained with low temperatures. When operating with just partial elimination of the gases and air there would be attendency for clarifiers to become muddy, producing inefficient clarification according to (Arca, 1988).

2.12.1.4 High juice density

The higher temperature the lower the juice density. Conversely the lower the temperature, the higher the density therefore at low temperatures the sedimentation of flocs bagacillo, and solids in suspension, would be slower difficult and incomplete, due to the higher juice density. This will result in muddy clarified juice, solids in suspension, and loss of sucrose by inversion according to (Arca, 1988).

2.12.2 The effect of heating and temperature on clarification at high temperature

With juice temperature higher temperature than 220 ° F (104 °C) the following problem happens are:-

2.12.2.1 Destruction of invert sugar

Sugar at higher temperature causes destruction of invert sugar at increased pH due to liming. The destruction of inverted sugar at high temperature and excessive lime, forms acid later that decrease the pH and cause sucrose inversion. This will increase organic acids that produce more inversion, as sucrose has a tendency to replace the loss of invert sugars, and as a consequence the sugar yield will be reduced stated (Mathur, 1986).
2.12.2.2 Color formation

In an alkaline medium reducing sugars decompose at high temperature increasing juice color. On other hand caramel formed resulted in sugar loss and color formation. These can be avoided by maintaining pH 6.9-7.1 and avoid temperature more than 104°C in heaters stated (Mathur , 1986).

2.12.2.3 Increase in molasses production

At high temperature, sucrose inversion, and invert sugar destruction, produces an increase in the production and purity of molasses. This causes more sucrose losses in final molasses, larger quantity of cane crushed and less commercial sugar according to (Mathur , 1986).

2.12.2.4 pH Drop in the clarifiers

A change or drop in juice pH is a reaction that occurs in the clarifiers. The change in pH increases with temperature. The higher the juice temperature in the heaters, the greater the pH drop caused by chemical reactions. This pH drop is determined to clarification and can cause sucrose losses according to (Mathur , 1986).

2.12.2.5 Effects of heating juice

When juice with a pH 7.2 – 7.4 is heated to a temperature of (215 – 220°F) or (102° - 104 °C), many of the compounds formed by non sugar's begin to combine. There are calcium salts formed from organic acids when the temperature approaches the boiling point. This is beneficial to flocculation. The different non sugar components react as follow: According to (Mathur , 1986).

(a) The waxes, gels, and pectins are generally emulsified and are eliminated in the mud.
(b) The pentosans coagulate and are eliminated in the mud.

(c) The phosphoric acid present in the juice combines with the lime (CaO) to form tricalcium phosphate. This is the most important reaction in floc formation during clarification.

(d) The metallic oxides are generally not affected, although silica (SiO$_2$) precipitates in combination with the sesquioxides.

(e) All of this will of course depend on juice pH. All nonsugar components will behave in accordance to the surrounding medium.
2.13 Flash tank

2.13.1 Operational parameters

Uniform flow of vapor and gasses

Incoming temperature = 215° - 220° F (102° – 104° C)

Outgoing juice temperature = juice boiling temperature at atmospheric pressure.

Tank capacity, 0.283 cubic meter per 37.85 cubic meter clarifier capacity:-

Uniform juice flow.

Tank free of sand and other materials.

Tank height, approximately 1.5 x diameter according to (Arca, 1988).

2.13.2 Incorrect capacity

The capacity of the flash tank is very important in obtaining adequate vapor and gasses elimination prior to the juice entering the clarifier. This will prevent turbulence when the juice enters the clarifies.

Generally the flash tank height should be 1.5 meters times its diameter.

It is convenient the juice enters and leaves at a tangent, to give a circular movement to the juice inside the flash tank. This benefits the separation of vapor and gasses from the juice.

There should be a manhole to regularly clean the tank interior.

The capacity of the flash tank should be correspond to the capacity of the grinding rate of the plant according to (Arca, 1988).

It is good practice to occasionally clean this tank since its capacity can be reduced by deposits of sand, extraneous materials, bagacillo, etc. as stated by (Arca, 1988).
2.13.3 Poor vapor flash

The flash tank function is very important for continuous clarifiers operation. Juice leaves the heaters at a temperature of 215 – 220°F (102°C – 104°C) at a higher than atmospheric pressure. The juice flashes when it comes into the flash tank at atmospheric pressure. The pressure drop releases heat in the form of vapor. This flash carries with it incondensable gases and air from the juice.

Steam exhausting should be very complete in order to achieve good clarification. As long as the juice temperature leaving the heaters is correct, the vapor flash should be substantial, continuous and uniform. It should be plainly visible at the flash tank chimney stated by (Arca, 1988).

2.13.4 Irregular vapor flashing

Vapor exhaust from the flash tank should be continuous and uniform, for maximum clarifier efficiency.

Usually an irregular vapor exhaust corresponds irregular temperatures and juice flow. When this happens, juice heaters operation should be checked stated by (Arca, 1988).

2.13.5 Flash tank filled with sand

In plant with mechanized sugar cane harvesting or loading, there is attendency for sand to accumulate in the flash tank.

Sand accumulation keeps reducing the flash tank capacity and efficiency. It is good operational practice to regularly clean the flash tank to prevent sand accumulation according to (Arca, 1988).
2.13.6 Juice spills from flash tank

Juice spills from the flash tank chimney, can occur. This happens due to small flash tank for the grinding rate.

(a) High juice levels.

(b) Restriction in juice entering the clarifier.

(c) High sand levels, and high juice temperatures and pressure.

All juice spill causes should be found and corrected. The represent sugar losses, are harmful to adjacent equipment, and is personnel safety hazard as stated by (Arca ,1988).

2.13.7 Incorrect juice distribution

In plants with more than one clarifier, there might be more than one flash tank. Juice flow distribution to the flash tanks should be proportional to the clarifier capacity served by each. This would assure good flash tank operation according to (Arca ,1988).
2.14 Clear juice quality and usage of flocculants

Mixed juice is a suspension of inorganic, organic and plant material which enters the juice during the milling process. If the juice is allowed to stand undisturbed, only a certain amount of this material is of sufficient size to settle according to (Shephard, 1979).

The purpose of clarification is to remove as much suspended impurity (measured as turbidity) as possible. At the same time, certain soluble non-sugars are also removed.

The particles present in mixed juice are stabilized partially by the presence of a negative electrical charge which they carry and partially by the salvation effects of adsorbed proteins or polysaccharides.

The commercial defecation process involves the addition of lime to raise the juice pH to predetermined levels, generally between 7.5 and 8.0. The lime also has the affect of supplying extra precipitation of calcium phosphate in the juice stated by (Shephard, 1979).

2.14.1 Primary flocculation

The raw particles of cane juice contain adsorbed to their surface Ca$^{2+}$. It is assumed that these act as enters for the precipitation of the calcium phosphate with the result that the impurity particles are built into the calcium phosphate precipitate which then acts as a bridge between impurity particles. This process is known as primary flocculation. The resulting flocs are small, slow settling and leave behind a very turbid juice stated by (Shephard, 1979).
2.14.2 Secondary flocculation

It is now possible to produce a secondary flocculation by means of the addition of PAA flocculants. These are long linear polymers which adsorb to the primary flocs and bind them up into bigger units which settle faster. At the same time, by collecting together the smaller primary flocs, it produces a far clear juice.

2.14.3 Polyelectrolytes

A number of synthetic water – soluble polymers bearing various trade names have been advocated and have come into fairly general factory use. Separan AP-30 in Louisiana State improved flocculation increased settling rates, mud volume decreased and pol percent filter cake was substantially reduced as stated by (Mead and Chen ,1977).

The most successful flocculating materials for the raw sugar industry are the partially hydrolyzed polyacrylamides according to (Mead and Chen ,1977).

The chain molecules forms inter Particle Bridge and the sugar industry are mainly anionics, which carry the same charge as the particles of the suspension in juice (J. M Coulson and J. F Richardson (2001). The molecular weight of useful flocculants range upwards from 1 million and are generally around 4 -6 million. It has been shown that the higher the molecular weight, the more efficient is the flocculant according to Shephard (1979). The mode by which flocculant adsorbed to primary floc has been postulated to be via absorbed Ca$^{2+}$ ions on the floc surface which bind to the acid groups along the polymer chain. It has been shown that for any juice, there is an optimum degree of hydrolysis at which settling rate is a maximum and turbidity at minimum stated by (Crees et al., 1977).
2.14.4 Flocculant solution preparation

2.14.4.1 Careful addition of solid to vortex of stirrer

Careful addition of solid to vortex of stirrer so that the solid granules of flocculant are independently dispersed in the solvent or the use of a patent dispersion apparatus. This insures that rapid hydration and dissolution of the solid can occur without the formation of insoluble jelly-like lumps.

2.14.4.2 Gentle agitation

Gentle agitation of this solution for 2 hours to insure complete dissolution.

2.14.4.3 Excessive stirrer speeds

Excessive stirrer speeds and centrifugal pumps should be avoided when dealing with flocculant solutions since the long flocculant molecules must be protected against strong shearing forces.

2.14.4.4 A stock solution

Stock solution can be prepared and then diluted for case of handling and for more efficient mixing with the limed juice. The dilution below 0.05% is disadvantageous stated by (Shephard, 1979).

2.14.4.5 Water of excessive salt

Since water of excessive salt content should be avoided, condensate water is the preferred solvent juice stated by (Shephard, 1979).
2.15 Fundamental clarification reaction

The reactions tacking place in the clarification process, are carried out under certain condition of pH, temperature, and reaction time.

2.15.1 pH

The soluble non-sugars forms the mixed juice are separated in the form of a precipitate at different pH range. Some are precipitated at higher pH while some are at a lower pH.

In order to achieve the separation of the non-sugars the juice pH to be kept at neutral position i.e. at 7.0 pH (Karmarkar, 1990).

2.15.2 Temperature

After addition of these chemicals (lime, phosphoric acid), the juice is heated to 2-4 degree above boiling point (100° C). At this high temperature almost all the bacteria's die if they exist in juice, such bacteria destroy certain amount of sugar by eating it as a food there by the loss of sugar in process increases according to Karmarkar (1990). In addition to this the advantage of boiling juice is as follow:-

(a) The coagulation of precipitate formed is effective at high temperature.

(b) The rate of reaction is faster at high temperature.

2.15.3 Reaction time

To complete any reaction, certain contact period is essential. In order to complete the reactions of lime, phosphoric acid and sulphur dioxide with the juice, a certain reaction period is necessary which is considered as 7 to 10 minutes in hot liming and 20 minutes in cold liming. The juice sulphitor therefore is to be so designed, that juice will be retain in it for about 8 minutes.
2.15.3.1 Contact time

If the contact time between juice and the chemicals is more, the formation of dark colorization occurs.

2.15.3.2 Sucrose inversion

Either inversion of sucrose or the destruction of reducing sugars may take place as the case may be:

Temperature, Alkalinity, time or temperature, acidity and time. the products due to inversion of sugar destruction of R.s should be as minimum as possible to avoid the adverse effects.

Is observed, that at proper conditions of pH, temperature and reaction time while treating the mixed juice with lime, and phosphoric acid following goals is achieved:

(i) Removal of soluble non-sugars by way of precipitation.
(ii) The nature of precipitate is heavy and so a tendency to settle down.
(iii) Removal of colloids and the suspended particles along with the heavy precipitate formed.
(iv) Removal of wax and gummy matter by heating the juice thus reduce the viscosity of the juice.

The precipitate formed should settle faster and should occupy compact mud volume; this is the sign of good clarification. Precipitate should be heavy and voluminous nature.

According to "Stock's Law"

\[ V = \frac{D^2 (d_1 - d_2) \times g}{18 \ U} \]
Where:

\[ V = \text{Rate of settling of the precipitate formed.} \]

\[ D = \text{Diameter of the precipitate.} \]

\[ d_1 = \text{Density of the precipitate.} \]

\[ d_2 = \text{Density of the juice.} \]

\[ g = \text{Gravitational force.} \]

\[ U = \text{Viscosity of the juice.} \]

Observing the formula it can be noted, that, the density difference between the precipitate and the juice should be more for better settling rate. Therefore the Brix of the mixed juice is to be kept between 12° to 15°.

During the clarification process the precipitate of Tricalcium phosphate \( \text{Ca}_3(\text{PO}_4)_2 \) and calcium sulphite \( \text{CaSO}_3 \) are formed. Precipitate of calcium sulphite is granular and heavy in nature. They settle down quickly due to their above properties. In the reaction, lime reacts with phosphoric acid to form calcium phosphate \( \text{Ca}_3(\text{PO}_4)_2 \) and calcium sulphite \( \text{CaSO}_3 \) respectively. The reactions are as under:

(i) \( 3\text{Ca(OH)}_2 + 2\text{H}_3\text{PO}_4 = \text{Ca}_3(\text{PO}_4)_2(\text{Insoluble}) + 6\text{H}_2\text{O} \)

(ii) \( \text{SO}_2 + \text{H}_2\text{O} = \text{H}_2\text{SO}_3 \) (Solphurous acid)

(iii) \( \text{Ca(OH)}_2 + \text{H}_2\text{SO}_3 = \text{CaSO}_3(\text{Insoluble}) + 2\text{H}_2\text{O} \) according to Karmarkar (1990).
2.16 Clarifiers or subsiders

The subsider is the industrial plant in which the concentration of suspension is increased by sedimentation, with the formation of a clear liquid. In most cases, the concentration of the suspension is high and hindered settling to take place.

The clarifiers may operate as batch or continuous units, and consist of tanks from which the clear liquid is taken off at the top and the thickened liquor at the bottom.

In order to obtain the largest possible throughout from clarifier of given size, the rate of sedimentation should be as high as possible. In many cases, the rate may be artificially increased by the addition of small quantities of an electrolyte, which causes precipitation of colloidal particles and the formation of flocs. The suspension is also frequently heated because this lowers the viscosity of the liquid, and encourages the larger particles in the suspension to grow in size at the expense of the more soluble small particles. Further, the clarifier frequently incorporates a slow stirrer, which causes a reduction in the apparent viscosity of the suspension and also aids in the consolidation of the sediment according to (Coulson and Richardson, 2001).

Subsiders or clarifiers may be anything from a few meters to several hundred in diameter. The small ones are made of wood or metal and the rakes rotate about 0.02 Hz (1rpm). The very large clarifiers generally consist of large concrete tanks and the stirrers and rakes are driven by means of traction motors which drive on a rail running round the whole circumference; the speed of rotation may be as low as 0.002 Hz (0.1 rpm) according to (Coulson and Richardson, 2001).

The clarifier has a twofold function. First, it must produce a clarified liquid, and therefore the upward velocity of the liquid must, at all times, be less than the settling
velocity of the particles. Thus, for given a throughout, the clarifying capacity is
determined by the diameter of the tank. Secondly, the clarifier is required to produce a
given degree of thickening of the suspension. This controlled by the time of residence of
the particles in the tank, and hence by the depth below the feed inlet. On the other hand
retention time is governed by the juice flow rate or crushing capacity and clarifier
capacity.

There are therefore two distinct requirements in the design-first, the provision of
an adequate (diameter: height ratio) which is employed result in only the first
requirement being adequately met.

The satisfactory operation of the thickener as a clarifier depends upon the
existence of a zone of negligible solids content towards the top. In this zone conditions
approach those under which free settling takes place, and the rate of sedimentation of any
particles which have been carried to this height is therefore sufficient for them to settle
against the upward current of liquid overflow. The volumetric rate of flow liquid upwards
through the clarification zone is equal to the difference between the rate of feed of liquid
in the slurry and the rate of removal in the under flow. Thus the required concentrations
of solids in the underflow, as well as the throughput, determine the conditions in the
clarification zone according to (Coulson and Richardson, 2001).

2.16.1 Rapi dorr clarifier

Clarifiers are generally divided into several compartments, so as to increase the area
of settling.

Since clarifiers are similar in principle, and vary in details only. Here by is the
description of the "Rapi dorr"", which is perhaps the most widely used.
It is provided with a central hollow shaft. Rotating very slowly (12 rev./hour), which carrying scrapers of sheet metal that slowly brush the bottom of each compartment according to (Hugot, 1986).

The juice to be clarified enters tangentially at the top, into a compartment half the diameter of the main clarifier. This is termed the feed compartment of flocculation chamber. Here some scum rises to the surface; this IS eliminated by special scraper which bushes it into a small lateral discharge canal leading to the mud outlet box according to (Hugot, 1986).

The Rapi dorr clarifier consist of 4 superimposed compartments, each forming a complete clarifier independent of the others, and fed separately by a rotating central tube by means of opening situated in the upper of the compartment. The entering juice encounters baffle plates designed to ensure good distribution of the juice. It flows radially towards the outer wall, the velocity decreasing in inverse ratio to the radius. Settling of the mud proceeds simultaneously, and the mud deposited on the bottom plate is removed by scrapers mounted on arms connected to the central tube and bushed towards the center; there they settle into a mud tray from which they are extracted by diaphragm pumps at controllable rates. The mud from the various trays is pumped to mud tank, from which it goes to the filtration plant according to (Hugot, 1986).

The clear supernatant juice is withdraw from each compartment by a circumferential internal pipe with several openings which withdraw the juice close to the roof of the compartment. The juice then passes through an over flow box, by vertical pipes fitted with sliding sleeves which permit regulation of the rate and overflow level according to (Hugot, 1986)
Vertical tubes through the roof of the equipment allow escape of gases from each compartment to atmosphere as shown in Fig 2.4.

The Rapi dorr clarifier does not require any addition of flocculant, but such addition does improve the subsidation and reduces the necessary settling time. The subsider has a capacity slightly greater than that of previous models.

The clarifier is enclosed, except for a door giving access to the flocculation chamber. It is completely lagged. After being shutdown (Normally done over Sunday in Kenana Sugar Factory in Sudan). Which leads to a cooling rate of $0.16 - 0.22 \degree C/ hr$ ($0.3 - 0.4 \degree F/hr$) in general for a clarifier of $100 - 200 m^3$ ($3.500 -7000 Cu.ft$) as stated by (Hugot ,1986).

FIG. 2.4 Rapi Dorr Clarifier
2.16.2 SRI clarifier

Since the introduction of continuous clarifiers, some defects have been apparent. It was found that in the laboratory, or with certain pilot units, the speed of settling could be much higher. In seeking the causes of this performance for equipment of industrial dimensions, it was found that certain very simple details were considered in modification to result in substantial improvement in the settling time of juice in the equipment. These were:

(a) Introduction of the juice to the subsider with the minimum disturbance, at much reduced velocity, without eddies; and regulating the flow as much as possible; for example by provision of a storage tank (20m³ (700 Cu.ft/100t.C.h) to smooth out fluctuations in the rate of flow.

(b) Reduction of length of travel of the juice between entry to the equipment and exit.

(c) Provision of more points for juice outflow, in order to reduce disturbance at those points.

(d) Arranging for the juice to travel upwards through the flocculated juice, so that the particles in suspension are retained in their flow by the existing flocs ("upward sludge filtration").

2.16.2.1 Division into compartments

Division into compartments was found to be detrimental to performance Hugot (1986). These considerations have led to the development of the S.R.I clarifier, designed by hale & Whayman at the Sugar Research Institute in Australia. Entry and distribution of the juice are effected by a circular channel into an annular down take, which direct the juice at the mid-height of the vessel; it then meets a deflector of double slope which
distributes it laterally in the equipment. The settled mud accumulates at the bottom, where it is scraped towards a mud well and removed. The scrapers are carried on rotating arms (Hugot, 1986).

The clarified juice overflows by two notched gutters, both circular and concentric; the first or inner one is of radius one-half or two-thirds that of the entry channel, the second approximately half-way between the latter and the outer wall of the tank. Fixed scrapers avoid accumulation of mud on the double-sloped deflector which is fixed to the rotating arms as shown in fig 2.5.

FIG. 2.5 SRI Clarifier
The rate of settling is of the order of 10 cm (4 inch) per minute calculated on the interior cross-section of the vessel reduced by that of the deflector. Area is about 0.2m²/t.c.h. The depth between the bottom of the annular feed and the conical bottom is approximately {1.2m (4ft)}. The residence time of the juice is approximately 20 min, that of the mud some hours according to (Hugot, 1986).

Considering the total cross-section of the vessels, we should allow about 0.15m²/t.c.h (1.3 sq.ft/t.c.h). On account of the brief time of the juice in the subsider, the pH falls only by 0.1 between limed juice and clarified juice; hence there is a decreased risk of decomposition of juice. It is considerable again to say that speed of settling and residence time is made possible only by use of flocculent. The dosage may vary between 1.5 and 3 ppm. It is in fact flocculants which have rendered rapid clarifiers possible stated by (Hugot, 1986).

The S.R.I rapid subsider now predominates in Australia and has to great extent replaced older clarifiers in Australian factories. These factories express very satisfaction and report no inconvenience or trouble resulting from stale cane or refractory juices stated by (Hugot, 1986).

The almost universal adoption of the SRI Type clarifier by the industry based on many reasons, not the least of which are the markedly cheaper cost of equipment, installation and maintenance, and the simplicity of operation. In general its clarification performance is consider equal to Rapi Dorr clarifier except that it is known to be sensitive to juice flow variations and has been found almost essential to have automated control of the juice flow in the clarifier for optimum operation according to Jullienne and Montocchio (1996). Although it has the reputation of using more flocculant this not
reflected in the industry figure for 1995 season (South Africa), with 3.3 ppm on mixed juice for both the SRI and rapi Dorr clarifier stated by (Anon, 1996).

The change in number and type of clarifiers operating in South Africa till 1995 according to (Jullienne and Montocchio, 1996) is shown in table 2.4.

<table>
<thead>
<tr>
<th>Type and Number of Clarifiers in the Sugar Industry (South Africa)</th>
<th>1975</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio 4 clarifiers (Dorr/Graver/Batch)</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>Ratio 2 Clarifiers (Rapi Dorr)</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Ratio 1 Clarifiers Rapi Dorr</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>SRI Type</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>BMA</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Envirotech</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>27</td>
</tr>
</tbody>
</table>

Reference Jullienne and Montocchio (1996)
CHAPTER THREE
MATERIAL AND METHODS

The methods that are used to get the data in this investigation are from South African Sugar Laboratory (Manual, 1985).

3.1 Materials

3.1.1 Mixed juice

In the manufacture of cane sugar, the juice extracted from cane which consists of water, organic and non-organic acid mud, sucrose and non-sucrose according to (Mead and Chain, 1977).

3.1.2 Clarified juice

As stated by Bricerio and Hurtadu, et al. (1999), The clarified juice, the clear juice were collected from subsidies or clarifier after chemical treated.

3.2 Chemicals

- Lead Sub-acetate powder.
- Kieselghure (acid wash).
- Filter aid celite 577 or equivalent.
- Fehlings solution A and B.
- EDTA solution (4%).
- Methylene blue solution.
- Glass bead.
- Pumice powder.
- Liquid paraffin.
- Ammonium molybdate solution (1.5%).
- Reducing solution.
- Hydrochloric acid (ca. 0.05 M).
- Sodium hydroxide (ca. 0.05 M).

### 3.3 Equipment

- Precision refractometer.
- Filter paper. Whatman No. 6, 91, 5 or equivalent (150 mm φ, 80 mm φ, 55 mmφ).
- Stemless funnel (100 φ).
- Squat beaker (100, 250 cm$^3$).
- Watch glass (100 φ, 80 φ).
- Saccharimeter and 200 mm pol tube.
- Stopped bottle (225 mm φ).
- Tall form beaker (250 cm$^3$).
- pH meter.
- Spectrophotometer.
- Pipettes (10 cm$^3$, 20 cm$^3$).
- Volumetric flasks (100 cm$^3$, 200 cm$^3$).
- Funnel (100 mm Φ).
- Light duty balance.
- Pipette (5 cm$^3$ and 20 cm$^3$).
- Burette (50 cm$^3$).
- Flat bottom narrow neck boiling flask (40 cm$^3$).
• Hot plate.
• Gauze (0.15 mm pore opening).
• Buchner funnel (60 mm φ).
• Beakers flask (500 cm³).
• Stirring rod.

3.4 Methodology

3.4.1 Determination of Brix% clarified juice and filter feed

The measurement is effected by the presence of suspended matter which must therefore be removed by filtration or centrifuging. Temperature changes have a predictable effect on refractometer readings of pure sucrose solutions and the temperature corrections which apply to pure sucrose solution may be used for juices without introducing serious errors. However, it is recommended by ICUMSA (1982) that the measurement be carried out at 20°C.

About 1 g filter aid was added to 100 cm³ juices in the bottle, stoppered and shaked to disperse the filter aid, Filtered through a fluid filter paper supported in the funnel which was rested directly on the mouth of the squat beaker. the funnel was covered with a watch glass to minimize evaporation, the beaker rinsed by first 10 cm³ of filtrate discarded, sufficient filtrate collected and its refractometer brix measured, note the temperature reading also recorded, the reading of the thermometer located on the prism mount if this differs from 20 ± 0.1°C, if
necessary the instrument reading to be converted to brix using the table supplied with instrument.

3.4.2 Determination of Pol% clarified juice and filter feed

Approximately 150 cm³ of the sample was taken in to bottle provided with a stopper, sufficient lead sub-acetate powder added to clarified juice, and mixture shacked vigorously to disperse the lead sub-acetate completely and then allowed to stand to permit flocculation of the precipitate (usually about 0.5 minutes). And mixture was filtered through fluted filter paper was held in the funnel which was rested directly on the Beaker and covered with the watch glass to minimize evaporation, the first 25 cm³ of filtrate were discarded, and transferred into saccharimeter and the polarization was recorded. Then the reading was multiplied by 2 to give Pol% of clarified juice.

3.4.3 Determination of purity% clarified juice and filter feed

The purity of a clarified juice sample was derived from the percentage ratio of pol% in juice to brix% in juice.

\[
\text{purity} = \frac{\text{Pol} \% \text{ juice} \ \text{uncorrected} \ \text{for insoluble solids}}{\text{brix} \% \text{ juice}} \times 100
\]

3.4.4 pH measurement

Hot samples was cooled to room temperature prior to pH measured as apart from cooling, no other treatment of the sample, the electrodes and beaker was rinsed with abortion of the sample, a sufficient sample was
taken in the beaker and the electrodes to be immersed in the sample, the electrodes allowed to remain in the sample for one minute and the pH reading taken.

3.4.5 Reducing sugars

The reducing sugars content of juices is determined using the method of Eynon and Lane in which a sample of juice containing about 0.15 to 0.3 g RS/100 cm$^3$ is titrated against Fehlings solution. It has been found that calcium interferes with determination and it is recommended that EDTA be used as sequestrant. In most factory products EDTA reduces the color significantly and improves the titration end point.

The sample of juice was pour for analysis through the piece of gauze any solid particles to be removed which might block the tip of the pipette or burette.

50 g of the screened sample was weighed into a clean volumetric flask, 10 cm$^3$ of EDTA (4%) was added and made to the mark with distilled water.

50 cm$^3$ burette was rinsed with the diluted juice before filled and adjusted to zero.

5 cm$^3$ Fehling A solution and 5 cm$^3$ Fehling B solution were pipetted into the boiling flask, a little pumice powder three glass beads and four drops of liquid paraffin was added, to prevent foaming.
15 cm³ diluted juice from the burette was added. A flask was placed on a fast hot plate and the mixture was heated to the boiling in not more than 2.25 minutes.

After, the liquid was boiled for 10-15 seconds, its color showed that much of the fehling's solution has not been reduced, further addition are made, 5 cm³ at time with a few second boiling after each, until the original color of the reagent faded.

Three or four drops of methylene blue were added and the addition of solution from the burette was continued until the indicator is completely decolorized.

At the boiling liquid the bright orange appearance resumed before the indicator added.

During the additions the burette was held in the hand. The burette reading was taken as an approximate titration.

A second titration was carried out in which all but 1 cm³ of the sample solution added at once.

The liquid was heated and boiled to boiling point stop watch was started and the liquid was kept boiling for 2 minutes. Methylene blue indicator added. The titration was completed by adding the solution drop by drop until the indicator became colorless. The titration was completed within 3 minutes from the commencement of ebullition and during this time the mixture was kept boiling continuously to exclude air. Duplicate titrations were agreed within 0.1 cm³.
3.4.6 Phosphate determination

The juice was filtered, the first running (about 10 cm$^3$) was rejected and about 150 cm$^3$ clear filtrate was collected.

The aliquot used depended on the concentration of phosphate, so as clarified juice contained about 40 ppm P$_2$O$_5$, it was made to the mark with distilled water and was mixed thoroughly.

20 cm$^3$ of the diluted solution were pipetted into each of two 100 cm$^3$ of volumetric flask, one of which was diluted to about 60 cm$^3$ with distilled water and the other was marked to the mark with distilled water and was used as blank.

10 cm$^3$ ammonium molybdate solution was added to the first flask and mixed by swirling.

10 cm$^3$ reducing solution was added, made to the mark with distilled water and mixed by shaking, the time at which reducing solution is added was noted.

The intensities of the blue color developed were measured using the spectrophotometer exactly 10 minutes after the reducing solution was added. A 10 mm cell was used and measured at 700 nm on the spectrophotometer. The reference is a 10 mm cell was contained with distilled water.

The optical density of the blank sample was measured also against distilled water.
From the calibration graph which provided the quantity of P₂O₅ corresponding to the optical density’s which was obtained.

3.4.7 Color and turbidity measurement

(a) 50 brix solution was prepared.

For example if the brix of the juice = 13.250 then to make 100 g of 50 brix solution was weight out make up to 100 g with distilled water and stir well.

(b) The prepared solution was divided between two 250 cm³ beakers, marked S1 and S2.

(c) The solution S2 was filtered under vacuum, the first cloudy running discarded.

(d) The filtrate was collected in a clean dry Buchner flask.

(e) Then transfer to a 100 cm³ beaker marked S2 and cover with a watch glass.

(g) The pH adjusted to 7.0 ± 0.1 using hydrochloric acid or sodium hydroxide.

(h) The optical density measured in a 5 mm cell at 420 nm against distilled water as reference and optical density recorded as OD2.

(I) The pH of solution S1 adjusted to 7.0 ± 0.1 using hydrochloric acid or sodium hydroxide.
(j) The optical density was measured in a 5 mm cell at 420 nm against distilled water as reference and optical density recorded as OD1.

**Reporting of Values**

(a) The optical density of the filtered juice solution (S2) was expressed as ICUMSA 420 color. This is calculated as follows:

$$\text{ICUMSA 420 color} = \frac{As \times 1000}{bc}$$

Where $As =$ absorbance at 420 nm

$b =$ cell length (nm)

$c =$ concentration of total solids (g/cm$^3$)

(b) The turbidity of the unfiltered juice solution (S1) is calculated as follows and used for in house control only:

$$\text{Turbidity} = [(\text{Absorbency index of unfiltered sample}) \times 1000] - \text{ICUMSA 420 color}$$

Where absorbency index of unfiltered sample

$$= \frac{Aus \times 10}{bc}$$

And $Aus =$ absorbance of unfiltered sample at 420 nm

$b =$ cell length (nm)

$c =$ concentration of total solids (g/cm$^3$)
4.1 Results

The study of clarification and performance of SRI and Rapi Dorr clarifiers and comparison between the two different designs done according to the output of both clarifiers. The study carried out at Kenana Sugar factory, the samples were taken from PH# 1 where the two SRI clarifiers installed. Samples taken from Clarifier #1 (SRI) and clarifier#2 (Rapi Dorr). Clarified juice and mud samples were collected from SRI and Rapi Dorr clarifier. The condition and characteristic of the mixed juice before being introduced to the clarifier was studied all through the crushing period, early season, mid season and at the end of the crushing season.

4.1.1 Early season results

Mixed juice analytical results for the period 5th to 15th Nov. 2004 is shown in Table 4.1., for the early season samples of the clarified juice of both SRI and Rapi Dorr.

4.1.2 Mid season results

Mixed juice analytical results for the period 4th to 15th Jan. 2005 is shown in Table 4.2., for the mid season sample of the clarified juice of both SRI and Rapi Dorr.
Table 4.1: Mixed Juice Analysis for the Sample at Period 5\textsuperscript{th} Nov. to 15\textsuperscript{th} Nov. 2004

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Flow Rate</th>
<th>pH</th>
<th>P\textsubscript{2}O\textsubscript{5}</th>
<th>Color</th>
<th>Pol%</th>
<th>Bx%</th>
<th>Pty%</th>
<th>Temp °C</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>599</td>
<td>8.0</td>
<td>297</td>
<td>8169</td>
<td>9.62</td>
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<td>2</td>
<td>494</td>
<td>7.9</td>
<td>289</td>
<td>9556</td>
<td>9.75</td>
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<td>4</td>
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<td>10.41</td>
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</table>

Table 4.2: Mixed Juice Analysis for Sample at the Period (4\textsuperscript{th} to 15\textsuperscript{th} Jan, 2005).

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Flow Rate T/hr</th>
<th>Ph</th>
<th>P\textsubscript{2}O\textsubscript{5}</th>
<th>Color ICUMSA</th>
<th>Pol%</th>
<th>Bx%</th>
<th>Pty%</th>
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<td>12.57</td>
<td>14.69</td>
<td>85.57</td>
<td>106</td>
</tr>
</tbody>
</table>

4.1.3 Late season results

Mixed juice analysis results for the period 4\textsuperscript{th} March. To 15\textsuperscript{th} March. 2005 are shown in Table 4.3., for the late season sample of the clarified juice of both SRI and Rapi Dorr.
Table 4.3: Mixed Juice Analysis for Sample at the Period (4th to 15th March, 2005).

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Flow Rate T/hr</th>
<th>pH</th>
<th>P₂O₅</th>
<th>Color ICUMSA</th>
<th>Pol%</th>
<th>Bx%</th>
<th>Pty%</th>
<th>Temp. °C</th>
</tr>
</thead>
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</tr>
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<td>105</td>
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<td>14.07</td>
<td>85.86</td>
<td>106</td>
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</tbody>
</table>

4.2 Discussion

From table (4.1 to 4.3) the parameters of mixed juice which introduced to SRI and Rapi Dorr clarifiers at a time flow rate, phosphate content, colour, Pol, Bx, Purity, and temperature showed normal results, a flow rate may be excepted which can impact the out put of clarifiers.

The study of the performance of SRI and Rapi Dorr clarifiers and comparison between the two different designs was done according to the output of both clarifiers; the following are the analysis of the output as Pol%, Bx%, pH% etc.

4.2.1 Clarified juice polarization

From Table (4.1 and 4.4) at the flow rate 599 T/hr which was the maximum flow rate at the first period when the sample was taken, the SRI clarifier scored 11.67 Pol% higher than the Pol% of Rapi Dorr which was
11.57. At the flow rate 455 T/hr the minimum flow rate the SRI clarifier scored 11.86 Pol% lower than the Pol% of Rapi Dorr which was 11.94.

From Table (4.2 and 4.4) at the juice flow rate 495 T/hr which was the maximum flow rate at the 2’nd period when the sample was taken, the SRI clarifier has 13.97 pol% less than the pol% of Rapi Dorr 14.24%. At the minimum flow rate flow rate 451 T/h in the same period the SRI clarifier showed 14.63 pol% higher than the pol% of Rapi Dorr which was 14.55%.

From Table (4.3 and 4.4) at the flow rate 532 T/h which was the maximum flow rate during the 3’rd period, the SRI clarifier showed 12.51 pol% which was less than the pol% 13.46 of the Rapi Dorr clarifier. At the minimum flow rate 451 T/h the minimum flow rate in the same period the SRI clarifier showed 14.86 pol%, that was higher than the result obtained by the Rapi Dorr 13.95 pol%. That means at lower flow rate the SRI showed a better result as in Table 4.4 and see scattering Fig. (4.1, 4.2 and 4.3).

An overall look was taken for Table (4.1 and 4.4). Only 11 samples out of 30 samples taken from SRI clarifier got the highest Pol%. This means that 19 samples out of 30 got Pol% of a lowest value among the clear juice samples, on the contrary for Rapi Dorr clarifier clear juice 19 sample out of 30 got the highest value of Pol%. The higher the Pol%, means the lesser non-sugars available the better quality of raw sugar. As from Table 4.4 and from Fig (4.1 to 4.3) it can be noticed that the SRI and
Rabi Dorr showed the same Pol% normal range. However Pol% is very important for the energy requirement during processing, low Pol% increase the energy consumption in the further processing as reported by (Humm, 1979).

**Fig. 4.1: Comparison of the Pol%, in the SRI versus the Rapi Dorr Clarifier (in early Season)**
Fig. 4.2: Comparison of the Pol%, in the SRI versus the Rapi Dorr Clarifier
(in mid season)

Fig. 4.3: Comparison of the Pol%, in the SRI versus the Rapi Dorr clarifier
(In late Season)
Table 4.4: Compile Table of Flow Rate and Pol% at Different Periods.

<table>
<thead>
<tr>
<th>Flow Rate t/h Early season</th>
<th>Pol%</th>
<th>Pol% Rabi Dorr</th>
<th>Flow Rate t/h Mid season</th>
<th>Pol%</th>
<th>Pol% Rabi Dorr</th>
<th>Flow Rate t/h End season</th>
<th>Pol%</th>
<th>Pol% Rabi Dorr</th>
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</thead>
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<td>14.19</td>
<td>496</td>
<td>13.49</td>
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</tbody>
</table>

4.2.2 Clarified juice Bx

From Table (4.1 and 4.5) at 599 T/h flow rate. The SRI clarifier showed soluble solid percentage 13.48 less than the Rapi Dorr 13.87. At 455 T/h flow rate was the minimum flow rate in the same period the SRI clarifier showed soluble 14.15 Bx% lower than the Rapi Dorr 14.40 Bx%.

From Table (4.2 and 4.5) at 495 T/h flow rate which was the maximum flow rate at the 2’nd period when the sample was taken, the SRI clarifier showed 17.00% Bx lower than the Rapi Dorr 17.11% Bx. At flow rate 451 T/h which was the minimum flow rate in the same period the SRI clarifier showed 17.30 higher than the Rapi Dorr 17.21 Bx%.

From Table (4.3 and 4.5) at the maximum flow rate 532 T/h for the 3’d period when the sample was taken, the SRI clarifier showed 15.70 Bx less than the Rapi Dorr 15.87% Bx. Where as the minimum 451 T/h in the same period the SRI clarifier showed 17.34% Bx higher than the Rapi Dorr 17.21% Bx.

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Generally from Table (4.5) and from fig. (4.4 to 4.6) it was noticed 11 samples out of 30 samples taken from SRI clarifier got the higher Brix% this means 19 samples out of 30 got Brix% of lower value among the clear juice samples, on the other hand the Rapi Dorr clarifier clear juice samples, 19 samples out of 30 got higher value of Brix%.

As from Table (4.5) and from Fig (4.4 to 4.6) the samples readings demonstrated slight differences between SRI samples readings and Rapi Dorr clarifier the obtained Bx% results were confirmed by Bx values (Bricerio et al., 1999).

Fig. 4.4: Comparison of the Bx%, in the SRI versus the Rapi Dorr Clarifier (in early Season)
Fig. 4.5: Comparison of the Bx%, in the SRI versus the Rapi Dorr Clarifier
(in mid Season)

Fig. 4.6: Comparison of the Pol%, in the SRI versus the Rapi Dorr Clarifier
(In late Season)
### Table 4.5: Compile Table of Flow Rate and Bx% at Different Periods.

<table>
<thead>
<tr>
<th>Flow Rate t/h</th>
<th>Bx% SRI</th>
<th>Bx% Rabi Dorr</th>
<th>Flow Rate t/h</th>
<th>Bx% SRI</th>
<th>Bx% Rabi Dorr</th>
<th>Flow Rate t/h</th>
<th>Bx% SRI</th>
<th>Bx% Rabi Dorr</th>
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</thead>
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<td>461</td>
<td>17.28</td>
<td>17.08</td>
</tr>
</tbody>
</table>

#### 4.2.3 Clarified juice purity

From table (4.1 and 4.6) at 599 T/h flow rate which was the maximum flow rate at the first period when the sample was taken, the SRI clarifier got a purity% of 86.57 higher than the Rapi Dorr purity% 83.42. At the minimum flow rate 455 T/h in the same period the SRI clarifier got a purity% of 83.82 higher than the Rapi Dorr purity% 82.92.

As noticed in table (4.2 and 4.6) at 495 T/h flow rate which was the maximum flow rate at the 2’nd period when the sample was taken, the SRI clarifier got a purity% of 85.95 less than the Rapi Dorr purity% 86.94. At 451 T/h flow rate which was the minimum flow rate in the same period, the SRI clarifier got a purity% of 87.05 less than the Rapi Dorr purity% 89.98.
As reported in Table (4.3 and 4.6) at 532 T/h flow rate which was the maximum flow rate at the 3’rd period when the sample was taken, the juice purity of the SRI clarifier was 79.68% less than the Rapi Dorr purity% 84.81. But at 451 T/h flow rate which was the minimum in the same period the obtained purity was 85.71% for SRI clarifier higher than the Rapi Dorr purity% 81.09, this means that at lower flow rate the SRI clarifier performed better than the Rapi Dorr.

It is noticed that from Table 4.6 and Fig (4.7 to 4.9) only 18 samples out of 30 samples taken from SRI clarifier got the higher Pol% this means 12 samples out of 30 got Purity% of lower value among the clear juice samples, but in the Rapi Dorr only 12 samples out of 30 got the higher value of Purity%. The higher Purity%, means the higher extraction of sucrose from mixed juice at boiling house as confirmed by as from Table 4.6 and Fig. (4.7 to 4.9) the samples readings gave slightly difference between SRI samples readings Rapi Dorr clarifier Purity readings (Bricerio et al., 1999).
Fig. 4.7: Comparison of the Purity%, in the SRI versus the Rapi Dorr Clarifier

(in early Season)

Fig. 4.8: Comparison of the Purity%, in the SRI versus the Rapi Dorr Clarifier

(in mid Season)
Fig. 4.9: Comparison of the Purity%, in the SRI versus the Rapi Dorr Clarifier  
(in late season)

Table 4.6: Compile Table of Flow Rate and Purity% at Different Periods.

<table>
<thead>
<tr>
<th>Flow Rate t/h Early season</th>
<th>Purity% SRI</th>
<th>Purity% Rabi Dorr</th>
<th>Flow Rate t/h Mid season</th>
<th>Purity% SRI</th>
<th>Purity% Rabi Dorr</th>
<th>Flow Rate t/h Later season</th>
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<th>Purity% Rabi Dorr</th>
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</tbody>
</table>
4.2.4 pH of clarified juice

From Table (4.1 and 4.7) at 599 T/h flow rate which was the maximum flow rate at the 1’st period when the sample was taken, the SRI clarified juice showed a pH value 7.7 which was higher than the Rapi Dorr pH 6.8. At 455 T/h flow rate which was the minimum flow rate in the same period the SRI clarifier scored a pH 7.4 which was higher than the Rapidorr pH 7.1.

From Table (4.2 and 4.7) at 495 T/h flow rate which was the maximum flow rate at the 2’nd period when the sample was taken, the pH of the SRI clarifier was 6.70, lower than 7.1 pH of the Rabi Dorr clarifier. At 451 T/h flow rate which was the minimum flow rate in the same period the SRI clarifier showed a pH 7.20 higher than the Rapi Dorr pH 6.9.

From Table (4.3 and 4.7) at 532 T/h flow rate which was the maximum flow rate at the 3’rd period when the sample was taken, the SRI clarifier showed a pH 7.20 higher than the Rapi Dorr pH 6.80. At 451 T/h flow rate which was the minimum flow rate in the same period the SRI clarifier gave a pH 7.20 higher than the Rapi Dorr 6.90. This means that the SRI clarifier showed better pH values than Rapi dorr.
Fig. 4.10: Comparison of the pH%, in the SRI versus the Rapi Dorr Clarifier

(in early Season)

Fig. 4.11: Comparison of the pH%, in the SRI versus the Rapi Dorr Clarifier

(in mid Season)
Fig. 4.12: Comparison of the pH%, in the SRI versus the Rapi Dorr Clarifier
(in late season)

Table (4.7): Compile Table of Flow Rate and pH at Different Periods.

<table>
<thead>
<tr>
<th>Flow Rate t/h Early season</th>
<th>SRI pH</th>
<th>Rabi Dorr pH</th>
<th>Flow Rate t/h Mid season</th>
<th>SRI pH</th>
<th>Rabi Dorr pH</th>
<th>Flow Rate t/h End season</th>
<th>SRI pH</th>
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<td>461</td>
<td>7.4</td>
<td>6.9</td>
</tr>
</tbody>
</table>
As from Table (4.4 and 4.7) and from Figure (4.10 to 4.12) the samples readings experienced slight differences between SRI samples readings and Rapi Dorr clarifier readings for pH values. Also pH results of SRI and Rabi Dorr falls under normal range of pH 6.8 to 7.0 according to Chen and Chou (1993).

4.2.5 Clarified juice phosphate content

In the clarification of cane juices the presence of an adequate amount of phosphoric acid is very important. Insufficient available $P_2O_5$ in cane juice is one of the causes of poor clarification. The amount of $P_2O_5$ present in cane juice must be not less than 300 ppm. If the juice is deficient in $P_2O_5$, it must be made up to this minimum amount before liming according to (Shephard, 1980).

From Table (4.1 and 4.8) at 599 T/h flow rate which was the maximum flow rate at the 1'st period when the sample was taken, the phosphate content in the SRI clarifier was 24 lower than 51 of the Rapi Dorr clarifier. At 455 T/h flow rate which was the minimum flow rate in the same period the SRI clarifier showed a phosphate content of 2 lower than 4 phosphate content of the Rapi Dorr.

From Table (4.2 and Table 4.8) at 495 T/h flow rate which was the maximum flow rate at the 2’nd period when the sample was taken, the phosphate content in the SRI clarifier was 4 ppm lower than 7 ppm phosphate content of the Rabi Dorr. At 451 T/h flow rate which was the
minimum flow rate in the same period the SRI clarifier showed phosphate content 7 ppm lower than 11 ppm phosphate content of the Rabi Dorr.

Fig. 4.13: Comparison of the P$_2$O$_5$%, in the SRI versus the Rapi Dorr Clarifier

( in early season)

Fig. 4.14: Comparison of the P$_2$O$_5$ ppm, in the SRI versus the Rapi Dorr Clarifier

(in mid Season)
Fig. 4.15: Comparison of the P$_2$O$_5$ in the SRI versus the Rapi Dorr Clarifier %,
(in late season)

Table (4.8): Compile Table of Flow Rate and P$_2$O$_5$ Content at Different Periods.

<table>
<thead>
<tr>
<th>Flow Rate T/h</th>
<th>P$_2$O$_5$</th>
<th>P$_2$O$_5$</th>
<th>Flow Rate T/h</th>
<th>P$_2$O$_5$</th>
<th>P$_2$O$_5$</th>
<th>Flow Rate T/h</th>
<th>P$_2$O$_5$</th>
<th>P$_2$O$_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Mid season</td>
<td>End season</td>
<td>Early season</td>
<td>Mid season</td>
<td>End season</td>
<td>Early season</td>
<td>Mid season</td>
</tr>
<tr>
<td>599</td>
<td>24</td>
<td>51</td>
<td>475</td>
<td>8</td>
<td>10</td>
<td>471</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>494</td>
<td>21</td>
<td>38</td>
<td>486</td>
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<td>485</td>
<td>8</td>
<td>11</td>
<td>532</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>477</td>
<td>6</td>
<td>6</td>
<td>472</td>
<td>10</td>
<td>10</td>
<td>509</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>461</td>
<td>4</td>
<td>5</td>
<td>479</td>
<td>10</td>
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<td>483</td>
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<td>9</td>
</tr>
<tr>
<td>473</td>
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<td>8</td>
<td>482</td>
<td>7</td>
<td>13</td>
<td>484</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>455</td>
<td>2</td>
<td>4</td>
<td>482</td>
<td>9</td>
<td>7</td>
<td>496</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>477</td>
<td>4</td>
<td>6</td>
<td>495</td>
<td>4</td>
<td>7</td>
<td>453</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>493</td>
<td>6</td>
<td>6</td>
<td>451</td>
<td>7</td>
<td>11</td>
<td>451</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>473</td>
<td>6</td>
<td>5</td>
<td>485</td>
<td>11</td>
<td>13</td>
<td>461</td>
<td>12</td>
<td>15</td>
</tr>
</tbody>
</table>
From Table (4.3 and 4.8) at 532 T/h flow rate which was the maximum flow rate at the 3'rd period when the sample was taken, the phosphate content in the SRI clarifier was lower than 10 phosphate content of the Rabi Dorr. At 451 T/h flow rate which was the minimum flow rate in the same period the SRI clarifier showed a phosphate content 10 lower than 11 phosphate content of the Rabi Dorr.

As from Table (4.4 and 4.7) and from Figure (4.13 to 4.15) the less phosphate content after clarification process means a complete reaction took place for good impurities settling as stated by Shephard (1980).

4.2.6 Clarified juice turbidity

As noticed from Table (4.1 and 4.9), when the flow rate 599 T/h, the juice turbidity in the SRI clarifier was 8 which considered higher than 4 which was the juice turbidity in the Rapi Dorr clarifier. But when the flow rate was 455 T/h in the same period the juice turbidity in the SRI clarifier was 3 which considered lower than 4 which was the juice turbidity in the Rapi Dorr clarifier.

As noticed from Table (4.2 and 4.9), when the flow rate was 495 T/h, the juice turbidity in the SRI clarifier was 4 which considered lower than 9 which was the juice turbidity in the Rapi Dorr clarifier. But when the flow rate was 451 T/h in the same period the juice turbidity in the SRI clarifier was 7 which considered lower than 13 which was the juice turbidity in the Rapi Dorr clarifier,
Fig. 4.16: Comparison of the Turbidity in the SRI versus the Rapi Dorr Clarifier, (in early season)

Fig. 4.17: Comparison of the Turbidity, in the SRI versus the Rapi Dorr Clarifier (in mid season)
Fig. 4.18: Comparison of the Turbidity, in the SRI versus the Rapi Dorr Clarifier (in late Season)

Table 4.9: Compile Table of Flow Rate and Turbidity% at Different Periods.

<table>
<thead>
<tr>
<th>Flow Rate T/h</th>
<th>Turb% SRI</th>
<th>Turbid% Rabi Dorr</th>
<th>Flow Rate T/h</th>
<th>Turb% SRI</th>
<th>Turb% Rabi Dorr</th>
<th>Flow Rate T/h</th>
<th>Turb% SRI</th>
<th>Turb% Rabi Dorr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early season</td>
<td></td>
<td></td>
<td>Mid season</td>
<td></td>
<td></td>
<td>Late season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>599</td>
<td>8</td>
<td>4</td>
<td>475</td>
<td>7</td>
<td>19</td>
<td>471</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>494</td>
<td>4</td>
<td>7</td>
<td>486</td>
<td>6</td>
<td>8</td>
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<tr>
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<td>7</td>
<td>485</td>
<td>6</td>
<td>9</td>
<td>532</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>477</td>
<td>4</td>
<td>5</td>
<td>472</td>
<td>8</td>
<td>12</td>
<td>509</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>461</td>
<td>3</td>
<td>4</td>
<td>479</td>
<td>8</td>
<td>12</td>
<td>483</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>473</td>
<td>4</td>
<td>6</td>
<td>482</td>
<td>5</td>
<td>13</td>
<td>484</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>455</td>
<td>3</td>
<td>4</td>
<td>482</td>
<td>6</td>
<td>9</td>
<td>496</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>477</td>
<td>3</td>
<td>5</td>
<td>495</td>
<td>4</td>
<td>9</td>
<td>453</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>493</td>
<td>4</td>
<td>5</td>
<td>451</td>
<td>7</td>
<td>13</td>
<td>451</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>473</td>
<td>5</td>
<td>7</td>
<td>485</td>
<td>4</td>
<td>12</td>
<td>461</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>
As shown in Table (4.3 and 4.9), when the flow rate was 532 T/h, the juice turbidity in the SRI clarifier was 9 which considered lower than 10 which was the juice turbidity in the Rapi Dorr clarifier. But when the flow rate 451 T/h in the same period the juice turbidity in the SRI clarifier was 5 which was lower than 9 which was the juice turbidity in the Rapi Dorr clarifier,

As from table (4.1 to 4.3) and from Figure (4.16 to 4.18), SRI clarifier showed better results of turbidity, this means due to low mud compaction as stated by (Hugot, 1986).

4.2.7 Reducing Sugars (RS)

As noticed from Table (4.1 and 4.10), when the juice flow rate was 599 T/h, the juice RS content in the SRI clarifier was 0.90 which considered higher than 0.85 which was the juice Rs content in the Rabi Dorr clarifier. But when the juice flow rate was 455 T/h in the same period the juice RS content in the SRI clarifier was 1.00 which considered higher than 0.95 which was the juice Rs content in the Rapi Dorr clarifier.

As noticed from Table (4.2 and 4.10), when the juice flow rate 495 T/h, the juice Rs content in the SRI clarifier was 0.63 which considered lower than 0.67 which was the juice RS content in the Rabi Dorr clarifier. But when the juice flow rate was 4 T/h which was minimum flow rate in the same period the juice Rs content in the SRI clarifier was 0.73 which considered higher than 0.64 which was the juice RS content in the Rapi Dorr clarifier.
Fig. 4.19: Comparison of the Rs in the SRI versus the Rapi Dorr Clarifier, (in Early Season)

Fig. 4.20: Comparison of the Rs, in the SRI versus the Rapi Dorr Clarifier (in mid Season)
Fig. 4.21: Comparison of the Rs, in the SRI versus the Rapi Dorr Clarifier
(in late season)

Table (4.10): Compile Table of Flow Rate and Rs% at Different Periods.

<table>
<thead>
<tr>
<th>Flow Rate T/h</th>
<th>Rs SRI</th>
<th>Rs Rappi Dorr</th>
<th>Flow Rate T/h</th>
<th>Rs SRI</th>
<th>Rs Rappi Dorr</th>
<th>Flow Rate T/h</th>
<th>Rs SRI</th>
<th>Rs Rappi Dorr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early season</td>
<td></td>
<td></td>
<td>Mid season</td>
<td></td>
<td></td>
<td>Later season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>599</td>
<td>0.85</td>
<td>0.90</td>
<td>475</td>
<td>0.78</td>
<td>0.78</td>
<td>471</td>
<td>1.05</td>
<td>1.00</td>
</tr>
<tr>
<td>494</td>
<td>0.93</td>
<td>1.00</td>
<td>486</td>
<td>0.71</td>
<td>0.84</td>
<td>486</td>
<td>1.08</td>
<td>1.14</td>
</tr>
<tr>
<td>496</td>
<td>0.89</td>
<td>0.86</td>
<td>485</td>
<td>0.76</td>
<td>0.8</td>
<td>532</td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td>477</td>
<td>0.70</td>
<td>0.72</td>
<td>472</td>
<td>0.24</td>
<td>0.22</td>
<td>509</td>
<td>1.16</td>
<td>1.10</td>
</tr>
<tr>
<td>461</td>
<td>0.80</td>
<td>0.75</td>
<td>479</td>
<td>0.65</td>
<td>0.61</td>
<td>483</td>
<td>1.09</td>
<td>1.12</td>
</tr>
<tr>
<td>473</td>
<td>0.97</td>
<td>0.90</td>
<td>482</td>
<td>0.74</td>
<td>0.73</td>
<td>484</td>
<td>0.88</td>
<td>0.96</td>
</tr>
<tr>
<td>455</td>
<td>1.00</td>
<td>0.95</td>
<td>482</td>
<td>0.68</td>
<td>0.69</td>
<td>496</td>
<td>1.18</td>
<td>1.28</td>
</tr>
<tr>
<td>477</td>
<td>0.86</td>
<td>0.88</td>
<td>495</td>
<td>0.63</td>
<td>0.67</td>
<td>453</td>
<td>0.85</td>
<td>0.96</td>
</tr>
<tr>
<td>493</td>
<td>0.93</td>
<td>0.88</td>
<td>451</td>
<td>0.73</td>
<td>0.64</td>
<td>451</td>
<td>0.89</td>
<td>0.91</td>
</tr>
<tr>
<td>473</td>
<td>0.86</td>
<td>0.94</td>
<td>485</td>
<td>0.61</td>
<td>0.62</td>
<td>461</td>
<td>0.93</td>
<td>1.01</td>
</tr>
</tbody>
</table>
As noticed from Table 4.3 and 4.10, when the juice flow rate was 532 T/h, the juice Rs content in the SRI clarifier was 0.89 which was the same as 0.89 which was the juice Rs content in the Rabi Dorr clarifier. But when the juice flow rate was 451 T/h in the same period the juice RS content in the SRI clarifier was 0.89 which considered lower than 0.91 which was the juice RS content in the Rapi Dorr clarifier.

Refer to Table (4.10) and Figure (4.19 to 4.21), although glucose and fructose are the building units of sucrose; they are called reducing sugars (RS) or invert sugar and are considered as non-sugars. Their presence in the process indicates loss of sucrose due to hydrolysis. They are also a source of color increase in the process, and they can slow down the crystallization rate. The obtained results matches with what was stated by Webster (1988) reported that high reducing sugars content will inhibit crystallization, lead to the increase in the viscosities, lengthen boiling time and increase problem in molasses.

4.2.8 Clarified juice color

As noticed from table (4.1 and 4.11) when the flow rate was 599 T/h the juice color in the SRI clarifier was 23093 ICUMSA, which considered higher than 14766 ICUMSA which was the juice color in the Rapi Dorr clarifier. But when the flow rate was 455 T/h in the same period the juice color in the SRI clarifier was 13038 ICUMSA which considered higher than the 12068 ICUMSA which was the juice color in the Rapi Dorr clarifier.
But in table (4.2 and 4.11) when the flow rate was 495 T/h the juice color in the SRI clarifier was 10540, which considered lower than 10827 ICUMSA which was the juice color in the Rapi Dorr clarifier. But when the flow rate was 451 T/h in the same period the juice color in the SRI clarifier was 8778 which considered lower than the 9021 ICUMSA which was the juice color in the Rapi Dorr clarifier.

As noticed from table (4.3 and 4.11) when the flow rate was 532 T/h the juice color in the SRI clarifier was 12533 ICUMSA, which considered higher than 11996 ICUMSA which was the juice color in the Rapi Dorr clarifier. But when the flow rate was 451 T/h in the same period the juice color in the SRI clarifier was 10988 which considered higher than the 12513 ICUMSA which was the juice color in the Rapi Dorr clarifier.

As from Table (4.11) and from Fig. (4.22 to 4.24) the samples readings are showing slightly difference between SRI samples readings and Rapi Dorr clarifier readings of color values (Bricerio et al., 1999).
Table (4.11): Compile Table of Flow Rate and Color at Different Periods.

<table>
<thead>
<tr>
<th>Flow Rate T/h Early season</th>
<th>Color ICUMSA SRI</th>
<th>Color ICUNSA Rabi Dorr</th>
<th>Flow Rate T/h Mid season</th>
<th>Color ICUMSA SRI</th>
<th>Color ICUNSA Rabi Dorr</th>
<th>Flow Rate T/h later season</th>
<th>Color ICUMSA SRI</th>
<th>Color ICUNSA Rabi Dorr</th>
</tr>
</thead>
<tbody>
<tr>
<td>599</td>
<td>23093</td>
<td>14766</td>
<td>475</td>
<td>10852</td>
<td>11282</td>
<td>471</td>
<td>12142</td>
<td>17157</td>
</tr>
<tr>
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</tr>
<tr>
<td>496</td>
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<td>12869</td>
<td>485</td>
<td>11656</td>
<td>11737</td>
<td>532</td>
<td>12533</td>
<td>11996</td>
</tr>
<tr>
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<td>472</td>
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<td>10998</td>
<td>509</td>
<td>13039</td>
<td>11785</td>
</tr>
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<td>14421</td>
<td>14171</td>
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<td>11025</td>
<td>11946</td>
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<td>24618</td>
</tr>
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<td>482</td>
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<td>11025</td>
<td>484</td>
<td>12914</td>
<td>10862</td>
</tr>
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<td>8778</td>
<td>9021</td>
<td>451</td>
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<td>9083</td>
<td>11864</td>
<td>461</td>
<td>11939</td>
<td>12991</td>
</tr>
</tbody>
</table>
Fig. 4.22: Comparison of the color, in the SRI versus the Rapi Dorr Clarifier

(in early Season)

Fig. 4.23: Comparison of the Colour, in the SRI versus the Rapi Dorr Clarifier

(in mid Season)
Fig. 4.24: Comparison of the Colour, in the SRI versus the Rapi Dorr Clarifier

(in late season)
CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions:

- The most readings of clarified juice Pol% of SRI clarifier and Rapi Dorr showed slight difference at different season periods early, mid and late respectively.
- The most readings of clarified juice Bx% of SRI clarifier was lower than Rapi Dorr clarified juice at different season periods, early, mid and late respectively.
- The pH of clear juice of SRI clarifier was slightly higher than the pH of Rapi Dorr that showed slight acidity at early, mid and late season period.
- The purity of SRI clarifier was higher than the purity of Rapi Dorr at early, mid and late season periods. Likewise the reducing sugars are always higher in Rapi Dorr clarifier. This might be due to longer retention time and low pH that leads to inversion of sucrose.
- The phosphate content of SRI clarifier was lower than Rapi Dorr at early, mid and late season period. This might be due to drop in temperature, which is a limiting factor in reaction, in Rapi Dorr clarifier caused by the long retention time.
- The SRI clarifier showed better turbidity values than Rapi Dorr at early, mid and late season period, except at high flow rate.
• The Rapi Dorr clarifier showed better color results than SRI at early and late season periods. Except at mid season period the SRI showed better results than the Rapi dorr due to higher purity at the mid season period and steady flow.

5.2. Recommendations:

• In order to improve the performance of SRI clarifier it is strongly recommended to adjust and control the mixed juice flow rate.

• The capacity of the flash tank should correspond to the capacity of the grinding rate of the plant. As stated by (Arca, 1988).

• The flash tank should be clean occasionally since its capacity can be reduced by deposits of sand, extraneous materials, bagacillo, etc.

• Due to popularity of tray less SRI clarifier, the SRI clarifier can eliminate Rapi Dorr progressively.

• The harvesting of cane should follow strict schedule considering the maturity of that to deliver cane of high purity and have better performance in clarifiers.

• To enhance clarifiers performance, with dominating mechanical harvest, sugar companies should concentrate on training of harvesters in order to avoid purity of pulling roots, sharp cut, cut of lowest possible level, and top of cane.

• Section of erect cane varieties should be considered are the best mechanical harvest during topping process.
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Shephard, G.S (1979). Communication from the SUGAR MILLING RESEARCH INSTITUTE N0. 120 Colloquium on Clarification and Filteration.