To increase the efficiency in sugar and ethanol industries by using a decanter centrifuge
a feasibility study made in the Dominican Republic

Bachelor Degree Project in Mech. Eng. Development Assistance
30 ECTS
Spring term 2007

Daniel Nilsson
Mikael Sjöberg
Pontus Widén

Supervisor: Per Hellström
Examiner: Tobias Andersson
Abstract

This Bachelor Degree Project is a study about possible improvements of the efficiency at sugar mills and ethanol distilleries by using a decanter centrifuge. The report handles background, purpose and result including conclusions and discussions. The implementation of the decanter at site is fully described, including problems and solutions during the project.

With the increased use of ethanol as a bio fuel, the question about bio ethanol’s energy balance have become of more importance. As a part of the project a study about the energy balance have been carried out. In our research we did only find one (moor or less) accepted investigation concerning ethanol energy balance from sugar cane. All other found information about the subject refers to this single assessment which is quit remarkable.

The sugar and ethanol production processes are almost similar until after the clarifier step. The clarifier is a gravitational settling tank where the juice is clarified and then sent to evaporation (sugar process) or fermentation (ethanol process). The by-product called molasses still contains some sugar and is therefore sent to a rotating vacuum filter to extract the remaining sugar. Rotating vacuum filters has high energy consumption, is dirty, creates a lot of smell and needs a lot of space. The objective with the study was to investigate the possibilities to replace the rotating vacuum filter with a decanter centrifuge and achieve better efficiency in the production.

A decanter is a centrifuge that separates solids from liquids. The decanter is based on the simple theory that solids fall to the bottom due to the force of gravity. The decanter centrifuge works with this principle but the difference is that the gravity force has been replaced by a centrifugal force.

The result of our test gives a good indication that the decanter is a good investment. The payback time is short and the investment gives many positive side effects such as less energy consumption, better working environment and it needs less space in the factory.
Resumen

El proyecto para el título de bachiller se basa en un estudio de las posibles mejoras a la eficiencia en los ingenios azucareros y destilerías de etanol mediante la aplicación de un decantador de centrifugación. El informe explica los antecedentes, las partes implicadas y de la finalidad del proyecto.

El procesamiento del azúcar es descripto en breve, ya que el proceso es similar al del etanol hasta después del proceso clarificador. El clarificador es un tanque de solución gravitacional donde el jugo se aclara y luego enviado para a la evaporación (proceso del azúcar) o para la fermentación (proceso del etanol). El sub-producto obtenido, denominado melaza de azúcar todavía incluye algunos azúcares y es por lo tanto enviado a un filtro rotatorio de vacío para extraer el azúcar restante.

El filtro rotatorio de vacío es una antigua técnica utilizada en el proceso del azúcar. Tiene un alto consumo de energía, es muy voluminoso, emana gran cantidad de olores, y necesita asimismo de mucho especio.

El Proyecto investiga la posibilidad de reemplazar el filtro de rotación al vacío por un decantador centrífugo y adquirir mayor eficiencia.

El decantador es un centrifugador que separa sólidos de los líquidos. Está basado en la teoría de que los sólidos caen al fondo por la fuerza de gravedad. Se basa en la sencilla teoría de que los sólidos caen a la parte inferior debido a la fuerza de la gravedad.
El decantador de centrifugado trabaja con este principio, pero la diferencia es que la fuerza de gravedad ha sido sustituida por una fuerza centrífuga.

La aplicación en el sitio se describe de forma detallada, incluyendo todos los problemas y soluciones durante el proyecto.
Con el aumento del uso de etanol como bio-combustible, la cuestión acerca del balance de energía de bio etanol ha tomado mayor importancia.

En nuestra búsqueda, encontramos únicamente una investigación precisa concerniente al etanol de la caña de azúcar.
Los resultados se presentaron y discutieron antes de dar la conclusión del proyecto.
Table of contents

Abstract............................................................................................................................... i
Resumen............................................................................................................................. ii
Table of contents ............................................................................................................... 3
1 Introduction...................................................................................................................... 5
2 Background ...................................................................................................................... 5
   2.1 Ingenio Consuelo ....................................................................................................... 5
   2.2 Cooperating parts ..................................................................................................... 6
   Swedfund ....................................................................................................................... 6
   Consorcio Tecno DEAH ................................................................................................. 6
   Alfa Laval ..................................................................................................................... 6
3 The Assignment ............................................................................................................... 6
   3.1 Test one .................................................................................................................... 6
   3.2 Test two ................................................................................................................... 7
   3.3 Main goal ............................................................................................................... 7
   3.4 Time schedule ........................................................................................................ 7
      Planned time schedule ............................................................................................... 7
      Actual time schedule ............................................................................................... 7
4 The sugar/ethanol process .............................................................................................. 8
   4.1 Reception of the sugar cane ..................................................................................... 9
   4.2 Milling the sugar cane ............................................................................................ 10
   4.3 The bagasse .......................................................................................................... 10
   4.4 Liming tank and heating ......................................................................................... 11
   4.5 Clarification Tank .................................................................................................... 11
   4.6 Rotating vacuum filter ........................................................................................... 12
5 Evaporation of the juice- four steps ................................................................................. 13
   5.1 Crystallization ........................................................................................................ 13
6 Measurement methods .................................................................................................... 14
   6.1 Purity ...................................................................................................................... 14
   6.2 Brix ......................................................................................................................... 14
   6.3 Pol ........................................................................................................................... 14
7 Equipment ......................................................................................................................... 15
   7.1 Door – Oliver Eimco Drum Filters ........................................................................... 15
   7.2 Design Rotating Vacuum Drum Filter ................................................................. 16
   7.3 Vacuum Drum Filters at Ingenio Consuelo ............................................................. 18
   7.4 The decanter .......................................................................................................... 18
      Function ................................................................................................................... 20
      Performance operation .............................................................................................. 21
      Taper lock ................................................................................................................ 21
8 Implementation ............................................................................................................... 22
   8.1 Installation of test rig ............................................................................................... 22
   Inlet decanter centrifuge ............................................................................................ 22
   After decanter centrifuge 418 .................................................................................... 25
9 Results ........................................................................................................................... 26
   Losses pol at Ingenio Consuelo .................................................................................. 27
9.1 Comparison with test results from Colombia ................................................. 28
   Payback ............................................................................................................. 29

10 Conclusion ........................................................................................................... 30

11 Discussion ........................................................................................................... 32

11.1 Ethanol as a transport fuel............................................................................... 33
   Bio-ethanol energy balance ............................................................................... 33
   Differences in ethanol energy analysis .............................................................. 33
   Local and geographical condition ..................................................................... 34
   Methological approach ...................................................................................... 34
   Energy analysis .................................................................................................. 35
   Exergi .................................................................................................................. 35
   Emergi .................................................................................................................. 35
   Energy balance assessments ............................................................................... 36

11.2 RVF system versus Decanter ........................................................................ 37
   Energy consumption .......................................................................................... 37

Referenser ..................................................................................................................... 38

12 Appendix ............................................................................................................. I
   A. Delayed transport .......................................................................................... I
   B. Customs ......................................................................................................... I
   C. Frequency diverter and transformer .............................................................. I
   D. Pulley .............................................................................................................. I
   E. The new taper-lock and the lock-rings ......................................................... II
   F. Solids clogging the bowl and conveyor ....................................................... II
   G. Bill of lading .................................................................................................. III
   H. Performa Invoice .......................................................................................... IV
   I. V-belt pulley ................................................................................................... V
   J. Order Confirmation copy ............................................................................. VI
   K. Lock ring ....................................................................................................... VII
   L. Time schedule ............................................................................................... VIII
   M. Flow sheet .................................................................................................... IX
1 Introduction

We are studying to become Development Assistance Engineers on the Development Assistant Engineers Program at the University of Skövde. The education is one of few, maybe the only, technical education for development assistance at University level. The education has a great width, with its focus on mechanical engineering.

The education is finished with a Bachelor Degree Project that should be carried out in a developing country. The Bachelor Degree Project comprises twenty weeks.

2 Background

In October 2006 contact was made with Mr. Kurt Karlsson at Swedfund to investigate the possibility to execute our Bachelor Degree Project in cooperation with any of Swedfund projects. Mr. Karlsson informed us about an ethanol project in the Dominican Republic (D.R.) they were involved in, the Ingenio Boca Chica project. Contact was established with the local partner in the Dominican Republic, Consorcio Tecno DEAH and their executive director Mr. Omar Bros. In a meeting with Mr. Bros in Stockholm in October 2008, Mr. Bros was positive to a Bachelor Degree Project in the sugar/ethanol industry in the D.R. No definite subject for a project was brought up, so work was initiated to investigate what could be improved in the ethanol sugar industry. In December 2007 we came in contact with Mr. Lars Klein at Alfa Laval. Mr. Klein informed us about the idea of using a decanter centrifuge to make the process more effective and extract sugar that is kept in the residue and the presumed possible effects by replacing the Rotating Vacuum Filter (RVF) with a decanter centrifuge. A meeting took place in January 2007 with Mr. Reine Van Eldik in Copenhagen where Alfa Laval’s centers for Decanters are located. Mr. Eldik who is responsible for decanter applications in the sugar area was positive to supplying a decanter from Alfa Laval for the tests.

Since Ingenio Boca Chica is still in the planning phase and not in operation Mr. Bros arranged so that the tests could be performed at Ingenio Consuelo.

Economical recourses for our work in D.R. was granted by scholar ship from SIDA, Minor Fields Studies and Föreningssparbankens utlandsstifftelse ALFA

The project was carried out with support from Consorcio Tecno DEAH, Alfa Laval and Swedfund.

2.1 Ingenio Consuelo

Ingenio Consuelo is located in the Macoris region in the Southern part of D.R about 15km north of San Pedro de Macoris and 50km east from Santo Domingo. Due to time aspect, the tests will be performed at the Ingenio Consuelo. This is the oldest sugar mill in the D.R. built in year 1881. The Consuelo mill operates from mid February to early June. The mill has a capacity of crushing from 100 to 150 tones of canes per hour giving
To Increase efficiency in ethanol distillery in the Dominican Republic by implementing a decanter centrifuge

around 3.5 tons of cake per hour. The cake is the remaining solids from the rotating vacuum filter.

2.2 Cooperating parts

Swedfund
Swedfund is a Swedish risk capital company investing in developing countries in Africa, Asia, Latin America and Eastern Europe (only non-EU members). Swedfund offers risk capital and competence to companies wishing to establish or expand operations in these regions (www.swedfund.se).

Consorcio Tecno DEAH
Consorcio Tecno DEAH is a union between the Dominican company Tecno 21 and the Haitian Company DEAH. They work with plantation of biomass in areas with high agricultural production and production of alcohol in the D.R and Haiti. Omar Bros is executive director of Consorcio Tecno DEAH and is technical responsible for Ingenio Boca Chica (www.tecno21.com.do).

Alfa Laval
Alfa Laval is a joint – stock company and a Swedish company by origin based on the invention of the continuous separator. The need to separate different liquid phases and solids from each other is part of practically every industrial process. Alfa Laval has more then one hundred and twenty years of experience in meeting this requirement using either decanter or disc stack centrifuge technology (www.alfalaval.com).

3 The Assignment

The idea was to investigate the possibilities to use a decanter centrifuge in the sugar/ethanol process to:

1. Extract the remaining sugar from the rotating vacuum filter (RVF) cake.

2. Replace the RVF with a decanter.

The assignment was planned to be carried out with two different tests. The first test was to extract the remaining sugar from the cake in the RVF.

The second step was to test the efficiency of the decanter to separate the molasses from the clarifier. Depending on the results from the first separation this test can be continued with a second separation of the liquid.

3.1 Test one

According to earlier tests, the use of a decanter to separate the sugar from the RVF cake has been very positive. The task, in this case, was to verify these results and to optimize the process. It is presumed to have significant economical benefits to use a decanter to separate remaining sugar from the RVF cake.
3.2 Test two
The RVF uses a lot of energy, is very bulky, dirty and creates a lot of smell. The second test was to investigate the possibility to replace the RVF with one or two decanters.

Possibly benefits by replacing the RVF with a decanter
- Energy savings
- Installation savings
- Cheaper purchase
- Less space requirements
- More pleasant working environment due to a closed handling of the sludge.
- Cleaner
- Less smell

Tests to replace the RVF with a Alfa Laval decanter have according to our knowledge never been performed.

3.3 Main goal
The main goal with the tests was to determine the possibility to improve the sugar and ethanol process both from an economical and energy saving perspective.

3.4 Time schedule

Planned time schedule
The production at Ingenio Consuelo sugar mill lasts until early June. It was planned to have the tests ready in the middle of May.

The time planned for the test was two weeks per test and one week of installation per test. One week of preparations before the decanter arrives, two weeks of termination of the test rig and about one week of enclosure. That means that the equipment needed to be in the D.R. in the beginning of April.

Shipments to D.R. take between two weeks to one month; in other words, the equipment had to be shipped in the middle/late of February. There is no direct connection between Scandinavia and D.R., ships departure from the larger harbors in Europe: Hamburg, Bremerhaven, Rotterdam etc.

A more detailed graphic presentation of the time planning can be found in appendix L.

Actual time schedule
The sugar season at Ingenio Consuelo mill appeared to be as long as to mid July. Though due to the fact that the shipment was two weeks delayed and that the decanter was stuck at the customs for almost three weeks (see appendix L), it was impossible to perform both
tests. The first test was canceled and all focus was laid on the second and more interesting test since this test never had been performed.

The scheduled time for installation of the test rig was five days. Due to lack of tools, not enough materials, materials in bad shape and inefficient workers at the sugar mill, the installation of the test rig took eleven days. Since the flow was around 3000 l/h and the necessary flow was at least 15000-20000 l/h, a reconstruction of the test rig was made and took two days.

In Europe the electrical frequency is 50 Hz and in D.R the frequency is 60 Hz. Alfa Laval Holland claimed that there was a frequency diverter on the decanter. Unfortunately there was none and a new pulley had to be ordered from Sweden (see appendix D, I and J). The transportation and the customs procedure took seven days.

When the new pulley arrived a new taper lock had to be constructed since the new pulley had a larger inner diameter and this work took three days (see appendix E, K, chapter 7.4 and figure 16).

The new taper lock was badly constructed and moved axially. The solution to the problem was to construct two lock rings (see appendix E and K). The construction took two days.

The total time for test two was five days instead of the planned ten days. One day was used trying to solve the conveyer/bowl issue (see appendix F) and finally one day for cleaning and enclosure.

4 The sugar/ethanol process
To understand the meaning and the implementation of the machine it is important to have knowledge about the whole process from sugar cane to sugar or ethanol. The process of sugar consists essentially in separating the sucrose from the different materials that are found in the sugar cane. An overview can be seen in figure 1 and a simple explanation to every step will follow.
4.1 Reception of the sugar cane

It is important to transport and use the cane as soon as possible after cutting it from the fields. The cane is always taken to the nearest sugar mill though the longer time waiting the more sugar is lost from the cane. The cane usually arrives to the mill by train or by truck, figure 1. All the sugar canes that arrive to the mill are weighed and analyzed. The purpose of these analyses is to determine the amount of solids, amount of sucrose, percentage of fiber and the amount of impurities present in the sugar cane. After analyzing and weighing, the sugar cane is unloaded from the train wagons or the trucks to be ready for the extraction of the juice. After the reception of the cane it is sent to a machine called “cuchillas” (knives, shredder) see figure 2 where it is cut into smaller fibers to improve the further extraction of the juice.
4.2 Milling the sugar cane

After cutting the sugar cane into smaller pieces/fibers with the “cuchilla”, it is washed and milled to extract all the juice from the cane, figure 3. The mill process is divided into five steps to extract all the juice from the sugar cane. The first two steps are manufacturing juice while the last three steps send the extract solution back to step one and two. When all the juice is extracted in the last step it is only the dry fibers left which is called bagasse.

4.3 The bagasse

The remaining fibrous solids after shredding and milling the cane are called bagasse. The bagasse is burned and the energy obtained by burning the bagasse is used during the whole process to heat water and to make the machinery run. It makes almost any sugar mill self-sufficient in energy and can also be used for animal feed or in paper manufacture. In figure 4, a boiler is shown where the bagasse is burned. The vapor is then used to run the crushing machine. The bagasse is also mixed with molasses before continuing to the RVF.
Figure 4. Boiler.

4.4 Liming tank and heating

The juice from the milling process is stored in a tank before it is continuing its process to become sugar. The milled juice consists of a number of solids and not only sucrose. Therefore, lime is added to the solution to reduce the acids and to avoid sucrose losses. The effect of liming the juice is that the juice settles the dirty solids of the juice that can be taken away later on. Before entering the clarifier the juice is heated in two steps to 105° C to optimize the clarification of the juice, figure 5.

Figure 5. Heating and liming.

4.5 Clarification Tank

A clarifier is a gravitational settling tank. The juice travels through the clarifier at a very low superficial velocity so that the solids settle out and clear juice exits. The clear juice goes to evaporation and the solids (cachaza or mud) to the vacuum filter, figure 6.
To Increase efficiency in ethanol distillery in the Dominican Republic by implementing a decanter centrifuge

4.6 Rotating vacuum filter

The clarifier separates the juice from the solids. The solids, still in a liquid shape, are called molasses (cachaza) are sent to a rotating vacuum filter. The cachaza is mixed with bagasse before entering the vacuum filter to get a better attachment to the filter and there by a better filtration. The function of the filter is pretty easy, the cachaza is attached to the cylindrical rotating filter and water is added. With vacuum the filter sucks the liquid part of the solutions through small holes where only the liquids can pass. Left on the outside of the filter is the cake, the dry cachaza, figure 7.

Figure 6. Clarifier.

Figure 7. Vacuum filter.
5 Evaporation of the juice- four steps

To be able to reach the formation of sugar crystals, all the water in the juice must be eliminated. This is made in four-step evaporation where water is eliminated in every step. This is made by concentrating the clarified juice to syrup by boiling excess of water in four steps. The four steps are four vessels that are connected to each other in a series. Each vessel operates under decreasing pressure with the last one working almost under a total vacuum, figure 8.

![Evaporators](image)

Figure 8. Evaporators.

5.1 Crystallization

It is also known as sugar cooking. The crystallization consists basically in the formation of sugar crystals from different syrups.

The process takes place in vacuum evaporators of simple effect called commonly "tacos". First, the molasses is concentrated until it reaches a saturation point. In this condition, seed crystals are added which serve as centers for the sugar crystals. While the water is evaporating, the molasses is added to increase the size of the sugar crystal. In this point the process is finished and the contents of the "tacho" are discharged by a valve collocated in the lower part.

The remaining product after cooking the syrup is also called molasses. The remaining of sugar in the molasses is to low and can not be used to fabricate any more sugar. The molasses is used to make alcohol, animal food and yeast.
6 Measurement methods

To get all the necessary information to produce the sugar/ethanol a number of different measurement methods are used. Information that is useful in the sugar industry is information such as: the amount of solids, the amount of sucrose, the purity of the cane and sometimes the dry substance. By measuring the purity or impurity of the cane, you get the knowledge of how much sucrose that has been lost since cutting it from the field.

6.1 Purity

The first thing that is important when making sugar out of sugar canes is to know the purity of the cane. The purity of the cane is used to see how “clean” the cane is. It measures the purity of the solids in the cane, in this case the sucrose. So if a cane solution has 100 solids and 25 of them is sucrose, the solution has a purity of 25 (25 out of 100).

6.2 Brix

Brix refers to the total content of solids in a sucrose solution. It is expressed in percentage. Brix does include sugars as well as non-sugars and it is measured easily with a refractometer equipped with a scale based on the relationship between refractive indices at 20°C and the percentage by mass of total soluble solids of sucrose solution.

6.3 Pol

Pol is the content of sucrose expressed in percentage of the mass. It is determined by the single or direct polarization method. The Pol divided with the Brix gives the purity.
7 Equipment

7.1 Door – Oliver Eimco Drum Filters

The rotating vacuum filters (RVF) at Ingenio Consuelo sugar mill are of the model Door – Oliver Eimco drum filter. These are filters that are designed to handle a wide range of slurries and are suitable for filtering solids. These drum filters belong to the bottom feed group with a scraper discharge, figure 9. In the sugar process RVF: s is used to extract the remaining sugar in the by-product molasses. The size of the filters required depends on the amount of mud that is produced by the clarifier which is proportional to the amount of cane crushed (information from FLSmidth Door-Oliver Eimco, Thomas Loeschmann, www.glv.com).

Figure 9. Rotating vacuum filters.
7.2 Design Rotating Vacuum Drum Filter

The filter drum is fabricated, as the rest of the machine, from metal parts for standard applications. To support the drum a large diameter trunnion on the valve end and a bearing is mounted on the drive end. The surface of the drum is divided into circumferential sectors each forming a separate vacuum cell, figure 10 (information from FLSmidth Door-Oliver Eimco, Thomas Loeschmann, www.glv.com).
Figure 11. The filter zones.

Cake formation:
With the slurry level set to a maximum the submergence area is approximately 34 %, between 04.00 and 08.00. Cake starts to form up once a sector enters submergence until it emerges from the slurry, figure 11.

Cake washing and drying:
After emerging from submergence the washing part of the cycle commences at 04.00 and ends at 11.30. Manifolds are mounted to a pair of splash guards bolted to the tank ends. The position and the quantity of the wash liquid are adjustable depending of the wash characteristics of the cake. Here the vacuum is cut off and the final cake drying starts until 09.00, figure 11.

Cake discharge:
At 10.00 cut off blow is applied to facilitate cake discharge and depending on the position of the tip of the scraper blade stop at approximately 09.00. This part is very different depending on the type of discharge. On belt discharge filters vacuum cuts off when the filter media leaves the drum but on scraper and roll discharge filters blow is used as explained above, figure 11.

Dead zone:
Because air can be drawn through the exposed filter media and causes loss of vacuum on the drum surface, once the blow is cut off, normally at 02.00, the sector passes through a zone blocked with bridges (information from FLSmidth Door-Oliver Eimco, Thomas Loeschmann, www.glv.com).

Since the RVF work in vacuum there is high energy consumption. And according to Eimco to reduce energy consumption the feed should be concentrated as much as possible
prior to filtration. One way to optimize the function of the RVF is to use pre-treatment by flocculation which increases the efficiency of the RVF (information from FLSmidth Door-Oliver Eimco, Thomas Loeschmann, www.glv.com).

### 7.3 Vacuum Drum Filters at Ingenio Consuelo

At Ingenio Consuelo there are three Door – Oliver Drum Eimco filter with a scraper discharge. Those were purchased from USA 1969 and are still in good condition. The diameter is 8 feet and the length 16 feet which gives a filtration area of approximately 30 square meters per RVF, total 90 square meters. Today the sugar cane production is around 2800 tons/day and therefore only two RVF are in use.

### 7.4 The decanter

A decanter is a centrifuge that separates solids from liquids. There are different kinds of decanter centrifuges, 2-phased and 3-phased. The 2-phased separates solids from liquid and the 3-phased can separate solids, and two liquids with different densities, see a decanter in figure 12.

![Decanter centrifuge](image)

**Figure 12. Decanter centrifuge.**

The decanter centrifuge is based on the simple theory of a clarifier or a settling tank in which the sediment, particles and the solids fall to the bottom due to the force of gravity. The theory is based on Stokes law, equation 1. Stokes law explains the velocity of a falling particle in a fluid. The velocity is defined by the diameter of the particle, the fluids viscosity and the difference between the density of the fluid and the particle.
Stokes’ Law

\[ V_g = \left( \frac{d^2 \rho_p - \rho_l}{18 \eta} \right) g \]

- \( V_g \): gravitational settling velocity (m/s)
- \( d \): particle diameter (m)
- \( \rho_p \): particle density (kg/m\(^3\))
- \( \rho_l \): liquid phase density (kg/m\(^3\))
- \( \eta \): liquid phase viscosity (kg/ms)
- \( g \): gravitational acceleration (m/s\(^2\))

The decanter centrifuge works with the Stoke’s principle but the difference is that the gravity force has been replaced by a centrifugal force. So instead of waiting for the solids to sediment and fall to the bottom it is sent to the bottom by the centrifugal force which in the decanter is the bowl, figure 13.
Stokes law explains the velocity of a falling particle in a fluid falling due to the force of gravity. In the decanter the conditions are different and therefore the formula looks like equation 2 where Stokes law are applied on a centrifugal separation (information from Alfa Laval, Reine Van Eldik, www.alfalaval.com).

\[ V_c = \left( \frac{d^2 \rho_w - \rho_o}{18 \eta} \right) r \omega^2 \]  

(2)

**Function**

The feed enters the decanter at intersection of the conical and the cylindrical part of the bowl through a central feed pipe in the hollow drive shaft. After leaving the feed pipe, the feed suspension is distributed into the rotating liquid in the bowl and smoothly accelerated to the full rotational speed. The centrifugal force makes the solids settle at the bowl shell. The screw conveyer continuously transports the solids toward the conical end of the bowl and through the conical bowl part.

The separation takes place throughout the total length of the cylindrical part of the bowl, and the clarified liquid discharges at the large end where it flows over the rim of
exchangeable and/or adjustable plate dams. The solids are discharged from the small end by centrifugal force through outlet openings.

The decanter is driven by an electric motor. The motor shaft carries a drive pulley, and motive power is transmitted through V-belts to the bowl pulley to drive the bowl.

The purpose of the back drive system is to make it possible to control the speed of the sunwheel shaft of the gearbox and consequently control the differential speed between bowl and conveyor.

The sunwheel is driven by an electric motor (with a variator) mounted on a bracket fixed to the decanter. The differential speed of decanters equipped with variator can be altered while the decanter is running.

**Performance operation**

The decanter can be adjusted to suit individual requirements by varying the following control parameters:

- **Bowl Speed**
  By varying the rotational speed of the bowl, the G-force can be adjusted to suit the application. The higher speed, the better separation.

- **Liquid level**
  Adjust the liquid level (pond depth) to give the optimal balance between liquid clarity and solids dryness by selecting different plate dams. In general terms, the separated liquid becomes more clear and the cake more wet when diminishing the liquid radius and vice versa.

- **Differential speed**
  The dryness of the cake can be increased when operating with a lower differential speed, but the separated liquid will be less clear and vice versa. The torque increases with the lower \( \Delta n \) (the difference in speed between bowl and screw conveyor). The differential speed can be regulated automatically to compensate for varying content of solids in the feed.

- **Feed rate**
  The lower feed rate, the better separation.

**Taper lock**

The taper-lock fastens the pulley to the engine shaft. Figure 16 illustrates a hub of a belt pulley secured with taper-lock bush. A new pulley had to be ordered due to the frequency issue (see Appendix C). Unfortunately the new pulley had a larger inner diameter and since there was no new taper-lock a new had to be made.
To Increase efficiency in ethanol distillery in the Dominican Republic by implementing a decanter centrifuge

Figure 16. Taper lock.

The inside of the split bush is cylindrical and its outside is tapered. In the outside there are two (in large-size bushes three) semi-cylindrical dead-end holes and one semi-circular threaded through hole. The belt pulley hub bore has the same taper as the clamping bush. In the hub bore there are three holes: two semi-cylindrical threaded through holes which face the dead-holes of the bush, and a semi-cylindrical dead-end hole which faces the threaded hole of the bush. Tightening the screws fitted in the threaded hub bores of the pulley installed on the shaft will press the clamping bush into the tapered hub bore. Being split, the bush will clasp with increasing force as the screws are tightened until the bush is pressed far enough into the hub bore and secured to the shaft with the same force as if fastened by interference fit, figure 16 (information from Alfa Laval, Reine Van Eldik, www.alfalaval.com).

8 Implementation

8.1 Installation of test rig

The maximum capacity of the decanter separator model 418 is 20000 l/h and the test rig was designed to obtain the highest flow as possible.

The rig was designed by using the materials available at the factory. Some materials, mostly all the required pipes and valves had to be taken from the existing process line. Some valves were bought since the factory could not spare more for our tests.

Inlet decanter centrifuge

Close to the cachaza pumps at the clarifier, a hole was cut in the main line and a 47 cm long 3 inch pipe was welded and fixated at a vertical angle including a 3 inch valve. The purpose of this was to have an easy system for maintenance and prevent having a pipe filled up with a heavy mass of cachaza (see appendix M). Inside the connection a stop
plate was installed in the main pipe to redirect the main part of the sludge flow down to our 3 inch pipe, figure 17 and eventually the decanter.

![Figure 17. Stop plate.](image)

From the valve a 3 inch pipe with 45 degrees angle was installed and then a 1457 cm 3 inch pipe leading all the way down to a 30 cm 2 inch pipe with a valve with the same dimension (see appendix M). This 2 inch valve was installed so if the flow was too low or high, simple adjustment could be made without any need to control the 3 inch valve at the top of the clarifier since this valve had a very difficult position. The transfer from 3 inch to 2 inch had to be done because of two reasons. There were no more 3 inch valves available at the factory and since the inlet connection of the decanter was 2 inch it was very easy to connect the decanter and the pipe system with a 2 inch flexible hose.

![Figure 18. The hot water connection with valve (right) and the cachaza line with valve (middle).](image)

The hot water connection was installed for testing, cleaning and if necessary to add water in the cachaza flow. A 2 inch pipe was fixed from the existing hot water pipe at the rotating vacuum filter above. To be able to control the water flow in a simple manner a 2 inch valve was installed, figure 18.
At the inlet of the decanter an 18 cm 2 inch flexible hose was installed to cope with the massive vibrations that occurred while running the machine. The flexible hose was fixated by using two throttle couplings, figure 19.

![Figure 19. In the middle the flexible hose with throttle couplings.](image)

The delivery height from the cachaza pumps at the top of the clarifier to the inlet of the decanter was 4.4 m. This gave a high pressure of the feed at the inlet of the decanter. Otherwise there would have been necessary with an additional feed pump.
A 6 inch valve, figure 21, was installed at the main cachaza pipe before the bagasse mixing tank (see Appendix M) so that the main flow could be regulated and the required flow redirected to the decanter.

To measure the flow and take samples of the cachaza before the decanter a T-connection was installed with two 2 inch valves, one before the flexible hose and one 30 cm below the T-connection. This made it possible to measure the flow by using a 200 liters barrel and a measuring stick made of an 8 mm reinforcement bar with a mark for every 10 l up to 200 l and a timer, figure 22.

**After decanter centrifuge 418**

At the outlet of the decanter a 23 cm flexible hose was attached to the pipe by using two throttle couplings to prevent any damage to the rig due to the heavy vibration caused by the machine.

Due to the location of the decanter at the factory the outlet system had to go around a pillar, which gave an outlet system with some extra angles.

To prevent losses of the separated liquid the outlet pipes were connected to the vacuum system by cutting a 2 inch hole in one of the pipes in the vacuum system and then a 503 cm 2 inch pipe was fixated. To measure the flow and take samples of the separated liquid after the decanter a T-connection was installed with two 2 inch valve, figure 22 (Appendix M).
This made it possible to measure the flow by using a 200 liters barrel and a measuring stick. The samples that were taken were brix, pol and purity (see chapter 6).

9 Results
The most interesting and important results of the tests are to compare the amount of pol (sucrose content) in the cake after the decanter and the amount after the RVF. This is interesting since the amount of sugar loss and the sugar recovered can be measured. The machine with the cake containing less sucrose is the most efficient.

Other factors that are important are the purity in the separated liquid. A high purity is necessary since that means that there are less suspended solids among the separated liquid. The optimal result is to have little value of pol in the cake and a high purity in the separated liquid. Samples were taken from the molasses, the separated cake and the separated liquid. The samples from the cake from the decanter were compared to the cake from the RVF.

According to the time schedule the test should have been performed during ten days. Test results were received during five days before the conveyor and the bowl clogged together.
These are the results obtained:

<table>
<thead>
<tr>
<th>Results</th>
<th>Day 1</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separated liquid l/h (average)</td>
<td>3200</td>
<td>7000</td>
<td>3000</td>
<td>2700</td>
<td>2600</td>
<td>18000</td>
<td>16800</td>
</tr>
<tr>
<td>Separated liquid Brix</td>
<td>18</td>
<td>14.3</td>
<td>20</td>
<td>20</td>
<td>20.2</td>
<td>22.8</td>
<td>18</td>
</tr>
<tr>
<td>Separated liquid Pol</td>
<td>9</td>
<td>6.94</td>
<td>11.19</td>
<td>11.15</td>
<td>11.17</td>
<td>15.2</td>
<td>10.43</td>
</tr>
<tr>
<td>Separated liquid Purity</td>
<td>50</td>
<td>48.53</td>
<td>55.95</td>
<td>55.75</td>
<td>55.3</td>
<td>66.67</td>
<td>57.94</td>
</tr>
<tr>
<td>Cake Pol</td>
<td>4.5</td>
<td>3.5</td>
<td>3.2</td>
<td>3.2</td>
<td>3.2</td>
<td>2.3</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Table 3. Test results Ingenio Consuelo 2007.

The best value (lowest) of pol in the cake was received when the flow of molasses was maximized. At that moment the separated liquid reached 18000 l/h and produced 2260 kg/h cake. The separated liquid had 15.2 pol and 22.8 brix. It was the best test result obtained for pol and purity. Though, the high value of brix made the separated liquid not preferable for further processing of sugar. The high value of brix could be seen visually since the separated liquid was dirtier then the other tests. The cake had a value of 2.3 pol and was one of the lowest result obtained.

The colour of the separated liquid was clearer with a lower flow and therefore the separated liquid contained less suspended solids. Though the purity was not that good, and the highest loss of sugar were received during tests with a low flow.

**Losses pol at Ingenio Consuelo**

Of all the sugar canes that are sent to Ingenio Consuelo mill, 32.4 – 37.1 % of all sucrose is lost due to several different factors. Some examples are bad transportation, old and inefficient equipment. The obtained sucrose and the losses are showed in table 4 and 5.

<table>
<thead>
<tr>
<th>Sucrose in cane/obtained (tonnes)</th>
<th>Sugar season 2004-2005</th>
<th>Sugar season 2003-2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose in sugar cane</td>
<td>44577.86</td>
<td>54457.50</td>
</tr>
<tr>
<td>Sucrose obtained in process</td>
<td>28056.65</td>
<td>36839.49</td>
</tr>
</tbody>
</table>

Table 4. Sucrose in sugar cane.

<table>
<thead>
<tr>
<th>Sucrose losses (tonnes)</th>
<th>Sugar season 2004-2005</th>
<th>Sugar season 2003-2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Losses in bagasse</td>
<td>7298.3</td>
<td>8036.08</td>
</tr>
<tr>
<td>Final honey</td>
<td>6999.16</td>
<td>7055.75</td>
</tr>
<tr>
<td>Cachaza</td>
<td><strong>771.90</strong></td>
<td><strong>625.99</strong></td>
</tr>
<tr>
<td>Unknown/undecided</td>
<td>1451.85</td>
<td>1900.19</td>
</tr>
<tr>
<td>Total losses</td>
<td><strong>16521.21</strong></td>
<td><strong>17618.01</strong></td>
</tr>
</tbody>
</table>

Table 5. Sucrose losses.

At Ingenio Consuelo the total losses of sugar (pol) in the cachaza for year 2003 – 2005 was, as seen in table 5, in average 699 tonnes which is 4.1% of the total losses (information from Ingenio Consuelo, Rafael Cimico).
The value of those losses counted with the current world sugar price of 309 USD/tonnes of pol (International sugar organization, www.isosugar.org, 2008-03-03) are 215974 USD.

9.1 Comparison with test results from Colombia
Alfa Laval performed tests in Colombia 1999 to extract the remaining sugar in the separated cake from the RVF by using a decanter centrifuge. Tests were also performed in Mexico but unfortunately we do not have the figures from those results.

<table>
<thead>
<tr>
<th>Tests to extract the remaining sugar</th>
<th>Pol value in the separated cake from the RVF</th>
<th>Pol value in the separated cake from the decanter</th>
<th>Pol recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombia</td>
<td>2 - 7</td>
<td>1.2</td>
<td>0.8 – 5.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40 % - 82.9%</td>
</tr>
</tbody>
</table>

Table 6. Tests results in Colombia to extract the remaining sugar in the separated cake.

The amount of pol in the separated cake (sugar losses) from the RVF was 2 – 7 in Colombia. As seen in table 6 they managed to reach a remaining pol value in the separated cake to 1.2 (information from Reine Van Eldik, Alfa Laval). The recovered pol value varied between 0.8 – 5.8 which is 40 % recovered pol up to as high as 82.9 % recovered pol. The amount of pol in the cachaza varies in time because of many reasons, for example the sugar canes have different amount of sucrose depending on area, climate and transportation.

The conditions at the sugar industry in the D.R and in Colombia are according to Alfa Laval similar and therefore comparable. In the tests made at Ingenio Consuelo D.R to replace the RVF with a decanter the values of the tests differed 2.2 – 4.5 (as seen in table 7). This gave a good indication that it is possible to get at least equal results by replacing the RVF with a decanter.

<table>
<thead>
<tr>
<th>Tests to replace the RVF with a decanter</th>
<th>Pol value in the remaining cake from the RVF</th>
<th>Pol value in the separated cake from the decanter</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.R Ingenio Consuelo</td>
<td>2 - 5</td>
<td>2.2 – 4.5</td>
</tr>
</tbody>
</table>

Table 7 Pol values from tests in D.R Ingenio Consuelo

It would be possible to retrieve at least 40 % of the sugar losses at Ingenio Consuelo by using a decanter after the RVF as done in Colombia. The investment would then be one decanter. The big advantage is that there will be no disturbance in the existing process line.

Our results showed that it is possible to replace the RVF with a decanter and receive at least equal results. To replace the RVF system with two decanters would then be possible. The advantages are many. The entire RVF system, such as vacuum pumps, bagasse mixing tank and vacuum pipes can be excluded.
Payback
A payback calculation is to see how fast an investment is repaid. The payback time is received by putting the base investment in relation to the annual revenues from the investment.

In these calculations only the base investment of a decanter centrifuge model 438 have been considered. The 438 has the double capacity of the 418 which is suitable for Ingenio Consuelo. In reality there will be additional costs, such as freight-, customs-, education, maintenance and installation costs. The calculations are made with the present world sugar price, 309 USD/tones (information from the International Sugar Organization www.isosugar.org 2008-03-06).

The efficiency of using a decanter after the RVF to extract the remaining sugar in the separated cake is assumed to be equal to the results received in Colombia by Alfa Laval (see chapter 10.1). The recovered efficiency is counted to be the lowest obtained in Colombia, 40 % and the highest 82.9 %.

Payback calculation 1 decanter centrifuge 438:
Base investment: 380 000 USD
Recovered sucrose: 279.6 tonnes (40 % of 699 tonnes)
Value of the recovered sucrose: 86390.2 USD
Payback time: 4.4 years

Payback calculation 2 decanter centrifuge 438:
Base investment: 760000 USD
Recovered sucrose: 279.6 tonnes (40 % of 699 tonnes)
Value of the recovered sucrose: 86390.2 USD
Payback time: 8.8 years

Calculation three and four shows the payback time with the maximum efficiency obtained in Colombia, 82.9 %.

Payback calculation 3 decanter centrifuge 438:
Base investment: 380 000 USD
Recovered sucrose: 579.5 tonnes (82.9 % of 699 tonnes)
Value of the recovered sucrose: 179065.5 USD
Payback time: 2.1 year

Payback calculation 4 decanter centrifuge 438:
Base investment: 760000 USD
Recovered sucrose: 579.5 tonnes (82.9 % of 699 tonnes)
Value of the recovered sucrose: 179065.5 USD
Payback time: 4.2 years
With the lowest efficiency (40 %), the investments have a payback time of 4.4 years and 8.8 years. With the maximum efficiency (82.9 %) the investments have a payback time of 2.1 and 4.2 years. The decanter centrifuge 438 has a life expectancy of at least 20 years. In reality the payback time will be something between minimum and maximum payback time. The payback time for one decanter centrifuge 438 will then be 2.1 – 4.4 years, and the payback time for two decanter centrifuges 438 4.2 -8.8 years. Therefore all four investments are profitable, but of course the most interesting one is the one with a payback time of 2.1 years.

A new Door- Oliver 30 sq. m RVF would cost 210000 USD (information from Door – Oliver GLV, Mody Viren, www.glv.com). At Ingenio Consuelo they use two 30 sq. m RVF and have one more 30 sq. m RVF if the production of sugar canes becomes very high. To invest in two new RVF would then cost 420000 USD. This is without additional costs, such as freight-, customs-, education, maintenance and installation costs.

A new factory with similar conditions as Ingenio Consuelo, DR could then invest in one decanter centrifuge 438 for a total cost of 380000 USD and receive the same efficiency as the RVF does at present time. With two decanter centrifuges, for a total cost of 760000 USD, it would be possible to receive a system with a very high recover (40 – 82.9 %) of the sugar losses at the cachaza step.

10 Conclusion

The decanter:

- Takes less space
- Gives a better working environment
- Consumes less energy
- Recovers more sugar
- Cheaper investment

The factory is very old, in bad shape and in need of a total makeover. Most of the machines are original from 1883. There are greater needs at the factory then to invest in one or two decanters. It would be profitable after a few years but the factory probably does not have the resources for such an investment.

A relatively modern built ethanol/sugar industry should definitely consider using decanters instead of the RVF system. The economic benefits and the improved working environment are two major arguments for using decanters. The decanter consumes less energy then the RVF.

With decanters implemented at the cachaza step 1.6 – 3.4 % of the total losses of sugar could be recovered. That is 0.9 – 1.8 % of the total sugar produced at Ingenio Consuelo. That is equivalent to 3900 – 7801 tones of sugar canes.

There are many different ways to carry out energy analysis on bio-ethanol. Analysis made according to the different methods energy, exergi and emergi answers according to
Nilsson (1997) to different questions and there is no point to compare the results. Therefore, it is of great importance to explain which method is used and that used data is presented to be able to compare different analysis.
11 Discussion

The use and importance of ethanol as an alternative fuel has increased rapidly the last few years. We therefore found it very interesting and stimulating to carry out our Bachelor Degree Project close to the ethanol project Swedfund were involved in at the D.R. Unfortunately things do not always go as planned and projects carried out in developing countries often tends to come across problems is something that we truly have experienced.

We still have not found answers to all of the problems we encountered, as for example what caused the two weeks delay of the decanter. The Problems with the Dominican custom seem difficult to avoid, but maybe it would have been easier if the delivery had been in corporation with the local Alfa Laval contact.

A new factory or an already operating one lacking RVF could rather invest in one or two new decanters though they approximately have the same costs as the RVF due to sugar recovering rate. A factory already using RVF, could be better off keeping the RVF and using a decanter as a complement.

The sensibility analysis shows that with a payback time of 2.1 years with high recovery, the investment is very interesting and the investment has a greater value. With the 40% recovery the payback time gets a little bit too long to make the investment interesting. It is not to say that an investment not should be done, but it has to be taken into consideration that the payback time is the double.

Concerning energy balance assessment in the beginning of our study it seemed like there was several different calculations conducted on bio ethanol from sugar cane, but with more research most of them referred to the same investigation. It is quit remarkable that there is only one acknowledged study made on ethanol from sugarcane. And of course, with only one investigation performed, the data is very hard to verify.

In personal mail contact with Oliviera, who has made one assessment that not has been accepted, he states “The problem with Macedo's data is that he is an employee of the sugarcane industries. Personally I don't think his data corresponds to the reality, and it is hard to get real data from distilleries.”

The energy consumption of an old sugar mill is vast and there are enormous energy losses. Since the decanter improves the efficiency and has several positive side effects we hope that there will be a positive future for decanters in the sugar/ethanol industry. The improvement of sugar recovery contributes in a positive manner to the energy balance by the fact that there is more sugar/ethanol produced from the same amount of sugar canes and therefore contributes to less environmental problems.
11.1 Ethanol as a transport fuel

There is a lively debate going on about positive and negative aspects of using bio-ethanol as a transportation fuel. The major questions are about the energy balance, greenhouse gas (GHG) balance and the competition between using land to produce energy or food. There are no conclusive answers to the debate but most scientists have today agreed that the energy balance and greenhouse balance in most cases can be made positive, but that the arable land is not enough to replace fossil fuels. Processes where fossil resources are used to produce ethanol, as coal in the USA, are examples where the GHG emissions most certain are negative. (The main reasons to produce ethanol with fossil coal are a try to reduce the dependence of oil producing counties.)

Today bio-ethanol is the most widely used renewable fuel world-wide. The largest production is made in Brazil and the USA. As feedstock, sugar cane is mainly used in Brazil, in USA corn is mainly used. In Europe ethanol is mainly produced from wheat and sugar-beets. From an energy and greenhouse gas perspective sugar canes are today considered as the best crop available to produce bio-ethanol.

Bio-ethanol energy balance

With the increased use of ethanol as a biofuel, the question about bio-ethanol’s energy balance have become of more and more importance. The question is of importance mainly because of the sustainability aspects. The process of making ethanol is not sustainable if it takes more energy to produce the ethanol then the amount of energy gained from the ready fuel.

Generally, the interest for energy analysis started to increase already during the first oil crises in 1973. With the increased interest the debate about how to make the analysis increased. To reduce the confusion the International Federation of Institutes for Advanced Study (IFIAS) arranged an international workshop in Stockholm in 1974. During the workshop general outlines of energy analysis were determined. The definition of energy balances that IFIAS declared was, “energy analysis is: the determination of the energy sequestered in the process of making a goods or service within the framework of an agreed set of conventions or applying the information so obtained” (Nilsson 1997, s. 64).

However, IFIAS declaration was criticised since the method of the energy analyses did not consider the parameters such as economy and ecology. To improve the analysis, additional methods like exergi, emergi and Life Cycle Analysis (LCA) have been developed.

Overall, the energy balance calculations are complex which results in large varieties between different calculations.

Differences in ethanol energy analysis

It is not surprising that there are a discussion about the ethanol energy balance due to the numerous of factors that have to be considered. Many of these factors change in time,
To Increase efficiency in ethanol distillery in the Dominican Republic by implementing a decanter centrifuge

making frequent reviews desirable. For example, agricultural yields tend to rise while current processing technologies are using less energy than those employed a decade ago.

According to Börjesson (2006) the source of differences in energy balance calculations can be divided between those related to local and geographical conditions, and those related to differences in the methological approach.

Local and geographical condition
Examples of local and geographical differences are climate, type of farming and type of factories used. Obvious, favourable climate, developed farming and modern factories give better energy balance.

In table 1 example are given of local and geographical a condition that according to Börjesson (2006) affects the energy balance.

<table>
<thead>
<tr>
<th>Sources</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic location</td>
<td>Climate</td>
</tr>
<tr>
<td></td>
<td>Crops available</td>
</tr>
<tr>
<td>Type of farming</td>
<td>Grade of mechanisation</td>
</tr>
<tr>
<td></td>
<td>Type of fertilizers</td>
</tr>
<tr>
<td>Feedstock quality</td>
<td>Sugar / starch / lignocelluloses</td>
</tr>
<tr>
<td>Transportation</td>
<td>Distance</td>
</tr>
<tr>
<td></td>
<td>Type of transport</td>
</tr>
<tr>
<td>Factory type</td>
<td>Size</td>
</tr>
<tr>
<td></td>
<td>Technical status</td>
</tr>
<tr>
<td></td>
<td>Use of by- products (combination factory’s)</td>
</tr>
</tbody>
</table>

Table 8. Local and geographical conditions that effects the energy balance.

Methological approach
The local and geographical conditions that give differences in the energy balances are quite easy and obvious to understand. The methological approaches are more complex, it is about system boundaries, allocation methods and different ways how to look upon energy.

There are no standard for how the different parameters should be considered and this makes it important to present how the assessments have been carried out. As an example, the calculations can differ by a factor of five depending on the definition of the system (system boundaries) and how the energy input is divided between the ethanol and the by-products generated in the process (allocation methods) (Börjesson, 2007).

There is a fundamental methological difference if the analyses are made according to “standard energy”- exergi- or emergi concept. Both exergi and emergi are trying to take in more parameters then standard energy analysis. Exergi calculates with the quality
reduction that occurs every time energy is transformed to another form, emergi analysis is very complex and tries to take “all” possible aspects in to account.

In the debate all these different ways of approaching the subject are mixed together without explaining the differences which is misleading and causes confusion. There are no standard for how energy balances should be carried out and that is of course a problem.

**Energy analysis**

The most common way to perform energy balance studies is to use the *energy input-energy output* method. The method estimate the energy requirements for production of goods and services. Except direct energy investments like diesel used for transportation, harvesting etcetera, indirect energy investments like energy used in the process of making fertilizers contributes. The Energy balance is expressed as the ratio of the energy content of the fuel to the energy input for the production of the fuel. If the quotient turns out to be over one, the energy gained from the ready ethanol is larger then energy used in the process making the fuel. The method uses primary energy and expresses the balance in Joule, it is practical, useful and relatively easy to perform. (Börjesson, 2006).

The problem is where to put the system boundaries. Issues discussed are for example how sunlight and labor should be considered. The energy input of human labor can for example be considered by measuring the metabolic energy. Generally the back system boundary is drawn at the level where the additional input energy is negligible. (Nilsson, 1997)

**Exergi**

All conversions of energy to other forms lead to reduction of its quality. Exergi analysis is supposed to locate and quantify these losses. H.T. Baehr defined exergi as: “that part of energy that is convertible in to all other forms of energy” (Nilsson, 1997). The Swedish scientist Göran Wall explains Exergi in the following way: “Energy is motion or ability to produce motion where exergi is work or ability to produce work”. Exergi analysis tries to express the maximum amount of useful work that may be extracted from a system. (Nilsson, 1997)

In exergi analysis all different input energy are multiplicated with a “quality factor” to get the flow of exergi.

According to Börjesson (2006), when comparing different bio-ethanol systems, exergi analysis do not brings a lot more additional information then standard energy analysis. This is because the energy quality losses are quite the same in all the production systems.

**Emergi**

The emergy analysis was developed by Howard Thomas Odum in late 1980s. Emergy describes the total amount of energy of one type required to form a unit of another type. Emergi analysis is the most complicated and complex of the methods.
The intention with emergi analysis is that it should be the most sophisticated method to calculate the sustainability for a product. Emergi takes “all” recourses and not “only” energy into account. It calculates with recourses like the sun, wind, rain, economy and labour. The problem is that it is too complicated and too complex to get any really practical use for.

Energy balance assessments

In our research we did only find one (more or less) accurate assessment concerning ethanol energy balance from sugar cane. This is also confirmed in the reports from Edward Smets and colleges (Smets, 2006), Harro von Blottnitz and Mary Ann Curran (Von Blottnitz, 2005) and Markus Quirin with colleges (M. Quirin et. al, 2004).

The existing investigation, Assessment of greenhouse gas emissions in the production and use of fuel ethanol in Brazil, by I C Macedo and colleges presented in 2004 (Mecado, 2004) is the updated version of two earlier reports Balanço de energia na produção de cana-de-açúcar e álcool nas usinas cooperadas from 1985 (Mecado, 1985) and Energy Balance/CO2 Emission from 1998 (CTC, 1998).

Other reports that have been performed but for different reasons not have been “accepted” are for example Ethanol as a fuel: Energy, carbon dioxide balances, and ecological footprint by Marcelo E. Dias de Oliviera (Oliviera, 2005). In this case Oliviera’s study is not founded on data from his own investigations but on data from different reports of which some are very old. Most data has been taken from David Pimentel’s work. Pimentel is known as one of the major opponents against bioethanol.

Mecado has in his latest investigation considered two cases, one based on the average values of energy and material consumption and one based on the best values being practiced in the sugar cane industry (minimum consumption with the use of the best technology). The ratios of output energy (renewable) to input energy (fossil) were calculated to 8.3 and 10.2, for average and best, respectively. This means that 8.3 respectively 10.2 times more renewable output energy are gained compared to fossil input energy that are used in the process.
11.2 RVF system versus Decanter

Energy consumption

A comparison between the RVF system and decanters energy consumption were made. The energy consumption of the RVF system was measured at Ingenio Consuelo and the energy consumption of the decanter was received from Alfa Laval. To replace the RVF system at Ingenio Consuelo with decanter requires one large decanter of model 438. Though to obtain the assumed best recovery, two decanters of model 438 are required and therefore used in this comparison.

<table>
<thead>
<tr>
<th>Door Oliver Vacuum filter</th>
<th>Hp</th>
<th>Quantity</th>
<th>Total energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter engine</td>
<td>3</td>
<td>2</td>
<td>17.6 MWh</td>
</tr>
<tr>
<td>Tami bones</td>
<td>5</td>
<td>2</td>
<td>29.5 MWh</td>
</tr>
<tr>
<td>Juice pump</td>
<td>15</td>
<td>2</td>
<td>88.5 MWh</td>
</tr>
<tr>
<td>Vacuum pump</td>
<td>75</td>
<td>1</td>
<td>221 MWh</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bagasse</th>
<th>Hp</th>
<th>Quantity</th>
<th>Total energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan</td>
<td>20</td>
<td>1</td>
<td>59 MWh</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cachaza mixer Engine</th>
<th>Hp</th>
<th>Quantity</th>
<th>Total energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
<td></td>
<td>20.7 MWh</td>
</tr>
</tbody>
</table>

| Energy consumption RVF at Ingenio Consuelo | 436.3 MWh |
| Energy consumption decanter 438 (two machines) | 395.9 MWh |

Table 9. Energy consumption.
To increase efficiency in ethanol distillery in the Dominican Republic by implementing a decanter centrifuge

Referenser


12 Appendix

A. Delayed transport
DHL and Danmar Lines were contracted for the transportation of the decanter which included transport from the factory in Denmark to Ingenio Consuelo sugar mill at the Dominican Republic. The shipment started from Rotterdam, Holland 2007-03-23 on board Philadelphia Express with an estimated arrival to the Boca Chica harbor, Dominican Republic 2007-04-14. The freight was sent as a test decanter for temporary export with a non negotiable (express bill) with everything prepaid. Due to unknown reasons (DHL and Danmar Lines do not know) the container was reloaded on board a different ship when passing through Miami harbor, Florida with an estimated arrival at the Boca Chica harbor, Dominican Republic two weeks later the 2007-04-28.

B. Customs
The decanter was shipped as a test machine on a temporary export with everything prepaid and arranged by DHL and Danmar Lines. Though the customs at the Dominican Republic did not accept the decanter under those conditions and claimed 7000 Euro as import tax. Mr. Kiki at Consorcio Tecno DEAH who had been working several years at the customs helped us with the procedures. The 2007-05-18 almost three weeks later, he managed to retrieve the decanter from the customs and arrange a transport to Ingenio Consuelo.

C. Frequency diverter and transformer
Arriving to the Dominican Republic we discovered that there were a higher frequency, 60 Hz and a higher current 440 V at the sugar mill. Since a higher frequency increases the engines RPM and would cause a major breakdown, the solution was to simple change to a pulley with a smaller diameter. Though this appeared to be unnecessary since after consulting Alfa Laval in Holland there should be a frequency diverter and a transformer installed at the decanter.
When the decanter arrived the transformer was quickly found but unfortunately the frequency diverter was not. After consulting Reine Van Eldik Alfa Laval he insured that there should be one. The chief electric engineer at the sugar mill was consulted to arrange the frequency and current issue and to make the decanter ready for running.
Unfortunately he did not inform us that he did not find the frequency diverter. This was discovered after the rest of the test rig was installed and we were ready to start the tests. After sending a photo of the control panel to Mr. Reine Van Eldik it was confirmed that there was no frequency diverter.

D. Pulley
The original pulley had a diameter of 380 mm and with a frequency of 60 Hz the main motor would have a drum speed of 4826 rpm which would cause a major break down.
The solution to the problem was as planned from the beginning to replace the pulley with a pulley with a smaller diameter. The maximum drum speed is 4000 rpm so the maximum diameter is 315 mm \((4000 \div 4826) \times 380 = 315\) (see appendix I). A pulley with the necessary diameter was found at Alfa Laval’s section in Tumba, Sweden and TNT was hired for the transportation. The transportation took four days by flight freight and the customs took two days.

E. The new taper-lock and the lock-rings
Figure 15 illustrates a hub of a belt pulley secured with taper-lock bush. Unfortunately the new pulley had a larger inner diameter and since there was no new taper-lock a new had to be made. Unfortunately the foundry did not make the taper-lock 100% accurate. The result became that the pulley was not fixated and moved axial with the risk that the pulley could fall of. To solve the problem two lock-rings with three tightening screws was made at the factory. It took two days to do this. This construction worked without any problems and the test could be started.

F. Solids clogging the bowl and conveyor
During the test a torque occurred on the small sun wheel of the gear box between 1.5 kNm and 3.7 kNm. One of the reasons for the high variation was because of the variation of the throughput. According to the manual the maximum allowed torque was 2.5 kNm. After consultation with Alfa Laval expertise the highest permissible torque up to 3.7 kNm was acceptable since the safety factor is very high.

The best performance at maximum throughput was of interest. And the optimal balance between liquid clarity and solids dryness could be achieved by 2 factors. To obtain a clearer separated liquid (clarified liquid) the liquid level had to be adjusted (see Liquid Level) and to get a dryer cake the differential speed should be lowered (see differential speed).

The last test ran at a maximum throughput (20000 l/h) with the liquid level set to get the clearest juice and with the lowest differential speed possible. This caused a very high amount of dry solids in the decanter with the result of clogging the conveyor and the bowl.
G. Bill of lading

**Shippers**

ALFA LAVAL COPENHAGEN A/S

MASKINEJ 5

DK-2860 SØBORG

DANMARK

**Companies (not negotiable unless consigned to order)**

BIOETANOL BOCA CHICA

SANTO DOMINGO

REPUBLICA DOMINICANA

**Notify address (see Clause 19)**

OFFICE ADDRESS:

AV. LOPE DE VEGA 59, C-10

SANTO DOMINGO

REPUBLICA DOMINICANA

**Pre-carriage by**

TRUKAN

**Place of receipt by pre-carrier**

ROTTERDAM

**Notify party**

PHILADELPHIA EXPRESS

Rotterdam

**Port of loading**

SANTO DOMINGO

**Place of delivery**

SANTO DOMINGO

**Marks and Nos.**

Number and kind of packages: description of goods

1 COLLI 1 MX 4185 TEST DECANTER FOR TEMPORARY EXPORT

SANTA DOMINGO

REPUBLICA DOMINICANA

**TOTAL:** ONE (1) PACKAGE ONLY

**LCL/LCL**

FREIGHT PREPAID

EXPRESS RELEASE

**CONTAINER NO.**

TGHU 7946111-0

**SHIPPED ON BOARD PHILADELPHIA EXPRESS FROM ROTTERDAM ON 23/MAR/2007.

**Pre-carriage charge**

**Freight prepaid in**

ROTTERDAM

**Place and date of issue**

ROTTERDAM 23-03-07

**Number of original bills**

0/NIL

**Consignee**

DENMARK, PHONE: +45 3250 5539

**KIRSTINERJ 42

DK-2770 KASTRUP

**Statement of the cargo received**

CONSIGNOR: INTERCONTINENTAL A/S

**Notice of arrival**

16 MAR 07 15:00 007 THisted to Rotterdam
**H. Performa Invoice**

Date: 12 March, 2007  
Our Ref: EX27-03-033  
Your Ref: Mr. Omar Bros

**Consignee:**  
Bioetanol Boca Chica  
Santo Domingo  
Republica Dominicana

**Office address:**  
Av. Lope de Vega 59, C-10  
Santo Domingo  
Republica Dominicana

---

**PF INVOICE No. 3350175003-1**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 NX 418S Test Decanter for temporary export</td>
<td>Eur 20,000.00</td>
</tr>
<tr>
<td>Serial number 2982907</td>
<td></td>
</tr>
<tr>
<td>Commodity code: 8421.23.90</td>
<td></td>
</tr>
<tr>
<td>VALUE FOR CUSTOMS PURPOSES ONLY:</td>
<td></td>
</tr>
<tr>
<td>Net/gross weight: 2900/3401 Kg</td>
<td></td>
</tr>
<tr>
<td>Carrier: Danzas Air Ocean</td>
<td></td>
</tr>
<tr>
<td>Delivery Term: CFR Santo Domingo</td>
<td></td>
</tr>
</tbody>
</table>

**ALFA LAVAL COPENHAGEN A/S**

Alfa Laval Copenhagen A/S  
Maskinvej 5  
DK-2860 Søborg  
Denmark

Account no: 5295 0013000735  
IBAN NO: DK45 5295 0013 0007 35  
SWIFT: ESSEDKKK  
Bank: Skandinaviska Enskilda Banken (SEB), Copenhagen

---

IV
## PULLEY, TAPER LOCK, and V-BELT

### 6120.7325

**for**

NX 414, NX 416, and NX 418

### MAIN MOTORS: 11 - 15 kW

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>315</td>
<td>7333-31</td>
<td>7330-17</td>
<td>3</td>
<td>4000</td>
<td>315</td>
<td>7326-31</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
<td>5 (5)</td>
</tr>
<tr>
<td>3500</td>
<td>280</td>
<td>7333-28</td>
<td>7330-17</td>
<td>3</td>
<td>3500</td>
<td>280</td>
<td>7333-28</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
<td>5</td>
</tr>
<tr>
<td>3250</td>
<td>262</td>
<td>7333-26</td>
<td>7330-13</td>
<td>3</td>
<td>3250</td>
<td>262</td>
<td>7333-26</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
<td>5</td>
</tr>
<tr>
<td>60 -</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60 -</td>
<td></td>
<td></td>
<td></td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
</tr>
<tr>
<td>3100</td>
<td>250</td>
<td>7333-25</td>
<td>7330-13</td>
<td>3</td>
<td>3100</td>
<td>250</td>
<td>7333-25</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
<td>5</td>
</tr>
<tr>
<td>2800</td>
<td>224</td>
<td>7333-22</td>
<td>7330-13</td>
<td>3</td>
<td>2800</td>
<td>224</td>
<td>7333-22</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
<td>5</td>
</tr>
<tr>
<td>1740 r.p.m</td>
<td>2250</td>
<td>7333-18</td>
<td>7330-13</td>
<td>3</td>
<td>1740 r.p.m</td>
<td>2250</td>
<td>7333-18</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>315</td>
<td>7326-31</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
</tr>
<tr>
<td>3500</td>
<td>280</td>
<td>7333-28</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
</tr>
<tr>
<td>3250</td>
<td>262</td>
<td>7333-26</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
</tr>
<tr>
<td>60 -</td>
<td></td>
<td></td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
</tr>
<tr>
<td>3100</td>
<td>250</td>
<td>7333-25</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
</tr>
<tr>
<td>2800</td>
<td>224</td>
<td>7333-22</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
</tr>
<tr>
<td>1740 r.p.m</td>
<td>2250</td>
<td>7333-18</td>
<td>7330-18</td>
<td>7330-19</td>
<td>7330-20</td>
</tr>
</tbody>
</table>

### Number of Grooves/V-belt

<table>
<thead>
<tr>
<th>MAIN MOTOR</th>
<th>Size: 11.5 kW</th>
<th>Type: 160 M/L</th>
<th>Shaft Diameter: φ 42</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIN MOTOR</td>
<td>Size: 18.5/22 kW</td>
<td>180 M/L</td>
<td>Shaft Diameter: φ 48</td>
</tr>
<tr>
<td></td>
<td>Size: 30 kW</td>
<td>200 L</td>
<td>ø 55</td>
</tr>
<tr>
<td></td>
<td>Size: 37 kW</td>
<td>225 S</td>
<td>ø 60</td>
</tr>
</tbody>
</table>
### J. Order Confirmation copy

**Order confirmation (copy)**

<table>
<thead>
<tr>
<th>Customer</th>
<th>Delivery address</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASINVEJ 5</td>
<td>P.C. Procesos Agro-Industriales S.A</td>
<td>1(1)</td>
</tr>
<tr>
<td>DK-2060 SOBORG</td>
<td>Attn. Pedro Carreño</td>
<td></td>
</tr>
<tr>
<td>DANMARK</td>
<td>Calle 3 # 19 Los Restauradores</td>
<td></td>
</tr>
<tr>
<td>DENMARK</td>
<td>Santo Domingo</td>
<td></td>
</tr>
</tbody>
</table>

#### Your reference

<table>
<thead>
<tr>
<th>Goodmark</th>
<th>Order no</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAROLD SCHROEVERS</td>
<td>5339180</td>
</tr>
<tr>
<td>Your qt</td>
<td></td>
</tr>
<tr>
<td>2007-05-31</td>
<td></td>
</tr>
<tr>
<td>Your order no</td>
<td>105899</td>
</tr>
</tbody>
</table>

#### Our reference

<table>
<thead>
<tr>
<th>Delivery method</th>
<th>Delivery term</th>
<th>Our reference</th>
<th>Payment terms</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>COURIER EXPRESS</td>
<td>GIP</td>
<td>Our VAT no</td>
<td>AS PER GROUP RULES.</td>
<td>2007-05-31</td>
</tr>
<tr>
<td>SANTO DOMINGO</td>
<td></td>
<td>SE 5569213863</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Customer</td>
<td>41706T</td>
</tr>
</tbody>
</table>

#### Invoice details

<table>
<thead>
<tr>
<th>Pos</th>
<th>Item no</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Warehouse</th>
<th>Delivery date</th>
<th>Price</th>
<th>Total</th>
<th>Discount</th>
<th>Total EUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6120733631</td>
<td>V-BELT PULLEY</td>
<td>1.00</td>
<td>PCE</td>
<td>TUM</td>
<td>2007-06-11</td>
<td>75.10</td>
<td>75.10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total**

75.10

**Total EUR**

75.10

---

VI
K. Lock ring
### L. Time schedule

<table>
<thead>
<tr>
<th>ID</th>
<th>Activity</th>
<th>Variability</th>
<th>Start</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Actual Time Schedule</td>
<td>0 day</td>
<td>07.01.22</td>
<td>07.06.23</td>
</tr>
<tr>
<td>21</td>
<td>Sugar cave session</td>
<td>160 day</td>
<td>07.07.02</td>
<td>07.07.05</td>
</tr>
<tr>
<td>22</td>
<td>Topper decalier</td>
<td>16 day</td>
<td>07.06.14</td>
<td>07.04.09</td>
</tr>
<tr>
<td>23</td>
<td>Custom</td>
<td>16 day</td>
<td>07.06.15</td>
<td>07.06.14</td>
</tr>
<tr>
<td>24</td>
<td>Local transport</td>
<td>1 day</td>
<td>07.06.23</td>
<td>07.06.23</td>
</tr>
<tr>
<td>25</td>
<td>Installation of heating</td>
<td>16 day</td>
<td>07.06.23</td>
<td>07.06.23</td>
</tr>
<tr>
<td>26</td>
<td>Test renovation/knowing new</td>
<td>16 day</td>
<td>07.06.14</td>
<td>07.05.18</td>
</tr>
<tr>
<td>27</td>
<td>Frequency counter</td>
<td>16 day</td>
<td>07.06.19</td>
<td>07.06.23</td>
</tr>
<tr>
<td>28</td>
<td>Topper new pulley</td>
<td>16 day</td>
<td>07.06.28</td>
<td>07.06.28</td>
</tr>
<tr>
<td>29</td>
<td>Custom</td>
<td>16 day</td>
<td>07.06.31</td>
<td>07.06.32</td>
</tr>
<tr>
<td>30</td>
<td>Fabrication new layer tech</td>
<td>16 day</td>
<td>07.06.02</td>
<td>07.06.03</td>
</tr>
<tr>
<td>31</td>
<td>Fabrication tool rings</td>
<td>16 day</td>
<td>07.06.02</td>
<td>07.06.03</td>
</tr>
<tr>
<td>32</td>
<td>Running test</td>
<td>16 day</td>
<td>07.06.02</td>
<td>07.06.03</td>
</tr>
<tr>
<td>33</td>
<td>Decalier breakdows</td>
<td>16 day</td>
<td>07.06.02</td>
<td>07.06.03</td>
</tr>
<tr>
<td>34</td>
<td>Sicker</td>
<td>16 day</td>
<td>07.06.31</td>
<td>07.06.32</td>
</tr>
</tbody>
</table>

### Planned Time Schedule

<table>
<thead>
<tr>
<th>ID</th>
<th>Activity</th>
<th>Variability</th>
<th>Start</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sugar cave song</td>
<td>16 day</td>
<td>07.07.01</td>
<td>07.07.20</td>
</tr>
<tr>
<td>2</td>
<td>Terms of reference/feasibility study</td>
<td>10 day</td>
<td>07.07.01</td>
<td>07.07.13</td>
</tr>
<tr>
<td>3</td>
<td>Define a location</td>
<td>10 day</td>
<td>07.07.23</td>
<td>07.07.23</td>
</tr>
<tr>
<td>4</td>
<td>Test with local partners</td>
<td>10 day</td>
<td>07.07.23</td>
<td>07.07.23</td>
</tr>
<tr>
<td>5</td>
<td>Arrange translation for decalier</td>
<td>10 day</td>
<td>07.07.23</td>
<td>07.07.23</td>
</tr>
<tr>
<td>6</td>
<td>Arrange transport decalier</td>
<td>10 day</td>
<td>07.07.23</td>
<td>07.07.23</td>
</tr>
<tr>
<td>7</td>
<td>Transport decalier</td>
<td>10 day</td>
<td>07.07.23</td>
<td>07.07.23</td>
</tr>
<tr>
<td>8</td>
<td>Local transport</td>
<td>1 day</td>
<td>07.07.31</td>
<td>07.07.32</td>
</tr>
<tr>
<td>9</td>
<td>Installation of decalier</td>
<td>16 day</td>
<td>07.07.01</td>
<td>07.06.05</td>
</tr>
<tr>
<td>10</td>
<td>Test of decalier</td>
<td>16 day</td>
<td>07.07.10</td>
<td>07.07.15</td>
</tr>
<tr>
<td>11</td>
<td>Test</td>
<td>16 day</td>
<td>07.07.10</td>
<td>07.07.15</td>
</tr>
<tr>
<td>12</td>
<td>Pervasion of testing</td>
<td>16 day</td>
<td>07.06.02</td>
<td>07.06.03</td>
</tr>
<tr>
<td>13</td>
<td>Writing report</td>
<td>16 day</td>
<td>07.07.10</td>
<td>07.07.10</td>
</tr>
</tbody>
</table>
M. Flow sheet

- Clarifier
- Decanter
- Cachaza pumps
- Main line
- 6inch valve
- Flexible hose
- 2inch valve
- Bagasse mixing tank
- 3inch valve and stop plate
- Hot water line
- Four 2inch valves
- 2inch valve
- 3inch pipe
- Juice pump
- 200 l Barrel
- 200 l Barrel