ENERGY AUDIT REPORT

PT. PINDO DELI PULP AND PAPER PERAWANG MILLS

TISSUE PAPER MACHINE 3.2

30 November – 2 December, 2015

BBPK-TUV RHEINLAND

EXECUTIVE SUMMARY

PT Pindo Deli Pulp and Paper Mills have three operational sites, which are Pindo Deli 1 and 2, located in Karawang District, West Java, and Pindo Deli 3 in Perawang, Riau Province. PT.Pindo Deli 1 & 2 is located in an industrial area around 75 km from APP's Jakarta headquarters. The mills' key products including writing, printing, copier, pre-print and other premium wood-free papers, cast coated paper, paperboards, carbon-less, thermal and art paper and tissue. The mills production capacity is around 1 million tonne per year and directly employs nearly 7,000 people. An extensive list of product specific certifications supports the range of the mills' products such as ISO 22000 for food hygiene and ISO 9706 for permanent acid free papers suitable for archiving purposes.

The Pindo Deli 3 is the smallest of the Pindo Deli Pulp and Paper Mills, with a specialty in jumbo roll tissue production and an annual capacity of 413,000 tonnes. It currently has around 1,900 employees. The energy audit activities focused on Pindo Deli 3.

Energy efficiency and reduction of the consumption of fossil fuels is an important issue for the sector and has both competitive and environmental implications.The paper industry could be generally described as energy-intensive. Energy is one of the highest contributors to the total costs in the papermaking process, accounting for approximately 10 – 25 % or more of the total production costs

The scope of the energy audit focused on the tissue paper machine 3.2, which consists of Yankee hood and cylinder : It was observed that Yankee steam cylinders and Yankee hood of paper machine. Refiner: It was observed that refiner consume energy to modified fiber. The energy used to modify the fiber is expected according to the strength of fibers obtained.

Methodology of audit consist of data collection, data processing, analysis of result include evaluation of performance test for Steam and Gas Consumption by comparing the results of the previous test performance on 2011 by Acelli Machine Performance Test and recommendation.

The results of the data analysis are presented in the table below.

Table 4 Specific Energy Consumption (SEC)

No	Parameter	Mill Condition	Benchmark/standard*
1	Product Type	Tissue	Tissue
2	Grammage, g/m^2	12.5	-
3	Freeness Stock, CSF mL	380-400	-
4	Inlet moisture content drying unit, %	66.7	-
5	Outlet moisture content drying unit, %	6.0	-
6	Hood System	Yankee hood	-
7	SEC, $ton_{steam}/ton_{product}$	1.53	1.24 to 1.3
8	SEC, GJ/ton_{evap}	3.62	-
9	SEC, $GJ/ton_{product}$	7.28	-
10	Gas consumption, $Nm^3/\ ton_{product}$	91.81	159 to 173
11	Specific Refining Energy (LBKP), kWh/ton Refiner 4 Refiner 5 Refiner 6	 57.42 33.71 52.95	40 - 80**
12	Specific Refining Energy (NBKP), kWh/ton	39.35	60 - 200**

*Based on Acelli Machine Performance Test, 2011 (PT. Pindo Deli); **Lumiainen, 1998

The Yankee hood is a key component in the production of tissue. As a result, it is important to maintain proper hood balance and to understand its effect on thermal energy use. Gas consumption is almost the same as the results of the performance test in 2011, while steam consumption value increased become to 1.31 - 1.61 tonnes of steam/tonne product. The steam flow of usage in the thermo compressor there is an imbalance of mass balance.

Disc refiner pattern for NBKP is good, so does the intensity, similar pattern better to be considered, but for LBKP need to evaluation. Specific Refining Energy and Specific Edge Load is Good but possible to be improved and the achievable fiber development should be checked / evaluated. Specific edge load (SEL) for NBKP is low, where as for LBKP high. Specific Refining Energy (SRE) for NBKP is very low.

Recommendation of energy audit include metering instrument need to be calibrated to showed accurate data, install humidity sensor on Yankee hood and exhaust air for calculating heated air, in general to suggestion for the inlet steam temperature in the main steam header should be 5℃-20℃ over saturation, i.e., slightly superheated steam, install metering to indicate air volume in Yankee hood system. Install CSF sensor at inlet and outlet of every refiner to reduces time consuming traditional checking, install rpm indicator to each motor of refiner, installed sampling point valve for taken refined pulp for fiber development evaluation, otimizes the fiber development by choosing the correct plate pattern (high bar edge length/revolution, in order to have low intensity) and optimizes the specific refining energy, SRE - kWh/t for LBKP.

PREFACE

Energy efficiency and reduction of the consumption of fossil fuels is an important issue for the sector and has both competitive and environmental implications.The paper industry could be generally described as energy-intensive. Energy is one of the highest contributors to the total costs in the papermaking process, accounting for approximately 10 – 25 % or more of the total production costs.

Electrical and thermal energy is the most expensive and important form of purchased energy. For this reason, its use must be confined to a minimum for efficient and economic operation. Pulp and paper mills are large and complex facilities consuming enormous quantity of steam and electricity. The industry is required to reduce energy consumption to become cost competitive in the open economy and globalization. At the same time there is public demand for improving product quality and reducing green house gas emissions. In view of these and world energy crisis, the industry has made important strides for reducing total energy use and increasing the cogeneration through self generated sources. Nowadays tissue makers are facing many challenges related to energy – the increasing energy cost, the regulations from government about limitation of energy consumption for per ton produced tissue.

In order to fulfil information about energy audit in paper machine, PT. TUV Rheinland Indonesia in cooperation with Center for Pulp and Paper (Balai Besar Pulp dan Kertas, BBPK) has conducted joint research on "Energy Audit in Paper-machine". The objectives of cooperation is to conduct audit energy consumption in refining and drying unit.

Balai Besar Pulp dan Kertas would like to express gratitude to PT. TUV Rheinland Indonesia for this great opportunity given to us to take part in performing this cooperation. Finally, we hope that this audit will contribute to energy conservation in the industrial sector and the result of this cooperation will be beneficial for PT. TUV Rheinland Indonesia.

BALAI BESAR PULP DAN KERTAS

ANDOYO SUGIHARTO
Director

CONTENTS

INTRODUCTION

Energy efficiency and reduction of the consumption of fossil fuels is an important issue for the sector and has both competitive and environmental implications. The paper industry could be generally described as energy-intensive. Energy is one of the highest contributors to the total costs in the papermaking process, accounting for approximately 10 – 25 % or more of the total production costs (Zhe Wen, 2012).

PT Pindo Deli Pulp and Paper Mills have three operational sites, which are Pindo Deli 1 and 2, located in Karawang District, West Java, and Pindo Deli 3 in Perawang, Riau Province. PT.Pindo Deli 1 & 2 is located in an industrial area around 75 km from APP's Jakarta headquarters. The mills' key products including writing, printing, copier, pre-print and other premium wood-free papers, cast coated paper, paperboards, carbon-less, thermal and art paper and tissue. The mills production capacity is around 1 million tonne per year and directly employs nearly 7,000 people. An extensive list of product specific certifications supports the range of the mills' products such as ISO 22000 for food hygiene and ISO 9706 for permanent acid free papers suitable for archiving purposes.

The Pindo Deli 3 is the smallest of the Pindo Deli Pulp and Paper Mills, with a specialty in jumbo roll tissue production and an annual capacity of 413,000 tonnes. It currently has around 1,900 employees. The energy audit activities focused on Pindo Deli 3.

Energy consumption in a tissue paper machine depends on several factors besides the design of the machine itself. As in any paper production process, consumption depends on the fibre composition, on the intensity and quality of refining, vacuum, retention of fibres, air content in stock, temperature of the water used for the process, design of the wire and felt, diameter of the former, speed of the machine and the design of the press roll, considering its structure and diameter.

The Yankee-Hood dryer is an extremly energy intensive section of the paper machine, which makes it the focus of crucial interest and studies. Massive dehydration process takes place in the dryer. As a consequence of continously increasing energy cost, determination of the proper operating conditions is essential to operate the tissue machine in the most efficient and economic means while ensuring paper quality.

When comparing energy consumption for paper mills of a certain grade or quality, the major influences on the specific energy consumption (SEC) of a given mill should be taken into account e.g. the system boundaries, the energy generation (power and steam supply, cogeneration of heat and power), the process areas operating in the mill (e.g. pulp production, RCF processing, papermaking), the process used (e.g. refining, coating, calendering), the specific product quality, the product mix and some other factors. The electricity consumption of the paper machine depends on the paper grades produced (e.g. higher grammage leads mathematically to better specific energy consumption), the speed of the machine and the raw material mix used. Energy use in the production of paper represents a high proportion of total costs, so historically energy use has always been a subject of prime importance to paper manufacturers. This is reflected in the activities of both manufacturers and trade associations within the paper industry and the amount of research devoted to reducing consumption or improving energy performance.

Nowadays tissue makers are facing many challenges related to energy– the increasing energy cost, the regulations from government about limitation of energy consumption for per ton produced tissue, various demands from customers in different locations of the world concerning how to recover heat from the production lines, etc.

In the framework of energy conservation, PT Pindo Deli 3 implemented energy audit. Energy audit conducted on paper machine 3.2 and was done on November 30 - December 2, 2015.

THE SCOPE OF AN ENERGY AUDIT

The scope of the energy audit focused on the paper machine 3.2, which consists of:

1. Yankee hood and cylinder : It was observed that Yankee steam cylinders and Yankee hood of paper machine.
2. Refiner: It was observed that refiner consume energy to modified fiber. The energy used to modify the fiber is expected according to the strength of fibers obtained.

DESCRIPTION OF PROCESS

Tissue is a collective name for crepe paper for sanitary and household purpose which is widely used all around the world. To get the final products with required quality, the raw materials will go through a series of important processes – stock preparation, forming, pressing, drying, and creping etc.

The paper machine is the mechanical system used to convert the pulp in to paper. All paper machines consist of a wet end or forming section, a press section and dryer section.

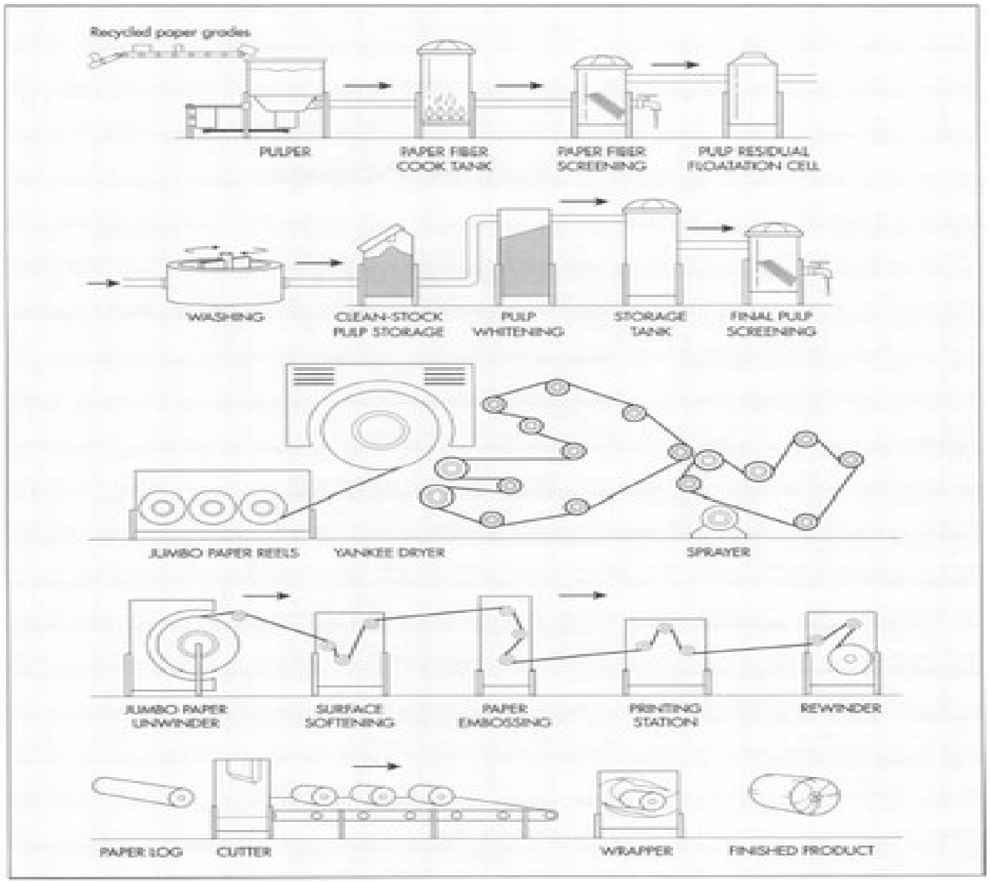


Figure 1 A diagram of toilet paper manufacturing process

Stock Preparation

The stock preparation involves a series of processes including pulping, beating, refining, fractionation and screening etc. It should be made clear that for different raw materials, product grades and mill conditions the stock preparation system could also be different. Beating pulp could increase the tensile strength and softness of the fibres and also gives the paper a suitable adhesion to the Yankee dryer.

Refining

Refiners are generally used to correct the longitudinal tensile strength which is a vital factor of the product quality. Surface qualities of the fibers are built up on the refiner plate which is the point-of-contact of the refiner and also the place where electricity energy from the refiner motor are transferred into mechanical force performing on the fibers.

Process of the refining is an important process to establish the physical properties and the strength of the fiber. Refining is the largest consumer of electrical energy in papermaking, therefore as important factor in the paper process, hence this operation requires special handling in process optimization and energy saving program in paper industry. This is a mechanical process which acts on fibers to give them increased surface area, greater flexibility and smooth surfaces. The consistency norm for the refiner is in the range of 4% to 4.5%.

The selection of the refining system starts from the end products, available pulps, and planned capacity range. End product and pulp blend establish requirements for desired refining results for each pulp in the blend. Thereafter, refining consistency, bar pattern of fillings/plates to give required nature for the refining, net energy requirement, and number of recommended refining stages (number of refiners in series) will be determined.

There are a number of variables that affect the refining result. Some of those variables such as all fiber-based variables are predetermined and cannot be influenced in refining. Process conditions such as consistency, pH, temperature, and pressure can to some extent be controlled. So-called "equipment parameters" (passive process variables) such as type of refiners, fillings (pattern, material, and condition), rotational speed, and rotation direction of refiners can be affected when selecting a refining system and the equipment for it.

Basically bar pattern should be suitable for the fiber, but sometimes bar pattern is not most suitable because pulps vary. If the fillings cannot be changed, the only possibility is to adjust the consistency to suit. An increased refining consistency with any fibers means slower vortex flow in grooves and increases fiber flocculation tendency, therefore requiring a coarser pattern than lower refining consistency.

The specific consumption of energy for different types of refiners can be seen on Table 1.

The refiner filling materials are made of steel. In recent developments ceramic filling materials have been invented to reduce the specific energy consumption by 15-20% (Siewert, 1995)

Table1. Comparative Power Consumption of Different Refiners Used

Type of Refiner	Specific Energy Consumption (kWh/tonne of poulp)
Conical	9 - 13
Double disc	7 - 9
Triple disc	6
Beaters (slushing and refining)	14 - 18
Hydra pulper (mainly slushing)	11 - 14

Source: Energy management Center, 1995

The most commonly used refining is to treat fibers in the presence of water with metallic bars. The plates or fillings are grooved so that the bars that treat fibers and the grooves between bars allow fiber transportation through the refining machine. The refining stages, at first, fiber flocs are collected on the leading edges of the bars. During this fiber pick-up stage, the consistency is typically 3%–5% (sometimes, in special applications, 2%–6%) and the fiber flocs comprise mainly water. When the leading edge of the rotor bar approaches the leading edge of the stator bar, the fiber floc is compressed and receives a strong hit. As a result, most of the water is compressed out of the floc. Simultaneously, short fibers with low flocculation ability are probably peeled off (escape the floc together with water) and flow into the grooves between the bars. Only those fibers remaining in the floc are compressed between two metallic bar edges and receive refining.

The main target of refining is to improve the bonding ability of fibers so that they form strong and smooth paper sheet with good printing properties. Sometimes the purpose is to shorten too long fibers for a good sheet formation or to develop other pulp properties such as absorbency, porosity, or optical properties specifically for a given paper grade. An efficient refining system can have a tremendous impact on reducing the electrical energy which is an important component of a mill's cost structure. Opportunities for energy savings in refining can be accomplished in many ways, with little or no capital investment. The first step is a refiner checkup or audit. Energy savings of 10% or more can be found through optimization of patterns, alloys, and refiner configuration. Proper mechanical condition of the refiner is crucial for efficient refining and energy conservation. Mechanical audits should be performed annually to minimize wasted energy.

Headbox

The headbox is the component located close to the forming section of the paper machine in which the pulp is distributed onto the wire. Together with the forming section, it plays a key role in the production of high quality paper as the hydraulic performance of the headbox largely determines the properties of the product. The well-prepared stock is distributed across the headbox with the aid of a header which is a tapered pipe connected to a stock nozzle.

Headbox sprays stock uniformly across the forming section with a high-speed stock jet through a slice lip. In tissue production, there is usually a speed difference between the jet and wire to obtain good formation. This is mainly because a difference in jet and wire speeds will orientate the fibres in the longitudinal direction, which will bring a favourable effect on the formation. The velocity inside the headbox is chosen to give clean surfaces, good distribution of fibres and a suitable internal turbulence without unnecessary loss of pressure (Zhe Wen, 2012). The consistency of fibres in the headbox could be as low as

0,2% to acquire a high-quality formation and varies with the jet speed. Besides, a higher consistency is at all times preferred to save the power used for pumping as long as the formation is acceptable.

Press Section

The stock jet from the headbox will go through the forming roll first and then be transferred by the felt to the press section. The dryness of the web is around 16% before the press and the web needs to be dewatered by mechanical pressing before being picked up at the drying section otherwise much more energy would be consumed in the drying section and the surface quality of the tissue will be poor. There are several reasons to install the press section – to dewater the web as much as possible, to pick up the wet web and transfer it to the Yankee cylinder and to rearrange the fibres in the web and create an intensive and smooth surface for the tissue. The felt plays an essential role in this section.

Firstly, it absorbs the water that dewatered from the web during pressing. Secondly, it uniformly distributes the pressure from the press to the web so that homogeneous dryness and surface properties of the web could be obtained. Thirdly, it works as the conveyer belt which drives the rolls and transfers the web to the cylinder. The cleanness influences the function of the felt to a large extent so shower water and blowing air are needed constantly to keep the felt clean. After pressing, the dryness of the web would reach between 35% and 42% and the web is sent to the drying section (Zhe Wen, 2012).

Drying section (Yankee drying)

The drying section is the heart of the tissue machine because more than 70% of the energy is consumed in the Yankee cylinder and hood which are two main components of this section.

The single large cylinder is generally made of cast-iron inside which steam at specific pressure is used to heat the paper sheet that is wrapped outside of the cylinder. In addition, a hood is arranged above the cylinder and hot air is blown onto the paper to increase the rate of drying. The cylinder has other functions except for heating and drying the paper sheet – it transports the sheet from the press roll to the reel roll during the drying process, acts as the basement for the pressing process and also provides a base for the creping process (Zhe.W, 2012).

In the Yankee-hood section, the energy consumption depends on the dryness and temperature of the web right before it passes onto the Yankee. It also depends on the adhesion of paper to the Yankee, the capacity of heat transfer of the cylinder, and capacity of drying by convection of the hoods, as well as their design.

The Yankee hood is combined by two parts – the dry end and wet end. The web is first picked up and dried at the wet end then further dried and creped at the dry end.

Fresh air is preheated by the exhaust humid air from the wet end then supplied to burners at both dry and wet ends as the combustion air where gas is used as the hot utility to heat the air to a higher temperature. Besides, part of the preheated air is supplied to the dry end as the make-up air. Several fans are involved in the air supply system, i.e. two combustion air fans, two recirculation fans and an exhaust air fan. There is also a counter flow which is drawn from the dry end and used to make up the air supply for the wet end. When the tissue sheet is dried to demanded dryness e.g. 95%, creping is finished at the dry end of the cylinder to give the paper a lower density, improved softness and better extensibility. Finally, the tissue is reeled on the reel roller as the product.

The describes structure of the drying section with the air supply system can be seen figure 1.

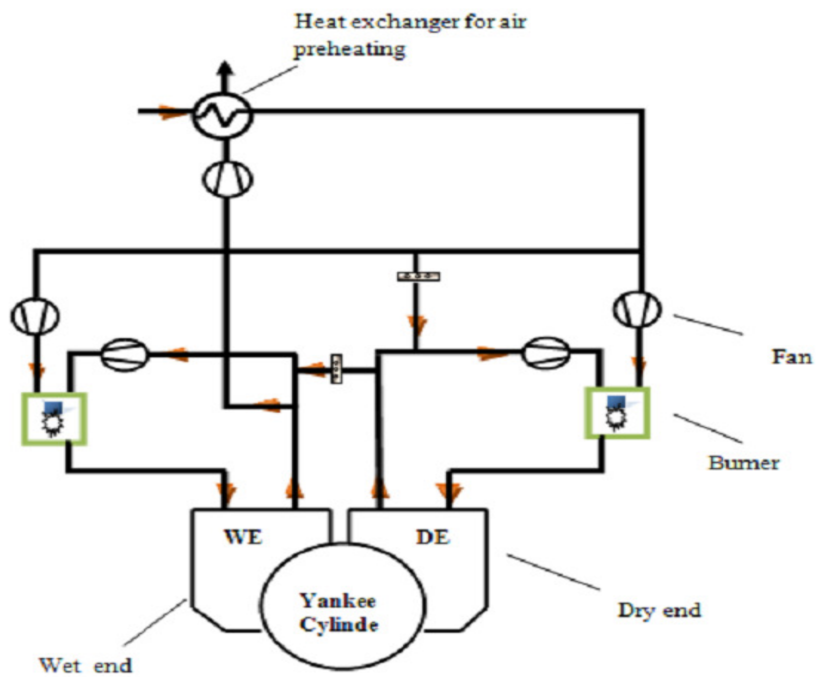


Figure 1 The drying section with air supply system

a) Tissue drying process

On a conventional dry crepe tissue machine, the sheet is dried on a single large cylinder called a Yankee dryer. The Yankee not only supplies the required energy for the drying of the web but also has three other functions:

- to transport the sheet during the drying process
- to function as a roll in the hot pressing operation
- to provide the base for the creping process.

The sheet is carried on a felt at a sheet dryness of 12%-18% and transferred to the Yankee in the first press nip. The sheet is dewatered in one or sometimes two press nips using the same felt in both nips. The first press roll is normally a suction roll. If a second roll is used, it is blind drilled roll. The nip load in the first press nip is typically 80-85 kN/m and in the second nip 85-90 kN/m. Since the diameter of the second press roll is smaller, the specific pressure in the second press is higher. This is important for the performance of the press. Occasionally, a steam shower is installed at the first press roll over its vacuum zone to heat the web and reduce the water viscosity. This improves water removal. Some steam showers have cross-direction control zones for improving sheet moisture uniformity.

Using only one press roll is the most common press configuration for new tissue machines. One press roll results in higher sheet caliper and better softness. Sheet tensile strength is lower. The dryness using only one press roll is lower at 2%-3%. Since the hood wrap can be increased with no second press, the production output is very similar for the two press concepts. A new concept has recently been introduced where shoe press roll has replaced conventional press roll. The use of a shoe press against Yankee dryer allows the production of tissue paper with higher bulk or higher production. This also improves crown match between press roll and Yankee. The typical tissue machine configuration can be seen figure 2.

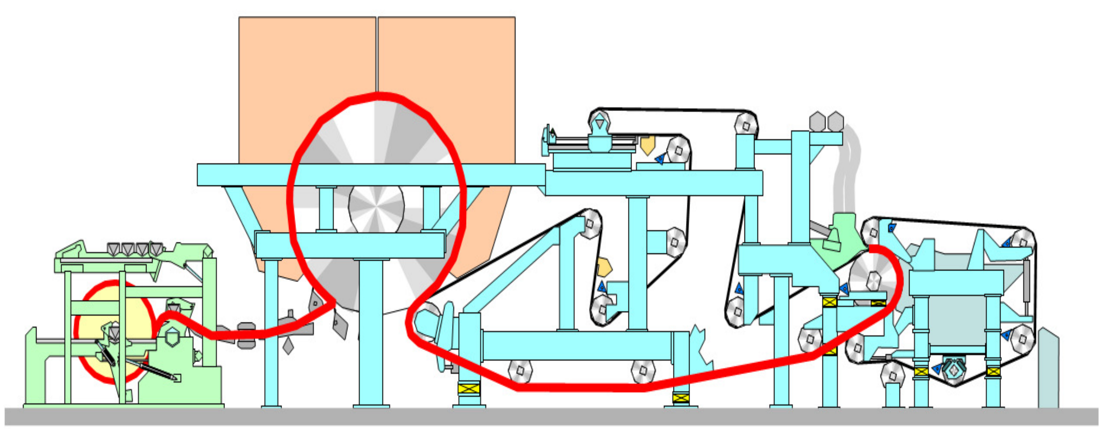


Figure 2 Typical tissue machine configuration

Conductive drying initiates from the first press roll nip and continues as long as the sheet remains in contact with the dryer surface. Convective and radiant drying begin under the area covered by the Yankee hood. The Yankee drying is a very intensive drying with drying rates of 150-240 kg H_2O/hm^2 vs 20-30 kg H_2O/hm^2 on a conventional can drying section. During the drying, the sheet is fixed on the dryer and not submitted to edge shrinkage as in other drying sections. This also means no open draws exist on a tissue machine until the sheet is almost dried.

For dry crepe tissue machines, the sheet is creped on the dryer at 93%-98% dryness. Machines where creping is performed at dryness less than approximately 90% are so-called wet crepe machines. These machines also have an after dryer section. Tissue machines normally have three doctors of which the creping doctor is the middle one. Before the creping doctor, a cut-off or skinning doctor is installed. This doctor is in use when the creping doctor blade is changed. A cleaning doctor is often used in the last position to remove fiber and excessive coating.

The drying capacity of a tissue machine is mainly affected by the size of the Yankee dryer. The machine speed of tissue machines has increased with the development of twin-wire formers. The need for higher drying capacity has resulted in bigger Yankee dryers. Today, the fastest tissue machines have cylinders with a diameter of 5,500 mm. In addition to the dryer, a high velocity impingement hood blows hot air with temperature up to 500°C to increase the rate of drying.

b) Yankee dryer design

The Yankee dryer is designed to work in different applications. The overall design and its components are optimized for each specific application for maximum safety and operational efficiency. It has use as a glazing and drying cylinder for the manufacturing of Machine Glazed paperboard and other special papers. In those applications, the resulting glaze of the paper surface is an important property. Due to high basis weights, these machines often operate at low speeds and below rimming speed. This will influence selection of the type of condensate removal system. A high basis weight also limits heat flow from the cylinder due to the risk for steam blowing (sheet blistering). These shells are therefore often plane bore shells designed for low steam pressures.

The Yankee dryer can also be designed for the production of lightweight tissue and towel where the paper is creped off the cylinder surface to create the creped structure of this product. In this case, the machine speed is normally very high. Sometimes, it is as high as 2, 150 m/min. For these machines, the heat capacity of the cylinder is an important property. Shells for these machines are therefore often grooved.

Due to the fact that the Yankee dryer is heated with high pressure steam, the design must also satisfy the requirements stipulated by the various pressure vessel codes such as ASME, DIN, and any local code prescribed in the place where the dryer is installed.

c) Cylinder design

Figure 3 shows a longitudinal section of a standard Yankee dryer design. Normally, it consists of only five different components. The largest of these is the shell that can be plain or ribbed. The unit has two heads and a through-going center shaft with the journals. The shaft normally has two parts with a flange connection in the center of the dryer. Between these two halves, a steam distributor ring is also possible.

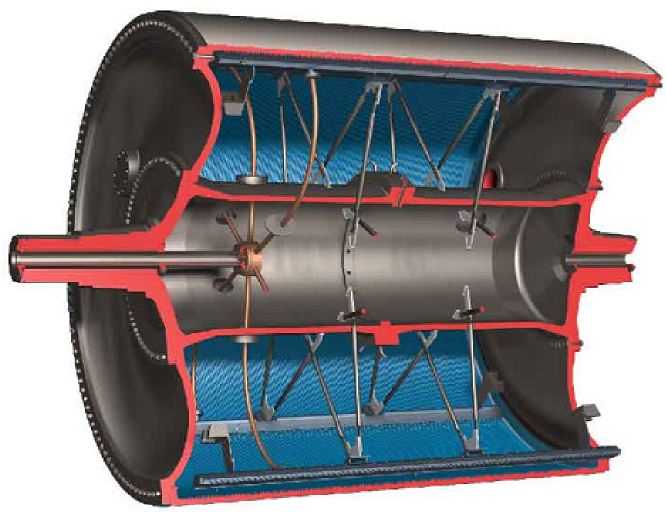


Figure 3 Longitudinal section of a Yankee dryer.

The center shaft carries about 50% of the axial load created by the internal steam pressure acting on the inside of the heads. Besides the center shaft, some designs also have axial beams installed between the heads (stay bars) to carry axial load and prevent excessive deformation of the heads.

To enter the dryer for inspections and maintenance, the two heads each have a man-hole positioned 180° apart. The internal shaft also has a manhole to access the parts of the condensate removal system installed inside the center shaft.

The steam inlet is normally on the front side. The steam passes through the steam joint and then goes through the insulated journal into the interior of the shaft. The reason for the insulation of the journal is to prevent excessively rapid heating of the journals, and reduce the heat flow to the bearings to prevent bearing damages. With insulated journals, the risk for cracked inner rings in the bearings decreases. Bearing life increases due to lower oil temperatures. From the internal part of the shaft, the steam is distributed into the cylinder through the steam distributor ring that has some angled pipes around its circumferance pointing in different directions for effective distribution of the steam. In some designs, the steam distribution uses holes in the center shaft.

The hot steam will condense when it hits the colder inside surface of the shell. The condensate will, in case of high speed tissue machines form a ring inside the shell. For low speed MG machines, the condensate will form a puddle in the bottom of the dryer. The speed at which the condensate transforms from puddle to rimming is normally 450-500 m/min.

From the inside of the cylinder surface, the condensate requires continuous removal through the drive side journal. This uses the condensate removal system that will have a design that depends on the speed of the machine and the shape of the condensate in the dryer.

d) Yankee hood

In general for the Yankee-Hood system, energy from gas, steam and electricity is about 45-55%, 35-45% and 10-15%, respectively. Electricity consumption should be minimized since it is found to be greatly effective on the total cost of drying due to the relatively high cost (Onel, S. 2000).

The critical drying parameters are the air supply velocity, wet-and dry-hood temperatures, and steam pressure in cylnder. Efficiency, defined as the ratio of energy required to evaporator the water to energy input through the system boundaries, is calculated as 28-30% for the overall system for the overall system for different grades of tissue paper production.

The Yankee hood uses air of high temperature with high impingement velocity to reach the required drying effect. The Yankee hood normally consists of two sections called the wet end section and the dry end section. The Yankee hood is an integrated part of the tissue machine. It is connected to a process air system by articulating (flexible) joints. The process air system is normally in a separate room in the direct vicinity of the paper machine room.

The main parts of the yankee hood areas follows:

- Framework and the hood retraction mechanism
- Supply air header and system
- Supply air distribution system

- Blow boxes
- Exhaust air plenum and system.

The exterior of the Yankee hood must be designed for the operation environment of a tissue machine room. The interior must withstand elevated temperatures, high air pressure levels, and the corrosive atmosphere from the evaporated water. Modern Yankee hoods must be sized for continuous operation with impingement air temperatures 300℃-540℃ and impingement velocities in the range of 90-180 m/s.

Drying of the tissue paper must also be even. Today's Yankee hoods normally have built-in profiling tools. This is a system enabling the papermaker to influence the drying performance of the hood in the crosswise direction of the paper.

The drying performance of the Yankee hood is a function not only of the temperature and velocity of the impingement air but also of the geometry, size, shape, and number of impingement nozzles in the blow boxes of the hood. Figure 16 shows a blow box with impingement nozzle.

Drying performance is also a function of the distance between the blow boxes and the Yankee cylinder. Since a modern Yankee hood operates with high temperatures, it must be designed to compensate for the thermal expansion such that the impingement distance is as constant as possible even at high operating temperatures of the Yankee hood.

The distance between the Yankee cylinder (paper sheet) and the Yankee hood is very small during normal operation (typical range is 1-20 mm). For the paper maker to be able to inspect the area between the cylinder and the hood, the hood sections can be retracted about 200 mm from the cylinder. This movement is controlled by screwjacks driven by an electrical motor or by an air motor. As an alternative, hydraulic cylinders are sometimes used. A well-functioning system normally has two screw jacks, one cross shaft, and one motor for each hood section so that opening and closing can occur without any distortion

Thermo-compressors system

This technique leads to steam savings in the drying hood by reducing the condenser losses. The use of thermo-compressors increases the energy efficiency of the drying process because less steam has to be sent to the condenser. Thermo-compressors are used to increase the pressure of the exhaust vapours from separators. The exhaust vapours from the last separators in a cascaded steam and condensate system have a very low pressure level which is not directly useable for the drying process. With a steam jet thermo-compressor, this exhaust vapour is boosted with high-pressure steam to a pressure level which enables a recovery of the exhaust vapour to use it.

The total burner load is the thermal energy needed to heat the sheet, to evaporate water, to make up for the heat lost to radiation, and to heat the makeup air. The thermal energy required to heat the sheet and evaporate the bound water is basically a function of the entering stock conditions and is tied to production requirements.

AUDIT ENERGY METHODOLOGY

The industrial energy audit consists of the following steps:

Step 1 Data collection

- The presentation of the process or stage. The first task of the energy audit is getting acquainted with the entire production process or stage. What is produced, which inputs are used? How much the amount of energy used, characteristics and quantity of raw materials used and other specific information that can be useful in the audit process.
- Data collection. Collection of data on the entire production process and a specific period is one of the main steps of the energy audit. When collecting data about the manufacturing process and systems, it is very important to collaborate with the employees as they know the systems very well.
- The benchmark. The collected data are compared with the data from similar companies.
- Defining the problem. After comparison of the consumption problematic systems, systems with relatively high energy usage can be defined.
- Observations of the Performance Test for Steam and Gas Consumption

Step 2 Data processing

- Calculations are carried out for refining unit and dryer unit, and the possible energy efficiency improvements are identified.
- Accurate scheme for the production of energy and raw material flows. A pre-established production scheme is improved, supplemented with information acquired in the energy audit process

Step 3 Analysis of results

- The most appropriate solutions are identified and justified.
- Exact energy efficiency suggestions are presented. The goal of the suggestions is decreasing energy consumption.
- Evaluate performance test for Steam and Gas Consumption by comparing the results of the previous test performance on 2011 by Acelli Machine Performance Test.

Step 4 Recommendations

- The results of the audit of energy compared with the benchmark, in order to obtain suggestions for saving energy.

RESULT OF ENERGY AUDIT

The audit process is focused on the refiner and the Yankee dryer on both the part because the energy used is quite high. Energy consumption in the papermaking process involves the use of electrical energy for the refiner and heat energy derived from steam and combustion gases to the Yankee dryer. Paper drying is a complex heat transfer, evaporation and water removal process and a multi-faceted approach is required to optimise of the dryer section of paper machine to improve efficiency and energy savings.

Refining unit

The main parameter to characterize the refining effect is the amount of energy that is delivered to the pulp.

The data of Specific Refiner Energy (SRE) and Refining Intensity (SEL) for Line-1 of NBKP can be seen in Table 4, while the Line-2 can be seen in Table 5.

Table 4 Specific Refiner Energy (LINE – 1, NBKP)

PARAMETER	Unit	REFINER 2	REFINER 1
Disc Diameter	Inch	30	Not operated
Motor speed	rpm	592	
Bar Edge Length	Km/rev	28	
Cutting speed of bars	Km/s	276	
Flow	lpm	2000	
Consistency	%	4.85	
Quantity flow	Ton/h	5.82	
Operating Power	kW	330	
No Load Power	kW	101	
Consumed Power	kW	229	

Source : data from questionairre and calculation

Table 5. Specific Refiner Energy (LINE – 2)

PARAMETER	Unit	REFINER 4	REFINER 5	REFINER 6
Disc Diameter	Inch	30	30	30
Motor speed	rpm	793	793	793
Bar Edge Length	Km/rev	28	28	28
Cutting speed of bars	Km/s	370	370	370
Flow	lpm	2000	2000	2000
Consistency	%	4.92	4.92	5.02
Quantity flow	Ton/h	5.90	5.90	6.02
Operating Power	kW	440	300	420
No Load Power	kW	101	101	101
Consumed Power	kW	339	199	319

Source : data from questionairre and calculation

In order to calculate the refining intensity, it is necessary to first determine the true load applied to the fibers. In a commercial refiner, there is significant power consumption resulting from hydraulic losses. The bars and grooves of the refiner filling accelerate and decelerate the fluid as it passes through the refiner, causing a heating of the fluid but no net refining effect on the fiber in the process. This is called the 'no- load power' and it must be subtracted from the total motor load in order to accurately define the net power actually applied to the fibers.

Subsequently calculation of the Specific Refining Energy (SRE) and Refining Intensity (SEL) of refiner used, it can be seen in Table 8.

Table 8. Specific Refining Energy and Intensity

Parameter	Refiner-2 (NBKP)	Refiner-4 (LBKP)	Refiner-5 (LBKP)	Refiner-6 (LBKP)
SEL (Ws/m)	0.83	0.92	0.54	0.86
Benchmark*	1,0 - 2,5	0.3 – 0.8		
SRE (kWh/ton)	39.35	57.42	33.71	52.95
Benchmark**	60 - 200	40 - 80		

Note : *Aikawa Fiber Technology, 2001.

**Lumiainen, 1998.

Low Intensity value at the Refiner-2 compared with the benchmark, it is caused Specific Refining Energy on the refiner-2 units shown the value lower than benchmark value (40 – 80 kWh/ton).

An estimate of the specific energy requirement can be made for a given type of pulp if the unrefined pulp freeness and the target freeness level are known. By subtracting the target freeness from the unrefined freeness, the total amount of freeness change is calculated. Values in Table 9 can then be used to predict approximately how much energy should be required to achieve the desired freeness drop.

Table 5 Freeness drop vs energy

Furnish	Freeness drop/net hpd/t	Benchmark*
LBKP	38.35 ml	60-100 ml
NBKP	32.70 ml	20-40 ml

*Aikawa Fiber technology, 2001.

Refiner process for LBKP still get into the range of benchmarks for CSF drop to the energy used. Refining pulp LBKP not meet the benchmark value, the freeness drop value still low. Pulp refining process for LBKP need to be evaluated and have the opportunity for energy savings.

Pattern refiner is good for NBKP, so does the intensity, similar pattern better to be considered and Specific Refining Energy is good but for LBKP it need to be improved.
Refiner is designed for a wide range of operational capacity. The optimization capacity could be done by using the whole capacity with less recirculation refined pulp, but the result of fiber development should be considered as the first priority.

Yankee Dryer

Determination of energy consumption parameters need to be measured and accurate supporting data to support the calculation of energy consumption. The data in Table 1 shows the parameters of the material conditions for the calculation of energy consumption.

Table 1 Mill data condition and observations

No	Parameter	Mill Condition
1	Grammage target, g/m^2	12.5
2	Grammage actual, g/m^2	12.0
3	Final moisture content target, %	4.5
4	Final moisture content actual, %	6.0
5	Inlet moisture content drying unit, %	66.70
6	Machine speed, mpm	1600**
7	Main steam pressure, bar	13**
8	Main steam flow, kg/h	4228**
9	Condensate flow, kg/h	2654**
10	Hood System	Yankee hood
11	Cylinder dryer diameter, m	4.572**
12	Water evaporation, ton/day	133.55*
13	Pope reel production capacity target, ton/day	75
14	Pope reel production capacity actual, ton/day	66.40**

Source : data from questionairre; * data from calculation; **data from DCS System

Data from Table 1 can be used to calculate the amount of water evaporated in the drying process at Yankee dryer. The amount of water evaporated will affect the energy consumption, especially for thermal energy.

Calculation of Water Evaporation

The process of water removal in the papermaking process includes forming, pressing and drying. Water removal occurs more frequently in the forming and pressing process with amount of 99.84% and the drying process approximately 0.16%. Although the water removal in the drying process only 0.16%, but the energy use in this process is very high. The process of water removal through evaporation using thermal energy. Drainage distribution on the Tissue Machine can be seen in figure 4.

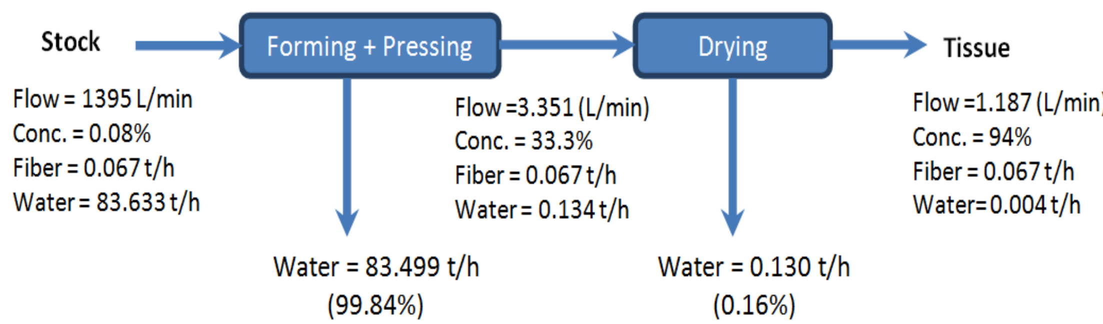


Figure 4 Water removal flow chart

Mass balance on the Yankee dryer unit can be seen in Table 2. The amount of water evaporated in one day production is 133.55 ton. This water removal depends on the performance of the process of forming, pressing and drying.

Tabel 2. Mass Balance on the Yankee dryer unit

No.	Variable	Yankee Dryer	
		In	Out
	Mass balance of fiber:		
1.	Mass of dry fiber, ton/day	68.87	68.87
2.	Mass of dry sheet, ton/day	68.87	68.87
3.	Mass of wet sheet, ton/day	206.82	73.27
	Water mass balance:		
4.	Mass of water in wet sheet, ton/day	137.95	4.40
5.	Mass of evaporated water, ton/day	0.00	133.55
6.	Moisture content, %	66.70	6.00
7.	Total mass of evaporated water, ton/day	133.55	

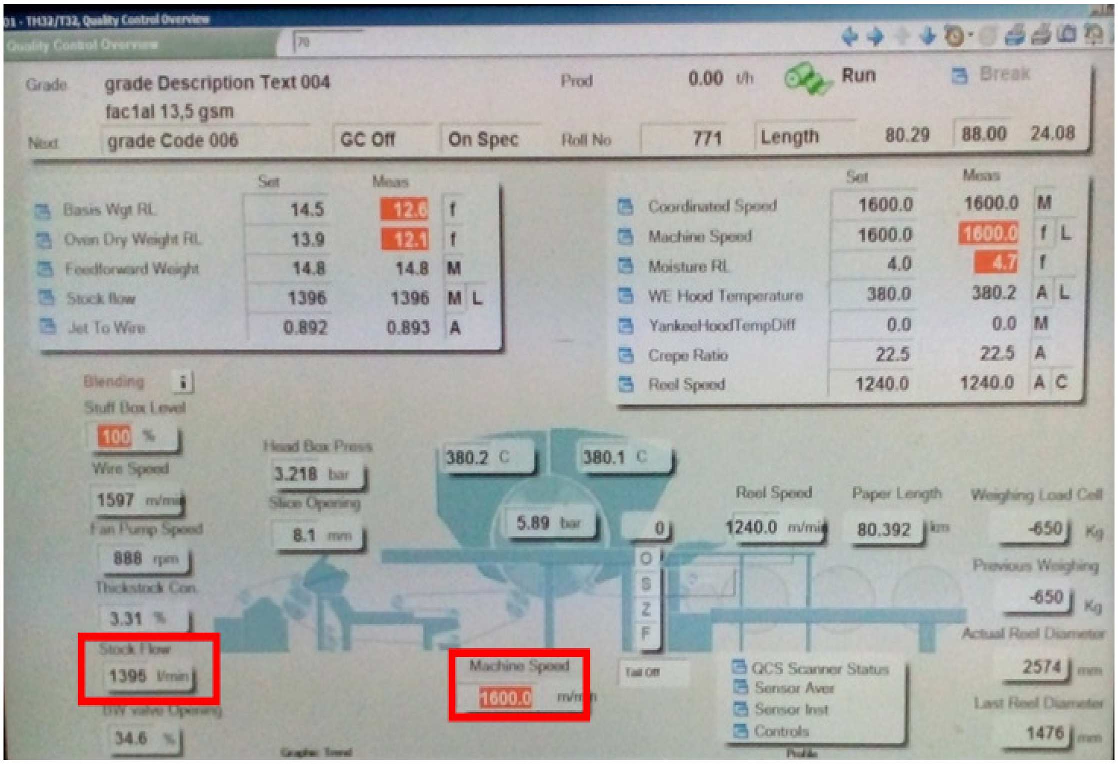


Figure 5 DCS Tissue machine overview

Calculation of Energy Consumption

The heat energy is used to evaporate the water comes from the Yankee dryer steam and combustion gases. Steam is used to dry out tissue paper through the Yankee cylinder with conduction process. Mechanism of drying tissue paper in Yankee cylinder and hood system can be seen in figure 6.

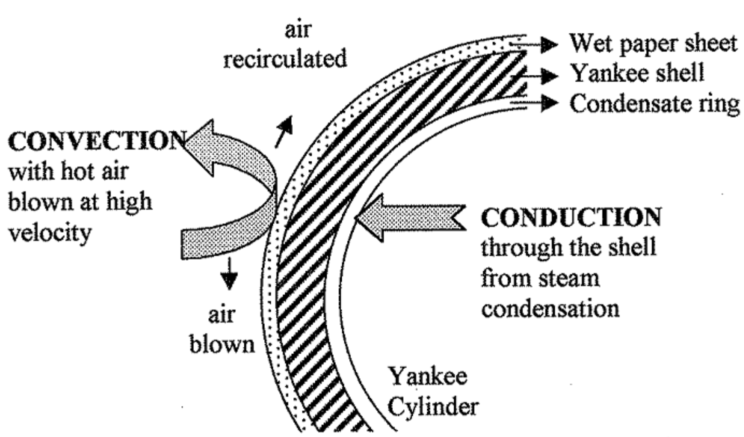


Figure 6 Mechanism of drying tissue paper in Yankee cylinder and hood system

Calculation of energy consumption of steam is obtained by processing the data obtained from direct observation at the DCS and the data from the questionnaires provided by the company. Figure 6 shows the data indicated on the screen DCS.

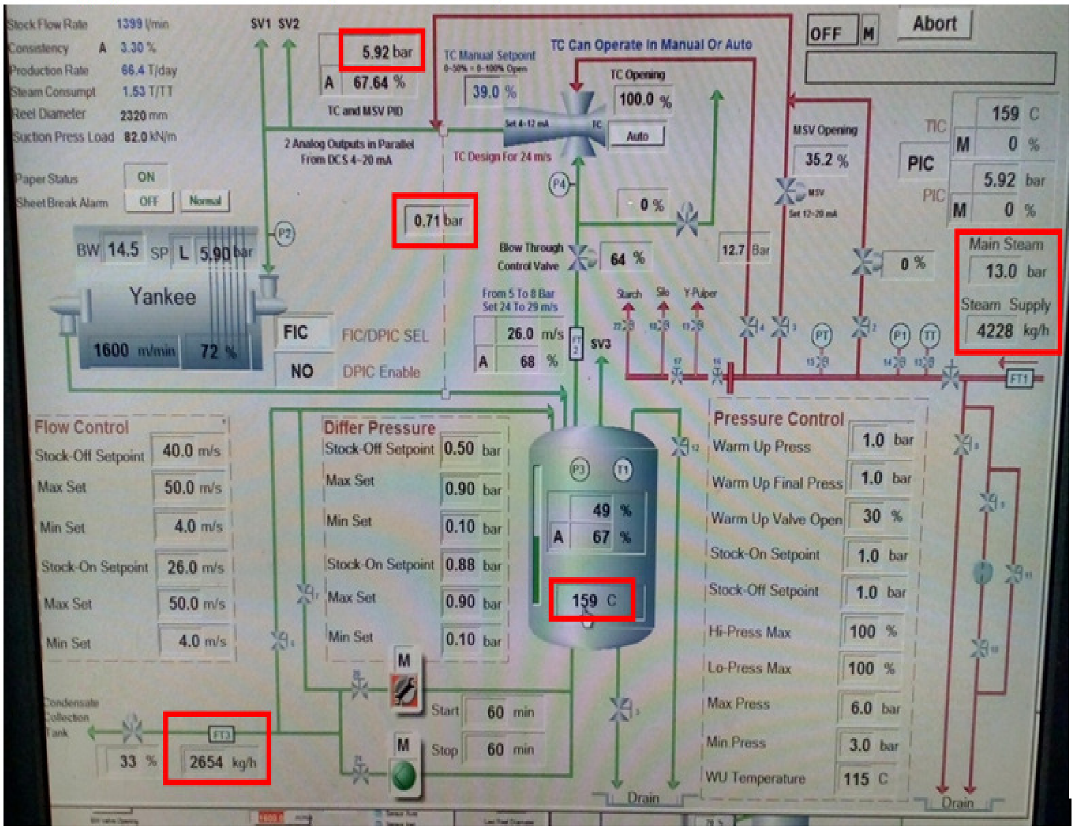


Figure 6 DCS steam system

The result of heat energy consumption calculations is obtained from steam gives the value of 243 GJ/day. This value is obtained from the flow rate of steam supply and condensate formation flow rate. These data can be seen in steam DCS system. Consumption of heat energy from the combustion gases is calculated based on the volume of fuel used and the specific calorific value of the gas. The flow rate of gas usage can be seen in Figure 7, while the specific heat of data can be seen in Table 3.

Table 3 Fuel gas composition

Component	27/09/2015	28/09/2015	29/09/2015	30/09/2015	Average
Methane	88.8448%	89.0374%	89.3902%	90.5599%	89.4581%
Nitrogen	0.2568%	0.2748%	0.2756%	0.2762%	0.2709%
Carbon Dioksida	3.5366%	3.8905%	3.7176%	2.9967%	3.5354%
Ethane	4.2764%	3.9526%	3.8613%	3.6557%	3.9365%
Propane	2.0118%	1.8279%	1.7665%	1.5823%	1.7971%
Water	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
Oxygen	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
i-Butane	0.3818%	0.3588%	0.3483%	0.3263%	0.3538%
n-Butane	0.4710%	0.4400%	0.4256%	0.3900%	0.4317%
i-Pentane	0.1220%	0.1190%	0.1167%	0.1151%	0.1182%
n-Pentane	0.0624%	0.0617%	0.0608%	0.0600%	0.0612%
n-Hexane	0.0364%	0.0371%	0.0373%	0.0377%	0.0371%
GHV, BTU/scf	1065.252	1054.899	1054.347	1055.890	1057.597
Temperature, °F	83.70	83.57	83.44	83.46	83.54
Pressure, psig	221.93	219.97	218.02	220.10	220.01

Source : data from company

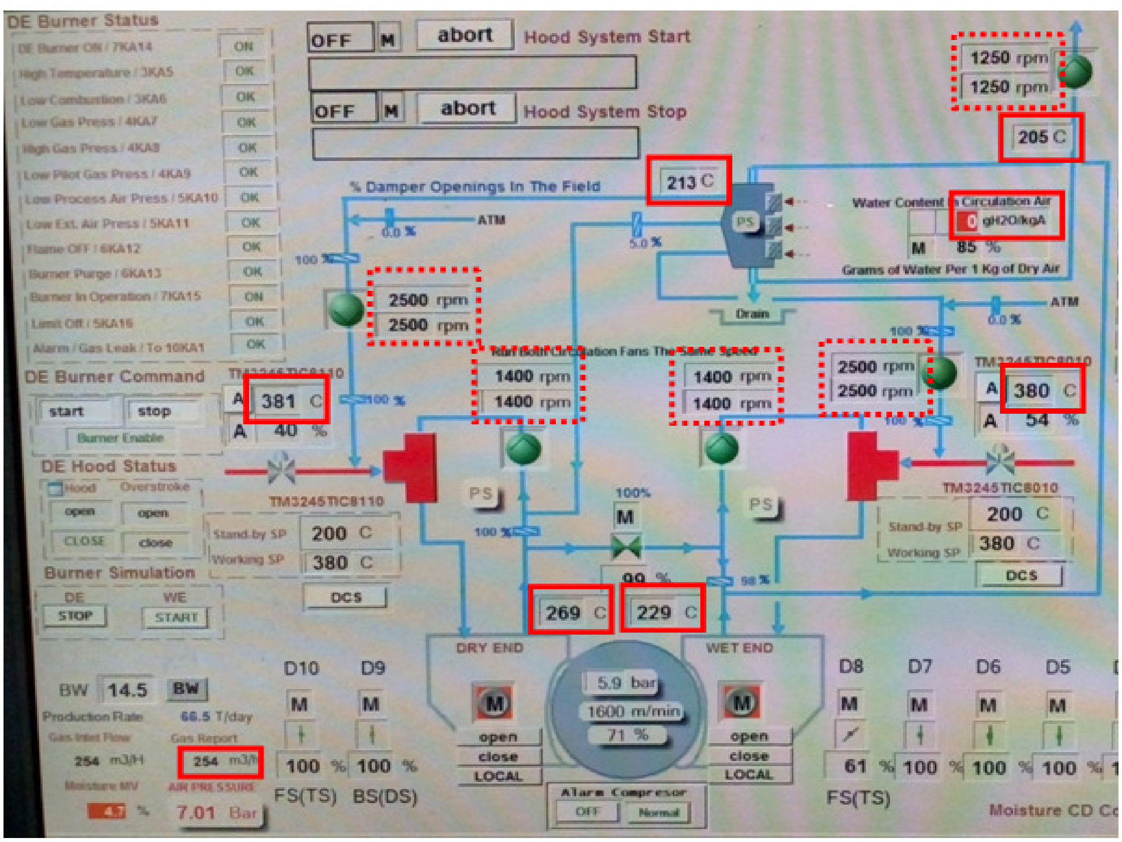


Figure 7 DCS gas burner system

Total energy consumption is obtained from energy balance on drying unit. Table 3 showed that heat from steam and gas burner approximately 483 GJ/day.

Table 3. Drying unit energy balance

No	Energy Consumption	Energy (kcal)	Energy (GJ/day)
1	Heat for sheet drying from steam	58.01×10^6	243
2	Heat for sheet drying from gas burner	57.36×10^6	240
3	**Total heat from steam and gas burner**	**115.37×10^6**	**483**
4	Steam Enthalpy	68.36×10^6	286
5	Condensate Enthalpy	10.28×10^6	43
6	Total Enthalpy (heat energy from steam consumption)	58.01×10^6	243

Source: data from calculation

Evaluation results of the steam flow of usage in the thermo compressor there is an imbalance of mass balance, steam supply flowrate indicator is seen on the DCS is not balanced with the rate of formation of condensate, so there are some steam mass can not be calculated. Figure 8 showed the flow diagram of thermo compressor system.

I

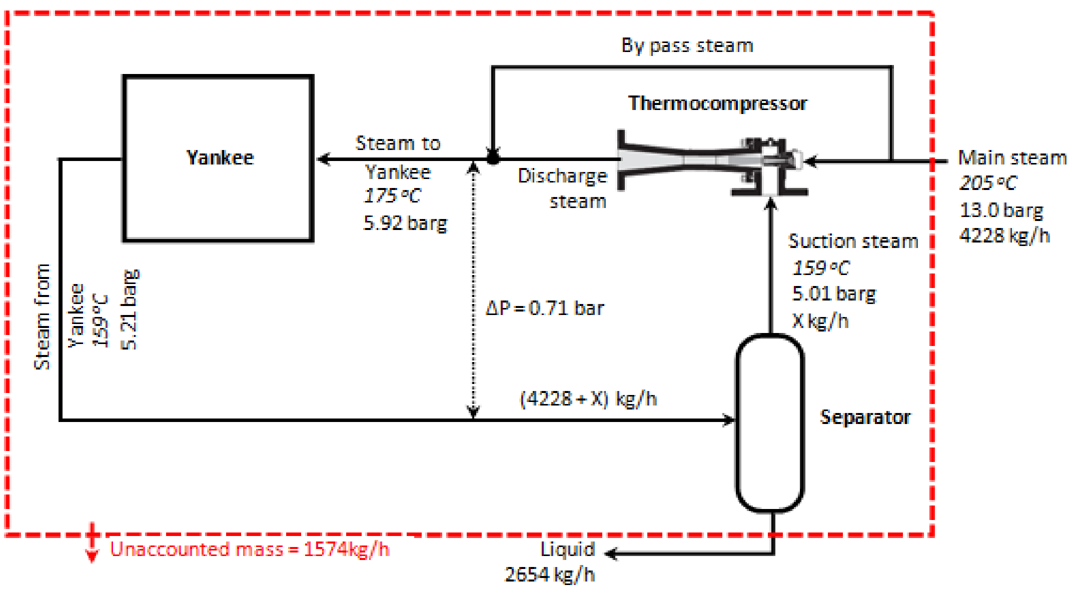


Figure 8 Thermocompressor system in Tissue Machine

Higher temperatures of supply air mean higher drying rates and therefore increased machine productivity. The higher rates of heat transfer can be obtained with higher supply air temperatures and/or with higher impingement air jet velocities. But, higher temperatures means using more natural gas. Operating at very high supply temperatures such as 650℃

allows one to reach the same drying rate with lower jet impingement air velocities to meet the same moisture evaporation; therefore lower electrical energy consumption is required. Also, higher air temperatures require smaller air volumes (for the same air mass) therefore less space is needed for the air system. Much lower recirculation fan kW usage is needed at the same production rate which means smaller motors and drives.

Specific Energy Consumption

The results of specific energy consumption for steam on Yankee dryer unit is 1.53 ton steam/ton product. This value is more higher than the value from Acelli Machine Performance Test at 2011, but this value is almost the same as the results of the performance test on 1st December, 2015 (The data can be seen on Table 5)

Table 4 Drying Unit Specific Energy Consumption (SEC)

No	Parameter	Mill Condition	Benchmark/standard*
1	Product Type	Tissue	Tissue
2	Raw Material	Virgin pulp	-
3	Grammage, g/m^2	12.5	-
4	Freeness Stock, CSF mL	380-400	-
5	Inlet moisture content drying unit, %	66.7	-
6	Outlet moisture content drying unit, %	6.0	-
7	Hood System	Yankee hood	-
8	SEC, $ton_{steam}/ton_{product}$	1.53	1.24 to 1.3
9	SEC, GJ/ton_{evap}	3.62	-
10	SEC, $GJ/ton_{product}$	7.28	-
11	Gas consumption, $Nm^3/ ton_{product}$	91.81	159 to 173

*Based on Acelli Machine Performance Test, 2011 (PT. Pindo Deli).

Based on the description above, SEC value from steam is increased. This is probably caused by the value of the measurement instruments are less accurate, the inlet steam temperature in the main steam header should be 5℃ - 20℃ over-saturation, there is no data humidity measurement from exhaust air and heat loss from steam leakage.Specific energy consumption of drying unit is slightly higher than the benchmark value. Still has potential energy saving.

Performance Test for Steam and Gas Consumption

Performance tests carried out on December 1, 2015 for periods ranging measurement from 11:00 until 20:00. The data collected to calculate the consumption of steam and gas by measuring the rate of use of steam, gas and production of tissue paper. The calculations were performed only for the consumption of steam and gas, while the calculation sheet on reel efficiency can not be calculated because there are changes grammage at 16:55. Performance test results can be seen in Table 5.

Table 5 Production data on the TM 3.2 at December 1st, 2015 (11.00-20.00)

Product	Unit	Toilet Guarantee	Performance test 2011	Actual 2015
Basis weight on Yankee	g/m2 (BD)	10.13	10.72	-
Basis weight on Yankee	g/m2 (AD)	10.64	11.20	-
Crepe Percentage	%	21.0	19.0	22.5
Basis weight on Reel	g/m2 (BD)	12.9	13.23	-
Basis weight on Reel	g/m2 (AD)	13.5	13.86	13.64
Dry content after press	%	38		-
Reel moisture	%	5	4.52	-
Yankee speed	m/min	1733	1797	1651
Yankee Steam Pressure	Bar gauge	Up to 7	6.2	5.82
Production at reel (100 eff)	t/d (BD)	65.4	70.8	-
Production at reel (100 eff)	t/d (AD)	68.7	74.1	21.30
Reel trim	mm	2630	2550	-
Estimated efficiency	%	89	-	-
Est. Net daily Production	t (AD)	61.1	62.1	-
Slice width		2690	2690	-
Web width on Yankee (+ trim)		2680	2680	-
Stock consistency	%	0.16 to 0.20	IN	-
Screen rejects	%	5.0	IN	-
Recirculation	%	5.0	IN	-
Retention	%	55 to 60	69	-
Fan pump flow rate	l/min			
Gas consumption (hood)	Nm^3/t	159 to 173	109	106
Electrical Consumption	kWh/t	630 to 830	735 to 785	693
Steam Consumption	t/t	1.24 to 1.3	1.06 to 1.30	1.31-1.61
Fresh Water Consumption	m^3/t	5 m3/t, with cooling tower and super filtered water used as per Suppliers recommendations-incalculable		

By comparing the results of the previous based on Acelli Machine Performance Test, 2011, show that the value of gas consumption is almost the same as the results of the performance test in 2011, while steam consumption value increased become to 1.31 - 1.61 tonnes of steam/tonne product.

CONCLUSION

Refiner

- Pattern for NBKP is Good, so does the intensity, similar pattern better to be considered, but for LBKP need to evaluation
- Specific Refining Energy and Specific Edge Load is Good but possible to be improved and the achievable fiber development should be checked / evaluated.
- Specific edge load (SEL) for NBKP is low, where as for LBKP high
- Specific Refining Energy (SRE) for NBKP is very low.

Dryer

- The Yankee hood is a key component in the production of tissue. As a result, it is important to maintain proper hood balance and to understand its effect on thermal energy use.
- Gas consumption is almost the same as the results of the performance test in 2011, while steam consumption value increased become to 1.31 - 1.61 tonnes of steam/tonne product.
- The steam flow of usage in the thermo compressor there is an imbalance of mass balance.
- There is heat loss from steam leakage.

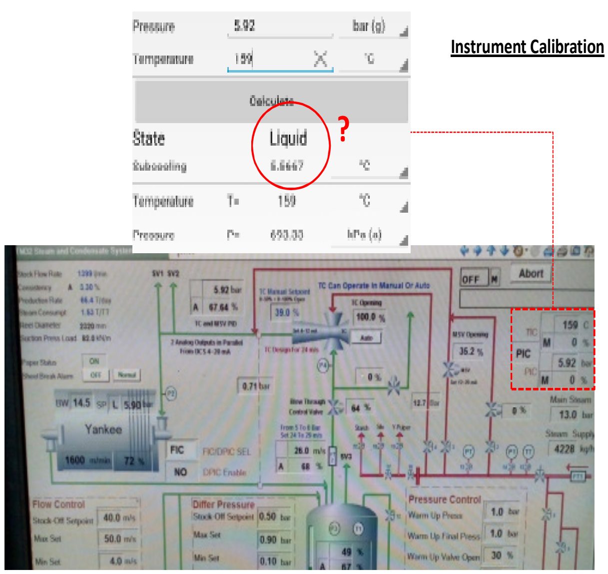
RECOMENDATION

REFINER

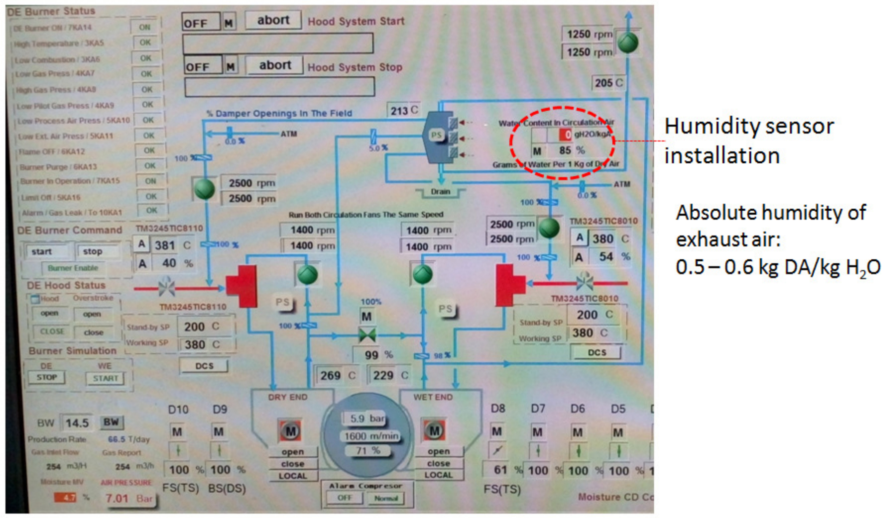
1. to measurement CSF at inlet and outlet of every refiner to reduces time consuming traditional checking.
2. to measurement rpm to each motor of Refiner
3. to installed sampling point valve for taken refined pulp for fiber development evaluation.
4. Optimizes the fiber development by choosing the correct plate pattern (high bar edge length/revolution, in order to have low intensity).
5. Optimizes the specific refining energy, SRE - kWh/t for LBKP

DRYER

- Metering intrument need to be calibrated to showed accurate data.



- Install humidity sensor on Yankee hood and exhaust air for calculating heated air.



- In general to suggestion for the inlet steam temperature in the main steam header should be 5℃-20℃ over saturation, i.e., slightly superheated steam.
- Install metering to indicate air volume in Yankee hood system.

REFERENCES

1. Onel, S. 2000. "*Energy Optimizing of the Yankee-Hood Dryer*". A Thesis submitted to the Graduate school of Natural and Applied Sciences of The Middle East Technical University
2. Zhe Wen, 2012. " Energy savings of tissue machines" Flexible application of technologies in different locations. Master's Thesis within the Innovative and Sustainable Chemical Engineering programme. Department of Energy and Environment, Division of Heat and Power Technology. CHALMERS UNIVERSITY OF TECHNOLOGY, Göteborg, Sweden.
3. Dinesh Fernando *, Dmitri Gorski , Marc Sabourin and Geoffrey Daniel, 2013 " Characterization of fiber development in high and low-consistency refining of primary mechanical pulp
4. Lumainen, J. 1998. Refining of chemical pulp. TAPPI FAPET production.
5. ---------------------, 2001. "Introduction to Stock Prep Refining"
   Aikawa Fiber Technologies, Canada

APPENDIX

KUISIONER AUDIT ENERGI TISSUE PAPER MACHINE
PT. PINDO DELI PERAWANG

Jenis mesin kertas : Acelli Tissue Papermachine

Distribusi Pengeluran Air di Mesin Kertas

Unit Proses	Konsistensi masuk, %	Konsistensi keluar, %
Forming	0.08-0.35	>
Pressing		33.3-38
Drying	33.3-38	94-95

Data *Pressing Unit*

Parameter	Nilai
Kadar air masuk, %	70-80
Tebal kertas keluar, µm	70 - 150
Jenis *roll press*: a. Top b. Bottom	Yankee Press Section Bottom Press
Rubber hardness, ^{O}P&J/Shore/JIS: a. Top b. Bottom	90
Tekanan *loading design*, kg/cm^2	82
Tekanan *loading* aktual, kg/cm^2	82
Lebar nip, in/mm	3.253

Data *Drying Unit*

No.	Input	Nilai
1.	Jenis kertas yang diproduksi	Tissue
2.	Bahan baku	Pulp (LBKP, NBKP)
3.	Persyaratan kertas produk (target):	
	a. Gramatur (dasar basah), g/m^2	11 - 45
	b. *Caliper*, µm	70 - 150
	c. *Moisture content*, %	4.5 – 5.0
	d. *Ash content*, %	0
4.	Produk kertas aktual:	
	a. *Gramatur* aktual (dasar basah), g/m^2	12 - 42
	b. *Caliper* aktual, mm	70 - 150
	c. *Moisture content*aktual, %	4.5 – 5.0
	d. *Ash content* aktual, %	0
4.	Kecepatan mesin desain, mpm	1800

No.	Input	Nilai
6.	Kecepatan mesin aktual, mpm	1500 - 1600
7.	Lebar kertas di *pope-reel*, m	2.65
8.	Kadar air kertas masuk, %	50 - 60
9.	Kadar air kertas keluar, %	4.5 – 5.0
10.	Suhu kertasmasuk, ^{o}C	28
11.	Suhu kertas keluar, ^{o}C	50-55
12.	Kandungan *filler*, %	-
13.	Kebutuhan *main steam*:	
	A. High pressure (HP) steam:	
	a. Tekanan *HPsteam*, kg/cm^2	12 – 15
	b. Suhu *HP steam*,^{o}C	250
	c. Laju *HP steam*, kg/h	4000 – 9000
	B. Low preessure (LP) steam:	
	a. Tekanan *LPsteam*, kg/cm^2	5 – 7
	b. Suhu *LP steam*,^{o}C	200
	c. Laju *LP steam*, kg/h	3000 – 7000
14.	Yankee hood air heater:	
	a. Sumber panas (steam, oil (kerosene), atau gas)	Gas
	b. Laju konsumsi bahan bakar	50 – 350 m3/h
15.	Kondisi udara *supply*:	
	a. Suhu udara di luar *hood*, ^{o}C	35-40
	b. Suhu udara dipanaskan,^{o}C	250-500
	c. Humiditas udara *supply*, kg/kg	0.45
	d. Laju udara *supply*, ton/hari	
16.	Kondisi udara *exhaust*:	
	a. Suhu *exhaust*,^{o}C	60
	b. Humiditas udara *exhaust*,kg/kg	50 – 75
	c. Laju udara *exhaust*, ton/hari	
17.	Yankee dryer:	
	a. Lebar silinder *dryer*, m	2.9
	b. Diameter silinder *dryer*, m	4.572
	c. Tekanan *steam* masuk dryer, kg/cm^2	8
	d. Tekanan *steam* keluar dryer, kg/cm^2	5-6
	e. Suhu *steam* masuk dryer, ^{o}C	150
	f. Suhu *steam* keluar dryer, ^{o}C	100
	g. Laju *steam* masuk dryer, ^{o}C	
	h. Laju kondensat, ton/hari	8

No.	Input	Nilai
	i. Suhu kondensat,^{o}C	70
18.	Sistem *hood*:	
	a. Tipe *hood*	Yankee hood duo system gas fired
	b. Dimensi *hood* atas (Panjang/Lebar/Tinggi) (m/m/m)	See attachment (Drawing Hood)
	c. Dimensi *hood* basement (Panjang/Lebar/Tinggi) (m/m/m)	See attachment (Drawing Hood)
19.	Harga steam, Rp/ton	88000
20.	Kapasitas produksi di *pope-reel*, ton/hari	75

Data Hasil Audit Bahan Baku dan Utilitas

No.	Parameter	Nilai
1.	Pemakaian bahan baku, ton/hari	
	a. NBKP	9
	d. LBKP	66
2.	Pemakaian bahan kimia, kg/hari atau ton/hari	
	a.	70
	b.	55
3.	Pemakaian air, ton/hari	1010
4.	Pemakaian listrik, kWh:	
	a. Stock preparation unit	88397.97
	b. Paper machine unit	48854.42
	c. Finishing unit	-
5.	*Freeness* stok masuk *paper machine*, ml CSF	300 - 450

Data Refiner

Parameter	Refiner 1	Refiner 2	Refiner 3
Motor speed, rpm	592	592	743
Plate diameter, inch	30	30	30
e. Bar width, 1/16 inch f. Groove width, 1/16 inch g. Groove depth, 1/16 inch	2.34 5.92 8.05	2.34 5.92 8.05	2.34 5.92 8.05
Bar edge length, km/rev	28.000	28.000	28.000
Power applied motor load, KW	250 - 480	250 - 480	250 - 480
Flow, liter per minute	1500 - 2000	1500 - 2000	1500 - 2000
Consistency, %	3.5 – 5.0	3.5 – 5.0	3.5 – 5.0
Target freeness, mL CSF	380 -450	380 -450	380 -450
Freeness inlet, mL CSF	400 – 650	400 – 650	400 – 650
Freeness outlet , mL CSF	400 - 550	400 - 550	400 - 550