Design of a Geothermal Energy Dryer for Tea Withering and Drying in Wayang Windu Geothermal Field

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ABSTRACT

The Wayang Windu power plant in West Jawa, Indonesia, has been producing power since June 2000 and is currently delivering 220 MW of electricity into the national grid. The plant is operated by Magma Nusantara Limited (MNL), which has a Joint Operating Contract (JOC) with Pertamina Geothermal Energy (PGE), and uses flash steam technology, in which steam is used to generate electricity by directly driving a large turbine. At present, 100% of the brine is injected into injection wells located 14 km south of the plant. The Wayang Windu power plant is surronded by tea plantations and villages. There are also three tea factories in this area. The Malabar tea factory is the largest among them and is located within 500 m of the brine pipeline. The maximum product capacity of the Malabar is 63 tonnes per day. Those tea plantation and factories are managed by PTP Nusantara VIII. Currently, the heat source for withering and drying tea leaves in Malabar tea plantation is Industrial Diesel Oil (IDO). Malabar burns about 1.25 millions liters per year of IDO. The hot brine can be used as a replacement for IDO.

Three parties (BPPT, MNL/PGE and PTP Nusantara VIII) proposed to utilize the brine to replace IDO. The engineering design for replacing IDO is presented here. Also, the thermodynamics and the main components (heat exchangers) for withering and drying are discussed.

1. INTRODUCTION

West Jawa is a province which has a huge geothermal potential – approximately 20% of Indonesia's total geothermal potential which equals 5311 MWe. These potentials spread out in 11 regencies, and in several fields have been used to generate electricity that are connected to the national grid. These fields are Gunung Salak Geothermal Power Plant (375 MW) at Bogor regency, Wayang Windu Geothermal Power Plant (2x110 MW) and Kamojang Geothermal Power Plant (200 MW) at Bandung regency, and Darajat Geothermal Power Plant (255 MW) at Garut regency. The total electricity produced is 1050 MW. In addition to generating electricity, in several geothermal fields direct applications such as natural tourism and hot water bathing at Ciater, Tangkuban Perahu, Cimanggu and Rancawalini are operating.

Geothermal energy can be used directly to help processes like heating, drying, sterilization, and/or pasteurization. Geothermal energy sources in Indonesia located in mountainous and inland regions are often close to agricultural fields, plantations, floristries, breeding include fisheries and tourism in the surrounding area. In such areas, geothermal energy can be used for drying and preservation of agricultural products (tea, coffee, cacao, etc), growing medium sterilization (mushrooms, potatoes, etc), breeding product pasteurization (milk, etc), bathing, and other processes like leather tanning, metals, and so forth.

Thus far, many agro industries use large amounts of oil as energy sources for drying, heating, sterilization, pasteurization processes, etc. Thermal energy from oil fuels for those agro industry businesses can be substituted with geothermal energy using heat transfer technologies (heat exchangers).

There are tea plantations and 3 tea factories near Wayang Windu geothermal field – West Jawa. Heating process in the tea factory are withering and drying, which are still fueled by oil. Oil fuels can be replaced by geothermal energy from Wayang Windu geothermal field.

With the backgrounds described above, the Agency for the Assessment and Application Technology – BPPT plans to optimize geothermal energy potential in West Jawa, especially at Wayang Windu geothermal field – West Jawa. For this, an engineering design of heat exchanger components is needed for withering and drying processes with geothermal energy as a energy source. This activity is centered around the Malabar tea plantation near Wayang Windu geothermal field.

2. THE MALABAR TEA FACTORY MALABAR

Based on history, all plantation areas in Pengalengan were developed by K.A.R Bosscha in the yea of 1896. All products from that tea plantation were processed by 3 tea factories in that area, i.e. Malabar, Kertamanah, and Purbasari tea factories. Among them, the Malabar tea factory is the biggest with maximum capacity around 63 tons per day. Now, the tea plantation area and the 3 tea factories are managed by PTP Nusantara VIII.

The Malabar tea plantation has a concession area of 2022.11 ha with producing tea plants (PTP) on 1207.67 ha, not producing tea plants (NPT) on 101.49 ha, producing cinchona plants (PCP) on 7 ha, and not producing cinchona plants (NPC) on 22.72 ha. The rest of this concession area is used for the factory and housing estate (115.03 ha), non-planted area (147.58 ha), seedbed (1.08 ha), and other uses (5.53 ha).

2.1 Tea Production

Tea production from the Malabar plantation in the period of 1955 to 1974 was relative constant at about 7500 tons per year. Since then, production has increased to about twice that of 1974. This increased production was caused by rejuvenation of tea plants in the year 1974 using a cutting system for tea plants in which a seed system was planted before. This cutting system has productive periods when plants are 5 until 50 years old.

The tea production depends on the season. During the rainy season, the production can reach 100 tons per day, whereas in dry season, the production is very low, just between 20 – 30 tons per day. Based on the production data in the year of 2004, wet tea products during 1 year were 15,383,241 tons and after processed to be dry tea were 3,425,999 tons. Figure 1 shows the tea production from the year 2004 to the year 2006.

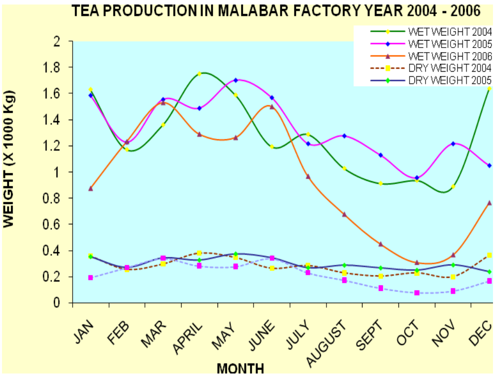

Figure 1: Dry Tea Production PTPN VIII factory Malabar Plantation – West Jawa

2.2 Tea Leaf Processing

Generally, fresh tea leaves which have been cut from the tea plantation are first processed by withering, and then grinding or milling, oxidation, drying, sorting, packing and storing in a storehouse.

The withering process is aimed to reduce water concentration of around 55%. This process is conducted by blowing mixed air (fresh air and hot air) to maintain a temperature of 24-28^{0}C. During rain season, the water concentration in the tea leaf is relatively higher than during dry season, so withering takes longer around (18-20 hours), whereas in dry season, it is just around 10-14 hours.

The milling process is carried out to break tea leaves to powder, and then the oxidation process is performed to achieve black tea powder. The aim in the oxidation process is to reduce smell of the leaves, giving red color when pouring with water.

The drying process is conducted by blowing hot air with temperatures of 100-120^{0}C. The drying process lasts between 2 and 3 hours. This process is aimed to reduce the water concentration to less than 2%.

The next processes are sorting, packing, and stockpiling in the storehouse. Figure 2 shows the flow chart of tea leaf processing at the Malabar tea factory, and Figure 3 shows the layout of machines in the Malabar tea factory – PTPN VIII.

2.3 The Energy Need in Tea Factory

The energy needs for tea processing is very high. In Malabar tea factory, this need is supplied by burning IDO (Industrial Diesel Oil). The largest energy requirement is needed for the drying process. The other process which requires also large amount of energy is the withering process. The IDO consumption of the Malabar is 0.35 liter for 1 kilogram dry tea per year, in which 0.24 liter is needed for the drying process and 0.11 liter for the withering process. The estimated IDO requirement for the Malabar tea factory is about 1.27 million liter per year. The IDO consumption for the Malabar tea factory in the year 2005 can be seen in Figure 4.

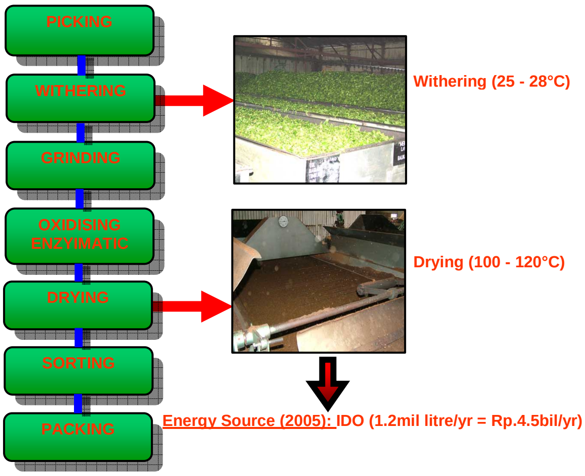

Figure 2: Tea Leaf Processing at Malabar Tea Factory PTP Nusantara VIII

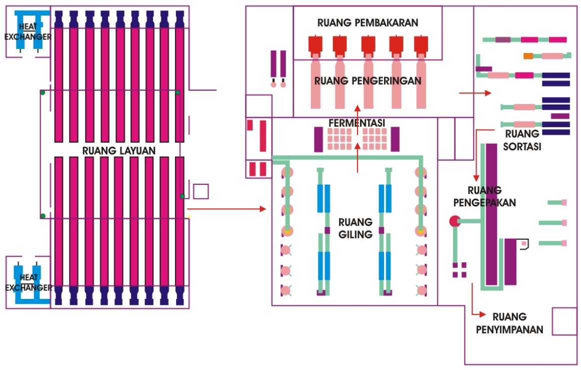

Figure 3: Machine layout Malabar tea factory – PTP Nusantara VIII

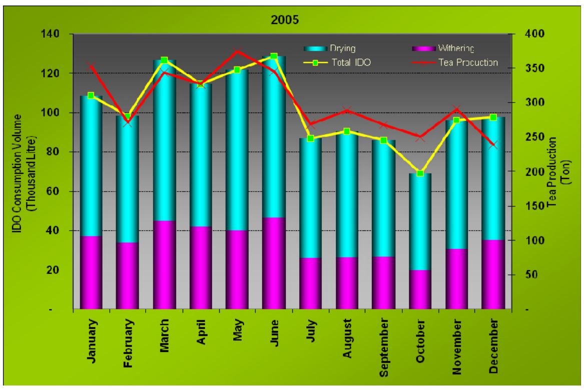

Figure 4: The IDO consumption 2005 in the Malabar tea factory

The energy need is used for 5 drying machines and 4 Heat Exchanger withering machines, with the total power as shown below: The dryer consists of 5 radiator units, each with a capacity of 3,000,000 BTU, and there are 4 radiator units for the withering process, each with a capacity of 1,500,000 BTU. Therefore, the total required heat for the withering and drying processes is at least 6.10 MWt.

3. THE CALCULATION OF SYSTEM AND HEAT EXCHANGER COMPONENTS FOR TEA DRYING PROCESS

3.1 The Work Principle and Main Character of Tea Drying Process (Thermodynamic Cycle)

Figure 5 shows the thermodynamic work principle in the tea drying process with a geothermal energy source schematically according to type of working fluid circulation. This system generally consists of 3 main loops:

1. *Loop 1:* geothermal energy
2. *Loop 2:* working fluid and
3. *Loop 3:* cold/hot air circulation

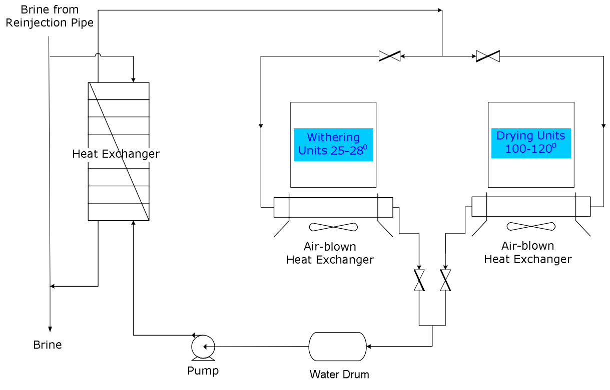

Figure 5: Scheme of System and Heat Exchanger Components for Tea Drying Process

1. Geothermal fluid is separated in a separator to be steam and brine. The steam is used to drive a turbine, and then the turbine generates electricity. Whereas the brine flows through a heat exchanger (evaporator) to change liquid working fluid to a vapor, in this study the working fluid is water. The brine which comes out from the evaporator flows to re-injection wells. The evaporator can also be called a steam generator.

2. The superheated vapor of the working fluid that is produced from the evaporator is used for withering and drying tea processes. Subsequently, the superheated vapor of the working fluid from the evaporator is condensed through air-blown heat exchanger. The cooling medium is air.

   The condensed working fluid is then circulated using a feed pump to the evaporator and so on in the working fluid loop. One kind of the feed pump which can be used is a hermetic centrifugal system.

3. The cooling medium is changed from fresh air to hot air. The hot air flows through withering radiators and the drying radiators, thus facilitating the tea drying processes.

3.2 Project Data

3.2.1 Wayang Windu Geothermal Brine Source

This calculation will use reinjection wells from WWF. WWF is located about 14 km south of the power plant unit 1 (110MW) , and the brine pipe to WWF is about 500 m from Malabar tea factory, as shown in Figure 6. The brine data of WWF is as follows:

Flow Rate=270 ton/hr=75kg/sec
Brine Temperature=180^0C
Pressure= 10 bar

For a maintenance purpose of the brine, the design will use only 55kg/sec of brine, which can substitute energy requirements of machines used for withering and drying processes.

If the thermal energy from this hot water is possible to extract until 150^0C without causing technical problems like scaling, 55 kg/sec of hot water can be re-injected to produce 9.57 MW, according to the following calculation:

$$Q = \dot{m}\, x\, C_p \text{ x } \Delta T \qquad (1)$$

Where $\dot{m}$, C_p, ΔT are water mass flow rate (kg/sec), water specific heat (kJ/kg.C), and reduction temperature (^{0}C).

This available heat of 9.57 MW can substitute energy requirements of machines for withering and drying processes.

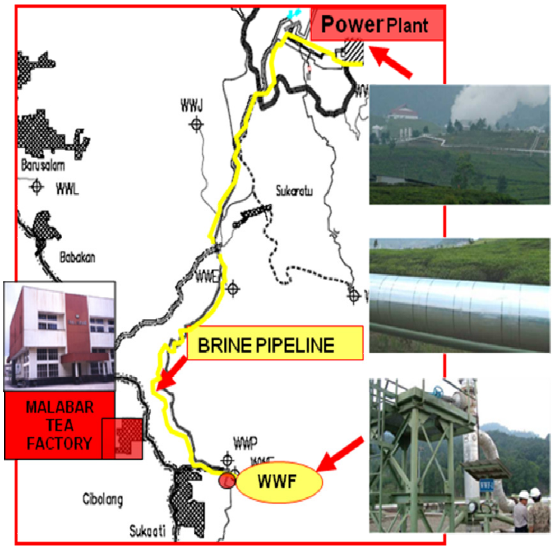

Figure 6: Layout Brine WWF

3.2.2 Silica Scaling Calculation from Brine

The available chemical data from the brine WWF mainly is of SiO_2 content (Quartz). Therefore, the silica scaling calculation requires that the dissolution of amorphous silica has been measured in the saturated pressure by Fournier and Rowe, 1977, with dissolving equation as below:

$$\log C = \frac{-731}{T} + 4.52 \qquad (2)$$

Where: C, and T are concentration (mg/kg) in solution and absolute temperature (K).

Table 1 shows WWF brine temperatures, SiO_2 content (Quartz), and SSI value from 2003 to 2006. SSI is calculated based on formula 2. SSI is the index ratio from silica concentrate in the brine with the amorphous silica solution. If SSI>1, the separated brine is supersaturated with respect to amorphous silica (silica scaling occurs). The average value of SSI 1.40, so the corresponding brine temperature SiO_2 content are 147.5^0C and 848 mg/kg, respectively.

Table 1. WWF Brine Data and SSI at Wayang Windu Geothermal Field.

Silica Saturation Index					
No	Date	WHP Barg	SP.Temp °C	SiO_2 mg/kg	SSI
1	05 January 2003	-	178,0	934	1,18
2	15 February 2003	-	176,6	883	1,13
3	08 March 2003	-	178,9	893	1,12
4	06 April 2003	-	176,4	883	1,13
5	17 May 2003	-	178,3	842	1,06
6	16 June 2003	-	177,2	831	1,06
7	12 July 2003	-	179	876	1,10
8	20 August 2003	-	175,2	889	1,15
9	22 Sept 2003	-	161,7	766	1,11
10	14 Oktober 2003	-	161,0	787	1,15
11	14 November 2003	-	167,2	751	1,04
12	18 December 2003	-	178	791	1,00
13	22 January 2004	7,00	173,4	851	1,12
14	13 February 2004	8,30	178,5	837	1,05
15	16 March 2004	8,50	178,0	839	1,06
16	17 April 2004	8,50	180,3	801	0,99
17	17 May 2004	9,00	179,4	834	1,04
18	21 June 2004	8,47	178,4	838	1,05
19	20 July 2004	8,31	174,3	736	0,96
20	12 August 2004	8,50	178,0	905	1,14
21	22 September 2004	8,62	177,0	799	1,02
22	12 October 2004	8,34	177,9	843	1,06
23	08 November 2004	8,43	178,0	817	1,03
24	16 December 2004	8,35	177,9	934	1,18
25	11 January 2005	8,14	178,4	874	1,10
26	08 February 2005	7,93	174,0	878	1,15
27	08 March 2005	8,45	178,6	823	1,03
28	19 April 2005	8,00	178,1	924	1,16
29	11 May 2005	8,29	177,7	861	1,09
30	19 June 2005	8,28	178,9	916	1,15
31	19 July 2005	8,40	177,4	866	1,10
32	15 August 2005	8,36	177,8	858	1,08
33	15 September 2005	7,92	174,3	792	1,03
34	12 October 2005	7,90	175,6	826	1,06
35	17 November 2005	7,94	176,3	861	1,10
36	15 December 2005	8,07	175,0	725	0,94
37	12 January 2006	7,90	174,5	886	1,15
38	16 February 2006	7,84	174,6	821	1,07
39	14 March 2006	7,89	175,0	826	1,07
40	13 April 2006	8,17	175,0	854	1,10
41	11 May 2006	8,22	174,8	850	1,10
42	20 June 2006	8,08	175,1	881	1,14
43	14 July 2006	7,99	174,9	856	1,11
44	28 August 2006	7,82	176,1	842	1,08
45	13 September 2006	7,96	174,8	819	1,06
46	11 October 2006	7,75	175,1	999	1,29

3.2.3 Technical Data of the Malabar Tea Factory

The main components in drying process consist of an oil burner, blower (main fan), and ducting. Technical data from this equipment is as follows:

1. Withering Trough and Mixing Chamber
   - Φ frime: 48”
   - Electric Motor: 7.5 kW
   - Voltage: 220/380
   - RPM: 975
   - Air Volume: 23000 CFM
   - Trough/Section Measurement (42 units):
     - Length: 245 cm
     - Wide: 183 cm
     - High: 93 cm
     - 1200 -1500 kg wet tea
2. NU Way Benson – Heat Exchanger (HE Withering Machine)
   a. HE Withering
      i. Brand name: Benson
      ii. Model: EM-440
   b. Burner
      i. Brand name : NU-Way L3
      ii. Voltage: 220/380
      iii. Power: 0,75 kW
      iv. RPM: 2800
   c. Main Fan
      i. Brand name: Brustead
      ii. Volume: 25000 CFM
   d. Electric Motor
      i. Power: 15kW
      ii. Voltage: 220/380
      iii. RPM: 1400
3. 5 units of radiators with capacity @ 3.000.000 BTU for drying process, 4 unit radiator with capacity @ 1.500.000 BTU for withering process
4. 5 drying units consist of 1 unit FBD (F Bed Dryer), 4 unit TSD (Two Stage Dryer (TSD)
   - 350 kg/jam/dry for unit FBD
   - 200-210 kg/jam/dry for unit TSD

3.2 Topography (Pipe Line Alternative)

Based on general information, the distance from the WWF brine pipeline to the Malabar tea factory is about 500 m. However, according to the tedoliod topography survey that was carried out, there are 2 feasible alternative lines, as shown in Figure 7:

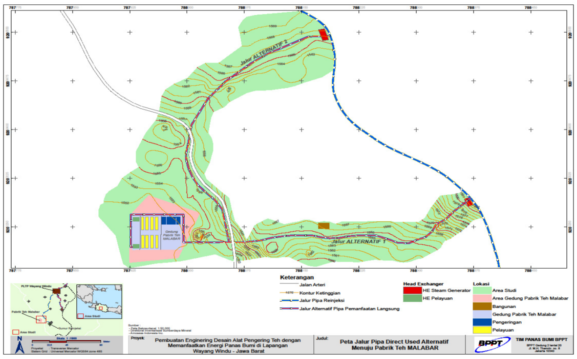

Figure 7: Possible Piping Layout from Brine to Tea Malabar Factory

Figure 7 describes that alternative line 1 takes place on the east side of the Malabar tea factory along the tea plantation. The point of the steam generator that transfers heat from the brine to the fresh water will be placed within a radius of 5 m from the brine pipeline. The work principle of the steam generator (one of the main components) is explained above. The soil contour differences along the line between the tea factory and the brine pipeline vary from 4 to 29 m. The highest difference of 29 m is between the HE steam generator and the factory. However, along a distance of ± 250 m, the soil contour difference is just ± 1 m. This alternative line 1 walks along the path side, so that there is no need to clear land of the tea plantation area. Pipeline 1, which carries fresh water from the steam generator to the factory boundary has a distance of about 500 m.

Figure 7 also shows that alternative line 2 is located on the north side of the Malabar tea factory along the tea plantation and the main road. The soil contour differences along the line between the tea factory and the brine pipeline differ from 1 m to 12 m, in which 12 m is the highest difference between the HE steam generator and the factory. This alternative line 2 goes along the path side to the main road, then along the main road to the tea factory so that also it is not required to clear land of the tea plantation area. Pipeline 2 has a distance of 535 m to the factory.

Based on the explanation above and a security factor, this alternative line 1 is confirmed for a pressure drop calculation that is described below.

3.3 Tea Drying Layout And Piping System

Figure 8 shows the Malabar tea factory layout with an area of 70 m x 128 m. This factory consists of the top and bottom withering rooms and areas for milling, and enzymatic oxidation, drying, sorting and packing.

Figure 8 also describes a piping system in which a red pipeline indicates steam from HE steam generator to the withering and drying processes and a blue pipeline shows hot water routed back to the HE steam generator. The piping system will be completed with measuring instruments like temperature and pressure gauges and flow meters.

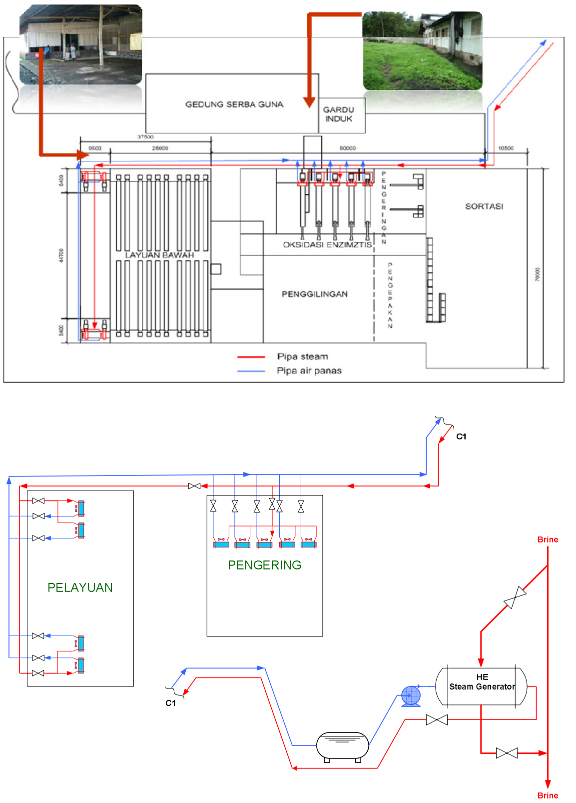

Figure 8: Tea Drying Layout and Piping System

3.4 General Information and Assumptions for Mass and Heat Balance Calculations

A mass and heat balance calculation with the thermodynamic parameters from WWF brine and the parameters from tea withering and drying process can be conducted analytically or by using software that can perform the fluid thermodynamic property calculations and run the models for each operating condition. Some examples of such software are EES and HYSYS.

The calculation is carried out with various assumptions shown below:

- The outside air temperature is 15^0C, and the brine temperature at t the outlet of the evaporator is greater than or equal to 147.5^0C, at which silica scaling will not occur (see silica scaling calculation).
- Air inside the drying room transfers thermal energy convectively; air transferred due to radiation processes can be neglected because convective flow moves rapidly.
- The drying room is perfectly isolated, so there is no heat loss from the drying room system.

The main components in the tea drying process consist of an evaporator (steam generator), withering machines, drying machines, fans and blowers. After the mass and heat balance calculation, the calculations of the thermal and main mechanical components, the steam generator and air heaters (withering and drying machines), are carried out.

The HTFS software developed by Brackenbury, et al (1993) can be used for these calculations. The design of a heat exchanger consists of three steps i.e. thermal design, mechanical design, and checking. In the thermal design stage, the process conditions and limitations are inserted to the program along with the preferences to meet process requirements and engineering designer interests. In this step, the configuration is set and the performance of the exchanger is calculated. The exchanger configuration is then evaluated to satisfy mechanical limitations. Then the corrected configuration is reexamined to evaluate the performance of the heat exchanger.

3.5 The Calculation Result and Analysis

Following is the calculation of the steam generator and air heaters design for the Malabar tea factory. The steam generator is designed to produce vapor from fresh water, and the hot fluid is the brine WWF. The air heaters are designed to heat air that will be used as a drying and withering medium. Vapor from fresh water is used as hot fluid.

The purpose of these design calculations is to modify the existing system in the Malabar tea factory. The factory uses direct fire heaters for heating air, and the energy source for direct fire heaters is IDO. In this installation, there are 5 fans including the ducting system to supply hot air to 5 drying rooms, while 4 unit fans together with the ducting system supply hot air to the 4 withering rooms. The air capacity of each fan is 14.16 kg/sec.

The existing ducting system must be considered in this design. Therefore, just 2 units of the air heaters for withering processes are designed, in which each air heater unit represents 2 withering rooms. In fitting to the required conditions, the engineering design is limited to: Fined Tube Air Heater design and Steam Generator with a type of Shell and Tube model BKU. The thermal and mechanical design of the Air Heaters and the Steam Generator can be performed with help of HTFS software.

With respect to all constraints above, the steam generator and air heater design will be fitted to within these boundaries and hopefully no big temperature differences will occur. The design calculations are considered with 3 temperature operation conditions below:

a) Model I :

The existing fans with the outside air temperatures are kept at 100^oC for withering process and 120^oC for drying process.

b) Model II:

The existing fans are maintained with brine utilization up to 55 kg/sec.

c) Model III:

Air temperature is 100^oC for withering process and 120^oC for drying process, and the brine utilization is limited up to 55 kg/sec.

The results of the design calculations of the steam generator and the air heaters for the three models is shown here.

a. Model I

a.1. Air heaters for withering process: (2 unit)

- Design data of every unit:
  - Air mass flow rate: 28.32 kg/sec
  - Air temperature inlet: 15^{o}C
  - Air temperature outlet: 100^{o}C
  - Vapor temperature: 140^{o}C
  - Condensate temperature: 140^{o}C
  - Vapor mass flow rate: 1.1359 kg/sec (from heat balance calculation)

a.2. Air heaters for drying process: (5 unit)

- Design data of every unit:
  - Air mass flow rate: 14.16 kg/sec
  - Air temperature inlet: 15^{o}C
  - Air temperature outlet: 121^{o}C
  - Vapor temperature : 140^{o}C
  - Condensate temperature: 140^{o}C
  - Vapor mass flow rate: 0.71 kg/sec (from heat balance calculation)

a.3. Shell and Tube Steam Generator, type BKU: (1 unit)

- Design data of every unit:
  - Fresh water mass flow rate: 5.8218 kg/sec
  - Fresh water temperature inlet: 135^{o}C
  - Vapor temperature outlet: 145^{o}C
  - Brine temperature inlet : 180^{o}C
  - Brine temperature outlet: 150^{o}C
  - Brine mass flow rate: 98.304 kg/sec (from heat balance calculation)

b. Model II

b.1. Shell and Tube Steam Generator, BKU type: (1 unit)

- Design data of every unit:
  - Brine temperature inlet : 180^{0}C
  - Brine temperature outlet : 147.5^{0}C
  - Geothermal brine mass flow rate: 55 kg/sec
  - Fresh water temperature inlet: 137.5^{0}C
  - Vapor temperature outlet: 142.5^{0}C
  - Fresh water mass flow rate: 3.6011 kg/sec (from heat balance calculation)
- Technical design specification every unit:
  - Measurement : 875/1199 – 5850mm
  - Thermal power: 7788 kW / unit
  - Tube type: Plain tube
  - Tube material: SS 304
  - Shell material: Carbon Steel
  - Channel, Cover, Nozzle, Flange, Tube-sheet (tube side) material: SS 304
  - Nozzle, Flange, baffle (shell side) material: Carbon steel
  - Total High: 1.1 m
  - Total Wide: 1.224 m
  - Total length: 7.815 m
  - Number of Tube: 1020 tubes

b.2. Air heaters for withering process: (2 units)

- Design data of every unit:
  - Air mass flow rate: 28.32 kg/sec
  - Air temperature inlet: 15^{o}C
  - Air temperature outlet: 72.72^{o}C (from heat balance calculation)
  - Vapor temperature: 140^{o}C
  - Condensate temperature: 140^{o}C
  - Vapor mass flow rate: 0.7026 kg/sec

b.3. Air heaters for drying process: (5 units)

- Design data of every unit:
  - Air mass flow rate: 14.16 kg/sec
  - Air temperature inlet: 15^{o}C
  - Air temperature outlet: 85.87^{o}C (from heat balance calculation)
  - Vapor temperature : 140^{o}C
  - Condensate temperature: 140^{o}C
  - Vapor mass flow rate: 0.4392 kg/s

c. Model III

c.1. Shell and Tube Steam Generator, tipe BKU: (1 unit)

- Design data of every unit is the same as a data b.1
- Technical design specification every unit the same as a data b.1

c.2. Air heaters for withering process: (2 unit)

- Design data of every unit:
  - Air mass flow rate: 18.642 kg/sec (from heat balance calculation)
  - Air temperature inlet: 15^{o}C
  - Air temperature outlet: 100^{o}C
  - Vapor temperature: 140^{o}C
  - Condensate temperature: 140^{o}C
  - Vapor mass flow rate: 0.7026 kg/sec
- Technical design specification every unit:
  - Thermal power: 1500.9 kW /unit
  - Tube type: tube fined
  - Tube material: Carbon Steel
  - Fin material: Aluminum 1060
  - Materials of Header, Cover, Nozzle, Flange, Tube-sheet : Carbon Steel
  - Total high: 1.305 m
  - Total wide: 1.25 m
  - Total thick: 0.63 m
  - Tube number: 420 units

c.3. Air heaters for drying process: (5 unit)

- Design data of every unit:
  - Air mass flow rate: 9.314 kg/sec (from heat balance calculation)
  - Air temperature inlet: 15^{o}C
  - Air temperature outlet: 120^{o}C
  - Vapor temperature : 140^{o}C
  - Condensate temperature: 140^{o}C
  - Vapor mass flow rate: 0.4392 kg/sec
- Data Technical design specification every unit:
  - Thermal power: 938.2 kW /unit
  - Tube type: tube fined

- Tube material: Carbon Steel
- Fin material: Aluminum 1060
- Materials of Header, Cover, Nozzle, Flange, Tube-sheet : Carbon Steel
- Total high: 1,304 m
- Total wide: 1,25 m
- Total thick: 0.60 m
- Tube number: 390 units

The calculation result of model I shows that the amount of brine is 98.304 kg/sec. This condition is not feasible because the maximum brine WWF has a capacity of 75 kg/sec.

If model II is used, the outside air temperature for the withering process is 72.72^{o}C, and 85.87^{o}C for the drying process. This is also not possible for the tea withering and drying process conditions in the Malabar factory.

If model III is used, the air mass flow rate per unit for withering process is 9.321 kg/sec, and 9.314 kg/sec for drying process. It is also not feasible for the fan to work at 100% of the production capacity, but just 66% of the fan capacity.

The positive side of the design calculation results is that the ducting system at the Malabar tea factory can still be used for all calculation models. In point of fact, the fan operating conditions in the factory are at 55% of the available fan capacity. Therefore, the model III can be applied for calculating the system and heat exchanger components of the tea withering and drying processes at the Malabar tea factory.

The figures of the steam generator and the air heaters from the calculation results are shown in the attachment.

3.2.3 Feed Pump

A feed pump is used to circulate working fluid in the loop that is suitable at the pressure and flow rate intended. The efficiency of this pump is commonly around 55% (ratio of hydraulic power to electricity consumption), but the adiabatic efficiency is about 75%. The power of the feed pump required for circulation in the tea factory is about 55 kW.

3.2.4 Pressure Drop

Pressure drop of steam or even hot water from the heat exchanger steam generator to the tea withering and drying units along the pipe can occur during the fluid transportation (see Figure 9). The pressure drop calculation below refers to CRANE TECHNICAL PAPER NO.410M, 1982.

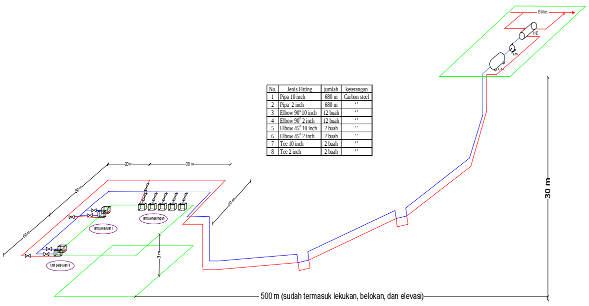

Figure 9: Piping road from the Steam Generator to the tea factory

The nominal size of the pipes is obtained from the nozzle information of the steam generator and air heaters, and also from the reasonable velocities. The nominal sizes for steam and hot water pipes are 10 in. and 2 in., respectively. The commercial steel pipe with its schedule can give the information of the friction-factor, which can reduce the pressure along the pipe. In general, the pressure drop calculations count on the following items:

- Type of the commercial steel pipe
- Representative resistance coefficients (K) for valves, fittings, and flanges. Figure 9 shows the minimum amount of 2 unit standard 90^0 elbows, 2 unit standard 45^0 elbows, and 0 – 2 unit standard tee that are needed.
- The straight-line pipe
- The level differences between components. In this study, the level difference between the steam generator and the factory is 25 m.

Therefore, based on the above considerations, the total pressure drop ΔP_{total} from the steam generator to the drying is about 0.35 bar, whereas to withering unit I ΔP_{total} is around 0.39 bar, and to withering unit II ΔP_{total} is about 0.43 bar.

CONCLUSION

There are several conclusions can be drawn from this study:

The separated brine WWF at Wayang Windu geothermal field can fulfill the substitution of IDO (industrial diesel oil) for all heating processes in the Malabar tea factory.

The design calculations of the system and heat exchanger components for tea heating processes were conducted with considerations of 3 temperature operation condition models, i.e.; **Model I** keeping the existing fans with the outside air temperatures are 100^{o}C for withering process and 120^{o}C for drying process; **Model II** maintaining the existing fans with brine utilization of up to 55 kg/sec; and **Model III** specifying air temperatures of 100^{o}C for the withering process and 120^{o}C for the drying process, with brine utilization limited to 55 kg/sec. Of the three models, Model III is most feasible if referred to all process parameters, although the fan just works at 66% of the fan full capacity. However, the most positive side of the calculation results is that the existing ducting system can still be used for all calculation models.

In fact, the 4th model can be proposed to simulate that vapor generated from the steam generator is totally used for 100% of the withering process. Correspondingly, the rest of the vapor is used for drying process by keeping one unit operating a direct fire heater.

The total pressure drop ΔP_{total} from the steam generator to the drying is about 0.35 bar, whereas to withering unit I ΔP_{total} is around 0.39 bar, and to withering unit II ΔP_{total} is about 0.43 bar.

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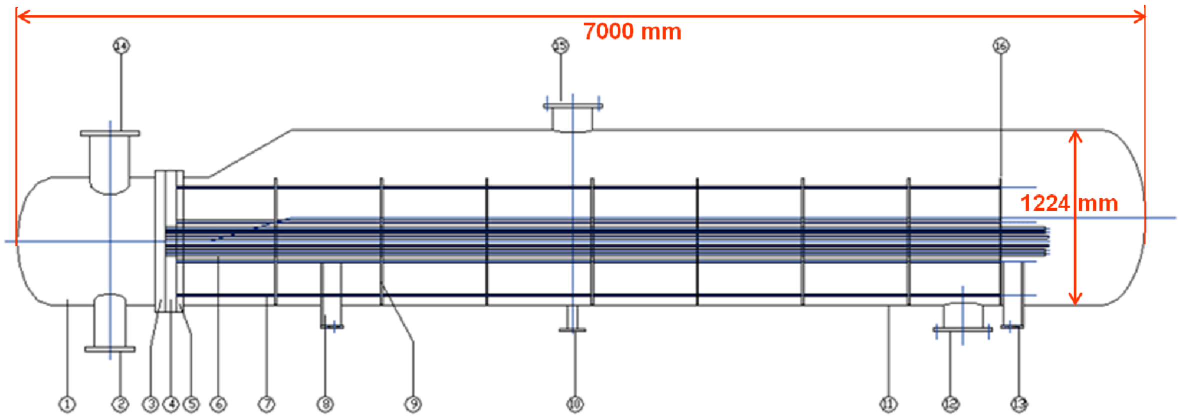
ENCLOSURE 1.: STEAM GENERATOR TYPE BKU



ENCLOSURE 2.: AIR HEATER FOR WITHERING AND DRYING