Analysing Energy and Water Flows

HANDOUT 1 – tasks

In a fruit concentrate production company, **energy (steam), raw material and water** were identified as the priority flows. As there are three focus areas reflecting the three priority flows (receiving, handling and washing for water, fruit extractors for material, and evaporator for steam), to simplify the exercise, it will focus only on the steam and water for the **evaporator**. Within the detailed analysis, the TEST team began to collect the data that will facilitate the understanding of the root cause of inefficiency within the evaporation process.

For the evaporator operation, fruit juice is pumped to the top of the evaporator and allowed to fall by gravity down the inside surfaces of tubes arranged in a shell-and-tube heat exchanger configuration. Saturated steam is needed as the heating medium. Through this process, water content from the juice is separated from the concentrate due to the difference in evaporation temperature, facilitating the collection of the concentrated juice. The output from the evaporator is the concentrate, the steam condensate and the condensate water content that is evaporated from the juice.

A detailed mass, steam and water balance was prepared for the evaporator alone and for the whole production line as illustrated in Figure 1 and 2 below. A few observations were noted from the evaporator balance:

- Around 1 ton/hr of the input juice is missing from the balance, and does not appear either as concentrate or as evaporated water content;
- Evaporated water when collected is still hot, with a temperature around 60-65^{o}C. This water is sent to the wastewater treatment plant, and then to drain;
- The steam input to the evaporator is generated at 10 bar from the boiler, yet it reaches the evaporator input at 9 bar;
- There is a difference of 0.8 ton/hr between the input steam to the evaporator and the condensate from that steam;
- Steam condensate is sent to the wastewater treatment plant, and then to drain;
- Concentrate leaving the evaporator at 60-65^{o}C is cooled to 5^{o}C, and then sent to the pasteurizer, which operates at 105^{o}C.

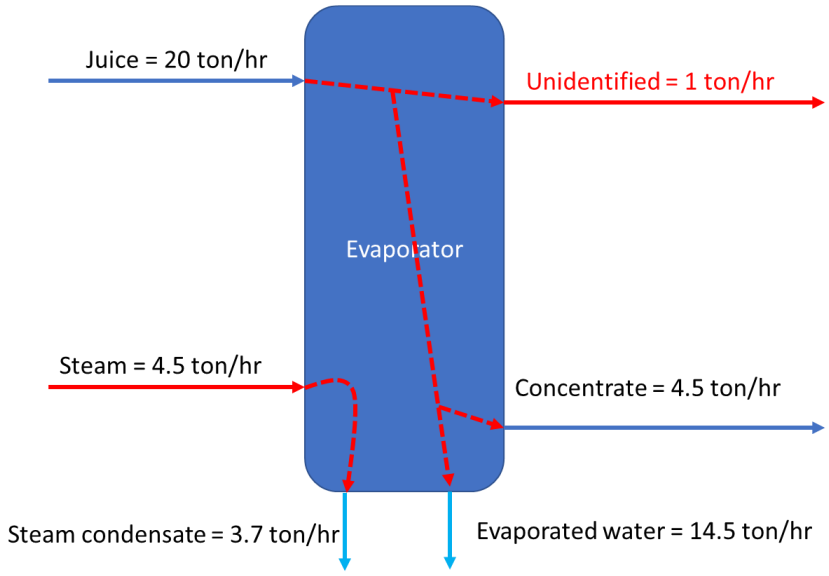

Figure 1 - Evaporator mass/water/heat balance

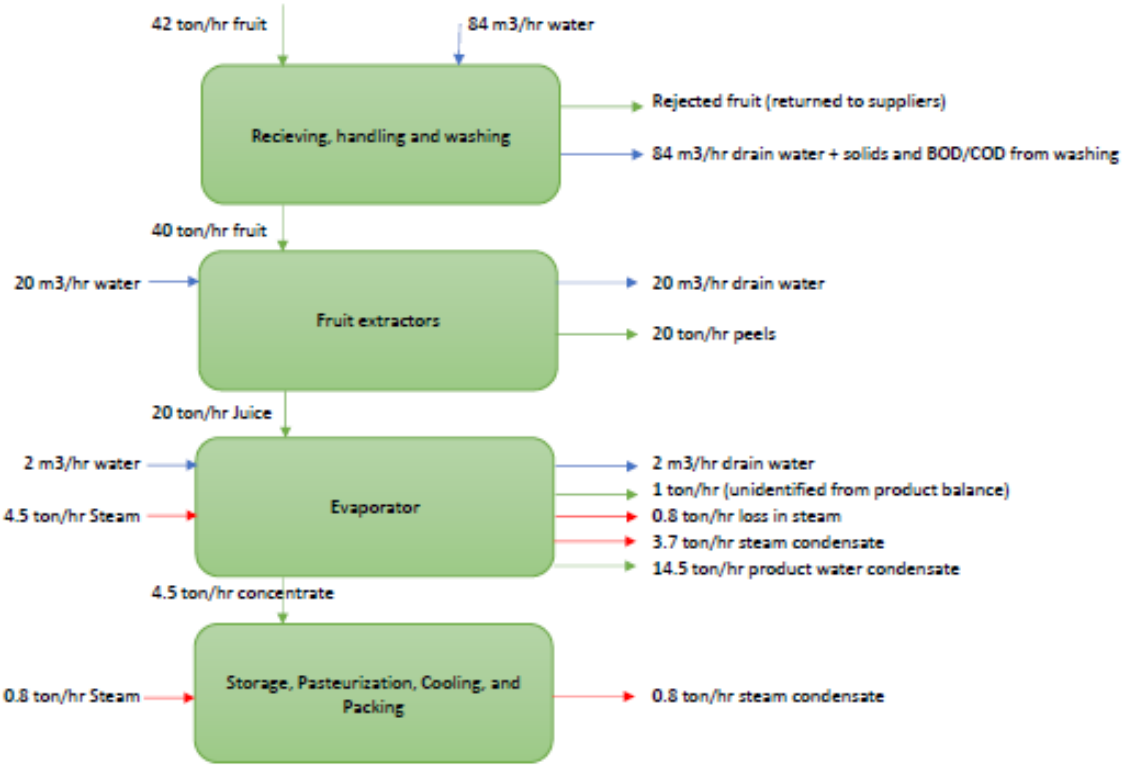

Figure 2 Production line mass/water/heat balance

TASK

Split into groups

1. **Discuss which data was needed to develop the balances and observations above? What approaches should be followed to collect such data?**
2. **Identify causes of losses within the focus area (evaporator)** with priorities beingEnergy (steam) and water flows
3. **Generate options for reduction of losses for each cause identified in the previous step, within the focus area**. YOUR GOAL AT THIS STAGE IS NOT TO FIND FEASIBLE MEASURES BUT TO GENERATE AS MANY OPTIONS AS POSSIBLE
4. Discuss your experience in a plenary

HANDOUT 2 – possible solutions

Discuss which data was needed to develop the balances and observations above? What approaches should be followed to collect such data?

Developing a mass/material balance is one powerful tool for understanding the causes of inefficiencies. Balance can start by drawing a flowchart at the company level analysing flows among the different production steps (cost centers). Such a balance with recording the inputs and outputs of priority flows for each production step was used already in step 1.5 with goal to have the NPO cost breakdown and to identify focus areas. The purpose of the balance within the step 1.6 is to understand the causes of losses for the **priority flows.**

A walkthrough the production line, together with discussions with company staff particularly the production and maintenance managers can serve in answering questions raised based on the flowchart.

A process flowchart should be already received from the company during the Initial Review in step 1.1 and should be readily available within the company:

- Equipment/technology providers usually provide such a flowchart at the time the technology was purchased by the company.
- Documents prepared for existing standards (such as ISO9001, ISO 14001, OHSAS,...) shall include a process flowchart, though prepared not necessarily for mass/material balance reasons.
- Company staff may have a flowchart for any reason different from those highlighted above. For example, maintenance engineers can have a flowchart to illustrate the steam network, or compressed air network.
- The above mentioned flowcharts can provide basis for a new flowchart to be drawn for the purpose of the detailed analysis.

At the focus area level, it is essential to understand the function of the focus area before developing the balance. BREF documents, best practices catalogue[1] or RECP manuals available on the internet are good starting points to get an understanding of the function of a chosen piece of technology and identify RECP opportunities. Then, draft a box indicating the focus area of concern, and illustrate the different inputs/outputs of that process. You can always refer to the data provided by technology provider and discussion with company staff. They are the most knowledgeable people on operation of a given technology, its inputs and outputs as well as the frequent issues coming within the process.

After developing the focus area level balances, data shall be verified from available records (submeters for energy and water). In the absence of records measurement plan can be set to validate the designated quantities. Measurement vary in complexity and accuracy. For the first balance can be recommended some simple methods to come-up with quick conclusion to guide next steps. If there is identified a significant source of losses recommendations for time demanding methods (such as installation of submeters, and waiting a couple of months to acquire representative records) can be considered.

Benchmarking can be utilized also for this step. For instance, it was noted from research that evaporator performance is measured in terms of energy input per unit of water evaporated (taken out of the product). Depending on the evaporator type, and number of effects, several guiding figures were obtained from the EU BREF as:

Type of Evaporator	Total Energy Consumption (kWh/ Kg water evaporated)
Thermal Vapor Recompression (TVR) - 3 stages	0.140
TVR - 4 stages	0.110
TVR - 5 stages	0.084
TVR - 6 stages	0.073
TVR - 7 stages	0.060
Mechanical Vapor Recompression (MVR) - single stage	0.015

The consumption of the company's evaporator was calculated at 0.31 ton steam/ ton evaporated water (appr. 0.19 kWh/kg water evaporated), therefore is much higher than the benchmark, and some technology change can bring down the consumption tremendously.

Identify causes of losses within the focus area (evaporator) with priorities being Energy (steam) and water flows

Below table represents a sample of root cause analysis for the evaporator, and some of the generated options. This is not a comprehensive list, but just an indication.

Flow	Source of loss	Cause of loss	Option
Water	Water consumption in evaporator	No water re-use practice adopted	Reuse water discharge from evaporator for first washing stages (2t/h + 3.7t/h +14.5 t/h to partially substitute 84 t/h needed for first step) Condensate recovery to serve as boiler feedwater Use the discharge water for floor washing, and/or irrigation needs (their quantities don't appear on the balance)
		Lack of maintenance	Maintain the evaporator to eliminate steam (water) loss
Steam	Loss of steam in evaporator (indicated by the miss-match of steam input to evaporator (4.5 t/h) and steam output from evaporator (3.7 t/h))	Poor maintenance for evaporator leading to steam leaks.	Adopt preventive maintenance practices.
		Low quality of used gaskets	Use high grade gaskets to eliminate steam leaks
	High specific steam consumption of Evaporator	No condensate recovery	Recover the heat content from the condensate
		Out-dated technology used	Train operators for energy efficient operation of evaporator Rehabilitate the existing evaporator Replace the evaporator with an up-to-date model (7 stage TVR, or MVR)