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SOLTRAIN

Solar heat for industrial applications

Our educational test case.

A food processing company has to wash boxes. There are two process steps: washing and drying.

10 000 kg/h of boxes with T=20°C are put into the washer. They are washed and thereby heated up to 70°C (cp_{box} = 1.9 kJ/kg). When they are wet, they carry 0.03 kg of water per kg of boxes (also at 70°C) out of the dryer. In the dryer, the water evaporates at 70°C and the temperature of the boxes stays at 70°C.

WASHER: The water enters the washer with 80°C and leaves it with 70°C. It is then heated up to 100°C with hot water from the boiler and recycled to the washer. Before entering, it is mixed with fresh water (11°C), achieving the temperature of 80°C that was found at the wash-water inlet. In order to keep the dirt in the circulation water low, waste water is drained; the waste water leaves the water cycle with 70°C. The amount of waste water corresponds to the amount of fresh water minus the water on the boxes. Assume that washer and dryer don't have heat losses[1].

DRYER: The dryer works with hot air and evaporates the water from the boxes. Hot dry air is entering the dryer with 90°C and is released as humid air at 70°C; the dry boxes leave the dryer with 70°C as well. The return temperature of the water from the air heater (air initial temperature = 11°C) cannot be measured, but the flow is known: 3.67 kg/s.

GENERAL CLEANING WATER: Furthermore, there is a heating demand for cleaning water which is needed for various applications. Within 2 hours 10.000 kg water have to be heated up from 11°C to 55°C in a third heat exchanger, supplied by hot water at 110°C coming from the boiler (return temperature 60°C).

HOT WATER DISTRIBUTION SYSTEM: The water for the washer, the cleaning water and the air for the dryer are heated with hot water of 110°C. All return water flows are mixed before entering the boiler. 0.1% of the circulation water has to be replaced per hour (and has to be heated up to 110°C).

GAS BOILER: The hot water is produced in a gas boiler (Methane, CH_4). The measurements of the exhaust gases showed a CO_2 content of 8.2% and 180°C. The counter of the gas supply company says that the company needs 189 m³/h.

All processes including supply technologies are operating 4.500 hours per year.

[1] As usual, we did not get enough information from the company at our first visit. So we had to go there once again and found out that the heating water from the boiler is being cooled down to 80°C in the heat exchanger that heats up the circulation water.

Your tasks (and chapters of the report at the end of the seminar):

- Draw a flow sheet.
- Carry out mass and energy balance calculations (flow rates, temperatures, energy flows).
- Discussion of a Sankey-diagram and set up the Sankey stream list therefor.
- Calculate the economic value of the in- and outgoing streams (energy: 60.-€/MWh, water: 1.-€ / 1000kg, boxes no value)
- Carry out a pinch analysis and estimate how much energy can be saved.
- Design a heat recovery system.
- Decide where to integrate a solar thermal collector and specify it.
- Are there any process modifications or technological changes possible? Propose RECP options.
- How much money is saved through the heat integration and solar thermal installation?

Thermodynamic data:

- cp specific heat capacity
  dHv heat of evaporation
- Water
- cp = 4.2 kJ/kgK
- dHv = 2 335 kJ/kg at 70°C
- Air
- cp = 1.0 kJ/kgK
- Flue gas
- cp = 1.2 kJ/kgK
- Methane:
  Heating value: 10.1 kWh/m³
- Boxes
- cp = 1.9 kJ/kgK
- For symbols please see:
  http://commons.wikimedia.org/wiki/Category:Chemical_engineering_symbols

Important Links to download software tools and information:

EINSTEIN: http://www.aee-intec.at/index.php?seitenId=64

Online tool to draw HCC/CCC for the Pinch Analysis: http://www.uic-che.org/pinch/

Sankey tool S-Draw: http://sdraw.com/en/index.html

Efficiency finder: http://wiki.zero-emissions.at/index.php/Main_Page

Information on solar thermal energy in Industry: http://task49.iea-shc.org/

RETScreen Software Suite – Free download: http://www.retscreen.net/ang/home.php