# APPENDIX A

## Mass flow calculations.

According to the data that the capacity of the process is 1000 kg per day with the solid content 85-92%, it is possible to calculate how many kg of dry solid is got after the process:

$$\omega = \frac{m_s}{m_p} \Longrightarrow m_s = m_p \cdot \omega = 1000 \cdot 0{,}85 = 850\ kg/day,$$

where: $\omega$ - mass proportion [kg/kg]; $m_s$ – mass of the solid [kg/day]; $m_p$ – mass of the pulp [kg/day].

First of all it is necessary to calculate the mass of the 1-st pulp (cellulose+water, with the solid content 10-12%):

$$\omega = \frac{m_s}{m_p} \Longrightarrow m_p = \frac{m_s}{\omega} = \frac{850}{0{,}1} = 8500\ kg/day,$$

The next step is to calculate how many kg per hour it is required including the information that the working day is 8 hours:

$$G_{p1} = \frac{m_p}{8} = \frac{10000}{8} = 1062{,}5\ kg/h,$$

$$G_s = \frac{m_s}{8} = \frac{850}{8} = 106{,}25\ kg/h,$$

where: $G_{p1}$ and $G_s$ - mass flow of the 1-st pulp and solid per hour, correspondingly [kg/h].

For the other parts the analogical formulas and calculations were used.

The data of air flow is 50 $m^3$/min and recalculate it to kg/hour using the equation:

$$G_{air} = Q_{air} \cdot \rho_{air}^{223} \cdot 60 = 50 \cdot 0{,}7129 \cdot 60 = 2238\ kg/h,$$

where: $G_{air}$ - mass flow of air per hour [kg/h]; $Q_{air}$ - volume flow of air per minute [$m^3$/min]; $\rho_{air}^{223}$- density of air with the temperature 223 °C [kg/$m^3$].

According to the data that 70% of the air goes to the recirculation system:

$$G_{air/rec} = \omega_{RA} \cdot 2238 = 1566{,}6\ kg/h,$$

$$Q_{air/rec} = \omega_{RA} \cdot 50 = 35\ m^3/min,$$

where: $\omega_{RA}$ - mass proportion of the air for the recirculation [kg/kg]; $G_{air/rec}$ and $Q_{air/rec}$ – mass and volume flow of recirculated air per hour [kg/h].

Energy flow calculations.

Energy flow calculations for the water and cellulose stream №1:

$$Q_{ov} = c_w \cdot m_w \cdot T_{F1} + c_{cel} \cdot m_{cel} \cdot T_{S1}$$

$$Q_1 = 4{,}187 \cdot 956{,}25 \cdot (70 + 273) + 1{,}55 \cdot 106{,}25 \cdot (70 + 273) = 1429798\ kJ,$$

where: $c_w$ and $c_{cel}$ - specific heat capacity of water and cellulose, correspondingly [kJ/kg·°C]; $m_w$ and $m_{cel}$ - mass of water and cellulose, correspondingly [kg]; $T_{S1}$ – temperature of the first stream [°C]; $Q_1$ – energy flow of the stream № 1.

The other calculations for the water and cellulose streams are analogical.

Temperature of the stream №8 is calculated by the equation:

$$T_{S8} = \frac{c_{air} \cdot m_{air7} \cdot T_{S7} + c_{air18} \cdot m_{air} \cdot T_{S18}}{c_{air} \cdot m_{air7} + c_{air} \cdot m_{air18}} = \frac{c_{air} \cdot (m_{air7} \cdot T_{S7} + m_{air} \cdot T_{S18})}{c_{air} \cdot (m_{air7} + m_{air18})}$$

$$T_{S8} = \frac{671{,}4 \cdot 20 + 1566{,}6 \cdot 79{,}4}{671{,}4 + 1566{,}6} = 752534\ ℃,$$

where: $c_{air}$ - specific heat capacity of air [kJ/kg·°C]; $m_{air7}$ and $m_{air18}$ - mass of the air stream № 7 and 18, correspondingly [kg]; $T_{S7}$, $T_{S8}$ and $T_{S18}$ – temperature of the air stream № 7, 8 and 18, correspondingly [°C].

Energy flow calculations for the air stream №8:

$$Q_8 = c_{air} \cdot m_{air8} \cdot T_{S8} = 1{,}005 \cdot 2238 \cdot (61{,}58 + 273) = 197704\ kJ,$$

where: $m_{air8}$ - mass of the air stream № 8, correspondingly [kg]; $T_{S8}$ – temperature of the air stream № 8 [°C]; $Q_8$ – energy flow of the stream № 8.

Energy flow calculations for the water, cellulose and air stream:

$$Q_{ov} = m_{w+air} \cdot (c_w \cdot \omega_w + c_{air} \cdot \omega_{air}) \cdot T_{S12} + m_w \cdot \lambda + c_{cel} \cdot m_{cel} \cdot T_{S12}$$

$$Q_{12} = 2377{,}88 \cdot (4{,}187 \cdot 0{,}02747 + 1{,}005 \cdot 0{,}97253) \cdot 100 + 136{,}275 \cdot 2260 + 1{,}55 \cdot 106{,}25 \cdot 100 = 1421185\ kJ,$$

where: $m_{w+air}$ - mass of water and air [kg]; $T_{S12}$ – temperature of the stream № 12 [°C]; $Q_{12}$ – energy flow of the stream № 12.

## Utilities calculations.

Air heater power expended:

$$N_{AH} = \frac{Q_{11} - Q_{10}}{3600} = \frac{1115598 - 769223}{3600} = 96{,}2154\ kW,$$

where: $N_{AH}$ – power of air heater [kW]; $Q_{10}$ and $Q_{11}$ – energy flow of the stream № 10 and11, correspondingly.

Air blower power expended:

$$N_{AB} = \frac{(P_{10} - P_{9}) \cdot Q_{air}}{\eta \cdot 60} = \frac{(160000 - 100000) \cdot 50}{0{,}95 \cdot 60} = 52632\ W = 52{,}6\ kW,$$

where: $N_{AB}$ - power of air blower [kW]; $P_{9}$ and $P_{10}$ – pressure of the stream № 9 and10, correspondingly; $\eta$ – efficiency of the blower.

Exhaust fan power expended:

$$N_{EF} = \frac{(P_{18} - P_{17}) \cdot Q_{air/rec}}{\eta \cdot 60} = \frac{(150000 - 90000) \cdot 35}{0{,}95 \cdot 60} = 36842\ W = 36{,}8\ kW,$$

where: $N_{AB}$ - power of air blower [kW]; $P_{17}$ and $P_{18}$ – pressure of the stream № 17 and 18, correspondingly; $\eta$ – efficiency of the fan.