	MODIFIED STARCH FLASH DRYER PROJECT						
	PROCESS CALCULATION						
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FLASH DRYER PROCESS CALCULATION

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TABLE OF CONTENT

1. DRYER CALCULATION

1.1. INTRODUCTION

The material in this calculation notebook (sheet) is of interest to agriculture engineers around the world because it views the problem of drying the (**Modified Starch**) starch as an agriculture product. The during time in these dryers is very short, only several seconds, therefore they can be used for drying of the Starch to high temperature in a short drying period. The objective of this project is the design of a high-efficiency Flash Drying system for Modified Starch. The system is engineered to reduce moisture content from a feed cake state to a final powder form. To ensure maximum energy efficiency, the design implements a Triple-Zone Heating System, which includes an innovative condensate heat recovery loop. The schematic diagram a typical flash dryer is shown in Fig.1 the process is as follows.

- Feedstock is introduced through a feed mechanism.
- The air after passes through an air filter is heated in a hot air generator of steam radiator. The feedstock is dispersed into the hot air-air stream and gets thoroughly mixed.
- The pulverized material mixed with hot air is conveyed through the drying duct to the cyclone by the pressure created by the blower (centrifugal fan).
- The time taken by the material to travel through the drying duct is called the residence time of drying.
- The material loses moisture, and this is absorbed by the hot air. The temperature of air is reduced while its humidity increases.
- Separation of dried product and air takes place in the cyclone. Powder is discharged from the cyclone through powder discharge rotary valves.

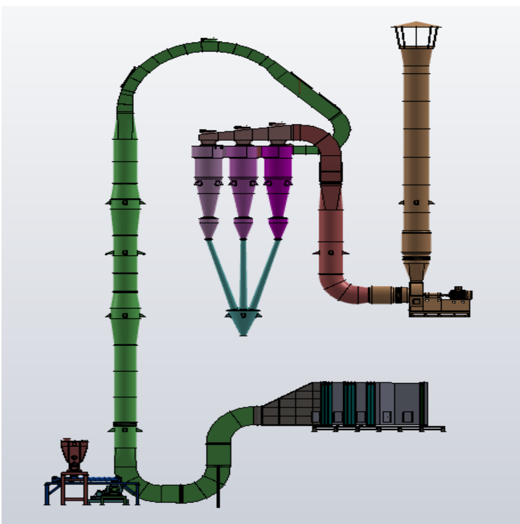

Fig.2 – Flash Dryer Schematic Diagram

1.2. Summary of Calculation results

Summary of calculation results table

Item	Quantity	Unit
Starch Feed Rate	**10,600**	**kg/hr**
Starch Feed Moisture	**42%**	
Product Moisture	**12%**	
Dried Starch Rate	**6,986**	**kg/hr**
Air Inlet Temperature	**170**	**©**
Air Outlet Temperature	**55**	**©**
Air Volume	**67,000**	**m3/hr**
Required Power for Drying	**2150**	**KW**
Duct Diameter	**1300 to 1400**	**mm**
Diffuser Diameter	**1625 to 1750**	**mm**
Max. Air Speed	**18**	**m/s**
Min. Air Speed	**9.7**	**m/s**
Saltation Velocity	**2.4**	**m/s**
Residence Time	**3.47**	**s**
Required Steam at Summer	**488**	**kg/ton**
Required Steam at Summer	**3.4**	**ton/hr**

1.3. Basis of the design

A. Feed characteristics

Product Type: Modified Starch

Moisture content: 42%

Starch mash density: 1500 kg/m^3

Feed rate: 10600 kg/h

Loading time: 10 min

B. Product characteristics

Moisture content: 12%

Output (from material balance): 6986 kg/h

C. Flash tube

Temperature in tube: 160 ˚C

Inlet air temperature: 170 ˚C

Ambient temperature: -20 ˚C to +40 ˚C

Largest particle size: 1.5 mm

Particle density: 550 -650 kg/m^3

D. Hearing Media Specifications

Heating Media: Steam

Steam Supply Pressure: 11 barg

Condensate Recovery Pressure: 8 barg

E. Material Mass Balance

Quantity of dried starch:

$$Ms = 10600 - 10600 \times \left(1 - \frac{100-42}{100-12}\right) = 6986\ kg$$

The energy required for evaporating the moisture from the starch has been calculated based on the formula provided in the book Unit Operations of Chemical Engineering by McCabe and Smith, calculates the energy required.

1.4. Energy balance and Air Volume (Method A)

For the flash drying system under consideration, the energy balance equation is stated as follows (McCabe et al.1993):

$$\frac{Qs}{Ms} = Cs(Tp - Tf) + XfCpl(Tv - Tf) + (Xf - Xp)\mathrm{I} + XpCpl(Tp - Tv) + (Xf - Xp)Cpv(Tvb - Tv)$$

Qs: Total heat transferred, J/s
Ms: Mass of dry solid:6986 kg
Cs: Specific heat of dry solid:1700 J/kg˚K
Cpl: Specific heat of pure water:4187 J/kg˚K
Cpv: Specific heat of water vapor:2043 J/kg˚K
Tp: Temperature of solid:160 ˚C
Tf: Temperature of feed:26 ˚C
Tv: Vaporization temperature:100 ˚C
Tvb: Final vapor temperature:170 ˚C
Xf: Moisture content of feed, kg moisture /kg dry solid:0.42
Xp: Moisture content of products, dry basis:0.12
I: Latent heat of vaporization:2256000 J/kg

$$\frac{Qs}{6986} = 1700(160 - 26) + 0.42 \times 4187(100 - 26) + (0.42 - 0.12) \times 2256000 + 0.12 \times 4187(160 - 100) + (0.42 - 0.12) \times 2043(170 - 100)$$

$$Qs = 7{,}739{,}363{,}411\ j/s$$
$$Qs = 2150\ Kw$$

Also:

$$Qs = Ma.\Delta H$$

Where:

Ma: Mass of air, kg/h
ΔH: Change in enthalpy of air: Ho – Hi
Hi: Enthalpy of air (Outlet air temp. 55 ˚C, 43 % Moisture)

Ho: Enthalpy of air (after heater 170 ˚C, 1% Moisture)

Hence:

$Ma = ra.Va$

ra: Density of air, kg/m^3

Va: Volume of air, m^3/h

$7{,}739{,}363{,}411 = Ma.(319768–171430)$

$Ma = 52{,}174\ Kg/h$

$53{,}121 = 0.78 \times Va$

$Va = 66{,}890\ m^3/h$

Required Air Volume is: 67000 $\mathbf{m^3/h}$

1.5. Air Velocity

Every conveying line is unique and will have its specific air velocity, however, some orders of magnitudes can be given for both dilute and dense phase.

Table 1: Minimum air conveying velocity for commons bulk solids

Material	**Minimum air conveying velocity**	**Minimum pick-up velocity for reliable transfer in dilute phase**
Very fine Material	10-12 m/s	at least 20% higher
Fine material	14-16 m/s	at least 20% higher
Coarse material	16 m/s and above	at least 20% higher

Note that the actual velocity of the product conveyed is lower than the conveying air velocity. The values given above are only orders of magnitude, actual values should be determined by pilot plant testing. According to our experience, air speed <u>15 m/s</u> has been selected.

In a pneumatic conveying system, the saltation velocity is the air conveying velocity below which the solids being conveyed starts to settle at the bottom of horizontal and vertical pipes. In order to be able to convey in dilute phase a bulk solids such as a starch or granulates, the minimum air conveying velocity in all part of the line must be higher than the saltation velocity.

the Saltation Velocity equation is stated as follows (Zenz & Othner)

$$Vsalt. = Sf.K(\sqrt{g.dp.(rp - rg)/rg}\ )$$

k :coefficient=1.5-3
Sf :Safety Factor= 1.2-1.5
rg :Air density, (kg/m^3) =780
rp :Starch density, (kg/m^3)=1550
$Vsalt$: Saltation velocity, (m/s)
dp Maximum Particle Size (m)=0.0015
g: 9.8 m/s^2

$$Vsalt. = 1.5 \times 3(\sqrt{9.81 \times 0.0015 \times (1500 - 780)/780}$$

$$Vsalt. = 0.524\ m/s$$

Saltation Velocity by Rizk correlation:

$$\frac{Ms}{ra.Vsalt.A} = (\frac{1}{10^{(1440d+1.96)}}) + (\frac{Vsalt}{\sqrt{g}.D})^{(1100d+2.5)}$$

Where:

Ms: Solid mass flowrate, (kg/s) =2.944
ra :Air density, (kg/m^3)=780
$Vsalt$: Saltation velocity, (m/s)
D: Average Pipe diameter, (m)=1.35
dp: Maximum Particle Size (m)=0.0015
g: 9.8 m/s^2

$$Vsalt. = 2.4\ m/s$$

Minimum air speed (9.7m/s from table 2) in the dryer duct is greater than 2.4 m/s

1.6. Flash Tube and Diffuser Dimension

The pipe diameter is:

$$Q = A.V$$
$$Q = \pi r^2.V$$
$$D = 2 \times \sqrt{\frac{Q}{\pi V}}$$

Where:
Q: Air flow rate (m^3/s)
V: Air velocity (m/s)
D: Flash tube diameter (m)

$$Q = \frac{67000}{3600} = 18.61\ m^3/s$$
$$V = 15\ m/s$$
$$D = 1303\ mm\ : \qquad 1300\ mm < D < 1400\ mm$$

Duct diameter size is considered between 1300 mm to 1400 mm

Radius of return in flash tube:

R >= 3 D

Where:

R: Radius of return (m)

D: Flash tube diameter (m)

$$R >= 3 \times 1400 = 4200\ mm$$

Diffuser diameter and length :

Diffuser Dia.= 1.25 D

Diffuser Length = 3 D

Where:

D: Flash dryer diameter(m)

$$1.25 \times 1300\ mm < Diffuser\ Dia. < 1.25 \times 1400\ mm$$

$$1625\ mm < Diffuser\ Dia. < 1750\ mm$$

Diffuser Diameter= 1730 mm

$$3 \times 1300\ mm < Diffuser\ Length < 3 \times 1400\ mm$$

$$3900\ mm < Diffuser\ Length < 4200\ mm$$

1.7. Residence Time

Residence time of particles during drying shall be checked:

$$Residence\ Time = \frac{L}{V}\ (s)$$

1s < Residence time < 3.5s

Where:

L: Length of flash dryer pipe(m)

V: Velocity of air (m/s)

Q: Air Volume=$18.61\ m^3/s$

Given that the cross-sectional area of the dryer varies in different sections, as shown in Figure 2, the air velocity differs across various cross-sections. To calculate the residence time with relatively good accuracy, the air velocity in each section was determined according to Table 2. Based on this velocity and the length of the respective section, the residence time was calculated. The total time was then obtained by summing the times of all individual sections.

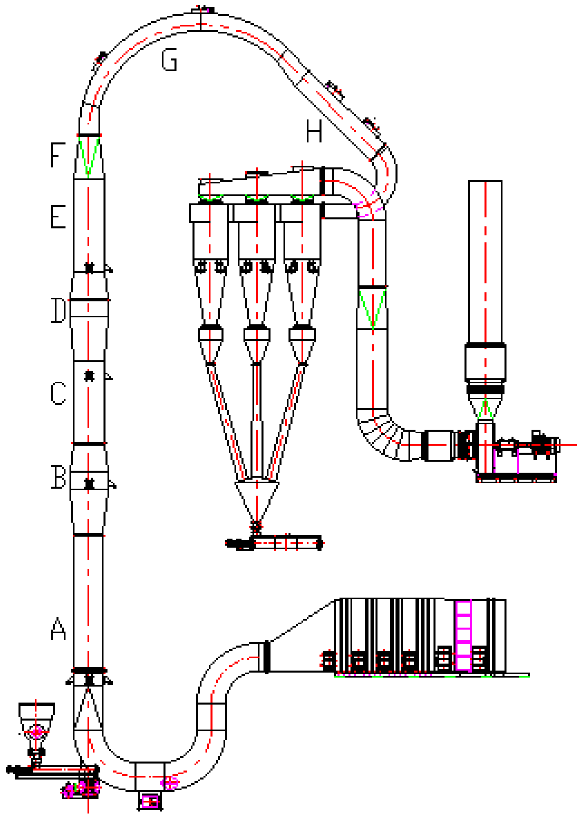

Fig-2: Flash Dryer

Table 2: Residence Time

Position	Length(m)	Section	Average Dia./Dimension(m)	Area(m2)	Air Velocity (m/s)	Residence Time(s)
A	8	Pipe	1.3	1.33	14.0	0.57
B	4	Pipe	1.515	1.80	10.3	0.39
C	4.5	Pipe	1.4	1.54	12.1	0.37
D	4	Pipe	1.565	1.92	9.7	0.41
E	4.22	Pipe	1.4	1.54	12.1	0.35
F	2	Pipe	1.2	1.13	16.5	0.12
G	11.7	Rectangular	0.75×1.37	1.03	18.1	0.65
H	8.8	Rectangular	0.95×1.37	1.30	14.3	0.62
Sum						**3.47**

$Residence\ Time = 3.47\ (second)$

2. Air Heater (Required Heat Power & Steam Consumption rate Calculation)

Required heat power calculated for summer and winter season. For saving energy and reducing steam consumption rate, steam condensate is used in second row of heat exchanger bundle tubes. Air heater consist of four stage heat exchanger, stage one(W6501) is used for anti-frosting, stage 2 (W6503A, B) consists of two row tube bundle heat exchanger that used of condensate water for saving energy, stage 3 and 4 (W6504-1 to 6) consist of 6 row of tube bundle heat exchanger for increasing air temperature up to 170°C

2.1. Required Heat Power in Summer

$Q = mc\Delta T$

Where:

Q: Requirement Heat Power (Kw)

m: Air mass flow (Kg/s)

ΔT: Heater air outlet Temp. – Ambient air Temp.

c: Specific heat, Kj/Kg

$Air\ Volume = 67{,}000\ m^3/h$

$ra : Density\ of\ air\ at\ 35\ °C = 1.145\ \text{kg}/m^3$

$ra : Density\ of\ air\ at\ 170\ °C = 0.78\ \text{kg}/m^3$

$Average\ Density\ of\ air\ = 0.963\ \text{kg}/m^3$

$$Air\ Mass\ Flow = ra.V = 0.963 \times \frac{67{,}000}{3600} = 17.91 Kg/s$$

$$Q = mc\Delta T$$

$$Q = 17.91 \times 1.006 \times (170 - 35) = 2432.8\ Kw$$

2.2. Steam Consumption Rate in Summer

$$Q' = (Qs - Qc) = ms.\frac{Lv}{3.6}\ \ Kw$$

Where:

ms: $Steam\ Consumption\ rate\ in\ summer\ , Ton/h$

Qs: $Heat\ Power\ from\ 2.1, Kw$

Qc: $Heat\ Recovery\ by\ Steam\ Condensate\ , Kw$

Lv: $Steam\ Latent\ Heat, Kj/Kg$=1998.55

$$Qc = m\Delta H$$

$$H1 = Condesate\ Water\ Enthalpy\ at\ 170\ °C = 720\ Kj/Kg$$

$$H2 = Condesate\ Water\ Enthalpy\ at\ 40\ °C = 163\ Kj/Kg$$

$$m = Condesate\ Water\ Mass\ (First\ guess) = 3{,}500\ kg$$

$$Qc = 3{,}500\ \times \frac{(720 - 163)}{3600} = 541\ Kw$$

$$Q' = (Qs - Qc) = ms.\frac{Lv}{3.6}\ \ Kw$$

$$Q' = (2432.8 - 586) = ms.\frac{1998.55}{3.6}\ \ Kw$$

$$ms = 3.41\ Ton/h$$

Steam Consumption rate in summer is between 3.4 to 3.6 ton per hours or 488 kg per ton of dry starch.