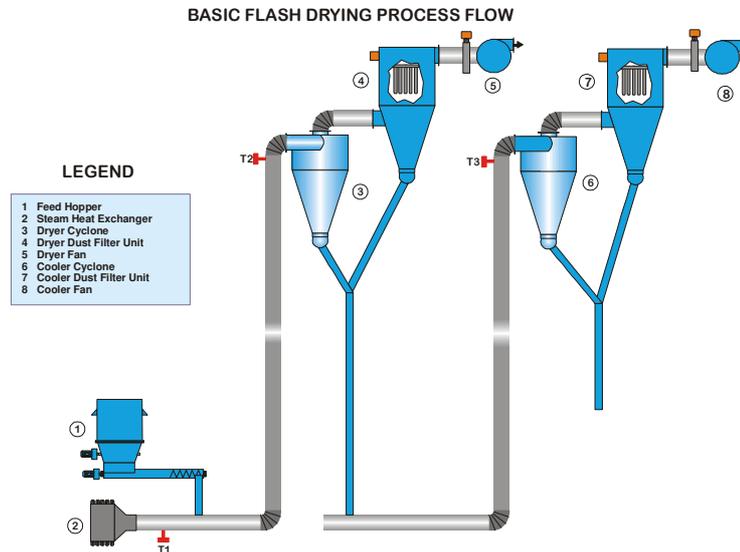


CONTROLLING FLASH DRYERS

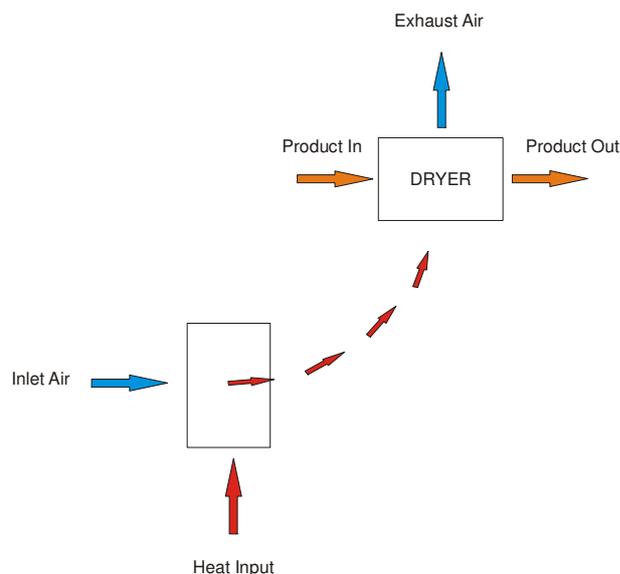
1.0 Simplified Model Dryer

A simplified process flow diagram for a flash dryer and flash cooler is shown below.



The powder product is metered in at the feed hopper and picked up in the first conveying pipe of the flash dryer. The air entering the flash dryer may be heated by several means, steam heat exchangers being shown in the diagram. In the design shown ambient air is heated, the controlling temperature being either T1 or T2.

The flow diagram can be simplified into a Mass Flow Balance Diagram, as shown below:



The following assumptions will be made for the rest of this article:

Powder Feed Rate	1,000 kg/hr
Moisture of Powder into Dryer	14.0%

Required Moisture of Powder after Dryer	8%
Ambient Air Temperature	20 deg C
Ambient Air Relative Humidity	30%

These numbers lead to the following calculations:

Ambient Air Absolute Humidity	4.3 gms/kg
Ambient Air Density	1.197 kg/m ³
Ambient Air Enthalpy	31.1 kJ/kg
Feed Rate of Dry Powder After Dryer	935 kg/hr
Water Evaporated by Dryer	65 kg/hr

Now select for now an arbitrary Air Temperature at T1 of 100 deg C
This gives the following calculated characteristics:

Density	0.9424 kg/m ³
Relative Humidity	0.7%
Absolute Humidity	4.3 gms/kg
Enthalpy	112.2 kJ/kg

To evaporate 65 kg/hr of water needs a minimum energy of 2256 kJ/kg water.
Allowing for heat losses in the system a practical number of 2,400 kJ/kg will be assumed.

The next stage is to calculate the volume of air in the flash dryer. The drying air is also conveying air. For wheat flour a minimum air velocity of 18.1 metres/second (3,500 feet per minute) is required. To size the pipe system and fan assume 20 m/s and the following calculations can be made:

Pipe Internal Diameter (mm)	Air Volume (m ³ /hr)
100	565
150	1,272
200	2,261
250	3,534
300	5,089

Now if a temperature at T2 is assumed at 60 deg C the energy of the air at this point can be calculated. Note that the air at T1 carries 4.3 gms water per kilogram of air and an extra 65 kg per hour of air is evaporated from the product. The above chart is duplicated showing enthalpy of the air at T2

I/D (mm)	100	150	200	250	300
Volume (m ³ /hr)	565	1,272	2,261	3,534	5,089
Mass (kg/hr)	596	1,190	2,258	3,641	5,296
Enthalpy (kJ/kg)	355	218	148	117	103
Absolute Humidity (g/kg)	113	60	34	22	16.4
Relative Humidity (%)	78	60	26	17	13
Density (kg/m ³)	0.898	0.967	0.999	1.030	1.040
Enthalpy (MJ/hr)	211.5	259.4	334.2	426.0	545.5

The Energy and Moisture Balance can be calculated. Note that flour going into the dryer at 20 deg C and 14% moisture and leaving the dryer at 60 deg C and 8 % moisture means that energy has to be put into the flour.

This energy 'gap' is 19,851 kJ/hr

Enthalpy of ambient air entering the dryer is 31.1 kJ/kg. The previous chart can be rewritten, entering only the enthalpy numbers.

I/D (mm)	100	150	200	250	300
Volume (m ³ /hr)	565	1,272	2,261	3,534	5,089
Mass (kg/hr)	596	1,190	2,258	3,641	5,296
Enthalpy (kJ/kg)	355	218	148	117	103
Absolute Humidity (g/kg)	113	60	34	22	16.4
Relative Humidity (%)	78	60	26	17	13
Density (kg/m ³)	0.898	0.967	0.999	1.030	1.040
T2 Enthalpy (MJ/hr)	211.5	259.4	334.2	426.0	545.5
Product Energy Gap (MJ/hr)	19.9	19.9	19.9	19.9	19.9
Evaporative Enthalpy (MJ/hr)	156.0	156.0	156.0	156.0	156.0
Enthalpy of Ambient Air (MJ/hr)	24.1	48.1	91.4	147.3	214.2
Energy Gap (MJ/hr)	35.6	83.5	158.3	250.1	369.6
Evaporative Cost (kWh/Tonne Product)	62.8	77.1	99.3	126.6	162.1
Excess Cost per Tonne Product (£)	1.05	2.48	4.70	7.43	10.98

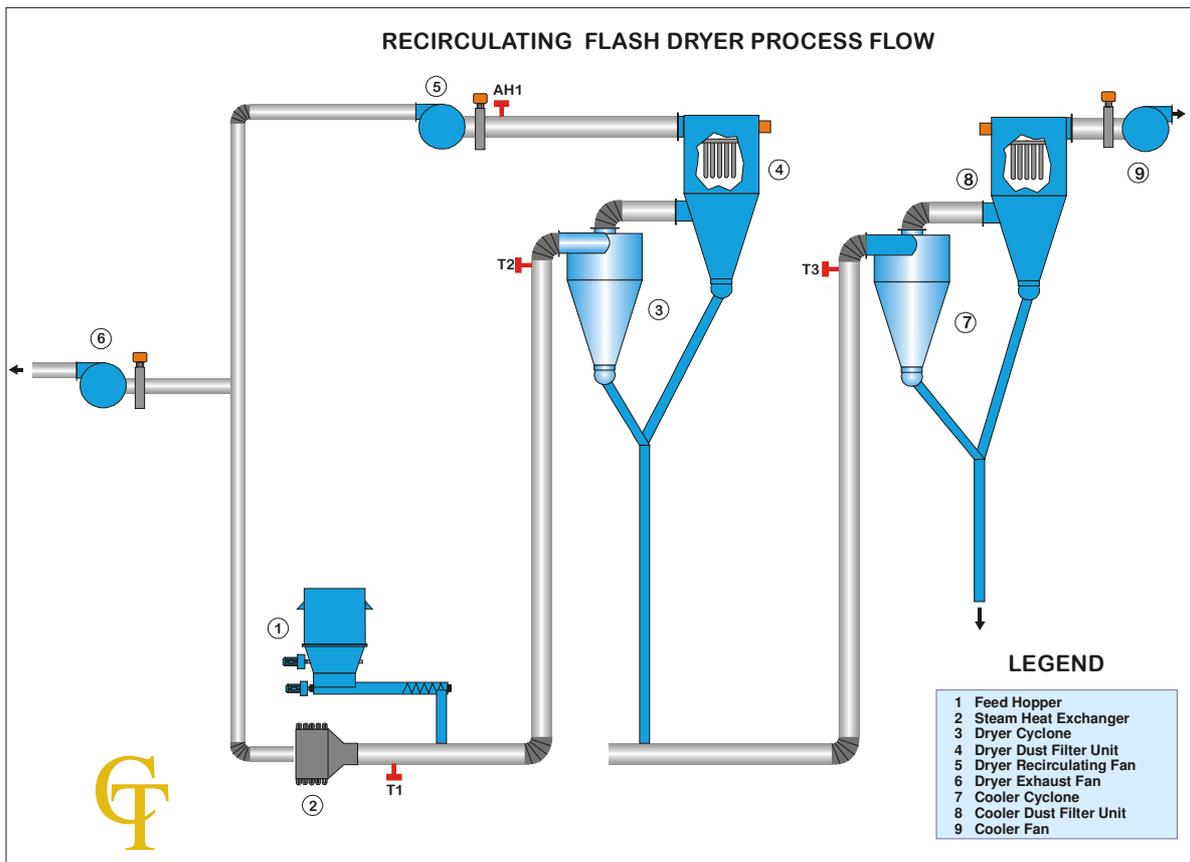
The 'Excess Cost' is an addition of the energy gap at minimum flow rate, where energy efficiency is highest, and the cost of warming up ambient air from 20 deg C to 60 deg C then blowing that air out to atmosphere.

For a Dilute Phase Air Conveying System an air to solids ratio of at least 5 to 1 is recommended. This means that a minimum 5,000 cubic metres of air per hour will be the design constraint on the airlift, which means that a simple system with no recirculation incurs an excess cost by design of almost £10 per tonne.

Also note that the excess energy shown in the charts above will not just disappear out with the exhaust air. It will evaporate water, meaning that it can be difficult to maintain moisture specification for the finished product. To avoid this temperatures will have to be adjusted, lowering T1 and T2. As ambient product and air temperatures change and product moisture specification changes it becomes more difficult to balance the system to minimise energy costs and tightly control final moisture content.

2.0 Recirculating Flash Dryer

The model below shows a flash dryer with recirculating air flow.



The differences in this design are listed below:

1. The main dryer lift fan recirculates air back to the heater
2. An extra 'exhaust' fan bleeds off required air from recirculating flow
3. An Absolute Humidity Sensor is placed at AH1

The biggest advantage of this design is that the conveying air requirements can be calculated independently of drying requirements of this air. For example the system can be sized with the internal pipe diameter between T1 and the Dryer Cyclone at say 250mm with air velocity that can be much higher to ensure pick-up of the few denser particles that may be found in the product stream, for instance when the flash dryer follows a steam pasteurising or heat treatment process. The design mathematics become much more simple so that only enough excess air is exhausted to carry the water load required. The humidity sensor balances airflow to exhaust and temperature at T1 or/and T2 to optimise thermal efficiency of the system. Using the mathematical model from the simple flash dryer the following can be calculated.

Powder Feed Rate	1,000 kg/hr
Powder Moisture into Dryer	14.0%
Powder Moisture from Dryer	8.0%
Required Evaporative Capacity (kg/hr)	65.0

Internal Diameter of Drying Lift (mm)	200
Air Velocity in Drying Lift (m/s)	25
Air Volume in Drying Lift (m ³ /hr)	2,827
Ambient Air Temperature (deg C)	20
Ambient Air Relative Humidity (%)	30
Ambient Air Absolute Humidity (g/kg)	4.3
Ambient Air Enthalpy (kJ/kg)	31.1
Ambient Air Density (kg/m ³)	1.197
Exhaust Air Temperature T2 (deg C)	60
Exhaust Air Volume (m ³ /hr)	600
Absolute Humidity of Exhaust Air (g/kg)	110
Enthalpy in Drying Lift at T2	350 kJ/kg
Energy in Exhaust Air (MJ/hr)	189.2
Evaporative Heat Input (MJ/hr)	156.0
Energy Difference (MJ/hr)	13.4

The recirculating air at 60 deg C and Absolute Humidity of 110 g/kg is blended with ambient air at 20 deg C and Absolute Humidity of 4.3 g/kg. This gives a mix of 2,600 m³/hr with Absolute Humidity of 85.1 g/kg, temperature of about 48 deg C and Enthalpy of 282 kJ/kg. It is required to add energy of about 190 MJ/hr or 73 kJ/kg, which means temperature of the mixed air needs to be raised to about 80 deg C.

The maths to calculate temperatures is very complicated, but the presence of the humidity sensor makes control much easier.

3.0 Control of Recirculating Flash Dryer

The Control System needs to 'know' how much water needs to be evaporated and needs to measure the amount of water that is evaporated. Input data should be as listed below:

- 3.1 Feed Rate of powder into the dryer. Preferably with loss in weight or gravimetric feeder.
- 3.2 Moisture Content of Powder into the dryer. Ideally on-line moisture measurement or alternatively manually feed in the measured moisture content.
- 3.3 Temperature of powder into the dryer.
- 3.4 Target Moisture Content of dried product
- 3.5 Ambient Air Temperature
- 3.6 Ambient Air Humidity
- 3.7 Exhaust Air Flow
- 3.8 Exhaust Air Absolute Humidity
- 3.9 Exhaust Air Temperature

Control is first by design, with recirculating air flow being set to give required dilution factor of solids to air. The minimum exhaust air flow is pre-established by calculation, for instance 600 cubic metres per hour in previous examples.

As the process runs evaporation is measured and then controlled by temperature and exhaust airflow adjustment. Temperature is increased first then exhaust airflow increased if humidity level approaches preset maximum.