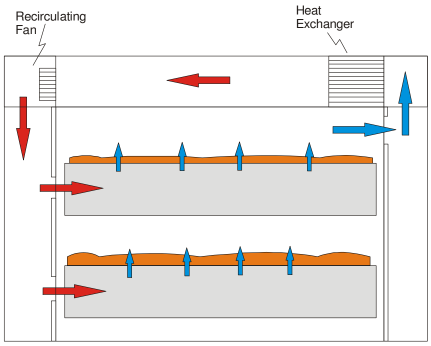
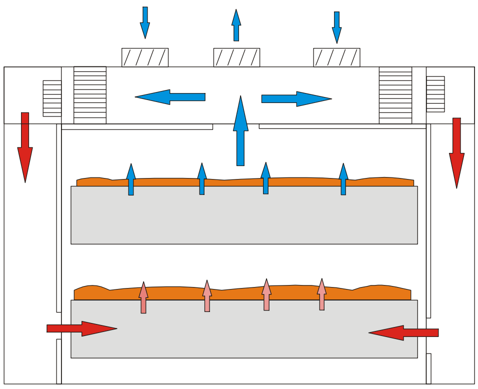
CONTROLLING HORIZONTAL DRYERS

1.0 Existing Problems

1.1 Airflow Control in Horizontal Dryers is always difficult to control. The dryers are multi-zone with respect to number of heating sections down the length of the dryer and recirculating fans tend to push air in the ‘easiest’ direction. The following diagram illustrates typical airflow through a ‘2-Pass’ conveyor dryer



The problem is that each section needs to be separated from sections before and after so that air flow can be forced through the bed of product in that section. There is also a problem with ensuring the balance between ‘make-up air’ and ‘exhaust air’ The ideal typical solution is shown below.



This diagram shows two recirculating fans in the section which then push air more evenly through the beds. The boxes at the top of the dryer show a central exhaust point with make-up air entering the air stream just before the two heat exchangers, the air then passing through the two recirculating fans before going through the product beds. Each of the sections needs to be separately balanced so that recirculating air temperature and velocity are optimised.

1.2 The exhaust from even a large horizontal dryer tend to be one common duct that collects all the individual exhaust streams from each dryer section. If just exhaust air temperature is measured and controlled this is not sufficient to control the dryer. It is necessary to provide instrumentation that allows direct measurement of the water being carried in the exhaust.

1.3 Dryer control systems typically do not ‘know’ how much water needs to be evaporated from product. Variation in production rate, moisture into the dryer and required moisture after the dryer need to be factored in.

2.0 Solutions

2.1 Instrumentation is required to first feed required information back into the control system so that outputs can be adjusted to give required control of product moisture content after the dryer. The instrumentation possibilities are described below:

2.1.1 Air humidity meter on exhaust air
2.1.2 Air Temperature measurement of exhaust air
2.1.3 Air flow measurement of exhaust air

2.1.4 Measured product moisture into dryer
2.1.5 Measured product feed rate into dryer
2.1.6 Programmed percentage removal of water from product recipe

2.1.7 Measured Temperature after heaters in each dryer section
2.1.8 Measured Temperatures on exhaust from each dryer section

2.1.9 On-line continuous measurement of product moisture after dryer

2.2 Looking at 2.1.3 it is possible to calibrate a fan so that air flow can be measured against fan motor load (measure the fan curve at different temperatures) This makes it possible to use fan motor load as a continuous and direct measure of airflow.

2.3 Outputs to the system ideally need to be as follows

2.3.1 Motorised choke valve on inlet side of exhaust fan with positional control

2.3.2 Temperature of each heating zone by steam control valves or gas burner system

2.3.3 Inverters to drive each recirculating fan

2.3.4 Motorised exhaust valves at each section with positional control

3.0 Basic control of exhaust air

3.1 If exhaust air humidity, exhaust air flow and exhaust air temperature are know some basic calculations can be carried out. Look at the following example.

Input Information

Air Absolute Humidity = 0.147 kg/kg
Air Temperature = 70 deg C
Air Flow = 20,000 cubic metres/hr

Calculation

Air Specific Volume = 1.2004 m^3/kg
Air Density = 0.833 kg/m^3
Enthalpy = 456.9 kJ/kg
Relative Humidity = 62%
Partial Vapour Pressure = 193.7 mbar
Saturated Vapour Pressure = 312 mbar
Atmospheric Pressure = 1,013 mbar (assuming sea level)
Dew Point Temperature = 59.4 deg C

Water Vapour carried per hour = 2,449 kg/hr
Energy carried in Exhaust Air = 7,611,954 kJ/hr

Apparent Energy used to evaporate water = 3,108 kJ/kg

These numbers can be used to compare with the ideal minimum energy, which is 2,400 kJ per kg water evaporated. If as a control method the exhaust air temperature was lowered to say 62 deg C with the same input numbers other than this.

Air Specific Volume = 1.172 m^3/kg
Air Density = 0.853 kg/m^3
Enthalpy = 445 kJ/kg
Relative Humidity = 88.5%
Partial Vapour Pressure = 193.4 mbar
Saturated Vapour Pressure = 218.6 mbar
Atmospheric Pressure = 1,013 mbar
Dew Point Temperature = 59.3 deg C

Water Vapour Carried per hour = 2,507 kg/hr
Energy Carried in Exhaust Air = 7,591,700 kJ/hr

Apparent Energy used to evaporate water = 3,028 kJ/kg

Now the energy in the exhaust air comes from a combination of energy put into the dryer by heat exchangers or gas flames and energy carried into the dryer by the product. Calculation below.

2,507 kg per hour water is equivalent to a wet feed rate into the extruder of 16,500 kg per hour of product at 22% moisture being dried down to 8% moisture. If inlet temperature of product is assumed at 80 deg C then energy difference between inlet product (16,500 kg/hr at 22% moisture at 80 deg C) and outlet product (13,989 kg/hr at 8% moisture at 80 deg C) can be calculated. In this case the energy difference is 840,840 kJ/hr. If this is subtracted from the above number 'Energy Carried in Exhaust Air' of 7,591,700 kJ/hr this gives energy number of 6,750,860 kJ/hr. This is equivalent to 2,700 kJ/kg water evaporated.

Exhaust Air flow and temperature can be further fine tuned to get below the ideal number of 2,400 kJ/kg water evaporated.

4.0 Cost of Energy

4.1 In the previous example 2,507 kg/hr of water was evaporated. If the energy cost can be reduced by just 100 kJ/kg the following calculation can be made.

First energy cost = 2,800 kJ/kg = 7,019,600 kJ/hr = 1,950 kWh

Second energy cost = 2,700 kJ/kg = 6,768,900 kJ/hr = 1,880 kWh

If an energy cost of $0.10 per kWh is assumed this means a cost reduction of $7 per hour, or $49,000 for a 7,000 hour year.

5.0 How to control for variable product feed rate

5.1 If production rate for product number one is at say 5,000 kg per hour and a second product run is started at say 3,000 kg/hr the dryer needs to be adjusted. For 5,000 kg/hr of finished product 900 kg of water needs to be evaporated per hour (using previous numbers of 22% to 8% moisture). For 3,000 kg/hr of finished product 540 kg/hr of water needs to be evaporated. If exhaust air temperature remains constant at say 60 deg C then exhaust air volume needs to be dropped. If the exhaust air volume is not dropped then energy carried in the exhaust air will be too high.

<u>Calculation</u>

	Product 1	Product 2
Wet Feed Rate (kg/hr)	5,900	3,540
Dry Product Rate (kg/hr)	5,000	3,000
Exhaust Air Volume (m^3/hr)	10,000	10,000
Exhaust Air Temperature (deg C)	60	60
Exhaust Air Humidity (kg/kg)	0.1	0.058
Exhaust Air Specific Volume (m^3/kg)	1.09	1.030
Exhaust Air Density (kg/m^3)	0.917	0.971
Exhaust Air Energy (kJ/kg)	326.5	211.9
Exhaust Air Energy (kJ/hr)	2,994,005	2,057,549
Product Energy Difference (kJ/hr)	300,664	180,398
Heater Energy Input (kJ/hr)	2,693,341	1,877,151
Input Energy (kJ/kg water evaporated)	2,992	3,476
Input Energy (kWh)	748	521
Input Energy Costs ($/tonne)	$14.96	$17.37

The above is what would happen if exhaust air volume and temperature remain constant as production rates change. This assumes that the inlet air temperature will be adjusted so that only the amount of water required is evaporated, so both products have exit moisture of 8%. Note that the $2.41 per tonne price difference is $12,050 per 5,000 tonnes production.

6.0 Effect of Overdrying

6.1 If the previous example is used as a starting point for this calculation it can be assumed that exhaust airflow and temperature is the same for both products.

Calculation

	Product 1	Product 2
Wet Feed Rate (kg/hr)	5,900	3,540
Dry Product Rate (kg/hr)	5,000	2,876
Exhaust Air Volume (m^3/hr)	10,000	10,000
Exhaust Air Temperature (deg C)	60	60
Exhaust Air Humidity (kg/kg)	0.1	0.098
Exhaust Air Specific Volume (m^3/kg)	1.09	1.092
Exhaust Air Density (kg/m^3)	0.917	0.915
Exhaust Air Energy (kJ/kg)	326.5	318.2
Exhaust Air Energy (kJ/hr)	2,994,005	2,,911,530
Product Energy Difference (kJ/hr)	300,664	222,277
Heater Energy Input (kJ/hr)	2,693,341	2,689,253
Input Energy (kJ/kg water evaporated)	2,992	4,050
Input Energy (kWh)	748	747
Input Energy Costs ($/tonne)	$14.96	$25.97

Note also that the finished product moisture is 4%. If it is assumed that 1,000 tonnes of product are made at 4% moisture instead of 8% moisture then loss with respect to ingredients costs is $25,000 (at average ingredient cost of $500 per tonne). On top of this energy costs are also high, costing $11,000 per tonne of dry product.

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