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ENERGY CONSERVATION IN INDUSTRIAL DRYING

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In this study, several ways have been suggested, which could result in considerable saving, by conserving energy in the industrial dryers.

Key words: Energy, Conservation of energy, Industrial drying.

Introduction

The drying of solids is a common activity within industry, but the diversity of the products being dried and the techniques used, has meant that there is little information on its importance in terms of energy usage. Estimate of energy consumed and the efficiency of drying are not taken seriously in many companies, due to lack of instrumentation of dryer, hence there is little motivation to improve drying efficiency.

There is no published data known to the author about the total amount of energy consumed or water evaporated in the industrial dryers in the UK. However, a first approximation of the amount of energy used in industrial drying has been made by estimating the amount of water removed by evaporation, for the 14 most common products in the U.K., for which data is published by the Central Statistical Office [1]. These data together with estimates of water removed by evaporation is given in Table 1.

The total water removed is 17.4 million tonnes per year. This does not include the majority of products which are dried in chemical, pharmaceutical, food stuffs, ore processing ceramics and sugar industries. So the total amount of water removed would certainly be more than 30 million tonnes. It is most probably greater than 40 million tonnes today. The average drying efficiency of these dryers, defined as the fraction of the heat supplied that is actually required to evaporate the moisture is certainly less than 50% [2]. If the latent heat of vaporisation of water is taken as 2350 KJ/Kg, then the annual energy requirement for industrial dryers in the U.K. is in the range of 3.10^{14} KJ or 6% of all the energy used. This is very approximate guess. However, the figure serves to indicate the significance of drying as an energy consuming process and the importance of improving its drying efficiency to conserve energy.

Table 1. Water Removed by Evaporation in Industry.

S. No.	Material	Annual Production in tonnes x 10^6	Average moisture content drop %	Water removed tonnes x 10^6
1.	Paper and board	4.6	200	9.2
2.	Bricks	15.7	15	2.4
3.	Milk dried	0.21	900	1.85
4.	Milk condensed	0.17	500	0.85
5.	Gypsum	3.7	20	0.74
6.	Plaster and plaster board	2.3	45	1.0
7.	Textile	1.4	30	0.4
8.	China clay	3.5	10	0.35
9.	Fertilizer	4.0	3	0.12
10.	Timber, softwoods	0.27	45	0.12
11.	Timber, hard woods	0.24	20	0.05
12.	Dyestuffs	0.1	50	0.05
13.	Vitrified China clay pipe	0.75	15	0.11
14.	Tiles,Pottery and sanitary ware	1.0	15	0.15
		Total:		17.4

This paper will review some ways, by which saving in energy consumption could be achieved. Attention is restricted to the technology which is currently available or is expected to be available shortly.

Material and Method

Theoratical parameters. The following ways to improve the drying efficiency in the dryers can be identified [2].

(a) Better operating conditions.
(b) Optimum thickness of insulation.
(c) Reduction of moisture content in the feedstock.
(d) Selection of suitable process equipment.
(e) To avoid overheating of the solids.
(f) Optimization of the exhaust air rate.
(g) Heat recovery exhaust air.

Each of these parameters which has direct effect on energy conservation will be further discussed in detail. Attention is mainly focussed on the dryers evaporating water, because this is by far the most common case and consume major portion of energy in the industrial dryers.

(a) Better operating conditions. The following points are considered as good operating practice, but are surprisingly neglected quite often, by the production oriented personnel. If a little care is taken, considerable amount of energy could be saved.

1. Keep the lagging in good order i.e. replace the lose or fallen off lagging immediately.
2. There should be no air leakage. When dryers have unavoidable openings, they should be operated under a slight negative pressure to avoid escape of hot air. Repair the lose oven door and chute openings and replace the worn off seals and packings immediately.
3. In case of dryers with air circulation, such as tray ovens and band dryers ensure that dampers are set to give maximum degree of circulation, consistent with product specifications.
4. Use maximum possible recirculated air under the existing conditions in order to conserve energy.
5. Keep the heat transfer surfaces clean, in indirectly heated dryers for maximum heat transfer rates.
6. Keep burners clean and operate at correct air fuel ratio. Regular monitoring of CO_2 in the exhaust gas could prove a useful check.

(b) Optimum thickness of insulation. The dryers should have optimum thickness of the insulating material. A heat balancing exercise should be performed regularly on the dryers. If the heat losses are in the upper range of 5% to 20% of the heat-input [3] then an extra layer of insulation could be justified.

(c) Reduction of moisture content in the feedstock. It can be safely assumed that the energy consumed is directly proportional to the evaporation load in the dryers. For example, if the material is to be dried to say 2% moisture content and the moisture content of the feed is reduced from 30% to 20%, the energy that can be saved mounted to;

$$\frac{30-20}{30-2} = \frac{10}{28} = 0.357 \times 100 = 35.7\%$$

$$\text{Say} = 36\%$$

For example spray dryer was used to dry crome concentrate from 35% moisture content to 0.1%. High initial moisture content was necessary in order to pump the feed through the nozzle of spray dryer. The moisture content of the feed was reduced from 35% to 14%. When spray dryer was replaced with rotary vacuum filter, thus for the same feed rate, energy requirement was cut down to 33% [5].

Any proposal to reduce the moisture content of the feedstock should be considered carefully, otherwise material handling problems or quality of the product could create serious complications.

(d) Selection of suitable process equipment. A careful selection of process equipment plays an important role in the energy conservation. For example, when preneutralizer process was used to manufacture mono Ammonium phosphate (MAP) and diammonium phosphate (DAP), the energy requirement per tonne of the product are tabulated in Table-2.

TABLE 2. AVERAGE ENERGY CONSUMPTION IN PRODUCTION OF AMMONIUM PHOSPHATE (4)

	KJ/tonne x 10^3			
Product	Fuel	Electricity	Steam	Total
DAP	340.8	399.8	200.9	941.6
MAP	571.9	511.6	91.7	1175.6

From these data it is clear that 36% of the total energy was consumed to dry one tonne of DAP and 46% for MAP. On introducing "Pipe Cross Reactor" process equipment, where the reaction took place inside the granulator/dryer, substantial amount of drying of the product was achieved from the heat of the reaction, the heat which otherwise would have been wasted. The plants formerly using preneutralizer process to produce MAP consumed between 564.7 x 10^3 to 582 x 10^3 KJ/tonne as fossil fuel to dry the product. By using pipe cross reactor process and acid containing 52.5% P_2O_5, the operators were abled to decrease fuel requirement by 80 %. In the second test where acid containing 57% P_2O_5 was used. No fuel was required at all to dry the product. These data shows that pipe cross reactor process made it possible to remove about 206 kilograms of water per tonne of product added to the system without need for fuel to dry the product [4].

(e) To avoid overheating of the solids. In many cases, the product is overheated in order to meet the final moisture content limits and to cater for the fluctuating feed rates and moisture content. This often lead to needless energy consumption and to lower the production efficiency of the unit.

The best way to eliminate overheating is to install an instrument to monitor the moisture content of the product continuously, and use the output of the instrument to modulate either heat input to the dryer on the feed rates. The moisture content of sheet or block materials can be measured, online fairly reliably by electrical capacitance, infra-red absorption or electrical conductance techniques. For fluid bed dryers SIRA temperature difference technique has been applied, successfully [6]. Where online direct measurement of the product's moisture content is not feasible with the present techniques, for example, in many continuous dispersion dryers, the best control can be achieved by modulating the heat input or feed rates, to keep the exhaust air temperature at set values.

Avoidance of mal-distribution of air across the width of band dryer is very important. Otherwise, uneven drying across the width of the band would result in overheating of part of the product inorder to achieve adequate drying of the whole product. A paper dryer is a classical example to demonstrate this effect. If the paper leaving the dryer is to have sufficient strength, its moisture content must be less than 7% at all the point across the width of the paper role. In order to achieve this, extra care is taken and the paper leaving the dryer usually have moisture content in the range of less than 4%. But if the last few drums are replaced by a radio frequency drying section, the moisture profile across the width would be smoothed, and uniform moisture content of 7% could be achieved with significant energy savings.

(f) Optimization of exhaust air rate through the dryers. Energy consumption can also be minimized by improving the efficiency by which the heat is supplied. The heat supplied to a dryer leaves partly with the dry product, partly in the exhaust air and partly as loss through the walls. If the whole of the system is well insulated, then heat loss through the walls may be neglected. Similarly, heat with the product is also of minor importance. This leaves the exhaust air as main carrier of heat from the dryers. If operating condition, are chosen to minimise the enthalpy of this stream, then the heat consumption of the dryer will also be minimised.

The water to be evaporated, and its quantity in the exhaust air is fixed by the duty specified for the dryer. Therefore, the quantity to be minimised is the exhaust gas's enthalpy per kg of water vapours. This quantity decreases with increasing exhaust gas temperature upto the boiling point of water. For instance, it is usually required that the temperature of the exhaust gas should be about 10° above its dew point when it leaves the dryer, in order to avoid condensation in the system. A comparison of enthalpy per kg H_2O in air verse water vapour mixture 10° above their dew point with dry bulb temperature ranging from 20° to 100° is given in Table 3.

TABLE 3.

Dry bulb Temp. °C	Enthalpy KJ/Kg H_2O
20	5600
40	4000
60	3320
80	2980
100	2750

The enthalpy per kg of water is defined as, the sum of the enthalpy of the kg. of water vapour itself and the enthalpy of the associated air. As the temperature rises the enthalpy of the kg of water increases linearly, but the quantity of air associated with it decreases exponentially. The net result is a decrease in the exhaust gas enthalpy per kg of water as the temperature increases. Therefore, it is recommended that under such circumstances, the best course is to select the biggest feasible exhaust gas temperature upto a maximum of 100°

Reay [2] has suggested the following for finding those operating conditions which could minimise fuel consumption.

1. Select the upper limits for exhaust gas temperature, air inlet temperature and the practical lower limit on air velocity in the dryer.
2. Calculate the safety margin by which the exhaust gas temperature must exceed its dew point, this involves an estimate of heat loss in the fines removal system.
3. If the air velocity is a limiting factor, then estimate if the additional economics can be achieved by circulating part of the exhaust gas.
4. After heat and mass balance calculations, select the highest exhaust gas temperature without violating the above limits.
5. Repeat steps 2 to 4 for a different safety margin i.e. different insulation thickness and if required a different recirculation rate until a design has been achieved which is optimal with regard to both operating and capital costs.

(g) Heat recovery from exhaust air. The exhaust air (after the removal of fines, if any) can be used to heat up the incoming feed stock, by the waste heat of the exhaust air, however, with gas on both sides of the heat exchanger, the overall heat transfer co-efficient will be poor and for the recovery of a worthwhile amount of heat, large heat transfer area would be required which may not be economically feasible. This is a situation needs frequent re-examination, as fuel cost rises and more efficient types of heat exchanger are developed, such as extended surface heat exchangers. However, if the feedstock is a liquid it can be heated up by the exhaust gas, as the presence of a liquid on one side of the heat exchanger will improve the overall heat transfer coefficient considerably. This may be possible with spray dryers to heat the incoming feedstock. Milk dryer is a possible example.

Some times partial circulation of the exhaust air is also practised for heat economy. Fig. 1 is a schematic diagram of such convectional dryers. The thermal efficiency (E) of such dryers is given by

$$E = \frac{T2 - T3}{(T2-T3)+(1-W)(T3-T1)}$$

T_1 is the ambient air temperature, T_2 is the temperature of the air entering the dryer.

T_3 is the exhaust air temperature, and

W is the ratio of recirculated air to total air flow.

Examination of the system clear indicates that the greater the amount of recirculation, the more efficient the dryer will be. However total recirculation is impossible in conventional dryers. A compromise has to be made between dryer rate,

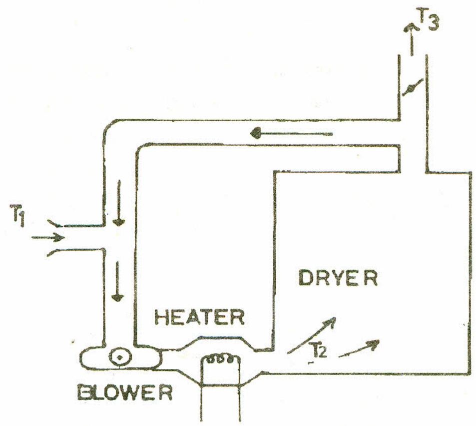

Fig. 1. Partial recirculation of exhaust air.

which decrease with increasing recirculation rate.

Fuel recirculation of the exhaust air can only be achieved in a closed chamber from which the moisture is removed by a demulsifier. The exhaust gas is passed over the evaporator coil of a dehumidifier. After dehumidification, the exhaust gas passes over the condenser coil, where the heat extracted in the evaporator coil is given back to it. The dehumidified, reheated gas then returns to the dryer. In this method, there is no heat loss at all from the exhaust gas.

Conclusion

The paper has outlined several ways by which energy saving could be achieved in industrial dryers. If these suggestions could be put into practice, the financial benefit to the individual companies and to the country as a whole would be considerable.

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