COALTECH 2020

Task 4.8.1

Dewatering and drying of fine coal:
Drying technology in non-coal industries

by

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1. INTRODUCTION

P Hand presented a comprehensive overview of dewatering and drying techniques used in the coal industry in a report entitled "*Coaltech 2020 – Dewatering and Drying of Fine Coal to a Saleable Product".*

It was proposed by the Coal Preparation sub-committee of CoalTech 2020 that the technologies used for dewatering and drying in other, non-coal, industries be investigated to provide a more comprehensive understanding of the technologies and techniques involved in dewatering and drying.

This report contains the findings of this investigation.

2. METHODOLOGY

The investigation carried out consisted largely of gathering of information from the literature and in particular from the Internet. During visits conducted to investigate the industrial application of agglomeration technology, information was also obtained on the drying techniques employed in those industries.

3. DEWATERING AND DRYING TECHNIQUES IN INDUSTRY

3.1 Dewatering

The dewatering technology employed in non-coal industries does not differ much from that used in the coal industry.

The equipment used for the dewatering and separation of materials such as sewage sludge, various minerals, chemicals, pharmaceuticals, food, wine, olive oil, sugar, waste oils, vitamins, polymers, pigments, lactose, etc. are, consists, as with coal, mainly of centrifuges and filters.

The centrifuges used range from solid-bowl (or decanter) centrifuges to centrifuges fitted with screen or filter segments.

A vertical centrifuge[11], of the type used in the dewatering of diverse types of materials, is shown in Figure 1.

Figure 1: Vertical basket centrifuge

The filters used in general industrial applications include drum, disc and belt filters, as well as pressure filters of various designs. The pressure filters used operate in either batch- or continuous mode.

A typical pressure filter[9], used in batch-mode to filter spent latex effluent in a carpet factory, is shown in Figure 2.

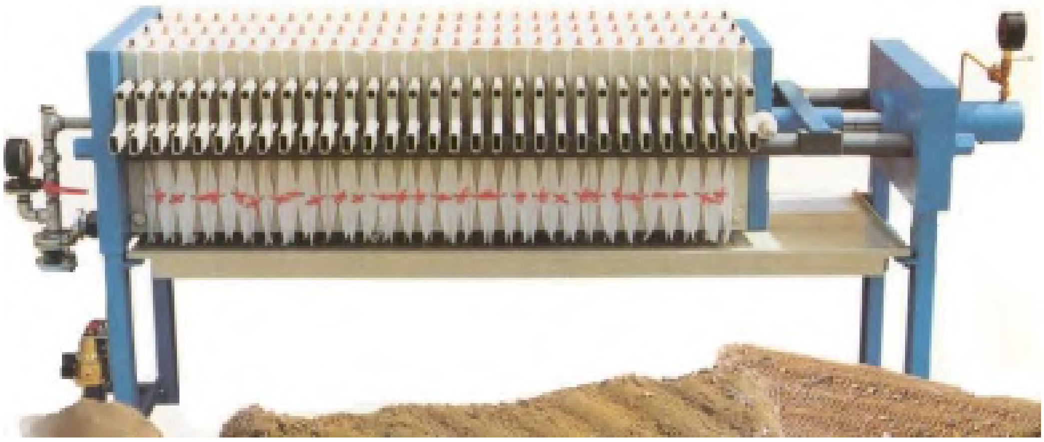

Figure 2: Pressure filter

3.2 Drying

Drying is used extensively in industry to dry, process and produce a large number of products. A range of different drying techniques and equipment is used.

Some of the applications of drying technology are described below.

3.2.1 Air-drying

Air-drying is the most basic form of drying used. One application of this drying technique is in the drying of laundry, where the equipment used varies from the most basic to the more advanced, as shown in Figure 3.
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Figure 3: Drying equipment for laundry

Other forms of air-drying are used for drying food and other materials. The drying method may be coupled to solar drying. Examples are the production of raisins, dried fruit etc.

In essence, the technique involves the removal of moisture from materials by allowing air, at either ambient or elevated temperatures, to flow through or over the materials and in so doing to carry the moisture away in the form of water vapour or steam.

In the USA, arid desert air is gainfully employed to assist with the drying of grain. The technique[8] used is shown in Figure 4.

Figure 4: Desert-air-assisted grain drying

Most drying techniques employed are variations on the theme.

3.2.2 Cabinet dryers

Cabinet dryers are used to dry relatively small batches (up to 4000 kg) of material that may initially be in liquid, slurry, paste, powder, granule, agglomerate or solid form.

Figure 5 shows a typical cabinet dryer[2].

Figure 5: Cabinet dryer

The material to be dried is placed inside the unit, usually on trays or trolleys, and subjected to heated air drawn through the unit by fans. Heat sources may be steam, electricity, thermal oil, liquid fuel or gas.

Maximum drying temperatures of about 600 ^oC are normally employed. Drying times are infinitely controllable.

This type of dryer offers low cost and good control but is labour intensive and of low capacity.

In Figure 6, a schematic view of a cabinet wood dryer is shown.

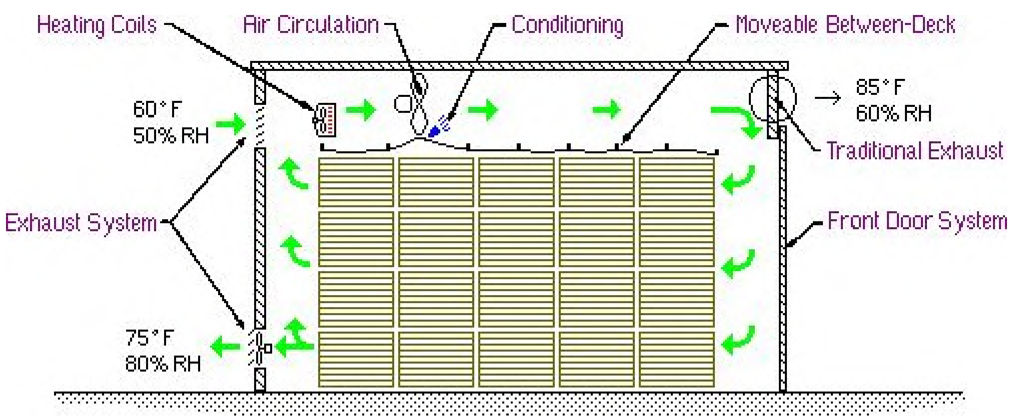

Figure 6: Schematic view of cabinet wood dryer

3.2.3 Conveyor dryers

Conveyor dryers use a perforated belt to transfer materials to be dried through the dryer. The dryer itself is similar in nature to a cabinet dryer, except that continuous operation is now made possible.

Residence time through the unit is highly controllable, as is the drying temperature. This type is dryer is very suited to products that require long drying times and gentle handling.

Charcoal briquettes are dried and hardened in dryers of this type.

A conveyor dryer[2], used for the de-hydration of vegetables, is shown in Figure 7.

Figure 7: Conveyor dryer

3.2.4 Fluidised bed dryers

Fluidised bed dryers use heated gas to lift and maintain the material to be dried in a fluidised state. The drying air is introduced into the dryer via a wind box or plenum chamber and distributed through a number of nozzles into the bed to impart a fluid-like flowing nature to the solids in the bed.

Very good particle/gas contact is provided in fluidised bed dryers. High temperatures can be employed if required.

The feed material can have a wide size range but too material that is too coarse will not fluidise and very fine material will be blown out of the unit. Dust-collection equipment is usually required with dryers of this type.

Heat sources can be steam, electricity, coal, liquid fuels or gas.

A fluidised bed dryer[2] is shown in Figure 8.

Figure 8: Fluidised bed dryer

3.2.5 Flash dryers

Flash drying employs a heated gas, supplied by a hot-gas generator, to pneumatically convey the material to be dried up a flash tube and into an air-separation device, usually a cyclone. The material is 'flash dried' whilst in transport and dry material is recovered as the underflow from the primary cyclone. A portion of the dried material is also recovered from the secondary dust-recovery equipment, which may be in the form of multiclones, bag houses, scrubbers and electrostatic precipitators, depending on the application.

The moist feed is fed into the throat of the feed area in a controlled manner, using a 'disintegrator' feeder mechanism. It is swept up by the stream of hot air and may attain a velocity in the order of 80 % of the velocity of the air stream.

A fairly narrow size distribution is required and oversized particles in the feed may cause problems in the conveying of the material up the flash tube.

Contact time between the gas and the solids to be dried is very short, typically only a few seconds. For this reason, flash drying is claimed to be suitable for the drying of heat-sensitive, explosive or reactive products.

A flash-drying installation for fine chrome ore[2] is shown in Figure 9.

Figure 9: Flash dryer for chrome ore

3.2.6 Spray dryers

Spray drying is currently one of the most important methods used for the dehydration of fluid foods in the world. The development of the process is associated with the dairy industry and the production of milk powders. The use of this technology has, however, been expanded to cover a large range of products. Nowadays, spray drying is applied in the production and drying of the following materials:

- Milk powder
- Instant coffee
- Tea
- Citrus juice
- Corn syrup
- Cream and creamers
- Pharmaceuticals
- Egg products
- Fish concentrates
- Potato products
- Proteins
- Shortening
- Starch derivatives
- Tomato purée
- Yeast
- Yoghurt
- Minerals

- Polymers
- Pigments
- Inorganic salts
- Other.

The material to be dehydrated, usually a liquid or dilute dispersion, is introduced into a heated chamber in an atomised form. By making the droplets small enough and the chamber large enough, the droplets can be dried before they reach the walls or floor of the chamber. The resulting product is a completely dry, free-flowing material. This material is removed either by gravity, screw systems or swept from the bottom of the chamber by an air stream.

Atomising of the material to be dried is achieved by spraying the material into the chamber under high pressure through small nozzles.
Alternatively, the material is introduced onto a spinning disk system. The spinning of the disk causes the liquid to thin and form small droplets at the edge of the disk.

These mechanisms[3] are illustrated in Figure 10.

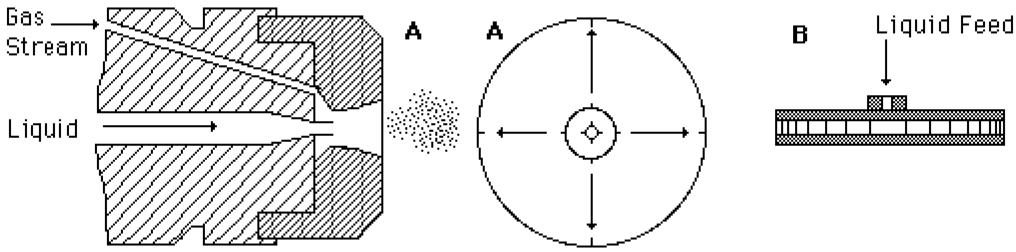

Figure 10: Spray nozzle and spinning disk systems for atomising feed

Examples of spray dryers[2] are shown in Figure 11.

Figure 11: Spray dryers

Spray drying is a one-step drying process: from liquid to solid in one step. The particulate size of the final product can be regulated to some degree by the conditions employed.

The throughput capacity of the process is relatively low compared with that of some of the more conventional types of dryers.

3.2.7 Indirect dryers

Indirect dryers employ the same principles of operation as direct dryers with the fundamental difference being the method of heat transfer. In indirect drying, heat transfer is predominantly by conduction as opposed to convection in direct drying.

The dryers operate on the principle that a contact surface within the dryer is heated and the material to be dried is then brought into contact with this surface, without being in contact with the heating medium.

Different types of indirect dryers are used. The main types are:

- ***Tube furnace dryers***

This type of dryer consists of a rotating, inclined drum that passes through a gas fired or electrically heated furnace. The outside surface of the drum is heated and the material to be dried is conveyed and brought into contact with the inner surface of the drum. Lifters within the drum facilitate forward movement of the material through the drum. The product is discharged through an airlock system whilst the evolved moisture is extracted from the drum by an induced-draft fan.

- ***Drum dryers***

In this type of dryer, a drum with a relatively large diameter, machined to a smooth surface on the outside, is heated internally. While the drum rotates, the material to be dried is metered onto the external surface of the drum. The material dries on the drum surface and is scraped off by means of a ‘doctor’ blade.

The evolved moisture is removed from the system through an exhaust hood and an induced-draft fan.

- ***Pan Dryers***

Pan dryers consist of a rotating, flat, circular surface on which is placed the material to be dried. A blade mechanism removes the dried material from the dryer.

Moisture removal is again by induced-draft fan.

- ***Paddle dryers***

Paddle dryers consist of either a single or a double paddle or screw arrangement, usually heated internally, running through a trough. The material to be dried is introduced into the trough. The heated paddles convey the material through the trough to the discharge end – continually mixing the material and exposing fresh surface area.

- ***Steam tube dryers***

This type of dryer consists of a number of tubes, arranged symmetrically along the length of the dryer. Steam or hot oil is introduced via a header arrangement into the tubes. The material to be dried is conveyed along the inside of the dryer, by air or by rotation of the dryer.

The material is dried as a result of contact with the heated tubes.

A steam tube dryer[2] is shown in Figure 12.

Figure 12: Steam tube dryer

3.2.8 Infrared dryers

By irradiating a material with infrared radiation, energy is transferred not only to the surface of the material but also well within the substance of the material. This energy is converted to heat and this heat dries the material. High energy utilisation can be achieved since the surrounding air is not heated.

There are various dryer configurations. One such dryer[2] is shown in Figure 13.

Infrared drying is suited to the drying of thin, flat surfaces. The process can also be used to dry powders, granules and solids in the forms of small particles.

Throughput rates are usually relatively low.

Figure 13: Infrared dryer

3.2.9 Microwave dryers

Microwave drying relies on the polarity of water molecules.
Microwave energy penetrates to the centre of most materials. The microwave electromagnetic field is reversed at a very high frequency, in the order of a few billion times per second. Water molecules, being dipolar in nature, react to this changing electromagnetic field by aligning the dipoles to the field. The continually changing alignment of the dipolar molecules produces energy which is converted into heat. This heat evaporates the water. Non-polar molecules are not affected.

Microwave dryers can be incorporated into a number of standard configurations such as cabinet or conveyor dryers.

In microwave dryers, it is important to allow the vapours formed during the drying process to evolve, since 'trapped' vapours will 'explode' out.

Normal air-drying is capable of removing water from the surface of a material or product. Drying stops once the surface is dry. Thereafter the moisture held within the product by capillary action will normally not be removed unless the product is heated to temperatures above the boiling point of water.

Microwave drying, by virtue of its capability to penetrate to within the material, will also remove the capillary water. This results in lower end-moisture than is possible with air-drying alone. In some industrial applications, microwave drying is used in conjunction with air-drying for optimal efficiency.

Microwave drying is currently used in industry for the drying of biscuits and other foods. It is also used for drying textiles and ceramic components and has been proved viable for the drying of fine chrome ore.

A prerequisite for effective drying is that the material to be dried should be presented to the unit as a thin, typically less than 50 mm, layer. Conveyor-type drying installations are therefore the predominant type used in microwave drying.

The size and thus the throughput capacities of microwave dryers are limited by the energy capacity of the magnetron used for the generation of the microwaves. In the last year or so, 100-kW magnetrons have become available at reasonable cost. However, it is still viewed as an expensive type of dryer. About 1 kW is theoretically required to evaporate 1 kg of water. One can therefore see that the largest unit currently available will only be able to evaporate at best (ignoring the efficiency of the unit) about 100 kg of water per hour.

A microwave dryer used for the drying of textile reels[19] is shown in Figure 14.

Figure 14: Microwave dryer for textile reels

3.2.10 Freeze dryers (vacuum dryers)

Freeze drying ('lyophilisation') is employed to dehydrate products in which it is important to sustain the physical, chemical and biological properties of the product. Examples are strawberries, other fruit and flowers. When dried conventionally, these products tend to change colour and/or lose some of their volatile or nutritional content. Freeze drying allows these products to be dehydrated while preserving their properties.

Freeze drying is also used to dry and preserve products such as vaccines, blood plasma, pharmaceuticals, various types of food, the dehydrated meat used by hikers and backpackers, etc.

The product to be dried is frozen to below its eutectic point and kept below this point throughout the drying process. This serves to stabilise the properties of the product. The frozen product is placed in a drying chamber and the air is evacuated from the chamber. In the vacuum thus created, water in the product changes directly into vapour without going through the liquid phase (sublimation).

Heat (heat of sublimation) is supplied through the shelf supporting the product within the drying chamber to assist in driving off the water.

The vacuum pump is protected from the vapours generated during the drying process by a condenser system. A condensing surface, kept at a temperature about 5 ^{o}C lower than the temperature of the product to be dried, is provided. The vapour is attracted to this surface where it releases heat energy and changes into ice which can be removed from the drying chamber.

Figure 15 shows some of the products[14] produced by freeze drying.

Figure 15: Freeze-dried products

A freeze dryer[16] is shown in Figure 16.

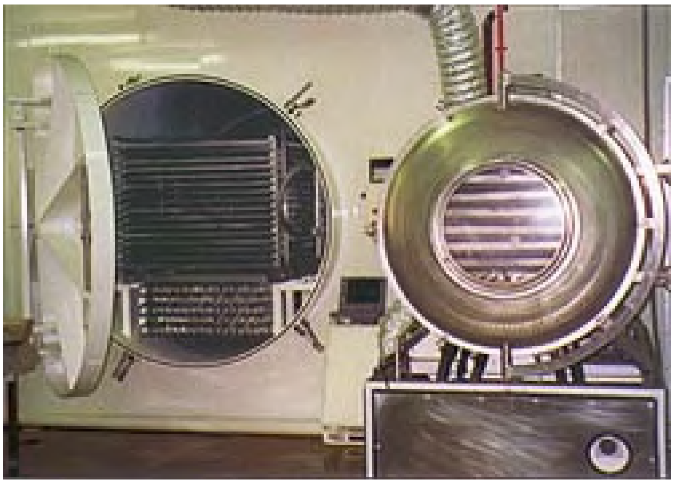

Figure 16: Freeze dryer

4. COST OF DRYING

The cost of drying is largely a function of the energy required to remove a certain amount of water from a product in order to render it suitable for the required end-use.

The energy requirements will differ between dryer types and for the same dryer, the energy requirements will differ between the products dried. By way of illustration, to dry 8 kg of green beans in a home-built dehydrator[13] will require 5,4 kWh of electricity. At an electricity cost of 20 c/kWh this amounts to R1,08 or R135/ton. To dry 8 kg of peaches in the same dryer will consume 19,35 kWh of electricity. This equates to R3,87 or R483/ton.

To dry and cure charcoal briquettes in a conveyor type of dryer, according to information obtained from a charcoal briquette manufacturer, costs R14/ton in coal and electricity costs alone. Another R11/ton is needed to maintain the dryer, thus bringing the total cost to R25/ton.
The capital cost of the dryer, which amounts to about R1 000 000, also needs to be taken into account if an accurate overall cost of drying charcoal briquettes is to be established.

A microwave dryer, capable of drying 50 tons of material, from an initial moisture content of 30 % down to 5 %, would consume about 10 000 kWh of electricity. This equates to an energy cost of R40/ton.

To remove the same amount of water using coal as the energy source, at a purchase price of R130/ton, would only cost R3,47/ton. A coal-fired dryer would also require some electricity, the cost of which will have to be added to the cost of the coal.

Spray-drying and freeze-drying are very expensive. The capacity of these dryers is also very small. They are therefore only used for small volumes of high-value products.

6. CONCLUSIONS

A number of different types of equipment and techniques are used in industry for the dewatering and drying of various materials and products. The principles employed in most of these technologies are not unlike those employed for the dewatering and drying of coal.

For coal dewatering and drying, the need for high throughput capacity, coupled with low cost, would make a number of the techniques discussed in this report unsuitable.

However, it is felt that an insight into the broad range of technologies available serves to stimulate thinking about the most viable methods to be employed in the dewatering and drying of fine coal.

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