17

Other Industries

There are some lower temperature drying applications employing industrial combustion that are briefly considered in this chapter. These include the paper industry, printing and publishing, textile manufacturing, and food processing. Drying is defined as

"a process in which a wet solid is heated or contacted with a hot gas stream, causing some or all of the liquid wetting the solid to evaporate" [1].

Kudra and Mujumdar have written a new book [2] on advanced drying technologies that cover a wide range of industries, including those discussed in this chapter. Unfortunately, emissions are not included in that book. Some of the more advanced drying techniques include: impinging steam dryers, pulsed fluid beds, airless dryers (see Fig. 17.1), sonic dryers, plasma torch dryers, slush drying, and a variety of hybrid methods. The authors call for more R&D and innovation to advance the state-of-the-art in dryers, which have received much less attention than other types of heating equipment and has been mostly evolutionary up until fairly recently. Table 17.1 shows a classification of typical dryers.

17.1 PAPER INDUSTRY

The paper industry is composed of two primary sectors [3]:

- Pulp and paper mills, which produce mechanical, thermomechanical, and chemical pulps and process these pulps to form paper, paperboard, or building papers.
- Converting operations, which manufacture boxes, tablets, and other finished paper products.

The first sector involves production of paper products from raw wood while the second involves converting those initial products into more specialized end products. The pulp and paper industry produces commodity grades of wood pulp, primary paper products, and paper board products such as: printing and writing papers, sanitary tissue, industrial-type papers, container board, and boxboard [4]. Fig. 17.2 shows a schematic of an integrated paper mill. The only part of the mill that uses industrial combustion is the drying machine. Even there it is only supplemental to the steam-heated cylinders, which do the bulk of the dyring. Figure 17.3 shows an

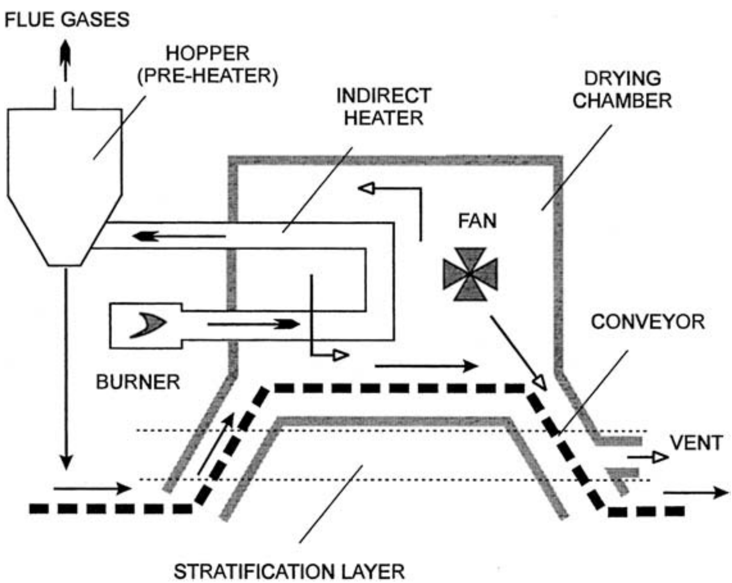

Figure 17.1 Continuous airless dryer. (From Ref. 2. Courtesy of Marcel Dekker.)

elevation view of a Fourdrinier paper machine commonly used to make paper. The steam-heated cylinders in the drying section can be seen in more detail. Figure 17.4 shows a schematic of the Kraft process for handling the pulp and bark used to make the paper, including the treatment of the chemicals in the various reactors, which are considered in more detail below.

Figure 17.5 shows pollution emissions from pulp and paper processes in the United States since 1970 [5]. The data show that CO emissions are the largest quantity of pollutants in this industry. The data also show that there has been a rise in emissions of VOCs since 1985. Other pollutants such as NO_x, PM_{10} and SO_x have been relatively flat since 1985. The Environmental Protection Agency (EPA) has established emission guidelines for Kraft pulp mills [6]. The combustion portion of the Kraft process includes the recovery furnace and the lime kiln as part of the recovery process shown in Fig. 17.6 [7] and the bark boiler to treat solid wastes from the process.

17.1.1 Black Liquor Recovery Boilers

A flow schematic of the Kraft process is shown in Fig. 17.7 [8]. It produces a strong, dark-colored fiber that is made from wood chips in either a batch or continuous digester, under pressure, in the presence of a cooking liquor [9]. The spent chemicals from the process are called black liquor, which is a highly viscous liquid waste containing inorganic cooking chemicals and organic materials such as lignin, aliphatic acids, and extractives. It is a by-product of the chemical pulping process. This black liquor is commonly concentrated and then burned in some type of recovery boiler to recover energy and chemicals. The molten inorganic process chemicals flow through the perforated floor of the boiler to water-cooled spouts and dissolving tanks for recovery in the recausticizing step. A significant pollutant from

Table 17.1 Classification of Dryers

Criterion	Types
Mode of operation	Batch
	Continuous[a]
Heat input type	Convection,[a] conduction, radiation, electromagnetic fields, combination of heat transfer modes
	Intermittent or continuous[a]
	Adiabatic or nonadiabatic
State of material in dryer	Stationary
	Moving, agitated, dispersed
Operating pressure	Vacuum[a]
	Atmospheric
Drying medium (convection)	Air[a]
	Superheated steam
	Flue gases
Drying temperature	Below boiling temperature[a]
	Above boiling temperature
	Below freezing point
Relative motion between drying medium and drying solids	Co-current
	Counter-current
	Mixed flow
Number of stages	Single[a]
	Multistage
Residence time	Short (< 1 min)
	Medium (1–60 min)
	Long (> 60 min)

[a]Most common in practice.
Source: Ref. 2. (Courtesy of Marcel Dekker, Inc.)

this process is particulates. Venturi scrubbers and electrostatic precipitators are commonly used to remove the particulates from recovery boilers. The particulates may also contain hazardous air pollutants (HAPs) [7]. Järvinen et al. [10] describe the development of a detailed computer model for simulating the combustion of black liquor. While the paper does not discuss pollution emissions, it does show the complexity of black liquor combustion

The primary air pollutants from Kraft recovery furnaces include fine particulates, sulfur oxides, and nitrogen oxides [4]. Proper process operation is used to control SO_x emissions [7]. Wallen et al. [11] experimentally demonstrated techniques for reducing NO_x emissions from recovery boilers. The NO_x emissions from recovery boilers are often lower than those from power boilers due to the differences in gas temperatures and fuels. Recovery boilers typically operate at lower temperatures and use fuels (wood chips and bark) that contain a significant amount of water, which lowers the gas temperatures in the combustor. Power boilers use fuels like natural gas that produce higher gas temperatures and therefore more thermal NO_x (see Chap. 6). Fuel NO_x is typically the dominant mechanism in recovery boilers, while thermal NO_x is typically dominant in power boilers. Approximately one-third of the nitrogen in the bark is converted into NO_x according to laboratory

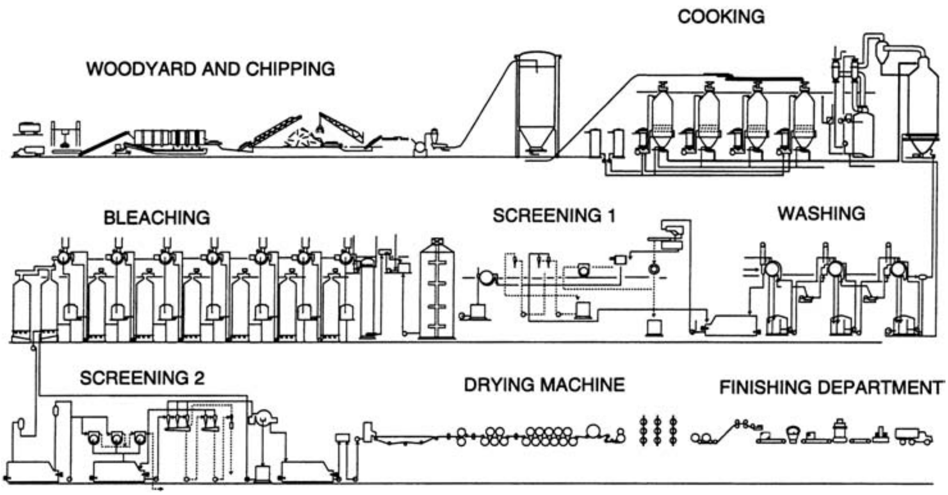

Figure 17.2 Integrated paper mill. (From Ref. 4.)

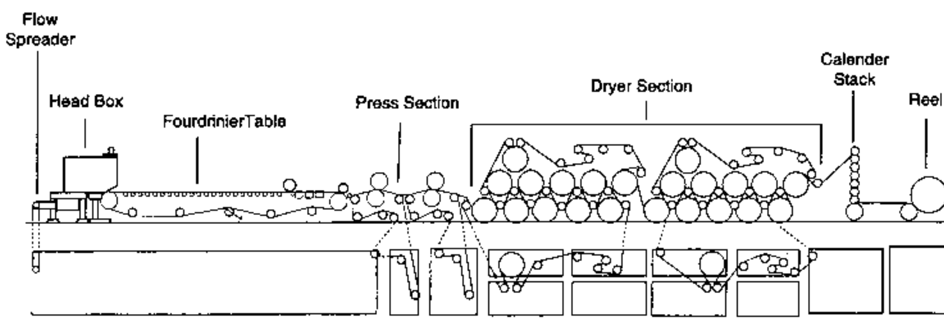

Figure 17.3 Fourdrinier paper machine. (From Ref. 4.)

experiments. Table 17.2 lists some of the factors that affect emissions from recovery furnaces.

The objective of the study by Wallen et al. [11] was to show that combustion modification techniques are preferred to post-treatment techniques like SCR or SNCR for controlling emissions from recovery boilers. Air staging in a recovery boiler was shown to reduce NO_x emissions by up to 50%. The more complete the burnout of the black liquor droplets in the furnace, the higher the NO_x emissions. Reducing excess O_2 reduced NO_x. This correlated with an increase in CO emissions as less air was available to combust fully the CO due to incomplete mixing. The results also showed that the location of the black liquor injection nozzles also influenced NO_x formation. When the burner was located below the liquor guns, NO_x emissions were reduced compared to the case with the burner located above the guns.

17.1.2 Lime Kiln

The concentrated waste black liquor is sprayed into a recovery furnace where the organic products are combusted. The inorganic compounds, mostly the cooking

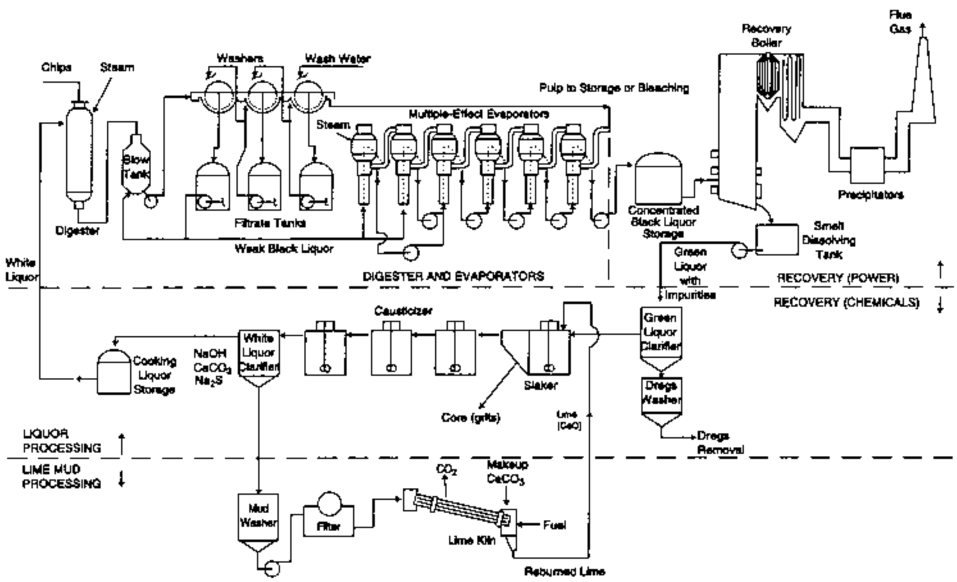

Figure 17.4 Kraft process flow diagram. (From Ref. 4.)

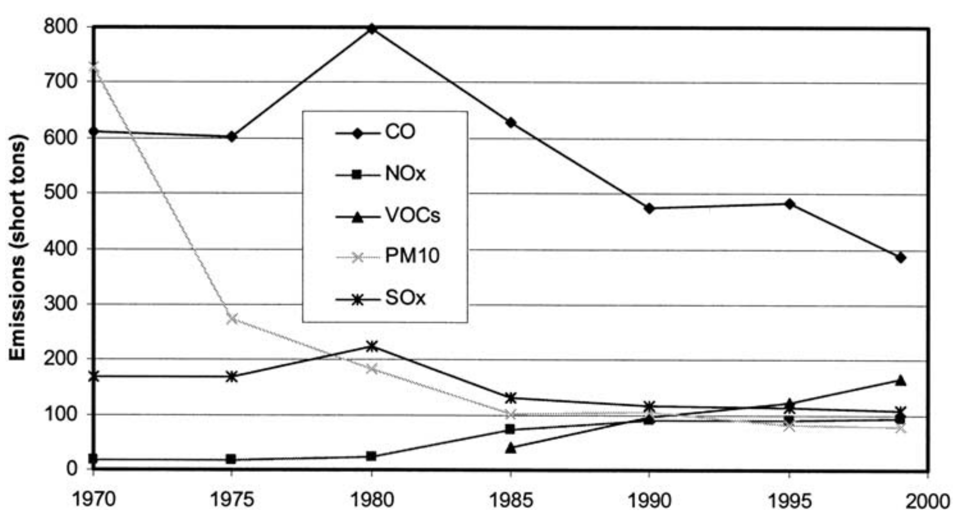

Figure 17.5 Emissions from pulp and paper processes in the United States since 1970 (From Ref. 5.)

chemicals, fall to the bottom of the furnace where chemical reactions occur in a reducing atmosphere. The chemicals are then removed from the furnace as a molten smelt containing mostly sodium sulfide and sodium carbonate. The smelt is dissolved in water in a tank and then treated with slaked lime in a causticizer to produce so-called "white liquor." The sludge resulting form the causticizer is burned or calcined to lime in a lime kiln (see Fig. 17.8). Particulate emissions are the primary pollutants from these lime kilns. The particulates contain sodium salts, calcium carbonate,

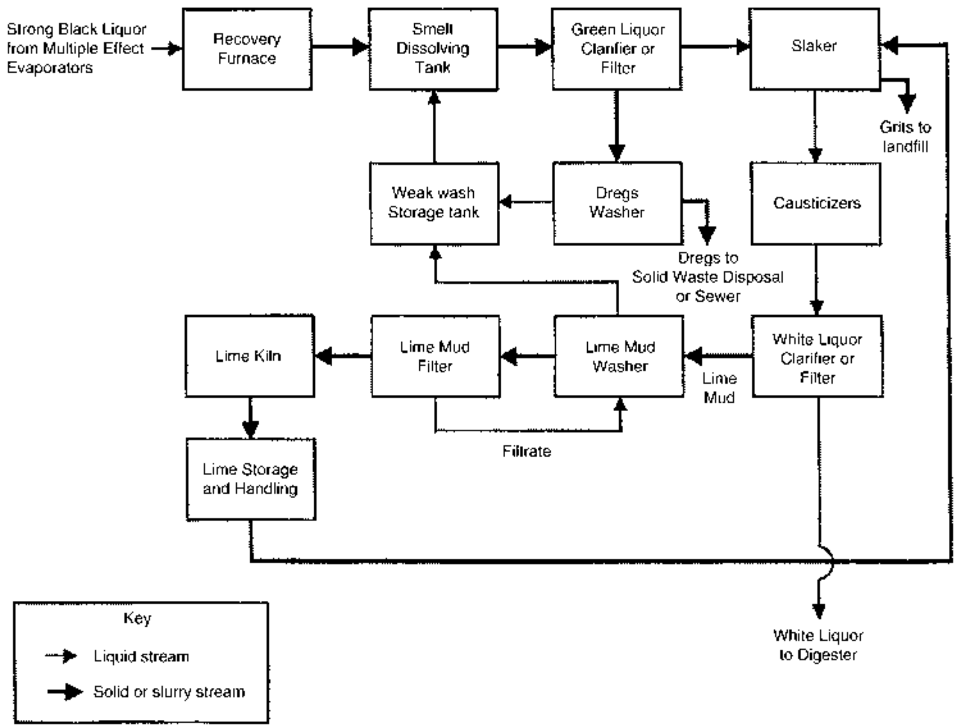

Figure 17.6 Flow diagram of the Kraft chemical recovery area. (From Ref. 7.)

calcium sulfate, calcium oxide, and insoluble ash. Cyclones and venturi scrubbers are commonly used to remove these particulates. Electrostatic precipitators may also be used. Fabric filters are not typically used because of the high moisture content of the particulates, which can cause caking and clogging of the filters [12].

The primary air pollutants from Kraft recovery furnaces include fine and coarse particulates [4]. SO_x emissions are generally not significant and are controlled by proper process operation [7]. Table 17.3 presents some of the factors that affect emissions from lime kilns including the kiln rotation rate, the oxygen level in the kiln, and the mud sodium content. Miner and Upton [13] discuss methods to calculate the CO_2 emissions produced by Kraft mill lime kilns. Paper mills have significantly increased fuel efficiencies over the past few decades, which indirectly reduces CO_2 emissions since less fuel needs to be consumed per unit of paper produced. The complication in estimating CO_2 emissions from Kraft mills is that much of the fuel is biomass—by-products of the waste from converting trees and recycled paper into paper products. These by-products may include wood chips, bark, pulp fibers, scrap paper products, pulping liquors, and the like. There are three sources of CO_2 from Kraft lime kilns: CO_2 produced from the combustion of fossil fuels, CO_2 released from the combustion of biomass fuels, and CO_2 released from $CaCO_3$ in the calcining process. The carbon in the last source originates from the wood chips and is therefore from a biomass source, which is not included in emissions inventories according to the U.S. EPA and the Intergovernmental Panel on Climate Change (IPCC). The fossil fuel is needed to provide the energy for the chemical reaction to

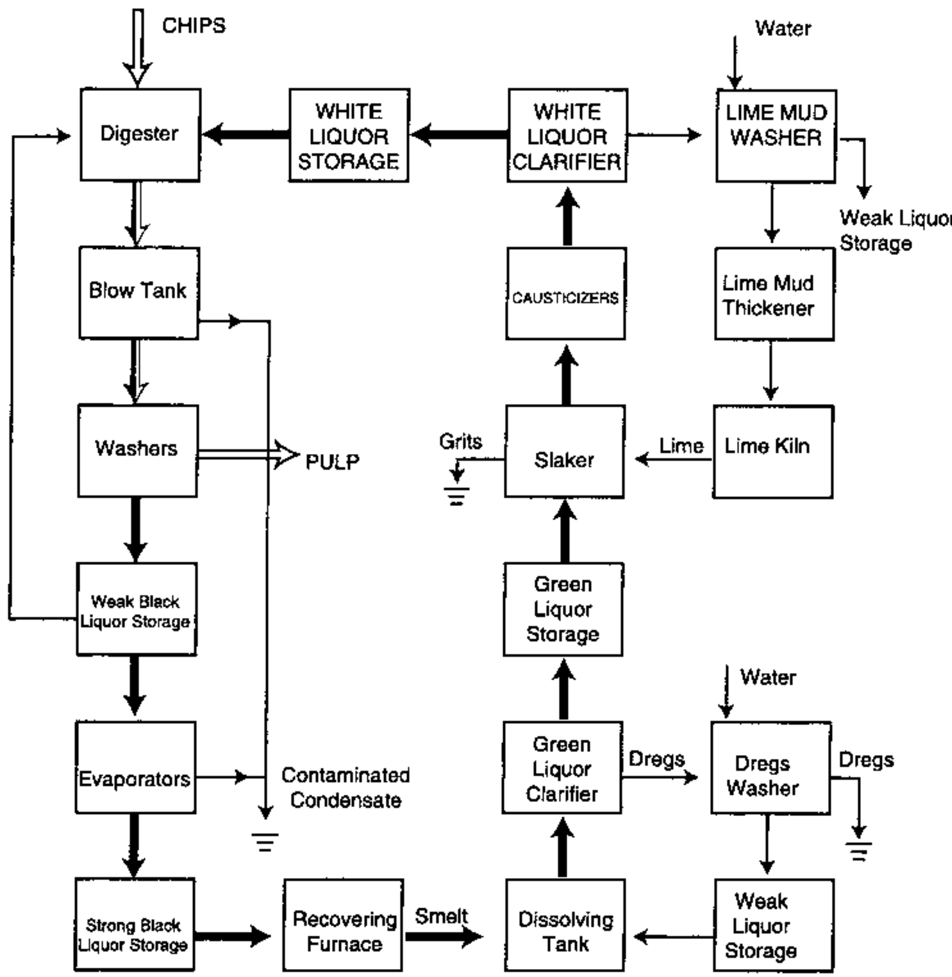

Figure 17.7 Typical Kraft pulping process. (From Ref. 8.)

produce calcium oxide (lime) from calcium carbonate in the lime kiln. The CO_2 emissions from a Kraft lime kiln can then be estimated using standard emission factors for the appropriate fuel being combusted in the kiln.

17.1.3 Bark Boilers

Bark boilers, sometimes referred to as hogged-fuel boilers, are used both to destroy waste products and produce steam for use in the plant. Most of the waste products in paper mills contain significant heating value and can be combusted to generate energy, rather than being disposed of. The primary pollutants from these boilers include particulates, NO_x, and SO_x [7]. Fuel sulfur levels are generally kept low to minimize SO_x emissions. Low-NO_x burners are commonly used to minimize NO_x emissions.

A variety of techniques are used to remove particulates from the products of combustion from bark boilers including gravity settling, cyclones, scrubbers,

Table 17.2 Recovery Furnance Operating and Maintenance Practices Affecting Uncontrolled Emissions

Operating parameter	Emission concern	Operation & maintenance/ assessment technique
Fixing rate	Higher-than design firing rate (flue gas volume) leading to: • increased uncontrolled PM emission rate and concentration • nature of particulates altered • increased TRS emission rate • decreased ESP efficiency	Establish baseline comparison of boiler firing rate and (1) grain loading air volume and (2) temperature at the ESP. There monitor parameters would be expected to increase with increased firing rate
Black liquor heating value and solids content	Increased black liquor heating value/solids content leading to increased PM emission rate, especially for heating value increases	Difficult to control/evaluate due to significant daily variations. Ensure inlet grain loading remains within allowable variation for specific ESP.
Total combustion air (excess air) (include primary and secondary air)	Insufficient total combustion air leading to "black out" (incomplete combustion)	Check total amount of combustion air—the amount needed for complete combustion is normally between 110 and 125% of theoretical air
	Total combustion air greater than 125% of calculated theoretical (stoichiometric) air leading to: • increased PM emission ratio • increased flue gas volume to ESP • increased SO_3 formulation, causing particulates to become sticky and to build-up on ESP collection plates—reduces ESP power input and efficiency	Graph (using DCS if possible) the relationships between percent excess/primary air and • particulates loading to ESP • visible emissions observed from ESP • air volumes to ESP • flue gas temperature to ESP
	Primary air exceeding 45% of total air volume leading to: • sharp increase in PM emission rate • increased TRS emission rate	Also, check electrical data–possible indicators of buildup on ESP collection plates include high secondary voltage (> 50 kv) and low secondary current (< 100 mA) in inlet fields
Char bed temperature	Increased cher bed temperature leading to • increased PM emission rate • increased flue gas volume to ESP	Assure proper combustion air and firing rate operation using techniques outlined above

Source: Ref. 7.
TRS = total sulfur; DCS = distributed control system.

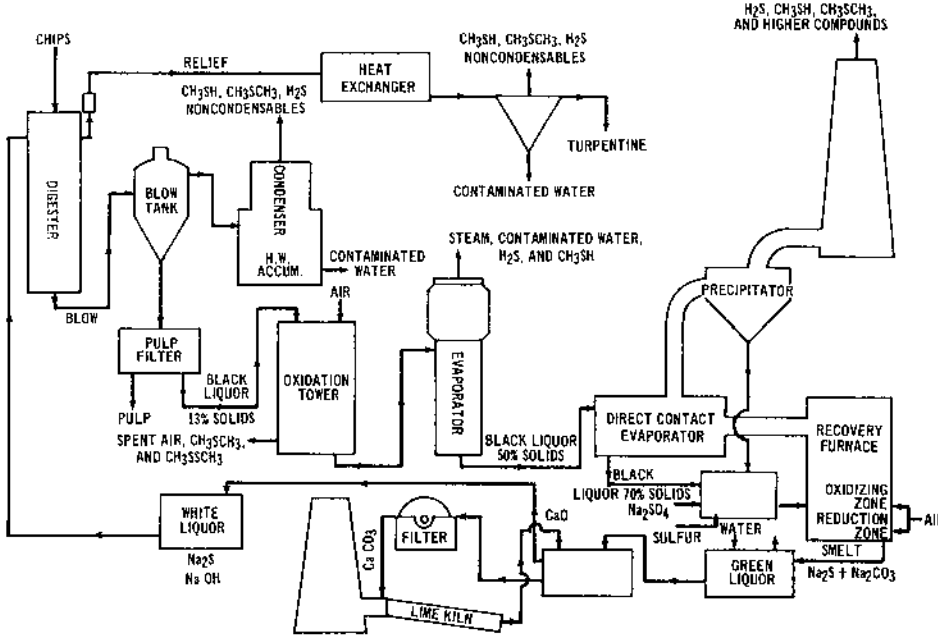

Figure 17.8 Kraft pulping and recovery process diagram. (From Ref. 8.)

Table 17.3 Lime Kiln Operating and Maintenance Practices Affecting Uncontrolled Emissions.

Operating parameter	Emission concern	Operation & maintenance/ assessment technique
Kiln rotation ratio	Increases above normal operating ranges can increase emissions	Compare rate to normal baseline rates using process monitor
O_2 level	Increases above normal operating O_2 levels exiting the kiln can increase emissions	Compare O_2 levels to normal baseline levels using O_2 process monitor, if available
Mud sodium content	Increased sodium in lime mud because of mud washing problems can lead to increased H_2S emissions and fine particulates	Check sodium content of lime mud entering kiln. Generally, should be in 0.5–1% range; 2–2.5% indicates likely problem

Source: Ref. 7.

electrostatic precipitators, and fabric filters. Schifftner and Hesketh [14] describe the use of wet scrubbers to control particulate emissions from bark boilers. They list some important considerations for this application:

1. Is the wood cut in sandy locations? Is it dragged on the ground after cutting? Is it hardwood or softwood? Does the mill stack pulpwood or furnish as logs or does it chip and then store?

2. Are ends, butts, and wood waste also burned? What percentage of the total feed does this represent?
3. If a multitube collector is used, is the char reinjected? If it is, the percentage of fines to the scrubber will likely increase, requiring higher pressure drops.
4. Four contributing factors combine to produce the net outlet emission:
   a. Percentage of reinjection
   b. Sand content of fuel
   c. Type and quantity of auxiliary fuel
   d. Fuel moisture
5. Is the mechanical collector functioning properly?

Yuan et al. [15] modeled NO_x emissions from bark boilers. A code developed at the University of British Columbia was used to simulate the combustion of wood chips. The numerical results were compared against experimental data. The NO_x predictions were generally higher than the measurements except for one case where they were lower. Because the temperatures were relatively low, the contribution from fuel NO_x (from the nitrogen in the bark) was dominant compared to thermal NO_x when the boiler was fired primarily on wood chips. NO_x increased significantly with fuel nitrogen content. Thermal NO_x was the dominant mechanism when the boiler was fired primarily on natural gas. The use of overfire air improved the burnout of the bark but did not reduce NO_x formation as is usually the case. Reducing excess air did reduce NO_x emissions as expected.

17.1.4 Paper Dryers

In many drying processes, moisture is removed from paper webs often traveling at high speeds. Radiant heating (see Fig. 17.9) is often used to supplement steam-heated

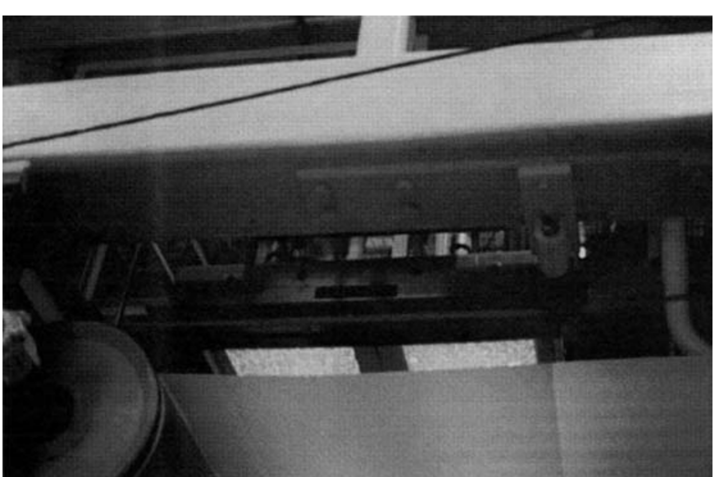

Figure 17.9 Infrared (IR) burner heating a continuously moving paper web. (From Ref. 16. Courtesy of Marsden, Inc., Pennsauken, NJ.)

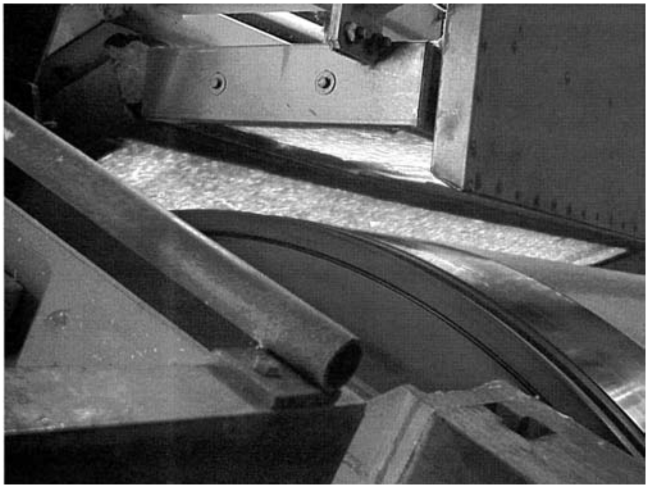

Figure 17.10 Supplemental IR burners for paper drying located over steam cylinders. (Courtesy of Marsden, Inc., Pennsauken, NJ.)

cylinder drying or high-velocity hot-air dryers [16]. The radiant heaters are either electric or fired with a fuel gas such as natural gas. These supplemental heaters may be located before the steam-heated cylinders, in between cylinders, over cylinders (see Fig. 17.10), and after the cylinders. The heaters may also be partitioned across the machine to vary the drying capacity. The moisture content of the paper web often varies across the machine direction. Some streaks may be significantly wetter than others and therefore require more drying energy. A fictitious example is shown in Fig. 17.11 where the peak is near 14% while the minimum is at 10%. The paper is normally specified to have a maximum moisture content. Assume for the sake of argument that it is 8%. This means that the entire paper must be dried so that the wettest streaks are at or below the maximum allowable moisture content. If the heating is uniform across the web, then enough energy must be supplied to reduce the moisture streak of nearly 15% down to 8%. This means that the section of the web at 10% will be dried well below 8%. However, this is detrimental for several reasons. Since paper is sold by weight, removing more moisture than necessary in dryer sections of the paper reduces profitability. More fuel than necessary is used to dry some sections well below the maximum allowable moisture limit. The paper quality also suffers when some sections of the paper are overdried, which causes handling problems for machines like copiers.

So-called moisture profiling is where the radiant output of the burners varies across the machine direction (see Fig. 17.12) to match the moisture levels. This fixes the problems of overdrying some sections that occurs with a uniform radiant heating level. Not only is this much more fuel efficient, but it also indirectly reduces pollutant emissions because less fuel needs to be burned for a given production rate.

Another example of predrying is in the paper industry where infrared (IR) burners are installed after the coating machine and are used to set the coatings on the paper prior to the paper contacting a steam cylinder drum dryer that is used to complete the drying [17]. The IR predryer is primarily used to increase productivity

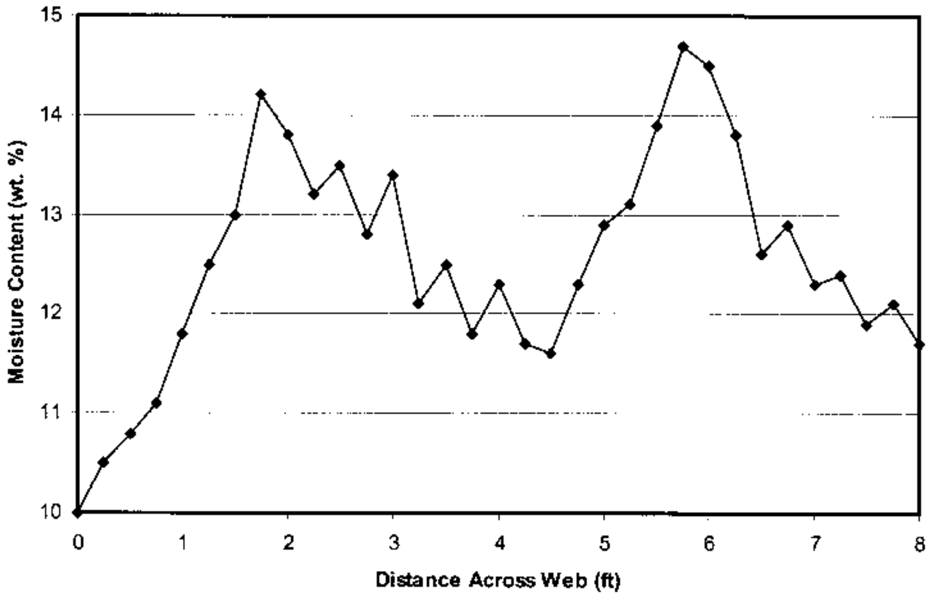

Figure 17.11 Moisture profile across a paper web prior to drying.

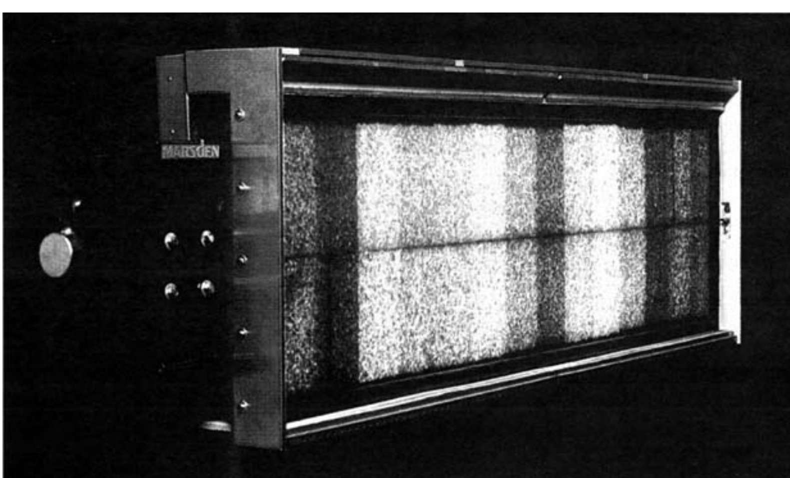

Figure 17.12 IR burners designed for moisture profiling. (Courtesy of Marsden, Inc., Pennsauken, NJ.)

and improve the paper coating quality. The productivity is increased because of the added heat. The quality is improved because the IR energy does not disturb the coating as convection or conduction heat-transfer methods could, which lets the coating set on the paper prior to contact with the steam cylinder, which relies on thermal conduction heat transfer.

Pettersson and Stenström [18] compared the use of gas-fired and electric IR burners used to set the coating before the paper reached the next cylinder in a paper

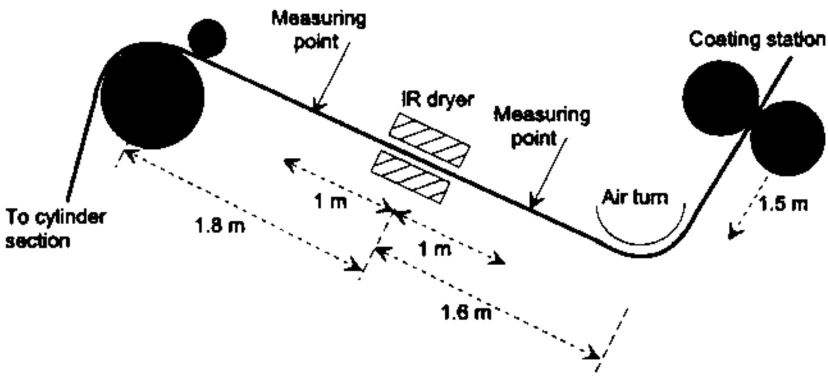

Figure 17.13 Schematic of IR heaters used to set the coating on paper, which is traveling from left to right in the figure. (From Ref. 18. Courtesy of Gas Technology Institute, Chicago, IL.)

line. Figure 17.13 shows the IR heaters between the coating station and the next steel cylinder in the paper machine. IR burners are preferred in this application, instead of convective or conductive dryers, because they are noncontact and have high power densities (10–40 kW/m^2 or 3000–13,000 Btu/hr-ft^2). The thermal efficiencies were calculated as 30 and 40%, respectively, for the gas-fired (propane) and electric IR burners. However, the burners were tested on two different machines and there was some uncertainty in the measurements.

The most common way for drying paper traveling at high velocities is by contact with steam heated drums or cans, usually referred to as steam cylinders. The paper wraps around the drums in a serpentine fashion to maximize the contact area with the drum. In this type of dryer, the primary method of drying is by thermal conduction [19]. One problem with this technique is that as the paper dries, the thermal conductivity goes down, which makes it harder to conduct the heat into the paper. This is known as the "falling rate period" where the downstream steam cylinders are much less effective at removing moisture than the upstream cylinders.

Infrared burners (see Fig. 17.14) are often used to supplement these dryers because the IR radiation can penetrate into the paper better when it is dry because there is less water to absorb the radiation. In a survey of paper makers by the Gas Research Institute (Chicago, IL), respondents believed that the best place to install IR burners on a paper drying line is in the preheat zone [20]. Other locations identified in the survey included in the forming section, above and below the steam cylinders in the constant rate zones, and above and below the steam cylinders in the falling rate zone.

One reason for the popularity of steam cylinder dryers is that there is usually plenty of steam available in paper mills because much of the waste bark and liquor from the trees used to make the paper is burned in hog fuel boilers. Another reason is that the cylinders help to guide and transport the paper. One disadvantage includes the large thermal inertia of the stainless-steel cylinders, which causes longer startup times and a reduced ability to change the drying rate quickly. An important disadvantage is the reduced drying effectiveness as the moisture content of the paper decreases because of the reduction in the thermal conductivity. There is a potential reduction in paper quality due to contact with the steel cylinders. These dryers do not typically have the capability to vary the drying capacity across the width of the

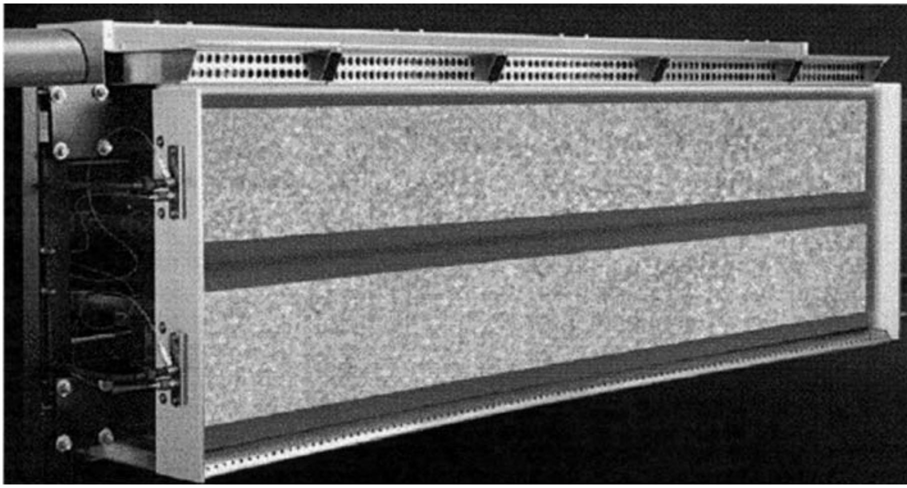

Figure 17.14 Example of a flat-panel gas-fired IR burner. (From Ref. 16. Courtesy of Marsden, Inc., Pennsauken, NJ.)

paper. Also, for thicker materials, the drying rate is reduced because the evolving water vapor is trapped between the cylinder and the paper as it is unable to exit the side of the paper in contact with the cylinder.

Another type of dryer uses very high velocity hot-air impingement on both sides of a moving web. The web "floats" through the nozzles, which is where this type of dryer gets its name—*floater dryer*. The primary mode of heat transfer for this dryer is convection. This technique combines heat and mass transfer in the same apparatus as the hot air both heats the web and carries away the moisture that evolves from it. This type of dryer has several potential advantages over other types of dryers. No additional systems are needed to remove the volatiles vaporizing from the material being dried. There is no direct contact with the product that could reduce the quality. It is possible to segment this type of dryer to vary the moisture removal rate across the width, although the reaction time is slow compared to that of IR dryers. There are also potential disadvantages. The air nozzles can become plugged because they are typically fairly small to achieve the high gas velocities. In drying materials like papers and textiles, this method also relies ultimately on conduction for the energy to reach the core of the product whose thermal conductivity decreases as the moisture content decreases. Another version of an air dryer is where heated air is blown only on to one side of a paper web traveling through a dryer where a coating is to be dried, as shown in Fig. 17.15 [21].

Hannum et al. [22] discuss the development of a high-intensity lean premix combustion system with low-NO_x emissions for use in drying applications such as tissue and plasterboard drying. The burner was used to heat air for use in drying in a loop drying system. Measured NO_x emissions were below 10 ppmvd (3% O_2).

In most paper drying applications, the only pollutant of significant concern is NO_x. The gaseous fuels used, such as natural gas, contain little or no sulfur to produce SO_x. These clean fuels and moist webs generate little if any particulates. There are no VOCs in the process. There is very little noise produced. While there are

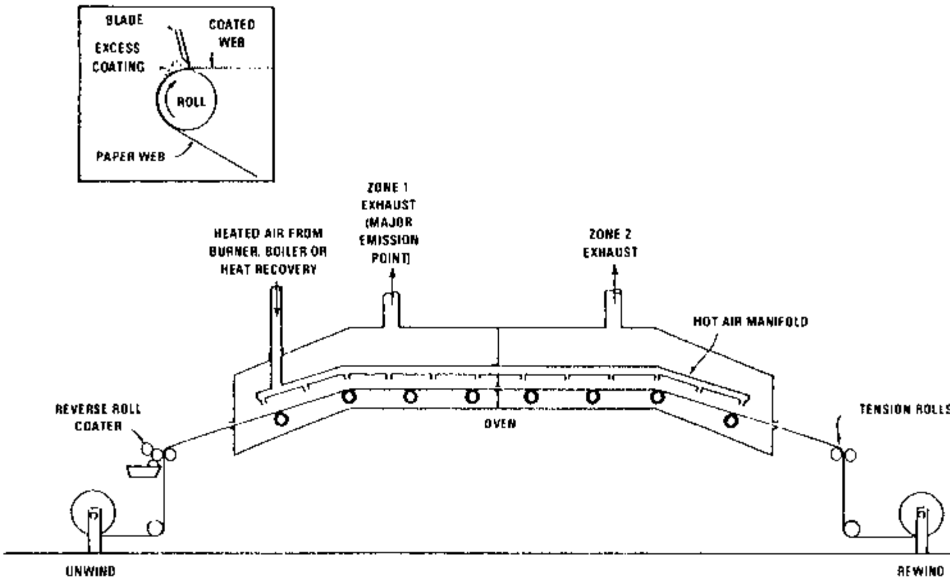

Figure 17.15 Schematic of a paper-coating dryer. (From Ref. 21.)

significant levels of thermal radiation, this is directed at the paper and is not usually a problem for personnel operating the equipment. Even NO_x emissions are typically low because of the relatively low operating temperatures.

17.2 PRINTING AND PUBLISHING

Web offset lithography is used to produce about 75% of books and pamphlets as well as an increasing number of newspapers [23]. Dryers and ovens are sometimes used to dry ink in the printing and publishing industry [24].One of the major environmental concerns related to the printing and publishing industry is VOC emissions. VOCs are used in ink to promote fast drying. This ink is commonly referred to as ‘‘heatset’’ ink. In many applications, no ovens or dryers are required to dry the ink during the production process because of the rapid vaporization of the VOC solvents in the ink compared to the slower speed of the production process. However, high-speed paper webs are used in some printing applications where dryers are required to set the ink before it contacts downstream rollers that would cause the ink to smear if it were not set. Fig. 17.16 shows a schematic of a web-fed high-speed rotary flexographic press with a printing and drying section used to dry the ink on the paper [25].

These printing presses often use multiple colors, which means that each color must be individually set before the next color can be applied, or otherwise the colors will smear. The heater to set the ink may be as simple as an electric IR or UV burner. Figure 17.16 shows a heater between each color application of the roller ink system. In some cases, natural-gas-fired burners may be used because of their lower operating costs compared to using electricity. Whichever technology is used, the burners must either be capable of very rapid cool down or there must be some type of shielding from

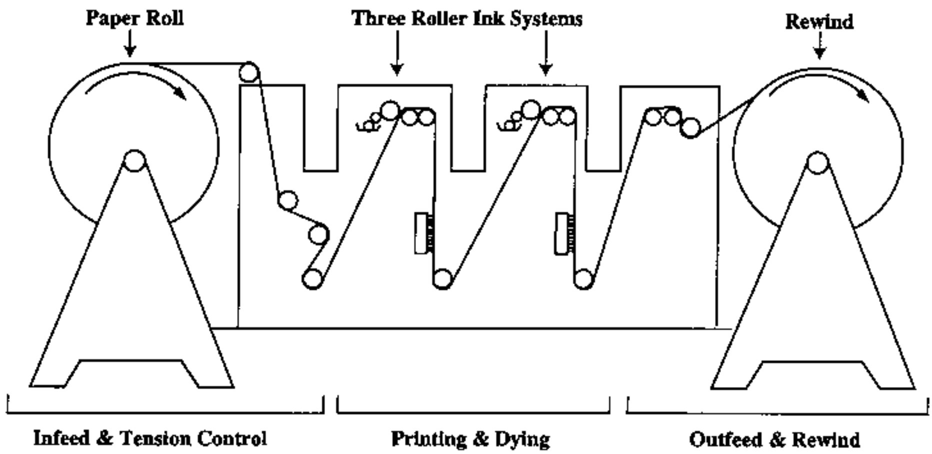

Figure 17.16 Schematic of a web-fed rotary flexographic press. (From Ref. 25.)

the web in the event of a sudden line stoppage in order to prevent the paper from catching on fire.

However, because of the increased concern about VOC emissions, inks are being made with less VOCs and with more aqueous-based solvents that require heat to set. The heaters may be gas-fired IR burners that produce NO_x emissions, although the temperatures are often low enough that these emissions are generally low. For larger and higher speed presses, gas-fired ovens may be used where air is heated and blown at high velocity on to the paper both to dry the paper and remove the vaporized solvents. These ovens are often designed to float the paper by having air nozzles on both sides of the paper. The floater dryer temperature is in the range 400°–500°F (200°–290°C). One or more burners are fired in the dryer to maintain a given air temperature. An afterburner may also be included in the drying system if there are significant VOC emissions in the recycled air containing ink solvents.

Besides VOCs, there are no other significant pollutants produced by the dryer. The fuel is typically natural gas, which contains little or no sulfur to produce SO_x. There are no significant sources for particulate emissions. Noise may be an issue for hot-air dryers because of the fans and high gas velocities. Radiation could be a consideration if radiant burners are used to set the ink.

17.3 TEXTILE MANUFACTURING

The textile manufacturing industry consists of the following segments [26]:

- Broad woven fabric mills and wool mills, including dyeing and finishing
- Knitting mills and knit goods finishing
- Other dyeing and finishing textile mills
- Floor covering mills, including dyeing and finishing.

The U.S. EPA ranks textile processing as number 44 on its prioritized list of 59 major source categories where the lower the number the higher the priority [27].

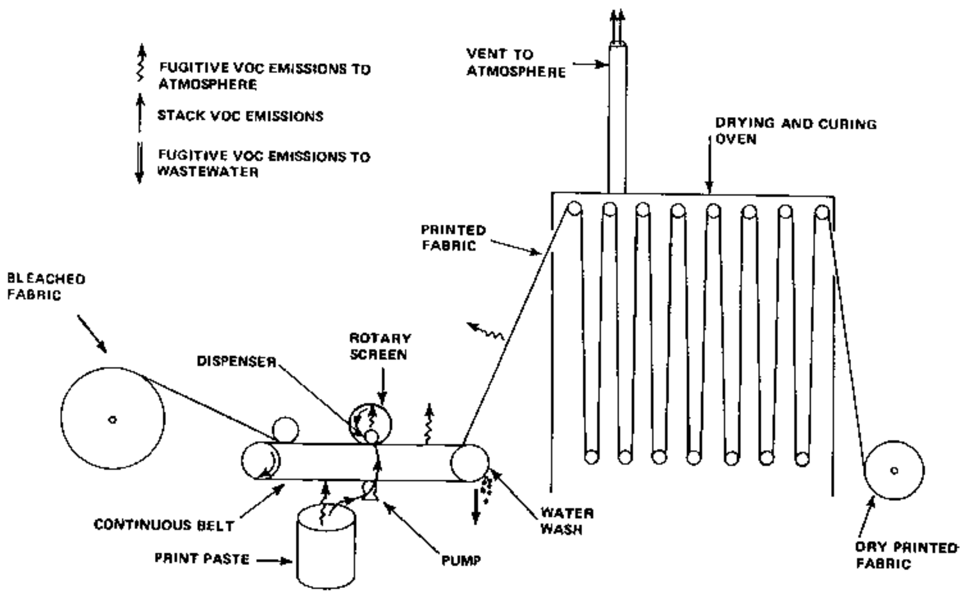

Figure 17.17 Schematic of a textile printing process. (From Ref. 30.)

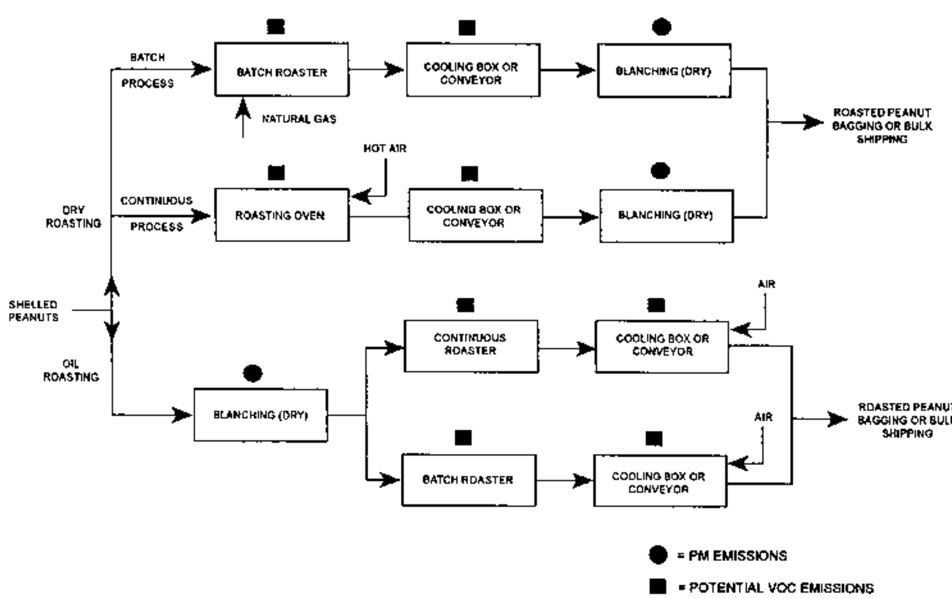

Figure 17.18 Typical shelled peanut roasting processing flow diagram. (From Ref. 32.)

Predryers are used in some applications prior to the final drying of the product. An example of this type of application is the use of IR burners to set the dyes in the dyeing of fabrics in textile manufacturing [28]. After the dyes are applied to the fabric, they must be set prior to contact with the dryer, otherwise the dyes will migrate to drier areas of the fabric, which reduces the quality of the textile. The IR burners in the predryer are used to set the dyes rapidly without the need to contact the material, as would be the case with, for example, a drum dryer [29]. Dryers and ovens are also used to cure inks used in textile printing, as shown in Fig. 17.17 [30].

17.4 FOOD PROCESSING

Cane sugar processing involves burning the fibrous residue, called bagasse, remaining after sugar extraction. This is usually burned in a boiler. This combustion process is the main source of air emissions in sugar cane production other than open field burning, which is completely uncontrolled and unmeasured [31]. The most common pollutant emissions include particulates, NO_x, unburned combustibles, and carbon dioxide.

Dryers are used in roasting seeds, almonds, and peanuts. Common pollutant emissions may include particulates and VOCs. Figure 17.18 shows a schematic of a typical peanut roasting process [32]. The primary air pollution emissions from fish processing are particulate emissions from the dryers [33].

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