FABRIC FINISHING

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Prepared for the Chemical Engineering Branch by SAIC

Introduction:

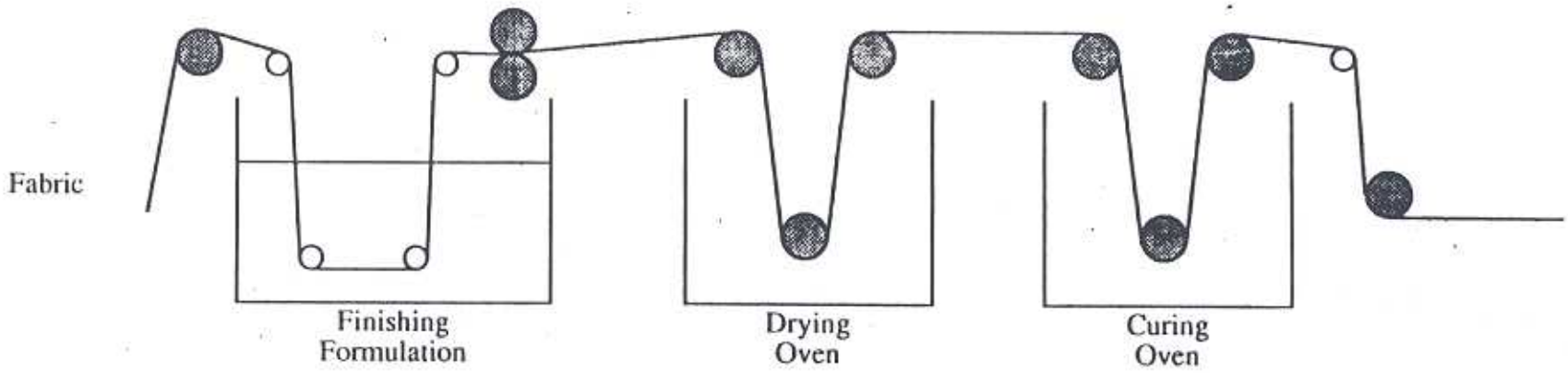
Typical finishing agents include permanent press, flame retardants, and water/stain repellents. Consumption in 1989 of finishing agents used for the processing of textile mill products is estimated to be 154 million pounds valued at $208 million. In the next five years, an average growth rate of 2.7% is projected for chemicals and polymers used in finishing textile products. Demand for organic specialty chemicals, which includes flame retardants, surfactants, and permanent press resins is expected to grow at an average rate of about 3.3% annually. Expected demand for polymeric products, which includes softeners and water/stain repellents, is diminished by reduced fabric application levels of these products as users develop improved formulation technology. (Frost and Sullivan, 1989).

Process Description:

Fabric finishing mills carry out the following unit operations: desizing, scouring, bleaching, mercerizing, dyeing, printing, and finishing (Bogle, 1977). This scenario addresses the final step in the processing of textile fabrics, finishing. Finishing may involve either mechanical treatments, such as calendering (rolling the fabric to produce a smooth finish) or napping (brushing the fabric to raise surface fibers), or chemical treatments such as permanent press or water repellent treatments. Almost all fabric receives some form of chemical treatment and many fabrics are treated with a number of chemicals. About two-thirds of fabric finishers purchase raw materials from intermediate formulators, while only about one-third purchase them from manufacturers (Frost & Sullivan, 1989). This scenario only addresses fabric finishing end use.

The conventional chemical finishing process for textile fabrics requires three steps, commonly referred to as pad/dry/cure. The fabric finishing operation is illustrated in the process flow diagram. In the first step, the fabric is immersed in an aqueous finishing formulation and then squeezed between metal rolls to remove excess padding solution and to aid in the even distribution of the finishing agent in the fabric. The fabric is then dried by passing over a series of heated metal rolls. The drying unit is 100-110°C. The fabric is next cured by passing through a long oven. Curing is performed to bond the chemicals with the cellulose or to polymerize them on the fabric surface. The fabric is transported through the oven by an adjustable conveyer called a tenter. The temperature of the curing unit ranges from 150-180°C. During the curing step, any PMNs in the fabric finishing solution are reacted or encapsulated. The IRER assessment stops at this point. Fabric finishing is a continuous process performed at rates that often exceed 10 m/min. A roll of cloth is run through the finishing bath over the course of a working shift.

Process Flow Diagram for Fabric Finishing



Typical Finishing Formulation:

5-9 wt%	crosslinking agent
0.4-3 wt%	acidic catalyst
1-3 wt%	emulsified polymer
	remainder water

The conventional permanent-press finishing solution contains about 10-15 wt% cross-linking agent, enough acidic catalyst to effect a cure (0.4-3.5 wt%, depending upon catalyst strength), and 1-3 wt% emulsified polymer which generally acts as a fiber lubricant or a stiffening agent. The remainder of the pad bath is made up of water (Kirk-Othmer, 1981). Pad baths are usually designed for 60% to 100% pickup of the finishing solution, based on the weight of fabric. This is achieved by using rollers to squeeze off excess finishing solution as the cloth leaves the bath. Typical percentages of this and other finishes are given in Table 1, which was derived by an analysis of trade literature on more than 3,150 textile chemicals compiled by Flick (1990). The numbers in parentheses after each category indicate the numbers of commercial products in that category for which Flick gave solution strengths.

Table 1: Finishes applied by pad-dry-cure method.

Function	**Percent in bath**
Flame retardants [6] *15-20% for ordinary fabric; higher for upholstery*	3-40
Flame retardant odor maskers [4]	0.0075-0.0098
Fluorochemical stain repellents [5]	0.5-2
Antibacterials [3]	0.06-3
Optical brightener [1]	1
Softener [30] *Often a silicone finish, used with or without a conventional permanent-press resin. 5% is typical*	0.5-15
Water repellent [5] *10% typical*	0.5-19
Standard permanent press resin [2] *These resins emit formaldehyde, which affects workers in the downstream clothing plants. Kirk-Othmer suggests a bath concentration of 5-9 for the standard mix. CNC recommends 10-15% for the newer low-formaldehyde versions.*	10-15

Number of Finishing Plants:

If the number of plants is not given, choose a use percentage for the PMN chemical from Table 1. This is the percent on-weight-bath (owb). In the standard pad-dry-cure finishing method, all of the fabric finish picked up by the cloth is cured onto it. Unlike dyes, there is no "unexhausted" material to consider. The fabric picks up 60-100% of its own weight of finishing solution, so the percent on-weight-fiber (owf) is given by:

$$\%owf = 0.8 \times \%owb$$

Based on an analysis of data provided in fabric finishing PMNs during 1993 and 1994, a typical fabric finishing plant treats 9,100 kg/day of cloth (range 3,520-50,000 kg/site-day). The use rate of the PMN chemical is therefore:

$$U = \frac{9,100 \times \%owf}{100}$$

in kg PMN/site-day. Compute the number of sites by using the PMN production volume and assuming 250 working days/year:

$$NS = \frac{PV}{250 \times U}$$

where:

NS = Number of sites that may use the PMN chemical as a finishing chemical
PV = Production volume of PMN chemical (kg/yr)

The value of NS should not exceed 1100. The Department of Labor has estimated that there are 1100 finishing plants (DoL, 1991) in the United States. These plants consume about 73 million kg of finishing agents per year (Frost and Sullivan, 1989).

Worker Exposure:

Given or assume 3-6 exposed workers per site. This number is based on an analysis of 9 IRERs for fabric finishes.

A. Inhalation

Assume no inhalation exposure. Fabric finishing chemicals are almost all high-molecular weight compounds with negligible vapor pressures. They are generally supplied as concentrated solutions or waxy solids, so there is no exposure to particulates.

For the rare case where a fabric-finishing chemical has vapor pressure > 0.001 mmHg, it may be possible to use the "analogous chemical" method to predict worker exposures. Standard permanent-press finishes contain formaldehyde. Preventive measures must be taken in the plant to reduce this chemical below the OSHA Permitted Exposure Limit of 1 ppm. The same controls will serve to limit the concentration of a volatile PMN chemical in the air.

B. Dermal

Assume 1,300 to 3,900 mg/day from routine two-hand contact with the pure chemical during mixing.

Environmental Releases:

Air: Generally negligible due to low vapor pressure.

Water: Releases to water result from dumping of the finishing bath. One PMN submitter indicated that this takes place every 4-6 weeks in large plants, but a more conservative assumption for smaller plants might be that the bath is dumped once a day. If the submitter does not provide more definitive information on the batch size, assume a 150-1,000 gallon finishing bath. The release rate to water is then:

$$R_w = \frac{(150\text{-}1000\,gal) \times 3.78\,kg/gal \times \%owb}{100}$$

where R_w is in kg released per dumping event. The 1,000 gallon bath size was given in a recent PMN submission. The 150 gallon bath size was recommended as a typical size by a supplier of permanent press resins (Bercen 1994).

Land: Releases to land are limited to drum residues.

Additional Textile Chemicals

Chemicals of the types listed in Table 2 also appear from time to time in PMN submissions. These are not finishes. Some of them, such as yarn lubricants, are scoured off before textile dyeing/printing. Others, such as sequestrants, remain in the aqueous phase and do not exhaust to the fiber during dyeing operations. They are included here because they are sometimes confused with the fabric finishing chemicals and are not described in other generic scenarios.

Table 2: Textile chemicals lost 100% to water

Function	Percent in bath
Lubricants [3] *Used to lubricate yarn during weaving*	0.5-10
Sequestrants [7] *Used to chelate metal ions during dyeing. Typical 0.1%*	0.05-0.25
Surfactants/detergents [10] *Used either during scouring or to control the dyeing process. Typical 2%*	0.2-20
Mercerizing assistant [2] *Used in the caustic mercerizing bath used to strengthen cotton and prepare it for dyeing.*	0.5-1.5
Scouring agents [3] *Used to clean oil and dirt from fabric.*	0.5-5
Wetting agents [7] *Used to ensure fibers are properly wetted in the dye bath. Typical 0.5%*	0.1-2

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