## 4.11 Textile Fabric Printing

### 4.11.1 Process Description[1-2]

Textile fabric printing is part of the textile finishing industry. In fabric printing, a decorative pattern or design is applied to constructed fabric by roller, flat screen, or rotary screen methods. Pollutants of interest in fabric printing are volatile organic compounds (VOC) from mineral spirit solvents in print pastes or inks. Tables 4.11-1, 4.11-2, and 4.11-3 show typical printing run characteristics and VOC emission sources, respectively, for roller, flat screen, and rotary screen printing methods.

In the roller printing process, print paste is applied to an engraved roller, and the fabric is guided between it and a central cylinder. The pressure of the roller and central cylinder forces the print paste into the fabric. Because of the high quality it can achieve, roller printing is the most appealing method for printing designer and fashion apparel fabrics.

In flat screen printing, a screen on which print paste has been applied is lowered onto a section of fabric. A squeegee then moves across the screen, forcing the print paste through the screen and into the fabric. Flat screen machines are used mostly in printing terry towels.

In rotary screen printing, tubular screens rotate at the same velocity as the fabric. Print paste distributed inside the tubular screen is forced into the fabric as it is pressed between the screen and a printing blanket (a continuous rubber belt). Rotary screen printing machines are used mostly but not exclusively for bottom weight apparel fabrics or fabric not for apparel use. Host knit fabric is printed by the rotary screen method, because it does not stress (pull or stretch) the fabric during the process.

Major print paste components include clear and color concentrates, a solvent, and in pigment printing, a low crock or binder resin. Print paste color concentrates contain either pigments or dyes. Pigments are insoluble particles physically bound to fabrics. Dyes are in solutions applied to impart color by becoming chemically or physically incorporated into individual fibers. Organic solvents are used almost exclusively with pigments. Very little organic solvent is used in nonpigment print pastes. Clear concentrates extend color concentrates to create light and dark shades. Clear and color concentrates do contain some VOC but contribute less than 1 percent of total VOC emissions from textile printing operations. Defoamers and resins are included in print paste to increase color fastness. A small amount of thickening agent is also added to each print paste to control print paste viscosity. Print defoamers, resins, and thickening agents do not contain VOC.

The majority of emissions from print paste are from the solvent, which may be aqueous, organic (mineral spirits), or both. The organic solvent concentration in print pastes may vary from 0 to 60 weight percent, with no consistent ratio of organic solvent to water. Mineral spirits used in print pastes vary widely in physical and chemical properties (see Table 4.11-4).

Although some mineral spirits evaporate in the early stages of the printing process, the majority of emissions to the atmosphere is from the printed fabric drying process, which drives off volatile compounds (see Tables 4.11-2 and 4.11-3 for typical VOC emission splits). For some specific print paste/fabric combinations, color fixing occurs in a curing process, which may be entirely separate or merely a separate segment of the drying process.

Table 4.11-1 (Metric And English Units). TYPICAL TEXTILE FABRIC PRINTING RUN CHARACTERISTICS[a]

| Characteristic | Roller | | Rotary Screen | | Flat Screen | |
|---|---|---|---|---|---|---|
| | Range | Average | Range | Average | Range | Average |
| Wet pickup rate, kg (lb)[b] print paste consumed/kg (lb) of fabric[c] | 0.51 - 0.58 | 0.56 | 0.10 - 1.89 | 0.58 | 0.22 - 0.83 | 0.35 |
| Fabric weight, kg/m$^2$ (lb/yd$^2$)[d] | 0.116 - 0.116 (0.213 - 0.213) | 0.116 (0.213) | 0.116 - 0.116 (0.213 - 0.213) | 0.116 (0.213) | 0.314 - 0.314 (0.579 - 0.579) | 0.314 (0.579) |
| Mineral spirits added to print paste, weight % | 0 - 60 | 26 | 0 - 50 | 3 | 23 - 23 | 23 |
| Print paste used per fabric area, kg/m$^2$ (lb/yd$^2$)[e] | 0.059 - 0.067 (0.109 - 0.124) | 0.065 (0.119) | 0.012 - 0.219 (0.021 - 0.403) | 0.067 (0.124) | 0.069 - 0.261 (0.127 - 0.481) | 0.110 (0.203) |
| Mineral spirits used per fabric area, kg/m$^2$ (lb/yd$^2$)[f] | 0 - 0.040 (0 - 0.074) | 0.017 (0.031) | 0 - 0.109 (0 - 0.201) | 0.0002 (0.0004) | 0.016 - 0.060 (0.030 - 0.111) | 0.025 (0.046) |
| Print paste used in run, kg (lb)[g] | 673 - 764 (1,490 - 1,695) | 741 (1,627) | 137 - 2,497 (287 - 5,509) | 764 (1,695) | 787 - 2,975 (1,736 - 6,575) | 1,254 (2,775) |

[a] Length of run = 10,000 m (10,936 yd); fabric width = 1.14 m (1.25 yd); total fabric area = 11,400 m$^2$ (13,634 yd$^2$); line speed = 40 m/min (44 yd/min); distance, printer to oven = 5 m (5.5 yd).
[b] Wet pickup rate is a method of yield calculation in which mass of print paste consumed is divided by mass of fabric used.
[c] Reference 3.
[d] Only average fabric weight is presented.
[e] Fabric weight multiplied by wet pickup rate.
[f] Fabric weight multiplied by wet pickup multiplied by percent mineral spirits in formulation.
[g] Print paste used per fabric area multiplied by area of fabric printed.

Table 4.11-2 (Metric Units). SOURCES OF MINERAL SPIRIT EMISSIONS FROM A TYPICAL TEXTILE FABRIC PRINTING RUN[a]

| Source | Percent Of Total Emissions | Roller | | Rotary Screen | | Flat Screen | |
|---|---|---|---|---|---|---|---|
| | | Range (kg) | Average (kg) | Range (kg) | Average (kg) | Range (kg) | Average (kg) |
| Mineral spirits used in run[b] | 100.0 | 0 - 458 | 193 | 0 - 1,249 | 23 | 181 - 684 | 288 |
| Wasted mineral spirits (potential water emissions)[c] | 6.2 | 0 - 28 | 12 | 0 - 77 | 1 | 11 - 42 | 18 |
| Overprinted mineral spirit fugitives[d] | 3.5 | 0 - 16 | 7 | 0 - 44 | 1 | 6 - 24 | 10 |
| Tray and barrel fugitives[e] | 0.3 | 0 - 1 | 1 | 0 - 4 | 0 | 1 - 2 | 1 |
| Flashoff fugitives[e] | 1.5 | 0 - 7 | 3 | 0 - 19 | 0 | 3 - 10 | 4 |
| Dryer emissions[e] | 88.5 | 0 - 405 | 170 | 0 - 1,105 | 21 | 160 - 606 | 255 |

[a] Length of run = 10,000 m; fabric width = 1.14 m; total fabric area = 11,400 $m^2$; line speed = 40 m/min; distance, printer to oven = 5 m.
[b] Print paste used in run multiplied by mineral spirits added to print paste, weight percent.
[c] Estimate provided by industry contacts.
[d] Estimated on the basis of 2.5 cm of overprint on each side of fabric.
[e] Emission splits calculated from percentages provided by evaporation computations.

Table 4.11-3 (English Units). SOURCES OF MINERAL SPIRIT EMISSIONS FROM A TYPICAL TEXTILE FABRIC PRINTING RUN[a]

| Source | Percent Of Total Emissions | Roller | | Rotary Screen | | Flat Screen | |
|---|---|---|---|---|---|---|---|
| | | Range (lb) | Average (lb) | Range (lb) | Average (lb) | Range (lb) | Average (lb) |
| Mineral spirits used in run[b] | 100.0 | 0 - 1,005 | 425 | 0 - 2,754 | 51 | 399 - 1,508 | 635 |
| Wasted mineral spirits (potential water emissions)[c] | 6.2 | 0 - 62 | 26 | 0 - 170 | 2 | 24 - 93 | 40 |
| Overprinted mineral spirit fugitives[d] | 3.5 | 0 - 35 | 15 | 0 - 97 | 2 | 13 - 53 | 22 |
| Tray and barrel fugitives[e] | 0.3 | 0 - 2 | 2 | 0 - 9 | 0 | 1 - 4 | 2 |
| Flashoff fugitives[e] | 1.5 | 0 - 15 | 6 | 0 - 41 | 1 | 6 - 22 | 9 |
| Dryer emissions[e] | 88.5 | 0 - 889 | 375 | 0 - 2,436 | 46 | 353 - 1,337 | 562 |

[a] Length of run = 10,936 yd; fabric width = 1.25 yd; total fabric area = 13,634 $yd^2$; line speed = 44 yd/min; distance, printer to oven = 5.5 yd.
[b] Print paste used in run multiplied by mineral spirits added to print paste, weight percent.
[c] Estimate provided by industry contacts.
[d] Estimated on the basis of 1 in. of overprint on each side of fabric.
[e] Emission splits calculated from percentages provided by evaporation computations.

Table 4.11-4 (Metric And English Units). TYPICAL INSPECTION VALUES FOR MINERAL SPIRITS[a]

| Parameter | Range |
|---|---|
| Specific gravity at 15°C (60°F) | 0.778 - 0.805 |
| Viscosity at 25°C (77°F) | 0.83 - 0.95 cP |
| Flash point (closed cup) | 41 - 45°C (105 - 113°F) |
| Aniline point | 43 - 62°C (110 - 144°F) |
| Kauri-Butanol number | 32 - 45 |
| Distillation range | |
| Initial boiling points | 157 - 166°C (315 - 330°F) |
| 50 percent value | 168 - 178°C (334 - 348°F) |
| Final boiling points | 199 - 201°C (390 - 394°F) |
| Composition (%) | |
| Total saturates | 81.5 - 92.3 |
| Total aromatics | 7.7 - 18.5 |
| $C_8$ and higher | 7.5 - 18.5 |

[a] References 2,4.

Two types of dryers are used for printed fabric, steam coil or natural gas fired dryers, through which the fabric is conveyed on belts, racks, etc., and steam cans, with which the fabric makes direct contact. Most screen printed fabrics and practically all printed knit fabrics and terry towels are dried with the first type of dryer, not to stress the fabric. Roller printed fabrics and apparel fabrics requiring soft handling are dried on steam cans, which have lower installation and operating costs and which dry the fabric more quickly than other dryers.

Figure 4.11-1 is a schematic diagram of the rotary screen printing process, with emission points indicated. The flat screen printing process is virtually identical. The symbols for fugitive VOC emissions to the atmosphere indicate mineral spirits evaporating from print paste during application to fabric before drying. The largest VOC emission source is the drying and curing oven stack, which vents evaporated solvents (mineral spirits and water) to the atmosphere. The symbol for fugitive VOC emissions to the waste water indicates print paste mineral spirits washed with water from the printing blanket (continuous belt) and discharged in waste water.

Figure 4.11-2 is a schematic diagram of a roller printing process in which all emissions are fugitive. Fugitive VOC emissions from the "back grey" (fabric backing material that absorbs excess print paste) in the illustrated process are emissions to the atmosphere because the back grey is dried before being washed. In processes where the back grey is washed before drying, most of the fugitive VOC emissions from the back grey will be discharged into the waste water. In some roller printing processes, steam cans for drying printed fabric are enclosed, and drying process emissions are vented directly to the atmosphere.

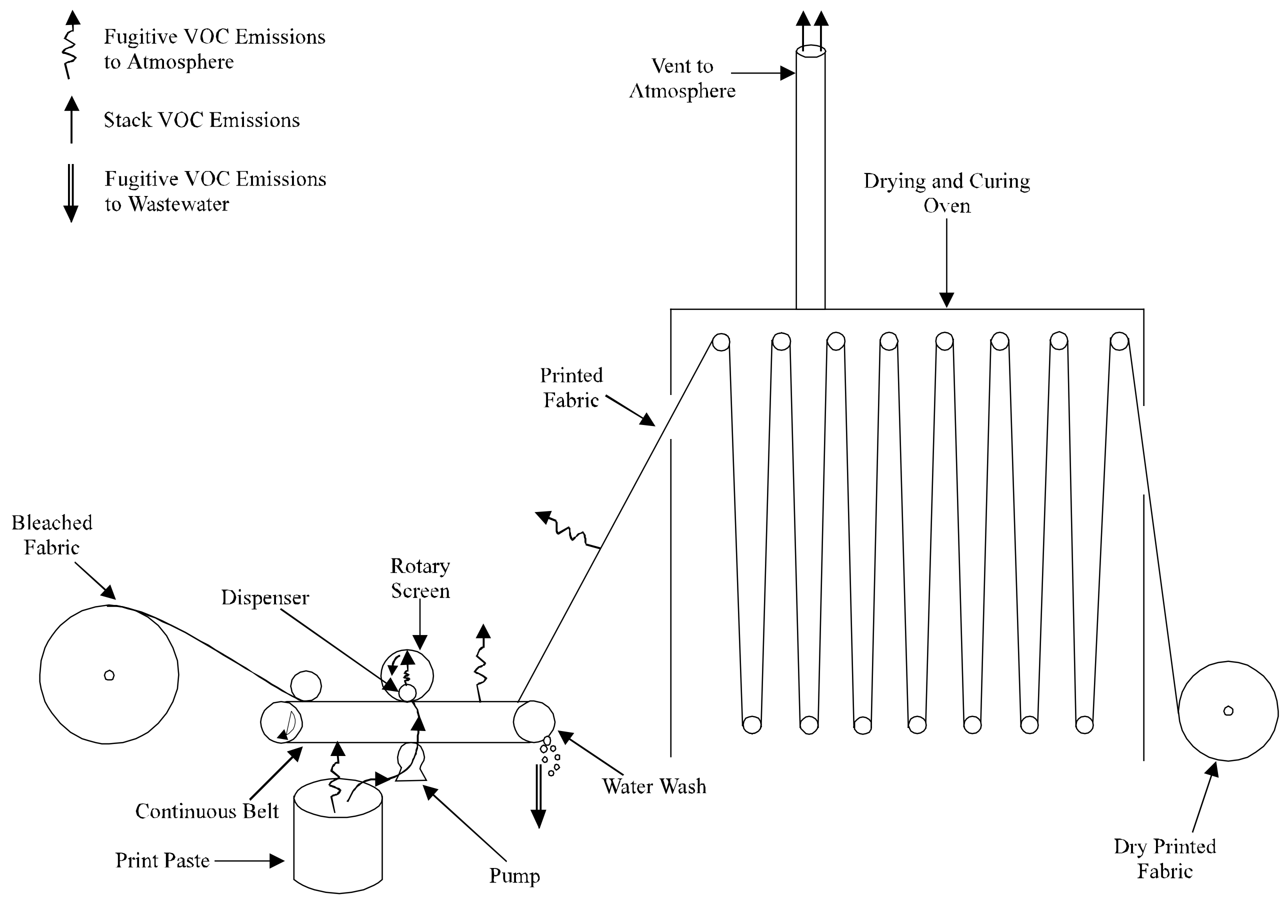


Figure 4.11-1. Schematic diagram of the rotary screen printing process, with fabric drying in a vented oven.

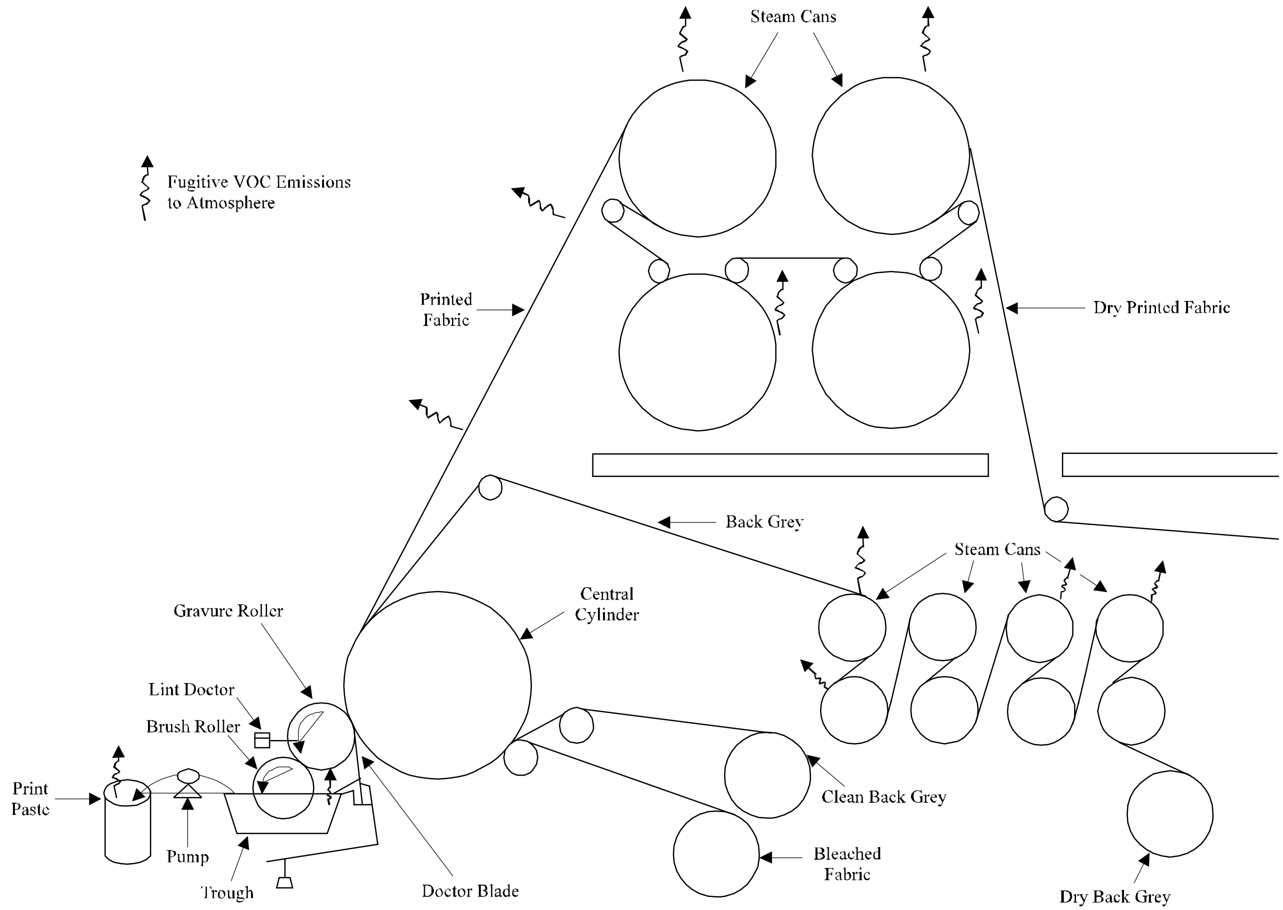


Figure 4.11-2. Schematic diagram of the roller printing process, with fabric drying on steam cans.

## 4.11.2 Emissions And Controls[1,3-12]

Presently there is no add-on emission control technology for organic solvent used in the textile fabric printing industry. Thermal incineration of oven exhaust has been evaluated in the Draft Background Information Document for New Source Performance Standard development[1] and has been found unaffordable for some fabric printers. The feasibility of using other types of add-on emission control equipment has not been fully evaluated. Significant organic solvent emissions reduction has been accomplished by reducing or eliminating the consumption of mineral spirit solvents. The use of aqueous or low organic solvent print pastes has increased during the past decade, because of the high price of organic solvents and higher energy costs associated with the use of higher solvent volumes. The only fabric printing applications presently requiring the use of large quantities of organic solvents are pigment printing of fashion or designer apparel fabric, and terry towels.

Table 4.11-5 presents average emission factors and ranges for each type of printing process and an average annual emission factor per print line, based on estimates submitted by individual fabric printers. No emission tests were done. VOC emission rates involve 3 parameters: organic solvent content of print pastes, consumption of print paste (a function of pattern coverage and fabric weight), and rate of fabric processing. With the quantity of fabric printed held constant, the lowest emission rate represents minimum organic solvent content print paste and minimum print paste consumption, and the maximum emission rate represents maximum organic solvent content print paste and maximum print paste consumption. The average emission rates shown for roller and rotary screen printing are based on the results of a VOC usage survey conducted by the American Textile Manufacturers Institute, Inc. (ATMI), in 1979. The average flat screen printing emission factor is based on information from 2 terry towel printers.

Although the average emission factors for roller and rotary screen printing are representative of the use of medium organic solvent content print pastes at average rates of print paste consumption, very little printing is actually done with medium organic solvent content pastes. The distribution of

Table 4.11-5 (Metric And English Units). TEXTILE FABRIC PRINTING ORGANIC EMISSION FACTORS[a]

EMISSION FACTOR RATING: C

| VOC | Roller | | Rotary Screen | | Flat Screen[b] | |
|---|---|---|---|---|---|---|
| | Range | Average | Range | Average | Range | Average |
| kg/Mg fabric or lb/1000 lb fabric | 0 - 348[c] | 142[d] | 0 - 945[c] | 23[d] | 51 - 191[c] | 79[e] |
| Mg (ton)/yr/print line[c] | | 130[c] (139) | | 29[c] (31) | | 29[c] (31) |

[a] Transfer printing, carpet printing, and printing of vinyl-coated cloth are specifically excluded from this compilation.
[b] Flat screen factors apply to terry towel printing. Rotary screen factors should be applied to flat screen printing of other types of fabric (e. g., sheeting, bottom weight apparel, etc.).
[c] Reference 13.
[d] Reference 5.
[e] Reference 6.

print paste use is bimodal, with the arithmetic average falling between the modes. Most fabric is printed with aqueous or low organic solvent print pastes. However, in applications where the use of organic solvents is beneficial, high organic solvent content print pastes are used to derive the full benefit of using organic solvents. The most accurate emissions data can be generated by obtaining organic solvent use data for a particular facility. The emission factors presented here should only be used to estimate actual process emissions.

References For Section 4.11


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2. *Exxon Petroleum Solvents*, Lubetext DG-1P, Exxon Company, Houston, TX, 1979.

3. Memorandum from S. B. York, Research Triangle Institute, to Textile Fabric Printing AP-42 file, Office Of Air Quality Planning And Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 25, 1981.

4. C. Marsden, *Solvents Guide*, Interscience Publishers, New York, NY, 1963, p. 548.

5. Letter from W. H. Steenland, American Textile Manufacturers Institute, Inc., to Dennis Crumpler, U. S. Environmental Protection Agency, Research Triangle Park, NC, April 8, 1980.

6. Memorandum from S. B. York, Research Triangle Institute, to Textile Fabric Printing AP-42 File, Office Of Air Quality Planning And Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 12, 1981.

7. Letter from A. C. Lohr, Burlington Industries, to James Berry, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 26, 1979.

8. Trip Report/Plant Visit To Fieldcrest Mills, Foremost Screen Print Plant, memorandum from S. B. York, Research Triangle Institute, to C. Gasperecz, U. S. Environmental Protection Agency, Research Triangle Park, NC, January 28, 1980.

9. Letter from T. E. Boyce, Fieldcrest Corporation, to S. B. York, Research Triangle Institute, Research Triangle Park, NC, January 23, 1980.

10. Telephone conversation, S. B. York, Research Triangle Institute, with Tom Boyce, Foremost Screen Print Plant, Stokesdale, NC, April 24, 1980.

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