ENGINEERING CONTROL TECHNOLOGY ASSESSMENT OF THE DRY CLEANING INDUSTRY

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Cambridge, Massachusetts 02140

CONTRACT NO. 210-77-0004

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Cincinnati, OH 45226

October 1980

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DHHS (NIOSH) Publication No. 80–136

ABSTRACT

An assessment of control technology in the dry cleaning industry was made through a program that included literature review, consultation with members of the industry, and surveys of approximately 25 plants. These plants included both commercial and industrial dry cleaners, and plants utilizing perchloroethylene, Stoddard solvent, and Fluorocarbon 113 as the principal solvents. A case study description of each surveyed plant is included, and an overall assessment is made of engineering control technology. Case studies address natural ventilation, general mechanical ventilation, local exhaust ventilation, heat exposure, personal protective equipment use, and exposure levels. In addition, work practices and workplace monitoring systems are documented where pertinent.

The results of this study are useful to those dry cleaning plants interested in adopting effective control technology, and to industry and government personnel responsible for formulating research and development plans.

This report was submitted in fulfillment of Contract No. 210-77-0004 by Arthur D. Little, Inc., under the sponsorship of the National Institute for Occupational Safety and Health.

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ACKNOWLEDGMENTS

The Project Manager of this study at Arthur D. Little, Inc., was R. Scott Stricoff. Key staff participating in the study included Jack Yee, J. Kevin O'Neill, Richard H. Smith, and Clifford H. Summers. The Arthur D. Little project team wishes to thank Donald E. Hurley (NIOSH Project Officer) for his assistance, and other staff of the Division of Physical Sciences and Engineering, specifically Robert Hughes and John Talty, for their interest.

The cooperation of the International Fabricare Institute (IFI) and the Institute of Industrial Launderers (IIL) was invaluable in the conduct of this work. Specifically, William Fisher and John Woolsey of IFI and Mervyn (Bud) Sluizer of IIL were extremely helpful.

In addition, the input and cooperation provided by a number of equipment manufacturers were appreciated by the project team, as were the information and assistance obtained from R.R. Street, Inc., DuPont, and Dow Chemical Co.

I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) has as its principal charge the conduct of research and development efforts which will advance health and safety in the workplace. Some of the major NIOSH programs include the development of recommended standards for occupational exposure to hazardous chemical and physical agents, the identification and evaluation of hazards through industrial hygiene and epidemiological studies, and the development of sampling and analysis methods for the evaluation of industrial environments.

Another important area addressed by NIOSH is the development of information on effective methods for the control of workplace exposures. This control technology research program involves a series of industry-wide engineering control technology assessments in which effective options for control are evaluated and documented. The follow-up to these assessments will entail dissemination of program results to aid industry in the voluntary application of demonstrated control technologies.

The dry cleaning industry, including both commercial and industrial dry cleaning, was selected as the subject for a control technology assessment because this industry is characterized by small employers who have few resources available for research into engineering control effectiveness. The contract to perform this assessment was awarded to Arthur D. Little, Inc., in August 1977. The results of work performed under this contract are presented in this report.

This study began with a review of available data on dry cleaning processes and equipment. Published literature, as well as data obtained from equipment and solvent manufacturers and trade associations, were evaluated.

Based upon information gathered from the above-mentioned sources, a set of plants was selected for field surveys. In selecting plants, the criteria considered included:

- Studying a variety of sizes, ages, and processes representing the diversity found in the dry cleaning industry.
- Evaluating plants utilizing all three principal solvents in use (perchloroethylene, Stoddard solvent, and trichlorotrifluoroethane).
- Surveying both commercial and industrial plants.
- Concentrating on commercial perchloroethylene plants, the dominant type of dry cleaning plant present in the United States.
- Selecting plants identified by industry sources as having effective control technology.

A "tripartite" meeting was held to inform interested industry, labor, and government representatives of the plans for this study. Following this meeting, the field survey program was conducted. At the conclusion of these surveys, the results were evaluated and an assessment of engineering control technology was made.

This report is organized into the following sections:

- Industry Description — describes the processes and operations, identifies the number of establishments and workers, and defines the scope of this study.
- Assessment of Existing Control Technology — explains and evaluates alternative engineering controls employed in the dry cleaning industry.
- Research Recommendations — describes areas in which research and development are needed to provide practical technology which permits achievement of required levels of control.
- Summary and Conclusions — provides an overview of the findings of this study and the recommendations made.
- Appendix A: Case Studies — contains individual case studies according to the subjects included, the types of plants studied, etc.
- Appendix B: Subject Index to Case Studies — lists case studies associated with specific key words.
- Appendix C: Experimental Methods — describes the methods employed in this study for the evaluation of airborne contaminant levels, physical agent exposures, and ventilation system performance.
- Appendix D: Health Effects and Exposure Standards — describes the chemical agents found in this industry and the standards on allowable employee exposure levels.
- Appendix E: Glossary — defines major terminology employed in this report.
- Appendix F: Bibliography — lists documents and sources of information reviewed in the preparation of this report.

It is anticipated that this study will have several uses, including:

- NIOSH can use the information in planning and guiding research and development of engineering control technology.
- Plant operators and their trade associations can use the information in selecting or recommending engineering controls for various types of dry cleaning plants.
- Equipment manufacturers can use this information to identify needed improvements in equipment.
- The OSHA staff can use the information primarily for training field personnel and providing them with a better understanding of the problems in the dry cleaning industry. This report is not designed to provide support for the promulgation of control technology across industrial segments.
- Industrial hygienists can use the study as a reference when advising plant personnel and their representatives on the availability and effectiveness of engineering controls.

2. INDUSTRY DESCRIPTION

2.1 OVERVIEW

The "dry cleaning" process, whereby garments are cleaned in a solvent that is primarily non-aqueous, originated in Paris, France, in the mid-19th century. This process has undergone many refinements and changes since its origin, as gasoline, and carbon tetrachloride have been replaced as dry cleaning solvents by Stoddard solvent, perchloroethylene, and fluorocarbon 113.

The dry cleaning industry encompasses three types of firms. "Commercial dry cleaners" are those engaged primarily in dry cleaning or dyeing apparel and household fabrics other than rugs. This segment of the industry is characterized by a large number of independent businessmen, each of whom operates his own small plant. "Industrial dry cleaners" are those engaged in supplying laundered or dry cleaned work uniforms, wiping towels, dust control items, etc. to industrial and commercial users. "Coin-operated" dry cleaning installations are those that are often found in conjunction with coin-operated laundries. Although the equipment utilized for coin-op dry cleaning is designed to require no attendant operator, many coin-op installations are manned with an attendant who both conducts routine maintenance procedures and assists customers. This study was designed to evaluate the commercial and industrial sectors.

The dry cleaning process utilized by both commercial establishments and industrial plants entails removing soils from garments through the use of a non-aqueous solvent. The dry cleaning solvents currently in use can be classified as "petroleum" solvents and "synthetic" solvents, where the synthetic category includes perchloroethylene (tetrachloroethylene) and trichlorotrifluoroethane (fluorocarbon 113), and the petroleum category includes Stoddard solvent and 140F solvent.

Based upon available census data and communications with industry sources, it is estimated that there are currently 25,000 commercial dry cleaners (SIC code 7216) in the United States, and approximately 75% of these establishments utilize perchloroethylene as their dry cleaning solvent. Most of the remaining commercial dry cleaners employ petroleum solvents, with only approximately 1-2% utilizing fluorocarbon 113 as their sole solvent. (Some larger dry cleaners utilize both fluorocarbon 113 and perchloroethylene.) Approximately 125,000 workers are employed in commercial dry cleaning, with an estimated 30,000 of these employees actually operating the dry cleaning machinery. While all employees in a commercial dry cleaning plant may be exposed to solvent vapors, the dry cleaning machine operators are most directly exposed.

Industrial dry cleaners (SIC code 7218) are those industrial launderers who operate their own cleaning facilities. Industry sources estimate that there are approximately 500 industrial establishments with dry cleaning operations, and these plants utilize either perchloroethylene or petroleum solvents in their dry cleaning operations. Industrial dry cleaners employ approximately 25,000 workers, with an estimated 2000 employees directly exposed to solvent as either cleaning machine operators or maintenance personnel.

In each dry cleaning plant (commercial or industrial), several discrete operations are performed. The following section will describe these operations and the potential of each in exposing employees to hazardous chemical and physical agents.

2.2 PROCESS DESCRIPTION

2.2.1 Garment Marking

"Marking" is the process of identifying garments by attaching tags to each garment or stamping an identification code onto an inner surface of the garment. Marking is the first operation performed upon garments entering a cleaning plant, and is a necessary prerequisite to garment processing. As garments are delivered to the cleaning plant, they are bundled; before processing can begin, garments must be identified so that, at the conclusion of the dry cleaning process, orders can be properly assembled for return to their owners. The marking process usually involves the sorting of garments, both by "due date" and by garment type (light or dark color, fragile or durable garments, etc.).

There are no hazardous chemical or physical agents inherent in the marking process. However, marking areas are often adjacent to the dry cleaning area, and marking personnel may be exposed to diffusing solvent emissions that originate from the dry cleaning equipment.

2.2.2 Spotting

"Spotting" involves the selective application of chemicals, steam, detergent, and/or water to loosen or remove specific stains from soiled garments. Spotting is sometimes done prior to dry cleaning (pre-spotting), but may also be necessary following the dry cleaning step to remove stubborn stains. Depending upon the size of the dry cleaning plant and the nature of the dry cleaning process, spotting can require a full-time employee; however, this step is usually handled by the dry cleaning machine operator. Industrial dry cleaning plants generally do not conduct spotting operations.

The chemicals typically utilized by spotters include chlorinated solvents, amyl acetate, bleaching agents, acetic acid, aqueous ammonia, oxalic acid, hydrogen peroxide, and dilute hydrogen fluoride solutions. These chemicals generally are applied from plastic squeeze-bottles and are then either rubbed into the fabric with a brush, a spatula, or by hand, allowed to soak into the fabric (which is subsequently handled), or flushed with steam applied from a steam gun. Thus, employees engaged in spotting may be exposed to toxic materials through both skin contact with liquids and inhalation of airborne vapors and mists. However, the problem of inhalation exposures is minimized by the small amount of time that an employee is typically engaged in spotting, the small quantity of chemicals used, and the intermittent nature of this operation.

2.2.3 Dry Cleaning

- Equipment/Process Categories

Dry cleaning is a process during which batches of garments are immersed in solvent and agitated within a horizontally mounted cylinder. This "washing" step is followed by a spin cycle to extract solvent and a drying operation to evaporate any remaining solvent from the damp clothing. Most equipment employing petroleum solvents combines the washing and extraction steps in a single machine, with a manual transfer of damp garments necessary prior to the drying (tumbling) step. Some older petroleum machinery involves three separate units: one for washing, a second for extraction, and a third for drying. This three-step process requires two manual transfers of garments, the first of which necessitates handling garments which are "wet" with solvent.

Most commercial perchloroethylene equipment involves the use of two machines, the first to wash and extract garments, and the second to dry. As with petroleum solvents, this "transfer" equipment requires the manual handling of damp garments. Some perchloroethylene equipment combines the washing, extraction, and drying steps into a single unit. This type of equipment, known as "dry-to-dry," is utilized by only a small number (less than 20%) of commercial dry cleaners; the need for larger capacity units to achieve production comparable to that of a transfer plant (due to longer residence of a load in a dry-to-dry machine) has limited its spread.

Fluorocarbon 113 equipment is exclusively of the dry-to-dry type. This design is necessary with fluorocarbon 113 since the solvent is both highly volatile and costly. In order to make fluorocarbon 113 economically competitive with perchloroethylene, the fluorocarbon 113 solvent manufacturer (DuPont) has established a program of machine certification which requires that a certified unit meet stringent criteria on solvent loss rates. The small (less than 4% of plants) extent of dry cleaning market penetration by fluorocarbon 113 is usually attributed to the need for this expensive special equipment.

- Employee Exposures from Cleaning Operations

The dry cleaning machine operator generally is exposed to the highest concentration of solvent within each plant. One major source of direct employee exposure to solvent vapor is the transfer of garments. Garment transfer usually is done manually, and typically involves holding garments wet or damp with either petroleum or synthetic solvents directly in the employee's breathing zone. Most dry cleaners comply with OSHA's current permissible exposure levels of 100 ppm perchloroethylene or 500 ppm Stoddard solvent over an 8-hour time-weighted average; however, manual transfer operations result in employee exposures which exceed the peak allowable concentration (300 ppm) specified by OSHA in 29 CFR 1910.1000 for perchloroethylene. Furthermore, it is unknown how many dry cleaners currently meet the exposure levels recommended by the recent NIOSH criteria documents on perchloroethylene and Stoddard solvent.*

There are several solvent emission sources compounding the employee exposures which occur during garment transfer operations. Among the common sources of solvent emissions are leaking washer and tumbler door gaskets, tumbler aeration dampers, lint trap and button trap doors, improperly operating water separators, and pump gaskets. These emission sources are generally indicative of inadequate maintenance programs; however, they highlight the need for equipment design that minimizes routine maintenance requirements.

Another source of emissions is the premature removal of garments from the drying cycle. This problem may result from attempts to shorten the cycle for increased productivity or from the presence of solvent-retaining items such as comforters.

- Employee Exposures from Solvent Treatment

Other recognized emission sources result from the techniques utilized by dry cleaners to maintain the purity of their solvents. During normal operation, solvent is continuously filtered. The filter medium typically consists of either a series of wire mesh strips coated with diatomaceous earth or of a replaceable filter cartridge. Periodically, the filter medium must be replaced. Where cartridge filters are utilized, they must be drained and discarded, a process which often results in excessive employee exposures to residual solvent. Where diatomaceous earth is employed, the filter medium is removed from its mesh carrier by a back wash system, by air bubbling, or by

*See Appendix D for a discussion of health effects and NIOSH-recommended exposure levels.

mechanical agitation. The collected filter medium is then either discarded (presenting a handling problem) or, as is usually done at perchloroethylene plants, is "cooked" to recover solvent from the filter "muck." Muck cooking can result in significant solvent emissions since the cooker itself contains gaskets which may leak and, if the cooking process is not properly carried out, large amounts of residual solvent may escape into the plant environment when the cooker is opened.

Most dry cleaners also employ distillation to purify their solvent. Petroleum dry cleaners employ continuous vacuum stills, while perchloroethylene cleaners utilize a batch atmospheric distillation process. In addition to the potential leak points (gaskets, joints, etc.) in the still itself, misadjustment of the still's water separator can result in the presence of solvent in open-top wastewater containers. Perchloroethylene stills have another potential emission source: the still's relief vent is often located inside the plant building, and may discharge small quantities of air saturated with perchloroethylene vapor.

Activated carbon adsorbers ("sniffers")*are utilized by most industrial cleaners and by approximately one-third of the commercial perchloroethylene dry cleaners to recover solvent from washer and tumbler exhaust lines and from the general plant environment. However, if the carbon bed is not regenerated frequently by steam stripping, significant quantities of solvent may be lost.

2.2.4 Garment Finishing

The term "finishing" is employed in the dry cleaning industry to indicate the "pressing" of garments to remove wrinkles and restore each garment to its original size, shape, and appearance. Pressing equipment is heated with super-heated steam, and pressers may be exposed to elevated heat levels throughout their work shifts. In addition, the application of heat during the garment finishing step will drive off any residual solvent from the garment, so that pressers may be exposed to solvent vapor.

2.2.5 Assembly

Following the finishing step, garments are sorted and assembled, generally in plastic bags. Employees engaged in assembly operations are exposed to the background levels of solvent and heat found throughout the plant.

*The term "sniffer" is a registered tradmark of the Hoyt Manufacturing Company.

3. ASSESSMENT OF CONTROL TECHNOLOGY

3.1 INTRODUCTION

A variety of control approaches are employed within the dry cleaning industry to minimize employee exposure to solvents. The demonstrated control technologies employed are discussed in this chapter.

For purposes of this discussion, the processes employed within the dry cleaning industry are defined as including:

- Perchloroethylene transfer systems
- Perchloroethylene dry-to-dry systems
- Carbon adsorption systems
- Fluorocarbon systems
- Petroleum systems

Carbon adsorption is identified as a separate process rather than a control technology in this report since adsorption is employed primarily to improve the efficiency of solvent use in perchloroethylene dry cleaning and can (if not properly operated) be a source of employee exposure.

3.2 PERCHLOROETHYLENE TRANSFER SYSTEMS

The most readily apparent source of exposure during this type of dry cleaning is the transfer of damp garments from the washer to the dryer. A number of control techniques are currently applied to this operation.

3.2.1 Work Practices

An important method of minimizing exposure levels during transfer is minimization of the time period during which the damp load is open to the atmosphere. Several work practices can contribute to the achievement of this objective:

- Placement of washer and dryer in close proximity to each other.
- Conduct of transfer as quickly as possible.
- Closing of dryer door immediately upon completion of transfer (rather than waiting until the washer is reloaded).

3.2.2 Local Exhaust Ventilation

Local exhaust ventilation has been applied to the control of transfer exposures in two manners: Exhaust hoods placed between the washer and dryer, and air exhausted through the washer and dryer doors when these doors are open.

The latter ventilation technique has long been recognized as important to exposure control. Standards for dry cleaning plants in Michigan have required 100 f.p.m. per square foot exhausted through washer and dryer doors for many years. While dry cleaning equipment is designed to provide such ventilation, equipment found in operation does not always deliver the desired rate of exhaust. Such failure often results from the connection of washers and dryers to carbon adsorption systems with poorly sized and designed ductwork. In such cases, the improperly balanced ventilation system does not provide optimum performance.

The use of exhaust hoods has been advocated as an adjunct to the use of carbon adsorption solvent recovery systems. For many years, the floor pick-ups provided with carbon adsorbers were accepted as an effective means of collecting solvent evaporating during transfer. This application was apparently based upon the belief that perchloroethylene vapors would sink in air. However, while the molecular weight of perchloroethylene is approximately 5.7 times greater than that of air, the density of air containing several hundred parts of perchloroethylene per million parts of air is virtually identical to the density of "clean" air. Thus, local exhaust hoods placed at the height of the solvent emission source (i.e., the height at which transferred garments are carried) would be expected to achieve better control than floor level hoods. Table 3-1 compares data on ceiling exposure levels in one plant with a properly functioning exhaust system employing floor ducts with data from two plants employing elevated ducts.

The operating conditions of seven commercial perchloroethylene transfer plants are tabulated in Table 3-2. This table indicates that those plants employing working-level exhaust hoods (see Figure 3-1) achieve the lowest ceiling levels, and plants employing relatively large volumes of exhaust through the dry cleaning equipment follow in control effectiveness.

The local exhaust hoods employed in the dry cleaning industry do not reflect the principles of good ventilation design. Hoods observed are best described as sheet metal "boxes" at the end of a duct. The exhaust face of the box may include four sides or a single (front) side. However, no use of flanges, canopies, or slot- or downdraft-type designs were observed. In attempting to capture vapor emissions from a load during transfer, these ventilation approaches do result in some improvement of results; however, hood height is a more important parameter than shape in achieving control (see Appendix A1). As Table 3-1 indicates, simple modification of the hood in one plant to direct exhaust to the emission source reduced the range of ceiling levels by more than a factor of 4. (see Appendix A12).

An additional problem with the local exhaust systems in place is the inability of operators to detect system failures. Several systems were observed in which important branches had failed without the knowledge of the plant operator. The use of permanently-mounted static pressure gages in duct lines would permit the rapid detection of changes in system operation.

3.2.3 General Mechanical Ventilation

General mechanical ventilation often is employed in dry cleaning plants as a means of heat and humidity removal. Concurrently, the general ventilation tends to dilute and flush solvent emissions within the plant.

The configuration of general mechanical ventilation can play an important role in influencing solvent levels within plant areas such as pressing, customer service, and assembly. To the extent possible, it is desirable to design general mechanical ventilation systems such that clean make-up air passes through the dry cleaning area last (i.e., just prior to exhaust). This arrangement tends to assure that emissions from the dry cleaning area are not spread throughout the plant. Figure 3-2 displays examples of desired and undesired exhaust arrangements. If freshly cleaned garments are hung prior to pressing, it is important to provide a positive air flow through the area in which hanging is done.

Table 3-1. Effect of exhaust hood configuration on ceiling exposure levels.

Plant #	Range of Ceiling Levels (ppm)	Size of Load kg(lb)	Height of Hood m(ft)	Hood Location
1	25-40	11(25)	1.2(4)	Between washer and dryer
12	16-43	9(20)	1.5(5)	Above washer door
3	40-71	14(30)	0(0)	Floor
12*	4-9	9(20)	1.5(5)	Above washer door

*Hood modified through placement of deflecting flange and increasing exhaust volume (see Appendix A12).

Table 3-2. Comparison of ceiling levels in commercial perchloroethylene transfer plants.

Plant #	Exhaust Hood Height m(ft)	Exhaust Volume Through Washer & Dryer m^3/s(cfm)	Size of Load kg(lb)	Range of Ceiling Levels (ppm)
12	1.5(5)*	0.10(220)	9(20)	16-43
1	1.2(4)**	0.09(200)	11(25)	25-40
18	None	0.21(440)	20(45)	24-43
3	0(0)	0.19(410)	14(30)	40-71
11	1.8(6)***	0.17(360)	27(60)	20-65
4	0(0)	0.17(350)	23(50)	7-111
19	None	0.12(250)	14(30)	34

*Hood located above washer door.

**Hood located between washer and dryer.

***Hood located above dryer.

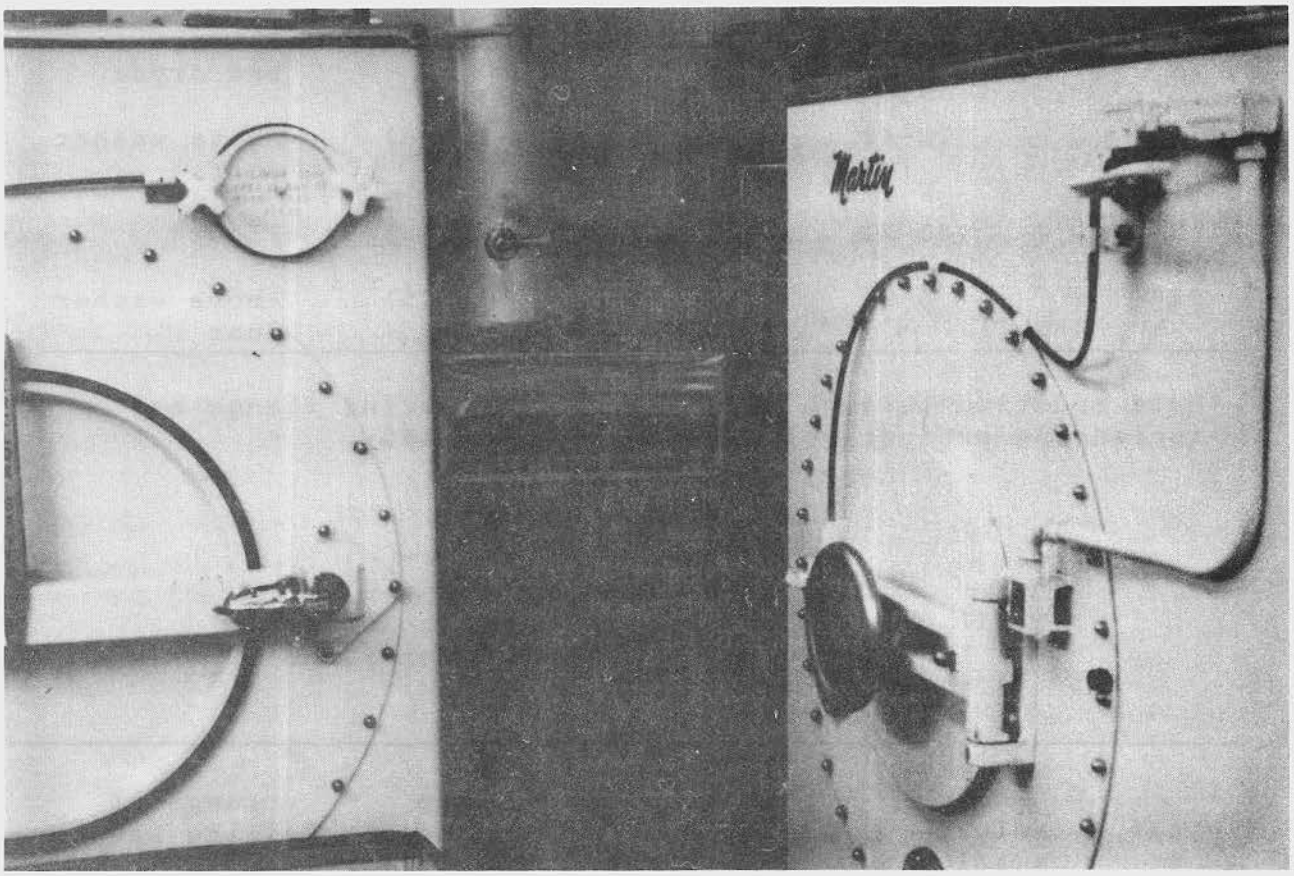


FIGURE 3–1 ELEVATED EXHAUST PICK-UP

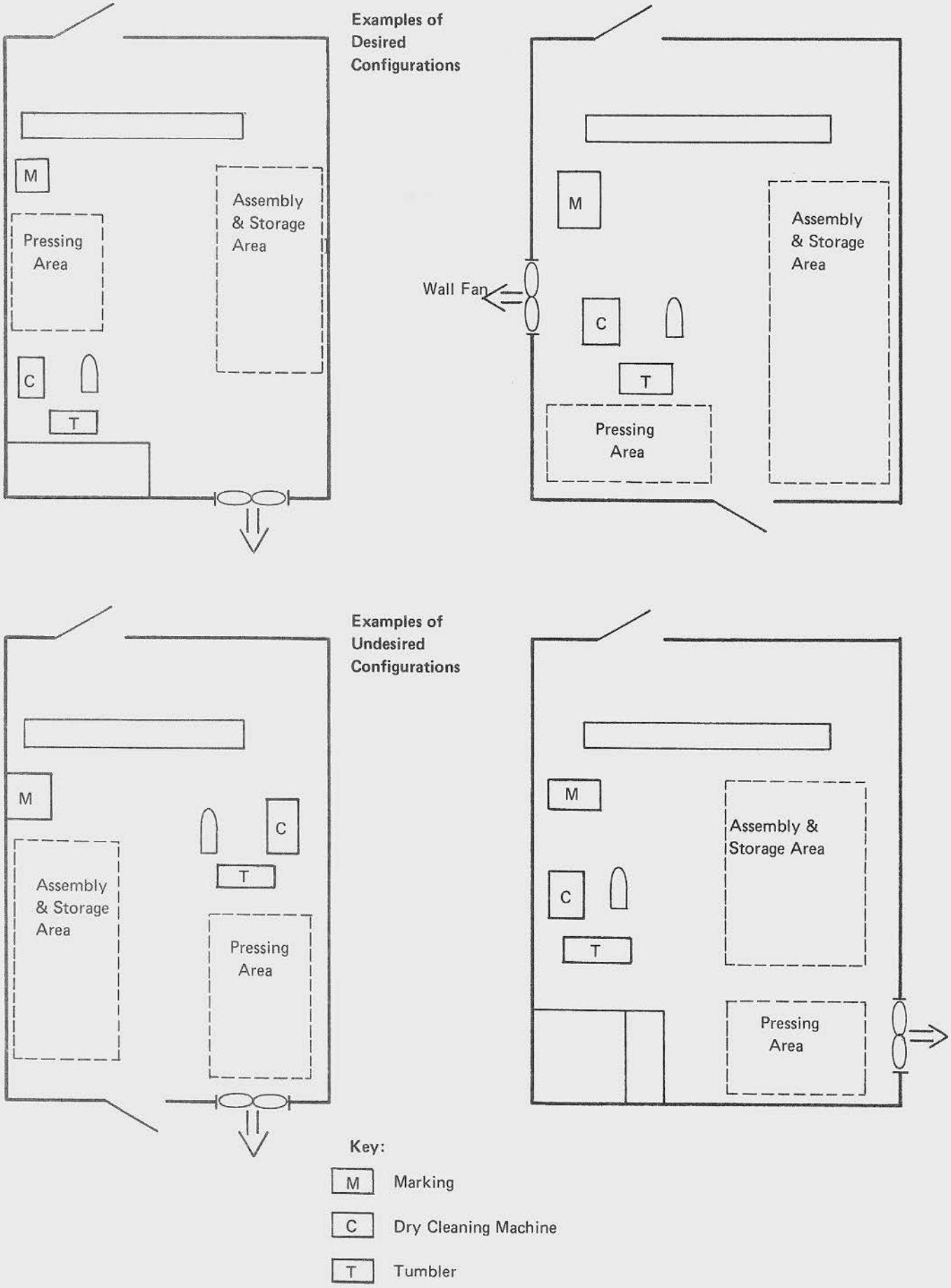


FIGURE 3–2 PRINCIPLES OF GENERAL MECHANICAL VENTILATION DESIGN

3.2.4 Process Isolation

The principle of process isolation has been employed by industrial dry cleaners in placing cleaning equipment in a room separate from other plant operations. This concept is successful where a sufficient quantity of air is exhausted from the dry cleaning room to maintain a slight negative pressure. However, the benefits of this approach are lost if the exhausted air is discharged within the plant without prior air cleaning.

In most industrial plants, isolation of the dry cleaning process minimizes solvent exposures of workers other than the dry cleaning operator; however, this operator spends most of his time within the dry cleaning room, and his exposure level is not directly affected by the isolation. In contrast, isolation of the dry cleaning operation in a commercial plant (see Appendix A19) can produce significant benefits in minimizing operator exposure. The practicality of this control approach for commercial dry cleaners is limited, since sufficient space must be available and the work volume must be light enough to permit the operator's absence from the cleaning area for long periods.

3.2.5 Maintenance

Leakage in gaskets and dampers of dry cleaning equipment is a common contributor to solvent exposures. The presence of leaks was widespread in plants surveyed, and leaks within the dry cleaning operator's work area were not uncommon.

In several plants, leak detection is systematically carried out with equipment such as a halide torch. This approach, which permits identification of vapor leaks that cannot be seen, is effective if used as part of a systematic maintenance program. However, the use of a halide torch is something of an art since fouled nozzles or aspirated dust can make meaningful color changes difficult to identify.

3.2.6 Automated Transfer

An attempt to automate garment transfer has been made through the introduction of perchloroethylene equipment employing the "kissing tumbler" design. This equipment includes a dryer and washer that can move together and tilt in such a manner that garments will be moved by gravity from the washer to the dryer as the units' drums rotate. The cost and complexity of this approach have limited its application to industrial equipment.

In principle, this seems to be a promising approach in that manual handling of damp garments is avoided. However, in practice the tendency of garments to clog the machine doors, necessitating manual freeing, resulted in little benefit being derived from this unit at the plant surveyed during this study. (See Appendix A17). With modifications, such as exhaust supplied to the washer and dryer during transfer and the alternate rotation (clockwise and counterclockwise), of the drum, the "kissing tumbler" approach might be an effective control technique for minimizing ceiling levels during transfer.

3.3 PERCHLOROETHYLENE DRY-TO-DRY SYSTEMS

The use of a single machine for washing, extraction, and drying (a "dry-to-dry" unit) is a relatively new concept in perchloroethylene dry cleaning. The major benefit attributed to this type of equipment is elimination of the need for damp garment transfer, with its attendant worker exposure and loss of solvent.

In many respects, control technology applicable to dry-to-dry systems is similar to that previously discussed for transfer systems. Specifically, discussions of general mechanical ventilation, maintenance, and process isolation will not be repeated. However, work practices and local exhaust ventilation require new consideration in controlling dry-to-dry units.

A dry-to-dry unit cannot process garments as quickly as a comparably sized (weight per load) transfer system since the process residence time in the dry-to-dry unit is longer than that of a transfer washer or dryer. Thus, there is a strong temptation to shorten the cycle time in a dry-to-dry unit. Since dry-to-dry units tend to have larger capacity (on average) than transfer systems, the shortening of drying and aeration time can result in significant residual solvent being left in dried garments. Thus, if garments are handled (e.g., individually sorted or hung) immediately upon removal, elevated ceiling levels may be seen. At two of the three perchloroethylene dry-to-dry plants surveyed, elevated ceiling levels during the garment unloading period were observed (see Table 3-3). Each of these two plants employed a short aeration period followed by immediate garment handling.

The potential retention of solvent emphasizes the importance of ventilation at the cleaning machine door. The air within the garment drum will contain perchloroethylene when the machine door is opened. Application of exhaust ventilation to prevent dragout of this contaminant will help to minimize worker exposures (as is shown in Appendix A16).

3.4 CARBON ADSORPTION SYSTEMS

Although carbon adsorption is often thought of as a control technique, within the context of occupational health, carbon adsorption is another process found in the dry cleaning industry. Adsorbers may be employed to reduce ambient emissions of perchloroethylene and/or to recover solvent for improved plant economics; however, the improper installation and operation of carbon adsorbers can result in intermittent emission of concentrated perchloroethylene vapor, and also can result in continuous emission of lower levels within the plant. (The air collection system employed to supply input to the adsorber is considered a local exhaust system, and discussed in Section 3.2.2 of this report.)

The stripping of adsorbers was found to result in emission of concentrated perchloroethylene vapor through the water separator vent. This emission occurred between the time that steam was introduced to heat the carbon bed and the time that condensation of solvent began. Lasting for 5-10 minutes, an effluent containing 1500-2000 ppm perchloroethylene was released into the plant. A second source of concentrated perchloroethylene was observed in those plants in which the adsorber air outlet terminated within the plant: Upon resumption of normal operation after stripping, the air leaving the adsorber contained high levels of perchloroethylene for a short time. Venting of the adsorber outlet and the water separator back to the adsorber inlet, or outside of the plant, would eliminate these sources of worker exposure.

Several other potential sources of exposure were found to be associated with poor adsorber operation. The use of open buckets for collection of recovered solvent introduces a source of uncontrolled solvent evaporation to the plant environment, and the emptying of these containers necessitates a manual operation with high exposure potential. (This practice is often found for collection of solvent recovered from the dryer as well as the adsorber.) An increasing number of plants employ a fixed pipe or tube to transfer recovered solvent continuously to the reservoir;

Table 3-3. Characteristics of perchloroethylene dry-to-dry plants.

Plant #	TWA Levels (ppm)	Ceiling Level During Unloading (ppm)	Load Size kg(lb)	Drying Time (min)	Aeration Time (min)	Handling of Garments After Unloading
13	15	15	68(150)	16	8	Left in basket
16	20-25	30-35	45(100)	20	0	Sorted and hung
20	5	30	27(60)	13	2	Sorted and

however, this approach curtails the operator's ability to monitor equipment operation as the quantity of recovered solvent cannot be seen. The use of a cumulative flow meter in a recovered solvent transfer line would permit daily monitoring of recovery without the use of open containers.

The dampers used to isolate the adsorber from associated ductwork during stripping can cause important problems when leaks occur. The concentrated perchloroethylene vapor evolving from the carbon bed can escape through leaking dampers into the ductwork, causing perchloroethylene to "back-up" into the equipment ducted to the adsorber (i.e., washer, dryer) and through the floor duct. (While the typical floor duct has a gravity damper to close the duct when no vacuum is applied, these dampers are not air-tight after a reasonable time in service.) Concentrated solvent vapor also can escape through a leaking "bottom" (downstream of bed) damper, entering the plant where the adsorber is not vented outdoors. The detection of adsorber damper leaks can be difficult and, to minimize this problem, in addition to periodic servicing of these dampers, the doors of equipment ducted to an adsorber should remain tightly closed during stripping, and the floor duct (or any other hood connected to the adsorber) should be closed off with a damper during stripping.

A final concern regarding carbon adsorbers is related to "poisoned" or otherwise ineffective carbon beds. Within one plant surveyed, the adsorber was collecting virtually no solvent and the plant operator had no basis for suspecting a malfunction. Since the adsorber was not vented outside the plant, the adsorber was serving to circulate solvent through the plant. The simplest manner of assessing bed performance is monitoring the quantity of solvent recovered, and there is a need for the development of guidelines for plant operators on the relationship between cleaning volume and expected solvent recovery.

3.5 FLUOROCARBON SYSTEMS

Fluorocarbon dry cleaning always employs dry-to-dry equipment to minimize loss of the highly volatile and costly F113 solvent. The users of fluorocarbon systems further benefit from the comparatively high permissible exposure level of 1000 ppm for trichlorotrifluoroethane.

As with dry-to-dry perchloroethylene dry cleaning, the key exposure control problem arises in the unloading of cleaned garments. As Table 3-4 indicates, high ceiling levels can be experienced during the unloading and subsequent hanging of freshly cleaned garments. These high ceiling levels have been overcome in one plant through the application of general mechanical ventilation through the dry cleaning area.

3.6 PETROLEUM SYSTEMS

Petroleum cleaning systems are more prevalent within the industrial dry cleaning sector than the commercial sector. These units always involve garment transfer, and the control problems parallel those of perchloroethylene transfer plants.

3.6.1 Work Practices

Garment transfer in the large petroleum plants often requires that an operator lean into the washer to remove garments. This practice should be avoided as much as possible since it is a major contributor to ceiling exposures.

Table 3-4. Characteristics of fluorocarbon cleaning plants.

Plant #	Load Size kg(lb)	TWA Exposure Level (ppm)	Ceiling Exposure Level (ppm)	Extraction Time (min)	Drying Time (min)
5	14-16(30-35)	40-65	50-550	1.5	13
6	16-18(35-40)	70	90-150	1	18
21	11(25)	20	20-33	2	17

3.6.2 Local Exhaust Ventilation

Since carbon adsorption systems for petroleum solvents have not been adopted within the industry, local exhaust ventilation has not been employed in petroleum dry cleaning plants. It is anticipated that the use of local exhaust would reduce ceiling exposures during garment transfer. The Environmental Protection Agency is currently testing a carbon adsorption installation at a petroleum dry cleaning plant.

3.6.3 General Mechanical Ventilation

As discussed relative to perchloroethylene transfer systems, general mechanical ventilation is most effective when designed to avoid spreading solvent vapor throughout the plant area.

3.6.4 Process Isolation

The separation of dry cleaning equipment from other plant areas is often made in petroleum cleaning plants. This separation may be required by local fire protection regulations. Placing dry cleaning equipment in isolated plant areas is effective in minimizing exposure of plant workers not directly concerned with the cleaning process.

3.7 NEW TECHNOLOGY

Several new developments in dry cleaning equipment offer opportunities to achieve reduced ambient emission of solvent. The effect of these changes on worker exposures is discussed in this section.

3.7.1 Totally Enclosed Perchloroethylene Machines

Two dry-to-dry perchloroethylene machines which do not vent any air to the atmosphere are now available. Each of these units employs refrigeration to condense solvent from the air passing through garments during aeration. These systems preclude the need for carbon absorption units; however, since these units do not vent to the atmosphere, it is not possible to draw air through the machine door during garment loading/unloading. One manufacturer is offering this recirculating refrigeration system as an add-on package to convert existing dry-to-dry units to totally enclosed machines.

A survey of one plant utilizing this technology indicated that employee exposures with the enclosed system are as low as those seen in the best conventional dry-to-dry operations. The refrigeration system appears to remove sufficient solvent to avoid elevated ceilings during unloading.

3.7.2 Petroleum Carbon Absorber

The Environmental Protection Agency (EPA) is sponsoring a pilot test of the use of carbon absorption for recovery of petroleum solvent. The use of carbon absorption systems at petroleum plants would reduce atmospheric emission of solvent and, simultaneously, provide local exhaust collection systems comparable to those used at perchloroethylene transfer plants. It is anticipated that this would permit reduction of employee exposure levels at many petroleum plants.

3.7.3 Petroleum Recovery Tumbler

A new petroleum recovery tumbler (dryer) has been introduced recently to permit reclaiming of solvent that is currently emitted to the atmosphere. This unit operates in a manner similar to the conventional perchloroethylene recovery tumbler, and reportedly avoids the potential fire hazard associated with the application of a recirculating heating-condensation cycle to petroleum solvents. This device will do little to reduce worker exposures, but its operation and maintenance will afford opportunities for increased exposures.

4. RESEARCH NEEDS

The dry cleaning industry has been the subject of relatively little applications-oriented research. Most control technology currently in place is the result of evolution rather than design. With the two major dry cleaning solvents under close scrutiny by both NIOSH and EPA, further research is needed to define the limits of feasible control and the effective approaches to achieving reduced exposure levels.

Several specific areas are identified in this section as topics for research activity. Because the dry cleaning industry is predominantly populated by small businesses which lack the resources to undertake research efforts, NIOSH should take the lead in sponsoring such research. This is a worthwhile area of activity for NIOSH since a relatively large number of workers (150,000-200,000) are exposed to chemicals which recent criteria documents have identified as being more hazardous than previously thought. In undertaking these research activities, close cooperation with dry cleaning industry groups will be important to assure that the research results have practical application within the industry.

4.1 OPTIMIZATION OF VENTILATION DESIGN

The use of local exhaust systems for control of exposures during transfer has not been optimized through experimentation with flanged slot and downdraft systems. The effectiveness of improved design and increased capture velocities should be investigated.

4.2 OPTIMIZATION OF CLEANING CYCLES

Both fluorocarbon and perchloroethylene dry-to-dry systems are capable of producing high employee ceiling exposure levels due to the retention of solvent in dried loads. The extent to which this retention occurs, and the extent to which it can be avoided through modification of the extraction, drying, and aeration cycle length should be determined.

4.3 GASKET MATERIALS

Gasket leaks within dry cleaning plants are a common problem. A variety of materials are used for these gaskets, and determination of the most durable materials would be useful.

4.4 DISSEMINATION OF CONTROL INFORMATION

Within the dry cleaning industry, plant operators are often unfamiliar with the basic principles of ventilation. Training materials which could familiarize dry cleaners with ventilation design and maintenance practices would help ensure the proper use of this control technique. Development of such self-administerable training materials should be undertaken.

4.5 EFFECTIVENESS OF MACHINE EXHAUST

There seems to be little data to support the choice of exhaust flow rate provided through open washer and dryer doors. Investigations should be made to determine whether increased exhaust rates are effective in achieving reduced employee exposure levels.

4.6 PORTABLE LEAK DETECTION EQUIPMENT

The halide torch is most commonly employed as a leak detector in the dry cleaning industry. However, this device requires subjective interpretation and is prone to misleading conclusions. Current detector technology is such that an inexpensive detector could be developed for use in leak detection by both synthetic and petroleum solvent dry cleaners. Such a detector need not be chemical-specific since only localized levels of several hundred ppm or more are of interest, and it can be assumed that only the solvent of interest will be present at these levels.

4.7 RECOVERY TUMBLER MONITOR

The drying cycle provided in commercial and industrial dry cleaning processes is generally controlled by time and the cleaner's experience or by temperature. No tumbler currently available employs a vapor concentration sensor to control the length of the drying cycle. Such a mechanism would be useful, particularly for controlling the drying time applied to heavy, solvent retaining items such as comforters. Exploration of the feasibility of this dryer control should be pursued.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Local exhaust, general mechanical ventilation, work practices, maintenance, and process isolation all may be effectively employed to control worker exposures in dry cleaning plants. Exposure levels below the OSHA standards for perchloroethylene, Stoddard solvent, and fluorocarbon 113 are achievable with existing technology except the current OSHA maximum allowable peak for perchloroethylene is exceeded during garment transfer. Exposure levels below those recommended in NIOSH Criteria Documents for perchloroethylene and refined petroleum products are also achievable. A complete discussion of the effectiveness of various control technologies is found in Section 3 of this report.

Due to reduced natural and (in some cases) general mechanical ventilation, employee exposures at plants in temperate climates are higher during cold weather than during warm weather. While the magnitude of this difference is difficult to quantify due to day-to-day and plant-to-plant variations in operating conditions, the winter levels appear to be approximately 10-40% higher than summer levels.

State-of-the-art control technology does not reflect the optimum level of control achievable since many basic principles of industrial hygiene engineering have not been applied to ventilation and plant design.

5.2 RECOMMENDATIONS

Improvements which should be adopted in existing operations are described in the discussion section of this report (Section 3). These recommendations are summarized below:

- Elevated hoods between the washer and dryer of transfer operations should be adopted as a collection device in a local exhaust system. Floor ducts are not effective in the control of transfer emissions.
- Exhaust ventilation should be supplied through the doors of all washers and dryers.
- Permanently mounted static pressure gages should be employed on each branch of the local exhaust system to allow the identification of changes in system performance.
- General mechanical ventilation should be oriented to avoid the dispersion of solvent into peripheral plant areas.
- When garments are individually hung immediately after removal from the dryer, adequate ventilation should be provided.
- When a carbon absorber or dryer is directly piped into the solvent reservoir, a cumulative flow meter should be installed to allow monitoring of the amount of solvent recovered daily.
- Carbon absorber outlet ducts should terminate outside of the plant. Also, the absorber water separator should be ducted to the adsorber inlet or should vent outdoors.

- Gaskets and dampers should be regularly checked for leaks with a halide torch or comparable device.
- Effective work practices should be used in transfer operations: The washer and dryer should be in close proximity, the transfer should be conducted quickly, and the dryer door should be closed immediately upon loading.
- Care should be taken to avoid abrupt changes in duct size in a local exhaust system.
- Where space permits, process isolation provides an effective means of minimizing solvent levels within the plant. It should be recognized that this technique is only effective in controlling the cleaning operation's exposure level if he spends a significant amount of time away from the cleaning equipment.
- Control systems in temperate climatic areas should be designed for effectiveness in winter conditions, when exposure levels will not benefit from natural ventilation.
- No open (uncovered) buckets should be used for collecting solvent from recovery tumblers or sniffers.

Research should be undertaken in the following areas (see Section 4 of this report):

- Ventilation design optimization
- Cleaning cycle optimization
- Gasket materials
- Dissemination of control information
- Machine exhaust
- Leak detection equipment
- Tumbler vapor monitor

APPENDIX A1
CASE STUDY NO. 1

A. PROCESS AND EQUIPMENT

This is a relatively small perchloroethylene transfer plant in the Middle-Atlantic area. The average dry cleaning volume of the plant is 567 kg/week (1250 pounds/week), and the average solvent mileage is reportedly 5000-6000. The plant employs 1 cleaner/spotter, 1 presser, and 1 presser/ cleaner, as well as 1 1/2 support employees.

The dry cleaning washer and tumbler are a Martin 30-0 and 30-PT, respectively. Each unit is approximately 11 1/2 years old. A Hoyt Sniff-O-Miser Model 4 (approximately 9 1/2 years old) is employed for solvent recovery. Filtration and distillation are performed in a 7571 L (2000 gal.) per hour capacity Per Autoflex AF20-3C/AF30-B which was purchased 5 years ago to replace a 5678 L (1500 gal.) per hour capacity unit. The original (smaller) unit necessitated replacement of filter aid after 8 loads, which often represented less than a full-day'swork. The general layout of this plant is depicted in Figure A1-1.

The adsorber is stripped daily prior to the beginning of cleaning. Recovered solvent, 15.5 L (4.1 gal.) from 128.4 kg (283 lbs.) of cleaning over 5 hours, is collected in an open bucket. Cooker condensate runs through a tube which is piped directly into the washer solvent reservoir. Tumbler condensate runs into a covered bucket (see Figure A1-2). Approximately 15.5 L (4.1 gal.) solvent were recovered from 91 kg (200 pounds) of cleaning.

Cleaning is done in 11-kg (25-pound) loads (average), with a 7 to 8-minute wash followed by a 5-minute extraction. During transfer, the damp load is exposed to the plant air for approximately 25 seconds, with reloading of the washer accomplished within another 30 seconds. The drying cycle includes 15 minutes for recovery, followed by a 5-minute aeration (timed). The dryer is run empty following unloading to preheat to at least 52°C (125°F) before transfer.

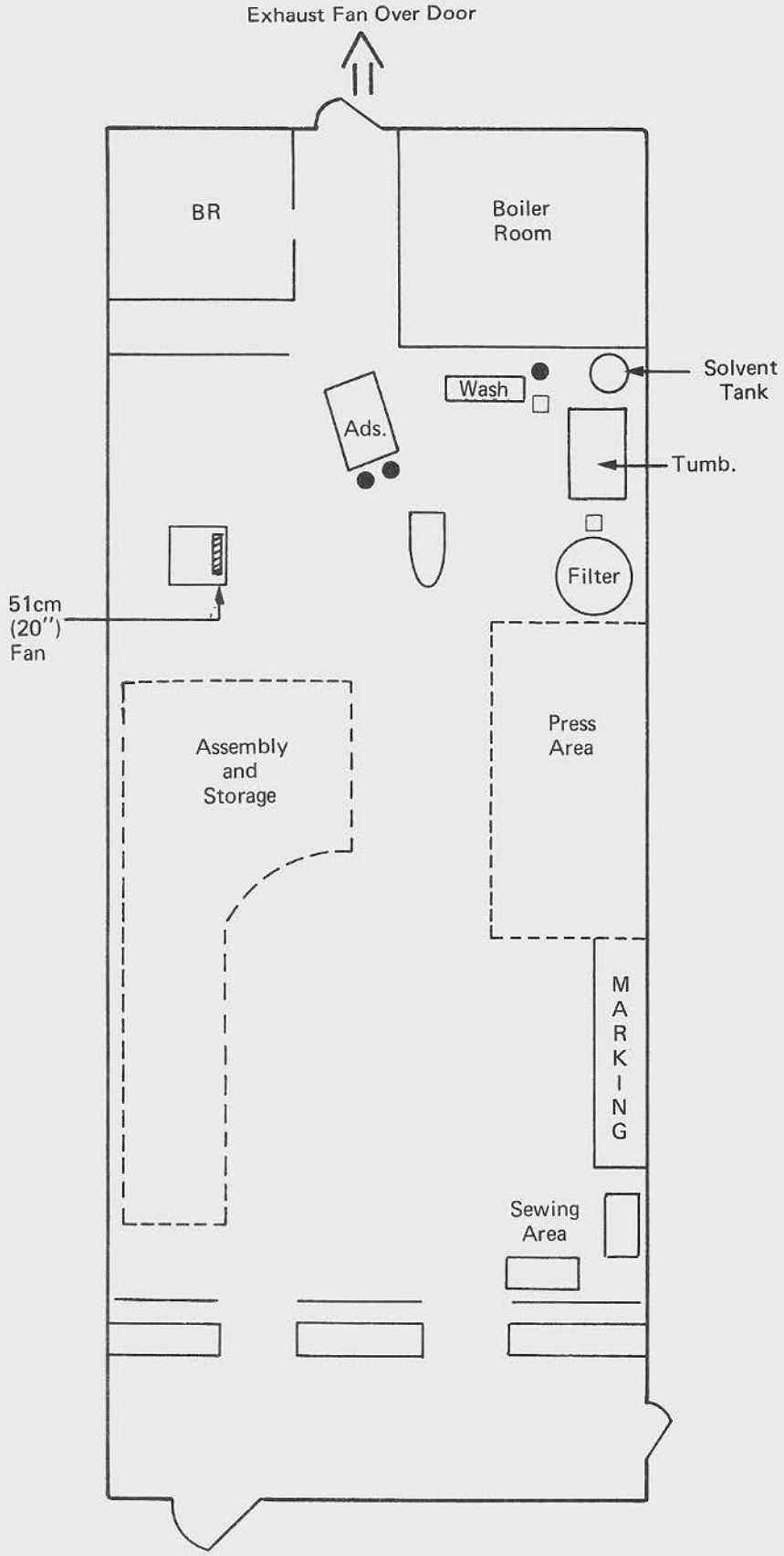
The filter is dropped, cooked, and cleaned out (demucked) at the end of the day. Muck is discarded as trash. Filter-aid is added to the washer as a slurry in perchloroethylene, requiring manual stirring prior to addition.

B. NATURAL VENTILATION

This plant has no windows. There are two doors in the front of the plant and one in the rear. The front doors are kept closed by mechanical door closers, and one had a partially open transom above it. The rear door is kept open or closed, depending upon weather conditions.

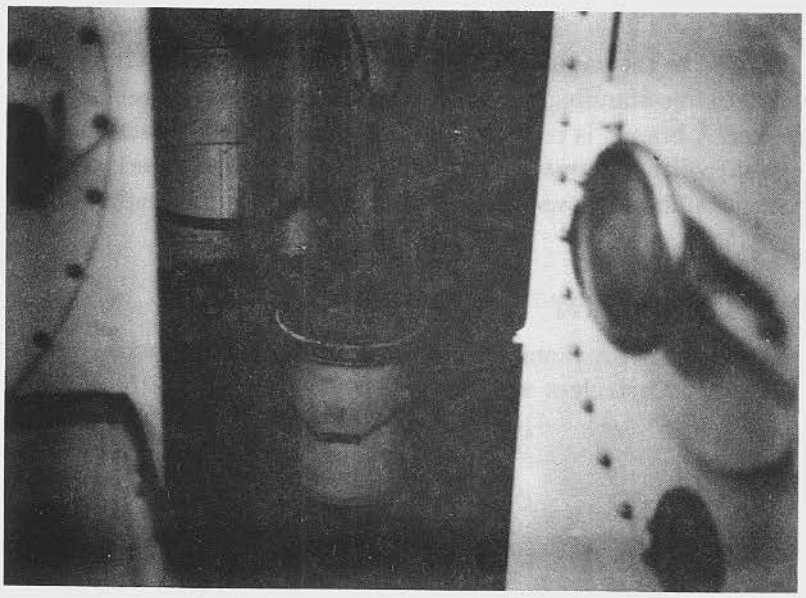
C. GENERAL MECHANICAL VENTILATION

A 76 cm (30-inch) fan is mounted above the rear door. This fan is started when the workers begin to feel warm. The face velocity of this fan was measured as 2.3 m/s (450 f.p.m.). A 51 cm (20-inch) fan is placed opposite the spotting board (see Figure A1-1) to provide cooling and vapor dilution at the board.



Key:
- □ Duct
- ● Solvent Collection Bucket

FIGURE A1–1 GENERAL PLANT LAYOUT



Covered Receptacle for Tumbler Condensate

Flexible Duct Exhaust Pick-up Used to Recover Vapor as Cooker Door is Opened

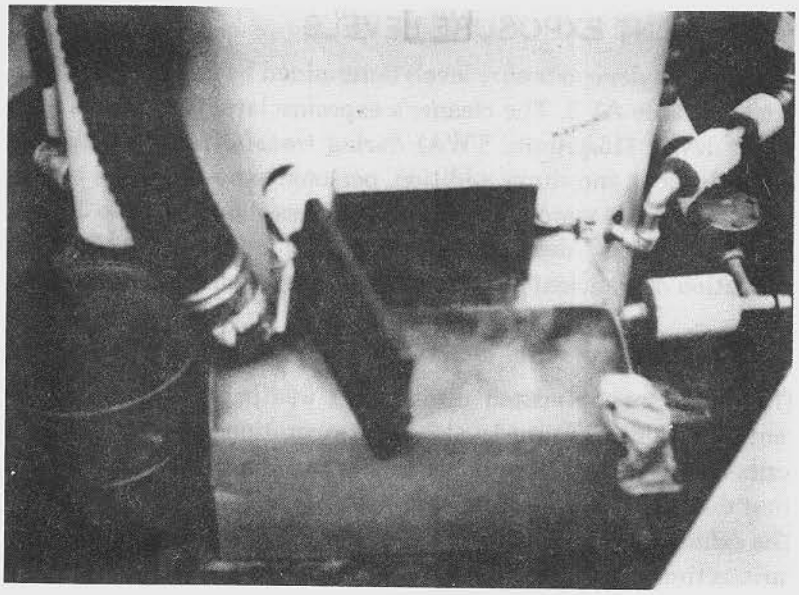


FIGURE A1–2

D. LOCAL EXHAUST VENTILATION

The local exhaust system, which is tied to the vapor adsorber, is shown schematically in Figure A1-3. This system includes branches to free-standing hoods between the washer and tumbler, and between the washer and filter/cooker. A branch is connected to the tumbler vent. In addition, a flexible duct is connected to the washer/filter duct permitting capture of vapor when the cooker is opened for muck cleanout. Dimensions and airflows measured in this system are displayed in Table A1-1.

E. PERSONAL PROTECTIVE EQUIPMENT

A dual-cartridge organic vapor respirator (MSA Comfo) is worn during garment transfer, muck cleanout, and filter-aid slurry mixing. Cartridges are changed when odor breakthrough is detected.

F. LEAK DETECTION

Small leaks were detected at the following locations:

washer door,
dryer door,
washer watch glasses,
cooker cleanout door,
cooker viewing part, and
tumbler water separator.

G. SOLVENT EXPOSURE LEVELS

Perchloroethylene exposure levels determined by charcoal tube samples/GC analysis are summarized in Table A1-2. The cleaner's exposure level (5 ¾ hours TWA) was less than 10 ppm, and ceiling levels (15-minute TWA) during transfer ranged between 25 ppm and 40 ppm. During muck cleanout and slurry addition, personal exposure levels were approximately 25-35 ppm. Area levels within the store area ranged from less than 1 ppm to 13 ppm. Area levels at various times during the survey (determined with a photo-ionization detector) are reported in Figure A1-4. An evaluation of transient solvent levels during garment transfer is displayed in Table A1-3.

H. COLD WEATHER SURVEY

This plant was re-visited during cold weather to determine the effect of decreased natural ventilation on exposure levels. Plant operations were found to be the same as previously described. No changes were found in flow rates in the local exhaust system. The transom above the front door was closed during this survey, and the fan opposite the spotting board was not in use. The exhaust fan above the rear door was not used; however, the rear door was partially opened at various times during the day by the cleaner to maintain his comfort.

The cleaner's personal exposure level, averaged over his workday, was 13.8 and 18.3 ppm on the two days of this survey. Ceiling levels (15-min. TWA) during garment transfer ranged from 23-35 ppm. These long-term levels are higher than those measured during warm weather (10 ppm work shift average); however, the ceiling levels are comparable to previously measured levels (24-40 ppm). In addition, the level measured during muck cleanout was approximately 38 ppm (15-min. TWA) versus 25-35 ppm during the previous survey. Personal exposure and background levels in the plant are listed in Tables A1-4 and A1-5.

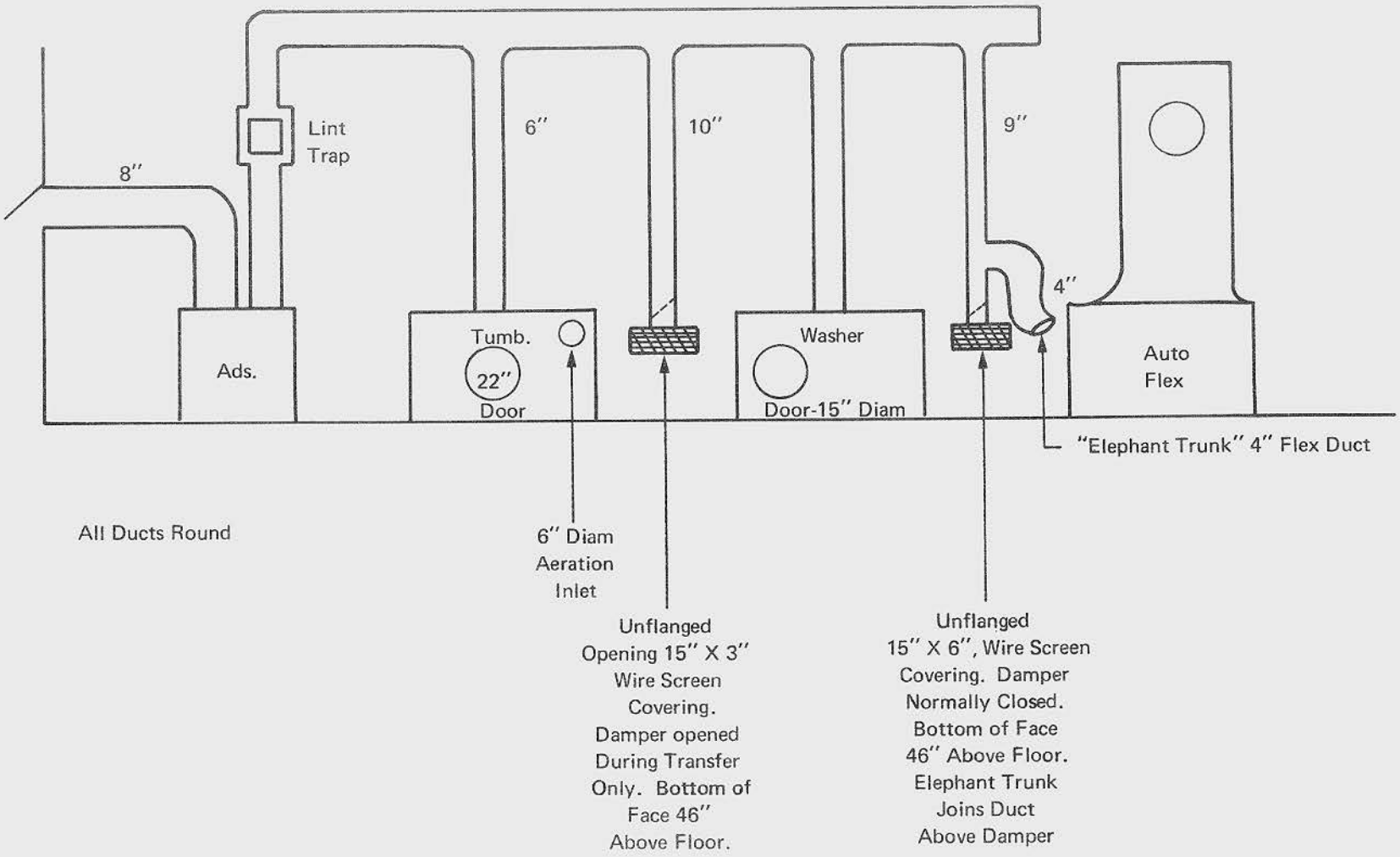


FIGURE A1–3 LOCAL EXHAUST VENTILATION LAYOUT

Table A1-1. Local exhaust ventilation system parameters.

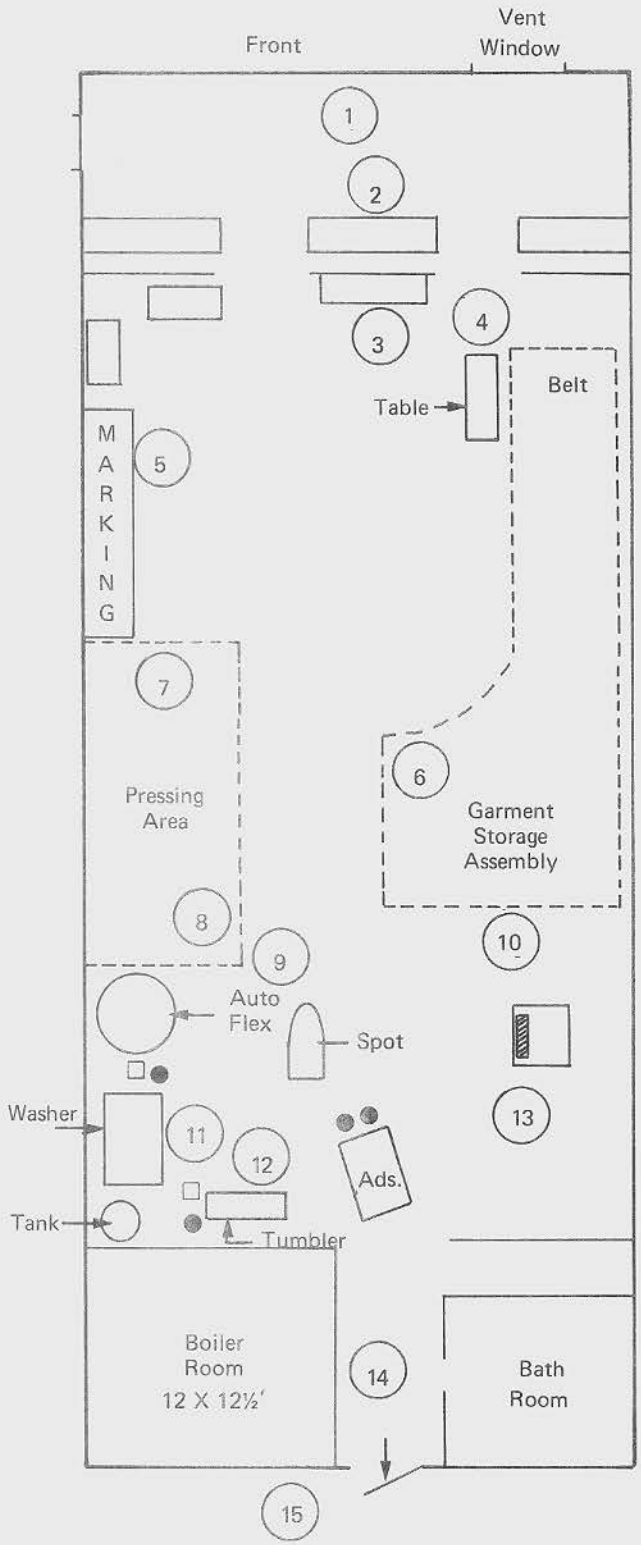
Location	Diameter cm(in.)	Air Flow m^3/s (cfm)			Static Pressure cm(in.)
		During wash	During aeration	During transfer	
Main out	20.3(8)	0.13(280)	0.13(270)	0.15(320)	0.58(0.23)
Tumbler	15.2(6)	0	0.07(140)	0.05(110)	-1.3(-0.5)
Between Washer/Tumbler	25.4(10)	- - - CLOSED[1] - - -		0.1(220)	--
Between Tumbler/Filter	22.9(9)	- - - - - CLOSED[1]- - - - - - -			-1.2(-.49)[2]
Flex Duct	10.2(4)	0.08(175)	0.06(130)	0.04(88)	--

1. Manual dampers used to close duct.

2. Measured in line upstream of damper and flex duct tap.

Table A1-2. Airborne concentration measurements.

Sample #	Location	Duration (hr:min)	Start time	mg/m^3	ppm
1	Cleaner personal sample	2:02	8:43	118	17
2	Pressing area	1:58	8:59	40	6
3	Researcher personal sample	2:00	9:04	91	13
4	Store area	1:14	9:48	30.5	4
5	Cleaner personal sample	2:00	10:45	54	8
6	Cleaner during transfer	0:15	11:29:20	260	38
7	Researcher personal sample	3:40	11:04	91	13
8	Pressing area	3:00	11:25	5.6	1
9	Cleaner during transfer	0:15	11:48:15	169	25
10	Cleaner during transfer	0:14:15	12:37:45	170	25
11	Store area	2:00	12:20	1.5	7.5
12	Cleaner personal sample	1:42	12:45	19.3	3
13	Cleaner during transfer and solvent additive	0:15	1:21	181	27
14	Cleaner during demucking	0:10	2:00	162	24
15	Pressing area	3:33	8:00	7	1
16	Cleaner area	2:40	8:05	97	14
17	Store area	3:24	8:08	7.6	1
18	Exhaust fan area (over door)	5:39	8:36	54	8
19	Void	--	--	--	--
20	On transfer duct	--	9:20	878	129
21	On floor below transfer duct	--	9:20	1060	156
22	On transfer duct	--	9:50	293	43
23	On floor below transfer duct	--	9:50	1481	218
24	Cleaner personal sample	--	10:16	132	19
25	Void	--	--	--	--
26	On transfer duct	--	10:40	771	114
27	On floor below transfer duct	--	10:40	223	33
28	Cleaner area	3:23	10:45	107	16
29	Store area	2:33	11:32	85	13
30	Pressing area	2:30	11:33	33	5
31	Cleaner personal sample	2:15	11:53	34	5
32	At transfer duct face	0:01:00	--	1000	147
33	On transfer duct	0:01:02	--	1570	231
34	At transfer duct face	0:01:02	--	1420	209
35	At transfer duct face	0:01:05	--	570	84
36	On transfer duct	0:01:05	--	319	47
37	Cleaner during demucking	0:28:20	--	246	36



Concentrations by Time and Location
(ppm)

Point	0830	0925	1020	1420	0830	0950	1355
1	5	5.5					
2	5.5		<1	3	3	2.5	1.8
3	5.5	7	<1	3	4	2.5	2
4	6	7	<1	3	4	2.5	2
5		7	<1	3	4	3	2.2
6	6		6	15	7	11	7.5
7	5	8	1	4	5	3	2
8	10	10	5	4	5	7	7
9	8	16	2	12	8	8	
10	6		6	14	11	11	9
11	10-15	15	2	12	5	7	
12	12-17	14	2	18	5	8	
13	9	13	2.5	18	4.5	18	8.2
14	8	13	3	9	14	13	
15	2		2	4	3		
		Following Transfer		Following De-muck		Following Transfer	

[1]Measured with h-nu photoionization meter

FIGURE A1–4 AREA LEVELS[1]

Table A1-3. Instantaneous airborne levels during garment transfer.

At operator's breathing zone[1]

Time from start of transfer (sec.)	Concentration read (ppm)
15	40
17	380
20	430
22	570
27	760
32	520
38	570
40	600
45	380
48	240
50	130
55	120
61	90
67	100
72	90

Excursion over peak PEL

At exhaust fan face[2]

Time (sec.)	Conc. (ppm)	Time	Conc.
0	3	110	11
10	3.5	120	11
20	4	135	12
30	8	150	11
40	14	165	10
50	30	180	12
60	24	195	10
70	18	210	7
80	20	225	7
90	15	240	0
100	13	255	7
		260	7

1. Measured with Gas Tech Halide Meter.
2. Measured with h-nu Photo-Ionization Meter.

Table A1-4. Airborne perchloroethylene concentration measurements during cold weather.

Sample #		Duration (hr:min)	Start Time	mg/m^3	ppm
1	Cleaner personal sample	2:53	8:00	97	14.3
2	Pressing area	1:58	8:00	58	8.6
3	Presser personal sample	1:00	8:00	70	10.3
4	Store area	3:11	8:00	52	7.7
5	Cleaner during transfer	0:05	8:23	450	66
6	Dryer area	1:29	8:00	420	62
7	Cleaner during transfer	0:05	8:41	289	43
8	Cleaner personal sample	2:11	9:00	41	6
9	Cleaner during transfer	0:05	9:16	360	53
10	Dryer area	1:42	9:29	310	45
11	Cleaner during transfer	0:05	9:47	240	35
12	Pressing area	1:13	9:58	21.5	3.2
13	Cleaner during transfer	0:05	10:14	320	47
14	Cleaner during transfer	0:05	10:35	430	63
15	Cleaner personal sample	0:29	10:54	74	11
16	Cleaner personal sample	2:00	8:16	103	15
17	Presser personal sample	1:52	8:56	55	8.1
18	Store area	2:59	9:03	77	11
19	Dryer area	1:10	9:03	239	35
20	Pressing area	3:00	9:03	66	9.7
21	Cleaner during transfer	0.05	9:38	286	42
22	Cleaner during transfer	0:05	10:07	400	59
23	Dryer area	1:50	10:13	380	56
24	Cleaner personal sample	1:49	10:16	149	22
25	Cleaner during transfer	0:05	10:37	340	50
26	Presser personal sample	1:20	10:48	80	12
27	Cleaner during transfer	0:05	11:06	300	44
28	Cleaner during transfer	0:05	11:28	340	50
29	Cleaner during demucking	0:05	12:00	530	78

Table A1-5. Background solvent levels during cold weather (ppm perchloroethylene).

Location	Time								
	8:00	9:00	10:00	11:00	8:00	9:00	10:30	11:30*	12:15
Outside rear door	<1	<1	<1	3	-	<1	<1	<1	1
Inside rear door	9	16	14	5	5	4	10	7	20
Front of washer	12	13	8	9	7	5	10	14	9
Front of dryer	12	12	8	7	7	5	8	15	9
Beside spotting board	10	18	10	7	6	3	7	14	9
Garment storage - rear	11	11	8	5	6	4	7	6	9
Garment storage - front	10	8	7	3	6	4	6	5	9
Pressing area - rear	10	8	7	3	6	3	6	5	7
Pressing area - front	10	8	7	3	6	3	6	5	7
Marking area	9	8	6	3	5	3	5	5	7
Customer service area	9	8	6	3	5	3	5	4	7

*Just after transfer
Day 1: Door closed until 8:30, then remained open
Day 2: Door closed until 8:45, then remained open until 11:15. Closed from 11:15 on.

It is apparent that background levels in the plant were higher when natural and general ventilation were reduced. Little change in ceilings during periods of high exposure were noted. While some of the elevation in backgrounds was probably due to a leak in the muck cooker, this leak was largely controlled by the flexible exhaust duct.

I. MODIFIED EXHAUST SYSTEM

During surveys of this plant, experiments were conducted to determine the effect of flanging and shaping of the collecting hood on its effectiveness in reducing exposure levels. The configuration of this hood is shown in Figure A1-5. The ceiling exposures during transfers with and without the modified hood are shown in Table A1-6. These data indicate that, while a slight reduction in ceiling level is observed with the hood, the hood height is the primary factor influencing its effectiveness, with shape a secondary factor.

CONCLUSIONS

The use of an elevated (from floor) hood to capture vapor during transfer is effective in controlling ceiling levels in this plant. Transfer and cooker cleanout do result in some elevation of background perchloroethylene levels within the plant. Hood height is more important than shape in controlling exposure levels.

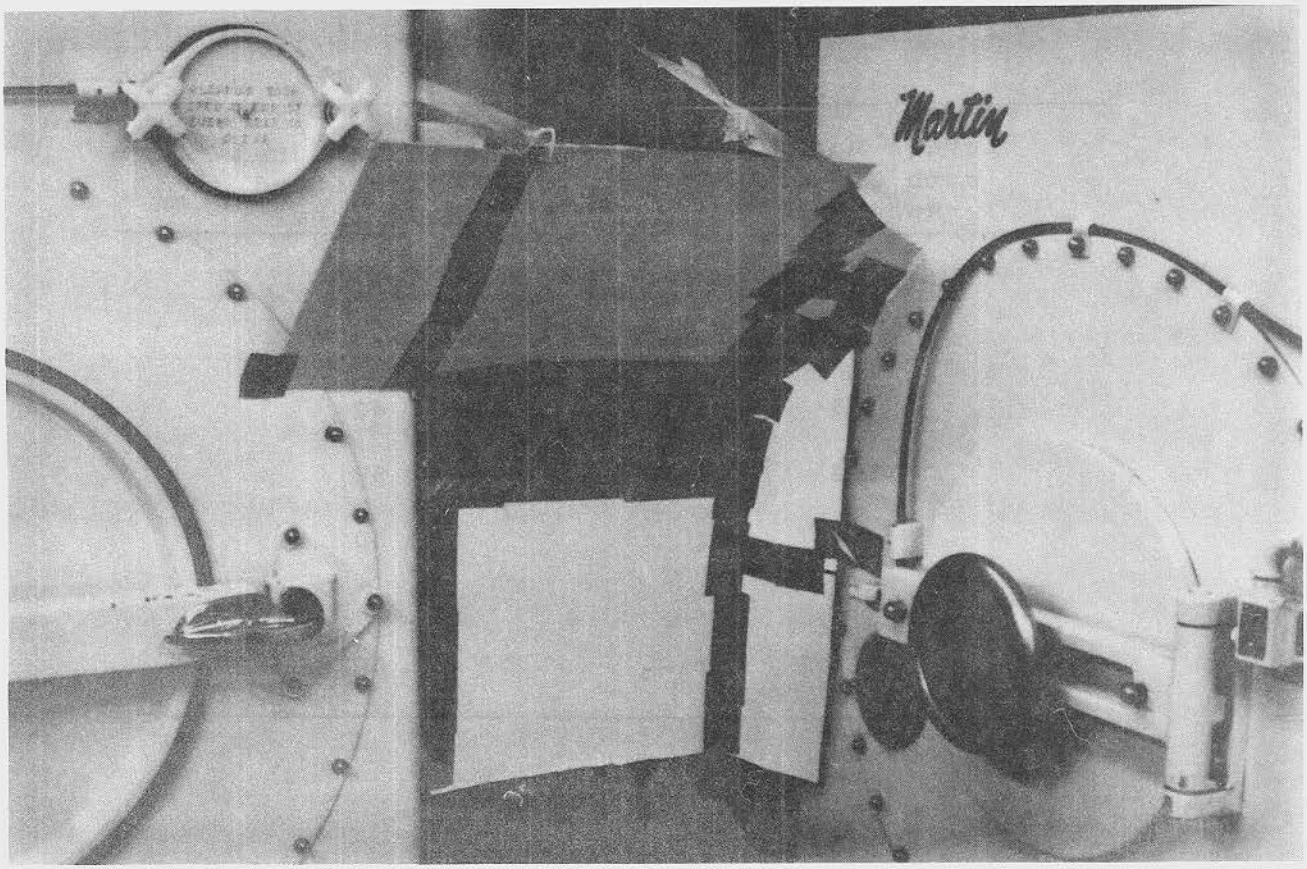


FIGURE A1–5 MODIFIED EXHAUST PICK-UP

Table A1-6. Effect of hood shape on ceiling level.

	Levels Measured With Original Hood (ppm)	Levels Measured With Modified Hood (ppm)
	66	35
	43	47
	53	42
	44	59
	50	50
Mean:	51.2	46.6

APPENDIX A2
CASE STUDY NO. 2

A. PROCESS AND EQUIPMENT

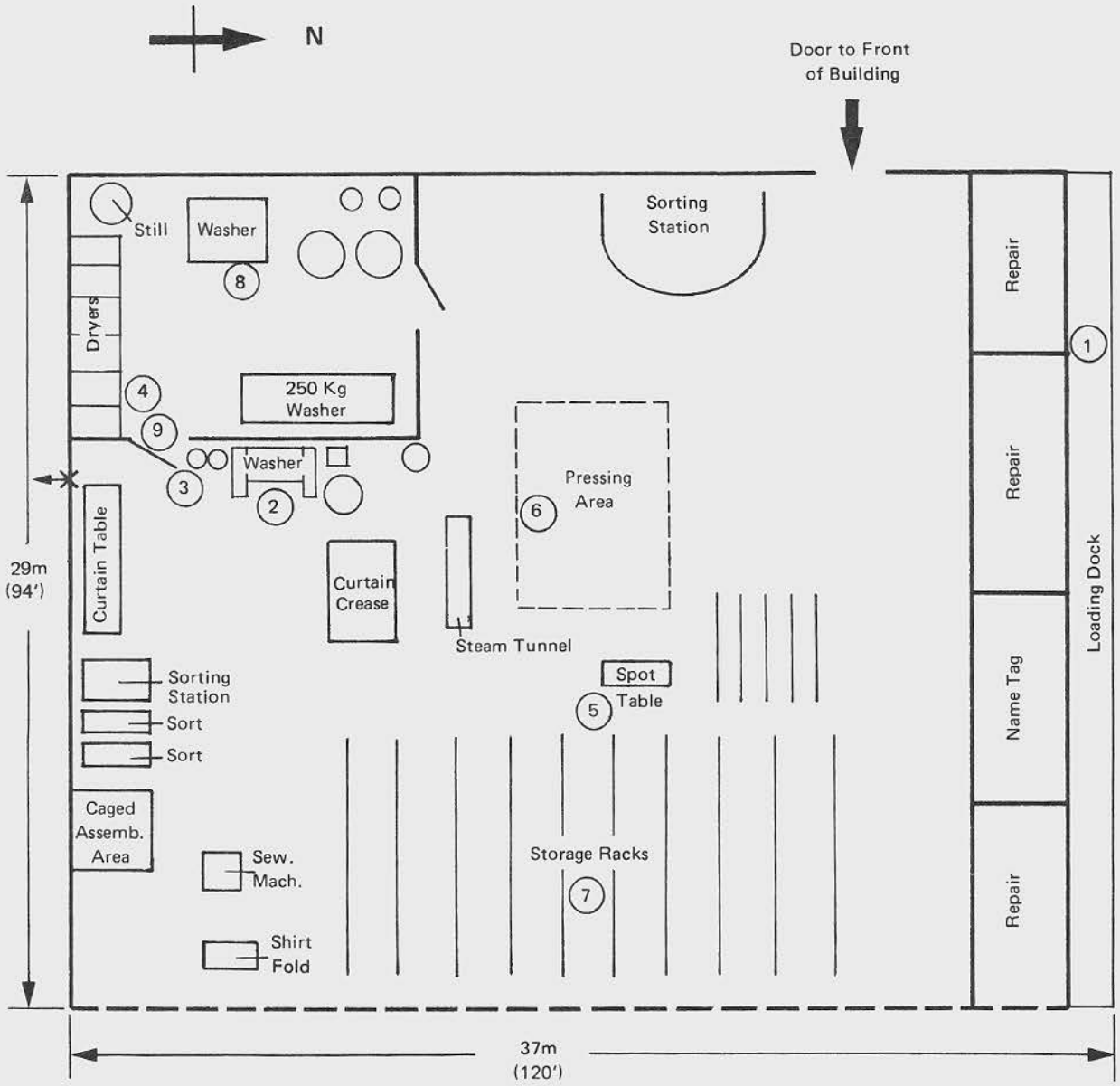
This is a large combination industrial (70%) and commercial (30%) Stoddard solvent and perchloroethylene plant in the Middle-Atlantic area. Three different single transfer systems are employed to process a total of 8845 kg (19,500 pounds) of dry cleaning weekly, including 2631 kg (5800 pounds) of perchloroethylene cleaning and 6214 kg (13,700 pounds) Stoddard solvent cleaning. Average solvent mileages are 7370 and 1940 for the perchloroethylene and Stoddard solvent systems, respectively. The dry cleaning occupies a staff of 2 cleaners, 1 spotter/foreman, 3 pressers, 3 drapery employees, 2 markers, and 3 assemblers. There are 150 other people involved in office work, truck driving, and the laundry department.

The layout of the dry cleaning departnent is shown in Figure A2-1, and the relationship of this area with the rest of the plant is shown in Figure A2-2. The perchloroethylene system consists of 1 Washex Syntomat washer/extractor, 2 Hoyt ASF Solvo-Miser dryers, 2 Washex Model W108 Solvent Sorber Sniffers, 1 Per Corp. Still/Muck Cooker, and 1 Washex Model 621118-H Tube Filter. All of this equipment is approximately 15 years old. Additionally, 1 unidentified older still/muck/cooker and an older Olson Model 243696 Superflow Tube Filter were available on a standby basis.

The perchloroethylene is recirculated through a tube filter. Once each day, the tubes are precoated with diatomaceous earth by adding 2.7 kg (6 pounds) of the material to the button trap. The 350-500 tubes are coated on the outside, and dirty perchloroethylene is forced through the filter cake. Activated carbon is usually added during the afternoon to clear up the color of the perchloroethylene. At the end of the day, the filter cake is blown off the tubes by steam and/or air pressure, and the residue is pumped over to the muck cooker where the perchloroethylene is distilled and condensed back to the perchloroethylene reservoir. The muck is drained about twice each week with a total of approximately 61 L (16 gal.) drained from the cooker per week. The muck cooker, which is rated at 568 L (150 gal.) per hour, is operated for 4 hours every other day. The dual carbon bed adsorber is continuously operated and is steam-stripped daily for 3-4 hours with a recovery of 11.4-15.1 L (3-4 gal.). The condensed perchloroethylene is collected in an open bucket.

The second dry cleaning system which does the majority of the dry cleaning consists of a Washex Floataire Model 500FLPA-02, a Washex Vacuum Still Model 36VS, a Washex Muck Stripper Model MS-22, a Washex Tube Filter Model 15 MAB, and a Washex Separator Tank Model 6271-2. All of this equipment is approximately 5-years-old.

The Floataire has 3 Stoddard solvent "work" tanks, each 3785 L (1000 gal.) capacity, beneath the floor from which solvent is pumped into the wash chamber (see Figure A2-3). Solvent is pumped through tube filters that are very similar to those described for the perchloroethylene system. The tube filter is precoated with 2.3 kg (5 pounds) of diatomaceous earth and is given a new charge of 0.5 kg (1 pound) per load. An activated carbon charge of 0.9 kg (2 pounds) is added each day to clear the color from the solvent. After going through the tube filters, the Stoddard solvent is held in an above-ground holding tank where solids are allowed to settle to the bottom for 20 hours. The



LAUNDRY

Celing in Stoddard Solvent Room ≈ 3.7m (12')

Celing in Perc Operation ≈ 7.6m (25')

– 264 cm (104") Dia. Louvred Wall Fan

(1) – Background Level Locations (see Table A2–3)

FIGURE A2–1 DRY CLEANING DEPARTMENT LAYOUT

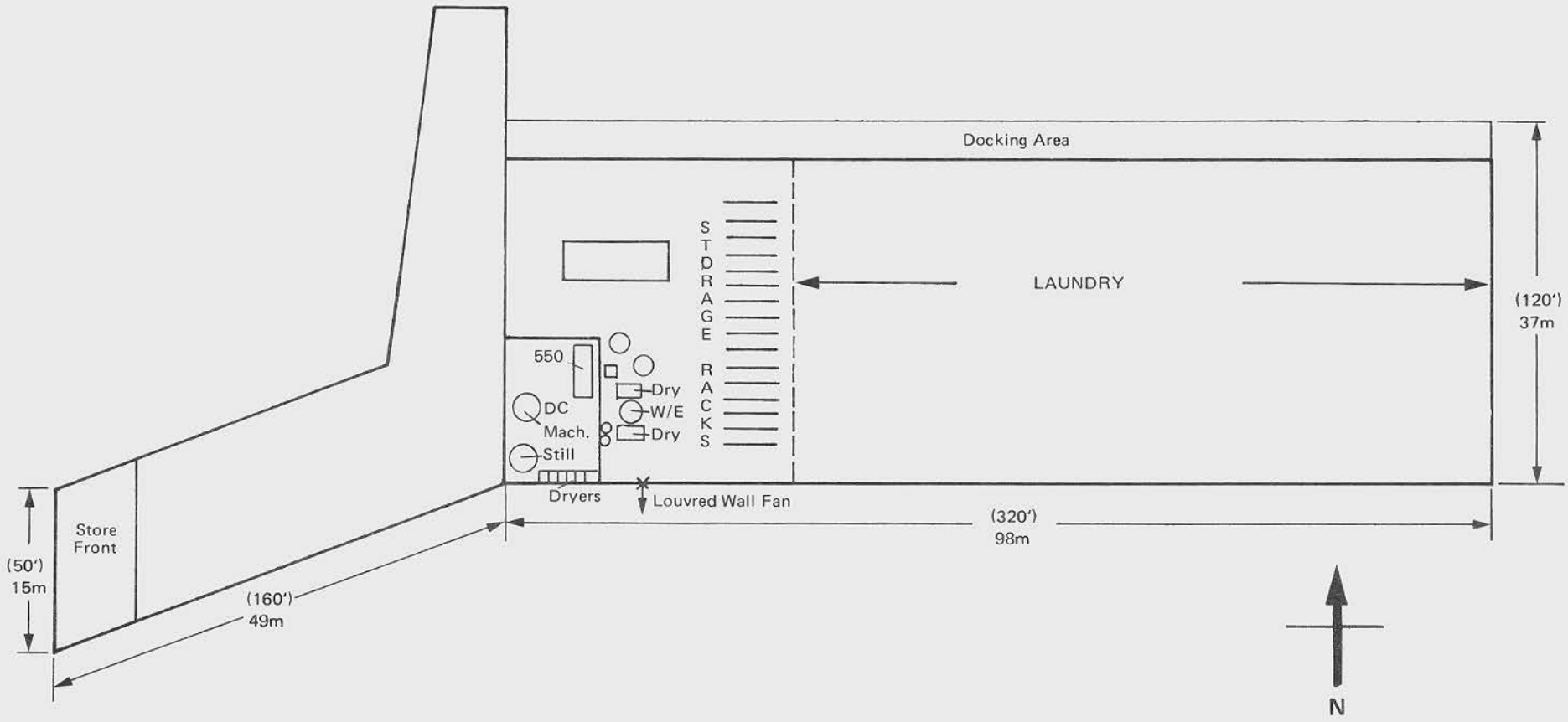


FIGURE A2–2 GENERAL PLANT LAYOUT

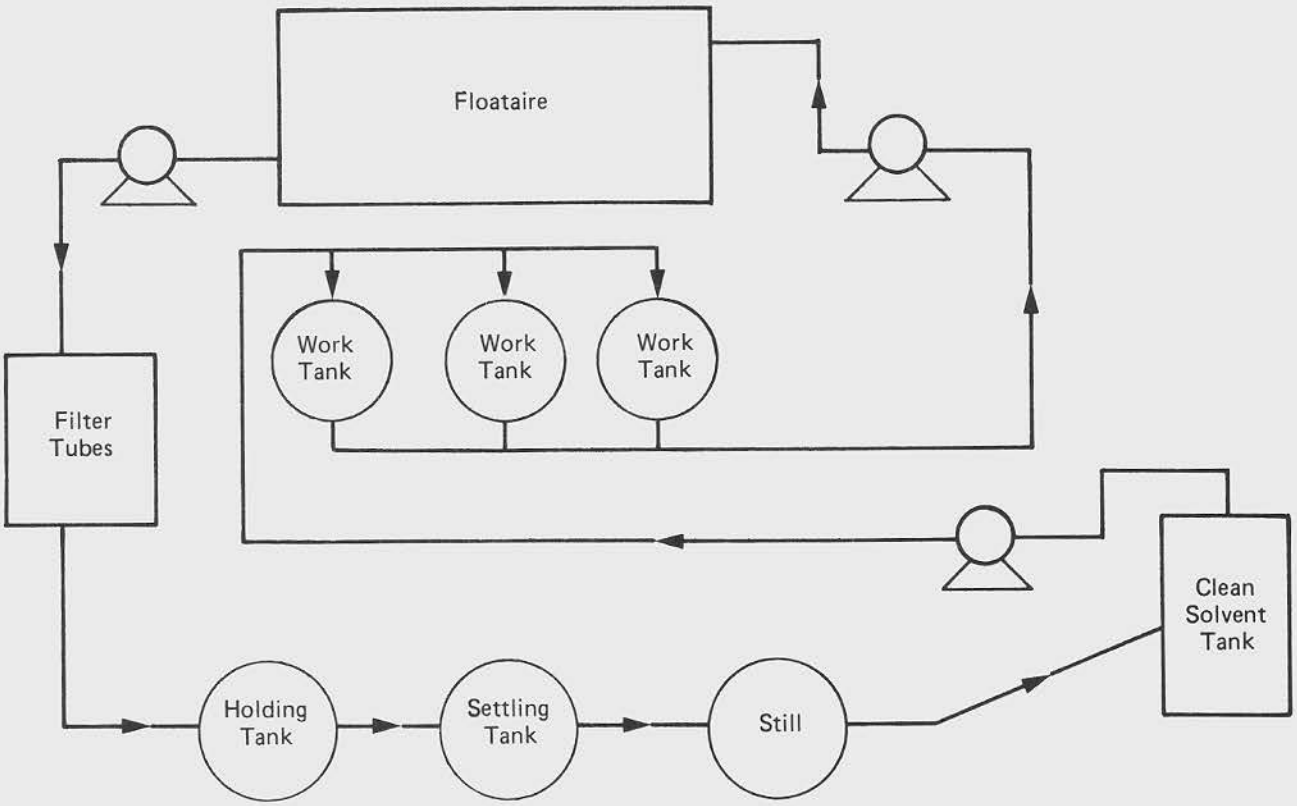


FIGURE A2–3 FLOATAIRE SYSTEM

next day, the solvent is pumped to a settling tank where it stands for several hours before entering the still. The still, which is rated at 568-681 L (150-180 gal.) per hour, is operated for 5 hours every other day. The collected condensed Stoddard solvent is stored in a 5678 L (1500 gal.), below-ground storage tank.

The third dry cleaning system is also a Stoddard solvent system and consists of an American Truclean washer/extractor and is estimated to be in the vicinity of 30 years old. It shares with the Washex Floataire the vacuum still, the muck stripper, the tube filter, and the separator tank. This machine appeared to be identical to the one at plant 11 (see Case Study No. 11).

The operating characteristics of the perchloroethylene system are as follows: Usually each load is about 40.8 kg (90 pounds), and an average of 13 loads are cleaned daily. The wash cycle ranges from 20-30 minutes in length, and the extraction cycle requires another 8 minutes. The cleaner will take an average of 50 seconds to unload the washer, 50 seconds to load the dryers, and another 40 seconds to load the washer with a new load. The Stoddard solvent dryers, with a 15-minute drying cycle, were used in lieu of the Hoyt dryers during this survey. This unusual procedure was instituted since a small fire had occurred in the Stoddard solvent room, causing a back-up in production. In order to catch up with and expedite the cleaning process, perchloroethylene cleaning was being dried in the Stoddard solvent dryers (Cissell) where no recovery of the perchloroethylene was possible.

In the Washex Floataire system, 250 kg (550 pounds) of clothing comprise a typical load. A daily average of 4 loads of dual phase cleaning and 2 other loads using just water and detergent is cleaned in this machine. In the dual phase mode, 30 minutes are required to wash the load with Stoddard solvent, 7 minutes for extraction, 30 minutes for water and detergent wash, and 7 minutes for the final extraction. The solvent phase is needed to dissolve the grease and oil, whereas the water phase is used to remove water-soluble and perspiration residues. Garments that are relatively grease- and oil-free are washed in the single phase mode (i.e., the solvent phase is eliminated). An average of 7 minutes are required for the cleaner to transfer the load to the dryers and to load the Floataire with a dirty load of clothes. It usually takes 15 minutes to dry a load of garments in one of the six Cissell dryers. In the American Truclean system, 40.8 kg (90 pounds) make up a load, and an average of 6 loads normally are cleaned per day. The wash cycle was 15 minutes, followed by a 3-minute extraction. Unloading and loading the machine required another 2-3 minutes.

B. NATURAL VENTILATION

The sources of natural ventilation in this plant are shown in Figures A2-1 and A2-2. To one side of the perchloroethylene system is a 264-cm (104-in.)-diameter louvred wall fan. Several fans of the same size are installed along the same wall at the laundry end of the building. It was evident that air was being sucked into the building from the open docking area, adjacent to the perchloroethylene dry cleaning machine.

In the Stoddard solvent room, air was introduced through the two doors at the rate of 0.94 m^3/s (2000 cfm) and 1.89 m^3/s (4000 cfm), respectively.

C. GENERAL MECHANICAL VENTILATION

As stated in the section above, a 264-cm (104-in.) diameter louvred wall fan is located to the left of the perchloroethylene system and operates continuously. In the Stoddard solvent room, make-

up air is introduced through a duct with 4 grills, each measuring 38 x 46 cm (15 x 18 in.), along the ceiling paralleling the door that leads to the sorting station. The grill nearest the door delivers air at a velocity in excess of 0.5 mps (100 f.p.m.). Another group of 4 grills is located along the ceiling paralleling the 6 Cissell dryers.

D. LOCAL EXHAUST VENTILATION

There is no local exhaust ventilation provided in the Stoddard solvent room. The perchloroethylene system, however, is provided with some local exhaust ventilation by way of the activated carbon solvent recovery system (see Figure A2-4). A summary of the ventilation system parameters is tabulated in Table A2-1.

E. LEAK DETECTION

No overt leakage was detected with the photo-ionization detector.

F. HEAT EXPOSURE

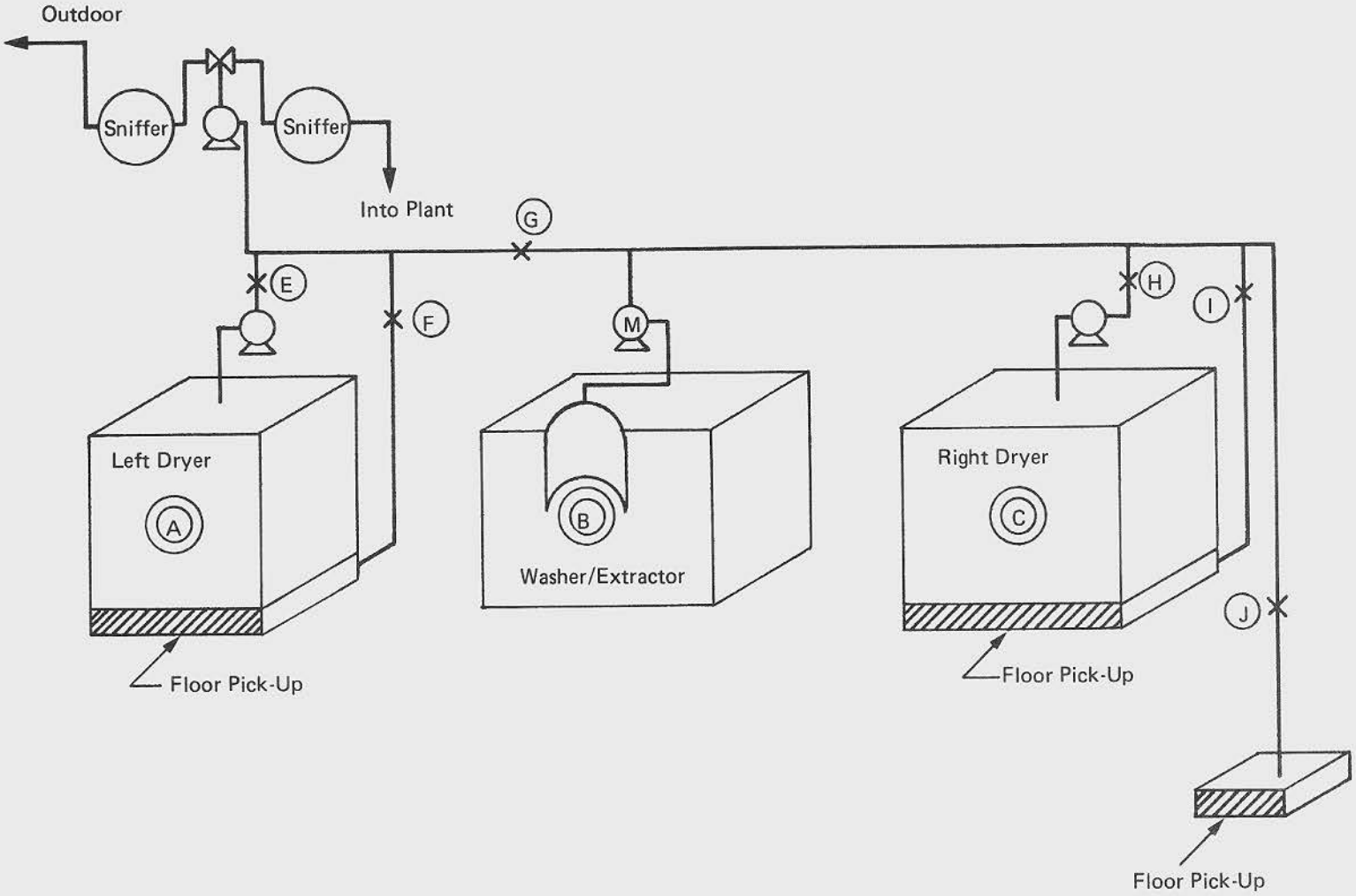
Wet bulb globe temperature (WBGT) in the pressing area was 27.2°C (81°F) and 27.6°C (81.7°F) on the two days of this survey. The higher of these WBGT levels was based upon a dry-bulb temperature of 34.0°C (93.2°F), wet-bulb temperature of 24.1°C (75.3°F), and black-globe temperature of 35.8°C (96.5°F).

G. SOLVENT EXPOSURE LEVELS

The perchloroethylene cleaner's personal exposure level in this plant was 25-30 ppm perchloroethylene and 5 ppm Stoddard solvent. During transfer, the ceiling (15 minute TWA) level was 49-161 ppm perchloroethylene and non-detectable to 21 ppm Stoddard solvent. The Stoddard solvent cleaner's personal exposure level in this plant was 20 ppm Stoddard solvent and 3 ppm perchloroethylene. During transfer, the ceiling (15-minute TWA) level was 1-157 ppm Stoddard solvent and 1-7 ppm perchloroethylene. In the pressing area, 1 ppm perchloroethylene and 1-8 ppm Stoddard solvent were measured. Solvent levels found within this plant are listed in Tables A2-2 and A2-3.

CONCLUSIONS

The use of the Cissell dryers to process wet perchloroethylene garments contributed, to a great extent, to the relatively high exposures to perchloroethylene experienced by the perchloroethylene cleaner. The misusage of the Cissell dryers also resulted in the Stoddard solvent cleaner experiencing some low levels of perchloroethylene. Due to the size of the Floataire machine, the Stoddard solvent cleaner is subjected to relatively high amounts of Stoddard solvent during the transfer operation.



A – Air flow measurement point
(See Table A2–1)

FIGURE A2–4 LOCAL EXHAUST VENTILATION SYSTEM

FIGURE A6–1 GENERAL LAYOUT – PLANT #6

Table A2-1. Local exhaust ventilation system parameters.

Location*	Diameter cm(in.)	Air Flow m^3/s (cfm)	Static Pressure cm(in.)
A	56(22)	0.19(400)	--
B	46(18)	0.02(44)	--
C	56(22)	0.09(200)	--
D	43 x 4(17 x 1.5)	0.04(88)	--
E	15(6)	0.14(300)	-0.56(-.22)
F	25(10)	ND	-0.41(-.16)
G	31(12)	ND	-0.51(-.20)
H	15(6)	0.12(260)	-0.51(-.20)
I	25(10)	ND	-0.43(-.17)
J	25(10)	ND	-0.51(-.20)

*See Figure A2-4 for identification of point locations.

ND - Non-detectable

Table A2-2. Airborne concentration measurements.

Sample #	Location	Duration (min)	Start Time	Stoddard Solvent mg/m^3	Stoddard Solvent ppm	Perchloroethylene mg/m^3	Perchloroethylene ppm
1	Perc cleaner personal sample	124	9:00	13.3	2	291	43
2	Perc cleaner during transfer	15	9:00	6.2	1	500	74
3	Perc machine area	60	9:00	2.2	<1	76	11
4	Pressing area	160	9:20	0.5	<1	0.4	<1
5	Clean storage area	170	9:20	0.8	<1	0.3	<1
6	Cissell dryers area	60	9:23	17.4	3	270	40
7	Perc cleaner during transfer	15	9:27	7.5	1	800	130
8	Perc cleaner during transfer	15	10:05	60	10	1090	161
9	Perc machine area	60	10:10	2.5	1	55	8
10	Perc cleaner during transfer	15	10:30	N.D.	N.D.	930	137
11	Cissell dryers area	120	10:27	20.4	4	690	102
12	Perc cleaner during transfer	15	11:02	8.1	1	680	100
13	Perc cleaner personal sample	133	11:04	48	8	121	18
14	Perc machine area	120	11:08	2.0	<1	129	19
15	Perc cleaner during transfer	15	12:05	120	21	330	49
16	Clean storage area	155	12:10	0.8	<1	0.3	<1
17	Pressing area	163	12:00	0.6	<1	0.3	<1
18	Cissel dryers area	75	13:10	37	6	222	33
19	Perc cleaner personal sample	78	13:17	32	6	88	13
20	Stoddard solvent cleaner personal sample	143	6:53	248	43	22.7	3
21	Cissell Dryers area	60	6:50	128	22	13.0	2
22	Stoddard solvent machine area	60	6:50	169	29	175	26
23	Pressing area	240	6:50	49	8	5.0	1
24	Perc cleaner personal sample	134	7:07	35	6	185	27
25	Stoddard solvent cleaner during transfer	15	7:12	6.4	1	3.8	1
26	Stoddard solvent cleaner during transfer	15	7:28	330	57	45	7

Table A2-2 (cont'd.)

Sample #	Location	Duration (min)	Start Time	Stoddard Solvent mg/m^3	Stoddard Solvent ppm	Perchloroethylene mg/m^3	Perchloroethylene ppm
27	Stoddard solvent cleaner during transfer	15	7:55	910	157	44	7
28	Stoddard solvent machine area	60	8:00	22.5	4	12.3	2
29	Cissell dryers area	60	8:35	13.3	2	279	41
30	Stoddard solvent cleaner during transfer	15	10:55	27.0	5	4.0	1
31	Stoddard solvent cleaner personal sample	123	9:16	100	2	16.1	2
32	Perc cleaner personal sample	121	9:20	5.2	1	140	21
33	Cissell dryers area	60	9:48	114	2	270	40
34	In duct before sniffer	15	10:00	N.D.	N.D.	1100	162
35	In duct after sniffer	15	10:00	N.D.	N.D.	39	6
36	Stoddard solvent cleaner personal sample	69	4:19	104	18	22.2	3
37	Perc cleaner personal sample	122	11:22	25.5	4	180	27
38	Cissell dryers area	60	11:24	118	20	235	35
39	Pressing area	157	11:32	N.D.	N.D.	0.1	<1
40	Stoddard solvent cleaner during transfer	15	11:40	760	131	47	7
41	In duct before sniffer	15	12:54	57	1	550	81
42	In duct after sniffer	15	12:54	N.D.	N.D.	9.0	1
43	In duct before sniffer	4	13:10	N.D.	N.D.	1010	149
44	In duct after sniffer	4	13:10	N.D.	N.D.	33	5
45	Stoddard solvent cleaner personal sample	83	13:28	53	9	13.9	2
46	Stoddard solvent cleaner during transfer	15	14:04	217	37	46	7
47	In duct before sniffer } during	15	13:48	N.D.	N.D.	20	3
48	In duct after sniffer } wash cycle	15	13:48	N.D.	N.D.	9.0	1
49	In duct before sniffer } washer door	15	14:03	88	2	1460	215
50	In duct after sniffer } open	15	14:05	68	1	80	12

Note: perc = perchloroethylene
N.D. = non-detected

Table A2-3. Background solvent levels (ppm).

Day	Time	Location* (see Figure A2-1) 1	2	3	6	5	6	7	8	9
1	1000	<1	2-3	45	7-15	1	1	1	--	--
1	1100	<1	4-5	30-35	6	1	1	1	--	--
1	1230	<1	4-20	35-40	6-12	1	1	1	--	--
1	1330	<1	3	25	22	<1	1	<1	--	--
1	1430	<1	2	1-5	7	<1	1	<1	--	--
2	0700	<1	20-55	20-55	16-20**	--	<1	--	50-60*	--
2	0800	1	5-20	15-35	15-20	--	1-2	--	8	60
2	0900	1	3***	20-50	15-20	--	1-2	--	10-15	50
2	1000	<1	10-12	15-20	15-20	--	<1	--	***	20

*
1 - outside air
2 - front of perc machine
3 - beside sniffer
4 - dryer room
5 - spotting table
6 - pressing area
7 - dry cleaning storage
8 - front of American Stoddard solvent machine
9 - door dividing perc and Stoddard operations

*Door opened to unload machine.

**Both span settings used; 760 for Stoddard, 745 for perc.

***Not operating.

Note: It can be assumed that the first three sets of readings above are primarily perchloroethylene since the Stoddard operation did not commence until 1300. The readings following 1300, however, are less definitive since both processes were operated.

APPENDIX A3
CASE STUDY NO. 3

A. PROCESS AND EQUIPMENT

This northern California plant is a moderately small perchloroethylene transfer plant. Approximately 544 kg (1200 pounds) per week of cleaning is handled.

One cleaner/presser, one presser, and three support persons are employed in this plant.

A Prosperity Model 40-CO washer and Hoyt 8F4518 tumbler are used. This rebuilt equipment was purchased in 1976. A cartridge filter (a three-tube unit with no nameplate), Detrex still, and Vic Model 128 Mileage Booster (sniffer) complement the cleaning equipment. The tumbler, sniffer, and still each return recovered solvent to the cleaning machine reservoir through fixed piping. The general layout of this plant is shown in Figure A3-1.

The adsorber is stripped daily for approximately one hour, during a lunch period when the washer and drier are shut down. In the initial stages of stripping, a perchloroethylene level of more than 1000 ppm was found at the wastewater outlet part of the water separator. After condensation of solvent began this level dropped off.

Loads of 13.6 kg (30 pounds) are run through a cleaning cycle of varying duration. Wash times range fron 5-17 minutes, with a 3-minute extraction and a drying cycle of longer than 20 minutes.

B. NATURAL VENTILATION

As Figure A3-1 indicates, this plant is separated into a production area and a support/customer area. These two areas are connected by a 3.8 m^2 (40.6 $ft.^2$) opening. The production area contains three doors (two in front, one in rear) which provide natural ventilation. During this survey, the two front doors were open (each 2.25 m^2, or 24.2 $ft.^2$) and the rear door was "cracked" open.

C. GENERAL MECHANICAL VENTILATION

No general mechanical ventilation was in use during this survey.

D. LOCAL EXHAUST VENTILATION

This plant has a local exhaust system running into the carbon adsorption unit. The outlet duct from the adsorber runs up to the roof and discharges outdoors. A single floor pickup of standard design (see Section 4.2 of this report) is located between the washer and the dryer. Three sides are open, with one side abutting a solid wall. The local exhaust system is shown schematically in Figure A3-2. Air flow rates through the exhaust system are listed in Table A3-1. It was observed that the floor duct tends to clog with dust and is difficult to clean. No regular cleaning is performed.

E. LEAK DETECTION

During sniffer stripping, it was noted that there is an apparent leak in the damper that serves to isolate the sniffer fron the inlet ducting. During stripping, a perchloroethylene concentration of

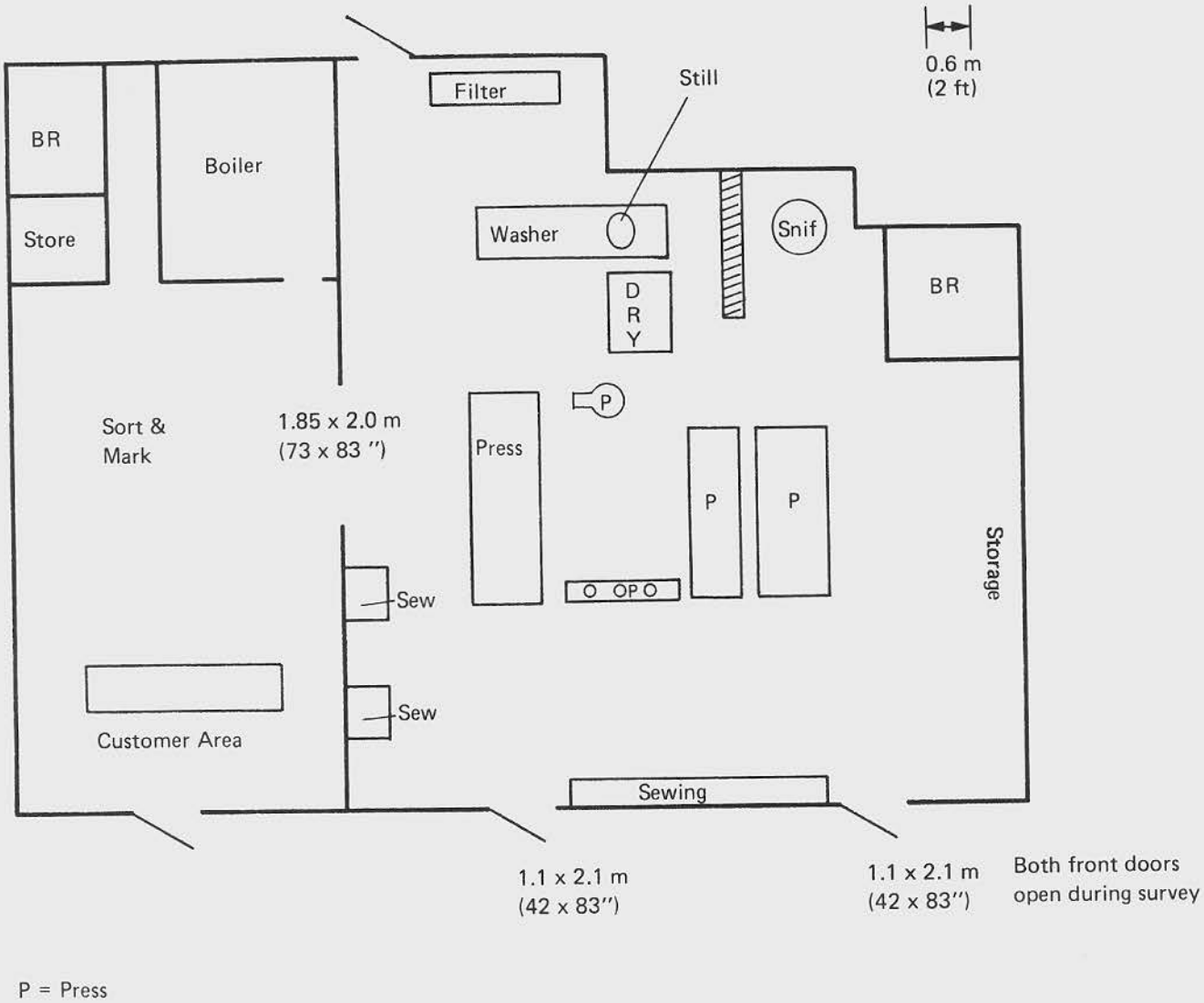
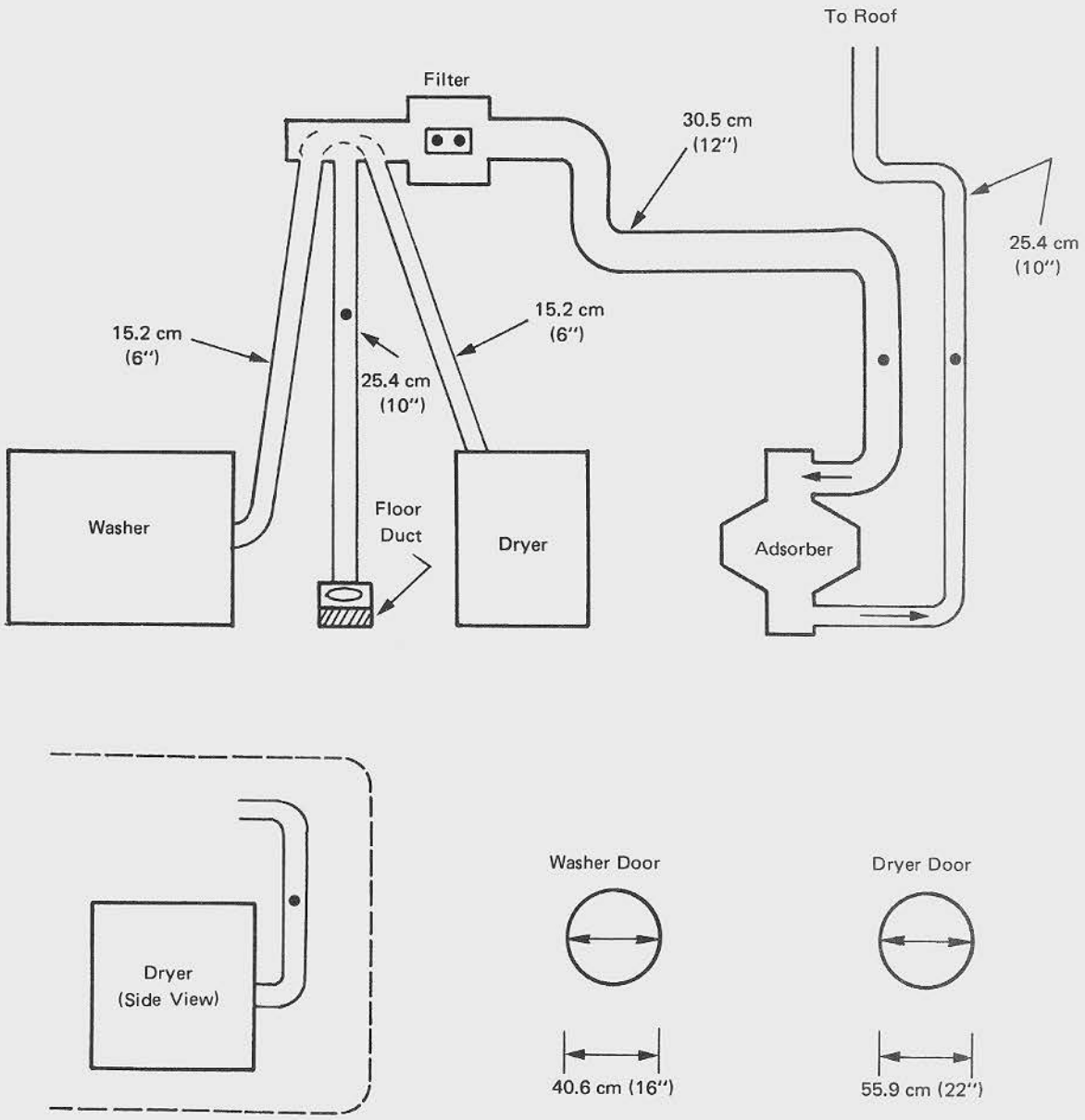


FIGURE A3–1 GENERAL LAYOUT – PLANT NO. 3



● = Air flow measurement point (see Table A3–1).

FIGURE A3–2 LOCAL EXHAUST VENTILATION SYSTEM

Table A3-1. Measured ventilation system flow rates.

Location	During Wash	Air Flow m^3/s(cfm) During Aeration	During Transfer	Static Pressure cm(in.)
Main into adsorber	0.21(440)	--	0.19(410)	-1.4(-0.55)
Main out of adsorber	0.20(430)	--	0.20(420)	0.5 (0.2)
Floor duct	0.21(450)	0.11(240)	ND	-0.38(-0.15)
Dryer duct	0	0.09(185)	0.08(180)	-0.33(-0.13)
Washer duct	0	0	0.11(230)	--

ND = None detected

approximately 800 ppm was measured in the main inlet duct and in the dryer's garment chamber. The main outlet duct contained a comparable level of solvent, indicating that the downstream damper also was leaking. Solvent was also backing up through the floor duct during this period.

Several major leaks were found in this plant. The most obvious involved the washer door, the gasket for which left a gap of approximately 2.5 cm (1 in.), permitting small amounts of solvent to splash out during the washing cycle (see Figure A3-3). Other leaks were found at the dryer door (750-1000 ppm), lint trap door (1000 ppm), and filter cartridge loading door (1000 ppm).

F. SOLVENT EXPOSURE LEVELS

Table A3-2 lists exposure levels determined by collection on charcoal tubes and passive diffusion monitors, with subsequent gas chromatographic analysis. Area levels measured with a photo-ionization detector are displayed in Figure A3-4. The cleaner's personal exposure level was approximately 25 ppm, with his ceiling level ranging from 40-71 ppm. Area levels within the production room ranged from 10-50 ppm near the cleaning equipnent to approximately 7 ppm in the sewing area, 5 ppm in the pressing area, and 15 ppm near the spotting board. Levels in the customer area were approximately 0.8-2 ppm.

CONCLUSIONS

The effectiveness of the local exhaust system in this plant is compromised by a large number of leaks in gaskets. The leaking adsorber dampers permit loss of solvent to both the plant environment and the outside atmosphere during stripping. The floor duct seems to have limited effectiveness in controlling ceiling levels during transfer, and also tends to clog with dust and dirt. Despite these problems in the control of in-plant solvent concentrations, the levels in the adjacent storefront room remain low since the latter area is largely separated from emission sources by a wall.

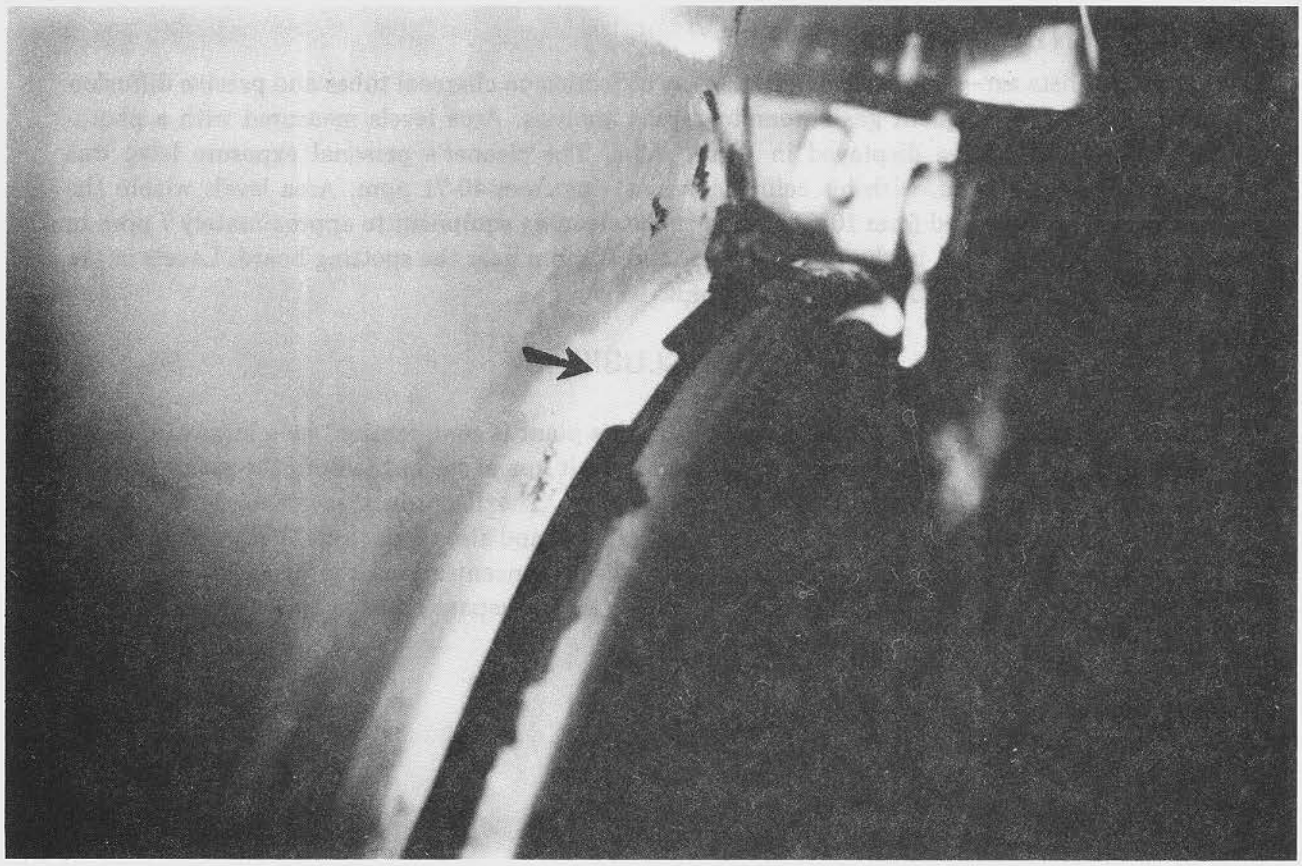
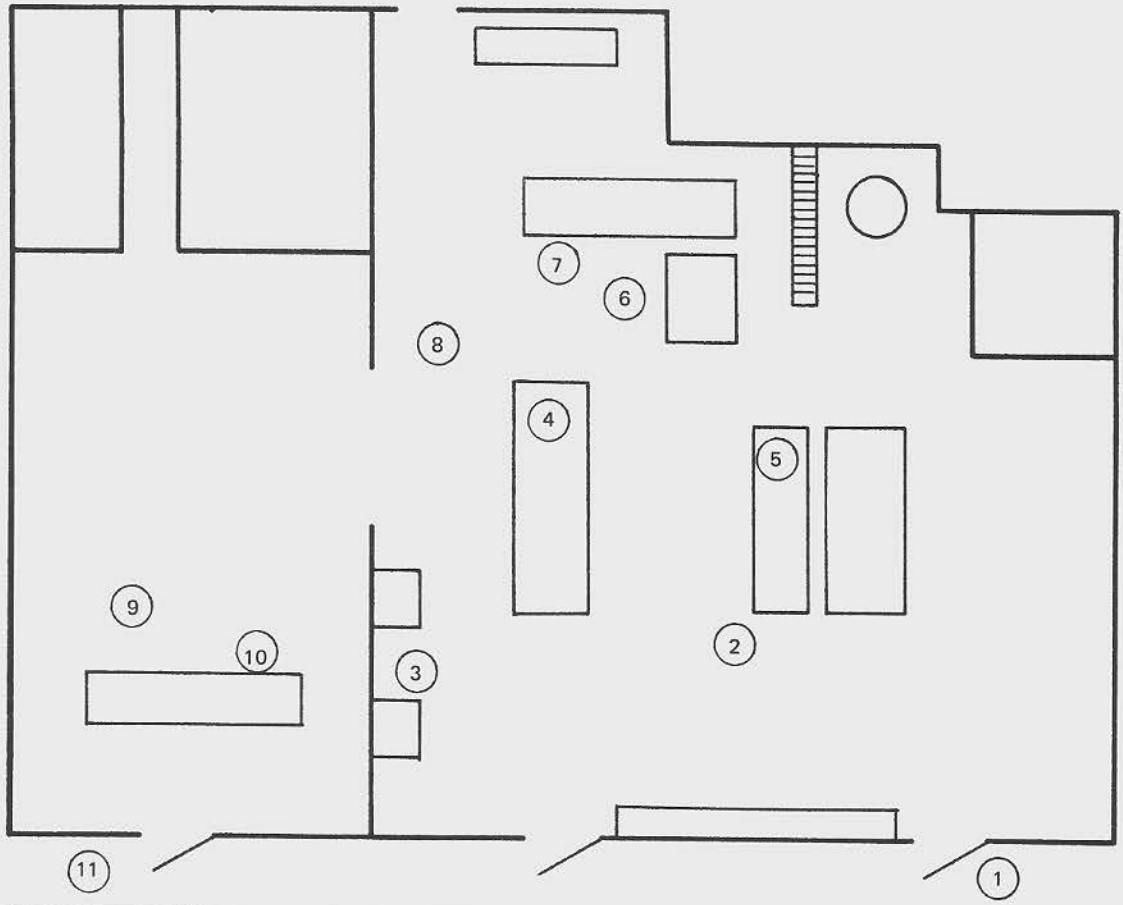


FIGURE A3–3 MISSING SECTION OF GASKET (arrow) IN WASHER DOOR

Table A3-2. Airborne concentration measurements.

Sample #	Location	Duration (hr:min)	Start Time	Perchloro-ethylene level mg/m^3	ppm
1	Cleaner personal sample	2:03	8:15	210	31
4	Pressing area	3:38	8:30	31	4.6
5*	Customer service area	3:36	8:32	5.5	0.8
6A	Area between washer/drier	0:21	8:46	370	55
7A	Area between washer/drier	0:21	8:46	350	52
8	Area between washer/drier	2:00	8:51	260	38
9	Sewing area	3:08	8:57	45	6.6
10	Sniffer area	2:24	9:42	130	19
11B	Area between washer/drier	0:15	9:24	640	94
12B	Area between washer/drier	0:15	9:24	590	87
13	Cleaner during transfer	0:15	10:35	480	71
14	Cleaner emptying drier	0:19	11:10	160	24
15B	Area between washer/drier	2:45	10:46	340	50
16B	Area between washer/drier	2:45	10:46	350	52
17A	Area between washer/drier	2:47	11:00	330	49
18A	Area between washer/drier	2:47	11:00	300	44
19	Water separator area	0:02	11:15	4100	604
20	Water separator area	0:02	11:20	8800	1296
21	Cleaner personal sample	1:45	12:27	100	15
24	Area between washer/drier	0:51	1:10	240	35
25	Cleaner during transfer	0:15	1:44	270	40
27B	Area between washer/drier	4:57	8:02	250	37

*The letter designation of the sample number indicates the collection device employed. No letter indicates a charcoal tube. A and B indicate two types of passive diffusion monitors.



PERCHLOROETHYLENE LEVELS (ppm) AT LOCATIONS INDICATED ABOVE											
TIME	LOCATION										
	1	2	3	4	5	6	7	8	9	10	11
0830	2.2	3.2	3.8	2.4	5–8	5	5	6	2	1.8	–
0900	1–3	5–7	2.0	1–2	2.6	10–13	10–20	8–11	1	1	1
1000	1.2–1.8	2	1.6	3–12	6–13	8–15	10–13	10–12	1	1	1
1100	1.6–2	5–7	2	5–15	4	30	30–50	30	1.2	1.2	1.2
1200	1	2.5	1.5	0.8	5	25	50	15–20	0.8	0.8	–
1300	1.6	7	5–7	4–7	11	30	40–70	20	1.8	1.6	1.6

FIGURE A3–4 PERCHLOROETHYLENE BACKGROUND LEVELS

APPENDIX A4
CASE STUDY NO. 4

A. PROCESS AND EQUIPMENT

This is a medium-sized commercial perchloroethylene plant in the Middle Atlantic area. A transfer system is employed to process approximately 621 kg (1370 pounds) of dry cleaning weekly. The solvent mileage for this plant is 19,800. The plant employs 1 cleaner/presser, 1 manager/presser, 1 assembler, and 2 part-time persons.

The layout of this plant is depicted in Figure A4-1. An 8-year old Detrex Kleen-O-Matic 50M Model 570 M cleaning machine is employed. A 15-year old (estimated) Vic Model 118 carbon bed adsorber, a 9-year old Vanguard Puritan Cartridge Filter, and an 8-year old Hoyt Solvo-Miser Model SF145 dryer comprise the remainder of the system. The cartridge filter sits on top of a still that is operated once weekly, and batches of 95 L (25-gal.) are distilled for 1-2 hours. Each distillation of 95 L of solvent produces about 4 L (1 gal.) of residue. The cartridge filter consists of 14 carbon core cartridges on the circumference of the unit and 2 activated carbon filters (i.e., solid carbon) through the center of the unit. The center filters are valved in such a manner that they are placed into service only when excessive color is detected in the solvent.

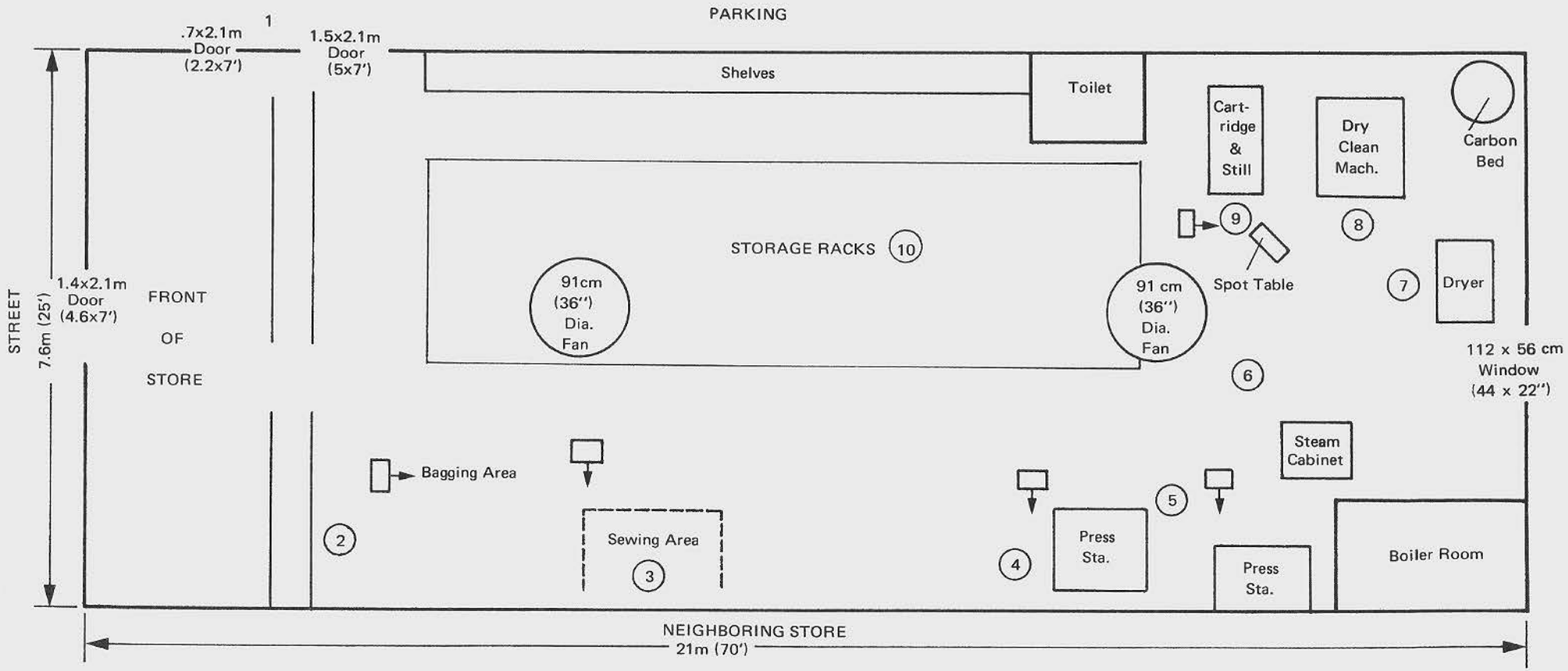
The carbon bed adsorber is constantly operated and is stripped once every 2 days. Stripping is conducted for approximately 1.5 hours, and 7 L (1.85 gal.) of solvent normally are recovered. To minimize solvent loss, the water separator is piped directly back to the solvent reservoir by means of a length of flexible tubing.

An average of 6 loads is processed daily, with each load weighing approximately 20 kg (48 pounds). A complete cycle typically includes 20 minutes for washing, 4 minutes for extraction, 20 minutes for drying, 3 minutes for cooldown, and 3 minutes for aeration. Average time measured for the cleaner to transfer a wet load into the dryer is 55 seconds, while the average time to load the dry cleaning machine is 30 seconds.

As a result of the dry cleaning plant being above some offices of other concerns, the dry cleaning machine has been mounted on top of a large shock absorber (see Figure A4-2). Prior to the installation of the shock absorber, the floor of the dry cleaning plant and the ceiling of its subterranean neighbors would vibrate vigorously whenever the load of clothes was unevenly distributed during the extraction cycle.

B. NATURAL VENTILATION

On warm days, such as the first day of the survey, all doors and windows of the plant are kept open. However, when climatic conditions are less favorable, as on the second day of the survey, only the window near the dry cleaning machine is left open. An airflow measurement revealed that approximately 1.6 m^3/sec (3360 cfm) were entering through the 112 x 56 cm (44 x 22 in.) window.



Ceiling Height = 4.6m (15')

Evaporative Cooling System Diffusers

(1) – Locations of Background Solvent Level Measurements (see Table 4–3)

FIGURE A4–1 GENERAL PLANT LAYOUT

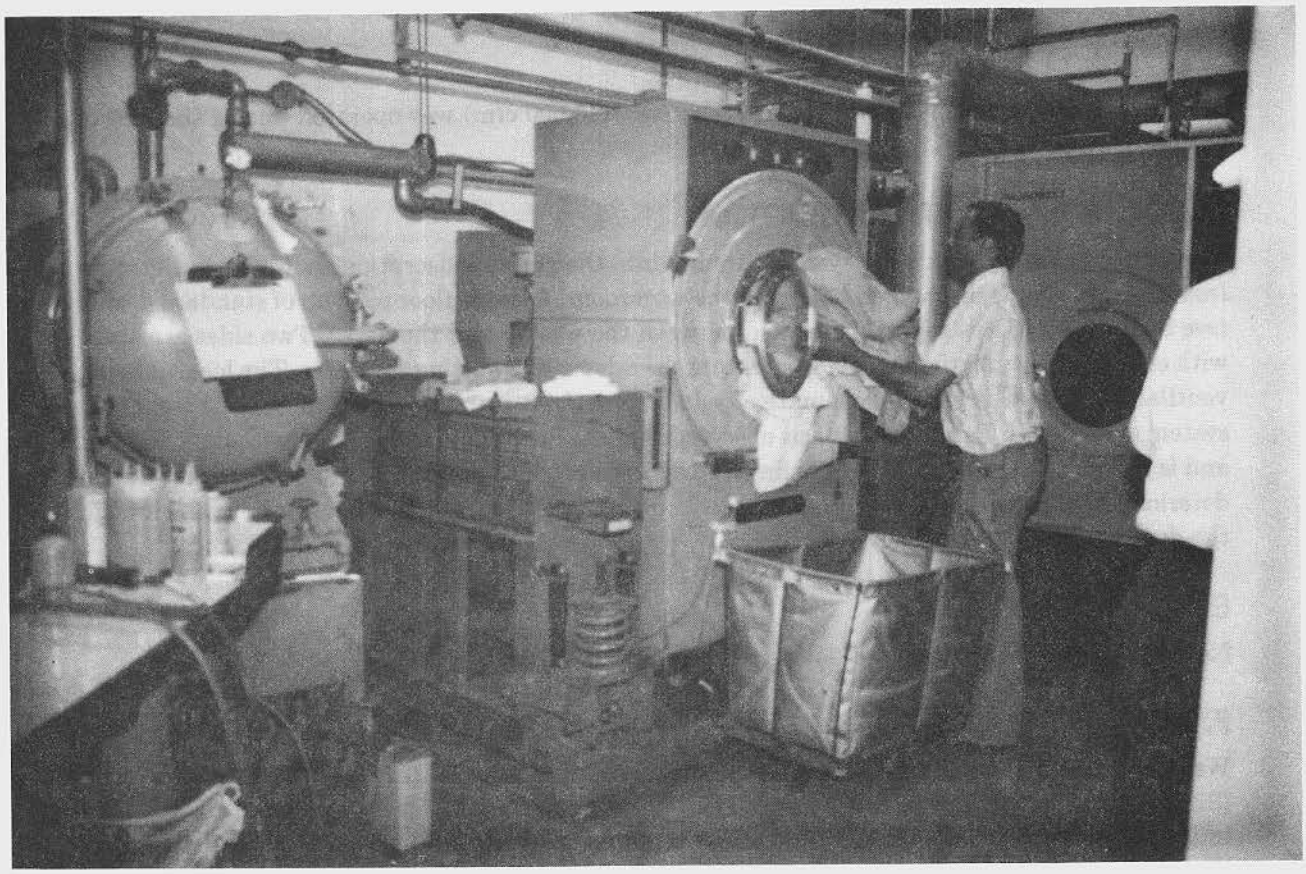


FIGURE A4–2 WASHER MOUNTED ON SHOCK ABSORBERS

C. GENERAL MECHANICAL VENTILATION

Two 91-cm (36-in.)-diameter ceiling exhaust fans, each rated at 6.6 m^3/sec. (14,000 cfm) at 0 cm static pressure, were operated during the first day of the survey. Only the fan near the dry cleaning machine was operated during the second day.

An evaporative cooling system rated at 7.1 m^3/sec. (15,000 cfm) was operated during the first of the two-day survey.

D. LOCAL EXHAUST VENTILATION

This plant has a local exhaust system running into the carbon adsorption unit. The outlet duct from the adsorber is discharged back into the workroom. A single floor pick-up of standard design (see Section 4.2 of this report) is located between the washer and the dryer. Two sides are open, with one side abutting the shock absorber and the other side abutting the dryer. The local exhaust ventilation system is shown schematically in Figure A4-3. Air flow rates through the exhaust system are listed in Table A4-1. It was observed that the floor duct tends to clog with dust and lint and is difficult to clean, and that the lint trap door gasket of the carbon bed adsorber's blower had deteriorated with age, resulting in a "short-circuiting" effect in which air was not drawn through the duct system.

E. LEAK DETECTION

No overt solvent vapor leaks were detected during this survey.

F. HEAT EXPOSURE

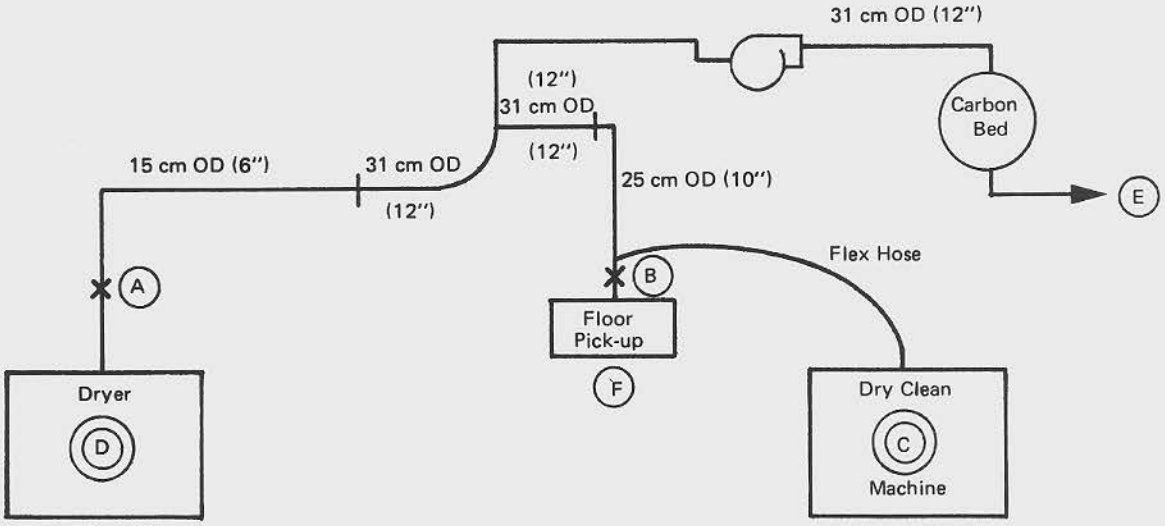
Wet bulb globe temperature (WBGT) in the pressing area was 22.8°C (73.1°F) and 27.4°C (81.3°F) on the two days of this survey. The higher of the WBGT levels was based upon a dry-bulb temperature of 33.0°C (91.4°F), wet-bulb temperature of 24.6°C (76.2°F), and black-globe temperature of 34.7°C (84.4°F).

G. SOLVENT EXPOSURE LEVELS

The cleaner's personal exposure level in this plant was 30-35 ppm perchloroethylene during the actual dry cleaning operation. During transfer, the ceiling (15-minute TWA) level was 7-111 ppm. Since the cleaning process is usually completed in this plant by 1 p.m. and the cleaner spends the remainder of the day on the pressing operation, his overall time-weighted average would be lower than the measured 30-35 ppm. Average levels of 1 ppm were found in the customer service area, pressing area and sewing area. Solvent levels found within this plant are delineated in Tables A4-2 and A4.-3.

CONCLUSIONS

Although this plant has a regular, pre-scheduled maintenance program, the adsorber lint trap door gasket had deteriorated to the point where no air was drawn from the floor duct or dryer. This often overlooked gasket, the failure of which cannot be readily detected by a dry cleaner, can result in substantial degradation of ventilation system performance.



A = Air flow measurement point (see Table A4–1).

FIGURE A4–3 LOCAL EXHAUST VENTILATION SYSTEM

Table A4-1. Measured ventilation system flow rates.

Location*		Air Flow m^3/s(cfm)	Static Pressure cm(in.)
B	During transfer	0.03 (62)	-0.3 (-0.12)
A	During transfer	0.04 (90)	--
F	During transfer	<0.01 (16)	--
B	During drying	0.04 (84)	-0.1 (-0.04)
A	During drying	0 (0)	-0.4(-0.165)
F	During drying	0.01 (23)	
A	During aerating	0.09(201)	-0.1(-0.035)
E	In all instances	0.13(279)	--
D	During transfer	0.09(198)	--
C	During transfer	0.07(153)	--

* Location

A - Dryer duct
B - Floor duct
C - Dry cleaning machine opening
D - Dryer opening
E - Carbon bed outlet
F - Floor pick-up as measured by Alnor Velometer

Table A4-2. Airborne perchloroethylene sampling.

Sample #	Location		Duration (min)	Start Time	mg/m^3	ppm
1.	Cleaner personal sample		120	7:35	2.5	<1
2.	Press area		215	8:55	1.8	<1
3.	Cleaner during transfer		15	9:53	227	33
4.	Carbon adsorber area		120	9:45	20.8	3
5.	Carbon adsorber area		60	9:45	31	5
6.	Customer service area		162	9:50	0.2	<1
7.	Cleaner during transfer		15	10:25	550	81
8.	In duct before carbon adsorber		53	10:27	72	11
9	Duct after carbon adsorber		53	10:27	3,900	574
10.	In duct before carbon adsorber	aeration cycle	6	10:47	27,900	4,109
11.	Duct after carbon adsorber		6	10:47	7	1
12.	In duct before carbon adsorber	drying & cool-down cycle	20	11:00	560	83
13.	Duct after carbon adsorber		20	11:00	340	50
14.	Cleaner during transfer		15	10:55	91	13
15.	In duct before carbon adsorber	stripping cycle	56	7:30	1,140	168
16.	Duct after carbon adsorber		56	7:30	169	25
17.	Cleaner personal sample		135	7:40	102	15
18.	Sewing area		180	7:48	4.2	1
19.	Below dry cleaning machine door		99	7:55	118	17
20.	Below dry cleaning machine door		99	7:55	150	22
21.	Cleaner during transfer		15	9:04	750	111
22.	In duct before carbon adsorber	drying & cool-down cycle	22	9:02	9,000	1,326
23.	Duct after carbon adsorber		22	9:02	600	88
24.	In duct before carbon adsorber	whole cycle	28	9:35	211	31
25.	Duct after carbon adsorber		28	9:35	1,610	237
26.	Below dry cleaning machine door		55	9:45	39	6
27.	Below dry cleaning machine door		55	9:45	96	14
28.	Cleaner during transfer		15	9:34	48	7

Table A4-2 (cont'd.)

Sample #		Duration	Start Time	mg/m^3	ppm
29. Cleaner personal sample		130	9:56	470	69
30. In duct before carbon adsorber	aeration cycle	8	10:28	3,700	545
31. Duct after carbon adsorber	aeration cycle	8	10:28	840	124
32. Cleaner during transfer		15	11:30	50	7
33. Cleaner during transfer		15	12:15	290	43
34. Cleaner during transfer		15	10:06	56	8

Table A4-3. Background solvent levels by location.

Day	Time	Perchloroethylene level (ppm)									
		1	2	3	4	5	6	7	8	9	10
1	0745	<1	<1	<1	<1	<1	1	1	1.2	2	<1
	0830	1	1	1	1.2	1.2	1.2	1.4	1.6	5	<1
	1000*	1.4	1.4	1.8	1.6	1.6	12	18	30	15	1.6
	1100	<1	1.0	1.3	1	1.4	5	6	9	2	1.4
2	0815	1.4	1.6	1.8	1.8	3	6	5	5	2	1.5
	0915*	1.6	1.8	1.8	1.4	7	18	18	17	8	1.8
	1015**	1.4	4	3	8	9	8	9	10	8	9
	1130	1.2	1.2	1.6	1.4	2	2.5	2	2	2	1.2
	1145***	1.2	3	5	7	12	20	15	20	18	11

*After a transfer or solvent-wet load.

**All doors in facility were closed.

***Blower to carbon adsorber was turned off inadvertently.

Location

1 - Outdoor
2 - Customer service
3 - Sewing area
4 - Pressing station
5 - Pressing station
6 - Steam cabinet
7 - Front of dryer
8 - Front of dry cleaning machine
9 - Front of cartridge/still
10 - Storage area.

(See Figure A4-1 for exact locations.)

APPENDIX A5
CASE STUDY NO. 5

A. PROCESS AND EQUIPMENT

This is a moderate-sized commercial fluorocarbon 113 plant in the Middle-Atlantic area. Approximately 680 kg (1500 pounds) per week are processed by this facility. Solvent mileage is estimated to be 25,000. One cleaner/spotter, 2 pressers, and 2 support persons are employed in this plant.

An AMA Universal Model 90, manufactured in Bologna, Italy, is used to process the dry cleaning. To minimize solvent loss, the unit is entirely enclosed with an integral still, separator, cartridge filters, etc. The general layout of the facility is depicted in Figure A5-1. The cartridge filter consists of 6 carbon core elements which are changed every 8165 kg (1800 pounds). The condenser used to recover solvent during the drying phase is chilled by a Freon 12 refrigeration system, and the Freon 12 reservoir is in turn chilled by cooling water from a cooling tower.

The still is rated at 466 L/hr. (123 gal./hr.) and, normally, is operated 3 times each week, with each distillation requiring a period of 15-20 minutes. Within that period, a total of 76 L (20 gal.) is distilled. Residue amounts to approximately 2.8 L (0.75 gal.) weekly. Vapor is condensed during the distillation cycle by a water-cooled condenser. Usual still operating temperature is 37.8-40.6°C (100-105°F).

An average of 10 loads per day is processed in this plant. Each load ranges from 13.6-15.9 kg (30-35 pounds) and is washed for 15 minutes. Two minutes are required for draining, while 1.5 minutes are used for extraction. Finally, the load is dried for 13 minutes at a maximum temperature of 35°C (95°F).

B. NATURAL VENTILATION

The front doors were closed during this survey; however, the side door was left open until 11:25 a.m. An average velocity of 1.65 m/s (325 f.p.m.) was measured at the door coming into the plant. This velocity is equivalent to an air flow rate of 2.5 m^3/s (5280 cfm).

C. GENERAL MECHANICAL VENTILATION

A two-speed, 91-cm (36-inch)-diameter exhaust ceiling fan rated at 6.6 m^3/s (1400 cfm) at 0 cm SP (0-in.) was at low speed during the survey. An evaporative cooling system rated at 5.7 m^3/s (12000 cfm) was operated sporadically during the survey. The location of these systems is shown in Figure A5-2.

D. LOCAL EXHAUST VENTILATION

There is no local exhaust system at this facility.

E. LEAK DETECTION

No overt leakage was found with a Gas Tech Halide Dector.

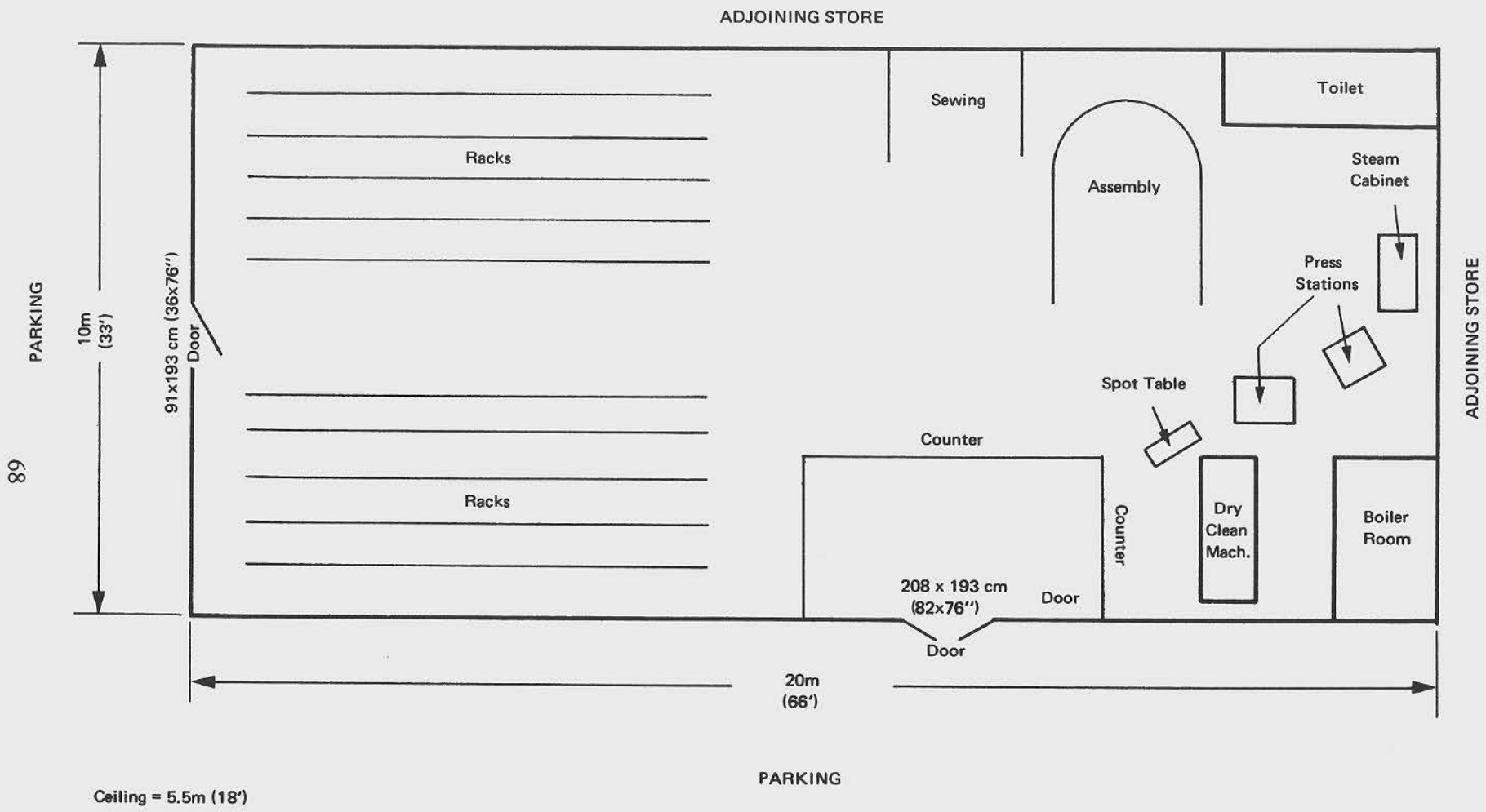


FIGURE A5–1 GENERAL LAYOUT – PLANT #5

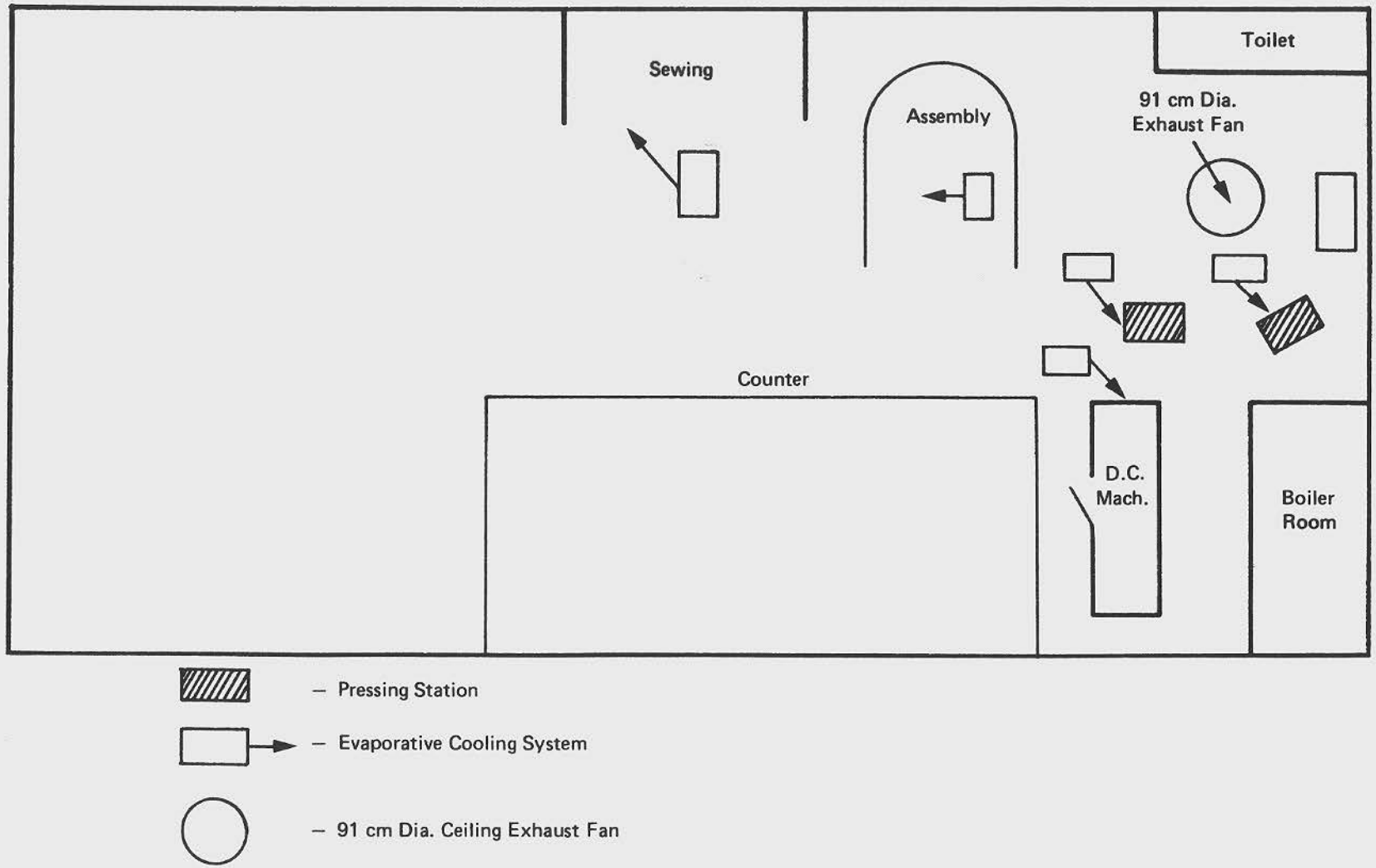


FIGURE A5–2 EVAPORATIVE COOLING SYSTEM LOCATION

F. HEAT EXPOSURE

A maximum wet-bulb globe temperature (WBGT) of 23.3°C (73.9°F) was measured at the pressing area. This WBGT was based on a dry-bulb temperature of 29.3°C (84.7°F), a wet-bulb temperature of 19.8°C (67.7°F), and black-globe temperature of 32.2°C (90.0°F).

G. SOLVENT EXPOSURE LEVELS

The personal exposure level of the cleaner was 40-65 ppm, and her ceiling (15-minute TWA) exposure level during garment unloading ranged between 52 and 549 ppm. In the areas surrounding the dry cleaning machine, readings were generally below 5 ppm. Levels measured in this plant are listed in Table A5-1.

CONCLUSIONS

Air samples taken in loads of garments taken out of the dry cleaning machine were found to have solvent levels between 10,000 and 15,000 ppm. The cleaner's exposure levels seem to have been raised by her work practices: Immediately after unloading the cleaning machine, the cleaner hangs each piece individually. It takes less than 30 seconds to unload the machine, but as much as 5 minutes to complete hanging the garments. Additional drying time of 10-15 minutes did not reduce the levels found in the garments to any appreciable degree. The use of improved ventilation in the machine area would probably reduce the cleaner's exposure level.

Table A5-1. Airborne concentration measurements.

Sample #	Location	Start Time	Duration (min.)	Fl13 mg/m^3	Level ppm
1	Beneath dry cleaning machine door	8:10	120	1,140	149
2	Beneath dry cleaning machine door	8:10	120	1,050	137
3	Cleaner's personal sample	8:19	117	31	4
4	Table near dry cleaning machine area	8:45	60	7.7	1
5	Customer service area	8:48	120	14.9	2
6	Garment storage area	8:50	240	12.3	2
7	Pressing area	8:51	245	11.3	2
8	Sewing area	8:53	240	8.1	1
9	Snack table area	9:10	120	10.9	1
10	In clothes just out of dry cleaning machine	9:40	6	116,000	15,167
11	Table near dry cleaning machine area	9:52	60	11.7	2
12	Beneath dry cleaning machine door	10:12	120	570	75
13	Beneath dry cleaning machine door	10:12	120	530	69
14	Cleaner during unloading	10:16	15	3,400	445
15	In clothes just out of dry cleaning machine	10:20	3	111,000	14,513
16	Customer service area	10:48	60	16.2	2
17	Table near dry cleaning machine area	10:52	60	11.7	2
18	Cleaner's personal sample	11:08	95	116	15
19	In clothes just out of dry cleaning machine	11:00	4	112,000	14,644
20	Cleaner during unloading	12:48	15	670	88
21	Table near dry cleaning machine area	12:08	60	5.2	1
22	Beneath dry cleaning machine door	12:16	120	208	27
23	Beneath dry cleaning machine door	12:16	120	174	23
24	Pressing area	12:28	120	14.4	2
25	In clothes just out of dry cleaning machine	∿12:00	4	82,000	10,721
27	Behind dry cleaning machine area	∿ 1:00	120	55	7
28	Cleaner during unloading	1:58	15	4,200	549
29	Cleaner during unloading	3:04	15	400	52

APPENDIX A6
CASE STUDY NO. 6

A. PROCESS AND EQUIPMENT

This is a medium-size commercial fluorocarbon 113 plant situated in the Middle-Atlantic area. Solvent mileage is estimated to be 9600. The plant employs 1 manager/assembler, 1 presser, 1 seamstress, 1 cleaner/presser, and a part-time person for the evenings.

A weekly average of 1090 kg (2400 pounds) of dry cleaning is processed in a Union Master dry cleaning machine. This Italian machine is 6 months old and has a capacity of 23 kg (50 pounds). As in other fluorocarbon 113 machines, the Union Master has its own integral still, reclaimer, Freon 22 refrigeration system, filter cartridge system, etc. The unique feature of this machine is that it has 2 work tanks. One is used for regular garments while the other is used for suede and leather. While many commercial facilities will wait until the solvent is at its dirtiest, and process all their suede and leather garments in one or two loads, this plant can provide one-hour service, if the occasion arises, without having to contaminate the regular work tank solvent.

Normal operation includes a 12-minute washing, 2-minute draining, 1-minute extraction, and 18-minute drying. The 4 carbon-core cartridge filters are replaced every 2720-3630 kg (6000-8000 pounds).

The still is operated about 2-3 times per week with each distillation ranging from 1/2-1 hour. Approximately 45 L (12 gal.) of solvent are distilled each time. Residue amounts to about 6 L (1.5 gal.) per week.

A daily average of 10-15 loads is processed in this facility. An average load will weigh 16-18 kg (35-40 pounds).

A layout of this plant is shown in Figure A6-1.

B. NATURAL VENTILATION

Normal infiltration was the only source of natural ventilation since both doors of the plant were kept closed during this survey.

C. GENERAL MECHANICAL VENTILATION

Three 91-cm (36-in.) diameter ceiling exhaust fans were available and operated as needed. Each of these fans is rated at 6.6 m^3/sec. (14,000 cfn) at 0 cn static pressure. Two evaporative cooling systems, each rated at 7.1 m^3/sec (15,000 cfm), were also available. For locations of the fans and evaporative cooling systems, consult Figure A6-1.

D. LOCAL EXHAUST VENTILATION

There is no local exhaust ventilation in this plant.

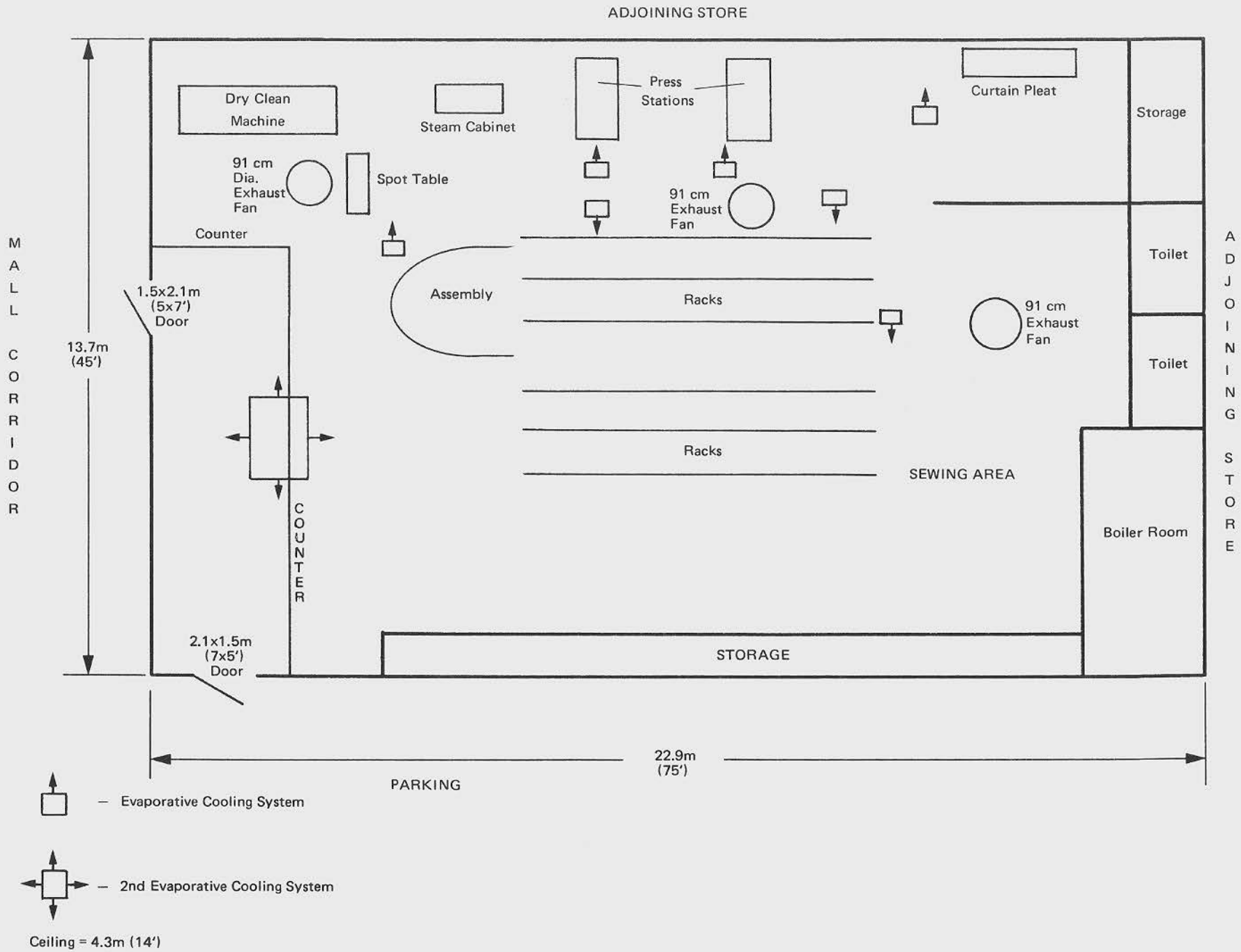


FIGURE A6–1 GENERAL LAYOUT – PLANT #6

E. LEAK DETECTION

Several small leaks were detected by a Gas Tech Halide Meter:

Location	Fluorocarbon 113 (ppm)
2 o'clock position of machine door	5-10
still door	10
drain	40-50

A leak in excess of 1000 ppm also was detected around the button trap by means of charcoal tube and subsequent G.C. analysis.

F. HEAT EXPOSURE

A maximum wet-bulb globe temperature (WBGT) of 24.7°C (76.5°F) was measured in the pressing area. This reading was based on a dry-bulb temperature of 28.7°C (83.6°F), a wet-bulb temperature of 22.4°C (72.3°F), and a black-globe temperature of 30.8°C (87.5°F).

G. SOLVENT EXPOSURE LEVELS

Fluorocarbon 113 exposure levels determined by charcoal tube samples and G.C. analysis are summarized in Table A6-1. The cleaner's exposure level was determined to be 70 ppm. Her ceiling levels during unloading (15 minute TWA) ranged between 92 ppm and 149 ppm. Area levels within the facility ranged from 1 ppm to 18 ppm.

CONCLUSIONS

As was seen in Case Study No. 5, the cleaner's principal exposure stems from her hanging of the garments immediately upon removal from the dry cleaning machine. Her exposure would be reduced dramatically if ventilation were supplied at the dry cleaning machine.

Table A6-1. Airborne concentration measurements.

Sample #	Location	Duration (min.)	Start Time	mg/m^3	ppm
1	Sewing area	120	8:14	8.1	1
2	Customer service area	120	8:15	18.7	3
3	Cleaner personal sample	120	8:15	ND	ND
4	Beneath washer door	120	8:25	960	126
5	Beneath washer door	122	8:25	950	124
6	Cleaner during loading/ unloading/hanging of garments	15		700	92
7	Customer service area	120	8:36	112	15
8	Pants press area	120	8:38	107	14
9	Press area	120	8:38	15.4	2
10	Sewing area	125	8:40	5.8	1
11	Behind dry cleaning machine area	120	9:22	135	18
12	In clothes just out of machine	5	9:30	78,000	10,198
13	Cleaner during loading/ unloading/hanging of garments	15	10:03	1,140	149
14	Sewing area	90	10:15	8.7	1
15	Customer service area	90	10:17	9.8	1
16	Customer service area	75	10:41	32	4
17	Pants press area	75	10:38	44	6
18	Press area	75	10:44	31	4
19	Sewing area	75	10:46	75	10
20	In clothes just out of machine	8	10:48	15,000	1,961
21	Cleaner personal sample	102	10:20	1,180	154
22	Cleaner during loading/ unloading/hanging of garments	15	10:19	910	119
23	Button trap area	3	12:00	8,000	1,046

ND - Non-Detectable

APPENDIX A7
CASE STUDY NO. 7

A. PROCESS AND EQUIPMENT

An industrial dry cleaner located in the north central United States, this plant consumes approximately 200,000 L (54,100 gal.) of Stoddard solvent annually, processing 9409 kg/week (20,700 pounds/week) of clothes for an average solvent mileage of 1095. The plant is efficiently staffed, relying on 1 dry cleaning machine operator, 2 dry cleaning pressers, 2 production supervisors, 1 laundry machine operator, 5 laundry pressers, 1 plant engineer, and 14 support persons.

Equipment is of moderate age, including a seven-year-old Washex 500 FPA-02 machine used for single-phase cleaning and a four-year-old Washex 500 FLPA machine used for dual-phase cleaning. Drying is done by a single Model 400 dynamic laundry tumbler manufactured by Challenge-Cook Brothers. Solvent cleaning is accomplished by two Washex 2 filters, Model 15 MAC, type 7106, and by a Washex Model 36 VS vacuum still.

Approximately six loads per day are processed in the single-phase washer, and three loads per day are cleaned in the dual-phase machine. The single-phase machine requires a three-step wash using fresh solvent, solvent plus soap, and rinse solvent, with extraction runs after each washing step. The dual-phase machine first washes the load in petroleum and then follows with a 30-minute wash and multiple rinse in water. The various quality solvents (fresh, soap, and rinse) are transferred from underground tanks to the machines as required by automatically operated pumps and manually operated valves. Although the washers were as large and as old as some other petroleum machines observed during the study, at this particular site solvent was well contained within the machines during extraction. Only occasional draining into the gutter beneath the machine doors was observed dripping onto the floor. The tumblers dry clothes at 71.1-76.7°C (160-170°F) for 20-45 minutes. The filters are dumped daily. Solvent is decanted from the dump solids prior to muck disposal. Solvent is distilled daily for approximately six hours and the remaining muck is boiled down every afternoon.

Solvent handling within the plant is quite complex, involving four solvent tanks holding fresh solvent, dirty solvent (dump tank), solvent containg soap (soap tank), and solvent for rinsing (contains no soap; rinse tank). The rinse and soap tanks are made up as necessary with fresh solvent. The rinse tank is emptied every two weeks to the dump tank; the soap tank is dumped every three weeks. Solvent from the dump tank passes through a gravity separator where heavy oil and grease are partially removed; the decanted dirty solvent is distilled daily and the distillate is returned to the fresh solvent tank.

Typical cleaning room activities are outlined in Table A7-1.

B. NATURAL VENTILATION

Doors are kept open at the unloading dock and occasionally at the shipping bay on the opposite side of the building, allowing for a large amount of natural ventilation.

Table A7-1. Cleaning room activities.

	Machine Status			
Time	Single-Phase Washer	Dual-Phase Washer	Tumbler	Still
9:00	Soap Cycle	Empty	On	On
9:05	↓	Soap Cycle	Unloading	↓
9:17	Soap Extraction	↓	↓	↓
9:20	↓	Soap Extract	↓	↓
9:22	Rinse Cycle	↓	↓	↓
9:23	↓	↓	↓	↓
9:25	Off	↓	↓	↓
9:28	Rinse Extract	Water Wash	On	↓
9:30	↓	↓	↓	↓
9:33	↓	↓	↓	↓
9:35	Off	↓	↓	↓
9:36	Open	↓	↓	↓
9:37	Unloading	↓	↓	↓
9:45	Finish Unloading	↓	↓	↓

C. GENERAL MECHANICAL VENTILATION

Forced ventilation of the building is provided by ceiling-mounted exhaust fans and evaporative cooling air conditioners. During this survey the two exhaust fans, each rated at 12.3 m^3/s (26,000 cfm) were operating, as were two of the fans for the cooling units, each fan rated at 7.6 m^3/s (16,000 cfm).

D. PERSONAL PROTECTIVE EQUIPMENT

A dual cartridge respirator is available to the cleaner and is reportedly used frequently during the summer months. During this survey in the fall, the respirator was not being used. The cartridge elements (ESB type R-25) are replaced when the wearer can smell solvent while wearing the mask.

E. LEAK DETECTION

No unusual leaks were detected within this plant.

F. SOLVENT EXPOSURE LEVELS

Solvent vapor concentrations as determined by charcoal sample tubes/GC analysis are summarized in Table A7-2. These measurements detected a maximum ceiling exposure for the operator of approximately 160 ppm. Longer duration samples, more representative of an eight-hour TWA, indicated concentrations of 90-95 ppm.

CONCLUSIONS

Solvent concentrations within this plant, although within existing and anticipated standards, were higher than they might otherwise have been due to the air flow arrangement which passed air through the cleaning room prior to entering the remainder of the plant.

Table A7-2. Air Sampling Data

Sample #	Location	Duration (min)	Start Time	Stoddard Solvent Concentration mg/m^3	ppm
1	Cleaner personal sample	128	8:00	630	109
2	Inspector personal sample	125	8:00	55	9
3	Dry cleaning machine area	50	8:15	133	23
4	Dryer area	50	8:15	277	48
5	Pressing area	115	8:15	67	12
6	Cleaner during transfer	15	8:20	710	122
7	Dry cleaning machine area	60	9:05	580**	100
8	Dryer area	60	9:05	450	78
9	Cleaner during transfer*	15	9:25	84	14
10	Cleaner during transfer	15	9:40	1170**	202
11	Inspector personal sample	190	10:05	39	7
12	Cleaner personal sample	184	10:07	500	86
13	Dry cleaning machine area	60	10:08	550	95
14	Dryer area	60	10:08	400	69
15	Pressing area	180	10:12	50	9
16	Cleaner during transfer*	15	11:12	450	78
17	Dryer area	120	11:15	300**	52
18	Dry cleaning machine area	60	11:17	560**	97
19	Cleaner during transfer	15	11:28	860	148
20	Pants folder personal sample	129	1:15	63	11
21	Cleaner personal sample	121	1:21	520	90
22	Dry cleaning machine area	60	1:26	370	64
23	Cleaner during transfer	15	1:43	1770	305
24	Cleaner personal sample	123	7:31	640	110
25	Inspector personal sample	136	7:31	131	23
26	Dry cleaning machine area	60	7:32	660	114
27	Dryer area	120	7:32	310	53
28	Pressing area	180	7:36	100	17
29	Cleaner during transfer	15	8:22	830	143
30	Cleaner during transfer*	15	8:42	370	64
31	Dry cleaning machine area	60	9:22	320**	55
32	Cleaner during transfer	15	9:38	1170	202
33	Dryer area	120	9:36	264	46
34	Cleaner personal sample	122	9:34	630	109
35	Inspector personal sample	125	9:47	108	19
36	Cleaner during transfer*	15	10:31	262	45
37	Dry cleaning machine area	49	10:32	620	107
38	Pressing area	180	10:47	172	30
39	Cleaner during transfer	15	10:54	390	67
40	Dry cleaning machine area	30	11:22	490	85

*Dual phase machine

**Greater than 25% of sample found in back-up section, data unreliable

Table A7-2. Air Sampling Data (cont.)

Sample #	Location	Duration (min)	Start Time	Stoddard Solvent Concentration mg/m^3	ppm
41	Dryer area	60	11:26	370	64
42	Dry cleaning machine area	30	11:53	470	81
43	Dry cleaning machine area	30	1:35	550	95
44	Dryer area	50	1:37	360	62
45	Cleaner during transfer	15	1:57	Lost	--

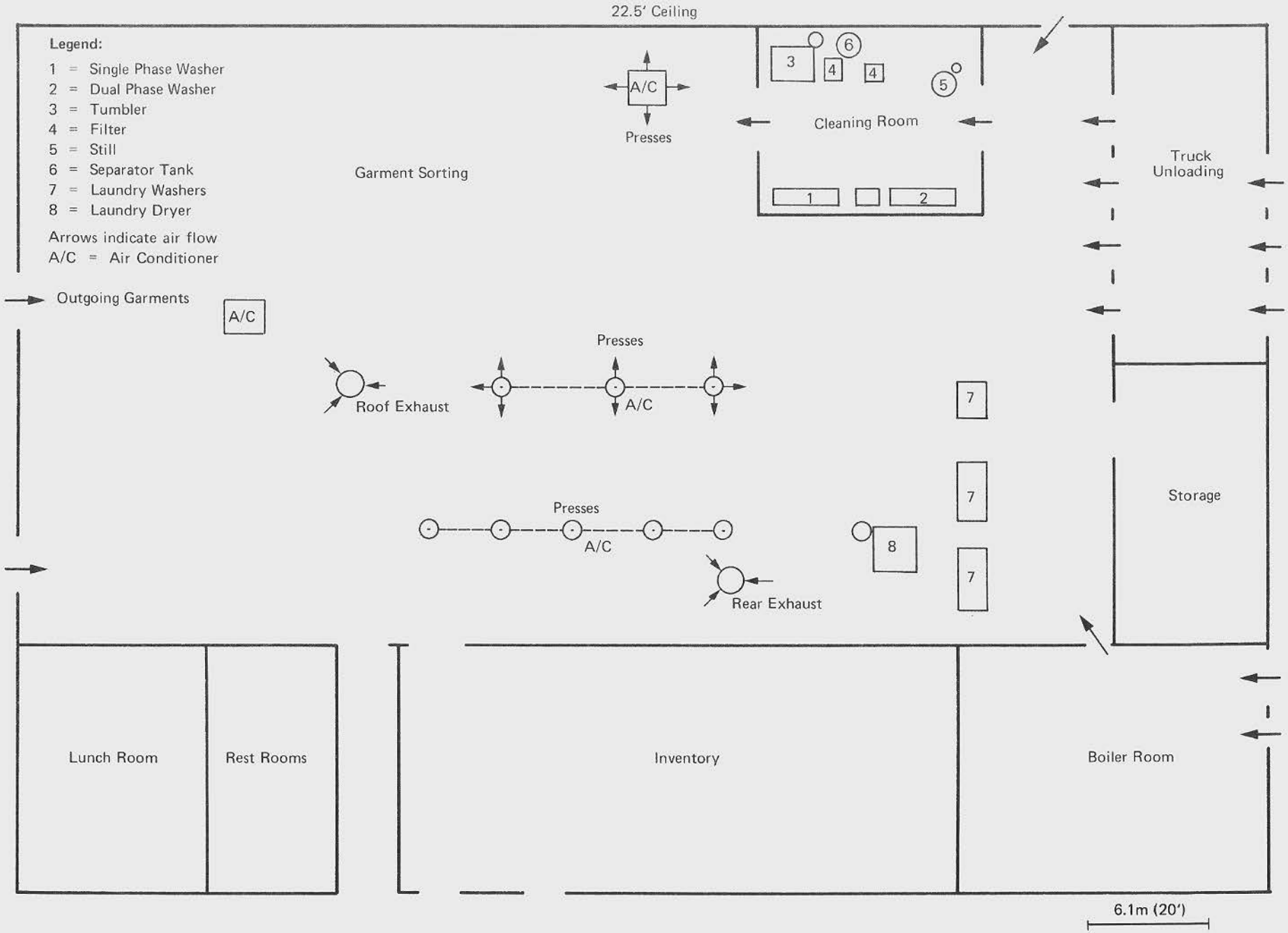


FIGURE A7–1 GENERAL ARRANGEMENT – PLANT #7

APPENDIX A8
CASE STUDY NO. 8

A. PROCESS AND EQUIPMENT

This plant located in the north central United States is a very large industrial cleaning plant using primarily water-based laundering equipment but doing a limited amount of dry cleaning. This mode of operation is relatively recent. Earlier in 1978, this same plant dry cleaned an average of 2,722 kg (6,000 pounds/day); however, at the time of this survey, dry cleaning volume had dropped to 2,722 kg (6,000 pounds/week) (2 loads per day). Thus, very little dry cleaning was observed. This reduced dry cleaning rate will prevail in this plant's foreseeable future. Prior to the change in operating mode, 140°F dry cleaning solvent was consumed at an annual rate in excess of 100,000 L/year (49,000 gallon/year). Average solvent mileage was approximately 1,925.

The dry cleaning equipment in this facility includes two Washex 500 FLPA-02 washers, both only four-years-old; one Challenge dry flow tumbler Model DFSD; 2 Washex tube filters, Model 15 MAB; 2 Washex 36 VS vacuum stills, and 1 Washex 24 VS vacuum still.

Plant operations are handled by one chief cleaner, 2-3 cleaning assistants, 4 miscellaneous persons working adjacent to the cleaning area, and approximately 35 persons working in pressing, packaging, and other related activities.

The general arrangement of this plant is indicated in Figure A8-1.

B. NATURAL VENTILATION

No significant natural ventilation was present in this plant.

C. MECHANICAL VENTILATION

Mechanical ventilation of the building is provided by three active roof exhaust fans, each expelling approximately 16.5 m^3/s (35,000 cfm), and two active evaporative coolers, each cooler injecting approximately 11.8 m^3/s (25,000 cfm) (evaporators not on during the survey). Relatively small volumes of air are exhausted by fans adjacent to the laundry equipment (1.9 m^3/s or 4,000 cfm) and by the machine exhausts of the seven dryers in the building.

D. PERSONAL PROTECTIVE EQUIPMENT

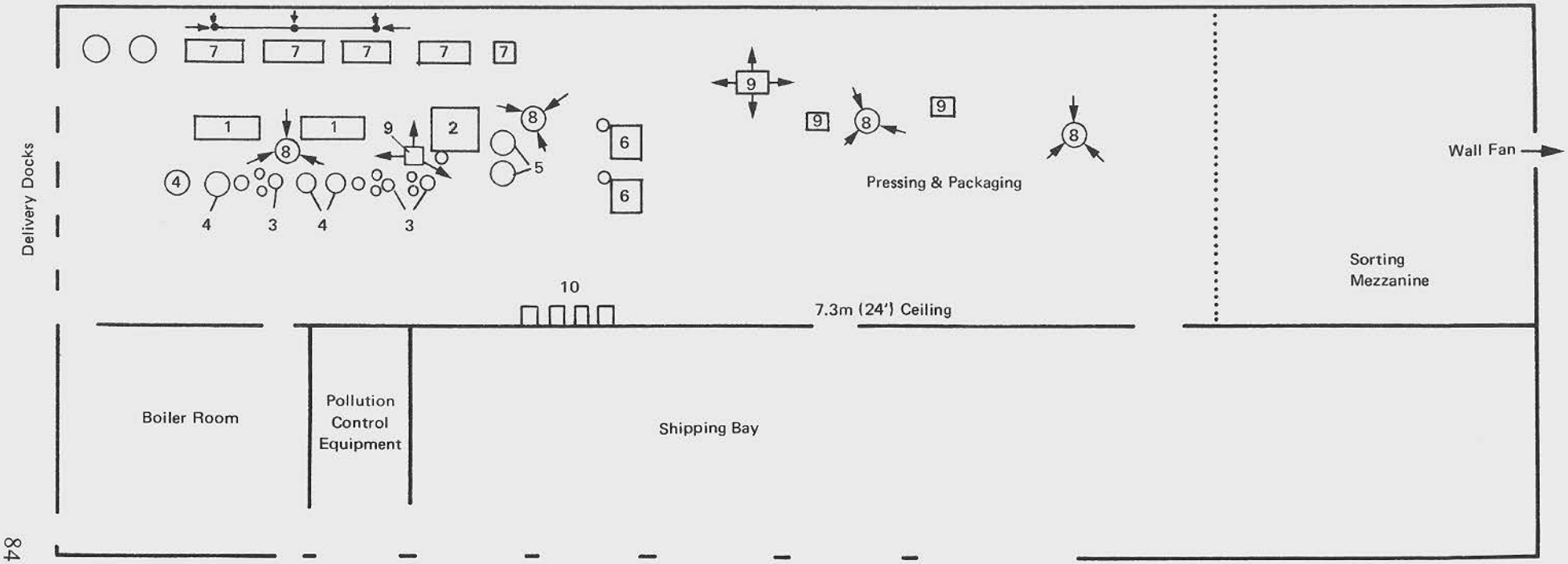
The chief cleaner wore rubber gloves. Use of no other protective devices were observed.

E. SOLVENT EXPOSURE LEVELS

Solvent concentrations, as determined by charcoal tube samples/GC analysis are summarized in Table A8-1. As one might expect from the low volume of dry cleaning, solvent concentrations are all quite low, with the personal sample of the cleaner being highest at approximately 5 ppm.

CONCLUSIONS

Due to the small amount of dry cleaning done in this plant, exposure levels are very low.



Legend:
1 = Dual-Phase Cleaning Machines
2 = Steam Heated Tumbler
3 = Stills
4 = Solvent Tanks
5 = Centrifuges
6 = Gas-Fired Dryers
7 = Laundry Washers
8 = Roof Exhausts
9 = Air Conditioning Units
10 = Dryers
Arrows indicate air flow

FIGURE A8–1 GENERAL ARRANGEMENT – PLANT #8

Table A8-1. Stoddard solvent air sampling data.

Sample #	Location	Duration (min)	Start Time	mg/m^3	ppm
1	Cleaner personal sample	134	10:36	33	6
2	Dry clean machine #1 area	43	10:36	8	1
3	Dry clean machine #2 area	44	10:36	33	6
4	Challenge dry flow area	47	10:36	16	3
5	Pressing area	165	10:41	2	<1
6	On dry clean machine #2	72	11:23	35	6
7	On challenge dryer	69	11:27	21	4
8	On dry clean machine #1	72	11:22	6	1
9	Cleaner personal sample	112	12:55	30	5
10	Cleaner personal sample	112	12:55	1	<1
11	Cleaner personal sample	119	12:50	28	5
12	Dry clean machine #2 area	60	12:35	26	5
13	Dry clean machine #1 area	60	12:34	4	<1
14	Dryer area	60	12:36	20	4
15	Dry cleaning machine #2 area	60	1:35	27	5
16	Dry clean machine #1 area	60	1:34	9	2
17	Dryer area	60	1:36	17	3

APPENDIX A9
CASE STUDY NO. 9

A. PROCESS AND EQUIPMENT

A commercial dry cleaning plant in southern New England, this establishment cleans an average of 1,640 kg/week (3,600 pounds/week) with perchloroethylene. Annual solvent use and average mileage were independently estimated by the owner at 3,000 L/year (850 gallons per year) and 10,000 respectively. The plant employs approximately twelve people; 1 cleaner/spotter, 3 pressers, 1 seamstress, 2 supervisors/launderers, 3 part-time shirt pressers, and 2-3 counter attendants.

The dry cleaning equipment used at this plant is relatively new, consisting of a 27 kg (60 lb) capacity Paramatic washer and a Hoyt "Solvo-Miser" (model SF-145) tumbler, both only one-year-old. The solvent is continously cleaned by a 12-year-old Puritan "Vanguard" cartridge-type filter/cooker. Fugitive solvent vapors are collected by a eight-year-old Vic "Mileage Booster" (Model 108) carbon adsorption system.

Approximately four loads per hour are handled by the washer. Each wash cycle involves a five-minute wash, three-minute solvent drain, nearly five minutes of extraction, and approximately forty-five seconds to transfer the wet clothes from the washer to the tumbler. Another forty-five seconds are required to load dirty, dry clothes into the washer.

The tumbler dries the clothes for approximately 15 minutes on a closed circuit reclaim cycle at 73.9-76.7°C (165-170°F). Following the 15-minute drying, the clothes are aerated for approximately 3 minutes or less at temperatures below 48.9°C (120°F). During aeration, the tumbler exhaust is ducted to the carbon adsorber. The seals around the tumbler door were in very good shape, and condensate reclaimed during drying is piped directly into the washer solvent reservoir.

The cartridge filter is changed every 7-8 weeks. Each afternoon approximately 180 L (50 gallons) of solvent are distilled and the condensed solvent is piped directly into the washer solvent reservoir. At the end of distillation, approximately 7.5 L (2 gallons) of liquid residue remain in the cooker, and this liquid is poured from the cooker door into an open can placed in front of the filter.

The carbon adsorber is steam stripped daily around mid-day. Recovered solvent is collected from the adsorber condenser at approximately 23°C (73°F) for approximately one hour, over which time approximately 13 L (3.6 gallons) of solvent are collected in an open bucket at the discharge of the condenser.

The arrangement of this equipment within the plant is illustrated in Figure A9-1.

B. NATURAL VENTILATION

As one might expect from its northerly location, the amount and source of natural ventilation in this plant varies considerably from day to day and season to season. At the time of this survey in early spring, windows adjacent to the carbon adsorber and to the shirt pressing area were partially open as indicated in Figure A9-1.

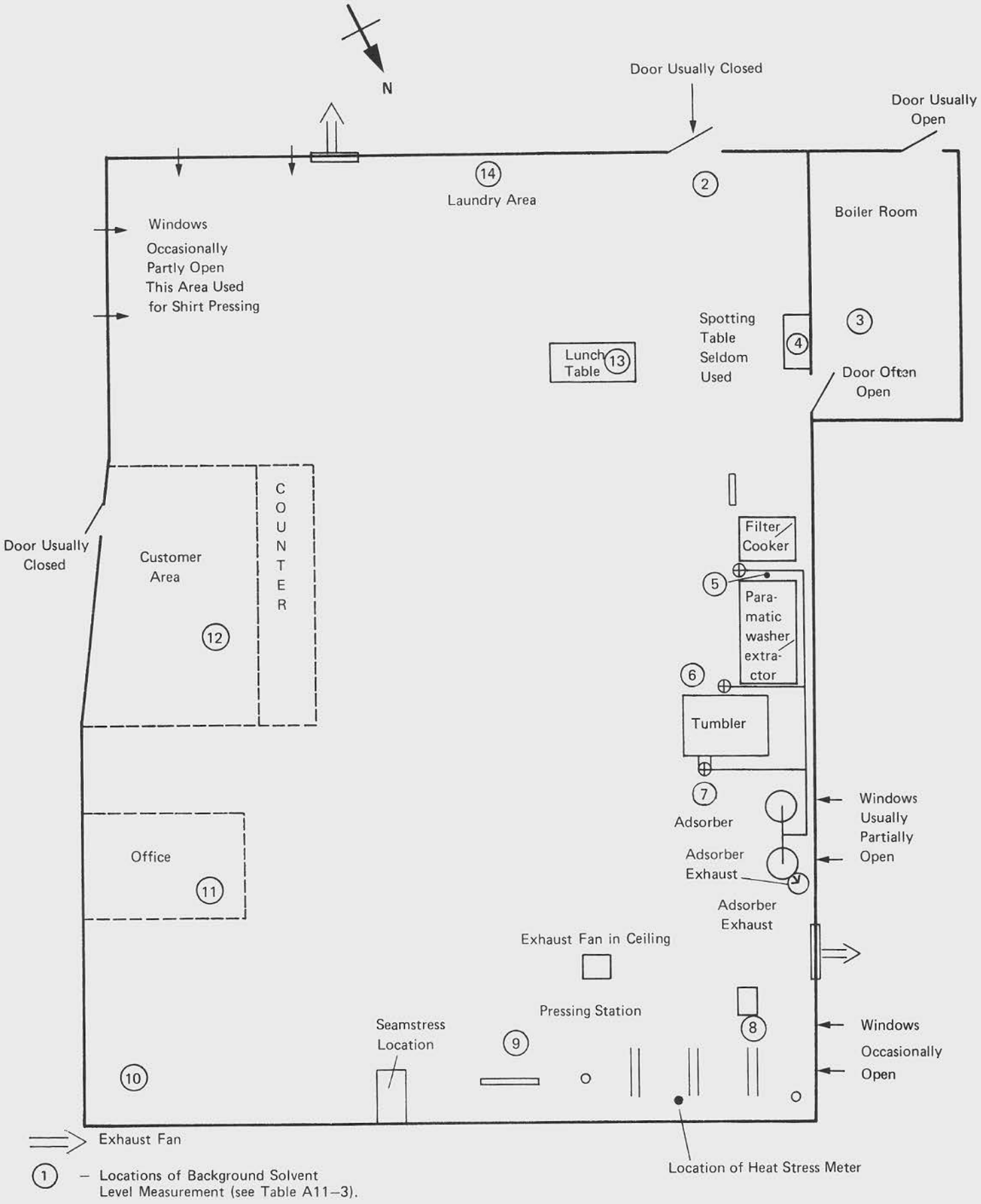


FIGURE A9–1 GENERAL ARRANGEMENT

C. GENERAL MECHANICAL VENTILATION

Forced ventilation of the building was provided by three exhaust fans, also identified in Figure A9-1. Two of the fans were wall mounted units exhausting approximately 1.9 m^3/s (4,000 cfm) from areas near the open windows. The third fan is ceiling-mounted, exhausting approximately 0.57 m^3/s (1,200 cfm).

D. LOCAL EXHAUST VENTILATION

A network of ducts exhausted the area around the dry cleaning equipment to the carbon adsorber. The adsorber exhaust was vented inside the building approximately 0.6 m (2 feet) above the floor by a duct pointing towards the open windows which are the main source of air in the plant. The numerous inlets to the adsorber ductwork are always open, but because of changing resistances caused by open or closed equipment doors, the flow-rate through the adsorber ductwork can vary considerably as illustrated in Figure A9-2.

E. LEAKS DETECTED

Relatively little leakage was detected around the dry cleaning equipment, per se. However, very high solvent levels (800 ppm) were measured in the steam venting from the carbon adsorber condenser during steam stripping, and concentrations as high 26 ppm were measured in the adsorber exhaust during normal operation.

F. HEAT EXPOSURE

Heat stress was negligible, as might be expected from the comfortable ambient temperature and the existence of ventilation. A summary of heat stress measurements is presented in Table A9-1.

G. SOLVENT EXPOSURE LEVELS

Perchloroethylene exposure levels determined by charcoal tube samples/GC analysis are summarized in Table A9-2. The cleaner's exposure level (2-hour TWA) was in excess of 30 ppm, and ceiling levels (15-minute TWA) ranged between 21 and 65 ppm. Area samples within the store indicated vapor concentrations between 2 and 25 ppm. Concentrations at various times during the survey (determined with a photo-ionization detector) are reported in Tables A9-3 and A9-4.

CONCLUSIONS

The vapor concentrations measured in this plant were higher than those measured in some other plants, probably because of the relatively poor system of ventilation employed. Rather than being exhausted outside, the carbon adsorber was exhausted directly into the main source of incoming air to the building. Exhaust fans and open windows were located adjacent to each other, thus local air circulation patterns were set up near the wall which did not penetrate the rest of the plant. Nevertheless, high solvent vapor concentrations were generally confined to the vicinity of the cleaning equipment and were seldom excessive in other areas of the plant used for clothes pressing, customer service, or administrative purposes.

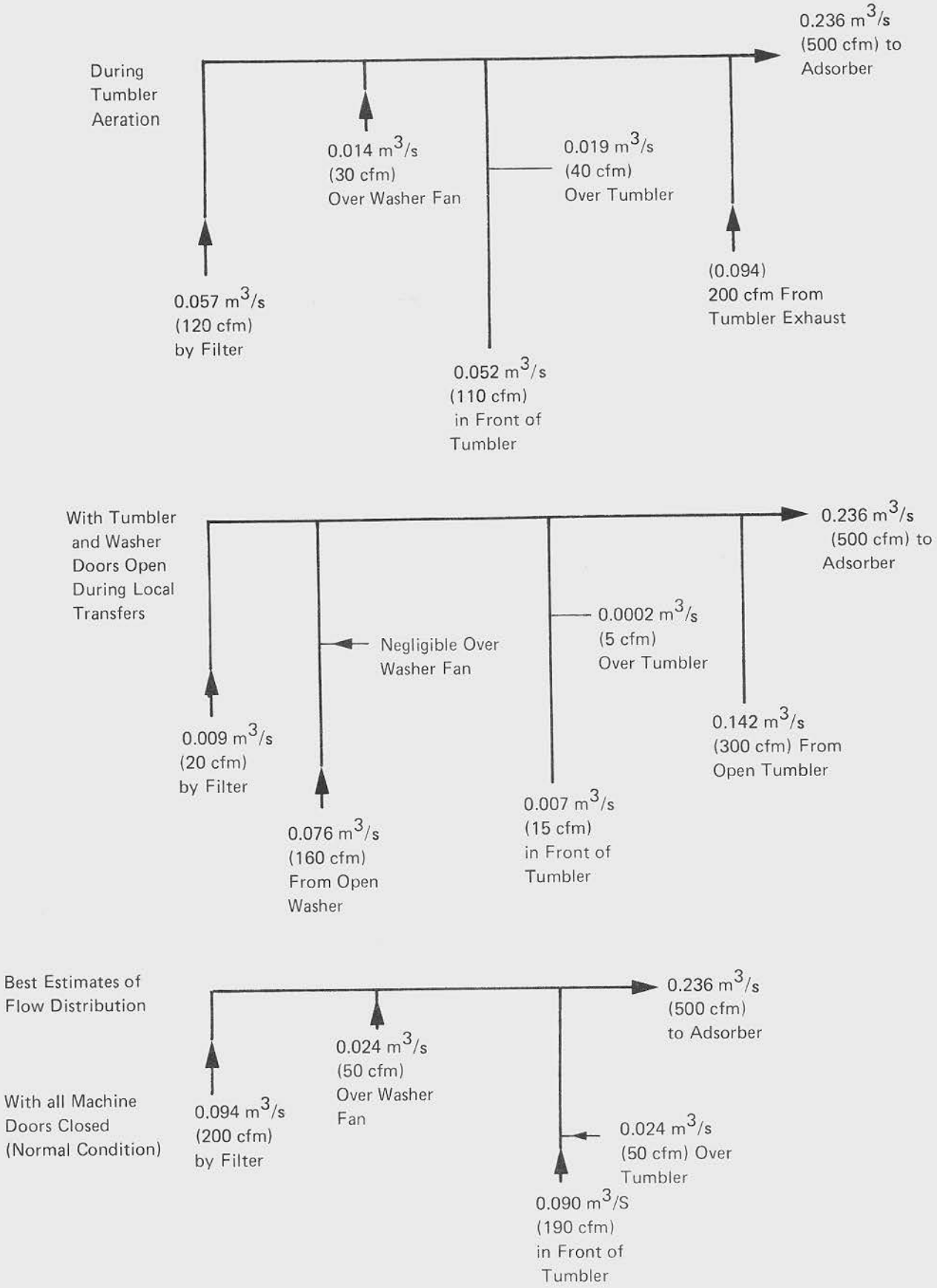


FIGURE A9–2 SOURCES OF AIR TO ADSORBER

Table A9-1. Heat stress measurements.

Time	Dry Bulb °C	Dry Bulb (°F)	Wet Bulb °C	Wet Bulb (°F)	Globe °C	Globe (°F)	WBGT (in) °C	WBGT (in) (°F)
9:30 am	27.6	(81.6)	17.8	(64.1)	31.1	(88.0)	21.6	(70.8)
10:30 am	--	--	--	--	--	--	22.6	(72.7)
11:30 am	29.8	(85.7)	19.8	(67.6)	33.9	(93.0)	23.6	(74.5)
12:30 pm	28.5	(83.3)	18.4	(65.1)	34.2	(93.6)	22.6	(72.7)
1:30 pm	29.6	(85.2)	18.7	(65.6)	34.9	(94.9)	23.1	(73.5)
2:50 pm	29.9	(85.8)	19.1	(66.4)	35.9	(96.6)	23.6	(74.4)
3:30 pm	30.0	(86.0)	18.6	(65.5)	35.3	(95.5)	23.0	(73.5)
9:45 am	27.6	(81.7)	17.1	(62.8)	31.2	(88.2)	20.9	(69.7)
10:30 am	29.1	(84.4)	18.1	(64.5)	32.8	(91.1)	22.1	(71.8)
1:15 am	31.1	(87.9)	18.2	(64.8)	33.7	(92.6)	22.5	(72.5)

Table A9-2. Air sampling data (perchloroethylene concentrations).

Sample #		Start	Duration (hr:min)	mg/m^3	ppm
1	Cleaner	7:56	2:24	void	---
2	Cleaning area	8:35	2:00	96	14.2
3	Boiler room entrance	9:00	2:00	160	23.6
4	Press area	9:10	2:15	41	6.1
5	Customer area	9:25	1:30	12	1.8
6	SE fan	9:55	3:28	47	6.9
7	Cleaner (ceiling)	10:35	10:15	440	65.0
8	Cleaner	10:45	2:11	230	34.0
9	Floor level during transfer	11:00	0:03	370	54.7
10	Above dryer	11:00	0:03	640	94.5
11	Cleaning area, floor level	11:05	2:00	150	22.2
12	Lunch table	11:30	1:10	76	11.2
13	Adsorber area	11:37	1:51	110	16.2
14	Cleaner	1:06	0:15	110	16.2
15	Cleaning Area, floor level	1:05	2:18	63	9.3
16	Press area	1:00	2:28	60	8.9
17	Cleaner	1:16	2:24	180	26.6
18	Adsorber vent	1:40	1:48	59	8.7
19	Above open washer door	2:00		160	23.6
20	Below open washer door	2:00		110	16.2
21	Below open washer door	2:30		260	38.4
22	Above open washer door	2:30		330	48.7
23	Customer area	2:50	0:30	52	7.7
24	SE corner	7:47	6:13	81	12.0
25	Customer counter	7:46	1:59	32	4.7
27	Press area	7:58	3:00	25	3.7
28	W fan	8:03	4:28	41	6.1
29	Adsorber inlet	8:45	2:02	135	19.9
30	Cleaner during transfer	9:55	0:17	220	32.5
31	Cleaner	10:10	3:00	220	32.5
32	Adsorber vent			150	22.5
33	Adsorber vent	10:54	0:23	89	13.1
34	Press area	10:58	3:00	24	3.5
35	Dryer vent inside duct	12:50	0:05	31000	4579.4
36	Cleaner during transfer	13:10	0:15	140	20.7

Table A9-3. Vapor concentration surveys - day 1 (ppm perchloroethylene).

Sample #	Location	8:00	9:00	10:00	11:00	12:25	1:00	2:00	3:00
1	Outside	1.0	0.7-1.3	0.6	0.7	0.8	0.7	1.1	0.8
2	Inside rear door	10.9-14.7	7-8	5-6	15-30	4	15-30	5	3.5
3	Boiler room	1.9-2.5	0.8	--	--	--	--	--	--
4	Outside boiler room	23	9-10	6.8	31-37	11	31-37	4	4
5	Near filter	13-29	--	--	--	--	--	--	--
6	Adsorber exhaust tumbler	--	--	--	13	13	13	8	7
7	Rear of tumbler	12.5-21	10-11	5.5	6	7	6	6	9
8	Coat presser	5.4	4-4.5	3.3	4	6	4	4	5
9	Pant pressers	5.0	2-3	2.4	3	2	3	4	4.5
10	Northeast corner	4.0	2-3	2.2	2	2	2	4	3
11	Office	4.6	4	2.4	4	2	4	5	4
12	Customer area	4.6	4	2.8	5	4	5	5	6
13	Lunch table	5.1-5.6	19	5.0	3	14	3	3	4
14	Laundry area	1.5	13	4.5	44	2	4	3	5

Note:

Around cleaning machine, levels rise from 10-30 ppm to about 200^{+} ppm during loading. Levels measured 100 ppm above door and 200 ppm below door during unloading.

Concentration at door of tumbler rose from 10-30 ppm to 80-90 ppm during unloading.

Table A9-4. Vapor concentration surveys - day 2 (ppm perchloroethylene).

Sample No.		Time				
		7:55	9:00	10:00	11:00	1:00
1	Outside	0.8	1.2	0.8	1.0	1.0
2	Inside rear door	5	8	6-7	5	5
3	Boiler room	--	--	--	--	--
4	Outside boiler room	5	15-20	5	7	5
5	Near filter	--	--	--	--	--
6	Adsorber exhaust	--	--	27	10-15	5
7	Rear of tumbler	12	22-28	8	8-10	8-10
8	Coat presser	8	8	4	5-6	5-6
9	Pant pressers	6	4	3	3-4	5
10	Northeast corner	5	3	3	3	3
11	Office	5	4	3	4	3
12	Customer area	4	3	3	5	4-5
13	Lunch table	--	--	3	4	7
14	Laundry area	1	1.5	2	1.5	6-7

APPENDIX A10
CASE STUDY NO. 10

An evaluation of exposure to airborne vapors of spotting chemicals was conducted at a garment analysis laboratory. The laboratory, in which spotting is conducted at much greater frequency than in any plant, consisted of a moderate-sized (approximately 127 m^3, or 4500 $ft.^3$) room with general ventilation supplied through ceiling diffusers. The airflow velocity at the spotting board was less than 0.1 m/s (20 f.p.m.).

The chemicals typically employed in spotting operations include petroleum solvents (halogenated and non-halogenated), detergents, acids, bleaches, and aqueous ammonia. Of the commonly used spotting fluids, none has a ceiling exposure limit under current OSHA regulations. Ammonia, which has a permissible exposure limit of 50 ppm (8-hour average), has been the subject of a NIOSH Criteria Document which recommended a ceiling exposure level of 50 ppm. Within dry cleaning plants, the use of spotting fluids is both intermittent and infrequent; thus, 8-hour TWA exposures to any spotting fluid will be quite low. In order to assess the effectiveness of reliance upon general room airflows in controlling spotting exposures, an assessment was made of transient ammonia levels during the use of this chemical.

Sampling was conducted with length-of-stain gas detector tubes as a normal operation using ammonia was performed. The operation entailed the application of ammonia from a plastic squeeze bottle to the garment, followed by flushing with steam. Although the odor of ammonia was strong during this operation, the airborne concentration was found to be between 5 and 10 ppm.

Since ammonia, heated through the application of steam and allowed to evaporate freely, remained at levels below 10 ppm during this test, it was concluded that spotting operations, which consume a cumulative total of less than 30 minutes daily in a typical dry cleaning plant, do not require any special control technology.

APPENDIX A11
CASE STUDY NO. 11

A. PROCESS AND EQUIPMENT

This is a moderate-size commercial Stoddard solvent plant in the Middle-Atlantic area. A single transfer and a double transfer system are utilized to process approximately 1200 kg (2650 pounds) of dry cleaning weekly. Average solvent mileage of approximately 1450 is achieved. A total of approximately 20 people are employed, with most either engaged in laundry operations or driving trucks, covering the several routes serviced from this plant. The plant employs 2 cleaner/spotters and 4 pressers to process its dry cleaning work.

The layout of this plant is shown in Figure A11-1. The bulk of the dry cleaning is processed through a Butler, size 48 x 36 cleaning machine, with a Butler Model 5433C pressure filter. After cleaning and extracting, the load is transferred to 4 separate Butler, size 36 x 30 dryers. One American Laundry Machinery, size 36 x 30 dryer is available also for use in case of breakdowns and increased workloads. Coats, gowns, and clothing that cannot withstand tumbling action are dried on hangers in a Butler Model 20, size 33.79 cabinet. Delicate fabrics usually are washed in a Butler Model M150, size 30 x 48, with a Butler Model 41330 pressure filter. The delicate load is transferred to a Butler Model 300, size 30 extractor before being dried in the aforementioned dryers. The large dry cleaning system is approximately 29 years old while the small system, for delicate work, is approximately 32-years-old. It appears that the dryers are of the same vintage — approximately 25-30 years old. Usual operating procedure is to distill about 200 gallons of solvent every two weeks, a process which usually takes about 3 hours to complete. At the time of the survey, the still was out for repair and the solvent had not been distilled for over 4 weeks.

Both the small and large cleaning systems have their solvent purified by pumping solvent through a pressure filter which consists of 13 mesh screens. The mesh screens are coated with diatomaceous earth and activated carbon. Periodically, the filter cake is scraped off by cranking an external handle that is connected to a set of internal scrapers. The cake settles to the bottom of the pressure vessel and is removed once every 8-10 days of operation. The diatomaceous earth and carbon are introduced into the pressure filter by mixing with the solvent entering the button trap. The mixture is pumped from the button trap into the pressure filter where it coats the 13 screens. Approximately 0.45 kg (1 pound) of filter aid is added to the button trap before each new load. Activated carbon (0.45 kg, or 1 pound) is added, usually once per day and more frequently, if needed, to clear the color from the solvent.

In the large system, an average load of 49 kg (108 pounds) is split into 3 fairly equal parts and loaded into the 3 chambers of the washing machine. Equal loading of the chamber is necessary to minimize vibration of the dry cleaning machine during the extraction cycle. Once the clothes are loaded into the machine, it takes about 4 minutes to pump and fill the machine to the proper level with the solvent. The clothes are agitated for 20-25 minutes. While still agitating, the solvent is pumped out of the machine over a 5-minute period. The load then is extracted for 5 minutes before being transferred to the dryers. The transfer usually requires about 90 to 120 seconds. and the drying cycle takes about 30-40 minutes to complete. An average of 5 loads per day is processed through the large system.

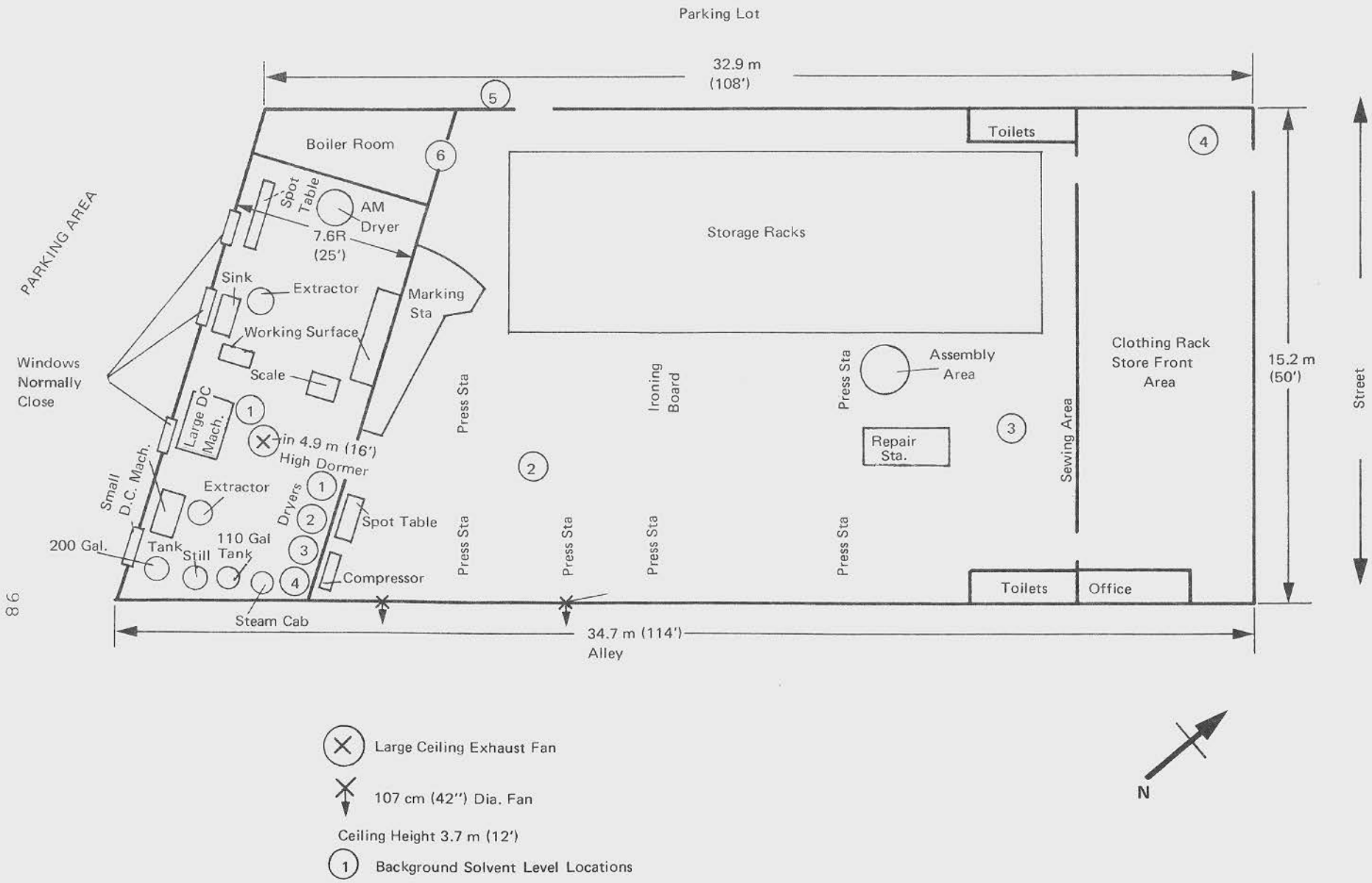


FIGURE A11–1 GENERAL PLANT LAYOUT – PLANT NO. 11

In the small system, the size of the load is variable with a maximum capacity of 16 kg (35 pounds). An average of 6 loads per day is processed through the small system. Wash cycle takes 10-15 minutes, transfer to the extractor averages about 80 seconds, extraction requires about 1-2 minutes, and transferring to the dryer can take as much as 3 minutes to complete. The drying time would be the same as that for the large system (30-40 minutes).

B. NATURAL VENTILATION

Since this plant is provided with 2 evaporative cooling systems and a large exhaust fan in the dry cleaning room, the deployment of natural ventilation is of minimal consequences.

C. GENERAL MECHANICAL VENTILATION

The finishing roon is provided with 2 evaporative cooling systems. Each system is rated at 9.4 m^3/s (20,000 cfm). Each work station is provided with a duct opening of 61 cm x 30.5 cm (24 x 12 in.) and each was emitting in excess of 1.5 m/s (300 f.p.m.) of cool air. The finishing room also has 1 operable 107-cm (42-in.) diameter wall fan rated at 7.1 m^3/s (15,000 cfm) which is usually on. The dry cleaning room has an 11.8-m^3/s (25,000-cfm) exhaust fan above the large dry cleaning machine. This fan is turned on and kept on during the course of the day. The front of the plant, which is the customer service area, has its own 4536 kg (5-ton) air conditioning system.

D. LOCAL EXHAUST VENTILATION

The dryers and the drying cabinet are provided with local exhaust ventilation and parameters of this system are tabulated in Table A11-1.

E. LEAK DETECTION

No leaks were detected.

F. HEAT EXPOSURE

Wet-bulb globe temperature (WBGT) in the pressing area was 25.9°C (78.7°F) and 24.2°C (75.6°F) on the two days of this survey. The higher of these WBGT levels was based upon a dry-bulb temperature of 31.0°C (87-8°F), wet-bulb temperature of 23.3°C (74,0°F), and black-globe temperature of 31.9°C (89-5°F).

G. SOLVENT EXPOSURE LEVELS

The cleaner's personal exposure level in this plant was 15-25 ppm Stoddard solvent. During transfer, the ceiling (15-min. TWA) level varied from 5-121 ppm. His assistant, who performed the cleaning in the small system, had a personal exposure level of 5-10 ppm. During transfer, the ceiling (15-min. TWA) level varied from 29-67 ppm. The pressing area, marking/sewing area, and the customer area exhibited only trace amounts of solvent (1 ppm). Solvent levels found within this plant are listed in Tables A11-2 and A11-3.

CONCLUSION

The cleaner's and his assistant's overall time-weighted average exposure levels were low due to the large amount of general mechanical ventilation present (both the evaporative cooling systems and the large exhaust fan above the large dry cleaning machine). Since no local exhaust or other controls are applied to the transfer steps, ceiling levels during transfer are relatively high.

Table A11-1. Local Exhaust Ventilation Systems - Air Flow Parameters.

Location	Diameter cm(in.)	Air Flow m^3/s(cfm)	Temperature °C.(°F.)	Static Pressure cm(in.)
Dryer #1	22.9(9)	0.50(1060)	64.4(148)	-1.3(-0.53)
Dryer #2	22.9(9)	0.48(1012)	87.8(190)	-0.9(-0.36)
Dryer #3	22.9(9)	0.67(1410)	68.9(156)	-1.2(-0.47)
Dryer #4	22.9(9)	0.76(1600)	65.6(150)	-1.0(-0.39)
American Dryer	22.9(9)	0.17(370)	61.7(143)	-1.9(-0.74)
Butler Cabinet	--	0.31(650)	-- --	-- --

Table A11-2. Airborne Stoddard solvent sampling.

Sample #	Location	Duration (min.)	Start Time	mg/m^3	ppm
1	Cleaner personal sample	120	7:00	104	18
2	Press area	180	7:10	4.6	1
3	Marking/sewing area	181	7:10	3.6	1
4	Cleaner assistant personal sample	120	7:28	5.6	10
5	Cleaner assistant ceiling during transfer	15	8:00	96	17
6	Customer service area	175	8:20	4.7	1
7	Cleaner assistant ceiling during transfer	15	8:26	167	29
8	Cleaner personal sample	120	9:00	205	35
9	Cleaner ceiling during transfer	15	9:10	29.9	5
10	Cleaner assistant personal sample	122	9:28	13.1	2
11	Press area	263	10:10	8.0	1
12	Marking/sewing area	262	10:12	5.8	1
13	Dry cleaning machine area	60	10:40	94	16
14	Cleaner ceiling during transfer	15	11:06	282	49
15	Cleaner personal sample	140	11:00	79	14
16	Customer service area	201	11:17	5.6	1
17	Dry cleaning machine area	90	11:41	33	6
18	Cleaner ceiling during transfer	15	12:42	123	21
19	Cleaner assistant ceiling during transfer	15	1:12	226	39
20	Cleaner personal sample	80	1:20	78	13
21	Cleaner personal sample	148	7:05	135	23
22	Cleaner assistant personal sample	136	7:17	70	12
23	Dry cleaning room area	240	7:05	22.8	4
24	Pressing area	189	7:05	6.4	1
25	Cleaner during transfer	15	7:17	700	121
26	Cleaner assistant ceiling during transfer	15	7:56	390	67
27	Cleaning room area	30	7:56	32	6
28	Cleaning room area	30	8:17	157	27
29	Cleaning room area	30	9:02	173	30
30	Cleaner ceiling during transfer	15	8:32	253	44
31	Cleaner during transfer	15	9:10	236	41
32	Cleaner personal sample	132	9:33	67	12
33	Cleaner assistant personal sample	133	9:35	8	1
34	Cleaning room area	30	9:39	10.4	2
35	Cleaner ceiling during transfer	15	10:12	136	23
36	Press area	193	10:14	3.0	1
37	Cleaner ceiling during transfer	15	10:45	290	50
38	Cleaner personal sample	97	11:45	76	13
39	Cleaner ceiling during transfer	15	1:05	360	62

Table A11-3. Background solvent levels.

Day	Time	Stoddard solvent level (ppm) Location* 1	2	3	4	5	6	7
1	0700	2	1	1	1	1	1	1
1	0800	7	1-2	1	1	1	1	1-2
1	0900	3	1-2	1	1	1	1	1-2
1	1000	7	1-2	1	1	<1	<1	2
1	1100	20	1-2	1-2	1-2	1-2	3	4
1	1200	15	3	2	1-2	1	2	2
1	1300	6	3	3	2	2	2	3
1	1420	2	1	1	1-2	1	1	1
2	0700	4	2	2	2	1-2	2	2
2	0800	7	5	4	1	1	4	4
2	1020	12-20**	1	1	1	2	4	1-2
2	1130	40	1	1	1	2	2	1-2
2	1300	25-35	1-2	3	<1	1	2	1-2

*See Figure A11-1 for location of points.

**Fluctuating between 12 and 20.

APPENDIX A12

CASE STUDY NO. 12

A. PROCESS AND EQUIPMENT

This small perchloroethylene transfer plant in the Middle-Atlantic area handles an average volume of 272 kg (600 pounds) per week. Average solvent mileage of approximately 17,000 is achieved. The plant is staffed with one cleaner/spotter/presser and one presser/support employee.

The washer and dryer in this plant are a Detrex Monarch 528 and Synth-O-Saver 326A, respectively. This equipment is more than 20-years-old. A 5-year-old carbon adsorber (Vic Mileage Booster 118) and cartridge filter (Kleen Rite) are also used. There is no still in this plant as the Kleen Rite filter is intended to preclude the need for distillation of solvent. The layout of this plant is shown in Figure A12-1.

The adsorber is stripped daily, and the recovered solvent is piped directly to the cleaning machine solvent reservoir. The duration of stripping is "timed" by the amount of waste water recovered: Stripping continues until 3 buckets of waste water are collected. The tumbler condensate also runs through a fixed pipe to the reservoir. During stripping, 900 ppm perchloroethylene was initially measured at the water separator vent. After condensation began, this level dropped off.

Although the cleaning machine has a 15.9 kg (35 pound) capacity, this plant runs 9.1 kg (20-pound) loads. A 10-minute wash cycle, 3-minute extraction, and 15-minute drying cycle are used.

B. NATURAL VENTILATION

This plant has no windows. A side door is kept closed, but the front door of the plant was left open for part of the time of this survey.

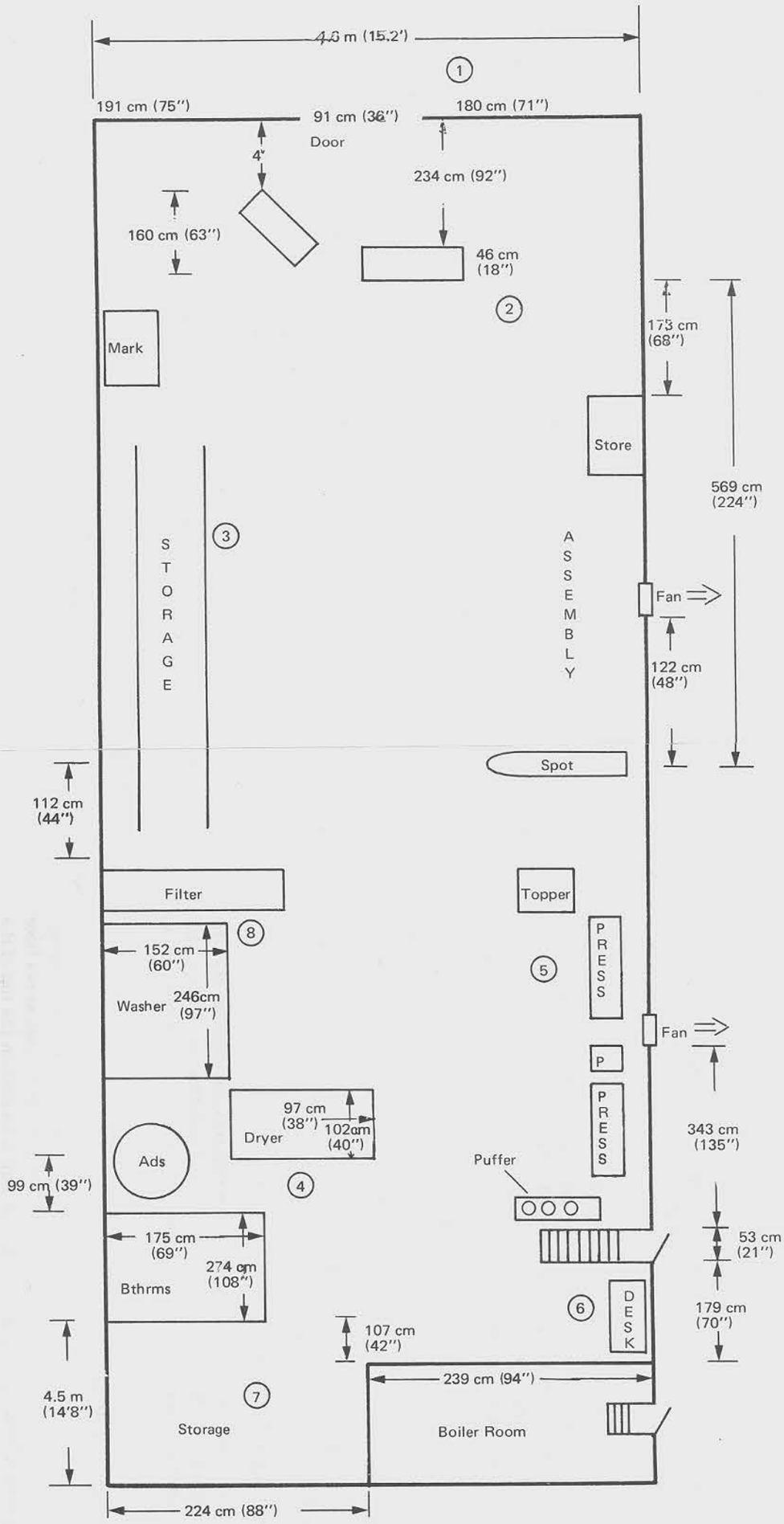
C. GENERAL MECHANICAL VENTILATION

Two exhaust fans are mounted in the plant wall, one over the pressing area and the other over the assembly area. Only the pressing area exhaust fan was in use during this survey. In addition, this plant has a roof-mounted cooling system which was not in use during this survey. The fan in use was exhausting 1.9 m^3/s (4000 cfm) air.

D. LOCAL EXHAUST VENTILATION

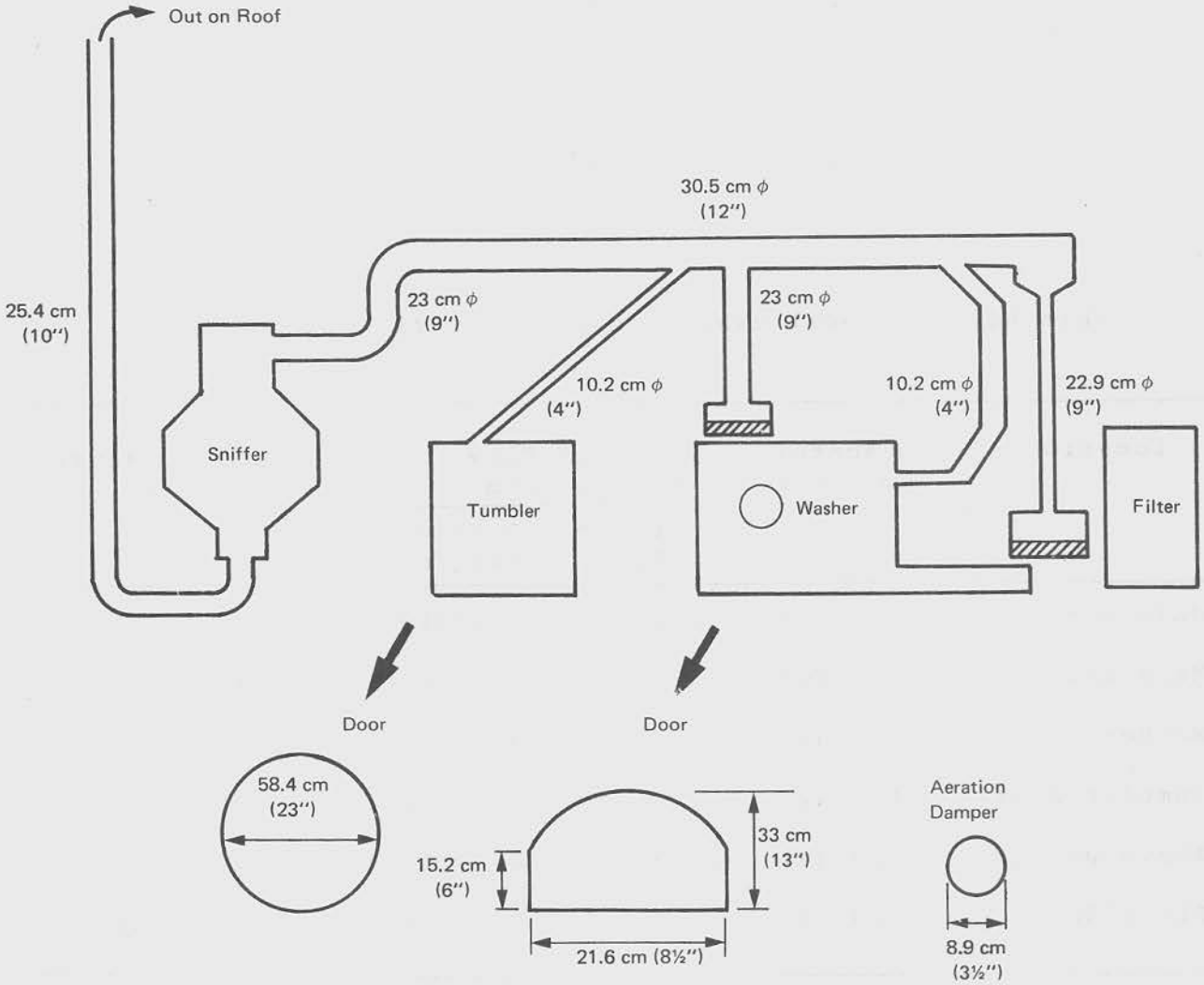
This plant has a local exhaust system tied to the carbon adsorption unit. This system is shown schematically in Figure A12-2. The tumbler and dryer ducts are tied into this system, as is a floor pickup located between the washer and filter. A second floor pickup is located on the top of the washer, above the loading door. Air flow parameters of this system are listed in Table A12-1.

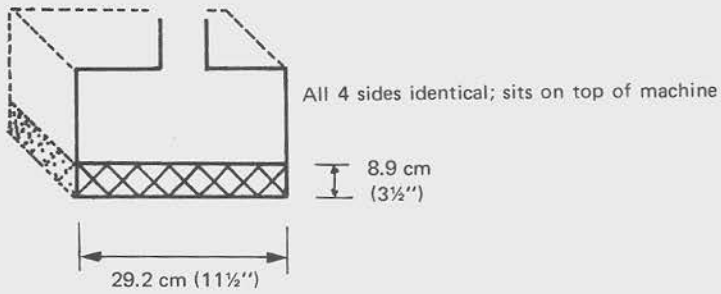
During this survey, it was postulated that improved ventilation system effectiveness would be achieved if a simple modification was made to the ventilation system. To test this assumption, the pickup located on top of the dry cleaning machine was modified by closing off part of its face area (see Figure A12-2). Specifically, the rear and most of the sides of the face area were blocked,



(1) = Area Sampling Points (see Table A12–3)

FIGURE A12–1 GENERAL PLANT LAYOUT





= Area of Opening

Arthur D. Little, Inc., modification closed off 77.5 cm (30½") of 117 cm (46") perimeter. Reduced opening from 0.1041 m^2 (1.12 Ft^2) to 0.0353 m^2 (0.38 Ft^2)

FIGURE A12–2 LOCAL EXHAUST VENTILATION SYSTEM

Table A12-1. Local exhaust system air flow parameters.

Location	Diameter cm (in.)	Air Flow m^3s (cfm)		Static Pressure cm (in.)
		During Wash	During Transfer	
Main outlet	25.4 (10)	0.22(460)	0.33(690)	1.5 (0.6)
Main inlet	30.5 (12)	0.22(470)	0.33(690)	-0.3 (-0.13)
Washer duct	10.2 (4)	0	0.04 (75)	-0.3 (-0.1)
Tumbler duct	10.2 (4)	0	0.07(145)	--
Above washer	22.9 (9)	0.09(190)	0.09(190)	--
Floor duct	22.9 (9)	0.13(280)	0.13(280)	-0.3 (-0.1)

reducing this area from 0.1 m^2 (1.12 $ft.^2$) to 0.035 m^2 (0.38 $ft.^2$). This change resulted in an increase in face velocity from 0.86 m/s (170 f.p.m.) and reduced exposures during transfer as noted in Section G of this Appendix.

E. LEAK DETECTION

One leak was found in the rear of the dryer, but its specific location could not be pinpointed.

F. HEAT EXPOSURE

Wet-bulb globe temperature (WBGT) in the pressing area was 18.7°C (65.7°F) and 20.8°C (69.5°F) on the two days of this survey. The higher of these WBGT levels was based upon a dry-bulb temperature of 27.2°C (80.9°F), wet-bulb temperature of 17.6°C (63.7°F), and black-globe temperature of 29.1°C (84.3°F).

G. SOLVENT EXPOSURE LEVELS

The cleaner's personal exposure level in this plant was 10-15 ppm perchloroethylene. During transfer, the ceiling (15-minute TWA) level was 16-43 ppm with the existing ventilation system and 4-9 ppm following the modification described in Section D of this Appendix. In the pressing area, 5-10 ppm perchloroethylene was found, and in the storefront 1-17 ppm levels were measured. Solvent levels found within this plant are listed in Tables A12-2 and A12-3.

CONCLUSION

The cleaner's exposure level in this plant was low; however, this was probably due, in part, to the large amount of the cleaner's time spent on other activities. Ceiling levels during transfer were moderate, and showed a four fold decrease after simple modifications were made to the ventilation system.

Table A12-2. Airborne perchloroethylene sampling.

Sample #	Location	Duration (hr:min)	Start Time	mg/m^3	ppm
1	Cleaner personal sample	3:00	6:40	94	14
2	Customer counter	3:00	6:47	92	14
3	Back of building	3:00	6:48	42	6
4	Researcher	3:00	7:17	59	9
5	Press area	3:00	7:25	34	5
6	Ceiling during transfer	0:16	7:57	160	24
7	Ceiling during transfer	0:15	8:20	110	16
8	Ceiling during transfer	0:15	9:57	26	4*
9	Cleaner	2:00	9:50	28	4
10	Back of building	2:00	9:55	17	3
11	Customer counter	1:38	10:22	--	--
12	Researcher	1:55	10:37	20	3
13	Cleaner personal sample	2:00	6:45	120	18
14	Fan (press area)	3:02	8:05	58	9
15	Ceiling during transfer	0:15	7:10	209	31
16	Researcher	2:00	7:30	69	10
17	Ceiling during transfer	0:15	7:30	290	43
18	Ceiling during transfer	0:15	7:47	170	25
19	Ceiling during transfer	0:15	8:12	60	9*
20	Ceiling during transfer	0:15	8:28	54	8*
21	Cleaner personal sample	2:00	8:50	80	12
22	Ceiling during transfer	0:15	8:53	36	5*
23	Researcher	1:47	9:57	55	8
24	Ceiling during transfer	0:15	10:18	190	28
25	Customer service area	0:53	10:50	42	6

*ADL hood modification in place.

Table A12-3. Background solvent levels.

Day	Time	Perchloroethylene Level (ppm)							
		Location*							
		1	2	3	4	5	6	7	8
1	0800	1	2	6	9	6	8	9	4
1	0830	1	2	4	-	5	10	5	2
1	0900	1	2	2	3	4	8	9	2
1	1000**	2	11	14	9	12	5	5	13
1	1100	2	6	6	7	6	4	3	5
1	1130	2	7	8	15	8	6	5	13
2	0700	1	5	4	4	5	3	4	-
2	0800	2	17	15	9	15	10	10	-
2	0900	1	3	7	14	7	4	4	-
2	1000	1	1	2	8	2	3	3	-
2	1100	1	1	2	4	3	3	3	-
2	1200	2	5	8	5	7	3	3	-

*Points are identified in Figure A12-1.

**Front door open until 0905, then closed for remainder of day.

APPENDIX A13
CASE STUDY NO. 13

A. PROCESS AND EQUIPMENT

This is a large industrial perchloroethylene plant in the North-Atlantic area. A weekly average of 6800 kg (15,000 pounds) is processed by two identical dry-to-dry units. The plant employs 1 cleaner, 5 pressers, and 22 others, most of whom are either engaged in laundry operations or are drivers for the routes serviced by this plant. Solvent mileages of 20,000 and 38,000 are reported for summer and winter, respectively.

Two Spencer (manufactured in Great Britain) Model GT1651, each about 7-years-old, are employed to process the dry cleaning. Each machine has its own integral still, muck cooker, condenser, etc. Two 7-year-old Puritan cartridge filters, each with a capacity of 21 carbon-core cartridges, are used to filter the perchloroethylene. A 4-year-old Hoyt Model 12 carbon bed adsorption system is used during the aeration phase and whenever the machine door is opened for unloading and loading. The layout of this plant is shown in Figure A13-1.

The filter cartridges are changed every 6 weeks, after approximately 39,000 kg (86,000 pounds) of dry cleaning have been processed. A unique feature of this plant is that the used cartridges are stored in a vented air-tight cabinet (see Figure A13-2). Whenever the west dry cleaning machine door is opened, air flows through the cabinet and joins the duct leading from the west dry cleaning machine to the carbon adsorption system. As a result of this arrangement, the cartridges are relatively devoid of perchloroethylene by the time they are discarded. Since each load of dry cleaning results in a quantity of solvent being dumped into a "solvent-to-be-distilled" tank, the still is operated for the majority of the time that dry cleaning is conducted.

The muck cooker is operated about once each week per machine. Each cooking requires about 4 hours, and approximately 38 L (10 gal.) of solvent is recovered per machine along with approximately 34 L (9 gal.) of muck.

Approximately 20 loads are dry cleaned daily. Each load weighs approximately 68 kg (150 pounds) and requires 4 minutes for washing with solvent that was used as the second wash of the previous load, 3 minutes for extraction, 10 minutes for cartridge-filtered perchloroethylene wash, 3 minutes for extraction, 16 minutes for drying at 65.5°C (150°F), and 7-10 minutes for aeration.

Each bed of the carbon bed absorption unit is stripped daily for approximately 45-55 minutes. Each bed will yield approximately 17 L (4.5 gal.) of solvent upon recovery. (More solvent is recovered when used cartridge filters are newly placed into the filter cabinet.)

B. NATURAL VENTILATION

Because of the two exhaust fans in the dry cleaning room, an east to west airflow into the room was detected through the door connecting the dry cleaning room to the receiving area.

C. GENERAL MECHANICAL VENTILATION

Two 61-cm (24-in.)-diameter exhaust fans continuously blow air out of the dry cleaning room into the adjacent dryer room.

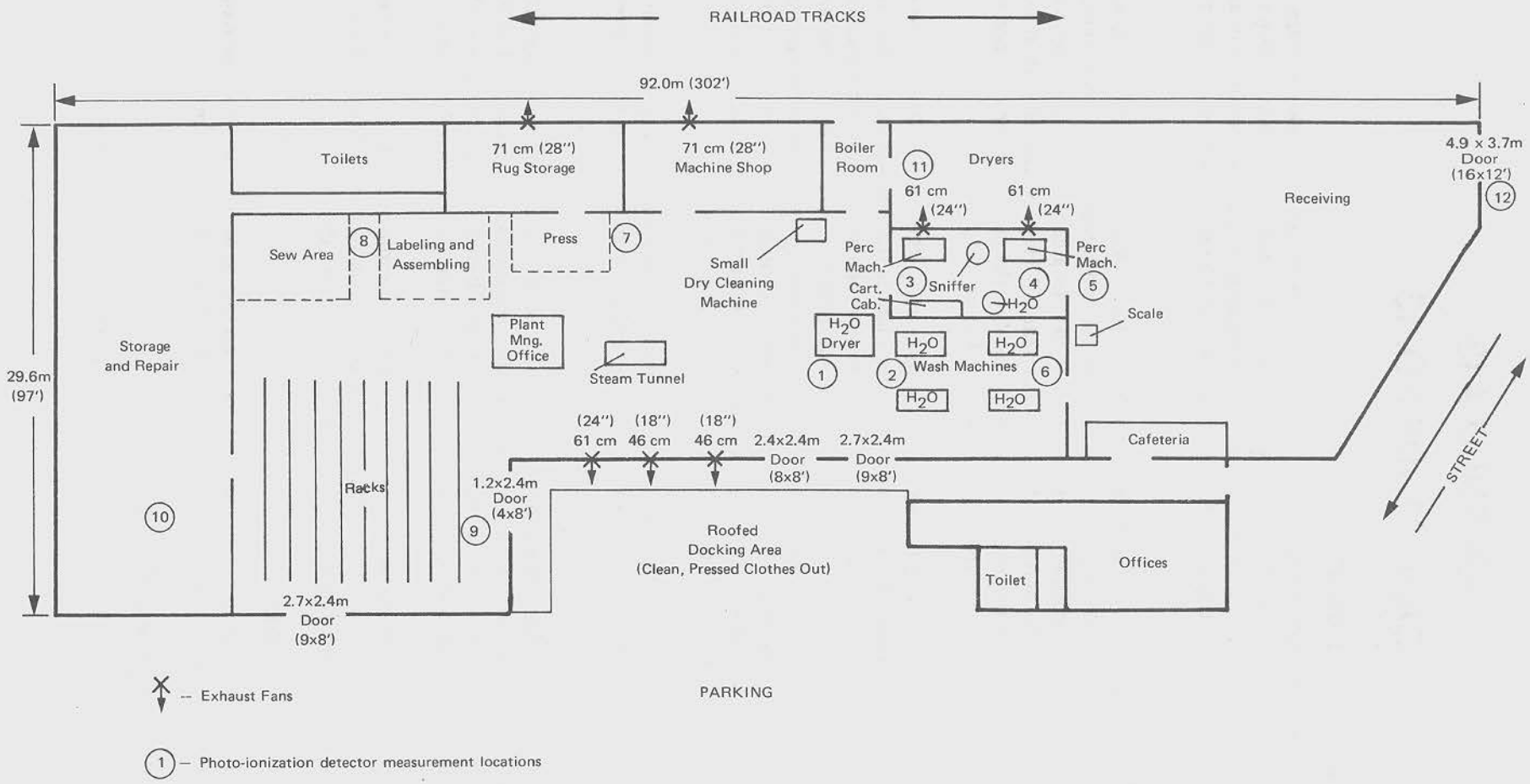


FIGURE A13–1 GENERAL PLANT LAYOUT

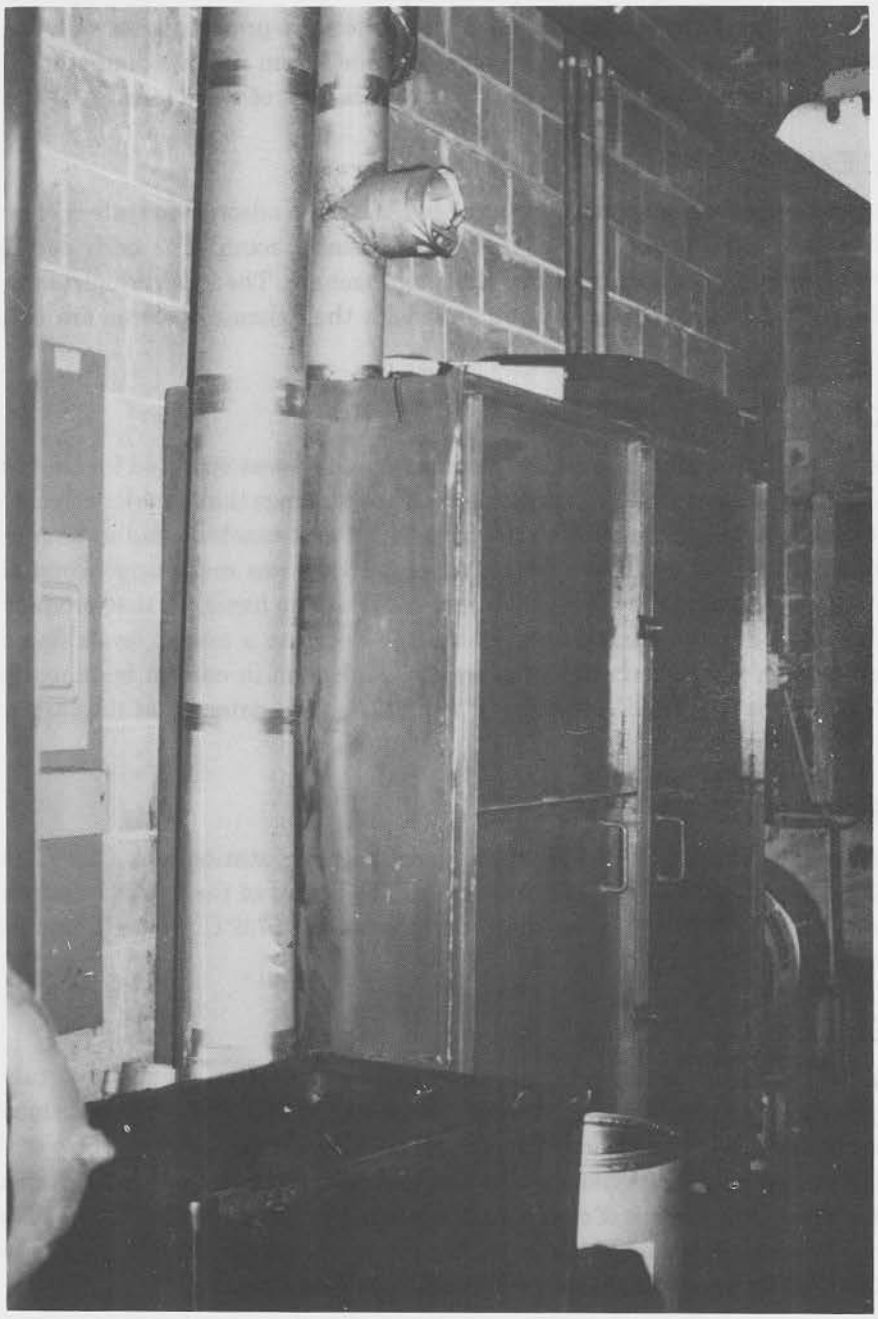


FIGURE A13–2 DRYING CABINET FOR USED FILTER CARTRIDGES

Aside from the two exhaust fans in the dry cleaning room, there are two 46-cm (18-in.)-diameter and one 61-cm (24-in.)-diameter exhaust fans along the shirt-pressing area wall, one 71-cm (28-in.)-diameter exhaust fan in the machine shop, and one 71-cm (28-in.)-diameter exhaust fan in the rug storage room. See Figure A13-1 for the exact locations of these fans.

D. LOCAL EXHAUST VENTILATION

This plant has a local exhaust system connected to the carbon adsorption system. The outlet from the adsorption system is recirculated into the dry cleaning room. The cartridge filter cabinet is vented simultaneously with the west dry cleaning machine. The local exhaust system is shown schematically in Figure A13-3. Airflow rates through the exhaust systems are listed in Table A13-1.

E. LEAK DETECTION

Around noon of the first visit, the east dry cleaning machine was operated for the first time that day. It was apparent from the photo-ionization detector readings that a major solvent leakage was occurring. It was reported that a door in the back of the east machine had to be replaced with a custom-made door to eliminate the leakage. A second visit was made approximately 3 months later and it was ascertained that the custom-made door was on hand but that production demand did not permit the time nor the labor to install the door. As a result, levels found in the dry cleaning room and in the surrounding area were as high, and in certain instances higher, than those found during the first visit. A leakage of 25 ppm also was detected at the east machine door gasket.

F. HEAT EXPOSURE

Wet-bulb globe temperature (WBGT) in the shirt-pressing station was 28.1°C (82.5°F) and 31.8°C (89.3°F) during the two days of the survey. The higher of the two is based on a dry-bulb temperature of 39.8°C (103.6°F), a wet-bulb temperature of 27.6°C (81.6°F), and a black-globe temperature of 43.5°C (110.3°F).

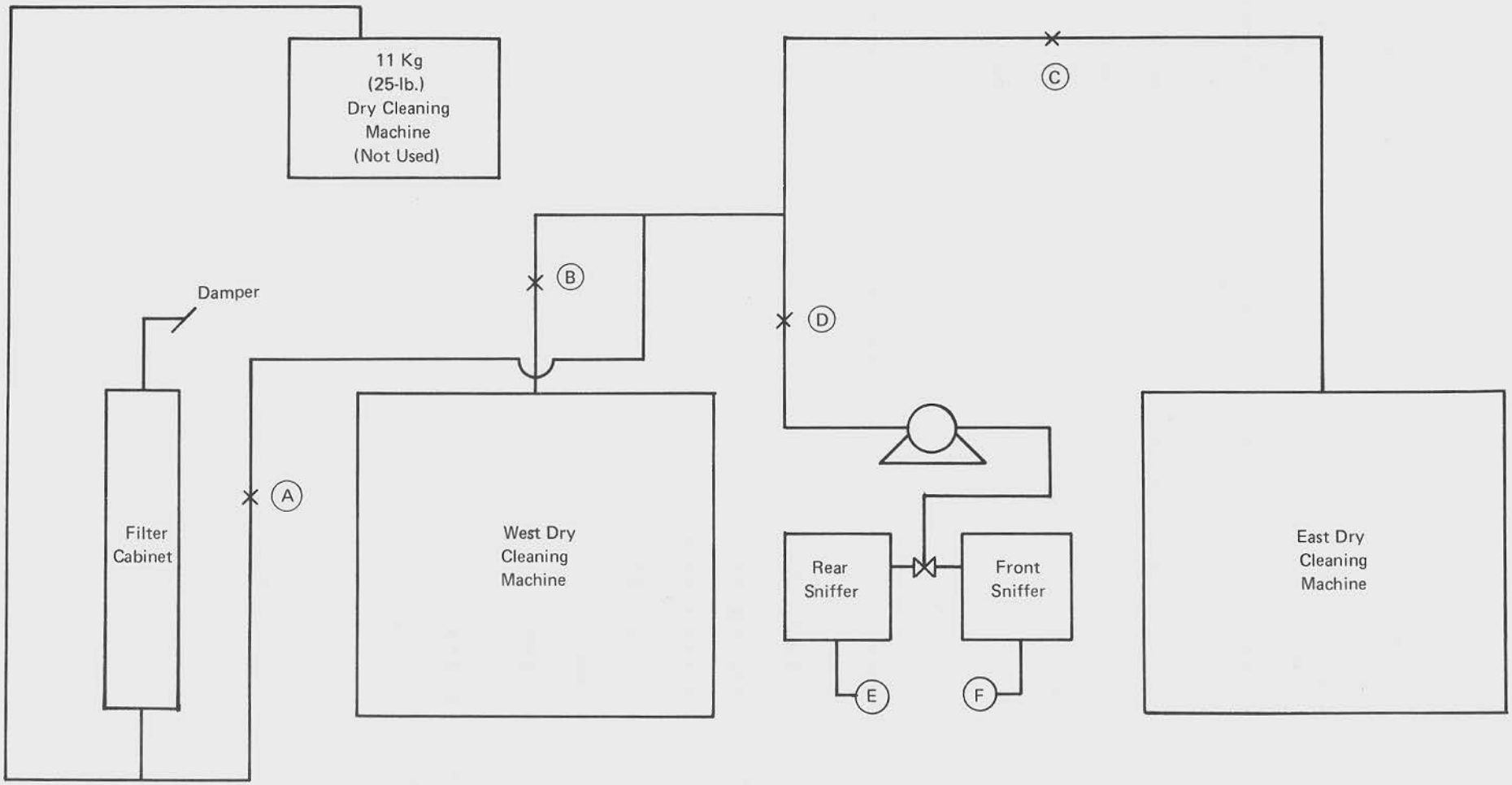
G. SOLVENT EXPOSURE LEVELS

Table A13-2 lists exposure levels determined by sample collection on charcoal tubes and subsequent gas chromatographic analysis. Area levels measured with a photo-ionization detector are contained in Table A13-3. The cleaner's exposure level, averaged over the course of the day, was 13 ppm and 40 ppm perchloroethylene on the first and second day of the survey, respectively. The higher reading was a direct result of operating the leaking east machine full time (10 loads) during the second visit versus part-time (2 loads) during the first visit. Ceiling samples collected during loading and unloading were comparable with long-term sampling.

H. COLD WEATHER SURVEY

When this plant was re-visited during cold weather, operations in the plant had not changed significantly. The leak around the rear door of the east machine had been rectified, but a leak in the rear carbon adsorption unit was detected.

Local exhaust ventilation throughout the system was checked and found comparable to that observed during the first survey.



A = Air flow measurement points

FIGURE A13–3 LOCAL EXHAUST VENTILATION SYSTEM

Table A13-1. Measured ventilation system flow rates.

Location*	Air Flow m^3/s(cfm)	Duct Size cm(in)
A	0.08(170)	20(8)
B	0.08(173)	20(8)
C	0.09(198)	20(8)
D w/east machine	0.21(443)	20(8)
D w/west machine	0.27(572)	20(8)
E	0.20(419)	20(8)
F	0.23(490)	20(8)

Locations*

A - Cartridge filter cabinet

B - West dry cleaning machine

C - East dry cleaning machine

D - Before carbon bed adsorber

E - Rear carbon bed

F - Front carbon bed

See Figure A13-3.

Table A13-2. Airborne concentration measurements.

Sample #	Location	Duration (min.)	Start Time	Perchloroethylene concentrations mg/m^3	ppm
1	Label checker personal sample	238	8:00	0.5	1
2	Water wash operator #1 personal sample	240	8:15	11	2
3	Water wash operator #2 personal sample	231	8:23	16	2
4	Cleaner personal sample	233	8:25	35	5
5	Back of dry cleaning machine area	228	8:22	17	3
6	Dryer room area	165	9:43	99	15
7	Cleaner during loading and unloading	15	10:46	65	10
8	Clean clothes storage area	153	10:20	0.7	1
9	Carbon bed exhaust	12	10:47	1.6	2
10	Cleaner during loading and unloading	20	2:45	24	4
11	Machine shop area	98	11:15	0.2	1
12	Cleaner personal sample	130	12:23	190	28
13	Dryer room area	115	12:30	260	38
14	Label checker personal sample	147	1:00	10	2
15	Water wash operator #1 personal sample	146	1:02	20	3
16	Water wash operator #2 personal sample	146	1:02	29	4
17	Steam tunnel area	146	1:04	29	4
1	Cleaner personal sample	120	6:30	280	41
2	Beneath west machine door	140	6:40		
3	Beneath west machine door	140	6:40	800	118
4	Clean clothes storage area	92	7:16	0.6	1
5	Clean clothes storage area	92	7:16	0.5	1
6	Exhaust of carbon adsorber	16	7:56	4,800	707
7	In duct before carbon adsorber	16	7:56	47,000	6,923
8	Exhaust of carbon adsorber	23	8:23	1,290	190
9	In duct before carbon adsorber	23	8:23	2,000	295
10	Exhaust of carbon adsorber- during stripping	18	8:46	1,240	183

Table A13-2 (cont'd.)

Sample #	Location	Duration (min.)	Start Time	Perchloroethylene concentrations mg/m^3	ppm
11	In duct before carbon adsorber during stripping	18	8:46	47,000	6,923
12	Cleaner personal sample	123	8:47	290	43
13	Dryer room area	60	8:58	610	90
14	Small dry cleaning machine area	140	9:08	46	7
15	Cleaner during loading and unloading	15	10:02	107	16
16	Beneath east machine door	167	10:28	116	17
17	Scale area	55	10:35	45	7
18	In duct before carbon adsorber	14	11:05	25,000	3,682
19	Exhaust of carbon adsorber	14	11:05	870	128
20	Scale area	195	11:30	143	21
21	Water wash area	93	1:30	56	8
22	In duct before carbon adsorber	16	1:32	31,000	4,566
23	Exhaust of carbon adsorber	16	1:32	2,800	412
24	Cleaner during loading and unloading	15	2:10	260	38

Table A13-3. Background solvent levels.

Time	Perchloroethylene (ppm) Location*											
	1	2	3	4	5	6	7	8	9	10	11	12
0830	2.5	5	15	5	7	4	5	<1	<1	<1	11	<1
0930	1	4.5	3	3	2	7	2	<1	<1	<1	9	<1
1030	2		15	8	6		3.5	<1	<1	<1	13	<1
1130	2	8	6	5	2	6	3	<1	<1	<1	22	<1
1230	26		10	3	1	2	5	<1	<1	<1		<1
1400	3	26	40	80	1	1	10	1	<1	<1	15	<1
1500	6	10	35	25	10	15	7	<1	<1	<1	35	<1
0700	2	6	20	11	6	7	2	3	4	3		2
0830	2	11	55	40	10	12	1	1	1	1	60	2
0930	8	17	95	30	25	35	3	3	2	2	55	3
1030	3	5	10	6	4	5	2	1	1	1	22	1
1300	7	10	20	20	20	20	13	1	1	1	60	1
1400	11	16	30	30	7	11	30	1	1	1	110	2

*Refer to Figure A13-1 for locations.

The dry cleaning operator was exposed to a time-weighted average level of 46 ppm perchloroethylene. The operator in the adjacent room was exposed to 14 ppm of perchloroethylene. In the dryer room, which receives air from exhaust fans in the dry cleaning room, the measured levels ranged from 43 to 169 ppm. A listing of the results of samples taken during this survey is provided in Tables A13-4 and A14-5.

CONCLUSION

The leakage of the east machine resulted in substantially increased exposures for the cleaner. Additionally, because the exhaust fans blew directly into the adjacent dryer room, employees who work in the dryer room also are exposed to increased levels of perchloroethylene. The leakage should be corrected and the two exhaust fans should be ducted to the outdoors.

This plant was more airtight during the winter than during the summer, resulting in higher exposure potential. The extent of increased exposure attributable to the reduced natural ventilation is difficult to determine due to leaks present in the system; however, the cleaner's exposure level was at least 15% higher.

Table A13-4. Airborne concentration measurements during cold weather survey (ppm perchloroethylene).

Sample #		Duration (min.)	Start Time	mg/m^3	ppm
1	Water wash operator personal sample	121	7:53	83	12.2
2	Cleaner personal sample	115	7:55	274	40
3	Small dry cleaning machine area	120	8:20	24.9	3.7
4	Clean clothes storage area	360	8:14	10.3	1.5
5	Beneath west machine door	60	8:40	24.4	3.6
6	Dryer room area	120	8:13	293	43
7	Water wash area	120	8:20	97	14.3
8	Cleaner during loading and unloading	15	8:45	570	84
9	Cleaner during loading and unloading	15	9:15	750	110
10	Cleaner during loading and unloading	15	10:25	320	47
11	Water wash operator personal sample	111	9:54	31	4.6
12	Cleaner personal sample	113	9:50	129	19.0
13	Beneath west machine door	74	9:56	720	106
14	Dryer room area	120	10:16	360	53
15	Water wash area	120	10:23	105	15.4
16	Small dry cleaning machine area	120	10:27	76	11.2
17	Cleaner personal sample	123	11:50	520	76
18	Water wash operator personal sample	124	11:52	133	19.6
19	Cleaner during loading and unloading	15		288	42
20	Dryer room area	60	1:43	570	84
21	Water wash area	97	1:39	206	30
22	Water wash operator personal sample	101	1:37	92	13.5
23	Cleaner personal sample	79	1:56	120	17.6
24	Dryer room area	82	1:53	300	44
25	Dryer room area	92	2:47	1150	169

Table A13-5. Background solvent levels (cold weather), perchloroethylene (ppm).

Time	Location											
	1	2	3	4	5	6	7	8	9	10	11	12
0830	3	11	30	15	13	13	6	2	2	<1	50	<1
0930	5	40	80-130	22	20	35	5	1	1	1	50	1
1030	10	17	50-200	7	8	16	22	3	4	1	100	<1
1130	13	17	35	100	15	17	18	3	6	1	40	<1
1330	8	8	50-150	17	19	50	5	2	2	1	150-200	1
1430	2	7	90	40	13	15	4	3	3	2	40	<1

NOTE: PM reading of area near rear carbon bed was around 1000 ppm.

APPENDIX A14
CASE STUDY NO. 14

A. PROCESS AND EQUIPMENT

This plant is an unusually large commercial dry cleaning operation employing petroleum solvents in large transfer-type equipment. Average cleaning volume is 18,500 kg/month (41,200 pounds/month). Annual use in 1977 was approximately 375,000 L (104,000 gallons). Average mileage was approximately 1,350.

This plant has a large labor force, employing: 2 cleaners, 6-8 spotters, 34 pressers, 3 clothing inspectors, 13 clothes sorters, 4 seamstresses, 1 operating supervisor, 4 customer service personnel, and roughly 6 miscellaneous support persons. In addition, perhaps a dozen more persons are employed in separate areas of the building devoted to business operation.

The dry cleaning equipment employed by the plant is relatively old, but well maintained. Seven washers are employed including four Washex 500-PA machines, one Washex 300-TD-DC, one Washex P100-PA and one Washex "combination washer-extractor" (not in use during the survey period). The six washers that were observed in operation are located in a separate room which is isolated from the remainder of the building by self-closing firedoors.

Damp clothes are transferred manually from the washers to 16 Cissell Model D4343 tumblers located in an adjacent room. As indicated in Figure A14-1, the two filters used to clean the petroleum solvent are located in a third room and include five Washex type 5911 and three Washex type 6502 tube filters. Additional equipment for solvent purification includes one Washex vacuum still, Model 36 V5, and one muck cooker of proprietary design. Each petroleum washer processes approximately two loads per hour. Cleaning employs a two-step process with a "soap" cycle followed by a "rinse" cycle. Each cycle employs a five-minute wash and five-minute extraction. As is typical of such equipment, the washers are sealed only by the interface formed by the washer doors and door channels. At the beginning of each extraction cycle, solvent usually leaks around the machine door and drips into a gutter located below it. Occasionally, solvent leaks in such quantity that it overflows the gutter and drips onto the floor.

The dryers operate at 65.6°C (150°F). Filters are dumped daily. Distillation occurs twice per week for approximately five-hours each time.

B. NATURAL VENTILATION

As illustrated in Figure A14-1, natural ventilation is prevalent throughout the building, through open doors at the delivery bay and through a series of open windows running along the roof.

C. GENERAL MECHANICAL VENTILATION

As indicated in Figure A14-1, natural ventilation is augumented by 19 active evaporative coolers, each injecting 6.6 m^3/s (14,000 cfm) of cool air. Both the cleaning room and filter room are equipped with exhaust vents located along the walls near the floor; however, this exhaust system was not operating during this survey.

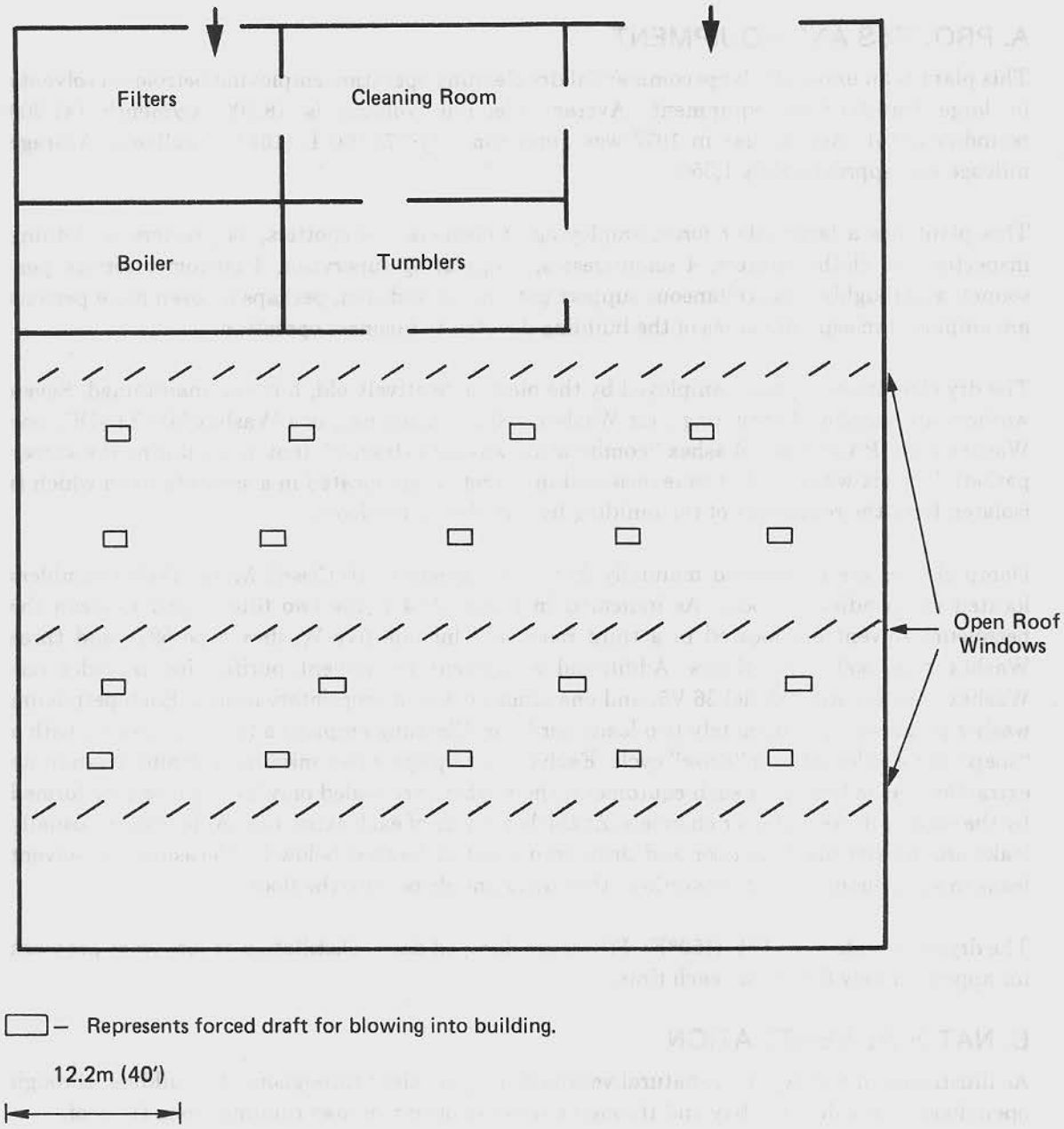


FIGURE A14–1 GENERAL ARRANGEMENT – PLANT #14

D. LOCAL EXHAUST VENTILATION

Each dryer is exhausted directly to the roof. Approximately 14 of the 16 tumblers are active at any one time, each exhausting approximately 1.4 m^3/s (3,000 cfm).

E. LEAK DETECTION

As mentioned earlier, occasionally leaks of petroleum solvent were observed around the doors of the washers during the extraction cycle. In addition, a leak was detected in the filter room during the morning of the second survey day, resulting in an unusually high vapor concentration throughout the plant.

F. HEAT AND NOISE EXPOSURE

A maximum of 98 dBA was measured in the cleaning room during the extraction cycle of the 227 kg (500-pound) machines. The normal sound level in the cleaning rooms at other times was 94-95 dBA. During washer extraction, the noise in the filter room reached as high as 90 dBA, although it was as low as 75-84 dBA, the rest of the plant was fairly quiet at 70-78 dBA.

Although this plant in northern California was surveyed during the summer, heat stress was negligible, as described in Table A14-1.

G. SOLVENT EXPOSURE LEVELS

Petroleum solvent vapor levels as determined by charcoal tube samples/GC analysis are summarized in Table A14-2. Depending on the relative amounts of time the cleaners spent in the washing room and filter room, their average exposure (2 hour TWA) was between 40 and 160 ppm. Since their operating routine throughout the workday was fairly constant, these short TWA's should be indicative of their normal 8 hour TWA exposure. Note that the personal exposure of the cleaners was considerably higher than the average solvent vapor concentration in the cleaning room. This difference might be explained by the large size of the washing machines which require that the cleaners reach into the machines to remove the clothes. Loading and unloading of a 227 kg (500 pound) machine required 2-4 minutes of concentrated exposure for the cleaners. Instantaneous vapor concentrations as measured by a photo-ionization detector are summarized in Table A14-3. Notice that concentrations outside the cleaning and filter rooms are quite low.

CONCLUSIONS

The large volume of clothes processed by this plant requires a steady exposure of the cleaners to high solvent vapor concentrations within the cleaning and filter rooms and to numerous concentrated exposures during loading and unloading of the washers. Vapor concentrations within the cleaning and filter rooms, although within present standards, were higher than they might be due to the absence of room ventilation and the presence of frequent solvent leakage from the washers. However, isolation of these rooms from the remainder of the plant and exhaust of the filter room by the numerous active dryers were adequate to keep vapor concentrations elsewhere in the plant generally below 2 ppm.

Table A14-1. Heat stress - measured at pressing stations.

Time	Dry Bulb °C	Dry Bulb (°F)	Wet Bulb °C	Wet Bulb (°F)	Globe °C	Globe (°F)	WBGT (in) °C	WBGT (in) (°F)
9:10	29.6	(85.3)	21.8	(71.3)	33.3	(91.9)	24.9	(76.8)
10:00	30.7	(87.2)	22.7	(72.8)	34.3	(93.7)	25.8	(78.4)
10:30	31.0	(87.8)	22.7	(72.8)	34.6	(94.3)	25.9	(78.6)
12:15	35.1	(95.1)	24.8	(76.7)	38.3	(101.0)	28.6	(83.4)
8:10	31.3	(88.4)	23.0	(73.4)	34.8	(94.6)	26.3	(79.4)
9:00	30.9	(87.7)	22.4	(72.3)	33.9	(93.0)	25.6	(78.1)
10:00	31.0	(87.8)	22.7	(72.8)	33.4	(92.2)	25.7	(78.2)
11:00	31.8	(89.3)	23.2	(73.8)	34.9	(94.8)	26.4	(79.5)
12:00	34.9	(94.8)	24.3	(75.8)	37.7	(99.9)	28.1	(82.5)
1:50	36.2	(97.1)	25.1	(77.1)	40.0	(104.0)	29.2	(84.5)

Table A14-2. Plant No. 14 - Air sampling data.

Sample No.	Location	Start (hr:min)	Duration (hr:min)	Solvent Concentration mg/m^3	Solvent Concentration ppm
1	Cleaner #1	10:19	1:59	1074	159
2	Cleaner #2	10:18	1:57	668	99
3	Supervisor	10:21	2:02	111	16
4	Cleaning Room	10:23	4:00	271	40
5	Wholesale Pressing	10:26	4:14	<12	<1.8
6	Retail Pressing	10:40	4:00	26	3.8
7	Cleaner #2	12:25	2:01	646	95
8	Supervisor	12:27	2:00	158	23
9	Cleaner #1	12:55	1:58	1005	148
10	Cleaning Room	14:24	0:28	897	132
11	Cleaner #1	6:15	1:52	1087	161
12	Cleaner #2	6:15	1:55	1026	152
13	Supervisor	6:15	1:50	129	19
14	Cleaning Room	6:18	0:32	563	83
15	Wholesale Pressing	6:20	5:20	2.6	0.4
16	Retail Pressing	6:20	5:20	5.8	0.9
17	Cleaning Room	6:50	0:30	536	79
18	Cleaning Room	7:20	0:35	340	50
19	Cleaning Room	7:55	1:08	481	71
20	Supervisor	8:05	2:02	160	24
21	Cleaner #1	8:07	1:57	734	108
22	Cleaner #2	8:10	1:52	1009	149
23	Cleaning Room	9:03	0:52	541	80
24	Cleaning Room	9:55	0:35	543	80
25	Cleaner #2	10:02	1:38	1246	184
26	Cleaner #1	10:04	1:36	258	38
27	Supervisor	10:07	1:33	27	4.0

Table A14-3. Background solvent levels (ppm)

	DAY 1				DAY 2				
	Time				Time				
Location	9:30	10:30	11:00	11:30	6:30	7:30	9:30	10:30	11:30
Outside, near building	4	4	2	4-6	5	5	3	40	7
Filter Room	--	20	35	35	24	24	37	158*	47
Cleaning Room	45	40	90	85	10	35	41	27	45
Drying Room	13	20	60	20	12	6	10	15-35	15
Spotting Area	2	2	2	2	1-2	1-2	1	3	3
Pressing Areas	2	2	1	2	1-2	1-2	1	3	2
	4	2	1	2	2	1-2	1	4	1-2
Customer Area	--	--	<1	<1	2	1	<1	3	2

*Leak detected in filter room at this time was probable cause of unusually high concentrations measured in all areas.

APPENDIX A15
CASE STUDY NO. 15

A. PROCESS AND EQUIPMENT

Located in southern California, this plant is a relatively small commercial dry cleaner using petroleum solvent in two transfer-type washers. Average cleaning volume is 825 kg/week (1,813 lb/week). Annual solvent consumption is 11,738 L (3,228 gal.) in 1977 for an average mileage of 1,400. Cleaning and spotting are handled by one person. Three persons are involved as pressers and launders, two as seamstresses, one as a clothes marker, two as counter attendants, one as a billing clerk, and two owners/managers.

The dry cleaning equipment used in this plant is very old but well maintained. The washers are 23-years-old and include a Washex P100-PA, and Butler Model No. P602. The tumblers include a 23-year-old Mitco dryer, size 48 x 36, and a Cissell Model D4242, which is 15-years-old. Delicate fabrics are dried in a drying cabinet which is 3.7 x 0.9 x 1.8m (12 ft. x 3 ft. x 6 ft.). Two cartridge-type filters, Puritan "Vanguard 42," were installed three years ago to process solvent from the two washers. Solvent is cleaned periodically in a Butler Model 50-C vacuum still. As illustrated in Figure A15-1, the washers are located in one room which can be isolated from the remainder of the plant by self-closing fire doors. The dryers are located in an adjacent room of similar design.

Approximately two loads per hour are processed in each washer. The dirtier work is cleaned in a Washex. Each load is processed through a twenty-five-minute wash and an extraction which lasts 1-4 minutes. The seals on both washers are in exceptionally good shape. The tumblers run for 10-25 minutes for each load, at the conclusion of which the clothes are normally removed at 57.2°C (135°F). Tumblers exhausts are vented to the roof. The filter cartridges are changed at 11-week intervals. Distillation of solvent occurs once or twice per week for 1.5-3 hours each time. Normally, over the course of a week approximately 300 L (80-100 gal.) are distilled.

B. NATURAL VENTILATION

As one might expect from the location of this plant, natural ventilation was prevalent, and was provided by open doors and windows illustrated in Figure A15-1. These airflows could not be reliably measured.

C. GENERAL MECHANICAL AND LOCAL EXHAUST VENTILATION

As shown in Table A15-1, a limited quantity of building exhaust is provided by wall vents located in the drying and cleaning rooms. However, these exhaust drafts are generally overwhelmed by the quantity of air exhausted by the three dryers. To maintain the building at a comfortable temperature, a much larger quantity of cool air is injected by evaporative coolers mounted in the ceiling, each rated at approximately 1.4 m^3/s (3,000 cfm). During this survey, four or five evaporative coolers were in simultaneous use.

D. LEAK DETECTION

No unusual leaks were detected.

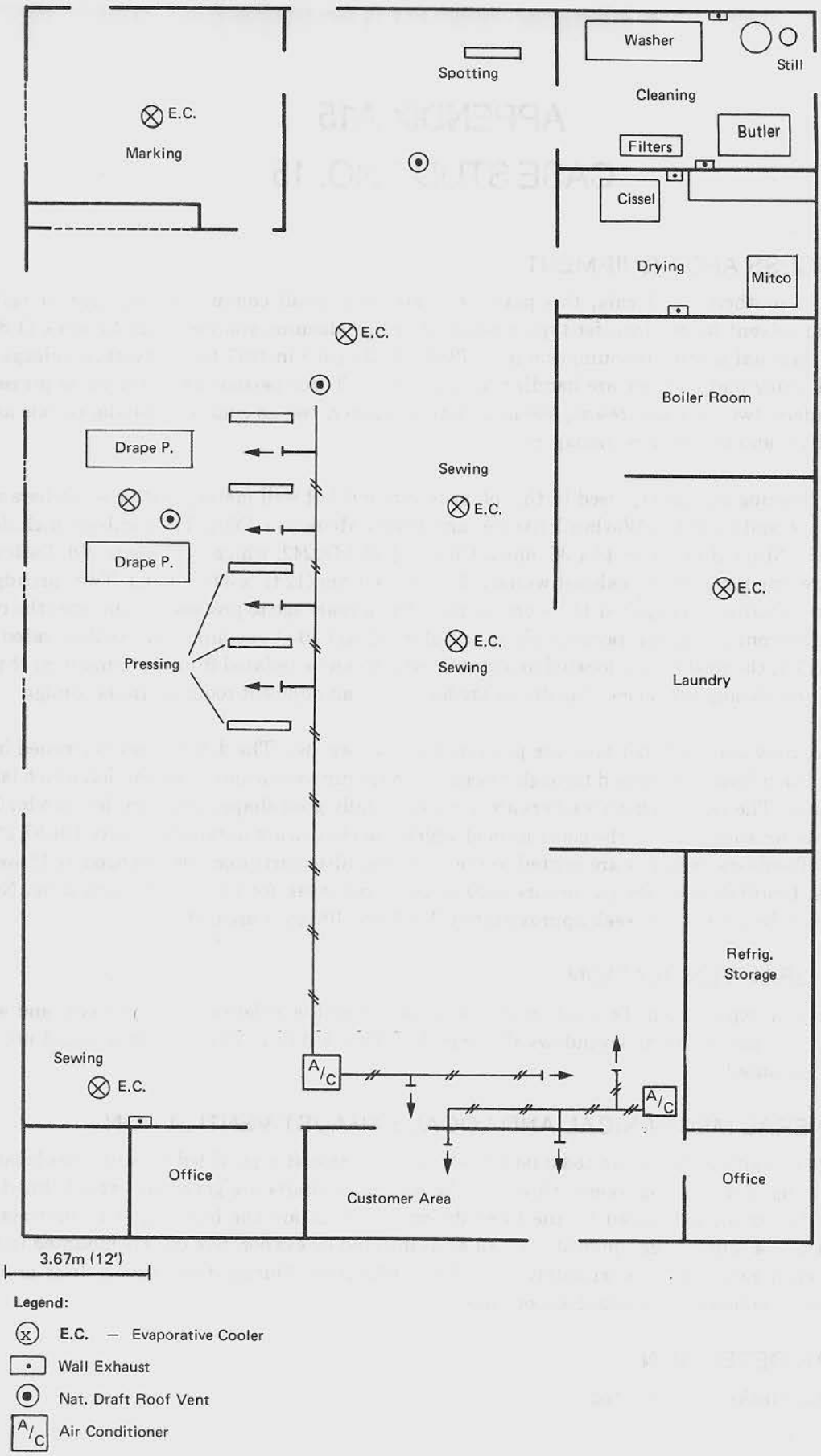


FIGURE A15–1 GENERAL ARRANGEMENT – PLANT #15

Table A15-1. Building ventilation flow rates.

Location	Type	Volume m^3/s (cfm)
	EXHAUSTS	
Dryer room, near Mitco	Wall vent	0.09 (200)
Dryer room, near Cissel	Wall vent	0.07 (150)
Dryer room, Mitco dryer	Machine exhaust	0.85 (1800)
Dryer room, drying cabinet	Machine exhaust	0.38 (800)
Dryer room, Cissel dryer	Machine exhaust	0.85 (1800)
Cleaning room, near Washex	Wall vent	0.14 (300)
Cleaning room, near Butler	Wall vent	0.12 (250)
Total measured exhaust, maximum.		2.50 (5300)
	INLETS	
Ceilings	Evaporative coolers (approx.)	1.4 (3000)
Total measured inlets due to 4 or 5 evaporative coolers operating simultaneously		5.66-7.08 m^3/s (12-15,000 cfm)

Balance of ventilation is provided by numerous open doors, windows, and natural draft roof vents as indicated in plant layout.

E. HEAT EXPOSURE

Despite outside temperatures of approximately 32.2°C (90°F), working conditions within the plant were quite comfortable with the exception of the drying room. With a complete lack of natural ventilation, temperatures in the drying room reached quite high levels as indicated in Table A15-2. However, the cleaner was the only one exposed to such high temperatures and his exposure was generally limited to five minutes or less.

F. SOLVENT EXPOSURE LEVELS

Solvent concentrations as measured by charcoal sample tubes/GC analysis are summarized in Table A15-3. All measurements except ceiling levels were quite low, generally below 25 ppm. The time-weighted-average exposure of the cleaner was considerably lower than the ambient concentration in the cleaning room because the cleaner generally spent most of his time near the spotting table. A typical sequence of the cleaner's activities is outlined in Table A15-4. Instantaneous measurements of vapor concentrations, as determined by a photo-ionization detector, are summarized in Table A15-5 and show that concentrations remain low throughout the working day.

CONCLUSIONS

This plant is an excellent model of how low vapor exposures can be achieved by simple building design. Taking advantage of year-round opportunities for natural ventilation of the building, numerous open doors and windows and excess of air injection by evaporative coolers provide good ventilation throughout the plant and an outward flow of solvent vapors through the drying and cleaning rooms away from the operating areas.

Table A15-2. Heat exposure (measured in drying room).

Time	Dry Bulb °C (°F)	Wet Bulb °C (F)	Globe Temperature °C (°F)	WBGT (in) °C (°F)
10:30	37.9 (100.2)	23.3 (74.0)	39.8 (103.6)	28.1 (82.6)
11:05	36.1 (97.0)	23.7 (74.6)	40.1 (104.2)	28.2 (82.7)
11:16	40.7 (105.3)	25.9 (78.6)	43.7 (110.6)	30.9 (87.7)
11:50	40.1 (104.1)	25.8 (78.5)	43.9 (111.0)	31.2 (88.2)
1:50	49.9 (121.8)	28.4 (83.1)	49.4 (120.9)	34.7 (94.5)
2:35	42.0 (107.6)	24.9 (76.9)	44.5 (112.1)	30.6 (87.0)
3:30	40.5 (104.9)	24.1 (75.3)	43.8 (110.8)	29.7 (85.4)
3:45	44.1 (111.4)	26.6 (79.8)	47.4 (117.3)	32.5 (90.5)

Table A15-3. Air sampling data.

Sample No.	Location	Start (hr:min)	Duration (hr:min)	Solvent Concentration mg/m^3	ppm
1	Cleaner	7:45	2:04	74	11
2	On Washex	7:50	1:23	136	20
3	On Butler	7:50	1:23	93	14
4	Pressing	7:55	5:55	6	0.9
5	Customer Service	7:55	5:55	3	0.4
6	On Washex	9:13	1:02	116	17
7	On Butler	9:13	1:02	93	14
8	Cleaner	9:49	2:00	79	12
9	On Washex	10:15	1:10	93	14
10	On Butler	10:15	1:12	100	15
11	On Washex } Stopped during lunch	11:25, 13:48	1:34	170	25
12	On Butler } Stopped during lunch	11:27, 13:48	1:32	101	15
13	Cleaner	13:48	1:42	54	8.0
14	Pressing	13:50	1:50	25	3.7
15	Customer Area	13:55	1:45	7	1.0
16	Cleaner	7:45	2:00	27	4.0
17	On Washex	7:48	1:27	342	51
18	Pressing	7:48	3:57	3.7	0.5
19	Customer Area	7:50	3:55	3.0	0.4
20	Cleaner, during last half of transfer	8:08	0:01	12	1.8
21	Cleaner, during transfer	8:43	0:01	1020	151
22	Cleaner, during transfer	9:43	0:02	932	138
23	On Washex	9:15	2:00	172	25
24	Cleaner	9:45	2:00	27	4.0
25	Sewing	9:50	1:55	7	1.0
26	On Washex during transfer	10:40	0:01	455	67
27	On Washex	13:00	2:45	21	3.1

Table A15-4. Typical cleaner's activities.

Time	Activity
10:25	Butler is on. Cleaner loading Washex. Forty-five seconds spent in cleaning room.
10:26	Spends 1 minute in drying room (DR) emptying Cissel and drying cabinet.
10:26	Hanging clothes and spotting.
10:36	Spends 20 seconds in cleaning room (CR) inspecting Butler.
10:40	Spends 60 seconds in CR unloading Butler.
10:41	Spends 90 seconds in DR loading dryers.
10:43	Two and one-half minutes in CR loading Butler and cleaning up solvent leaking from pump gasket.
10:46	Spotting.
10:53	Twenty seconds in DR to empty Mitco.
10:54	Thirty seconds in CR to empty Washex. Twenty-five seconds in DR to load Mitco.
10:55	Sorting clothes near spotting area.
10:59	Four minutes in CR to load Washex and clean lint filter.
11:08	Fifteen seconds in DR to empty Cissel.
11:13	One hundred five minutes in CR to empty Butler.
.	
.	
.	
etc.	

Cleaning started at 7:00 a.m., finished at 2:00 p.m.

Table A15-5. Background concentration levels.

Location	DAY 1 Time 8:00	9:00	10:30	11:30	14:00	DAY 2 Time 8:00	10:00
Outside Air	1	2-3	1	1-2	1	1	1
Cleaning Room	6	12	4	16-22	8-40	6	2
Drying Room	1	16	3	6	--	4	1
Clothes Pressing	<1	2	1-2	1	1	1	<1
Drapery Pressing	<1	<1	<1	<1	1	<1	<1
Customer Area	<1	1	1-2	<1	<1	<1	<1
Spotting Area	--	--	--	--	--	6	1

APPENDIX A16
CASE STUDY NO. 16

A. PROCESS AND EQUIPMENT

This is a large commercial perchloroethylene plant in the Middle-Atlantic area. A dry-to-dry unit is employed to process approximately 2994 kg (6,600 pounds) of dry cleaning weekly. A total of approximately 30 people are employed, most of whom are either engaged in laundry operations or are drivers for the five routes serviced by this plant. The plant employs 2 cleaners and 2 pressers to process its dry cleaning work.

The layout of this plant is shown in Figure A16-1. A Spencer 45 kg (100-pound) cleaning machine is used, with the filter and still that are an integral part of this machine. A Vic Model 118 Mileage Booster (carbon adsorber) is also used. This plant was purchased by its current ownership approximately 11 years ago and the Spencer machine was brought in; however, the adsorption unit was inherited with the plant and is of unknown age. It appears to be approximately 20-years-old. The adsorption unit is rated by its manufacturer as having a 15-liter (4-gallon) capacity, and is advertised as adequate for the "average-sized" plant. Since this plant handles a cleaning volume far above average, the adsorber would seem to be undersized.

Cleaning is done in 45 kg (100-pound) loads over a period of 11-12 hours each day. The cleaning cycle includes a 10-minute wash, 3-minute extraction, and 20-minute drying. During this survey, the aeration cycle was being by-passed manually since a leaking valve controlling solvent inlet to the garment wheel would cause streaking of cleaned clothes if the aeration cycle were run.

The adsorber outlet duct vents within the dry cleaning area. The sniffer blower is operated through a microswitch on the cleaning machine door; thus, the sniffer is in operation only during aeration and unload/load cycles. The adsorber is stripped once every two days, and approximately 11 1 (3 gal.) of solvent are recovered.

B. NATURAL VENTILATION

The rear (west) wall of the plant contains one 1.7 m^2 (17.9 $ft.^2$) louvred panel through which an air flow of approximately 5 $m^3/2$ (10,700 cfm) was measured. Along the length of the north and east walls of the plant, a series of 71 cm x 71 cm (28 in. x 28 in.) louvred panels is present. During this survey, three panels were open, providing a total of approximately 0.6 m^3/s (1200 cfm) into the plant.

C. GENERAL MECHANICAL VENTILATION

Two roof-mounted exhaust fans, each approximately 107 cm (42 in.) diameter, were in use. These fans were not accessible and air flow measurements could not be made.

D. LOCAL EXHAUST VENTILATION

The carbon adsorption system is tied to the cleaning machine and a single floor duct located adjacent to the cleaning machine. This system is shown schematically in Figure A16-2. The outlet duct from the sniffer delivered approximately 0.15 m^3/s (315 cfm), and all of this flow was found

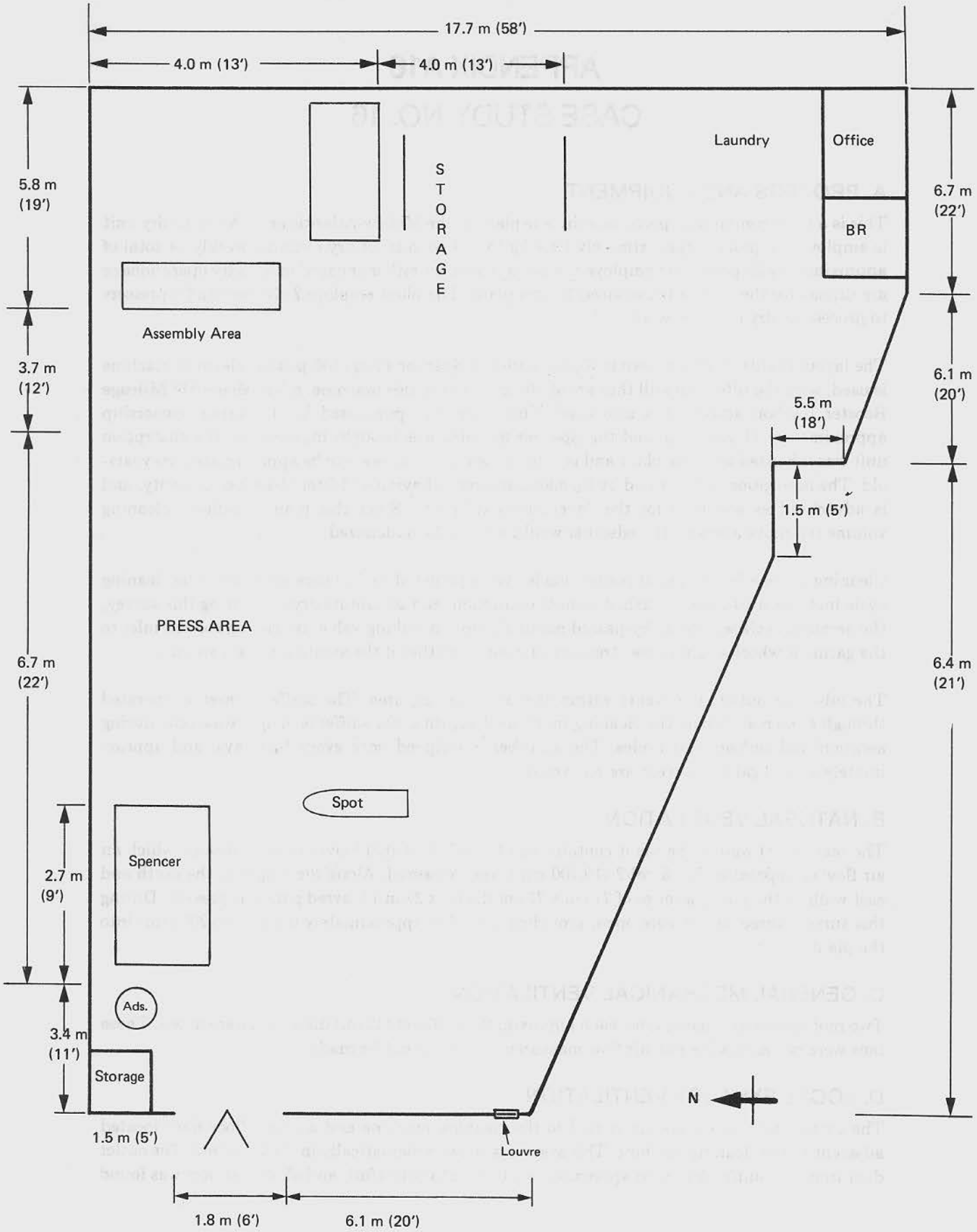
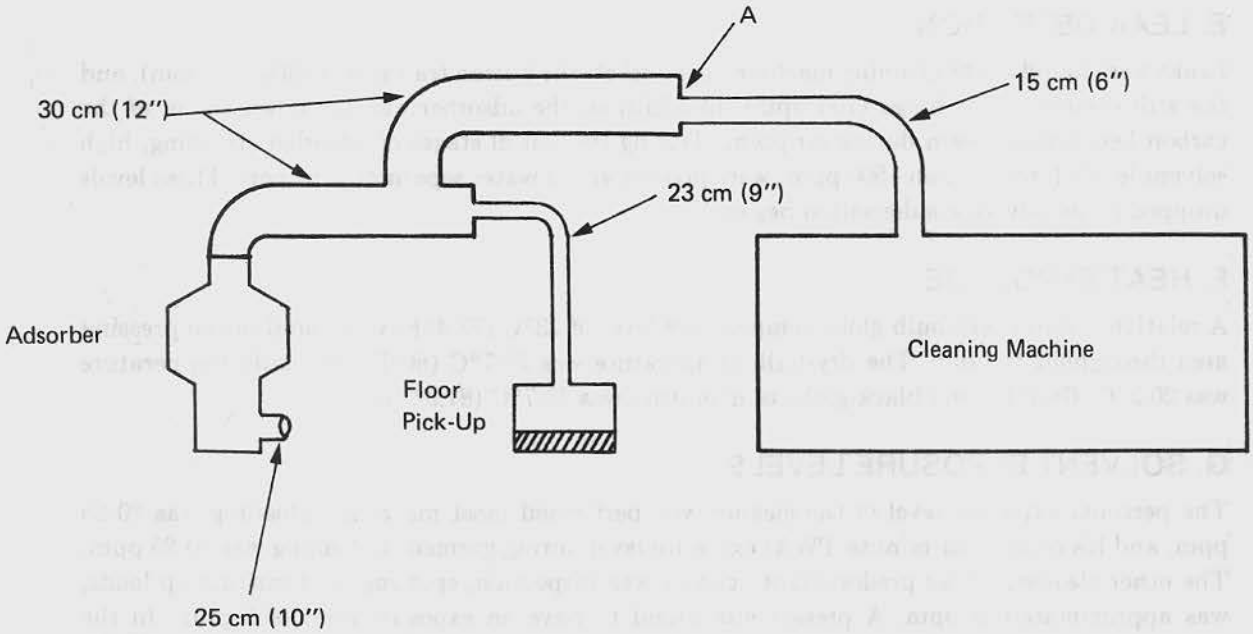


FIGURE A16–1 GENERAL PLANT LAYOUT



Note: At junction A, joint of 15 cm to 30 cm diameter duct is off center: (o)

FIGURE A16–2 LOCAL EXHAUST VENTILATION SYSTEM

to originate at the floor duct, that is, even when the cleaning machine door was open, no measurable air flow occurred through the machine to the adsorber. Blocking the floor duct did redirect air flow, causing flow through the machine door.

When the sniffer operated, high solvent levels were found in the sniffer exhaust. The improperly sized adsorber, low solvent recovery (relative to cleaning volume), and high solvent levels in sniffer exhaust all suggest that this system is saturated and possibly poisoned.

E. LEAK DETECTION

Leaks were found at the cleaning machine door gasket, the button trap gasket (300-700 ppm), and the still cleanout door hinge (700 ppm). In addition, the adsorber damper downstream of the carbon bed leaked steam during stripping. During the initial stages of adsorber stripping, high solvent levels (greater than 1500 ppm) were present at the water separator vent part. These levels dropped off as solvent condensation began.

F. HEAT EXPOSURE

A relatively stable wet-bulb globe temperature level of 23°C (73.4°F) was found in the pressing area throughout the day. The dry-bulb temperature was 26.7°C (80°F), wet-bulb temperature was 20.3°C (68.5°F), and black-globe temperature was 30.7°C (87.3°F).

G. SOLVENT EXPOSURE LEVELS

The personal exposure level of the cleaner who performed most machine unloading was 20-25 ppm, and his ceiling (15-minute TWA) exposure level during garment unloading was 30-35 ppm. The other cleaner, whose predominant activity was inspection, spotting, and making up loads, was approximately 9 ppm. A presser was found to have an exposure level of 5 ppm. In the storefront area, a level of 1 ppm was measured. Levels measured in this plant are listed in Table A16-1. Measurements made with a photo-ionization detector indicate that in the pressing area, the general area solvent level rises from a baseline level of ppm up to a peak of 65 ppm during garment unloading. A level averaging approximately 45 ppm persists in the pressing area for up to 3 minutes after the cleaning machine door is closed. This solvent level increase appears to be due to the emission of solvent by the sniffer (see Section D of this Appendix).

H. COLD WEATHER SURVEY

This plant was re-surveyed during cold weather to examine the effect of reduced natural and general mechanical ventilation on exposure levels. The plant operating conditions during the winter survey were identical to conditions during the initial survey. As previously noted, the design of the local exhaust system was such that no air was exhausted through the cleaning machine door during garment loading and unloading.

The wall louvres which provide air during the summer were all closed during this survey; however, these louvres did not make an air-tight seal with their frames and were a significant source of air leakage in the plant during cold weather. The doors of the plant were kept closed.

Exposure level data measured under these conditions are listed in Table A16-2. These data indicate a small rise in exposure levels during the winter survey. The cleaner's exposure, as a time-weighted average over all survey periods, was 20.0 ppm for the initial survey vs. 23.6 for the

Table A16-1. Airborne exposure levels.

Sample #	Location	Duration (hr:min)	Start Time	Perchloroethylene level mg/m^3	Perchloroethylene level ppm
1	Cleaner personal sample	2:23	7:02	168	25
2	Cleaner/spotter personal sample	2:15	7:06	49	7.2
3	Presser personal sample	1:56	7:39	31	4.6
4	Cleaner personal sample	2:04	9:26	167	25
5	Cleaner/spotter personal sample	2:11	9:21	59	8.7
6	Presser personal sample	2:01	9:35	47	6.9
7	Sniffer vent	0:24	10:57	88	13
8	Sniffer vent	0:04	11:21	1,680	247
9	Cleaner personal sample	2:41	11:32	150	22
10	Cleaner/spotter personal sample	2:44	11:33	64	9.4
11	Presser personal sample	2:39	11:40	35	5.2
12	Cleaner/spotter personal sample	2:10	6:50	78	11
13	Cleaner personal sample	2:07	6:50	144	21
14	Cleaner during unload	0:16	6:57	198	29
15	Store area	7:00	7:00	7	1.0
16	Sniffer outlet area	0:33	7:12	200	29
17	Presser personal sample	2:02	7:18	37	5.5
18	Cleaner during unload	0:15	7:40	209	31
19	Sniffer outlet area	0:17	8:20	500	74
20	Cleaner during unload	0:15	8:22	280	41
21	Cleaner personal sample	2:01	8:57	100	15
22	Cleaner/spotter personal sample	2:00	9:00	90	13
23	Inside sniffer duct	0:03	9:08	36,000	5,302
24	Sniffer outlet duct	0:03	9:08	1,190	175
25	Cleaner during unload	0:15	9:08	222	33
26	Presser personal sample	2:00	9:20	36	5.3
27	Cleaner during unload	0:15	9:49	230	34
28	Area during solvent delivery	0:08	10:07	740	109
29	Cleaner during unload	0:15	10:35	228	34
30	Cleaner personal sample	2:10	10:58	73	11
31	Cleaner/spotter personal sample	2:08	11:00	43	6.3
32	Presser personal sample	2:05	11:20	28	4.1
33	Sniffer duct	0:02	--	2,830	417
34	Sniffer duct	0:02	--	37,000	5,450

Table A16-2.
Airborne perchloroethylene levels during winter survey.

Sample #		Duration (hr:min)	Start Time	mg/m^3	ppm
1	Cleaner personal sample	2:04	7:20	165	24
2	Cleaner/spotter personal sample	1:08	7:19	135	20
3	Store area	4:00	7:25	37	5.4
4	Pressing area	3:20	7:30	71	10
5	Cleaner during unload/load	0:15	8:09	330	49
6	Sniffer area	0:04	8:09	520	76
7	Office area	4:52	7:55	20.8	3.1
8	Store area	4:05	8:40	22.6	3.3
9	Cleaner during unload/load	0:18	9:02	273	40
10	Cleaner personal sample	3:23	9:24	111	16
11	Cleaner/spotter personal sample	2:36	10:06	78	11.5
12	Cleaner during unload/load	0:18	NA	172	25
13	Pressing area	1:57	10:50	84	12
16	Sniffer area	0:02	NA	550	81
17	Pressing area*	1:01	12:43	196	29
18	Store area*	1:00	12:45	161	24
19	Office area*	1:00	12:47	186	27
20	Cleaner personal sample*	1:01	12:47	223	33
21	Cleaner/spotter personal sample	1:47	6:46	141	21
22	Cleaner personal sample	3:52	7:01	201	30
23	Office area	6:04	6:50	20.1	3.0
24	Pressing area	4:04	6:48	116	17
28	Cleaned clothes basket	0:03	NA	5700	840
31	Cleaner/spotter personal sample	3:08	9:47	130	19
33	Pressing area	2:02	10:52	77	11
34	Cleaner personal sample	3:31	10:54	141	21
35	Cleaner/presser during muck cleanout	0:11	2:25	960	141

*During this period, an air-dry load (2 coats) was hung approximately 4 feet from the spotting board.

NA - not available.

cold weather survey. Similarly, the cleaner/spotter (who opens the plant, thus receiving exposure to vapor that accumulates over night) experienced warm and cold weather exposures of 9 and 17 ppm, respectively. The vapor level measured in the store area was 3 ppm during cold weather, as contrasted with 1 ppm during warm weather.

I. MODIFIED EXHAUST SYSTEM

To determine the effect of airflow through the machine door on ceiling levels during unloading and loading dry-to-dry machines, a series of tests were run. During these tests, two modifications were made to the plant's ventilation system. First, the floor duct was completely blocked to force all airflow through the washer door (see Figure A16-2). This resulted in the flow of approximately 0.45 m^2/sec (950 cfm) through the machine door during loading/unloading. Next, a duct fan was placed in the system to boost the airflow rate. This fan, which had 20 cm (8") blades and a 1/100 HP motor, was found to deliver approximately 0.04 m^2/sec (85 cfm) additional flow when running against the static pressure of this system. A comparison of ceiling levels measured with and without these modifications is shown in Table A16-3.

The results of this test are not statistically significant due to the small number of samples available; however, the results do clearly suggest that airflow through the machine door is a key factor in minimizing ceiling exposures. It is also believed that the results of this test were partially obscured by the work practices employed: Following removal of a load, the garments were immediately sorted and hung by the cleaner and cleaner/spotter. Solvent retained by the garments evaporated off in the breathing zone of these employees, and no ventilation was supplied in this area. Thus, ceiling levels were influenced by evaporation during garment hanging as well as by exposures at the machine face.

CONCLUSION

The improperly operating adsorber in this plant contributes to overall solvent levels by emitting solvent during garment loading. Further, poorly sized ductwork results in all air fed to adsorber originating from the floor duct, with no air drawn from the garment wheel during unloading. This causes elevated ceiling levels during transfer.

Exposure levels within this plant are noticeably elevated during cold weather due to a reduction in natural ventilation. The use of exhaust air pulled into the machine door during garment loading/unloading helps in the control of ceiling exposures. It is also important to provide exhaust ventilation when freshly cleaned garments are hung prior to finishing.

Table A16-3. Effect of modified ventilation system.

Floor Duct (Open/Blocked)	Booster Fan (On/Off)	Ceiling Level* (ppm)	
Open	Off	49	
		40	
		30	Avg. = 39.7
Blocked	Off	23	
		46	
		33	Avg. = 34.0
Blocked	On	34	
		27	
		32	Avg. = 31.0

*15-minute time-weighted average during garment unload/load.

APPENDIX 17
CASE STUDY NO. 17

A. PROCESS AND EQUIPMENT

This is a very large industrial perchloroethylene plant that employs both a transfer and a dry-to-dry unit to process the dry cleaning. The plant is located in the Southwest and processes a weekly average of 11,930 kg (26,300 pounds) of garments. A combined solvent mileage of 18,500 was reported. Employment in the plant includes 1 cleaner, 1 assistant cleaner, and 48 other employees in production, of which 4 are pressers. Thirty-five other people are employed as supervisory personnel, office workers, and truck drivers.

The single transfer system consists of a 6-year-old American Laundry Machinery Model 60x44 Washer/Extractor; a 5-year-old American Laundry Machinery Model 60x60 Reclaimer Dryer; a 5-year-old American Laundry Machinery Still; and a 2-year-old American Laundry Machinery 363 kg (800 pounds) carbon bed adsorption unit. The dry-to-dry system consists of an American Laundry Machinery Model 250 which was purchased second-hand approximately one year ago and is estimated to be 3-years-old. A layout of the plant is shown in Figure A17-1.

In the single transfer system, both the washer and dryer are equipped with hydraulic arms so that they may be tilted. The dryer is also equipped with a set of rollers and sits on a set of tracks permitting it to be mechanically moved to the washer during the transfer operation. Figure A17-2 shows this arrangement, known as a "kissing tumbler." When the two machines are brought together, rotation of the garment cylinders tends to move garments out of the washer and into the dryer.

The carbon adsorption unit is stripped once a day, at the end of the day, with 0.35 kg/cm^2 gage (5 psig) for 15 minutes followed by 1.97-2.11 kg/cm^2 gage (28-30 psig) steam for 45 minutes. A daily average of 38-45 L (10-12 gal.) is recovered by routing the vapor through the dryer's reclaiming system.

The transfer system usually is reserved for shirts while the dry-to-dry system is used exclusively for pants. The shirts are washed in batches of 91 kg (200 pounds) and require 7 minutes for water-detergent wash; 3 minutes for extraction; 10 minutes for wash with the solvent that was used as second solvent wash of the previous load; 2 minutes for extraction; 8 minutes for wash with newly distilled solvent (that will be used as first solvent wash of the next load); 4 minutes for extraction; an average of 45 seconds to transfer the load from the washer to the dryer; an average of 90 seconds to load the washer with a new load of shirts; 30 minutes to dry at an air maximum entrance temperature of 126.7°C (260°F) and at an air temperature exiting the dryer of 67.8°C (154°F); and 2 minutes to deodorize (aerate).

Pants are washed in batches of 136 kg (300 pounds) and require 5 minutes for washing with solvent that was used as second solvent wash of the previous load; 4 minutes for extraction; 5 minutes for wash with newly distilled solvent (that will be used as first solvent wash of the next load); 4 minutes for extraction; 40 minutes to dry; and 2 minutes to deodorize (aerate).

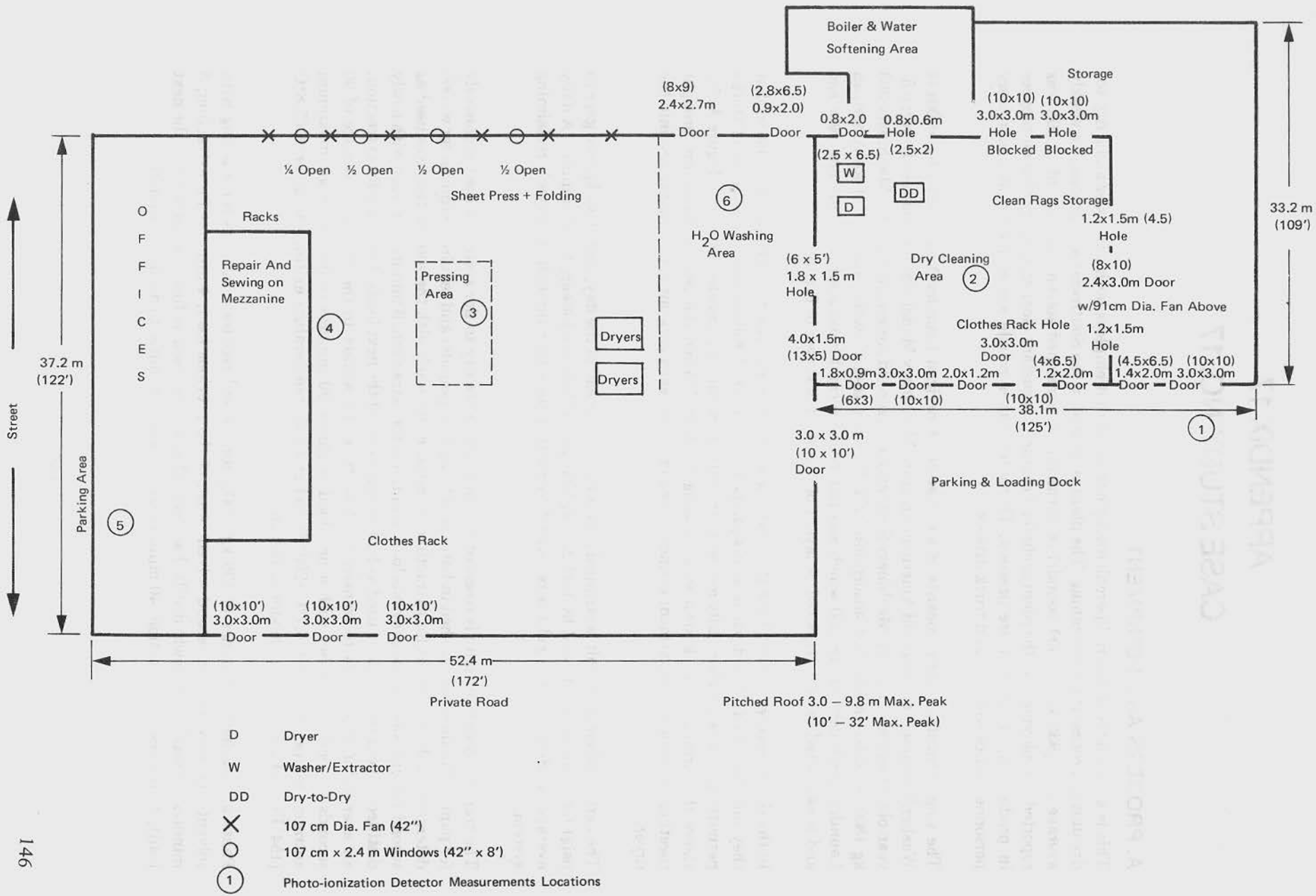
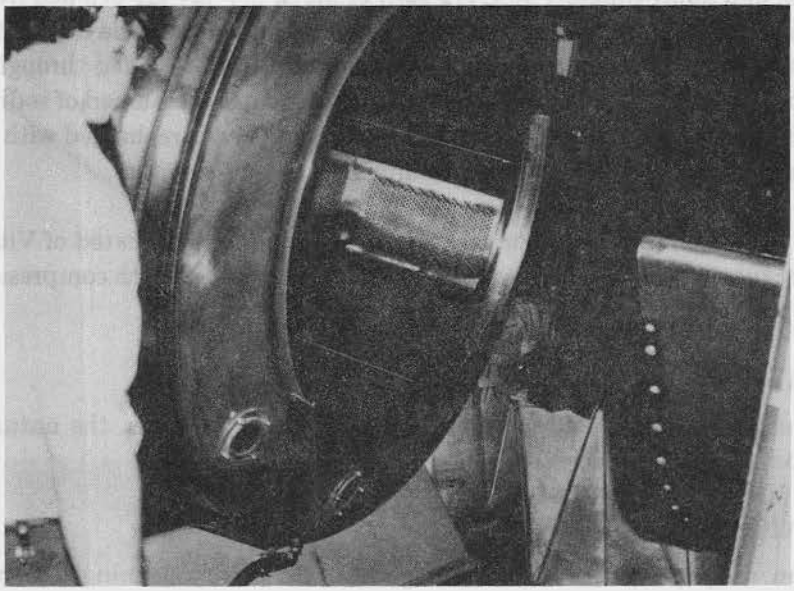


FIGURE A17–1 GENERAL PLANT LAYOUT



Washer (left) Tilts as Units Prepare for Transfer

Transfer in Progress

FIGURE A17–2

The stills of both systems operate for an average of 10-14 minutes per load. The muck cooker is interconnected with the still, and approximately 45 L (12 gal.) of muck per day are drained from the transfer system. Approximately 30 L (8 gal.) of muck per day are drained from the dry-to-dry system. In both systems, the solvent recovered from the reclaimer and the still is fed through a gravity separator before being stored in the clean solvent tank. In each separator, a bed of sodiun chloride is used to absorb trace amounts of water. Every two months the bed is recharged with 23 kg (50 pounds) sodium chloride, and the bed is charged totally once every 6 months.

Another interesting feature of this plant is the door gaskets, all of which are fabricated of Viton and are analogous to an inner tube. After the door is closed, the gasket is inflated with compressed air to form a good, air-tight seal.

B. NATURAL VENTILATION

During the course of this survey, all doors and ventilation ports were open. Thus, the natural ventilation is estimated to be of significant importance.

C. GENERAL MECHANICAL VENTILATION

A 91-cm (36-in.) diameter fan was present between the storage area and the dry cleaning area, but this fan was not utilized during the survey. There are also six 107-cm (42-in.) diameter, low-speed fans along the rear wall near the sheet press and folding area. These were operated continuously. The locations of these fans are shown in Figure A17-1.

D. LOCAL EXHAUST VENTILATION

This plant employs a local exhaust system connecting the transfer cleaning system to the carbon adsorption unit. The outlet duct from the adsorber runs up to the roof and discharges outdoors. The dry-to-dry system is ducted directly through the roof with no carbon adsorption recovery. The two systems are shown schematically in Figure A17-3, and the air flow rates through the two systems are listed in Table A17-1.

E. LEAK DETECTION

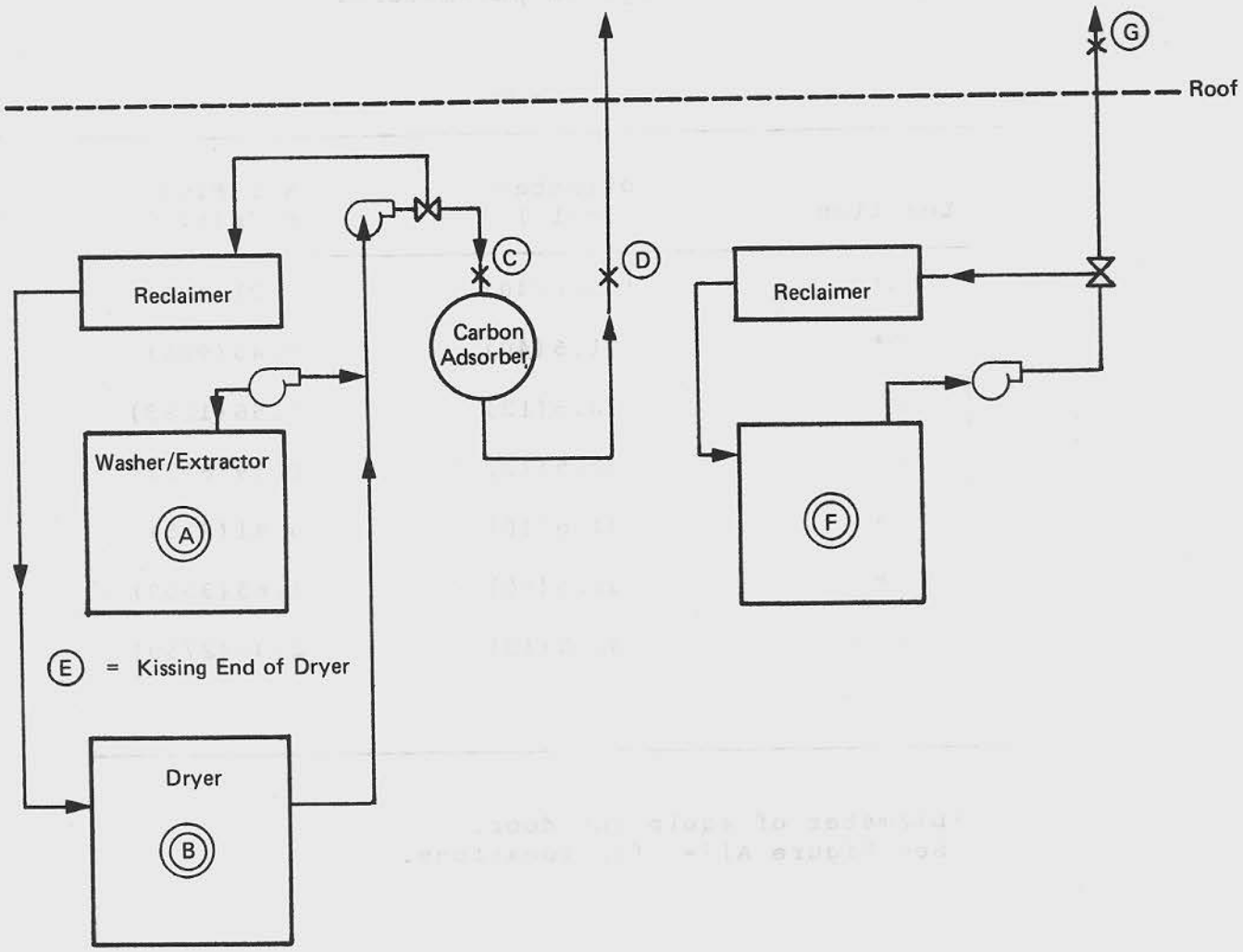
No overt leakage was detected by the photo-ionization detector. However, a level of 675 ppm was detected at the gravity separator vent in a charcoal tube sample.

F. SOLVENT EXPOSURE LEVELS

Table A17-2 lists exposure levels determined by collection on charcoal tubes with subsequent gas chromatographic analysis. Area levels measured with a photo-ionization detector are shown in Table A17-3. The cleaner's personal exposure level was approximately 30-35 ppm, with his ceiling level (15-minute TWA) ranging from 59-121 ppm. Area and personal samples outside of the dry cleaning area ranged from 1-4 ppm.

CONCLUSIONS

Because the "automatic" transferring from the washer to the dryer frequently clogged, the operator found it necessary to reach between the machines' interface to untangle the load. This is believed to be the cause of a substantial amount of his exposure. Increasing the airflow through the machine doors and/or instituting some sort of a push-pull system may ameliorate the situation.



A = Air flow measurement point

FIGURE A17–3 LOCAL EXHAUST VENTILATION SYSTEM

Table A17-1. Local exhaust ventilation system parameters.

Location	Diameter cm(in)	Air Flow m^3/s(cfm)
A*	101.6(40)	0.21(440)
B*	101.6(40)	0.45(960)
C	30.5(12)	0.56(1193)
D	30.5(12)	0.39(825)
E*	101.6(40)	0.41(875)
F*	101.6(40)	1.65(3500)
G	30.5(12)	1.30(2759)

*Diameter of equipment door.
See Figure A17-3 for locations.

Table A17-2. Airborne concentration measurements.

Sample #		Duration (min)	Start Time	mg/m^3	ppm
1	Cleaner personal sample	120	8:50	200	30
2	Pressing area	155	9:00	13	2
3	Dry cleaning area	95	9:00	11	2
4	Gravity separator vent	5	9:40	4580	675
5	Cleaner during transfer	16	10:27	400	59
6	Garment preparator personal sample	75	10:55	0.3	<1
7	Cleaner personal sample	150	10:50	210	31
8	Pants press area	106	10:37	15	2
9	Dry cleaning area	165	10:42	12	2
10	Cleaner during transfer	14	11:27	820	121
11	Sewing machine area	200	11:40	4	1
12	Cleaner personal sample	105	1:22	150	22
13	Garment preparator personal sample	90	1:30	0.3	<1
14	Dry cleaning area	144	1:27	8	1
15	Cleaner during transfer	15	2:15	420	62
16	Cleaner personal sample	140	7:45	350	52
17	Dry cleaning area	125	7:50	190	28
18	Pressing area	110	8:45	0.04	<1
19	Sewing machine area	195	8:45	6	1
20	Presser personal sample	127	8:10	0.2	<1
21	Presser personal sample	129	8:10	16	2
22	Cleaning during transfer	15	8:20	590	87
23	Cleaner during transfer	14	9:40	600	88
24	Dry cleaning area	110	9:55	85	13
25	Cleaner personal sample	113	10:05	0.1	<1
26	Presser personal sample	120	10:20	0.2	<1
27	Presser personal sample	120	10:35	24	4
28	Pressing area	225	11:35	3	<1
29	Cleaner during transfer	18	11:45	550	81
30	Dry cleaning area	150	11:57	25	4
31	Dry cleaning area	63	11:57	240	35
32	Sewing machine area	187	12:02	4	1
33	Presser personal sample	130	12:20	19	3
34	Presser personal sample	128	12:22	0.2	<1
35	Cleaner personal sample	132	1:00	180	27
36	Cleaner during transfer	15	1:06	470	69
37	Cleaner during transfer	18	1:55	580	85

Table A17-3. Background solvent levels.

Day	Time	Perchloroethylene Level (ppm) Location* 1	2	3	4	5	6
1	0800	<1	2.5	1	1	1	-
	0900	<1	2	2	1	2	-
	1000	1.5	2.5	2	2	2	-
	1100	<1	4	5	2	3.5	-
	1330	<1	1	<1	<1	2	-
	1500	<1	3	5	1	3	-
Other Readings							
	0800	Mezzanine 3ppm					
	0900	In cleaned clothes 2-3					
	0900	Unpressed shirts 4-5					
	1000	Unpressed pants 40					
		Pants just pressed 20					
		At interface of machine during transfer 800-900					
	1500	Pants just pressed 700					
	1600	Lint filter duct 700-800					
		Lint filter 240					
	1700	Muck just drained from cooler 300-350					
2	0800	<1	1	<1	<1	2	3
	0930	<1	1.5	4.5	4.5	2	-
	1300	<1	1	1.5	1	2	3
	1500	<1	1	2	1	2	2
Other Readings							
	0800	In cleaned clothes 3.5					
		Pants just pressed 8					
		Machine interface during transfer 700					
		Pants deodorized an additional 15 minutes and just removed from dryer 20-30					
		In carbon adsorber exhaust duct during stripping 15-18					

*See Figure A17-1 for locations.

APPENDIX A18
CASE STUDY NO. 18

A. PROCESS AND EQUIPMENT

This is a medium-size commercial perchloroethylene plant in the Pacific Coast area. An average of 1180 kg (2600 pounds) of dry cleaning is processed weekly. An estimate of 9500 was reported as the solvent mileage. The employees in this plant include: 1 cleaner/spotter, 2 pressers, 1 seamstress, and 2 part-time assemblers/counter workers.

A Strato Model 173 washer/extractor and a Strato Model 64A dryer, both approximately 13-years-old, are used to process a daily average of 227 kg (500 pounds) of garments. A Harcons Universal Rebel fluorocarbon 113 system, which is used very infrequently and only for very delicate fabrics, was also available in the facility. A 7-year-old Kleen-Rite cartridge filter system containing 4 carbon-core cartridges is used in lieu of a still in the perchloroethylene system. One filter cartridge is replaced every 1814 kg (4000 pounds) of dry cleaning. Thus, each filter cartridge is used for 7257 kg (1600 pounds)of dry cleaning. A layout of the plant is depicted in Figure A18-1. Each load of approximately 20 kg (45 pounds) is washed with recirculated perchloroethylene for 15 minutes and then extracted for 5 minutes. An average of 1.5 minutes are required for the cleaner to empty the dryer, transfer the load from the washer to the dryer, and reload the washer. The garments are dried at 60°C (140°F) for approximately 20 ninutes.

B. NATURAL VENTILATION

Since this plant is located in a semi-tropical area, the louvres along the front and side of the building (see Figure A18-1) are expected to be open for most of the year.

C. GENERAL MECHANICAL VENTILATION

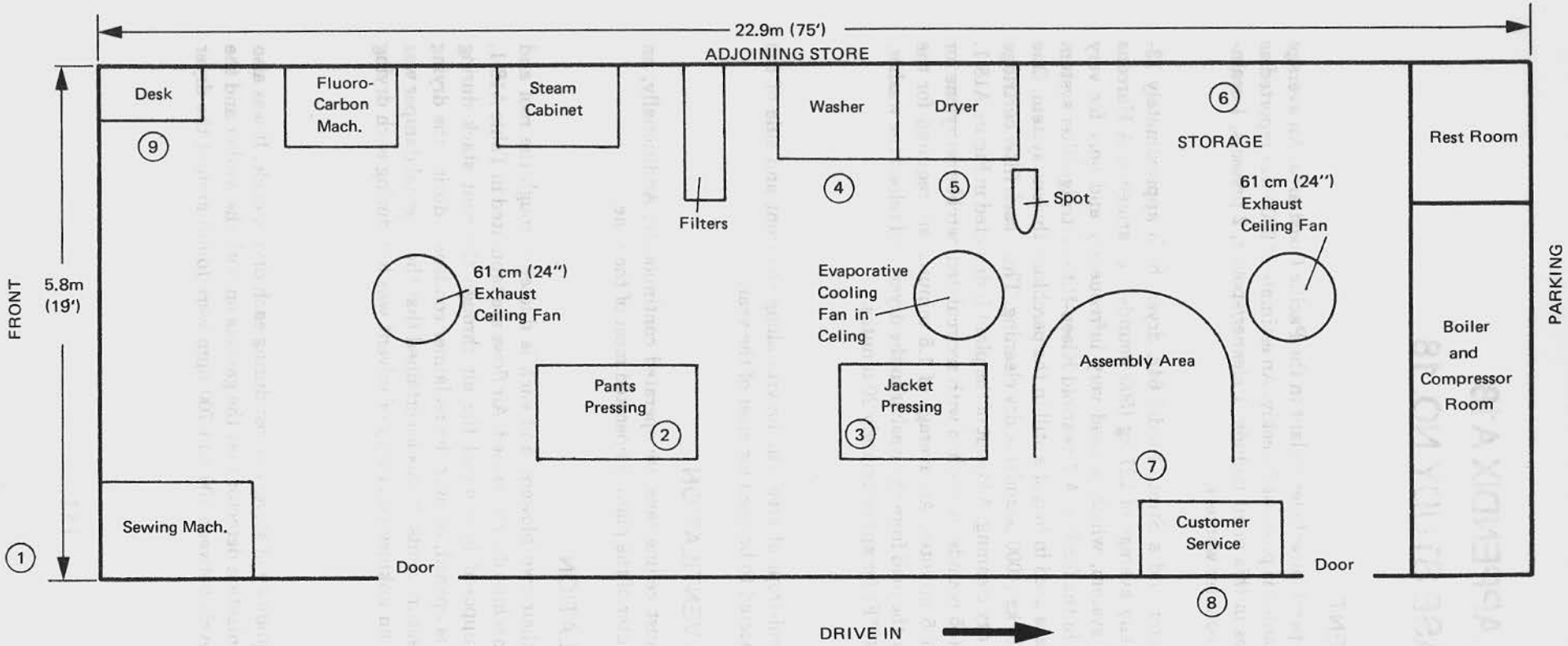
Two 61-cm (24-in.) diameter exhaust ceiling fans are operated continuously. Additionally, an evaporative cooling fan near the center of the plant is operated most of the time.

D. LOCAL EXHAUST VENTILATION

Both the washer and dryer have their own blowers, and each is ducted through the roof and operated whenever the respective machine door is opened. Air flows are tabulated in Table A18-1. An internal aeration damper is supposed to channel the air through the vent stack during aeration and when the dryer door is opened, or over the reclaimer condenser during the drying cycle. As a result of the air flow measurements, it was ascertained that the internal damper was malfunctioning (leaking) and that an unknown quantity of solvent was lost during each drying cycle.

E. LEAK DETECTION

As explained above, an unknown quantity of solvent is lost during each drying cycle. It was also determined by means of a photo-ionization detector that the gaskets on both the washer and the dryer doors should be replaced. Levels between 100 and 700 ppm were found around the dryer door.



94 cm (37") High Louvres Along Front and Side of Building
Aprox. 0.74 m^2 (8 sq. ft.) of Opening at Front
Aprox. 10.78 m^2 (116 sq. ft.) of Opening at Side
Ceiling ~4.6 m (15')

(1) — Photo-ionization Detector Measurement Locations

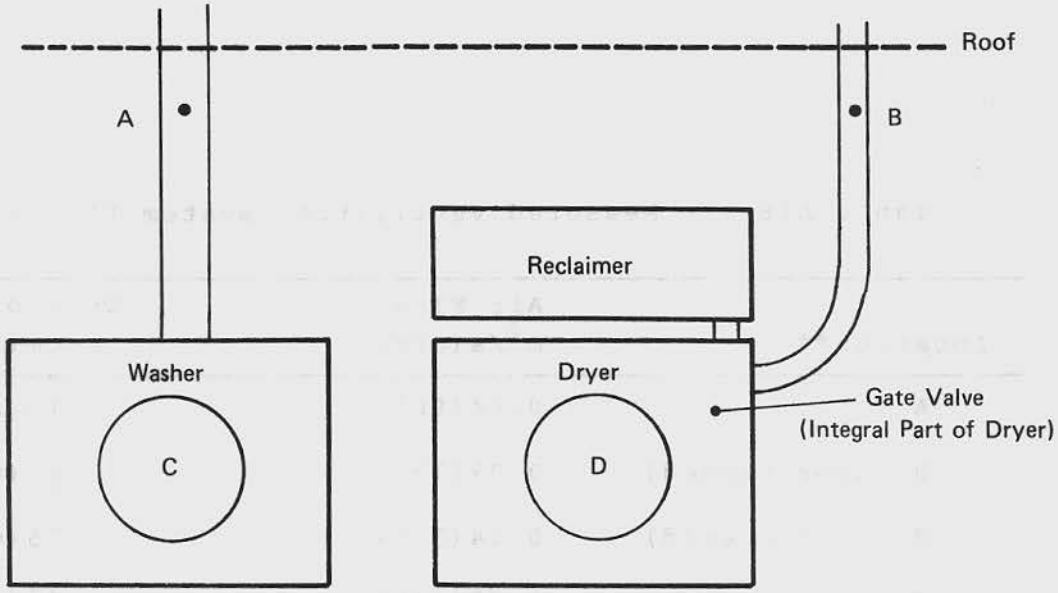
FIGURE A18–1 GENERAL PLANT LAYOUT

Table A18-1. Measured ventilation system flow rates.

Location**	Air Flow m^3/s(cfm)	Duct Diameter cm(in)
A	0.04(80)	15(6)
B (door closed)	0.07(157)	15(6)
B (door opened)	0.14(300)	15(6)
C	0.06(130)	46(18)*
D	0.15(310)	46(18)*

*Diameter of door.

**Refer to Figure A18-2 for the locations of flows.



Letters represent air flow measurement points.

FIGURE A18–2 LOCAL EXHAUST VENTILATION MEASUREMENTS

F. HEAT EXPOSURE

Wet-bulb globe temperatures (WBGT) of 26.7°C (80.1°F) and 29.4°C (84.9°F) were measured in the pressing station area during the two-day survey. The higher of the two is based on a dry-bulb temperature of 36.4°C (97.5°F), a wet-bulb temperature of 26.0°C (78.8°F), and a black-globe temperature of 37.7°C (99.9°F).

G. SOLVENT EXPOSURE LEVEL

The personal exposure level of the cleaner was 30 ppm, and his ceiling (15-minute TWA) exposure level during garment unloading and loading was 24-43 ppm. The pressers who were closest to the dry cleaning machine were found to have exposure levels between 1 and 6 ppm. Average levels of 12 ppm were found in the customer service area. Levels in other plant areas were determined with photo-ionization detection measurements which are listed in Table A18-3. Results of the charcoal tube samplings and their subsequent gas chromatographic analyses are delineated in Table A18-2.

CONCLUSIONS

Leakage from defective and worn gaskets contributed a significant amount of solvent to the workroom environment (especially in the pressing and the customer service areas).

Table A18-2. Airborne concentration measurements.

Sample #	Location	Duration (min)	Start Time	Perchloroethylene level mg/m^3	ppm
1	Cleaner personal sample	72	7:31	160	24
2	Jackets presser personal sample	120	7:25	16	2
3	Pants presser personal sample	125	7:20	9	1
4	On washer area	129	7:23	110	16
5	Customer service area	155	7:25	53	8
6	Pants press area	147	7:33	7	1
7	Cleaner during transfer	15	7:54	220	32
8	Cleaner personal sample	129	9:20	200	30
9	Jackets presser personal sample	120	9:27	29	4
10	Pants presser personal sample	106	9:27	17	3
11	On washer area	120	9:32	260	38
12	Cleaner during transfer	21	9:42	260	38
13	Press area	69	10:00	29	4
14	Customer service area	92	10:02	63	9
15	Cleaner during transfer	15	10:07	190	28
16	Cleaner during transfer	15	10:27	210	31
17	Cleaner personal sample	120	6:30	220	32
18	On washer area	120	6:35	340	50
19	Customer service area	120	6:35	120	18
20	Jackets presser personal sample	130	6:55	38	6
21	Pants presser personal sample	128	6:55	25	4
22	Cleaner during transfer	15	6:40	230	34
23	Cleaner during transfer	15	7:01	250	37
24	Jackets press area	122	7:13	57	8
25	Cleaner during transfer	15	7:21	190	28
26	Cleaner during transfer	15	7:44	190	28
27	Cleaner during transfer	15	8:08	290	43
28	On washer area	133	8:35	170	25
29	Customer service area	125	8:35	66	10
30	Sample lost	-	9:03	-	-
31	Jackets presser personal sample	131	9:06	29	4
32	Press area	132	9:15	68	10
33	Cleaner personal sample	133	9:24	200	30
34	Cleaner during transfer	15	9:48	160	24
35	Cleaner during transfer	15	10:09	220	32
36	In duct of dryer exhaust	13	10:37	5440*	801
37	On washer area	75	10:45	240	35
38	Customer service area	75	10:45	61	9
39	In duct of dryer exhaust	20	11:10	2870*	423

*Back-up section contained >25% of front section.

Table A18-3. Background solvent levels.

Time	Perchloroethylene level (ppm) Location*								
	1	2	3	4	5	6	7	8	9
0700	<1	10	20	45	35	12	14	2	-
0800**	<1	1	5	10	9	2	2	<1	-
0930	<1	2	3	7	9	2	2	<1	-
1118	<1	4	25	35	55	9	5	<1	-
Other Readings									
0700	Immediately in front of washer 43 ppm								
0730	Inside clean clothes plastic wrap 19								
1115	Around dryer door 100-700								
0730	1	9	4	17	11	6	5	<1	5
0830	1	5	5	25	20	5	6	<1	18
0900***	<1	1	1	2	1	1	1	<1	<1
1000	1	16	19	18	14	5	10	1	6
Other Readings									
	Face of washer during transfer 800-900 ppm								

* *See Figure A18-1 for locations.
**Washer gasket was tightened.
***Washer and dryer not in operation.

APPENDIX A19
CASE STUDY NO. 19

A. PROCESS AND EQUIPMENT

This is a small perchloroethylene transfer plant in northern California. The average dry cleaning volume of the plant is 272 kg/week (600 pounds/week), with approximately 54 kg (120 pounds) cleaned daily. One of a small chain, this plant is staffed by 1 cleaner/presser and 1 manager/sewer/support employee.

The physical arrangement of this plant is unusual in that the cleaning machine and dryer are located in a small building physically separated from the main plant (see Figures A19-1 and A19-2). A lightweight plastic roof covers the area between the two buildings, and the cleaner/presser spends most of his work time in the main plant, entering the dry cleaning building only to remove, transfer, and start loads, and occasionally to use the spotting board.

An Ametek 8A15CK-1-1 washer with 15.9 kg (35-pound) capacity is used along with a Hoyt Solvo-Miser SM130 tumbler with 13.6 kg (30-pound) capacity. The Ametek washer, which was purchased in 1970, contains a cartridge filter integral to the unit. A Detrex DCS-30 still is employed, and no sniffer (carbon adsorption unit) is used. The washer and tumbler are vented directly to the outside. Solvent recovered from both the tumbler and the still is returned through fixed pipe to the solvent reservoir in the washer.

Cleaning is done in a 13-minute cycle (10-minute wash, 3-minute extraction). The drying cycle includes 20 minutes of drying, 5 minutes of aeration, and 5 minutes of cooldown. Filter cartridges are discarded as trash.

B. NATURAL VENTILATION

Taking advantage of the favorable year-round climate in northern California, this plant employs natural ventilation as a means of isolating the solvent-emitting operations from other plant areas. The dry cleaning building door is 6.4 m (21 ft.) from the rear door of the main plant. Within the dry cleaning building, the 1.8 m (6 ft.) by 1.2 m (4 ft.) side window is kept open, as is the main 239 cm (94 in.) by 201 cm (79 in.) door. During this survey, the window provided a 1 m^2 (11 $ft.^2$ opening, and the door a 2.2 m^2 (23.6 $ft.^2$) opening as each was partially opened.

The main plant contains a front door (opening onto the main street) in addition to the rear door (adjacent to the dry cleaning building), and contains three windows along one side of the plant. Each of these windows measures approximately 1.2 m (4 ft.) by 0.9 m (3 ft.). At the time of this survey, the main plant windows and front door were closed, and the rear door was kept open.

C. GENERAL MECHANICAL VENTILATION

There is no general mechanical ventilation provided in the dry cleaning building. A small exhaust system is present in the main plant building.

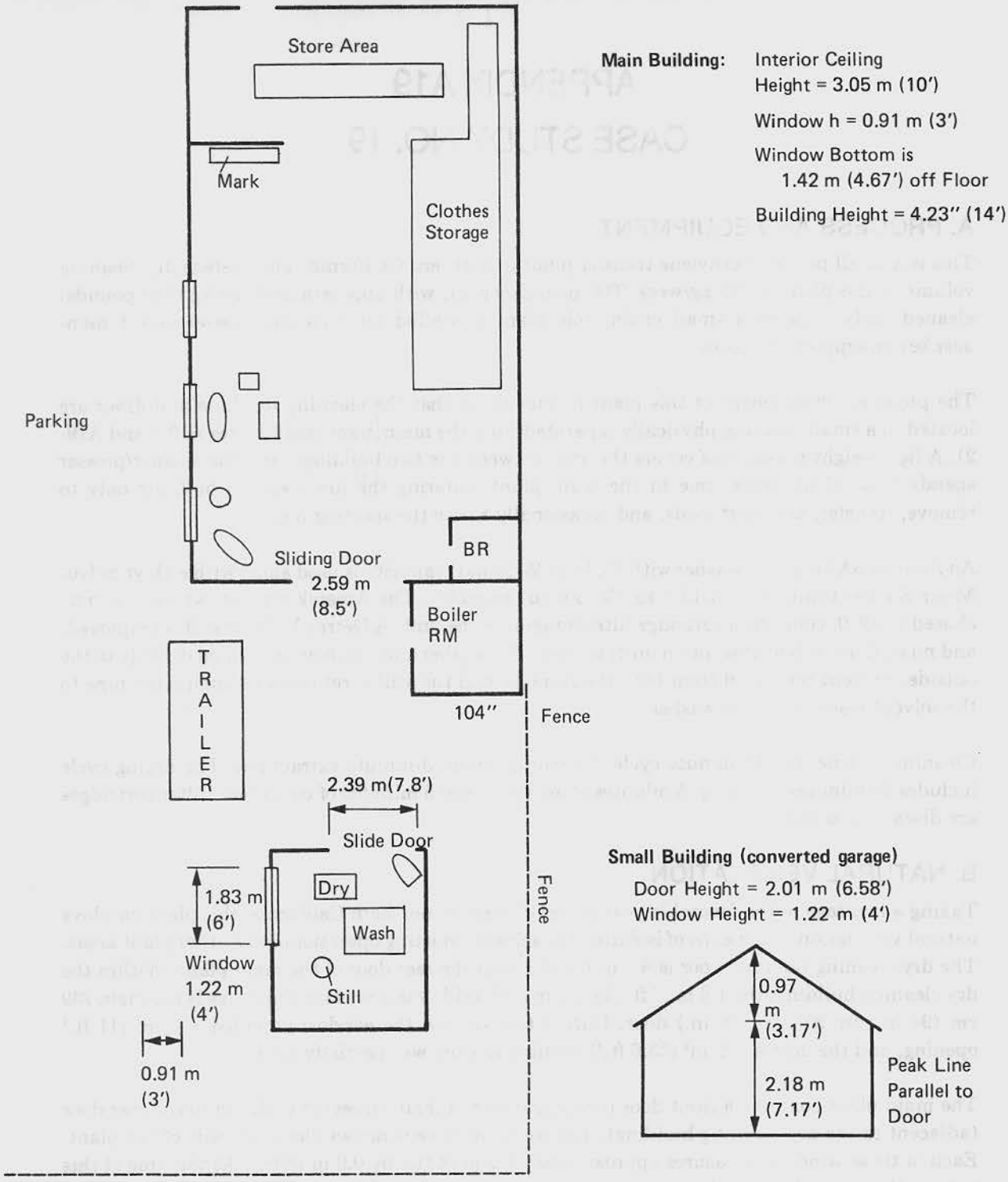


FIGURE A19–1 GENERAL PLANT LAYOUT

Side View Shows Main Building (left) and Small Dry Cleaning Building (right)

View from Rear Door of Main Building, Looking Toward Dry Cleaning Building

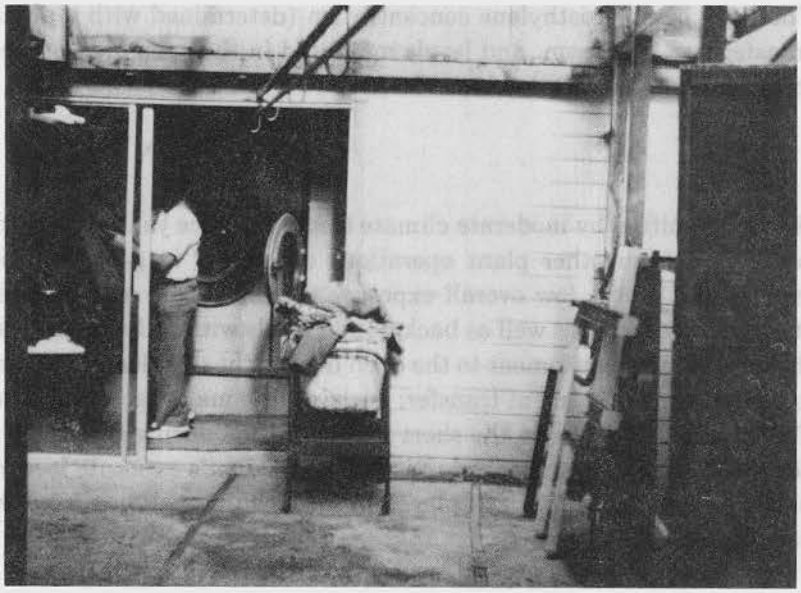


FIGURE A19–2

D. LOCAL EXHAUST VENTILATION

No local exhaust ventilation is employed in this plant other than the exhaust fans built into the washer and dryer. These fans draw approximately 0.02 m^3/s (50 cfm) and 0.09 m^3/s (200 cfm), respectively, and exhaust through the dry cleaning building roof.

E. LEAK DETECTION

A large leak (700-1000 ppm) was detected in the washer door gasket. Other leaks were detected at the filter outlet (50 ppm), dryer door (100 ppm), dryer lint trap cleanout door (200 ppm), and water separator gasket of the dryer (200 ppm).

F. HEAT EXPOSURE STRESS

Wet-bulb globe temperature readings in the pressing area remained below 23°C (73°F) throughout the work day. This reflected dry-bulb temperature of approximately 27.5°C (81.5°F), wet-bulb temperature of 19.3°C (66.8°F), and black-globe temperature of 30.7°C (87.2°F).

G. SOLVENT EXPOSURE LEVELS

Perchloroethylene exposure levels determined by charcoal tube or passive diffusion monitor sampling and GC analysis are summarized in Table A19-1. The cleaner/presser's exposure level (208-minute TWA) was 13 ppm, and his ceiling exposure (15-minute TWA) during transfer was approximately 35 ppm. Area levels within the dry cleaning building ranged from approximately 19-40 ppm (2-hour TWA), and during the 15-minute period, including transfer,the dry cleaning building level reached 65 ppm. The area levels within the main plant building were 1 ppm or less. The peak perchloroethylene concentration (determined with a photoionization detector) during transfer was 1000 ppm, and levels measured in the open area between the two buildings ranged from 0.8-2 ppm.

CONCLUSION

Where permitted by moderate climate throughout the year, separation of dry cleaning and drying equipment from other plant operations can result in good control of exposures. The cleaner experienced a very low overall exposure (i.e., averaged over his shift), and the exposure of the other plant worker (as well as background levels within the plant) was minimal. The proximity of the dry cleaning equipment to the open door of the dry cleaning room helped to hold down ceiling exposures during garment transfer; however, the major factor influencing the cleaner's 15-minute TWA level seemed to be the short period of time during which the cleaner remained in the dry cleaning building. Further reduction of the cleaner's exposure level could presumably be accomplished if an exhaust fan was placed in the cleaning building window to prevent accumulation of vapor within the building.

Table A19-1. Airborne concentration measurements.

Sample #*	Location	Duration (hr:min)	Start Time	Perchloroethylene Level	
				mg/m^3	ppm
1	Cleaner personal sample	2:01	7:52	84	12
2A	Cleaner personal sample	2:01	7:52	110	16
3B	Cleaner personal sample	2:01	7:52	77	11
4	Pressing area	3:35	7:55	5.6	1
5	Storefront area	3:10	8:20	1.8	0.3
6	Area between washer/dryer	2:02	8:23	260	38
7	Area above spotting board	2:02	8:33	220	32
8	Area as #6, during transfer	0:22	9:33	350	52
9B	Area as #6, during transfer	0:22	9:33	240	35
11	Cleaner during transfer	0:15	10:14	230	34
12	Area as #6, during transfer	0:15	10:14	440	65
13B	Area as #6, during transfer	0:15	10:14	270	40
14A	Area as #6, during transfer	0:15	10:14	300	44
15	Area as #6, during transfer	0:05	10:36	130	19
16B	Area as #6, during transfer	0:05	10:36	120	18
17A	Area as #6, during transfer	0:05	10:36	120	18
18	Area near still	1:10	10:35	190	28
19	Cleaner personal sample	1:27	11:34	95	14
20	Solvent reservoir tank area	1:12	11:45	140	21
21	Area as #6, during transfer	0:23	12:11	420	62
22B	Area as #6, during transfer	0:23	12:11	210	31
23A	Area as #6, during transfer	0:23	12:11	160	24
24	Cleaner during transfer	0:15	1:01	230	34
25B	Area above cleaning machine	4:34	8:11	440	65

*The letter designation of the sample number indicates the collection device employed. No letter indicates a charcoal tube. A and B indicate two types of passive diffusion monitors.

APPENDIX A20
CASE STUDY NO. 20

A. PROCESS AND EQUIPMENT

This is a fairly large northern California plant which handles a large amount of laundry and a small amount of dry cleaning, specializing in high quality work on fragile and otherwise special articles. A 27 kg (60-pound) capacity Spencer dry-to-dry machine is employed to process 272-318 kg (600-700 pounds) of cleaning weekly, and solvent mileage achieved is approximately 7200.

Since the cleaning machine capacity is large relative to the plant's dry cleaning volume, only 2-3 loads of cleaning are run daily. Most of the plant workers are involved in laundry operations, with only 1 cleaner/presser and 1 presser handling dry cleaning work.

The Spencer cleaning machine is 12-years-old and includes an integral still and filter. The general plant area and the cleaning machine itself appears to be in excellent condition (i.e., clean, with covers intact, and not lubricated in excess). No carbon adsorption recovery unit is employed. A typical cleaning cycle includes a 15-minute wash, 3½-minute extraction, 13-minute dry, and 2-minute aeration. This cycle is modified for special types of garments by altering the length of the wash and dry or, in the case of fragile items, not drying at all in the machine (i.e., air drying). The unit's vent is ducted directly out through the plant roof.

The general layout of this plant is shown in Figure A20-1.

B. NATURAL VENTILATION

This plant contains a large number of windows and doors. Four of the seven 1.2 m^2 (13.4-$ft.^2$) windows on the long straight wall of the building were open during the survey, and air flow velocities of 0.25-0.36 m/s (50-70 f.p.m.) were measured into the building from these windows. In addition, the two front windows which were 0.37 m^2 (4 $ft.^2$) and 0.51 m^2 (5.5 $ft.^2$) in size, were found to have air flow velocities of 0.4 m/s (80 f.p.m.) and 0.5 m/s (100 f.p.m.), respectively. An air flow velocity of 0.5 m/s (100 f.p.m.) was measured through the 3 m^2 (32.5 $ft.^2$) rear receiving door, and 0.76 m/s (150 f.p.m.) was measured through the 2 m^2 (22-ft.) boiler room door. All of these air flows were into the plant, resulting in an overall air flow rate of 5 m^3/s (10,700 cfm). In addition, several louvres were open at the ceiling level of the wall adjacent to the laundry washers. The natural ventilation in this plant serves as make-up air to balance the general mechanical system described below.

C. GENERAL MECHANICAL VENTILATION

General ventilation was provided by two large roof-mounted exhaust fans and an air-conditioning system with five inlet vents located at work stations in the dry cleaning and pressing areas. The air conditioner was delivering a total of approximately 5 m^3/s (10,500 cfm) of air. The two exhaust fans (one above the assembly area and the other above the pressing area) were each estimated to be moving approximately 6.6 m^3/s (14,000 cfm) air out of the plant.

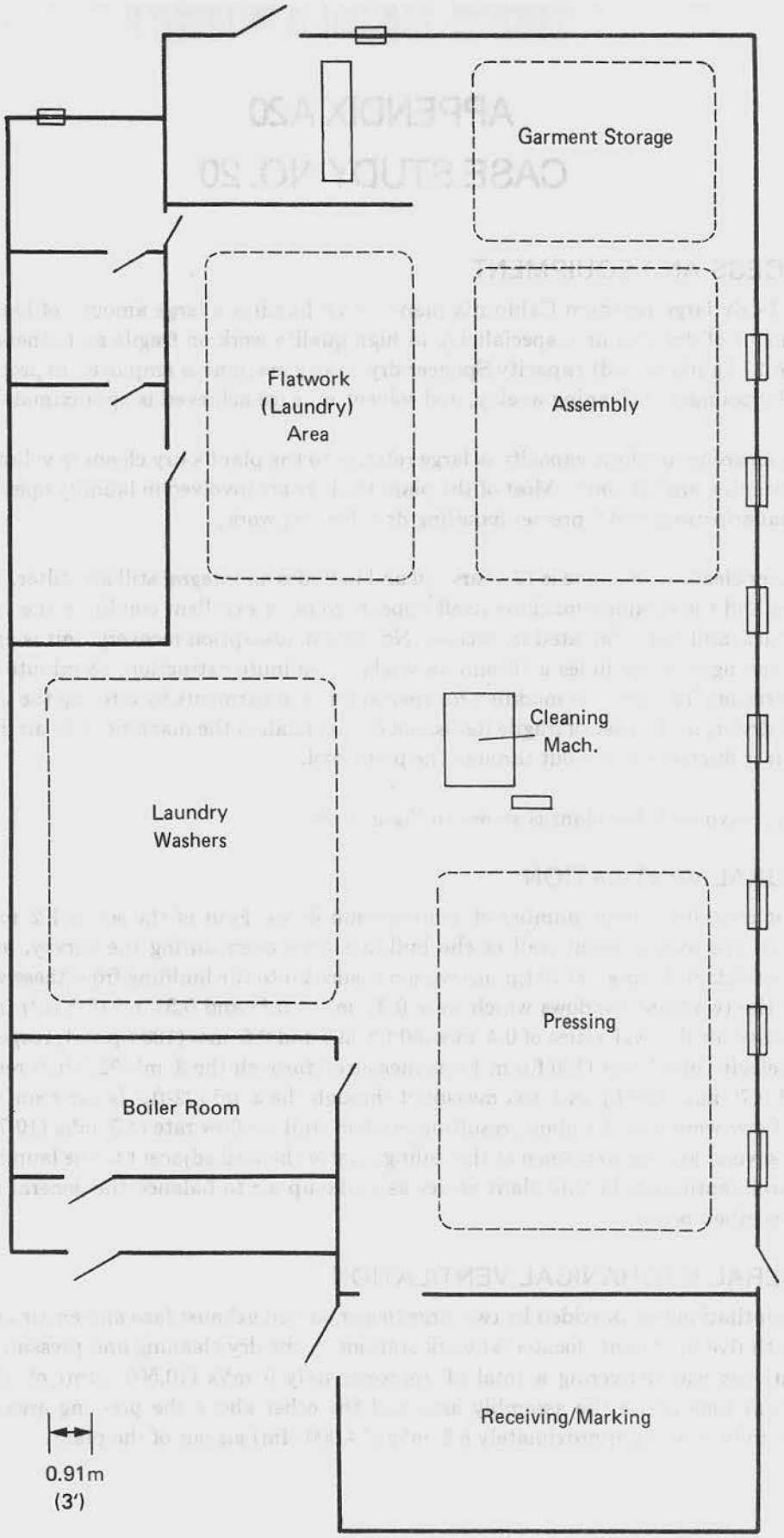


FIGURE A20–1 GENERAL PLANT LAYOUT

D. LOCAL EXHAUST VENTILATION

There is no local exhaust system associated with dry cleaning operations. A local system with a canopy hood is used above the flatwork press for steam and heat removal.

E. LEAK DETECTION

The only leak found in this plant appeared to be a pneumatic valve of the cleaning machine. The inaccessibility of this valve made confirmation of the specific location of the leak difficult.

F. HEAT EXPOSURE

Wet bulb globe temperatures (WBGT) in the pressing area of this plant ranged from 21°C (70°F) to 23.9°C (75.1°F) during the survey. These readings reflected dry bulb temperatures of 24.3°C (75.8°F) to 30°C (86°F), wet bulb temperatures of 18.8°C (65.9°F) to 21°C (69.8°F), and black globe temperatures of 27.4°C (81.4°F) to 31.3°C (88.4°F). During this time, the outdoor temperature ranged from 18.9°C (66°F) to 25.6°C (78°F).

G. SOLVENT EXPOSURE LEVELS

The cleaner/presser's personal exposure level was approximately 5 ppm. When removing garments from the cleaning machine, the ceiling level (15-minute TWA) experienced by the operator was approximately 30 ppm. Area samples collected in the customer service area, laundry area, pressing area, and spotting area indicated perchloroethylene levels of 2 ppm, 7 ppm, 1 ppm, and 5 ppm, respectively. Results of exposure sampling are listed in Table A20-1. Figure A20-2 displays background levels measured with a photoionization detector.

CONCLUSIONS

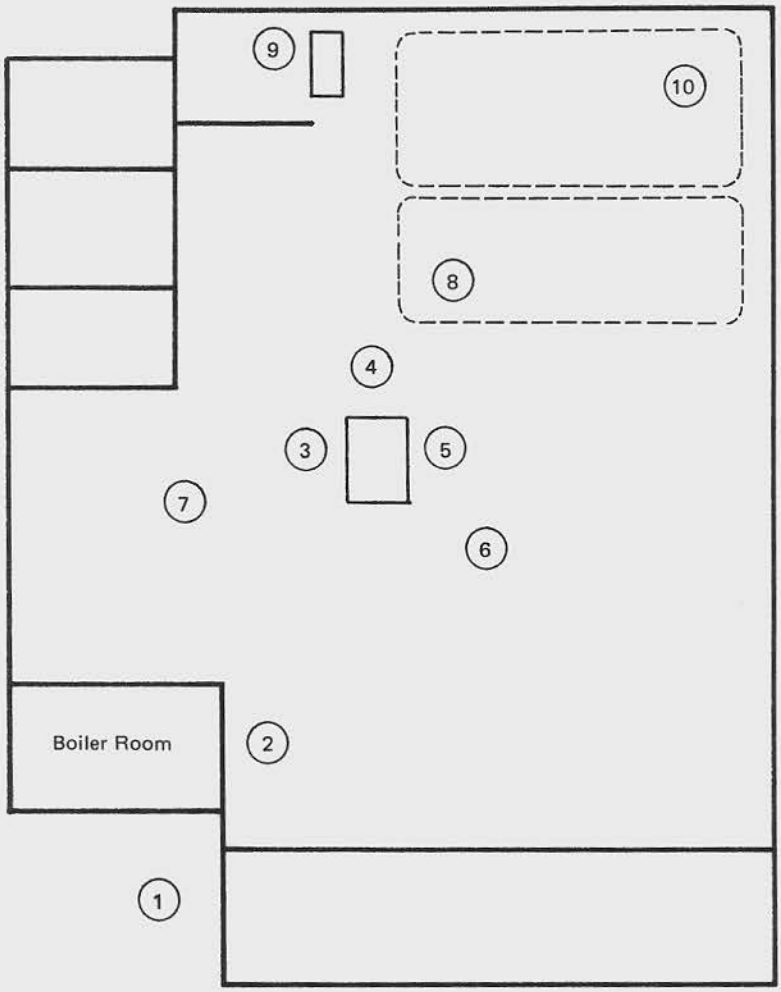
This plant reflects very low perchloroethylene levels due, primarily, to the small number of loads processed and the large amount of general ventilation (natural and mechanical) provided. This ventilation system is also very effective in maintaining in-plant temperatures close to outdoor temperatures. The use of a cleaning machine with a large capacity relative to plant work volume minimizes the number of loads cleaned daily, thus, minimizing time-weighted operator exposure and improving labor productivity.

Table A20-1. Airborne concentration measurements.

Sample # *	Location	Duration (min.)	Start Time	Perchloroethylene level mg/m^3	Perchloroethylene level ppm
1	Cleaner personal sample	3:29	8:14	36	5.3
2	Washer operator	2:02	8:50	18	2.6
3	Lint trap area	1:00	9:03	1000**	147**
4	Washer area	2:22	9:08	45	6.6
5	Pressing area	2:29	9:12	8.3	1.2
6	Machine door during unload				
7	Under machine door	1:47	9:47	45	6.6
8	Storefront area	1:16	9:54	12	1.8
9	Adjacent to machine	1:05	10:05	37	5.4
10A	Cleaner during unload	0:15	10:12	330	49
11	Lint trap area	0:43	10:16	1140	168
12	Machine door during unload	0:15	10:55	110	16
13B	Machine door during unload	0:15	10:55	320	47
14	Cleaner area during unload	0:17	11:24	210	31
15	Cleaner personal sample	2:41	8:04	26	3.8
16	Clothing storage area	2:08	8:06	5.3	0.8
17	Under machine door	2:21	8:15	15	2.2
18	Washer area	1:00	8:22	22	3.2
19	Press area (near end)	2:08	8:25	6.9	1.0
20	Press area (far end)	2:05	8:28	3.2	0.5
21	Adjacent to machine	1:00	8:33	32	4.7
22	Flatwork press area	2:10	8:38	13	1.9
23	Rack in front of cleaning machine, elevated 1.8 m	1:54	8:45	33	4.9
24	Under machine door	0:13	8:57	26	3.8
25	Marking area	1:21	9:25	16	2.4
26	Under machine door	0:17	9:36	33	4.9
27	Lint trap area	0:52	9:40	1420**	209**
28	Under machine door	0:15	10:24	25	3.7
29	In garment after removal	--	--	3900	574

*The letter designation of the sample number indicates the collection device employed. No letter indicates a charcoal tube. A and B indicate two types of passive diffusion monitors.

**Greater than 25% of total sample found in backup section.



PERCHLOROETHYLENE LEVELS (ppm) AT LOCATIONS INDICATED ABOVE										
Time	Location									
	1	2	3	4	5	6	7	8	9	10
0930	2.2	2	7	4	4	2.5	4	2.5	2	–
1030	1.4	1.6	7–12	4	2	1.4	5	2.5	1	–
1130	2.2	2.4	8–15	10–13	7	2.2	5	2.5	2.5	10
0900	2	2	7	3	6	2	4	2	2	4
1000	2	2	7	7	5	2	3	2	2	5

FIGURE A20–2 AREA SOLVENT LEVELS

APPENDIX A21
CASE STUDY NO. 21

A. PROCESS AND EQUIPMENT

This is a small commercial fluorocarbon 113 plant in the North-Atlantic area. Solvent mileage is estimated to be approximately 41240. One cleaner/spotter/cashier and one seamstress/presser/assembler/cashier are employed in this plant.

A Neil and Spencer LTD Model GTV25MK II, manufactured in Great Britain, is used to process the dry cleaning. As in all fluorocarbon units, the apparatus has its own integral still, Freon 22 refrigeration system, filter cartridge, etc. The general layout of the facility is depicted in Figure A21-1. The unique feature of this six-month-old machine is that there is a "balloon" that sits on top of the machine. During the wash and extraction cycle, the evaporated fluorocarbon expands into the flexible bag and, during the drying (reclaiming) phase, the balloon empties its contents back into the system. The solvent filtering system consists of 1 carbon-core cartridge which is changed when the pressure drop across the cartridge reaches 2.46 kg/cm^2 gage (35 psig). At approximately 346 kg (750 lbs) per week of dry cleaning, the cartridge is changed once per month. After the used cartridge is removed, it is transferred to an air-tight draining compartment that empties into the work tank. Normally, the spent cartridge is allowed to drain for several days before it is discarded. Normal operation includes a 3-minute wash with fresh distilled solvent, a 2-minute extraction, an 8-minute wash with recirculated, filtered solvent, a 2-minute extraction, a 15-minute drying at 35°C (95°F), and a 2-minute cool-down (i.e., a 32-minute cycle).

A daily average of 6 loads is processed at this facility, with each load weighing approximately 11.3 kg (25 pounds). The solvent extracted following the first wash of each cycle is sent directly into the still. Thus, the still is continuously operated as long as the machine is operated.

B. NATURAL VENTILATION

On cool days, normal infiltration is the only source of natural ventilation since both doors of the plant are kept closed.

C. GENERAL MECHANICAL VENTILATION

At approximately 11 a.m. during this survey (after the pressing operation had been in progress for several minutes) the 76 cm- (30-in.) diameter louvred wall fan above the rear door was turned on and the louvres above the front door were opened. The resulting induced draft through the French door was measured and found to be:

	Exhaust Fan Speed m^3/s	**Volume of Air (cfm)**
High	1.79	(3800)
Low	0.80	(1690)

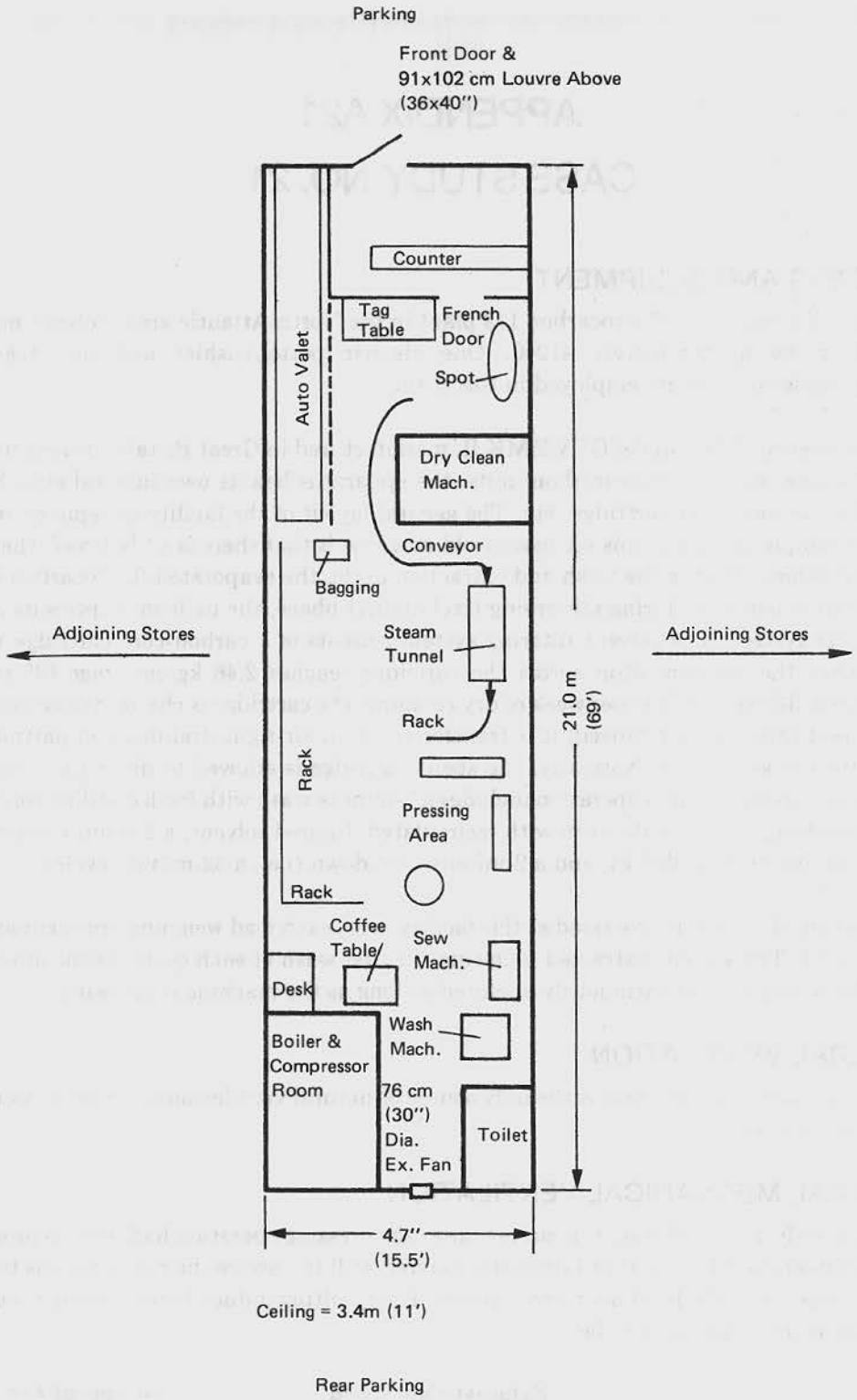


FIGURE A21–1 GENERAL PLANT LAYOUT

D. LOCAL EXHAUST VENTILATION

There is no local exhaust ventilation in this facility.

E. LEAK DETECTION

Several small leaks were detected using a halide torch. The leaks were rectified by tightening the gaskets of the malfunctioning equipment.

F. HEAT EXPOSURE

Wet-bulb globe temperatures (WBGT) of 25.7°C (78.2°F) and 25.8°C (78.5°F) were found on the two days of this survey. The higher of the two was based on a dry-bulb temperature of 32.8°C (91.0°F), a wet bulb temperature of 22.4°C (72.4°F), and a black-globe temperature of 34.3°C (93.7°F).

G. SOLVENT EXPOSURE LEVELS

Fluorocarbon 113 exposure levels determined by charcoal tube samples and gas chromatographic analysis are summarized in Table A21-1. The cleaner's exposure level averaged 20 ppm during the 4 hours per day that the dry cleaning machine was operated. The presser's exposure level averaged 4 ppm during the same period. The cleaner's ceiling level during unloading (15-minute TWA) ranged between 20 and 33 ppm.

CONCLUSIONS

Of the three fluorocarbon 113 plants visited, this undoubtedly was the best insofar as the cleaner's ceiling exposure during machine unloading and garment hanging was concerned. The garments coming out of the machine contained amounts of solvent comparable with those found in other fluorocarbon plants; however, low personal exposure levels were maintained by the fresh air flow, induced directly through the cleaner's work station. This air flow does contribute to the spread of solvent within the plant, as demonstrated by the solvent levels in the pressing area.

Table A21-1. Airborne concentrations measurements.

Sample #	Location	Duration (min)	Start Time	Perchloroethylene concentration mg/m^3	Perchloroethylene concentration ppm
1	Presser personal sample	146	10:06	N.D.	N.D.
2	Cleaner personal sample	127	10:16	135	18
3.	Cleaner during unloading	15	10:50	152	20
4.	Front of dry cleaning machine area	60	10:16	330	43
5.	Press area	60	10:16	70	9
6.	Customer service area	120	10:10	N.D.	N.D.
7.	In clothes just out of machine	5	10:56	128,000	16,736
8	Back of dry cleaning machine area	60	10:31	102	13
9	In clothes just out of machine	3	11:01	3,100	405
10.	Front of dry cleaning machine area	60	11:19	2	<1
11.	Press area	180	11:23	11	1
12.	Back of dry cleaning machine area	64	11:31	6	1
13.	Cleaner during unloading	15	12:01	251	33
14.	In clothes just out of machine	3	12:06	111,000	14,513
15.	In clothes just out of machine	3	12:09	50,000	6,537
16.	Front of dry cleaning machine area	120	12:22	1	<1
17.	Cleaner personal sample	80	12:23	89	12
18.	Presser personal sample	111	12:32	6	1
19.	Back of dry cleaning machine area	115	12:35	17	2
20.	Cleaner during unloading	24	12:52	173	23
21.	In clothes just out of machine	4	12:53	141,000	18,436
22.	Cleaner during unloading	15	1:30	186	24
23.	In clothes just out of machine	4	1:30	13,843	1,810
24.	Cleaner personal sample	147	10:07	209	27
25.	Presser personal sample	147	10:07	48	6

Table A21-1 (cont'd.)

Sample #	Location	Duration (min)	Start Time	Perchloroethylene concentration mg/m^3	Perchloroethylene concentration ppm
26.	Front of dry cleaning machine area	60	10:07	11	1
27.	Pressing area	60	10:07	54	7
28.	Back of dry cleaning machine area	60	10:07	1	<1
29.	In clothes just out of machine	4	10:50	156,000	20,397
30.	Cleaner during unloading	15	10:40	218	29
31.	Front of dry cleaning machine area	92	11:08	60	8
32.	Press area	84	11:09	19	2
33.	Back of dry cleaning machine area	116	11:10	37	5
34.	Near spot table area	113	11:15	3	<1
35.	Cleaner during unloading	15	11:20	219	29
36.	In clothes just out of machine	8	11:30	119,000	15,559
37.	Cleaner during unloading	15	12:17	216	28
38.	In clothes just out of machine	3	12:17	86,000	11,244

APPENDIX A22
CASE STUDY NO. 22

A. PROCESS AND EQUIPMENT

This is a moderate size commercial perchloroethylene plant in the mid-Atlantic area. A weekly average of 1360 kg (3000 lbs.) is processed by the transfer method. The plant employs 1 cleaner, 2 pressers, 1 stitcher, 2 counter/marker persons, 1 cobbler, and 1 laundry operator. An average mileage of 9,430 was reported.

A Detrex Monarch Model 527 dry cleaning machine and 2 Detrex Model 326-A dryers, all of which are approximately 21-years-old, are employed to process the workload. A cartridge filter system with 3 chambers is employed. Each chamber contains 2 carbon-core filter cartridges and 1 all-carbon cartridge. The cartridges are changed periodically, with one chamber receiving new cartridges every other week.

A continuously operated Vic Model 118 carbon adsorption unit is used to recover the solvent. This unit is approximately three years old. Solvent recovery is accomplished daily during the afternoon by heating the carbon bed with 0.67 kg/cm^2 (9.5 psig) steam for 20-25 minutes. Average recovery is 11.4 L (3 gal.) per day and is collected in a plastic bucket.

One of the dryers (nearest side door) is piped directly to the solvent reservoir while the other dryer is not. The latter dryer is piped by a piece of plastic hose into an open plastic bucket. There is no still in this plant. The solvent is cleaned only by the cartridge filters. A layout of this plant is shown in Figure A22-1.

Approximately 17 loads, each weighing 15.4 kg (34 pounds) are dry cleaned daily. Each load is washed for 7-12 minutes, extracted for 3 minutes, dried for 10-15 minutes, and aerated for 3 minutes. Average time spent in transferring the washed clothes into the dryers and loading the dry cleaning machine with a new load is 50 seconds.

B. NATURAL VENTILATION

Although this survey was conducted during cold weather, the bottom louvres near the spotting table were open approximately 25%. All other sources of natural ventilation were closed.

C. GENERAL MECHANICAL VENTILATION

Two 107-cm (42-in.) diameter roof exhaust fans are available in the plant. The fan closest to the dry cleaning machine was occasionally operated and induced a draft through the wall louvres such that the temperature averaged approximately 10°C (50°F) around the spotting table. The exact fan locations are shown in Figure A22-1.

D. LOCAL EXHAUST VENTILATION

The plant has a local exhaust system connected to the carbon adsorption unit. The outlet for the adsorption unit is ducted to the outdoors. The local exhaust system is shown schematically in Figure A22-2, and the air flow rates through the exhaust system are listed in Table A22-1.

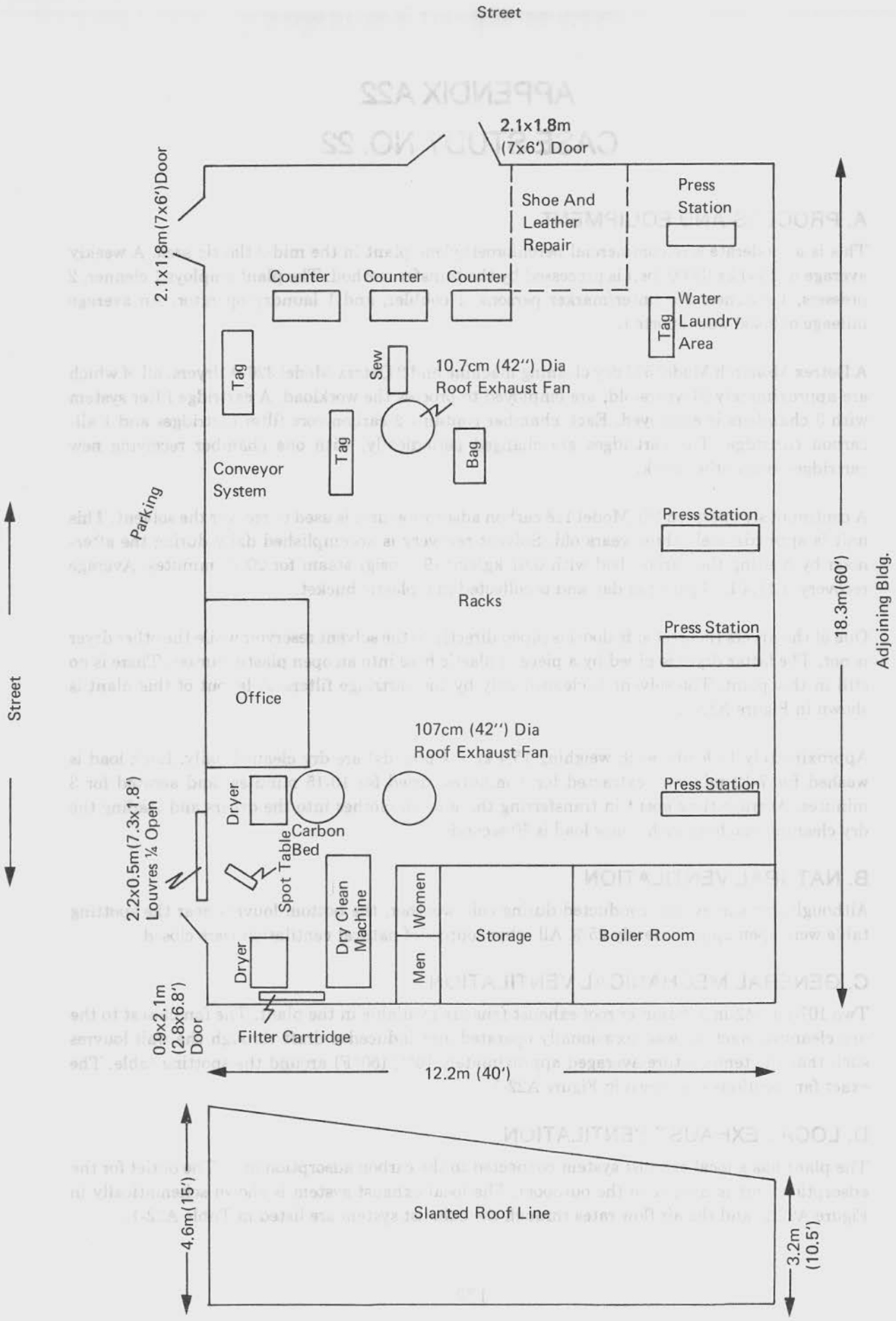
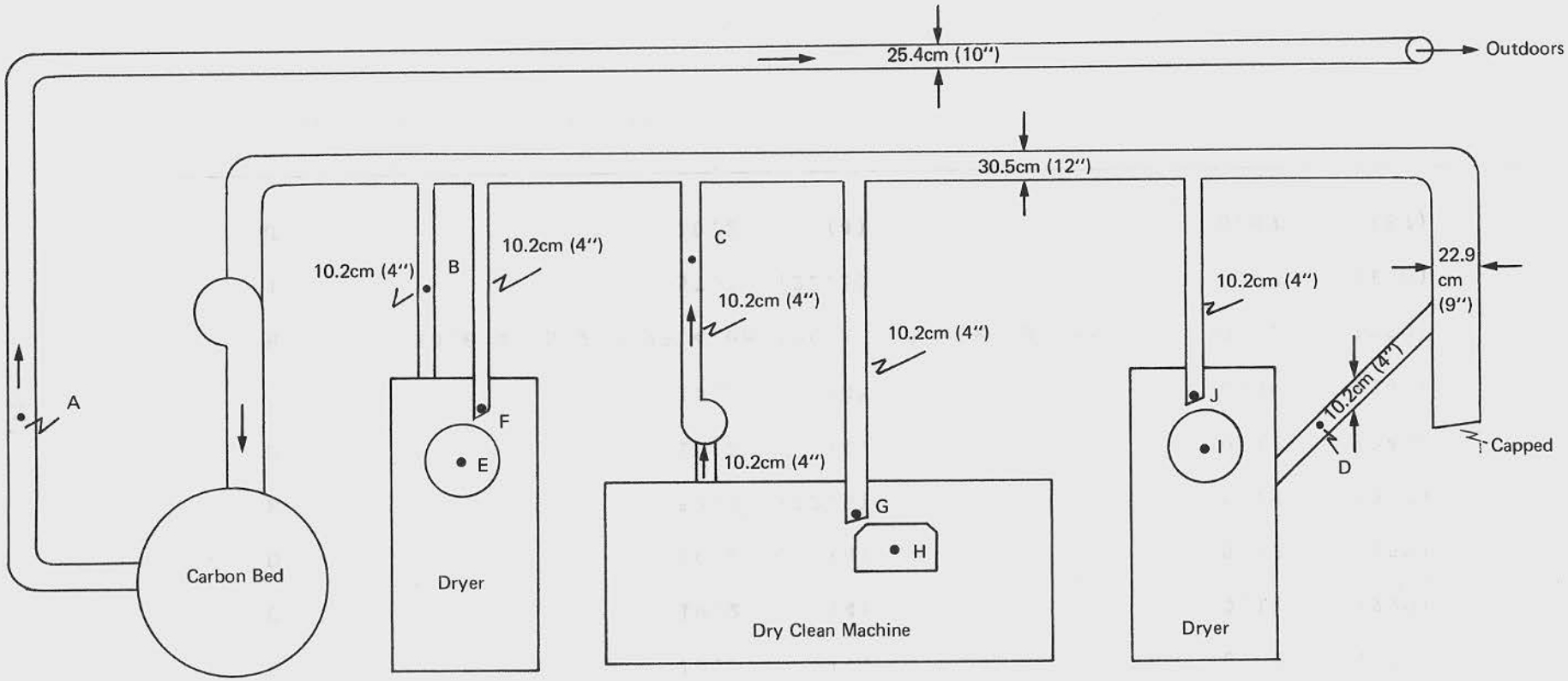


FIGURE A22–1 GENERAL PLANT LAYOUT



• A = Air flow measurement point

FIGURE A22–2 LOCAL EXHAUST VENTILATION SYSTEM

Table A22-1. Local exhaust ventilation system parameters.

Location *	Duct or Door Dimension	Airflow m^3/sec	(cfm)
A	25.4 (10)	0.22	(473)
B	10.2 (4)	0.09	(183)
C	10.2 (4)	0.11	(229)
D	10.2 (4)	0.03	(57)
E	57.2 (22.5)	0.10	(207)
F	10.2 (4)	0.12	(244)
G	10.2 (4)	0.09	(201)
H	50.8 x 15.2 x 25.4 cm [20 l x 6 h x 10 (peak)]	0.12	(250)
I	57.2 (22.5)	0.07	(138)
J	10.2 (4)	0.07	(157)

*See figure A22-2 for locations

E. LEAK DETECTION

With a photoionization unit, leaks were detected in the button trap gasket and in the lint filter gasket. A reading of 1200 ppm was also recorded for the carbon bed separator vent during its stripping cycle. A visual check revealed that the gasket around the dryer door had a small section missing and needed replacement.

F. HEAT EXPOSURE

Wet-bulb globe temperature (WBGT) in the pressing area was 22.5°C (72.5°F) during the visit. The reading is based on a dry-bulb temperature of 30.8°C (87.5°F), a wet-bulb temperature of 18.6°C (65.5°F), and a black-globe temperature of 32.5°C (88.7°F).

G. SOLVENT EXPOSURE LEVELS

Table A22-2 lists perchloroethylene exposure levels determined by sample collection on charcoal tubes and subsequent gas chromatographic analysis. Area levels measured with a photoionization detector are listed in Table A22-3. The cleaner's exposure level averaged over the work day was 10 ppm perchloroethylene. During the loading and unloading period his ceiling exposure was 12 ppm. It should be noted that the regular dry cleaner didn't arrive until 9:15, and another worker washed the first two loads of clothes. The substitute cleaner took 120 sec. for a garment transfer, versus 50 sec. for the regular operator. Further, the regular dry cleaner enjoyed fresh air and, in spite of the cold weather prevalent during this survey, maintained some fresh air flow in the dry cleaning area.

CONCLUSION

The open louvres, the occasional operation of the roof exhaust fan nearest the dry cleaning operation, and the swiftness of the regular dry cleaning operator resulted in a very low exposure profile for this worker. However, because the louvres and the exhaust fan were so close in proximity, a short-circuiting effect took place and only the dry cleaning area was ventilated. The relatively high levels found in the rest of the plant reflect this.

Table A22-2. Airborne concentration measurements.

Sample #	Location	Duration (min)	Start Time	Finish Time	Perchloro-ethylene concentration mg/m^3	ppm
1	Cleaner personal sample	128	9:23	11:31	56	8.1
2	Customer service area	120	8:10	10:10	89	13.2
3	Washer area	60	8:15	9:15	54	7.9
4	Pressing area	120	8:15	10:15	87	12.8
5	Cleaner during transfer	15	8:50	8:55	1000	148
6	Marker personal sample	124	9:06	11:10	90	13.2
7	Cleaner during transfer	15	9:12	9:27	259	38
9	Washer area	60	9:32	10:32	1.8	0.3
10	Cleaner during transfer	15	9:48	10:03	71	10.5
11	Customer service area	120	10:13	12:13	65	9.5
12	Pressing area	120	10:18	12:18	87	12.8
13	Cleaner during transfer	15	10:22	10:37	93	13.7
14	Washer area	60	10:44	11:44	88	13.0
15	Cleaner during transfer	15	10:50	11:05	59	8.7
16	Marker personal sample	146	11:12	13:38	99	14.6
17	Cleaner during transfer	15	11:19	11:34	96	14.2
18	Cleaner during transfer	15	11:53	12:07	54	8.0
19	Marking area	60	12:15	13:15	127	18.7
20	Customer service area	120	12:20	14:20	41	6.0
21	Pressing area	120	12:24	14:24	70	10.3
22	Cleaner during transfer	15	12:25	12:40	83	12.3
23	Marking area	60	13:34	14:34	59	8.7

Table A22-3. Background solvent levels (ppn).

Location	Time					
	8:00*	9:00*	10:00*	11:00	12:00	2:00
Outside air	<1	<1	<1	<1	<1	1
Front of washer	13	14	8	13	4	15
Pressing	10	23	10	10	13	12-15
Shirt finishing	12	17-25	11	10	14-16	12-13
Customer service	15	18	8	9	9	8
Clothes marking	23	25	26	17-22	21-31	13
Office	-	-	-	-	3	11

*Ceiling fan off until ~10:40

APPENDIX A23

CASE STUDY NO. 23

A. PROCESS AND EQUIPMENT

This is a large commercial perchloroethylene plant in the mid-Atlantic area. A weekly average of 1701 kg (3750 pounds) is processed by two different transfer units. The plant employs 2 cleaners/spotters, 1 stitcher, 1 counter person, 3 pressers, and 3 part-time persons. Solvent mileage could not be determined since the necessary records were not maintained.

A Washex Model P65-SA, built in 1965, with a rated capacity of 31.8 kg (70 pounds), and an Ametex Model Co-45, approximately 15 years old, with a rated capacity of 20.4 kg (45 pounds) are used for dry cleaning. Although these machines are rated at 31.8 kg (70 pounds) and 20.4 kg (45 pounds), respectively, actual loads run are 15.9 kg (35 pounds) and 11.3 kg (25 pounds). Each machine has its own filtration system: The system connected to the Washex was an Autoflex filter Model A1-40-30, and the filter connected to the Ametex could not be identified although it did appear very similar to the Autoflex but smaller in dimensions. Each of these filters is about 12 years old, and each is mounted on top of a muck cooker. Every two days, the filter-aid material is dropped to the bottom and cooked for solvent recovery. Recovery is accomplished by cooking 3-4 hours with 3.2 kg/cm^2 (45 psig) steam. About 75.7 L (20 gal.) are recovered from each filter and piped directly back to each corresponding cleaning system. Daily additions of 3.2 kg (7 lbs.) diatomaceous earth and 0.7 kg (1.5 lbs.) activated carbon are placed in the Washex system while 2.7 kg (6 lbs.) of diatomaceous earth and 0.7 kg (1.5 lbs.) activated carbon are placed into the Ametex system.

The workloads are dried in 3 dryers, each of which is connected to the carbon adsorption system. Two 20-year-old 13.6 kg (30 lb.) Hoyt Model SF-124 dryers and a 15-year-old 31.8 kg (70-pound) Huebsch model 42 x 24 dryer are employed. The dual carbon bed adsorption unit is a 15-year old Hoyt Sniff-O-Miser which is stripped once every two days by heating with 0.7 kg/cm^2 (10 psig) steam for 3 hours. Simultaneous stripping of both beds will yield 37.9 L (10 gal.) of perchloroethylene, which is collected in 18.9 L (5 gal.) plastic buckets.

An average of 25 loads are dry cleaned daily. In the Washex system, 15 minutes are required for washing, 8 minutes for extracting, and depending on the dryer employed, between 50-70 seconds for transferring the load from the Washex to one of the dryers. Finally, 10 seconds are required to reload the Washex. In the Ametex system, the wash and extraction cycles are very similar. The difference is the time required to transfer the load to the dryer, which will range from 30-50 seconds. The drying cycle ranges from 21 to 37 minutes, with the last 5 minutes comprising aeration. The variability of the drying cycle is dependent upon size of load, fabrics, etc.

B. NATURAL VENTILATION

Since it was a fairly cold day, all sources of natural ventilation were kept closed during this survey. At approximately 11 a.m., when the 3 pressers had worked for about an hour and the outdoor temperature warmed above the freezing point, 4 of the 5 small windows (104 cm w x 38 cm 1 [41 in. x 15 in.]) by the presses were opened.

C. GENERAL MECHANICAL VENTILATION

There are three 66-cm diameter (26 in.) louvred wall fans at the pressing stations, one of which (SE corner) was turned on at 10:15 a.m. A 122-cm (48 in.) diameter ceiling exhaust fan directly above the spotting tables also was available although it was not operated. Five man-cooler fans ranging from 38 cm (15 in.) to 91 cm (36 in.) are available for the dry cleaners and the pressers. (See Figure A23-1 for sizes and locations of fans.) Only one of the man-coolers was operated during the visit, this a 61 cm (24 in.) diameter fan above the Washex machine.

D. LOCAL EXHAUST VENTILATION

The plant has a local exhaust system connected to the carbon adsorption system. The outlet from the adsorption system is returned to the dry cleaning and pressing area. The local exhaust system is shown schematically in Figure A23-2. Air flow rates through the exhaust system are listed in Table A23-1.

E. LEAK DETECTION

From the photo-ionization readings and from the charcoal tube area sampling, there appear to be significant leaks, although their exact locations could not be pinpointed.

F. HEAT EXPOSURE

Wet-bulb globe temperature (WBGT) in the pressing stations was 19.5°C (67.1°F) during the day of the visit. This was based on a dry-bulb temperature of 27.5°C (81.5°F), a wet-bulb temperature of 14.2°C (57.5°F) and a black-globe temperature of 32.0°C (89.6°F).

G. SOLVENT EXPOSURE LEVELS

The results of air samples collected on charcoal tubes with subsequent gas chromatographic analysis are listed in Table A23-2. The instantaneous readings of the photo-ionization instrument are tabulated in Table A23-3. The worker who did the majority of the dry cleaning was exposed to 70 ppm perchloroethylene averaged over his workday. During transfer of loads to the dryer and reloading of the dry cleaning machines, his exposure ranged from 28 ppm to 194 ppm, as determined by 15-minute ceilings.

CONCLUSIONS

Old equipment with a poor maintenance program results in solvent leaks. Recovered solvent is collected in open buckets. No good administrative control on solvent utilization is maintained as recordkeeping is poor. Adsorber ventilation ducting is poorly located and sized. This plant has a number of solvent emission points, which result in high exposure levels.

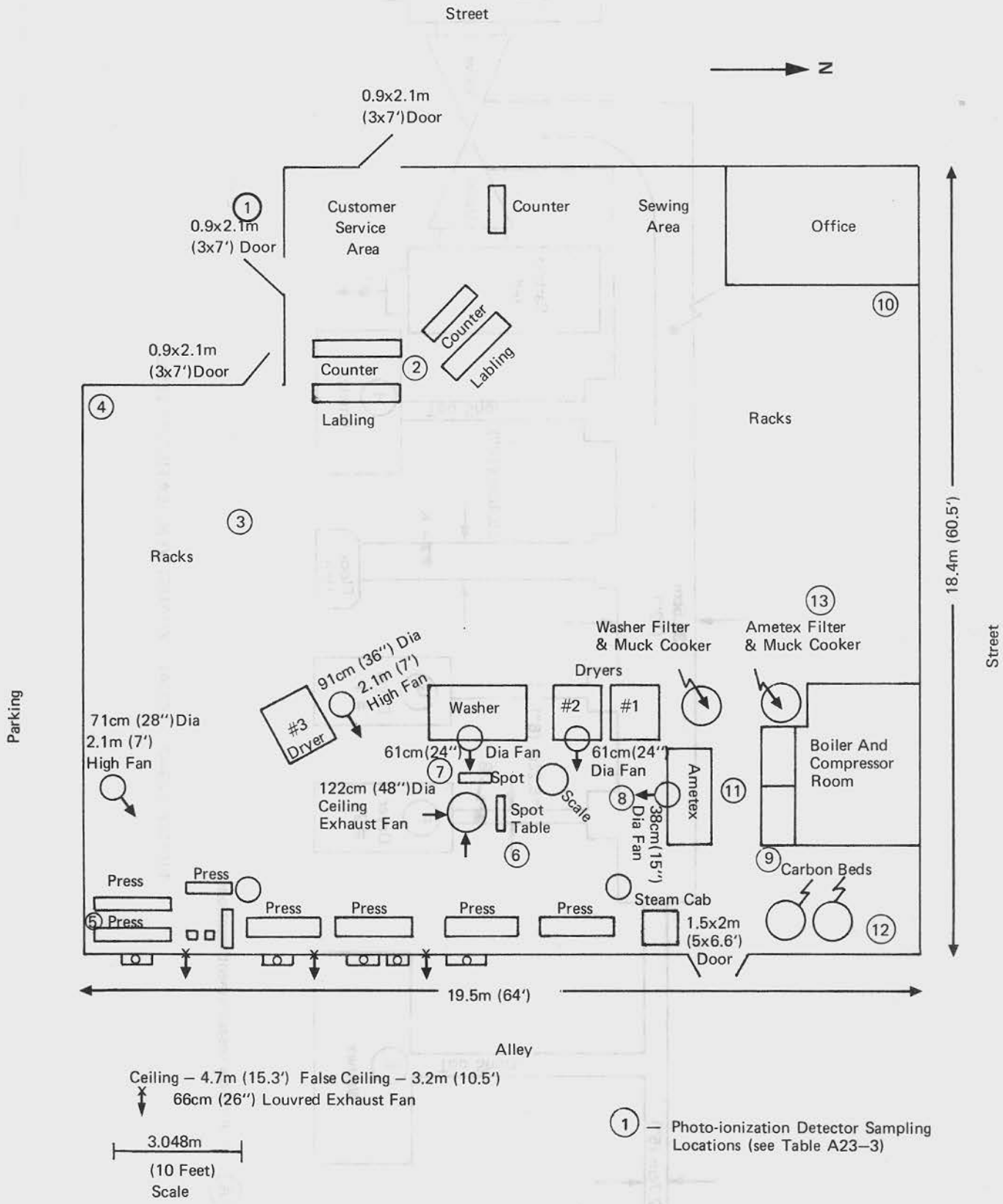

Street
N
0.9x2.1m
(3x7')Door
1
0.9x2.1m
(3x7') Door
Customer
Service
Area
Counter
Sewing
Area
Office
10
Counter
Labling
0.9x2.1m
(3x7')Door
Counter
2
Labling
4
Racks
3
Racks
18.4m (60.5')
Street
13
Washer Filter
& Muck Cooker
Ametex Filter
& Muck Cooker
Dryers
91cm (36") Dia
2.1m (7')
High Fan
#3
Dryer
Washer
#2
#1
Parking
71cm (28")Dia
2.1m (7')
High Fan
61cm(24") Dia Fan
7
Spot
61cm(24")
Dia Fan
Boiler And
Compressor
Room
122cm (48")Dia
Ceiling
Exhaust Fan
Spot
Table
Scale
8
38cm(15")
Dia Fan
Ametex
11
6
9
Carbon Beds
Press
Press
Press
Press
Press
Press
Press
5
Steam Cab
1.5x2m
(5x6.6')
Door
12
19.5m (64')
Alley
Ceiling – 4.7m (15.3') False Ceiling – 3.2m (10.5')
66cm (26") Louvred Exhaust Fan
3.048m
(10 Feet)
Scale
1 — Photo-ionization Detector Sampling
Locations (see Table A23–3)

FIGURE A23–1

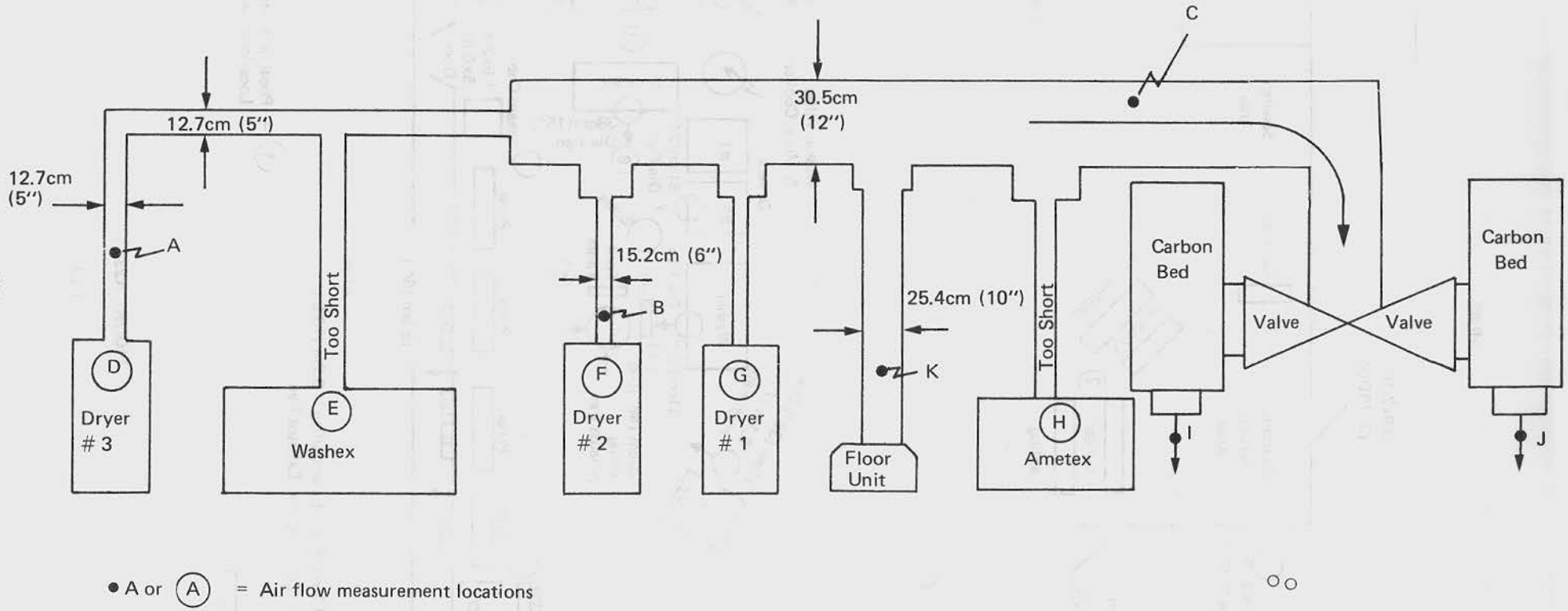


FIGURE A23–2 LOCAL EXHAUST VENTILATION SYSTEM

Table A23-1. Measured ventilation system flow rates.

Location*	Air Flow m^3/s	(cfm)	Duct/Door Diameter cm	(in.)	Static Pressure cm	(in.)
A (only Dryer #3 open)	0.04	(76)	12.7	(5)	0.18	(0.07)
B (only Dryer #2 open)	0.05	(100)	15.2	(6)	0.18	(0.07)
C (with everything closed)	0.15	(328)	30.5	(12)	0.41	(0.16)
C (with Dryer #2 open)	0.16	(344)	3.05	(12)	0.41	(0.16)
K (with everything closed)	0.06	(120)	25.4	(10)	0.20	(0.08)
D	0.09	(188)	55.9	(22)		
E	0.04	(93)	47.0	(18.5)		
F	0.14	(304)	57.2	(22.5)		
G	0.11	(240)	53.3	(21)		
H	0.06	(131)	39.4	(15.5)		
I	0.09	(200)	22.9	(9)		
J	0.09	(200)	22.9	(9)		

*Refer to Figure A23-2 for locations of flow.

Table A23-2. Airborne concentration measurements.

Sample #		Duration (min.)	Start Time	Perchloroethylene mg/^{3}	ppm
1	Personal - Operator 1	120	0742	560	82
2	Personal - Operator 2	108	0755	295	44
3	Area - Sniffer	30	0747	98	15
4	Area - Washex	30	0747	153	23
5	Area - Cust. service	108	0802	275	41
6	Ceiling - Operator 1	15	0818	1040	154
7	Area - Lunch table	60	0822	230	34
8	Area - Sniffers	30	0834	252	37
9	Area - Washex	30	0836	600	89
10	Ceiling - Operator 1	15	0842	910	133
11	Area - Sniffers	30	0910	360	52
12	Area - Washex	20	0912	480	71
13	Area - Lunch table	61	0922	420	62
14	Ceiling - Operator 1	15	0923	190	28
15	Ceiling - Operator 1	15	0938	1310	194
16	Personal - Operator 1	129	0943	490	72
17	Area - Sniffers	30	0952	640	95
18	Personal - Operator 2	116	0954	410	60
19	Ceiling - Operator 1	15	1002	330	49
20	Area - Washex	30	1107	500	23
21	Area - Presses	39	1028	234	35
22	Ceiling - Operator 1	15	1101	1080	159
23	Area - Cust. service	190	1104	192	28
24	Area - Presses	60	1108	288	43
25	Ceiling - Operator 1	15	1201	530	78
26	Area - Washex	30	1141	790	117
27	Personal - Operator 1	125	1152	350	52
28	Personal - Operator 2	148	1151	310	49

Note: Operator #1 - Operated majority of dry cleaning operation

Operator #2 - Conducted majority of spotting

Table A23-2. Background solvent levels, perchloroethylene (ppm).

	Location*												
Time	1	2	3	4	5	6	7	8	9	10	11	12	13
0800	<1	8	15	13	8	18	32	32	20	18	165	18	--
0900	0	45	43	31	19	18	40	23	40	25	55	50	43
1000	1	67	--	72	67	100	68	100	85	73	75	59	83
1110	2	47	55	53	37	47	40	40	31	33	37	33	35
1200	1	55	72	67	50	67	85	60	50	50	52	39	45
1315**	--	28	50	35	17	33	35	63	27	27	35	29	23

*Refer to Figure A23-1 for locations.
**Washex - not operated.

APPENDIX A24
CASE STUDY NO. 24

A. PROCESS AND EQUIPMENT

This midwestern plant combines a commercial perchloroethylene dry cleaning operation with a coin-operated laundry facility (see Figure A24-1). The average cleaning volume in the plant is approximately 544-907 kg (1200-2000 lb) weekly. There are generally three employees working during the day; however, the unusual hours that this plant operates (keyed to the laundry operation) result in trade-off among workers' duties. The reported solvent mileage was 13,000 for the perchloroethylene system, and reported solvent consumption for the fluorocarbon system was 3.8 L/79 kg (1 gal/175 lb. garments).

The dry cleaning equipment had been replaced approximately seventeen months prior to this survey. A Spencer GTV25 Mark II fluorocarbon machine (S/N H373) and a Spencer dry-to-dry perchloroethylene machine (variously designated Model EES and SSP-25), S/N H3525, are both employed. Each of these units has nominal 11 kg (25-lb.) capacity. The perchloroethylene machine is connected to a Kleenrite Filter, Model 1600 US (S/N 7212-348), employing four cartridge filter chambers. No still is used.

This plant employed a Spencer "Resolver" refrigerated condensing unit for recovering solvent during garment aeration. The "Resolver" is employed in place of a carbon adsorption recovery unit, but is designed to permit return of air to the washer (see Figure A24-2). Thus, the cleaning system airflow becomes self-contained, with no emissions (nominally) to the atmosphere.

The dry cleaning cycle pre-programmed in the perchloroethylene system includes an 11-minute wash, 3.5-minute extraction, 9.5-minute dry, and 2-minute aeration. Standard procedure in this plant is to manually run an additional aeration of approximately 3 minutes.

Solvent recovered by the Resolver is drained daily from the recovery unit and added to the washer solvent reservoir. During the 11-day period immediately preceding this survey, 867 kg (1912 lb.) of clothing were cleaned and 53.2 L (1,799 oz.) of solvent were recovered.

The fluorocarbon cleaning system in this plant was rarely used. Since its use is limited to special fragile garments and drapes, there is no single cleaning cycle routinely employed.

B. NATURAL VENTILATION

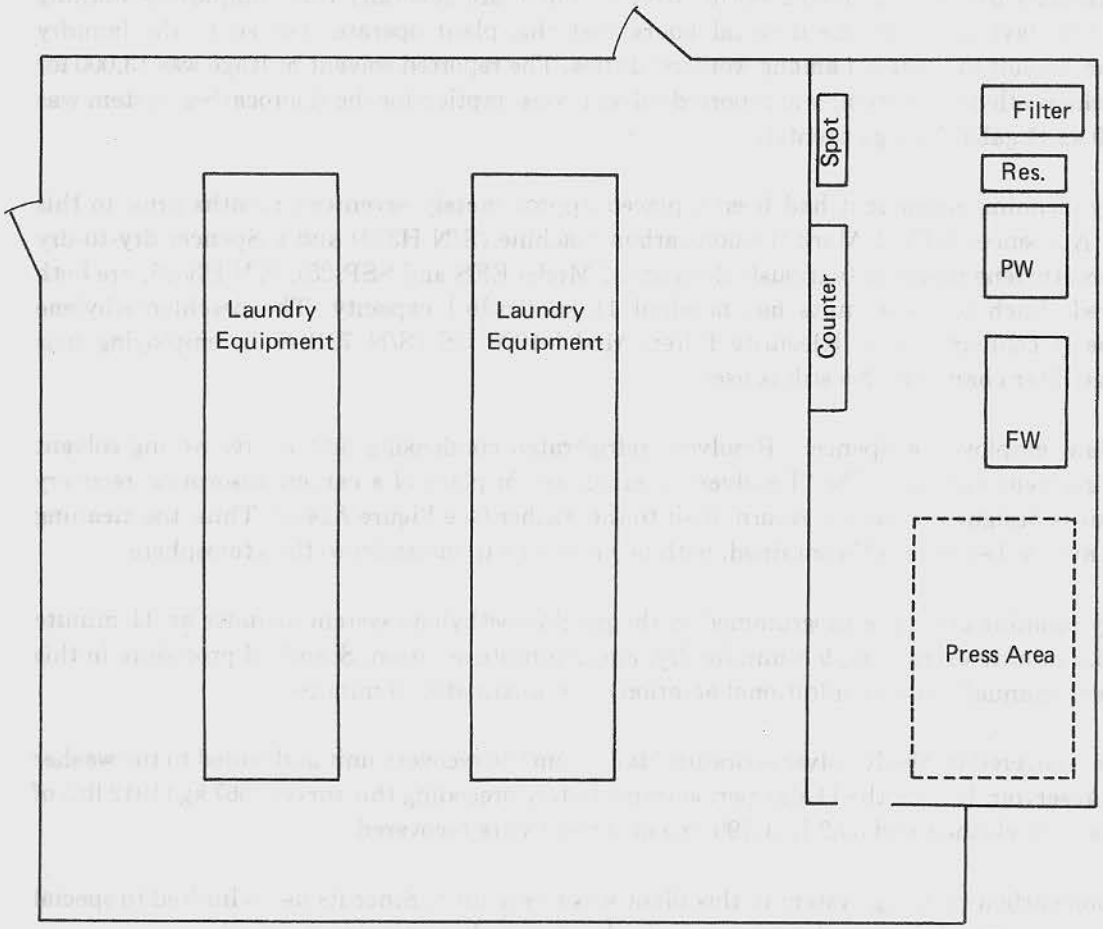
This plant has no windows. The two doors are normally closed.

C. GENERAL MECHANICAL VENTILATION

Ceiling diffusers in the laundry area supplied approximately 2.2 m^3/s (4,700 cfm). This supply rate is equivalent to approximately 25 air changes per hour.

D. LOCAL EXHAUST VENTILATION

No local exhaust ventilation was employed in this plant.



PW = Perc Washer
FW = Fluorocarbon Washer
Res. = Resolver

FIGURE A24–1 PLANT LAYOUT

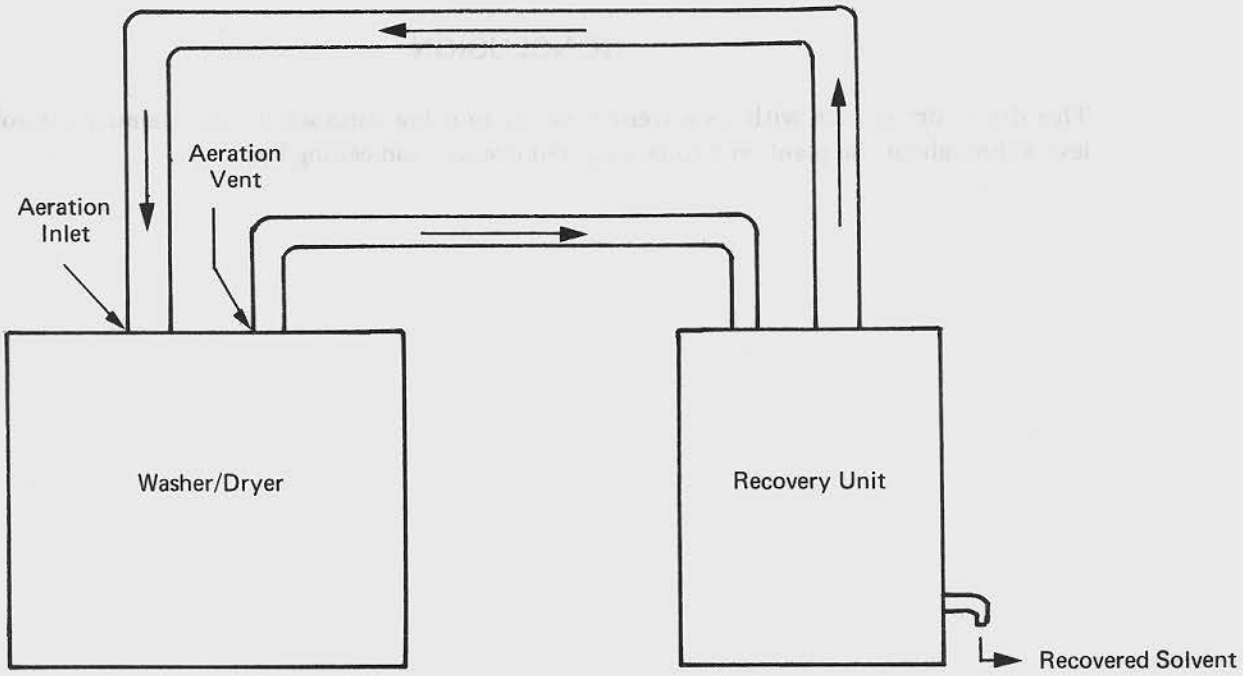


FIGURE A24–2 AIR FLOW WITHIN SOLVENT RECOVERY LOOP

E. LEAK DETECTION

A level of 60-90 ppm was detected behind the perchloroethylene machine. This level seemed to be the result of a water separator without a water layer, and several small gasket leaks.

The fluorocarbon system contained several significant leak points, including the filter cartridge container and the still. The filter canister leaked visibly and actually splashed solvent at one point during system operation.

F. SOLVENT EXPOSURE LEVELS

Results of charcoal tube sampling are shown in Table A24-1. Background levels are displayed in Table A24-2. The dry cleaning operator's exposure level was approximately 7 ppm perchloroethylene, with ceilings during loading and unloading of approximately 8-30 ppm. Levels throughout the plant were low throughout the survey.

CONCLUSION

This dry-to-dry system with its solvent recovery unit are successfully maintaining low solvent levels throughout the plant on a time-weighted average and ceiling basis.

Table A24-1. Perchloroethylene exposure levels.

Sample #		Duration (hr:min)	Start Time	mg/m^3	ppm
1	Cleaner personal sample	2:29	7:31	52	7.7
2	Front of washer	0:30	7:34	19	2.9
3	Customer service area	2:00	7:34	23	3.4
4	Laundry area	2:00	7:43	19	2.7
5	Cleaner during unload	0:15	8:15	147	22
6	Front of washer	0:30	8:29	25	3.7
7	Cleaner personal sample	1:46	10:00	45	6.7
8	Customer service area	2:00	10:06	19	2.8
9	Laundry area	2:00	10:07	22	3.2
10	Front of washer	0:30	10:10	72	11
11	Cleaner during unload	0:15	10:24	120	18
12	Front of washer	1:00	10:47	37	6
13	Cleaner during load	0:15	10:49	203	30
14	Cleaner during unload	0:15	11:27	56	8.3
15	Laundry area	1:49	12:20	15	2.2
16	Customer service area	1:47	12:20	18	2.6
17	Cleaner personal sample	1:54	12:26	34	5.0
18	Front of washer	1:00	12:31	42	6.2
19	In basket after unload	0:02	12:44	3100	460
20	Cleaner during unload/load	0:15	12:35	114	17
21	Cleaner during unload/load	0:35	1:20	117	17
22	In basket after unload	0:02	1:26	5500	800
23	Cleaner during unload	0:15	2:04	50	7.4

Table A24-2. Perchloroethylene background levels (ppm).

Location	Time					
	8:00	9:00	10:15	11:30	12:30	1:45
Outside	<1	<1	<1	<1	<1	<1
Counter	3	5	2	6	1-2	3
Door	4	4	2	6	1-2	2
Laundry area	3	4	2	3	1	2
Laundry area	4	7	2	4	2	2
Pressing area	-	-	-	6	3	3

APPENDIX B
SUBJECT INDEX TO CASE STUDIES

Subject	Case Study Nos.
Perchloroethylene:	
Transfer	1,2,3,4,9,12,17,18,19,22,23
Dry-to dry	13,16,17,20,24
Petroleum solvent	2,7,8,11,14,15
Fluorocarbon 113	5,6,21
Commercial Plants	1,2,3,4,5,6,9,11,12,14,15,16,18,19,20,21,22,23,24
Industrial plants	2,7,8,13,17
Ventilation:	
Local exhaust	1,3,4,9,11,12,13,16,17,22,23
General mechanical	4,5,6,7,8,9,11,12,13,14,15,16,17,18,20,21,22,23,24
Natural	2,3,4,7,9,13,14,15,16,17,18,19,20,22
Process isolation	7,11,13,14,15,19
Carbon adsorption	1,3,4,9,12,13,16,17,22,23
Personal protective equipment	1,7,8

APPENDIX C
EXPERIMENTAL METHODS

1. AIRBORNE SOLVENT LEVELS

During the course of the surveys conducted during this program, three different solvents were encountered. These were perchloroethylene, fluorocarbon 113, and Stoddard solvent. The sampling and analytical methods used were taken, in large part, from the following NIOSH Standard Methods:[1]

- Tetrachloroethylene (Perchloroethylene) Sampling and Analytical Method No. S335.
- Trichlorotrifluoroethane (Fluorocarbon 113) Sampling and Analytical Method No. S129.
- Stoddard Solvent Sampling and Analytical Method No. S382.

Each of these methods entails collection of sample on activated carbon, desorption with carbon disulfide, and gas chromatographic analysis. These methods have been validated and have known precision and accuracy. They provide a reliable measurement according to the requirements set forth by OSHA: the true value is known at the 95% confidence level within 25% of the value.

Modifications made in the sampling and analytical methods were mainly in the area of sampling period. Based on results from the initial surveys, sampling periods were adjusted so that a maximum amount of organic solvent would be collected with a minimum risk of breakthrough.

The remainder of the analytical method was carried out as specified. Charcoal tubes were used as a collection medium; samples were then desorbed with carbon disulfide containing an internal standard. The resulting solutions were analyzed by gas chromatography with a flame ionization detector, as indicated in the NIOSH methods.

During several surveys, passive diffusion organic vapor monitors were employed as collection devices to supplement charcoal tubes. These samples were collected to help assess the capabilities of passive monitors and were not relied upon as a primary data source. Both the Abcor "Gasbadge" and the 3M Model 3500 Organic Vapor Monitor were used, with analyses of these devices performed as recommended by their respective manufacturers.

Additional data were collected through the use of an h-nu Systems, Inc., PI-101 portable photoionization detector. This unit, which responds to perchloroethylene and Stoddard solvent, was used for leak detection and the measurement of plant background levels. A Gas-Tech Halide Meter was used to collect similar data in fluorocarbon 113 plants.

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1. NIOSH Manual of Analytical Methods, Second Edition, April 1977, DHEW (NIOSH) Publication No. 77-157.

2. VENTILATION SYSTEM EVALUATION

Data on air flow velocities within ventilation system ducts were obtained through the use of a Pitot tube and inclined manometer. Standard evaluation techniques[2] were employed. Face velocities and static pressure levels were measured with an Alnor velometer.

3. PHYSICAL AGENT EXPOSURES

Wet bulb globe temperature, along with dry bulb, wet bulb, and black globe temperatures, were measured with a Reuter-Stokes RSS-211 Wibget Neat Stress Monitor. All readings were made in the pressing area to determine the most severe conditions.

Noise levels were measured in selected plants with a Quest Model 215 Sound Level Meter. Readings were taken to determine maximum sound pressure levels within the plant.

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2. American Conference of Governmental Industrial Hygienists' "Industrial Ventilation Manual." 1978, Section 9.

APPENDIX D
HEALTH EFFECTS AND EXPOSURE STANDARDS

1. PERCHLOROETHYLENE (TETRACHLOROETHYLENE)

Perchloroethylene (C_2Cl_4) is a colorless liquid with a boiling point of 121°C (250°F). This solvent can be irritating to the eyes, nose, and throat; can cause sinus congestion and headache; and can cause CNS depression, marked by general complaints of dizziness, incoordination, and nausea if inhaled at high concentrations. Chronic exposure to perchloroethylene can cause liver and kidney damage. Perchloroethylene has been studied by the National Cancer Institute and found to be carcinogenic in laboratory mice. Further studies of potential carcinogenic action of perchloroethylene are in progress.

The current Federal OSHA standard[1] for perchloroethylene is:

8-Hour TWA level:	100 ppm
Acceptable ceiling level:	200 ppm
Acceptable maximum peak above ceiling for an 8-hour shift:	300 ppm for 5 minutes in any 3 hours.

NIOSH has published a Criteria Document for perchloroethylene[2] in which a permissible exposure level of 50 ppm averaged over a work shift of up to 10 hours, with a ceiling of 100 ppm averaged over a 15-minute period, was recommended. NIOSH has also published a Current Intelligence Bulletin on tetrachloroethylene[3] in which it is recommended that "it is prudent to handle tetrachloroethylene (perchloroethylene) in the workplace as if it were a human carcinogen. The recommendation is based on a recent study by the National Cancer Institute (NCI) indicating that tetrachloroethylene causes liver cancer in laboratory mice."

2. STODDARD SOLVENT

Stoddard solvent is a colorless liquid with a kerosene-like odor. This chemical is a petroleum blend with a boiling range of 150-200°C (302-392°F). The solvent consists of organic compounds whose chain lengths range from C7 to C12, and typically contains less than 0.1% benzene. Stoddard solvent is irritating to the eyes, nose, and throat, and can cause dizziness at high concentrations.

The current Federal OSHA standard for Stoddard solvent is 500 ppm (2950 mg/m^3) averaged over an 8-hour work shift. NIOSH has published a criteria document for refined petroleum products[4] in which a permissible exposure level of 350 mg/m^3 averaged over a work shift of up to 10 hours, with a ceiling level of 1800 mg/m^3 averaged over a 15-minute period, is recommended.

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1. Code of Federal Regulations, Title 29, Section 1910. 1000, Table 2.
2. Criteria for a Recommended Standard...Occupational Exposure to Tetrachloroethylene, DHEW(NIOSH) Publication No. 76-185, July 1976.
3. NIOSH Current Intelligence Bulletin 20, HEW(NIOSH) Publication No. 78-112, January 1978.
4. Criteria for Recommended Standard . . . Occupational Exposure to Refined Petroleum Products, DHEW(NIOSH) Publication No. 77-192, July 1977.

3. TRICHLOROTRIFLUOROETHANE (FLUOROCARBON 113)

1,1,2-Trichloro-1,2,2-trifluoroethane (CCl_2FCClF_2) is a colorless liquid with a boiling point of 47.8°C (118°F). At high concentrations, this solvent can cause throat irritation and feelings of drowsiness.

The current Federal OSHA standard for fluorocarbon 113 is 1000 ppm (7600 mg/m^3) averaged over an 8-hour work shift.

APPENDIX E
GLOSSARY

AERATION — The final stage of the drying cycle, in which fresh air is passed over garments to remove residual solvent odor.

CEILING — An exposure level measured as a 15-minute time-weighted average during a period of expected high exposure.

DRY CLEANING — The use of non-aqueous solvents for the removal of dirt from garments.

DRY-TO-DRY — A machine or process in which cleaning, extraction, and drying are all conducted in a single machine.

DRYER — Machine used to recover solvent from damp garments by passing warm air through the garment load as the load is rotated.

DUAL PHASE CLEANING — The use of both a solvent (nonaqueous) wash and an aqueous wash, with an extraction between the two, in a single machine.

LAUNDRY — The use of aqueous systems for removal of dirt from garments.

MILEAGE (or Solvent Mileage) — A measure of efficiency of solvent use, determined by the ratio of cleaning volume to solvent consumption. This parameter is expressed in terms of pounds of cleaning per drum of solvent.

MUCK COOKER — A distillation unit used to purify solvent and reclaim solvent from filter aid (where powdered filter aid is used).

SNIFFER — A carbon adsorption unit, with associated ductwork and air mover, employed to recover solvent from plant air and dryer aeration air.

SPOTTING — The use of various chemicals to remove particular stains from individual garments.

TRANSFER — The removal of garments from the washer and movement of these garments to the dryer. This term also refers to the process in which a transfer is required.

TUMBLER — A dryer employed in the dry cleaning process.

TWA — Time-weighted average, the basis for calculating employee exposures to chemical and physical agents.

WASHER — The machine used for dry cleaning garments. This machine typically performs washing (agitating garments with solvent) and extraction (spin) steps.

APPENDIX F

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☆ U.S. GOVERNMENT PRINTING OFFICE:1980--657-147/1043