IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR FORMALDEHYDE EMISSIONS

AT

Hillcrest Veneer Plant
High Point, North Carolina

Report Written By:

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NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

PLANT SURVEYED:	Hillcrest Veneer Plant 1327 Lincoln Drive High Point, North Carolina
STANDARD INDUSTRIAL CLASSIFICATION OF PLANT:	2435: Hardwood Veneer and Plywood 2436: Softwood Veneer and Plywood
DATE OF SURVEY:	September 20-24, 1982
SURVEY CONDUCTED BY:	Vincent D. Mortimer, Jr. Bruce A. Hollett Kenneth F. Martinez Sharon L. Kercher John C. Frede
EMPLOYER REPRESENTATIVES CONTACTED:	Mr. Fred Belk, Plant Manager Mr. Reginald Rouse, Assistant Plant Manager Mr. Roger Hedrick, Hot-Press Supervisor Mr. Daryl Metcalf, Panel Lay-up Supervisor Mr. Manuel de Bettencourt, Maintenance Supervisor
EMPLOYEE REPRESENTATIVES CONTACTED:	no employee organization
ANALYTICAL WORK PERFORMED BY:	Robert Phillips, NIOSH/IWSB Utah Biomedical Test Laboratory, Salt Lake City, Utah

INTRODUCTION

BACKGROUND FOR CONTROL TECHNOLOGY STUDIES

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Organizationally located in the Department of Health and Human Services (formerly Health, Education, and Welfare), it was established by the Occupational Safety and Health Act of 1970. This legislation mandated that NIOSH conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

As in the past, current studies involve three phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities is added to the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

BACKGROUND FOR THIS STUDY

This research study began as an assessment of occupational health hazard controls associated with the industrial use of adhesives. Plants in the aerospace, automotive, footwear, wood-products, and some other industries were visited to observe the relation of the workers to the use of adhesives in the manufacturing processes and the types of controls being used. This preliminary work identified hot-process veneering with urea-formaldehyde resin adhesives as the operation which could benefit most from control technology research.

Formaldehyde, a commonly used substance in industry and the life sciences, has long been recognized as a potential irritant of the eyes, nose, and skin. In the last few years, the results of some animal toxicity studies have shown a relationship between formaldehyde exposure and cancer in some laboratory animals. It is not known how long it will be until the risk of cancer for humans exposed to formaldehyde is determined. In the meantime, as a prudent public health measure, plants should reduce occupational exposure to formaldehyde as much as possible with engineering controls and work practices.

In response to this need, the Engineering Control Technology Branch of NIOSH is studying the control of formaldehyde emissions from hot-process veneering operations which use a urea-formaldehyde resin adhesive. The goals of this study are to evaluate a number of different approaches which some furniture and wood-panel manufacturing firms have taken to control these emissions, and then to disseminate useful information and practicable recommendations on effective methods for controlling occupational formaldehyde exposure.

BACKGROUND FOR THIS SURVEY

Early in the study, the Hillcrest Veneer Plant was identified as one which recently had undergone extensive engineering modifications to control formaldehyde emissions from hot-press veneering operations. The ventilation system and environmental sampling data which showed low exposure levels were impressive. In addition, this plant contained three types of hot-platen presses. This in-depth survey of the Hillcrest Veneer Plant was conducted on September 20 - 24, 1982 to evaluate their operations and associated controls for formaldehyde exposure. This report documents the information pertinent to that evaluation.

GENERAL INFORMATION ABOUT THE PLANT AND PROCESSES

INTRODUCTION

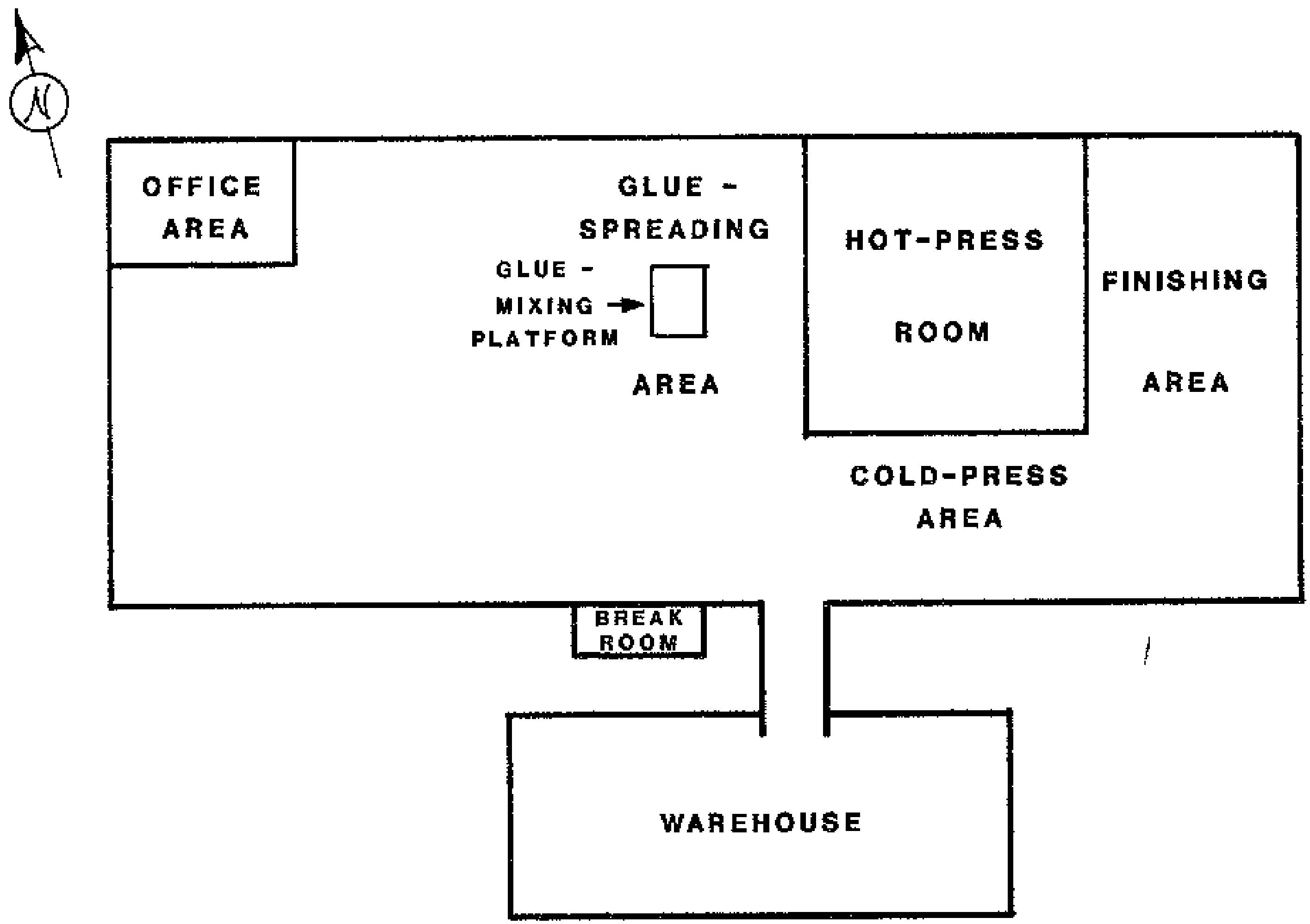
The Hillcrest Veneer Plant manufactures veneered panels for furniture made by Burlington Industries, Inc. at other plants in this geographical area. This plant employs from 100 to 150 people, approximately 90 percent of which are hourly production workers. The building is a concrete and steel-frame structure originially built as a textile plant. This facility was bought and converted to a veneer plant by Burlington circa 1979. At that time, modifications were made to the heating, ventilation, and air-conditioning (HVAC) system. The HVAC system is currently configured with three chillers, totalling over 1000 tons of cooling capacity, three steam-coil heat exhangers, and a dew-point controller to mix recirculated air with outside air. Most of the local exhaust ventilation system is new.

The layout of the plant is diagrammed in Figure 1. The hot presses are located in a separate room, approximately 12,000 square feet in area with a 25-foot ceiling, within the building. Particleboard and fiberboard panels are stored in a warehouse on the south side of the building. Bundles of veneer pieces are received at the west end of the plant. The facilities include a "fancy-face" department which prepares sheets of veneer stock featuring decorative veneer patterns. The adhesive-mixing and -spreading operations are located in the center of the building, just west of the hot-press room. The cold-press operation is set up on the other side of the south wall of the hot-press room. Offices in the northwest corner and both breakroom and restroom facilities along the south side are separated from the main area of the plant by a wall.

PROCESS

The simplest veneered panel consists of three plies, a face and a back veneer glued to each side of a core. Additional plies may be added to make a panel which is stronger and more stable dimensionally. An established way to achieve a high rate of production is to reduce the glue-curing time by heating the glue while pressure is being applied to the panels. One way to do this is to heat the metal plates which apply the pressure, generally referred to as a "hot-press" process. Another way is to generate heat in the glue-line with radio-frequency (R/F) radiation in much the same way that food is cooked in a microwave oven. In this "R/F-press" process, the hydraulic press only applies pressure. "Cold-press" processes, those for which pressure is applied while the boards are maintained between 60° and $100^{\circ}F$, require much longer periods of time for the glue to cure.

For most applications, the glue which currently provides the best performance for the least cost is a urea-formaldehyde (U/F) resin adhesive. The core may be veneer, particleboard ("chip-core"), fiberboard, or a piece of edge-glued solid-wood "lumber-core." Almost all particleboard and fiberboard are made with formaldehyde resin binders, and a formaldehyde resin glue may be used to assemble lumber-core. To improve the appearance of a panel, the core may be "banded" with solid wood edges prior to veneering. Here again, the adhesive may contain formaldehyde. A variety of hardwoods and softwoods, including



NOT DRAWN TO SCALE

Figure 1. Plant Layout

oak, walnut, poplar, and pine, are used for veneer stock. Some plastic laminates are being used for certain products; usually these panels are cold-pressed.

The veneers are received in flitch form, thin strips bundled together as they were cut from the log. The veneer flitches are pressed, trimmed, and joined into sheets, which are then cut to the proper size for the panel being produced. The large panels of particleboard and fiberboard are cut into pieces of the appropriate nominal size. The cores are then banded, if necessary, and trimmed to the desired size. This plant does not have facilities for manufacturing lumber-core.

Most of the flat panels produced use particleboard or fiberboard for the core. Some lumber-core is used. Three-ply panels, from all types of cores, make up about 90% of the total production. Less than a fifth of the panels produce are cold-pressed.

POTENTIAL HAZARDS

Formaldehyde is emitted while the boards are being pressed, although the escape of vapors seems somewhat restricted by the closed press. Consequently, much formaldehyde vapor is released when the press opens. The emission of formaldehyde from the hot boards continues as the boards are unloaded, stacked, and cooled. The primary route of exposure is inhalation.

The cold resin does not give off much formaldehyde; thus the mixing and the spreading of the glue and cold-press operations are not considered to be significant sources. Edge-gluing operations for making lumber-core and for banding, which are characterized by much smaller glue lines and more mechanization, are also not considered significant emitters of formaldehyde. There is the potential for dermal exposure during the glue-mixing, panel lay-up, and press loading operations.

Formaldehyde is a commonly used substance in many industries as well as in medicine and biology. Those who have been exposed to high concentrations of airborne formaldehyde can attest to its ability to make the eyes water and cause a burning sensation in the nose and throat.

This potential for irritation necessitates that formaldehyde exposure be limited to a few parts of the substance per million parts of air (ppm). The OSHA permissible exposure limit is an 8-hour time-weighted average of 3 ppm with a two-level ceiling limit for excursions above 3 ppm. However, from a review of known health effects and exposure levels completed in 1976, NIOSH determined that workers can still experience significant discomfort even though these limits are adhered to. Based on these findings, the NIOSH "Criteria Document: Recommendations for an Occupational Exposure Standard for Formaldehyde" recommended that workers not be exposed to more than 1 ppm in any 30-minute period.

In the past few years, the results of experiments conducted by Battelle Columbus Laboratories for the Chemical Industry Institute of Toxicology and by New York University's Institute for Environmental Medicine, each lasting approximately 2 years, have linked formaldehyde to cancer in laboratory animals, albeit at exposure levels higher than those found in most plants. NIOSH reported these findings in "Current Intelligence Bulletin 34," published in April of 1981. In another recent study, conducted for the Formaldehyde Institute, no cancers occurred in animals exposed for 6 months to formaldehyde at 3 ppm and below under different experiment parameters. There has been considerable debate about the conclusions which should be drawn from these results. With all that has been learned, there is still much that is not known about how formaldehyde is related to cancer.

But the fact remains that formaldehyde is a potent irritant; and, at this point, it cannot be discounted as a potential carcinogen. For this reason, NIOSH recommended in CIB 34 that, until the cancer risk to workers exposed to various levels of formaldehyde is determined, as a prudent public health measure, occupational exposures should be controlled to the lowest level feasible sith engineering controls and good work practices.

METHODOLOGY

Air movement and airborne formaldehyde concentrations were measured to evaluate the effectiveness of the controls. Table 1 lists some of the major pieces of equipment used.

Table 1. Equipment Used on Field Surveys.

Item	Model	Used for
Hot-wire anemometer	Kurz model 441	Air velocity
Hot-wire anemometer	TSI model 1650	Air velocity
Pocket anemometer	Kurz series 480	Air Velocity
Pitot tube	5-ft x 5/16 OD	Air velocity pressure
Pitot tube	2-ft x 5/16 OD	Air velocity pressure
Inclined manometer	Dwyer 0 - 1 in.	Air velocity pressure
Personal sampling pump	MDA 808	personal twa* samples
Personal sampling pump	DuPont P-200	area twa* samples
Organic vapor monitor	CEA-555	continuous monitoring
Detector tubes	Drager 0.5a	short-term samples

* time-weighted average

MEASUREMENT OF CONTROL PARAMETERS

The volumetric flow rate through each of the three major HVAC ducts entering the press room was measured by performing pitot-tube traverses. The three rectangular ducts were each divided into cells, with approximately 6-inch centers. For one of the ducts, there was no location sufficiently far away from some type of disturbance, and due to the presence of numerous outlet grills on the duct and obstructions around the duct, only one site was possible. The airflow from the supply-air system was checked by measuring the velocity of the airstream from each of the outlets with a hot-wire anemometer. For each outlet, the average velocity was determined from a 16-point traverse on approximately 5-inch centers.

The volumetric flowrate through the local exhaust ventilation (LEV) system was estimated by measuring the velocity of the airstream from the discharge ducts on the roof. For each opening, two 10-point traverses, 90° apart, were conducted with a hot-wire anemometer. The airflow into each LEV hood was estimated by measuring the average velocity at the face of each slot with a hot-wire anemometer.

Air movement at various points in the vicinity of the LEV hoods and the work stations, through the doorways into the press room, and at other selected points in the press room was assessed by observing the flow of smoke from a smoke tube. Where there seemed to be a relatively steady airflow with a measurable velocity, the average velocity was determined using a hot-wire anemometer.

To determine daily personal exposures and average concentrations at selected points in the plant, personal and area samples for formaldehyde were collected using Supelco XAD-2 Formaldehyde Resin tubes and personal sampling pumps calibrated for approximately 50 milliliters of air per minute (ml/min). The solid sorbent tubes were analyzed for formaldehyde according to NIOSH method P&CAM-354, a procedure involving desorption of a formaldehyde reaction product from the sorbent coating and analysis by capillary-column gas chromatography with flame ionization detection. The analysis was performed with the following modifications: the desorption solution contained 0.25 ul/ml hexadecane as an internal standard; the oven conditions were 8 minutes at 160°C, programmed at 32°C/minute to 200°C. A 25m x 0.20mm ID flexible fused silica Carbowax capillary column was used with a Hewlett-Packard Model 5711A gas chromatograph with a flame ionization detector. Helium was used as the carrier gas in the split mode of operation with a split ratio of 20 to 1. The limit of quantification for this method is typically 5 micrograms of formaldehyde per tube. Theoretically, sampling at the maximum rate (for this method) of 50 ml/min for over 6 hours should detect concentrations less than 0.25 ppm.

All workers in the press room were sampled, including those responsible for moving panels to be pressed into the press room and moving pressed panels to the cooling/staging area. Some area samples were spaced throughout the press room. One glue-spreader crew and the glue-mix man were sampled and an area sample collected at each of the two locations. In the warehouse, two workers were sampled and two area samples were collected. Five other area samples were collected: one each in the lunch room, by the edge-gluing spray booth, close to the cold-press operation, in the veneer inspecting department, and in the sanding area--the latter two only on the last two days.

Upon first receiving the results from the lab, a definite bias in the reported values was noticed, seemingly stemming from a wide difference in the background levels of the different lots of tubes. The results used to assess the controls (tabulated in Appendix A.) have been corrected for the field blank values of each lot to compensate for this background level difference; however, due to an undetectable background level in four of the lots of solid sorbent tubes, this correction deserves some comment.

Essentially, the blank correction procedure involves shifting the calibration curve representing the gross analyte signal to one representing the net analyte signal with the zero point corresponding to the average field blank value. Mathematically, for each sample, the average field blank value of its lot is subtracted from either the reported value of the sample or the limit of detection for the lot, whichever is greater. For the four lots for which the area under the formaldehyde peak of the gas chromatograph response for each of the blanks was below the integrator threshold, this involved subtracting a negative value.

In accordance with guidelines published by the American Chemical Society, the limit of detection is taken to be the value which is three standard deviations above the average field blank value for each lot. Since there are only two or three field blanks for each lot, it is felt that a standard deviation calculated from these few samples would not be a good estimate of the field blank variability. Therefore, the variance of the gross analyte signal has been estimated by calculating a root mean square error from a least squares regression of the calibration data. This yielded the same limit of detection value reported by the laboratory. Assuming that the variability of the blank-tube background level for each lot of sample tubes is no greater than for the tubes used to determine the calibration curve, this detection limit can be used for all sample results. This assumption is supported by calculations of the variability of the quality control samples run during the analysis of the two groups of tube lots and of the variability of the blank background level for the two lots (16 and 17) of tubes with detectable background levels on the blank (unexposed) tubes.

The daily results for each location category were averaged to obtain the results presented in Tables 3 - 8. For those samples which were reported to be below the detection limit (BDL), either the detection limit (the value in parentheses in Tables A-1 and A-2) or half this value was used in computing the average concentration. If more than 50 percent of the values to be averaged were below the limit of detection, then the detection limit was used and the average is preceded by a "less than" symbol in the table. Otherwise, a value equal to half the detection limit was used as an estimate of the sample concentration.

The air at various points around the presses was analyzed for formaldehyde using a CEA-555 Organic Vapor Monitor to ascertain the order of magnitude of representative short-term formaldehyde concentrations. The CEA-555 continuously analyzes a sampled airstream for formaldehyde, employing a colorimetric procedure. Thus, this method is appropriate for evaluating short-term and ceiling exposures, but it has not yet been validated for determining compliance with standards. Also, only area samples were taken with this instrument on this survey. Therefore, these results should not be directly compared to any OSHA standards.

The standard "CEA 555-FO: Formaldehyde in Air" procedure was followed. The full-scale calibration for the CEA-555 that day was 1 part formaldehyde per million parts of air (ppm); the full-scale rise time for responding to the calibration input was approximately 4 minutes.

Some short-term samples for formaldehyde were also taken with colorimetric gas detector tubes. Some of these samples were taken close to the location of a CEA sample, but not necessarily at the same time. The tubes (Draeger 0.5/a) have a detection range of from 0.5 to 10 ppm. The manufacturer states that a standard deviation of 30 to 20 percent (relative to the mean, with the higher value corresponding to the lower range of measurement) be associated with this type of detector tube. Thus, this method only provides a rough estimate of formaldehyde concentration, not acceptable for evaluating compliance with any OSHA standards. It is, however, an appropriate method to determine approximate breathing-zone and area concentrations for the purposes of this study.

CONTROL TECHNOLOGY

INTRODUCTION: PRINCIPLES OF CONTROL

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring. These principles may be applied at or near the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals. Controls applied at the source of the hazard, including engineering measures (material substitution, process and equipment modification, isolation or automation, local ventilation) and work practices, are generally the preferred and most effective means of control in terms of both occupational and environmental concerns. Controls which may be applied to hazards that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping. Control measures may also be applied near individual workers, including the use of remote control rooms, isolation booths, supplied-air cabs, work practices, and personal protective equipment.

In general, a system comprised of more than one of the above control measures may be required to provide worker protection under normal operating conditions and also under conditions of process upset, failure and/or maintenance. Process and workplace monitoring, personal exposure monitoring, and medical monitoring may be used to provide feedback concerning the effectiveness of the controls in use. The maintenance of equipment and controls to insure proper operating conditions and the education of and commitment from both workers and management concerning occupational health are also important ingredients of a complete, effective, and durable control system.

Not all principles apply to all situations, and their optimal application varies from case-to-case. The application of these principles at the Hillcrest Veneer Plant is discussed below.

PRESS ROOM

Description

A room has been constructed for the hot-press operation. Three concrete-block walls were erected from floor to ceiling, enclosing a space (100 x 120 ft) along the north wall of the building. Eighteen doorways of various sizes maintain an unimpeded movement of workers and materials, while reducing the surface area for airflow between the press area and the rest of the plant by 95 percent to less than 400 square feet.

Hot-press veneering is accomplished on one of four steam-heated platen presses, operated at around 250°F. There are two multiple-opening presses (one ten- and one six-opening), a shuttle press, and a feed-through press. Stacks of panels to be pressed are moved into the press room on roller conveyors by the material handler. After being pressed, stacks of panels are moved on another set of roller conveyers by the expeditor to the staging area of the room to cool and await further processing. Hot-press production was averaging about

40,000 square feet per day at the time of the survey, usually approximately equally divided between the four presses.

Controls

Although the three types of presses are different, they each have similar control systems. In addition to enclosures around each press, the press room features a well-engineered ventilation system, which is summarized in Table 2.

Table 2. Press-Room Ventilation Flow Rates.

Ventilation Category	Volumetric Flow Rate, cfm	
Total Exhaust	93,000	
Local Exhaust Ventilation		63,000
General Ventilation		30,000
Total Make-up Air	65,000	
Functional Supply Air		18,000
General Heating, Ventilation, & Air-Conditioning		47,000

Local exhaust ventilation (LEV) hoods have been installed above each of the press openings and above the area where the panels are stacked upon being unloaded from the press. Approximately 63,000 cubic feet of air per minute (ft^3/min or cfm) is exhausted by the four press LEV systems combined. Another 30,000 cfm is removed by the four fans installed in the press room ceiling to exhaust vapors which have risen to the ceiling zone.

Supply-air outlets, each with a 3 square-foot opening, have been installed above the location where each press worker stands most of the time while working. The 16 outlets (4 at each press) blow a total of approximately 18,000 cfm of air into the press room through a press worker's breathing zone. An additional 47,000 cfm of air is supplied to the room by the HVAC system to replace most of the air removed by the exhaust ventilation system. A large supply fan installed in the press room ceiling can be run to bring in large quantities of outside air when heat in the press room is excessive. This fan was not used during our survey, and its volumetric flow rate was not measured.

There is a net deficit of make-up air supplied to the room of approximately 28,000 cfm which flows through the open doorways of the press room. Most of this enters through the eight doorways on the west side of the room. Some air (about a fourth of the amount than enters) flows out of the press room through open doorways on the east and south sides of the room. The result is a mild airflow across the press room from the west side to the south and east sides averaging less than 20 ft/min.

Sampling Results

Although all time-weighted average concentrations were quite low (none exceeded 0.5 ppm averaged over the 3 days of sampling). Table 3 shows that the average press-room formaldehyde concentrations were somewhat greater than the average for the general plant--not including the warehouse and the panel lay-up areas. Table 4 shows that the area concentrations for the west side of the press room were higher than for the glue-spreading/mixing area on the other side of the west wall, and the east-side concentrations were higher than those for the cold-press and sanding activities on the other side of the adjacent press-room walls.

Table 3. Press-Room and Plant Time-Weighted Average Area Concentrations.

Area	Number of Samples	Average Concentration ppm	Standard Deviation ppm
General Plant	13	<0.18	0.02
Press Room	23	0.25	0.07
	36	.2	

Table 4. Press-Room and Adjacent Area Time-Weighted Average Concentrations.

Area	Number of Samples	Average Concentration ppm	Standard Deviation ppm
Glue Spreading and Mixing	6	<0.19	0.02
Press Room - West	6	0.19	0.08
Press Room - Center	9	0.23	0.04
Press Room - East	9	0.30	0.09
Cold-Press/Finishing	5	<0.19	0.02
		.2	

Within the press room, measured area concentrations were higher on the east side than either the west or central regions. (Refer again to Table 4.) As a group, the workers loading the presses were exposed to half as much formaldehyde as the unloaders. In fact, as can be seen in Table 5, the average exposure for the loaders was less than the average area concentration for the west and central region of the press room. The average exposure for the unloaders, including both operators for the shuttle press and the expeditor, were somewhat greater than the average concentration for the east and central regions.

Table 5. Press-Room Time-Weighted Average Personal and Area Concentrations.

Grouping	Number of Samples	Average Concentration ppm	Standard Deviation ppm
West and Central Areas	14	0.21	0.06
Loaders*	13	0.17	0.06
Unloaders**	16	0.35	0.15
East and Central Areas	17	0.27	0.08

* not including the shuttle-press west-side operator

** including the shuttle-press east-side operator and the expeditor

Discussion

While it seems clear that the pressing operations and the stacks of hot boards are significant sources of formaldehyde, the worker exposure at this plant was low due to the excellent control of these emissions. In fact, the difference in average concentration between the loading and unloading sides of the press may have been accentuated by a slight ambient airflow from west to east within the plant. This was mostly due to the large quantity of air exhausted at the far east end of the plant by the dust control systems on the sanders and other finishing equipment. This flow was not strong enough to cause significant cross-drafts and did not seem to be otherwise detrimental to control in the press room.

The daily level of production did not seem to have a major effect on the average concentrations. This is consistent with the existence of an effective control system. If the system were not able to handle the formaldehyde emissions, additional emissions from increased production would show up as greater measured concentrations.

Although it is difficult to assess individually each of the four presses due to their being situated so close together in the press room, there are some unique aspects of controlling each press. These are discussed in the following three sections.

MULTIPLE-OPENING PRESSES

Description

The multiple-opening presses are characterized by a series of heated, thick, metal plates, one above the other, which open for loading and unloading and close to apply pressure. As is typical for this type of press, processing the panels through the press is facilitated by sandwiching the panels to be pressed between large, thin sheets of metal called caul plates. Each of the multiple-opening presses has an automated loading mechanism. Four workers are required to operate each press: two loaders and two unloaders.

While the previous load is being pressed, the loaders prepare a stack of triplets, each consisting of a caul plate, a layer of panels, and another caul plate--one triplet for each opening of the press. When the press opens, one worker pushes-out the triplets of pressed panels. Then the next load is inserted into the now-empty openings. After the press has been loaded and activated, and information about the current load of panels has been recorded on the production log, they begin preparing the next load.

Meanwhile, the unloaders are separating the pressed panels from the caul plates, stacking the panels and standing the caul plates on edge on a wheeled plate rack. Then they move the stack of panels on roller conveyors towards the finishing area, push the rack of caul plates to the plate cooling area, and wait for the next load.

The ten-opening press does not necessarily produce more panels than the six-opening press by virtue of the greater number of openings because additional time is needed to load and unload another four layers. In fact, during our survey, the six-opening press produced a slightly greater square-footage each day than the ten-opening press.

Controls

The sides of the presses were enclosed with sheet metal to reduce the effect of the steam and the heat. The enclosure featured doors to provide access for maintenance. The ten-opening press was fitted with plastic curtains around the unloading area.

The hood above each opening had a single 6- by 96-inch slot with a flange projecting 12 inches in front, 3 inches to the rear, and 9 inches on each side. Each of these hoods exhausted an average of 4500 cfm of air with an average velocity of 1100 feet per minute (ft/min) at the face of the hood. The hood above the opening on the unloading side of each press was located just above the level of the top opening. On the loading side, the hood must clear the automated loading mechanism and, thus, was over 2 feet above the top opening.

The hoods above the stacks on the unloading side each had a single 9- by 60-inch slot and exhausted an average of 3500 cfm with an average face velocity of 900 ft/min. Having to be high enough to clear a rack of plates being pushed through the aisle, the hoods on the adjacent sides of the two presses were approximately 7 1/2 feet above the floor. On the other side of each press, the hoods were only about 5 feet above the floor.

The supply-air outlets for the unloaders of both presses and for the loaders on the six-opening press were located roughly in line with the side edges of the caul plates and approximately 2 feet beyond the corner of the caul plates as they lay on the loading or unloading platform. For the loaders of the ten-opening press, the supply-air outlets were approximately 4 feet beyond this corner position. For the multiple-opening presses, volumetric flow rates for the supply-air outlets ranged from approximately 800 to 1300 cfm, with an average exit velocity of 350 ft/min.

Sampling Results

Table 6 shows that the personal and area time-weighted average concentrations on the loading side were less than on the unloading side. Not shown in the table is the fact that the daily average values for the ten-opening press were slightly less than those for the six-opening press.

Table 6. Multiple-Opening Press Time-Weighted Average Personal and Area Concentrations.

Grouping	Number of Samples	Average Concentration ppm	Standard Deviation ppm
West and Central Areas	8	0.22	0.06
Loaders	11	0.17	0.06
Unloaders	8	0.31	0.16
East and Central Areas	11	0.26	0.07

Continuous sampling at various areas around the multiple-opening presses showed levels generally less than 1 ppm, except immediately in front of the input openings and around the unloading operations. Personal breathing-zone detector-tube samples of one loader on each multiple-opening press pushing-out a load of pressed panels (a potentially high-exposure activity) indicated exposures less than 1 ppm, and this activity occupied less than 1 minute out of every 20 for these workers.

The highest readings on the unloading side, those taken to assess the relative source contribution above the stacks under the ventilation, were over 2 ppm. Other continuous samples in this area were generally less than and never much greater than 1 ppm. Breathing-zone detector-tube samples for some of the unloaders indicated short-term exposures between 1 and 3 ppm.

Discusssion

Airflow around the press and the workers was well controlled except for the ten-opening press loaders, who received only about 50 ft/min airflow from their supply-air outlets compared to 250 ft/min for their counterparts on the six-opening press. This may be due to the fact that the ten-opening loaders worked over 3 feet away from their supply-air outlets while supply-air was introduced almost directly above the six-opening press loaders when they stood at their work stations.

Airflow for each of the unloaders from the supply-air outlets was approximately 250 ft/min. For each press, the lower hood above the pressed panels being stacked captured the air above the stack better than the higher hood. For both presses, the capture zone from the hood above the unloading opening extended approximately 2 feet out from the press. The supply air was effective in improving control in the breathing-zone of the unloaders in the area from 3 to 6 feet out from the press. The airflow to control exposures in this region for this type of press must be carefully directed so as to be minimally interfered with by movement of the workers and the large metal caul plates.

SHUTTLE PRESS

Description

A two-level shuttle press is manned by two workers, one on each side (east and west). Each worker loads panels to be pressed from a roller conveyor along the north side of the press, onto the single tray which is out of the press on his side. When that load goes into the press, the other tray comes out of the press. The worker goes around to the south side of the press and unloads the pressed panels, then back around to the north side to start another load.

Controls

The control system for this press was similar to that for the multiple-opening presses: hoods above the opening on each side (east and west) of the press, hoods above the roller conveyor where the pressed panels are stacked upon being unloaded from the press and supply-air outlets above each work station on both sides (north and south) of the press.

The hood above each press opening had a 6- by 78-inch up-draft slot with a flange extending 12 inches in front, 3 inches to the rear, and 2 inches on each side. These hoods were about 1 foot above the level of the plates. They each exhausted about 4000 cfm with an average face velocity of over 1300 cfm. The hoods above the stacks each had a 9- by 60-inch side-draft slot with a flange. They exhausted approximately 3000 cfm each with an average face velocity of 800 cfm.

Three of the supply-air outlets for this press were located roughly at the corner of the plates at their full-out position. The supply-air outlet for the unloading station (south side) on the west side of the press was positioned closer to the stack of newly pressed panels than to the press platform. The supplied flow rates ranged from 600 to 1100 cfm with an average exit velocity of 290 ft/min.

Sampling Results

Table 7 shows that the average personal exposures for each operator on this press are greater than the average concentrations for the area in which he works. The continuous sampling showed levels around the press less than 1 ppm. A breathing-zone detector-tube sample for the worker unloading on the west side of the press indicated approximately 3 ppm.

Table 7. Shuttle-Press Time-Weighted Average Personal and Area Concentrations.

Grouping	Number of Samples	Average Concentration ppm	Standard Deviation ppm
West and Central Areas	9	0.23	0.07
West-side Operator	2	0.31	0.01
East-side Operator	2	0.39	0.17
East and Central Areas	12	0.28	0.07

Discussion

The time-weighted average exposures for the worker on the west side were higher than those for the loaders on the other presses. (Compare Tables 4 and 7.) This indicates that the unloading operation and the stack of hot panels was a significant source of exposure.

The fact that the personal and area time-weighted average concentrations on the west side of the press were lower than those on the east side is probably due mostly to the generally higher average concentrations for the east side of the press room. Another factor may be that on the west side of the press, there was a mild ambient airflow diagonally across the platform towards both the press opening and the stack of pressed panels. For the most part, this airflow aided the local exhaust ventilation, which had a capture zone up to 2 feet from the slot. However, on the other side, there was less air movement beyond the capture zones of the hoods, and these zones seemed somewhat smaller.

Generally, the supplied airflow did not seem as effective as for the multiple-opening presses. This is primarily due to the fact that the job tasks for this type of press force the workers to spend most of their time working outside the airflow provided by the supply-air outlets.

FEED-THROUGH PRESS

Description

A Wemhoner feed-through press is operated by two workers: a loader and an unloader. The loader places the panels to be pressed onto the loading-platform conveyor belt. When he has filled the proper area of the platform and the load being pressed is finished, the new load is conveyed into the press as the pressed panels are rolled out onto the unloading-platform conveyor belt. Having only to press a foot pedal to move the conveyor belt, he is able to work at the end of the platform approximately 20 feet from the press opening.

The unloader activates the unloading-platform belt and hydraulically raises the end of the platform, feeding the panels off the platform onto stacks being formed against a back-plate. She primarily monitors and controls the stacking of the pressed panels. She spends most of her work-time at the end of the platform, approximately 25 feet from the press exit opening.

Controls

The control system for this press was similar in principle to the other ones: hoods above the openings on each side of the press, a hood near the stacking location, and four supply-air outlets. The hood above the press input opening had a 5- by 80-inch up-draft slot with a flange extending 15 inches in front and 1 inch to the rear. The one above the exit opening had a 6- by 80-inch up-draft slot with a flange extending 15 inches in front and 8 inches on each side. Each hood was less than 1 foot above the platform level. There was only one hood above the stacking area, it had a 5- by 80-inch side-draft slot with a flange extending about 12 inches above and 6 inches on each side. This hood was positioned about 4 feet above the platform, approximately 2 feet in from the stacking end, with the slot on the stack side. These three hoods each exhausted about 4000 cfm with an average face velocity of 1450 cfm.

The four supply-air outlets were positioned at the outer corners of the press platforms, aligned with the side of the platform about 5 feet from the end of each platform. The volumetric flow rates ranged from 900 to 1500 cfm with an average exit velocity of 410 ft/min.

Sampling Results

Table 8 shows that the personal and area time-weighted average concentrations on the east side of the press were higher than those on the west side. Short-term continuous sampling at various locations around the press, including near the press openings and at the work stations, showed levels ranging from approximately 0.5 ppm to slightly greater than 1 ppm. A detector-tube sample collected in the unloader's breathing-zone while panels were being unloaded indicated approximately 1 ppm.

Table 8. Feed-Through Press Time-Weighted Average Personal and Area Concentrations.

Grouping	Number of Samples	Average Concentration ppm	Standard Deviation ppm
West Area	3	0.20	0.11
Loader	2	0.13	0.07
Unloader	3	0.35	0.23
East Area	3	0.34	0.09

Discussion

The hoods above the openings control the emissions from the ends of the press and captured emissions at least 2 feet out from the openings. Except at the loading end, the general room airflow from west to east was not as prominent around the feed-through press. The loader stood in a mild flow from the panel lay-up area just beyond the west wall of the press room. Some fresh air was provided by the supply-air outlets, but these were too high and too far away from his work area to contribute much airflow directly into his breathing-zone.

Due to the location of this press and the position of the work stations with respect to the ambient airflow, the unloader was probably exposed to emissions for the shuttle press as well as from the hot panels being unloaded from the feed-through press. The hood above the end of the unloading platform captured much of the air rising from the stacks, but most of the air above the unloading platform drifted upward and toward the center of the room. On this side, not only were the supply-air outlets positioned away from the actual work station, but also the recently constructed stacking structure interfered somewhat with the supply airflow.

OTHER AREAS OF THE PLANT

Description

In a warehouse on the south side of the building, core-stock is stored and inspected by one worker to ascertain that the dimensions are as specified in the order. The core-stock warehouse, a room enclosing approximately 20,000 square feet, is mostly separated from the general plant by rooms along the south wall of the plant except for a 40- x 10-foot passageway opening.

In the west half of the plant, the veneer sheets are prepared for panel lay-up. After the veneer strips have been trimmed, glue is applied to the edges by one worker who sprays the side of a stack of the strips. This operation uses a high-solids U/F adhesive, different from the glue used in laminating the panels.

In the panel lay-up area, the panels are prepared for pressing by one of the three glue-spreader crews. Three people are assigned to each glue spreader. The appropriate layers are passed through the glue spreader, and the stack of panels is built-up like a pile of sandwiches. The stack is moved to the loading end of a press on roller conveyors.

On an elevated platform constructed over this area, glue for panel lamination is mixed. One worker is responsible for mixing the U/F adhesive used for flat panels.

Controls

There are four wall fans and two ceiling fans for the warehouse. The veneer edge-glue spraying is performed on a cart about 3 feet in front of a spray booth, with the spray directed towards the booth. The other areas of the plant have only the building HVAC system, except when equipment is fitted with local exhaust ventilation for dust control.

Sampling Results

Personal and area time-weighted average concentrations indicated that the levels in these and probably other general plant areas were very low, averaging less than 0.2 ppm over the 3-day sampling period. In the lunch room and the veneer inspecting department, all samples were below the reported limit of detection for the analytical procedure. A detector-tupe sample indicated less than 0.5 ppm in the worker's breathing-zone while spraying the high-solids U/F adhesive on the edges of veneer stips.

CONCLUSIONS AND RECOMMENDATIONS

The control system at this plant is effective. All sampling results were low compared to existing standards. None of the personal or area time-weighted average concentrations exceeded 0.5 ppm averaged over the 3-day sampling period. More importantly, continuous and short-term sampling showed that peak exposures were well controlled, none being measured in excess of 3 ppm. These levels were achieved with a combination of area and local exhaust ventilation, exhausting a total of less than 100,000 cfm from the press room, and supply-air ventilation, infusing approximately 18,000 cfm into the primary work area of the press workers. Daily production during this period averaged about 10,000 square feet of panels per press.

There are a number of features which contribute to the success of this system. In addition to the LEV, each press has some type of partial enclosure. The building's HVAC system provides adequate tempered replacement air, some of which is supplied into the breathing-zone area of each press work-station.

An operating press will emit formaldehyde on all four sides. The mixture of formaldehyde vapor, air, and steam given off from the press will naturally rise somewhat because initially it is hot. But the hot vapors can cool quickly, and, even when rising, they are easily carried away by cross-drafts. Enclosing the press blocks cross-drafts, channels the emission upward, and retains some heat so the rising air leaves the top of the press with a higher velocity carrying it up to the ceiling where the general area ventilation can remove it from the building. Doors in the sheet-metal enclosure permit access to the equipment for maintenance.

Placing flanged LEV hoods above the opening of each press controls emissions on the opening ends without obstructing the openings. In this plant, the slots were sized to draw an average face velocity of 1500 ft/min and to exhaust at least 500 cfm per foot of press-opening width. In fact, this configuration draws air from up to 2 feet from the edge of the slot, exhausting some of the emissions from the hot panels while they are still on the unloading platform.

The hoods above the stacks are potentially good for exhausting much of the formaldehyde given off by the hot panels until the stack of panels is moved to the cooling and staging area at the back of the room. They also provide some additional ventilation for the unloading area. These hoods exert better control over air around the stack when they are closer to the top of the stack.

The curtains around the pressed-panel unloadng/stacking area of the ten-opening press add to the effectiveness of the controls--although this cannot be proven from the survey data due to the relatively high variablilty of the concentrations measured compared to the generally low levels and to the absence of strong cross-drafts in the press room. Not only do they block room air currents which could carry emissions out into the plant before they were exhausted through one of the hoods, but they also reduce the area from which the ventilation draws air, increasing the average velocity through the regions where airflow is desired.

The supply-air ventilation is an exemplary feature. The local exhaust ventilation cannot draw air from all areas where formaldehyde is emitted. Unfortunately, the breathing zones of the workers while performing their jobs are usually among those areas difficult to control with any type of exhaust ventilation. Supplying tempered air from properly positioned outlets above the workers cleanses their breathing-zone with fresh air and pushes air towards the local exhaust ventilation while reducing the heat stress from working around the press.

RESEARCH RECOMMENDATIONS

It is possible that the supply-air outlets are not optimally configured. There is little information available on the design of this type of system. Such a system could be useful in many situations where the source covers a large area and adequate local exhaust ventilation would interfere with the work. Research is needed on the quantity of air to supply, the location of the outlets with respect to the worker and the work station, the velocity and direction of flow of the airstream, and the temperature and humidity of the supplied air.

Appendix A. Survey Sampling Data

Table A-1. Personal Samples.

Worker	Date mo/dy/yr	Sample Lot	Sample No.	Volume liters	Duration minutes	Concentration ppm
10-o Press Loader N	09/21/82	17	88	26.9	489	0.17
	09/22/82	3	10	25.1	533	0.17
	09/23/82	10	332	22.5	501	0.18
10-o Press Loader S	09/21/82	17	94	26.9	489	0.23
	09/22/82	3	3	23.8	507	BDL*(0.17)
	09/23/82	10	330	23.5	499	BDL(0.17)
10-o Press Unloader N	09/21/82	17	86	22.2	482	0.48
	09/22/82	3	13	5.7	514	**
	09/23/82	12	28	27.2	503	BDL(0.14)
10-o Press Unloader S	09/21/82	17	93	24.4	487	0.21
	09/22/82	3	14	22.3	496	0.38
	09/23/82	10	329	22.6	502	0.23
6-o Press Loader N	09/21/82	17	100	23.5	469	0.22
	09/22/82	3	12	26.9	508	BDL(0.15)
	09/23/82	10	334	16.0	445	**
6-o Press Loader S	09/21/82	17	95	22.0	469	0.23
	09/22/82	3	17	24.9	509	0.26
	09/23/82	12	26	23.6	503	0.20
6-o Press Unloader N	09/21/82	17	99	21.5	467	0.55
	09/22/82	3	15	21.0	524	**
	09/23/82	10	336	23.9	509	0.31
6-o Press Unloader S	09/21/82	3	21	10.5	310	**
	09/22/82	3	18	14.9	532	**
	09/23/82	10	335	23.2	505	0.25
F-T Press Loader	09/21/82	17	89	3.4	479	**
	09/22/82	3	4	22.6	503	0.18
	09/23/82	10	333	25.9	488	BDL(0.15)
F-T Press Unloader	09/21/82	17	87	23.6	481	0.51
	09/22/82	3	6	20.7	506	0.44
	09/23/82	10	343	22.2	493	BDL(0.18)
Shuttle Press Operator W	09/21/82	17	90	21.7	482	0.30
	09/22/82	3	2	15.9	332	**
	09/23/82	10	331	22.0	488	0.31

Table A-1. Personal Samples (continued)

Worker	Date mo/dy/yr	Sample Lot	Sample No.	Volume liters	Duration minutes	Concentration ppm
Shuttle Press Operator E	09/21/82	17	84	22.8	474	0.51
	09/22/82	3	5	9.0	188	**
	09/23/82	10	341	19.7	492	0.27
Expeditor	09/21/82	17	96	21.6	470	0.52
	09/22/82	3	1	22.1	480	0.41
	09/23/82	10	328	25.9	507	0.28
Material Handler	09/21/82	17	92	21.5	447	BDL(0.18)
	09/22/82	3	19	17.2	479	BDL(0.23)
	09/23/82	12	30	24.8	460	BDL(0.16)
Glue-mix Worker	09/21/82	17	81	18.1	441	BDL(0.22)
	09/22/82	3	16	22.3	465	BDL(0.18)
	09/23/82	10	344	17.5	460	**
Glue Spreader Worker A	09/21/82	17	85	19.7	440	0.26
	09/22/82	9	305	25.4	470	BDL(0.16)
	09/23/82	12	31	19.9	462	BDL(0.20)
Glue Spreader Worker B	09/21/82	17	83	17.4	445	0.23
	09/22/82	3	11	25.1	464	BDL(0.16)
	09/23/82	12	27	22.1	460	BDL(0.18)
Glue Spreader Worker C	09/21/82	17	82	21.3	443	0.26
	09/22/82	3	7	21.1	469	BDL(0.19)
	09/23/82	12	29	22.6	462	0.22
Forklift Driver	09/21/82	17	98	23.8	440	BDL(0.17)
	09/22/82	3	8	25.8	496	BDL(0.15)
	09/23/82	10	327	22.5	478	BDL(0.18)
Quality Control Inspector	09/21/82	17	91	21.0	447	0.20
	09/22/82	3	9	22.8	495	BDL(0.17)
	09/23/82	10	326	24.0	490	BDL(0.16)

* Below Detection Limit (Limit of Detection is value in parentheses)

** Problem with sample, resulting concentration not representative of a full-shift time-weighted average.

Table A-2. Area Samples.

Worker	Date mo/dy/yr	Sample Lot	Sample No.	Volume liters	Duration minutes	Concentration ppm
Lunch Room	09/21/82	16	53	20.2	420	BDL*(0.20)
	09/22/82	9	318	24.1	502	BDL(0.16)
	09/23/82	12	42	24.0	500	BDL(0.16)
Inspection Department	09/22/82	9	314	21.2	472	BDL(0.19)
	09/23/82	12	40	25.3	496	BDL(0.16)
Spray Booth	09/21/82	16	52	18.9	420	BDL(0.21)
	09/22/82	9	308	25.5	500	BDL(0.15)
	09/23/82	12	41	23.0	499	BDL(0.17)
Glue-mix Platform	09/21/82	16	57	18.0	384	BDL(0.22)
	09/22/82	9	303	21.7	433	BDL(0.18)
	09/23/82	16	73	22.5	468	BDL(0.18)
Glue Spreader Area	09/21/82	16	65	19.3	378	BDL(0.21)
	09/22/82	9	300	20.5	437	BDL(0.19)
	09/23/82	12	34	22.9	467	BDL(0.17)
Press Room Area 1	09/21/82	16	58	20.8	442	0.30
	09/22/82	9	313	24.4	461	0.22
	09/23/82	16	74	25.2	514	BDL(0.16)
Press Room Area 2	09/21/82	16	54	18.8	401	BDL(0.21)
	09/22/82	9	306	22.5	499	0.20
	09/23/82	12	38	23.8	506	0.24
Press Room Area 3	09/21/82	16	59	23.0	434	0.23
	09/22/82	9	312	23.1	491	0.26
	09/23/82	12	44	23.0	511	0.17
Press Room Area 4	09/21/82	16	51	19.1	424	0.26
	09/22/82	9	316	24.5	501	0.25
	09/23/82	12	37	24.2	504	0.29
Press Room Area 5	09/21/82	16	62	20.8	434	0.37
	09/22/82	9	301	23.9	498	0.41
	09/23/82	12	43	25.5	509	0.23
Press Room Area 6	09/21/82	16	60	20.4	425	0.27
	09/22/82	9	309	25.6	501	0.32
	09/23/82	16	75	25.9	508	0.33
Press Room Area 7	09/21/82	16	63	20.9	435	BDL(0.19)
	09/22/82	9	315	23.5	501	0.33
	09/23/82	12	36	24.4	509	0.33

Table A-2. Area Samples (continued)

n	Date	Sample		Volume	Duration	Concentratio
Worker	mo/dy/yr	Lot	No.	liters	minutes	ppm
Press Room Area 8	09/21/82	16	69	10.3	205	**
	09/22/82	9	317	24.0	499	0.19
	09/23/82	12	39	25.8	506	0.21
Sanding Room Area	09/22/82	9	310	22.1	480	0.22
	09/23/82	12	45	23.1	492	BDL(0.17)
Cold Press Area	09/21/82	16	56	19.5	383	BDL(0.20)
	09/22/82	9	304	24.9	509	0.20
	09/23/82	12	33	22.2	493	BDL(0.18)
Warehouse Area A	09/21/82	16	64	21.2	432	0.20
	09/22/82	9	307	23.2	484	BDL(0.17)
	09/23/82	12	32	24.3	506	BDL(0.16)
Warehouse Area B	09/21/82	16	61	20.8	434	BDL(0.19)
	09/22/82	9	302	23.5	489	BDL(0.17)
	09/23/82	12	35	23.7	505	BDL(0.17)

* Below Detection Limit (Limit of Detection is value in parentheses)

** Problem with sample, resulting concentration not representative of a full-shift time-weighted average.