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Validation of Models for Predicting Formaldehyde Concentrations in Residences Due to Pressed Wood Products Phase I

Richard A. Grot
Samuel Silberstein
Kunimichi Ishiguro

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
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Center for Building Technology
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Validation of Models for Predicting Formaldehyde Concentrations in Residences due to Pressed-Wood Products
Phase I

Richard A. Grot
Samuel Silberstein

Kunimichi Ishiguro
Guest Worker
Taisei Corporation, Tokyo, Japan

Abstract

This interim report describes procedures and presents results of the first phase of a laboratory project undertaken at the National Bureau of Standards for the Consumer Product Safety Commission (CPSC). The purpose of the ongoing project is to assess the accuracy of emission and indoor air quality models to be used by CPSC in predicting formaldehyde (HCHO) concentrations in residences due to pressed-wood products made with urea-formaldehyde bonding resins, namely particleboard underlayment, hardwood-plywood paneling and medium-density fiberboard (MDF). In phase I, these products were characterized in "medium-size" dynamic measuring chambers by measuring their HCHO surface emission rates over a range of HCHO concentrations, at 23°C and 50% RH. They were then installed in a two-room prototype house and the equilibrium HCHO concentrations were monitored as a function of air exchange rate. Excellent agreement was obtained between measured HCHO concentrations and those predicted by a mass-balance indoor air quality model. In the next phase, the study will be repeated at various different temperatures and relative humidities so that models predicting HCHO surface emission rate as a function of temperature and humidity can be tested.

Key words: Formaldehyde; indoor air quality; modeling; paneling; particleboard; plywood; tracer gas; underlayment.

Disclaimer

"Certain commercial equipment, instruments, or materials are identified in this paper in order to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose."

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NOMENCLATURE

A^* and B^* are coefficients, given in tables 23-25, for the linear regression equation:

$$ER = A - B \cdot C$$

AI = air exchange rate, h^{-1}

$$AI = AI + \sum_{i=1}^{n} AREA_i \cdot B_i / g \cdot V$$

$AREA^*$ = area of board, m^2

C = C(t) = HCHO concentration in chamber or prototype house

$C_{eq} = \lim_{t \to \infty} C(t)$

C_{ext} = chamber-background HCHO concentration, ppb

C_o = initial HCHO concentration, ppb

C_s = HCHO concentration in the span gas

e = emission rate of HCHO from permeation tube, ng/min

F = air flow rate through gas standards generator, L/min

g = the density of HCHO, mg/cm^3 (= MW_{HCHO}/V_g)

MW_{HCHO} = molecular weight of HCHO, 30.03

R = HCHO concentration monitor reading for chamber or prototype house

R_o = HCHO concentration monitor reading for zero air

R_s = HCHO concentration monitor reading for span gas

SER^* = HCHO surface emission rate, $mg/m^2 \cdot h$

SER_{100} = HCHO surface emission rate for C = 100 ppb, $mg/m^2 \cdot h$

V = volume of enclosure, m^3

V_g = volume occupied by 1 kg-mole of HCHO at 25°C, 24.45 m^3

*Subscript "i" indicates "for the ith emitter."

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1. Introduction

Formaldehyde (HCHO) has been implicated as an indoor air pollutant causing both irritation and damage to health [1, 2]. A principal source in residences, at present, is pressed-wood products made of urea-formaldehyde bonding resins, such as particleboard, plywood and medium-density fiberboard (MDF) [1].

One would like to be able to predict a house's HCHO concentration from a characterization of the pressed-wood products inside it. Characterizing pressed-wood products is a complicated task, however, as the HCHO surface emission rate depends on temperature, relative humidity (RH), ambient HCHO concentration, as well as the history of the product [3-5]. Fick's diffusion law, which states that the rate of diffusion between two spaces is inversely related to the concentration gradient between them, implies that HCHO surface emission rate is linear in concentration, with negative slope. Oak Ridge National Laboratory (ORNL) confirmed this model for pressed wood products (except possibly for paneling). ORNL then derived an empirical HCHO emission-rate model that generalized Fick's Law model, predicting surface emission rates of pressed wood products at nearby combinations of ambient temperature, RH and HCHO concentration from knowledge of the surface emission rate under standard conditions, that is 23°C, 50% RH, and HCHO concentration of 100 ppb [3-5]. To obtain the surface emission rate under standard conditions, a series of surface emission rate measurements is made at standard temperature and RH and varying HCHO concentrations straddling 100 ppb. The surface emission rate is interpolated to 100 ppb. If boards can be adequately characterized by one or both emission models, the next step is to test whether an air quality model based on mass balance can be used to predict HCHO concentration in a residence, and to modify both emission and air quality models to improve their predictive performance if they are inadequate.

The Consumer Product Safety Commission (CPSC) requested that the National Bureau of Standards (NBS) validate the emission model based on Fick's diffusion law, the ORNL generalization of this model, and test a simple mass-balance indoor air quality model. ORNL previously tested the emission models in "small-size" chambers having a volume of 7 ft^3 (0.2 m^3) that required that the pressed-wood products, which are usually installed as intact 4' x 8' (1.2-m x 2.4-m) boards, be cut into much smaller pieces. CPSC built "medium-size" dynamic measuring chambers, whose internal dimensions are 4' x 8' x 2' (1.2 m x 2.4 m x 0.6 m), for a volume of 64 ft^3 (1.8 m^3), which are large enough to accommodate intact boards for board characterization. NBS built a a two-room prototype house (or "large-size" dynamic measuring chamber) whose internal dimensions are 10' x 20' x 8' (3 m x 6 m x 2.4 m), for a volume of 1600 ft^3 (45 m^3), to validate the models' ability to predict HCHO concentrations in residences.

Twelve medium-size dynamic measuring chambers were installed, and the prototype house was built, in an environmental chamber at NBS, in which temperature and RH can be carefully controlled. The general procedure used in this experimental project was to 1) condition the pressed-wood products; 2) characterize their surface emission rates in the medium-size dynamic measuring chambers by varying the air exchange rate to obtain different HCHO concentrations; and 3) install them in realistic combinations in the prototype house, vary the air exchange rate over a range encountered in normal houses (about 0.1 to 1 h^{-1}) and compare the resulting HCHO concentrations with those predicted from the medium-size dynamic measuring chamber results using a mass-balance indoor air quality model. The surface emission rates are determined by automated equipment that measures air exchange rates by the decay of sulfur hexaflouoride (SF_6) tracer gas concentration, and measures HCHO concentrations. The experiments reported here are the first phase of the study. See appendix A for the experimental plan. In phase I, HCHO surface emission rates of pressed wood products were measured at "standard" temperature and RH, to characterize their emission properties. The mass-balance model was then able to predict successfully prototype house HCHO concentrations from those measured in the medium-size dynamic measuring chambers. In the future, these experiments will be repeated at different combinations of temperature and RH in order to test the ability of the ORNL emission model to predict surface emission rates under nonstandard conditions from those under standard conditions.

In phase I, the surface emission rates obtained in the medium-size dynamic measuring chambers were also compared to those measured by HCHO surface emission monitors (FSEM) developed by ORNL. It was found that the surface emission rates measured by FSEMs agreed only qualitatively, at best, with those measured in the medium-size dynamic measuring chambers.

2. Medium-Size Dynamic Measuring Chambers for Determining the Emission Rates of Individual Product Specimens

The medium-size dynamic measuring chambers for determining the HCHO surface emission rates of individual pressed-wood products are shown schematically in figure 1. The chambers are 8′6" (2.6 m) long by 4′6" (1.4 m) wide by 2′ (0.6 m) high. Interior dimensions and volume are given above. The chambers were constructed of 3/4" 20-mm exterior grade plywood. All inner exposed surfaces were lined with teflon sheets to minimize HCHO sorption. The outer surfaces were painted with a fireproof paint. The tubing used for this system was 1 1/2" (38-mm) PVC drain pipe. Two small DC fans with a rated capacity of 15 ft^3/min were (7 L/s) installed at both ends of the chambers to supply and exhaust the air. Three valves in the system controlled the amount of air brought in, exhausted and recirculated. The DC fans permitted the air velocity to be controlled by varying the voltage to the fans but this was not done. The fans were run at constant speed and the air exchange rate was controlled by the three valves in order to try to maintain a constant air velocity over the sample. The outlet valve was usually adjusted to slightly pressurize the chamber, thus assuring that the air entered only through the inlet.

An air-flow meter was attached to the inlet. This flow rate was used only for adjustment, but not the determination, of the air exchange rate, which was done using a tracer-gas decay method. Sulfur hexafluoride tracer gas was injected into the inlet of the chamber and sampled at the outlet. The sampling and injection lines were 1/8" (3-mm) O.D. nylon tubing. The HCHO concentration was sampled at the outlet using 3/16" (5-mm) O.D. FEP-teflon tubing. Air was supplied and exhausted by manifolds, which were made of two 40" (1-m) lengths of 1 1/2 (38-mm) PVC tubing teed together and capped at the ends. Eight 1/8" (3-mm) holes were drilled around the circumference of the tubing at 6" (15-cm) intervals. Thus air entered and left the chamber in a circular pattern along a 1-m long tube, and not at single points.

Good air mixing within the chambers was demonstrated as follows. The first chamber constructed had one side made of plexiglass to permit smoke visualization of the air-flow pattern. The smoke density quickly became uniform in the chamber and there were no dead spots.

3. The Two-Room Prototype House

The two-room prototype house constructed in the environmental chamber is shown schematically in figure 2. The interior dimensions and volume are given in the introduction. The two equal-sized rooms are connected by a doorway which was left open during the testing. The side walls of the prototype house were constructed of 1 1/2" x 4" (4-cm x 10-cm) framing 16" (40 cm) on center. The floor and ceiling were constructed of 2" x 5" (5-cm x 25-cm) framing 12" (60 cm) on center. The floor was made of 1 1/2" (2-cm) exterior plywood. The floor, ceiling and sidewalls were covered with a 4-mil (0.1-mm) polyethelyne vapor barrier overlapped at the edges. Over this was applied 1/2" (13-mm) gypsum board on 1/2" (13-mm) firring strips. Six of the sheets of gypsum board were screwed in place to facilitate removal later if necessary. The prototype house had two supply registers and two return registers, one near the ceiling and one near the floor of each room. Two duct-booster fans were used to supply and exhaust air. A recirculation loop was included in the air-handling system and the system was balanced by three dampers, one in the inlet, one in the outlet, and one in the recirculating loop. Thermistors and 3/16" (5-mm) FEP teflon air-sampling tubes were installed in the center of each room at heights of 2′ (0.6 m), 4′ (1.2 m), and 3′ (1.8 m), and in the inlet and exhaust air. The temperature and RH were also monitored in each room using chart recorders. In general HCHO was sampled by the computer-based instrumentation system at the inlet, outlet and one height in each room at a time. Two air-flow meters installed in the inlet and outlet airstreams were used only for adjustment of the air exchange rate. The actual room air exchange rate was determined using the tracer decay method. Sulfur hexafluoride was injected into the inlet air and sampled in the outlet air using 1/8" (3-mm) nylon tubing. Additional 1/8" (3-mm) nylon tubing was installed in each room at the same locations as the air-sampling tubing above to allow checking of stratification, but have not been used to date.

4. Description of the Instrumentation System

A HCHO surface emission-rate measurement system was constructed by linking an airborne HCHO concentration monitor (a TGM-555 air monitor fitted with with a HCHO analytical module) to a computer-based NBS automated tracer-gas decay system used to measure air exchange rate, and writing programs to automate collection and storage of HCHO concentration data as well. One HCHO surface emission-rate measurement system each was used for the prototype house and for the medium-size dynamic measuring chambers. Figures 3 and 4 give schematic descriptions of the two systems.

Details of the instrumentation are given in appendices B and C. Experimental protocols for calibrating and using the equipment are given in appendix D. Listings of the programs, and their subroutines are given in appendices E and F. The basic algorithms of these two monitoring programs (one for the medium-size dynamic measuring chambers, the other for the prototype house) are the same. Formaldehyde concentrations of the zero air, span gas, and environmental chamber background are monitored by each HCHO concentration monitor by automatically opening appropriate sampling ports. ("Zero air" and "span gas" are explained in section 5 below and in appendix D.) One monitor then measures

HCHO concentration of three medium-size dynamic measuring chambers, while the other monitor measures those of the outlet and one location in the center of each room of the prototype house. Each site is monitored for 15 minutes because of the duration of the delay time of the HCHO concentration monitor. Sulfur hexafluoride concentration is monitored every 5 minutes in the prototype house, the large environmetal chamber and 3 medium-size dynamic measuring chambers. During this 90-minute sequence, analogue data (temperature and air-flow rates) are monitored approximately each second and a 90-minute average is calculated. Similarly, one-minute average HCHO concentration readings are calculated. The one-minute averages are averaged over the interval specified by the delay and averaging times. The HCHO concentration is determined from:

$$C = C_s \cdot \frac{R-R_o}{R_s-R_o} \qquad (1)$$

where

C = HCHO concentration in chamber or prototype house
C_s = HCHO concentration in the span gas
R = HCHO concentration monitor reading for chamber or prototype house
R_o = HCHO concentration monitor reading for zero air
R_s = HCHO concentration monitor reading for span gas

At the start of each 90-minute measurement cycle, the systems determine SF_6 concentration and inject the required amount of tracer gas to bring it up to 300 ppb in the prototype house, and 60 ppb in the medium-size dynamic measuring chambers (approximate saturation concentrations of each gas chromatograph). Air exchange rates are calculated by linear regression analysis of log (SF_6 concentration) against time. The data collected in each 90-minute sequence are displayed on the computer video display as they are collected, and recorded on a data disk.

5. Calibration and Use of Equipment

The HCHO concentration monitor measures HCHO concentration by a modified of pararosaniline procedure [2, 6-8]. The preparation and use of reagents, and the calibration of the monitor are described in appendix D.

Formaldehyde concentrations were measured automatically using the HCHO concentration monitor. An air sample stream is continuously pumped into the monitor at a fixed air flow rate between about 0.5 and 1.0 L/min and scrubbed with pararosaniline-HCl solution. Sodium sulfite solution and water are then added, resulting in a pararosaniline concentration of 0.013% in 67 mN HCl, and a Na_2SO_3 concentration of 0.17 g/l (1.3 mM). The mixture reacts for about eight to ten minutes as it is pumped through a coil to a photometer, where its absorbance at a wave length of 570 nm relative to a pararosaniline-HCl blank is measured.

In order to calibrate the HCHO concentration monitor, HCHO-free "zero air" and "span gas" contaning a known concentration of HCHO must be supplied. Span gas was prepared by heating a permeation tube containing polyoxymethylene, a HCHO polymer, at 80°C in the oven of a gas standards generator and passing a HCHO-free airstream over it. Polyoxymethylene decomposes into HCHO when heated.

The polymer is sealed in teflon, which is slightly permeable to HCHO [9]. (The teflon lining the medium-size dynamic measuring chambers did not absorb formaldehyde during the tests; data not shown.) The detailed preparation of zero air and span gas is described in appendix D. The span gas concentration was calculated by the following equation:

$$C_s = (V_g/MW_{HCHO})\cdot e/F \qquad (2)$$

where

MW_{HCHO} = molecular weight of HCHO, 30.03
V_g = volume occupied by 1 kg-mole of HCHO at 25°C, 24.45 m^3
e = emission rate of HCHO from permeation tube, ng/min
F = air flow rate through gas standards generator, L/min

The air flow rate, F, was determined by both a wet test meter and a gas flow meter to be 2.37 L/s (data not shown). Weighing the permeation tubes approximately monthly for 4 months gave an emission rate, e, of 192 ng/min (see figure 5), with $r^2 = 0.998$. Equation 2 thus gives a concentration of 66 ppb for the two permeation tubes used simultaneously. It is estimated from the value of r^2 and the agreement between two flowmeters that the errors in e and C_s are of the order of 1%. It can be seen from figure 5 that the emission rate is stable during the measuring interval.

Prior to the experiment shown in figure 5, a stable emission rate from the two permeation tubes used was shown as follows. A series of permeation tubes having a wide range of HCHO emission rates was kept at room temperature, except for the two tubes used in the gas standards generator. In order to ensure that the emission rate of these two tubes had not changed appreciably after about three months of continuous use, the emission rate of the two tubes was compared with those of the other tubes that were presumably still emitting HCHO at their initial rates. As shown in figure 6, a linear relationship, determined by linear regression analysis, still held between measured HCHO concentrations and the nominal emission rates supplied by the manufacturer. This was consistent with the manufacturer's claim that these tubes emit stably for more than two years at 80°C. Because this procedure only showed consistency among tubes, but did not yield absolute emission rates, it was supplanted by weighing the tubes periodically, as described above.

The two electron-capture detectors were calibrated as described in appendix D. The calibration curves for each instrument are shown in figures 7 and 8.

6. Formaldehyde Surface Emission Rates of the Pressed-Wood Products

The pressed-wood products used in the study were supplied by various manufacturers and trade asssociations as 4′ x 8′(1.2-m x 2.4-m) boards (area 32 ft^2 (3.0 m^2)). The underlayment came from one manufacturing plant, the MDF from another. The hardwood-plywood overlays of the paneling came from a single plant, but each paneling board was fabricated from blanks from one of two different plants. The MDF was cut into four 2′ x 4′ (0.6-m x 1.2-m) pieces at NBS, which were made into "table tops" by covering all edges and one side of each with formica.

The pressed-wood products were conditioned at 23 °C and 50% RH for about one month. Their HCHO surface emission rates were then measured ("first test") in the medium-size dynamic measuring chambers as a function of HCHO concentration. Most of the specimens were then placed into the prototype house as described below and in appendix D. About a month later, the boards were removed from the prototype house, measured again in the medium-size dynamic measuring chambers ("second test"), and replaced into the house. They were then measured again after completion of the measurements in the prototype house ("third test"). Between the first and second tests, underlayments 5 and 12 were cut into several pieces in order to cover the floor of the prototype house completely with underlayment. Underlayment 18 was not placed into the prototype house but was measured twice; its "first test" was measured at about the same time as the second tests of the remaining underlayment, its "second test" at the same time as the third tests of the remaining underlayment. Paneling was measured only before ("first test") and after ("second test") being placed into the prototype house.

During each test, HCHO concentration was controlled only by varying the air exchange rate. The HCHO concentrations ranged from less than 100 ppb to over 400 ppb. A sufficient number of 90-minute cycles was run for each air exchange rate to ensure that the HCHO concentrations were stable. (The experimental protocols (appendix D) describe what is meant by "stable.") Once HCHO concentrations stabilized, they were averaged together. Air exchange rates were also averaged together after stabilization. According to the expermental protocols, air exchange rate measurements were discarded if the SF_6 concentration in the environmental chamber exceeded 10% of the SF_6 concentrations in the prototype house or any medium-size dynamic measuring chamber. In practice, the concentration in the environmental chamber rarely exceeded 0 ppb. Formaldehyde surface emission rates were then calculated according to the following equation:

$$SER = MW_{HCHO} \cdot 10^{-3} / V_g \cdot C \cdot (V/AREA) \cdot AI \qquad (3)$$

where

SER = HCHO surface emission rate, $mg/m^2 \cdot h$
V = volume of enclosure, m^3
AREA = area of board, m^2
AI = air exchange rate, h^{-1}

(Note: Although the actual temperature may have been several degrees higher or lower than 25°C, V_g was not corrected because it would have changed by less than 2% for a 5°C excursion in either direction.)

For each board, HCHO surface emission rate was assumed to be linear in concentration, in accordance with Fick's diffusion law. The straight line was derived by calculating slope and intercept by linear regression analysis. The HCHO surface emission rate at a concentration of 100 ppb, SER_{100}, and the cutoff concentration, that is the concentration at which SER = 0 $mg/m^2 \cdot h$, were then calculated. The results of these tests are given in tables 1 to 38 and figures 9 through 39.

Formaldehyde surface emission rates were also measured by FSEMs, whose use is described elsewhere [10]. The results of the FSEM measurements are given in table 39. Comparison of the FSEM measurements and the medium-size dynamic measuring chamber measurements is given in table 40. Although there is considerable variation in the data for each product, the surface emission rates clearly decay from 8/28/84, during the conditioning period, until 10/2/84, when the first series of medium-size dynamic measuring chamber tests was begun, as expected. The HCHO surface emission rates measured by FSEM reached their minimum value on 10/25/85, after the first series of tests was completed and just after the boards were placed into the prototype house, and then increased several fold for the two underlayments measured, 2 and 10. This is in contrast to the surface emission rates for underlayments 2 and 10 measured in the medium-size dynamic measuring chambers which remained nearly constant (see figures 9 and 18). Note that even the lowest average surface emission rate for all spots, 0.17 $mg/m^2 \cdot h$, was more than 40% greater than 0.12 $mg/m^2 \cdot h$, the average surface emission rate for all uncut boards for all medium-size dynamic measuring chamber data. Thus the FSEM measurements behaved as expected in a qualitative manner as long as they were done in a location nearly free of ambient HCHO. It is unknown why the surface emission rates apparently increased when they were measured by FSEM in the house; the high background concentration may be responsible.

The results for the medium-size dynamic measuring chambers are summarized in tables 36-38. It was found that HCHO surface emission rates decreased as HCHO concentration rose for all specimens tested. The relationship could be described well by a straight line for underlayment and table tops, as predicted by Fick's diffusion law.

The results for particleboard underlayment are presented in tables 1-18 and figures 9-24. They are summarized in table 36. Because HCHO surface emission rates were measured over an insufficient range of concentrations during the first tests of underlayment 2 and 10, and the few measurements were entirely consistent with those of the second test (see figures 9 and 18), the data were combined in tables 1 and 12, respectively. Among uncut underlayment, SER_{100} may have increased between the first and second tests only for underlayments 8 and 9, but the increase for underlayment 8 does not appear convincing because of the overlap of the data for the two tests (figure 14). The increase for underlayment 9 is more convincing (see figure 16), but is difficult to explain. Underlayment 9, and perhaps underlayment 8 as well, may have absorbed HCHO in the relatively high background concentration of the prototype house (70 to 200 ppb), but one would then have expected this to occur for underlayment 2 and 10 as well. It is true that the first test was incomplete for boards 2 and 10. However, HCHO surface emission rates were measured at low concentrations for these two boards in the first test, and they agreed with those measured in the second test (see figures 9 and 18). It is at low concentrations that the surface emission rate for board 9 increased the most. A possible explanation of the anomalous results for underlayment 9 is that the first test was performed before there was much experience with the automated system, and thus might have been flawed. Thus, except for underlayment 9, the relationship between surface emission rate and concentration appeared to be be stable between the first and second tests. Specifically, no further decay in surface emission rates took place in the prototype house. Between the second and third tests, SER_{100} and the cutoff concentration increased to some extent for all uncut underlayment (see figures 9-10, 14-19). While the increases were hardly dramatic, one would have expected them to increase or decrease randomly if the explanation were data scatter. The increases may be due to absorption of formaldehyde in the prototype house. For underlayment 18, which was not placed into the prototype house, SER_{100} and the cutoff concentration did not increase (and may even have decreased, but only slightly) between the first and second tests (figures 23-24). For all three tests, the cutoff concentration was about 260 ppb for uncut boards and SER_{100} was about 0.12 $mg/m^2 \cdot h$.

For cut underlayments 5 and 12, the cutoff concentrations decreased between the first and second tests, while the SER_{100}'s nearly doubled (see figures 11-12 and 20-21). The SER_{100}'s then decreased about 25% by the third test, while the cutoff concentrations rose slightly (see figures 13 and 22). It appears that cutting underlayment markedly stimulated HCHO emission from the edges of the boards. As this release continued, it depleted the HCHO reservoir so that the surface emission rate declined between the second and third tests, more than compensating for any increase in surface emission rate that might have been caused by absorbtion of HCHO in the prototype house.

The results for paneling are presented in tables 19-27 and figures 25-33. They are summarized in table 37. A striking feature of paneling, even from the same manufacturer was the nonuniform behavior of paneling boards even from the same manufacturer. This can be seen clearly by the wide range of cutoff concentrations in table 37. Before being placed into the house, paneling 6 and 8, both from manufacturer #1 behaved similarly (see figures 25 and 27); surface emission rate varied linearly with concentration, SER_{100} was about 0.03 $mg/m^2 \cdot h$ (about one quarter that of underlayment), and the cutoff concentration was just over 300 ppb. For paneling 14 (see figure 32), also from manufacturer #1, the surface emission rate fell sharply as the concentration rose, and then leveled off, much like a hyperbola of the form SER = constant/C. Only paneling 6 and 8 were placed into the prototype house; their surface emission rates declined when measured after removal from the prototype house (see figures 26 and 28). Their cutoff concentrations declined to the region of 100 ppb, making it either impossible to calculate SER_{100} (paneling 6), or ensuring that its indeterminacy would be as great as its value, judging by the standard error (paneling 8). The decline in surface emission rates can be attributed to further HCHO decay, even in the high background concentrations of the prototype house. Because of the heterogeneity of the boards, composite data are of limited usefulness.

From manufacturer #2, paneling 9 in its second test (figure 30) and paneling 17 (figure 33) had surface emission rates somewhat like those of underlayment, but in a pattern like paneling 14 (figure 32), while paneling 10 had SER_{100} and cutoff concentration about twice as large as those for the first two boards and underlayment (figure 31). Only paneling 9 was placed into the prototype house. The data were so scattered before paneling 9 was placed into the prototype house (figure 29) that it is difficult to compare the results of the first and second tests. The most that can be said is that surface emission rates were in the same range for the two tests. Because of the scattered data in the first test for paneling 9 and the heterogeneous behavior of the 3 boards, the composite data are not of much value, as in the case of manufacturer #1.

The results for MDF table tops are presented in tables 28-35 and figures 34-39. They are summarized in table 38. The table tops behaved in a reasonably uniform manner, with an overall cutoff concentration of about 672 ppb. In the first tests it seemed that the 4 table tops' behavior was quite nonuniform; table tops 2 and 12 seemed to have slightly higher surface emission rates than table top 9 and about twice those of table top 24 (see figures 34, 36-37, and 39). The magnitudes of the slopes of table tops 2 and 12 were also much larger than those of the other two table tops during the first tests. During the second tests (figures 34 and 37), however, the surface emission rates of table tops 2 and 12 were a little lower than those of table top 24, and the magnitudes of the slopes decreased so that they were between those of table tops 9 and 24. After removal from the house, their surface emission rates behaved in a manner nearly identical to each other. Surface emission rates of table top 2 were intermediate to those of the first two tests; surface emission rates of table top 12 were similar to those found during the first test. Assuming there was no measurement error, one can postulate that further decay in HCHO concentration took place between the first and second tests, even in the high HCHO background concentrations of the prototype house, and that HCHO was absorbed between the second and third tests, just as it was for underlayment.

7. Comparison of Results to those Predicted by ORNL Emission Model

The ORNL emission model given by:

$$\frac{SER(T,RH,C_V)}{SER_{100}} = \qquad (4)$$

$$\frac{[1+B(T-296)] \cdot [1+E(RH-50)] \cdot [e^{-C(\frac{1}{T} - \frac{1}{296})} \cdot (RH/50)^A \cdot C_{B_{std}} - C_V]}{C_{B_{std}} - 0.1}$$

where

T = absolute temperature, K
RH = relative humidity, %
C_V = HCHO concentration, ppm
A, B, C, E, C_B are model coefficients

Note that A and B should not be confused with the A and B defined in the nomenclature section. Note also that the concentrations, C_V, are given in ppm, rather than in ppb, as in the rest of this paper. To use this model with $C_{B_{std}}$ and C_V in ppb, the "0.1" in the denominator must be replaced by "100."

Equation 4 contains five coefficients: A, B, C, E, and $C_{B_{std}}$. The best values of these that fit measured data were determined by ORNL by computer optimatization, not by any physical measurements, and the model is consequently not a physical one. In particular, ORNL attributes physical meaning to $C_{B_{std}}$ (calling it the "bulk-phase HCHO concentration"), but it is treated here only as a model parameter because the validity of ORNL's interpretation has yet to be demonstrated. Table 41 gives values of the five coefficients for paneling, underlayment, and medium-density fiberboard.

For standard temperature and RH, equation 4 becomes:

$$\frac{SER(C_V)}{SER_{100}} = \frac{C_{B_{std}} - C}{C_{B_{std}} - 0.1} \qquad (5)$$

where concentrations are expressed in ppm. To express concentrations in ppb, the "0.1" in the denominator must be replaced by "100."

Substituting appropriate values of ${}^{C}B_{std}$ from table 41 into equation 5, one obtains the following equations for underlayment, paneling and MDF, with concentrations in ppb:

$$SER/SER_{100} = 1.38 - 0.0038 \cdot C \text{ for underlayment} \quad (6)$$
$$SER/SER_{100} = 1.32 - 0.0032 \cdot C \text{ for paneling} \quad (7)$$
$$SER/SER_{100} = 1.12 - 0.00125 \cdot C \text{ for MDF} \quad (8)$$

Note that at standard temperature and RH for any board, the line predicted by ORNL is determined by two points: 1) C = 100 ppb, SER/SER_{100} = 1; and 2) C = cutoff concentration, SER/SER_{100} = 0. The cutoff concentration is invariant under normalization by SER_{100}, and as mentioned above, the data cannot even be formally normalized if the cutoff concentration is not greater than 100 ppb. In practice, the line is not well determined unless the cutoff concentration is substantially greater than 100 ppb. Since the standard deviation of HCHO concentration is usually of the order of about 10% (see tables 1-35), one would want the cutoff concentration to be at least 150 ppb, and would be even more comfortable with a cutoff concentration of 200 ppb.

The SER's for each specimen of underlayment, paneling (where meaningful), and table tops were normalized by division by the SER_{100} of that specimen. The SER/SER_{100}'s were plotted against HCHO concentration for each board, and also for all boards of a given type, for all tests before the end of the prototype house experiment, after the experiment, and both together. The SER/SER_{100}'s were calculated in this way even when composite data were plotted together, that is, the composite SER_{100}'s shown in tables 36-38 were not used. In practice, this should not be much different from dividing all SER's by composite SER_{100} if all the specimens in the combined set have similar cutoff concentrations. This was, in fact, found to be the case (data not shown; they will be presented in phase II). Because of the way the data were normalized, if SER_{100} cannot be calculated for even one specimen in a set, the data for the entire set cannot be compared to the ORNL model. Normalization was impossible for the data of the second test of paneling 6 (cutoff concentration 81 ppb; see figure 25) and the only test of paneling 14 (cutoff concentration 93 ppb; see figure 32), and meaningless for the data of the second test of paneling 8 (see figure 28; cutoff concentration 128 ppb). Hence, normalization was also impossible for combined data for paneling from manufacturer 1 without biasing the data by discarding data for boards for which SER_{100} was meaningless.

Normalized results are shown in figures 40-68 for individual boards. Figures 69-71 show normalized results for uncut underlayment before removal from the prototype house [including the first test of underlayment 18], after removal [including the second test of underlayment 18], and both before and after removal combined. Similar combinations of cut underlayment are shown in figures 72-74. As mentioned above, surface emission rates of combinations of paneling from manufacturer #1 could not be normalized. Figure 75 shows normalized results for paneling from manufacturer #2 before installation into the prototype house. The only paneling from manufacturer #2 measured after removal from the prototype house was paneling 9; this result is shown in figure 59. Figure 76 shows the combined results for paneling from manufacturer #2 before and after the prototype house experiment. Combinations of MDF table tops similar to those of underlayment are shown in figures 77-79.

At standard temperature and RH, SER/SER_{100} will automatically agree with the model in the neighborhood of 100 ppb; that this was found to be true here is no particular accomplishment of the model. What is noteworthy is that in nearly every case, the ORNL model consistently underpredicts the magnitude of the slope of the line fitting HCHO surface emission rate to concentration. (Equivalently, the ORNL model overpredicts the cutoff concentration, and underpredicts the HCHO surface emission rate at low concentrations.) The only specimens for which the magnitude of the slope was overpredicted are: paneling 9 before being placed in the house (figure 58), paneling 10 (figure 60), and table top 24 (figure 68). The data for paneling 9 before being installed in the prototype house are so scattered, as described above, that any comparison to any model other than possibly a random-walk model would be meaningless. For table top 24, HCHO surface emission rates were not measured for concentrations above 300 ppb; it is not valid to extrapolate the regression line much beyond 300 ppb. Thus there remains only one specimen for which the ORNL model unequivocally overpredicted the magnitude of the slope. The ORNL model predicted 0.0032, vs. 0.0023 obtained for paneling 10, an overprediction of about 40%. The data for paneling 9 and 10 contributed to a slope of magnitude 0.0024 for all paneling from manufacturer #2 both before and after (figure 76) being in the prototype house; the ORNL model overpredicted this by about 30%. For paneling 6 and 8 before being placed into the house (figures 56-57), the magnitude of slopes, 0.0043 and 0.0048, respectively, were both underpredicted by about 30%. The magnitudes of the slopes, 0.0064 and 0.0063 for uncut (figure 71) and cut (figure 74) underlayment, respectively, both before and after being placed in the prototype house were underpredicted by about 40% each. The best agreement between the ORNL model and measured results were obtained for table tops, where the magnitude of the slope for all table tops both before and after being placed in the house, was underpredicted by about 20% (see figure 79).

Of course, an implicit prediction of the ORNL model is that HCHO surface emission rate is linear with concentration, which may not be true for paneling 9 (after house), 14, and 17.

8. Formaldehyde Concentrations in the Two-Room Prototype House

After their HCHO surface emission rates were determined, the pressed-wood products were installed in the prototype house and the HCHO concentrations were measured at four air exchange rates. This sequence was carried out for three different loadings, that is combinations of HCHO emitters. The loadings were (1) particle-board underlayment, (2) loading 1 plus three hardwood-plywood paneling boards, and (3) loading 2 plus two table tops. The paneling was installed in one room of the prototype house on two opposite walls and the medium-density fiberboard in the other room. This was intended to simulate a living room-kitchen arrangement in a house. Two samples of panelling from manufacturer #1 were installed on one wall and one sample from manufacturer #2 was installed on the opposite wall. Six underlayment boards were used to cover the floor in both rooms (two of the boards had to be cut). The surface emission rates of the cut boards were determined both before and after cutting. After the prototype-house studies, HCHO surface emission rates of all pressed-wood products were again measured in the medium-size dynamic measuring chambers.

Formaldehyde concentrations in the two rooms of the prototype house were found to be so close together (see tables 42-44 and figures 80-82) that it was unnecessary to use a two-room model to predict HCHO concentration from the surface emission rates of the pressed-wood products it contained. Instead a model relating HCHO concentration to n HCHO emitters was derived from a mass-balance equation, assuming a single well-mixed chamber:

$$g \cdot V \frac{dC}{dt} = -g \cdot V \cdot AI \cdot (C - C_{ext}) + \sum_{i=1}^{n} AREA_i \cdot SER_i \qquad (9)$$

where

g = the density of HCHO, mg/cm^3 (= MW_{HCHO}/V_g)
C_{ext} = chamber-background HCHO concentration, ppb
$AREA_i$ = area of the i^{th} emitter, m^2
SER_i = HCHO surface emission rate of the i^{th} emitter, $mg/m^2 \cdot h$

The SER_i are given by:

$$SER_i = A_i - B_i \cdot C \text{ if } C < B_i/A_i \qquad (10)$$

$$= 0 \text{ otherwise}$$

where

A_i and B_i are the regression coefficients A and given in tables 23 to 25

Equation 9 can be solved to give:

$$C(t) = C_o \cdot e^{-AI \cdot t} + \frac{\sum_{i=1}^{n} AREA_i \cdot A_i/(g \cdot V) + AI \cdot C_{ext}}{AI} \qquad (11)$$

where

$$\tilde{AI} = AI + \sum_{i=1}^{n} AREA_i \cdot B_i/(g \cdot V) \qquad (12)$$

C_o = initial HCHO concentration, ppb

As $t \rightarrow \infty$ for $C_{ext} = 0$, $C(t)$ C_{eq}, given by:

$$C_{eq} = \sum_{i=1}^{n} AREA_i \cdot A_i/(g \cdot V \cdot AI) \qquad (13)$$

The computer program listed in appendix G solves equations 10-12, given the characteristics of the emitters in the prototype house, the volume of the prototype house, and air exchange rates between 0.1 to 1.0 h^{-1}.

9. Results for the Prototype House at 23°C, 50% RH

The results for the two-room prototype house for the three loadings of (1) underlayment, (2) underlayment and paneling, and (3) underlayment, paneling and medium-density fiberboard are given in tables 42-44 and figures 80-82. The two-room prototype house was measured at four air exchange rates of 1.2, 0.47, 0.14 and 0.78 h^{-1}. After changing the air exchange rate, a period of at least four days was required before the HCHO concentration in the prototype house stablized. This lag in response to change in air exchange rate is believed to be caused by absorption of HCHO by the bare gypsum wall and ceiling boards in the prototype house; a study confirming this will be included in phase II of this study. The data in table 42 show the HCHO concentrations due to the installation of the underlayment varied from 48 ppb at 1.28 h^{-1} to 136 ppb at 0.14 h^{-1}. Figure 80 shows the comparison of the measured HCHO concentrations in the prototype house and the predicted concentrations from the model developed in section 8 for the loading of particleboard underlayment. The theory seems to predict the measured values well. The maxium deviation occurred at the lowest air exchange rate, where the HCHO concentration was less than 20% below that predicted.

The data for the loading of underlayment and paneling are given in table 43. Five days after installing the paneling, the loading of underlayment and paneling produced a concentration of 70 ppb of HCHO in the prototype house with an air exhange rate of 0.86 h^{-1}. This increased to 80 ppb at 0.54 h^{-1} and to 182 ppb at 0.26 h^{-1}. When the air exchange rate was increased to 0.75 h^{-1}, the HCHO concentration decreased to 73 ppb. A comparison of the predicted and measured values for this loading is shown in figure 81. The agreement is good except at the lowest air exchange rate, where the addition of the paneling results in a HCHO concentration about 25% lower than predicted by the theory.

The results for the loading of underlayment, paneling and two table tops made of medium-density fiberboard are given in table 44. The addition of the two table tops produced HCHO concentrations of 116 ppb, 120 ppb, 200 ppb and 123 ppb at air exchange rates of 0.80, 0.58, 0.27 and 0.75 h^{-1}, respectively. The comparison of these measured concentrations with the concentrations predicted by the theory of section 7 is shown in figure 82. The agreement is good at all air exchange rates. The greatest deviation between predicted and actual HCHO concentrations was about 15% at 0.58 h^{-1}.

It should be noted that the HCHO concentration usually increased from the outlet to room 1 to room 2, but that the difference between concentrations at the lowest and highest sites was always less than 30 ppb, and the difference between rooms 1 and 2 was always less than 12 ppb. As mentioned earlier, this made the use of a two-chamber model unnecessary.

10. Summary

Measurements were made of the HCHO surface emission rates of underlayment, paneling and medium density fiberboard in medium-size dynamic measuring chambers to characterize the surface emission rate of HCHO at 23°C, 50% RH. These measurements showed that the relationship between surface emission rate and concentration is basically linear with negative slope (except possibly for paneling). Emission rate decreases to 0 ppb as the HCHO concentration approaches a cutoff concentration. If this dependence of the surface emission rate on HCHO concentration is used in a mass-balance equation for a well-mixed chamber, the resulting theory seems to predict satisfactorily the measured HCHO concentrations in the two-room prototype house. The ORNL emission model consistently underpredicts the magnitude of the slope of the straight line that fits surface emission rate vs. concentration by 20% for table tops and 40% for underlayment. It may not always be possible to apply the ORNL model to paneling because of the low cutoff concentration; even when possible, however, no consistent relationship was found between the magnitude of the slope predicted by the ORNL model and that obtained by experiment.

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Table 1

Results of Medium-Size Chamber Tests of Underlayment #2
first* and second** tests

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
10/1-2	69	8	2.98	0.42	0.154	0.039
11/13	130	5	0.84	0.39	0.082	0.041
11/14	83	9	1.85	0.27	0.115	0.029
11/14	41	11	5.52	0.06	0.167	0.049
11/14-15	153	19	0.20	0.18	0.023	0.024
11/15-16	193	11	0.22	0.13	0.032	0.021

* 10/1-2
** 11/13-16

Table 2

Results of Medium-Size Chamber Tests of Underlayment #2 -- third test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
2/9-10 10/85	28	2	11.79	0.80	0.248	0.031
2/10-11/85	66	2	3.12	0.12	0.153	0.011
2/11	117	7	1.08	0.29	0.095	0.031
2/11-12/85	155	8	0.66	0.16	0.076	0.023
2/12-13/85	197	4	0.25	0.13	0.037	0.020
2/13-14/85	261	5	0.02	0.01	0.004	0.003

Table 3

Results of Medium-Size Chamber Tests of Underlayment #5
first test (uncut)

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
9/28	65	5	2.66	-	0.130	-
9/28	102	4	1.07	-	0.082	-
9/29	98	4	1.29	-	0.094	-
9/29	74	4	1.86	-	0.103	-
9/28	161	11	0.63	-	0.076	-

Table 4

Results of Medium-Size Chamber Tests of Underlayment #5
second test (cut)

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
11/10-11	96	7	2.76	0.13	0.199	0.23
11/11-12	44	2	8.42	-	0.282	-
11/12-13	248	30	0.14	0.09	0.023	0.18

Table 5

Results of Medium-Size Chamber Tests of Underlayment #5 third test (cut)

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
2/20/85	177	16	0.38	0.13	0.050	0.022
2/20-21/85	102	3	1.11	0.04	0.085	0.006
2/21-22/85	52	2	5.12	0.57	0.198	0.029
2/22/85	138	10	0.96	0.18	0.099	0.026
2/22-23/85	135	3	1.01	0.19	0.102	0.022
2/23/85	184	6	0.50	0.17	0.069	0.026
2/24-25/85	265	21	0.05	0.06	0.010	0.013
2/25/85	159	12	0.97	0.13	0.116	0.024
2/26/85	150	3	0.93	0.12	0.105	0.015

Table 6

Results of Medium-Size Chamber Tests of Underlayment #8 -- first test

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
9/28	37	3	2.96	-	0.082	0.007
9/28	108	5	0.70	-	0.057	0.002
9/29	144	4	0.34	-	0.037	0.001
9/29	83	5	1.41	-	0.088	0.005
9/30	156	4	0.39	-	0.046	0.001

Table 7

Results of Medium-Size Chamber Tests of Underlayment #8 -- second test

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
11/13	61	3	2.96	-	0.135	0.006
11/14	89	7	1.75	0.27	0.117	0.027
11/14	38	5	3.98	-	0.112	-
11/15	146	18	0.34	0.14	0.037	0.020
11/15-16	176	22	0.27	0.15	0.035	0.023

Table 8

Results of Medium-Size Chamber Tests of Underlayment #8 -- third test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
3/1-2 /85	29	2	9.49	1.07	0.210	0.035
3/2/85	68	2	3.21	-	0.163	0.004
3/2-35 /85	120	8	1.48	0.32	0.133	0.037
3/3/85	171	11	0.63	0.12	0.080	0.021
3/3-4 /85	217	7	0.25	0.16	0.041	0.027
3/4/85	259	15	0.04	0.01	0.007	0.002
3/4-5 /85	102	7	2.15	0.29	0.165	0.033

Table 9

Results of Medium-Size Chamber Tests of Underlayment #9 -- first test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
9/28	45	1	2.96	-	0.100	-
9/28	119	6	0.88	-	0.078	-
9/29	165	8	0.34	-	0.042	-
9/29	86	4	1.37	-	0.088	-
9/30	175	9	0.46	-	0.060	-

Table 10

Results of Medium-Size Chamber Tests of Underlayment #9 -- second test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
11/13	172	6	0.88	-	0.113	-
11/14	102	10	2.95	0.18	0.226	0.037
11/14	53	3	4.64	-	0.184	-
11/15	43	6	7.42	0.51	0.241	0.051

Table 11

Results of Medium-Size Chamber Tests of Underlayment #9 -- third test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
3/1-2 /85	35	2	6.22	0.41	0.161	0.020
3/2/85	79	2	2.77	-	0.163	0.003
3/2-3 /85	128	6	1.19	0.03	0.114	0.008
3/3/85	180	13	0.44	0.20	0.059	0.031
3/3-4 /85	230	8	0.19	0.14	0.032	0.025
3/4/85	256	10	0.03	0.01	0.005	0.002
3/4-5 /85	145	9	1.37	0.11	0.149	0.021

Table 12

Results of Medium-Size Chamber Tests of Underlayment #10
first* and second** tests

Date	HCHO Concentration Average ppb	S.D. ppb	Air Exchange Rate Average h^{-1}	S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
10/1-2	74	1	1.39	-	0.077	-
10/2	62	9	3.23	0.02	0.150	0.022
11/10	55	6	3.21	-	0.113	-
11/10-11	58	7	2.72	-	0.118	-
11/11-12	127	8	0.99	0.26	0.094	0.028
11/12	202	50	0.22	0.09	0.033	0.018

* 10/1-2
** 11/10-12

Table 13

Results of Medium-Size Chamber Tests of Underlayment #10 -- third test

Date	HCHO Concentration Average ppb	S.D. ppb	Air Exchange Rate Average h^{-1}	S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
2/15-16	31	1	7.27	0.93	0.171	0.028
2/16-17	63	2	2.57	0.04	0.121	0.006
2/17-18	96	3	1.32	0.06	0.095	0.007
2/18-19	143	5	0.71	0.16	0.076	0.020
2/19-20	221	5	0.29	0.11	0.049	0.019

Table 14

Results of Medium-Size Chamber Tests of Underlayment #12
first test (uncut)

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
9/28	41	4	3.38	-	0.103	-
9/28	98	4	1.02	-	0.075	-
9/29	119	5	0.69	-	0.061	-
9/29	60	4	2.62	-	0.177	-

Table 15

Results of Medium-Size Chamber Tests of Underlayment #12
second test (cut)

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
11/10-11	100	8	2.07	0.47	0.158	0.047
11/11-12	30	3	9.80	-	0.223	-
11/12	200	33	0.15	0.06	0.023	0.012

Table 16

Results of Medium-Size Chamber Tests of Underlayment #12
third test (cut)

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
2/15-16/85	28	1	9.33	1.87	0.197	0.049
2/16-17/85	72	2	2.61	0.03	0.141	0.005
2/17-18/85	128	3	1.12	0.40	0.108	0.041
2/18-19/85	190	6	0.43	0.17	0.061	0.026
2/19-20/85	221	5	0.21	0.12	0.034	0.021

Table 17

Results of Medium-Size Chamber Tests of Underlayment #18 -- first test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
11/16	228	9	0.26	0.15	0.044	0.026
12/21-28	29	4	12.68	2.18	0.272	0.083
1/14-16	30	3	8.08	0.80	0.181	0.035
1/16-19	65	2	3.55	0.22	0.173	0.016
1/19-22	136	2	1.19	0.19	0.120	0.021
1/22 /85	111	12	1.25	0.14	0.105	0.023
1/23-25/85	142	7	1.19	0.13	0.126	0.020
1/28-29/85	132	2	1.33	0.20	0.131	0.022
1/31-2/2/85	146	4	1.16	0.15	0.126	0.020
2/4-6 /85	67	5	3.95	0.17	0.197	0.023
2/6-8 /85	63	3	3.72	0.14	0.175	0.015

Table 18

Results of Medium-Size Chamber Tests of Underlayment #18 -- second test

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
3/28 /85	31	3	11.52	0.08	0.264	0.031
3/30-31/85	27	3	8.46	0.22	0.170	0.023
3/31 /85	39	2	5.89	0.36	0.170	0.020
3/31-4/1/85	108	5	1.77	0.66	0.143	0.060
4/1-2 /85	237	14	0.10	0.06	0.017	0.011
4/2/85	139	6	1.19	0.18	0.124	0.025

Table 19

Results of Medium-Size Chamber Tests of Paneling #6 -- first test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
10/12	24	2	3.13	-	0.059	-
10/16-17	234	8	0.07	0.03	0.012	0.006
10/22	253	16	0.06	0.02	0.012	0.006
10/23	78	-	0.67	-	0.041	-
10/15	68	4	0.78	0.08	0.041	0.006
11/1-2	22	2	2.16	-	0.035	-
11/2	45	1	1.14	-	0.041	-
11/2	95	8	0.58	0.09	0.041	0.011

Table 20

Results of Medium-Size Chamber Tests of Paneling #6 -- second test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
2/26-27/85	16	3	1.50	0.37	0.018	0.008
2/27-28/85	65	4	0.10	0.08	0.005	0.004
2/29-3/1/85	56	4	0.16	0.14	0.007	0.006

Table 21

Results of Medium-Size Chamber Tests of Paneling #8 -- first test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
10/16-17	223	10	0.06	0.02	0.011	0.006
10/22	239	19	0.05	0.02	0.011	0.006
10/22	89	-	0.54	-	0.035	-
10/14-15	75	4	0.58	0.06	0.035	0.006
11/1-2	27	3	1.87	-	0.035	-

Table 22

Results of Medium-Size Chamber Tests of Paneling #8 -- second test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
2/26/85	8	1	9.61	0.02	0.059	0.005
2/26-27/85	16	2	3.23	0.39	0.038	0.010
2/27-28/85	88	5	0.15	0.11	0.010	0.008
2/28-3/1/85	125	4	0.05	0.06	0.004	0.005
11/1-2	35	2	2.24	-	0.058	0.004

Table 23

Results of Medium-Size Chamber Tests of Paneling #9 -- first test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
10/11	101	2	1.71	-	0.129	-
10/17-18	298	25	0.07	0.02	0.015	0.006
10/19	336	17	0.24	0.03	0.061	0.012
11/2	51	2	0.85	-	0.033	-
11/3-5	147	8	0.39	0.01	0.043	0.003
11/5-6	81	6	0.35	0.22	0.021	0.015

Table 24

Results of Medium-Size Chamber Tests of Paneling #9 -- second test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
3/5-6 /85	28	5	10.13	0.85	0.213	0.055
3/6-7 /85	50	3	2.96	0.06	0.111	0.009
3/7/85	77	5	1.50	0.24	0.086	0.019
3/7-8 /85	99	5	1.25	0.05	0.093	0.009
3/9/85	110	8	1.06	0.08	0.087	0.013
3/10/ /85	41	3	6.51	0.61	0.201	0.034
3/10 /85	29	1	8.12	1.10	0.178	0.033
3/10- 11/85	26	3	8.01	1.61	0.155	0.046
3/11 /85	52	1	2.74	0.02	0.106	0.003
3/11 12/85	244	17	0.09	0.05	0.016	0.010
3/12 13/85	276	8	0.10	0.04	0.020	0.009

Table 25

Results of Medium-Size Chamber Tests of Paneling #10

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
10/11	173	4	1.60	-	0.208	-
10/17-18	309	31	0.65	0.10	0.151	0.038
10/19	339	22	0.07	0.03	0.017	0.000
11/2	202	13	1.52	-	0.230	-
11/2	253	-	1.01	-	0.191	-
11/3-4	370	13	0.51	-	0.141	-
11/15	45	4	6.80	-	0.227	-
12/6	50	0	7.97	-	0.299	-
12/7	108	4	2.99	0.06	0.241	0.013
12/8	370	16	0.32	0.16	0.090	0.048
12/11-12	245	13	0.76	0.22	0.141	0.048

Table 26

Results of Medium-Size Chamber Tests of Paneling #14

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
11/16	14	2	8.52	-	0.088	-
11/17-19	27	6	1.34	0.76	0.029	0.023
11/20	54	6	0.43	0.22	0.018	0.012
11/20-21	98	7	0.13	0.12	0.012	0.012
11/21-23	16	4	6.81	0.68	0.082	0.029
11/23-24	38	6	1.30	0.52	0.035	0.018
11/24-25	23	2	3.28	0.99	0.059	0.023
11/25	15	2	5.41	0.61	0.059	0.012

Table 27

Results of Medium-Size Chamber Tests of Paneling #17

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
11/17-18	46	2	3.02	-	0.104	0.006
11/18-19	84	6	2.90	0.10	0.057	0.011
11/19-20	137	9	0.54	0.21	0.056	0.026
11/20-21	224	10	0.13	0.14	0.022	0.024
11/21-25	20	4	12.07	1.88	0.180	0.067

Table 28

Results of Medium-Size Chamber Tests of MDF Table Top #2 -- first test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
12/14-15	138	9	4.38	0.18	1.81	0.20
12/15-16	69	5	12.31	0.39	2.55	0.25
12/16-17	76	8	11.09	1.63	2.54	0.62

Table 29

Results of Medium-Size Chamber Tests of MDF Table Top #2 -- second test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
1/28-29	153	11	1.38	0.38	0.63	0.22
2/1-2	174	5	1.44	0.27	0.75	0.16
2/4-6	107	6	2.52	0.11	0.82	0.08

Table 30

Results of Medium-Size Chamber Tests of MDF Table Top #2 -- third test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
3/9/85	144	6	3.29	0.32	1.419	0.196
3/10/85	52	2	12.08	1.05	1.876	0.237
3/10/85	97	9	4.48	0.42	1.304	0.244
3/10-11/85	193	5	1.63	0.22	0.944	0.147
3/11/85	109	1	3.49	0.17	1.141	0.068
3/11-12/85	138	6	2.45	0.45	1.009	0.229
3/12-13/85	241	11	1.23	0.13	0.891	0.131

Table 31

Results of Medium-Size Chamber Tests of MDF Table Top #9

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
12/20-26	88	6	7.90	1.05	2.08	0.41
12/26-1/2	497	30	0.63	0.16	0.95	0.29
1/11-14	71	2	9.86	1.41	2.09	0.37
1/14-16	66	3	12.00	1.45	2.38	0.30
1/16-19	158	6	3.78	0.29	1.78	0.20
1/19-20	338	4	1.35	0.24	1.37	0.25

Table 32

Results of Medium-Size Chamber Tests of MDF Table Top #12 -- first test

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
12/12	78	6	5.84	1.06	1.36	0.35
12/14-15	151	4	3.05	0.12	1.39	0.08
12/16-17	84	4	7.76	2.60	1.95	0.74

Table 33

Results of Medium-Size Chamber Tests of MDF Table Top #12 -- second test

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
1/28-29	166	14	0.86	0.06	0.43	0.06
2/1-2	207	8	0.77	0.20	0.48	0.14
2/2	406	9	0.28	0.16	0.33	0.20
1/19-	338	4	1.35	0.24	1.37	0.25

Table 34

Results of Medium-Size Chamber Tests of MDF Table Top #12 -- third test

Date	HCHO Concentration Average ppb	HCHO Concentration S.D. ppb	Air Exchange Rate Average h^{-1}	Air Exchange Rate S.D. h^{-1}	Surface Emission Rate Average $mg/m^2 \cdot h$	Surface Emission Rate S.D. $mg/m^2 \cdot h$
3/9/85	308	18	1.04	0.10	0.964	0.150
3/10/85	102	6	4.74	0.22	1.448	0.158
3/10/85	48	5	10.99	1.55	1.576	0.391
3/10-11/85	158	4	2.98	0.09	1.409	0.080
3/11/85	93	3	5.17	0.19	1.439	0.097
3/11-12/85	353	13	0.93	0.09	0.986	0.128
3/12-13/85	161	5	2.28	0.44	1.102	0.250

Table 35

Results of Medium-Size Chamber Tests of MDF Table Top #24

Date	HCHO Concentration		Air Exchange Rate		Surface Emission Rate	
	Average ppb	S.D. ppb	Average h^{-1}	S.D. h^{-1}	Average $mg/m^2 \cdot h$	S.D. $mg/m^2 \cdot h$
12/21-26	38	2	6.39	0.70	0.72	0.12
1/11-14	112	4	3.04	0.40	1.02	0.16
1/14-16	53	5	7.13	0.82	1.14	0.24
1/16-19	119	9	3.12	0.29	1.11	0.18
1/19-22	307	6	0.87	0.14	0.80	0.15

Table 36

Characterization of Underlayment from Medium-Size Chamber HCHO Emission Rate Data

Specimen	Date	SER_{100}	A^*	B^*	Cutoff Conc	Std Error	R^2
		$mg/m^2 \cdot h$	$mg/m^2 \cdot h$	$mg/ppb \cdot m^2 \cdot h$	ppb	$mg/m^2 \cdot h$	
U-2	11/13/84	0.107	0.209	1.020×10^{-3}	205	0.020	0.91
U-2	2/9/85	0.138	0.236	0.981×10^{-3}	241	0.029	0.91
U-5	9/28/84	0.097	0.144	0.472×10^{-3}	305	0.014	0.68
U-5**	11/10/84	0.205	0.328	1.224×10^{-3}	268	0.014	0.99
U-5**	2/20/85	0.133	0.211	0.779×10^{-3}	270	0.025	0.79
U-8	9/28/84	0.064	0.104	0.402×10^{-3}	259	0.013	0.76
U-8	11/13/84	0.089	0.163	0.747×10^{-3}	219	0.023	0.82
U-8 combined first and second		0.077	0.138	0.615×10^{-3}	225	0.023	0.68
U-8	3/1/85	0.148	0.237	0.893×10^{-3}	266	0.011	0.98
U-9	9/28/84	0.081	0.120	0.395×10^{-3}	305	0.010	0.86
U-9	11/13/84	0.185	0.262	0.771×10^{-3}	340	0.043	0.63
U-9 combined first and second		0.131	0.213	0.817×10^{-3}	261	0.062	0.37
U-9	3/1/85	0.136	0.213	0.770×10^{-3}	277	0.026	0.87
U-10	11/10/84	0.099	0.161	0.618×10^{-3}	260	0.025	0.72
U-10	2/15/85	0.109	0.168	0.594×10^{-3}	283	0.018	0.88
U-12	9/28/84	0.076	0.140	0.646×10^{-3}	217	0.014	0.81
U-12**	11/10/84	0.146	0.266	1.202×10^{-3}	222	0.012	0.99
U-12**	2/15/85	0.130	0.211	0.805×10^{-3}	262	0.009	0.99
U-18	11/10/84	0.154	0.242	0.886×10^{-3}	274	0.027	0.81
U-18	3/20/85	0.145	0.232	0.872×10^{-3}	266	0.039	0.81

Table 36 (continued)

Specimen Date	SER_{100} $mg/m^2 \cdot h$	A^* $mg/m^2 \cdot h$	B^* $mg/ppb \cdot m^2 \cdot h$	Cutoff Conc ppb	Std Error $mg/m^2 \cdot h$	R^2
Combined uncut first	0.110	0.186	0.761×10^{-3}	245	0.041	0.47
Combined uncut second	0.135	0.214	0.786×10^{-3}	272	0.035	0.76
Combined uncut first and second	0.119	0.194	0.744×10^{-3}	260	0.040	0.58
Combined 5 & 12 first	0.089	0.138	0.492×10^{-3}	280	0.014	0.64
Combined 5 & 12 second**	0.175	0.295	1.197×10^{-3}	246	0.027	0.95
Combined 5 & 12 third**	0.131	0.208	0.65×10^{-3}	271	0.023	0.83
Combined 5 & 12 second and third**	0.147	0.239	0.18×10^{-3}	260	0.039	0.74

*A and B are coefficients for the linear regression equasion:

$$SER = A - B \cdot C$$

**cut

Table 37

Characterization of Paneling from
Medium-Size Chamber HCHO Emission Rate Data

Specimen	Date	SER_{100}	A*	B*	Cutoff Conc	Std Error	R^2
		$mg/m^2 \cdot h$	$mg/m^2 \cdot h$	$mg/ppb \cdot m^2 \cdot h$	ppb	$mg/m^2 \cdot h$	
P-6(1)	10/12/84	0.035	0.050	0.151×10^{-3}	330	0.007	0.83
P-6(1)	2/26/85	-	0.022	0.273×10^{-3}	81	0.0004	0.998
P-8(1)	10/16/84	0.030	0.044	0.145×10^{-3}	305	0.003	0.96
P-8(1)	2/26/85	0.013	0.059	0.459×10^{-3}	128	0.013	0.81
P-14(1)	11/16/84	-	0.077	0.831×10^{-3}	93	0.003	0.65
P-21(1)	12/14/84	0.006	0.034	0.274×10^{3}	123	0.006	0.18
P-9(2)	10/11/84	0.054	0.058	0.047×10^{-3}	1246	0.046	0.02
P-9(2)	3/5/85	0.111	0.176	0.651×10^{-3}	271	0.035	0.74
P-10(2)	10/11/84	0.245	0.300	0.555×10^{-3}	541	0.045	0.71
P-17(2)	11/17/84	0.085	0.150	0.648×10^{-3}	231	0.037	0.73
Combined(1) first		0.065	0.046	0.133×10^{-3}	347	0.019	0.24
Combined(1) second		0.037	0.047	0.432×10^{-3}	108	0.017	0.57
Combined(1) first and second		0.029	0.044	0.152×10^{-4}	288	0.020	0.24
Combined(2) first		0.148	0.182	0.341×10^{-3}	535	0.078	0.22
Combined(2) second		0.121	0.135	0.146×10^{-3}	925	0.063	0.13
Combined(2) first and second		0.137	0.172	0.351×10^{-3}	491	0.069	0.26

(1) Manufacturer #1
(2) Manufacturer #2
*A and B are coefficients for the linear regression equation:

$$SER = A - B \cdot C$$

Table 38

Characterization of Medium-Density Fiberboard from Medium-Size Chamber HCHO Emission Rate Data

Specimen	Date	SER_{100}	A*	B*	Cutoff Conc	Std Error	R^2
		$mg/m^2 \cdot h$	$mg/m^2 \cdot h$	$mg/ppb \cdot m^2 \cdot h$	ppb	$mg/m^2 \cdot h$	
TT-2	12/14/84	2.24	3.36	11.23×10^{-3}	299	0.04	0.99
TT-2	1/28/85	0.80	0.94	1.44×10^{-3}	654	0.11	0.28
TT-2 first and second combined		1.67	3.30	16.06×10^{-3}	206	1.70	0.51
TT-2	3/9/85	1.40	1.84	4.47×10^{-3}	413	0.22	0.66
TT-9	12/21/85	2.08	2.37	2.94×10^{-3}	807	0.12	0.96
TT-12	12/12/84	1.58	1.91	3.29×10^{-3}	580	0.43	0.16
TT-12	1/28/85	0.42	0.43	0.14×10^{-3}	3085	0.07	0.11
TT-12 first and second combined		0.92	1.08	1.69×10^{-3}	641	0.65	0.10
TT-12	3/9/85	1.43	1.63	2.02×10^{-3}	808	0.11	0.84
TT-24	12/21/84	0.97	1.02	0.48×10^{-3}	2134	0.21	0.07
Combined first and second		1.34	1.58	2.35×10^{-3}	671	0.67	0.15
Combined third		1.39	1.64	2.48×10^{-3}	662	0.19	0.59
Combined first, second, and third		1.36	1.60	2.38×10^{-3}	672	0.54	0.18

*A and B are coefficients for the linear regression equation:

$$SER = A - B \cdot C$$

Table 39

HCHO Emission Rates Measured by FSEM
$mg/m^2 \cdot h$

Specimen	Spot	8/28	8/31	9/4	9/5	9/10	9/11	9/14	10/2
	1	1.46	-	-	0.82	0.55	0.80	0.52	-
U-2	2	1.11	-	-	-	-	-	-	-
	3	1.18	-	-	0.70	0.56	0.75	0.59	-
	avg	1.25	-	-	0.76	0.55	0.77	0.55	-
	std dev	(0.18)	-	-	(0.08)	(0.00)	(0.04)	(0.05)	-
	1	-	1.53	0.50	0.48	0.53	0.62	0.57	0.35
U-5	2		1.16	0.82	-	-			0.43
	3		1.55	0.73	1.06	0.41	0.65	0.53	0.43
	avg		1.41	0.68	0.77	0.47	0.64	0.55	0.40
	std dev		(0.22)	(0.16)	(0.41)	(0.09)	(0.02)	(0.03)	(0.04)
	1		1.31	0.72	0.91	0.45	0.71	0.61	0.44
U-8	2		1.48	0.61	-	0.35	0.53	0.56	0.32
	3		1.63	0.88	0.90	-	0.56	0.52	0.44
	avg		1.47	0.74	0.91	0.40	0.60	0.56	0.40
	std dev		(0.16)	(0.14)	(0.01)	(0.07)	(0.09)	(0.05)	(0.07)
	1		1.44	0.55	0.57	0.49	-	0.23	0.40
U-9	2		1.68	0.95	-	-	-	-	0.54
	3		1.73	0.67	0.80	0.42	0.80	0.54	0.55
	avg		1.62	0.72	0.69	0.45	0.80	0.38	0.50
	std dev		(0.16)	(0.21)	(0.16)	(0.05)	-	(0.21)	(0.08)
	1		1.24	0.47	0.65	0.54	0.49	0.59	-
U-10	2		1.55	0.44	-	-	0.51	0.62	-
	3		1.63	0.50	1.16	0.54	0.87	0.14	-
	avg		1.47	0.47	0.91	0.54	0.62	0.45	-
	std dev		(0.20)	(0.03)	(0.36)	(0.00)	(0.22)	(0.27)	-
	1		1.09	0.63	0.65	0.52	0.55	0.50	0.45
U-12	2		1.24	0.23	-	0.50	0.72	0.54	0.42
	3		1.46	0.45	0.64	0.53	0.64	0.49	0.32
	avg		1.26	0.44	0.65	0.52	0.64	0.51	0.40
	std dev		(0.18)	(0.20)	(0.00)	(0.01)	(0.08)	(0.02)	(0.07)
All Spots	mean		1.45	0.61	0.78	0.49	0.66	0.50	0.42
	std dev		(0.20)	(0.19)	(0.20)	(0.07)	(0.12)	(0.14)	(0.07)

Table 39 (continued)

Specimen	Spot	10/2	10/25	10/29	11/6	11/7	11/27	11/30	12/4
U-2	1	0.38		0.24	0.21	0.32	0.75	1.01	0.58
	2	0.43		0.17	0.20	0.33	0.57	0.98	0.64
	3	0.48		0.24	0.24	0.39	0.55	1.13	0.70
	avg	0.43		0.22	0.21	0.35	0.62	1.04	0.64
	std dev	0.05		(0.04)	(0.02)	(0.04)	(0.11)	(0.08)	(0.06)
U-10	1	0.49	0.22	0.27	0.34	0.41	0.67	1.03	0.47
	2	0.51	-	0.22	0.19	0.37	0.21	0.92	0.61
	3	0.34	0.12	0.26	0.49	0.48	0.18	1.09	0.64
	avg	0.45							
	std dev	0.09							
U-12	1	-	-						
	2	-	-						
	3	-	-						
	avg	-	0.17	0.25	0.34	0.42	0.35	1.01	0.58
	std dev	-	(0.07)	(0.02)	(0.15)	(0.05)	(0.28)	(0.09)	(0.09)
All Spots	mean	0.44	0.17	0.23	0.28	0.39	0.49	1.03	0.61
	std dev	(0.07)	(0.07)	(0.03)	(0.06)	(0.06)	(0.24)	(0.08)	(0.08)

Table 40

Comparison of FSEM Measurements versus SER_{100}

Specimen	SER_{100} $mg/m^2 \cdot h$	Emission Rate Predicted by FSEM Method $mg/m^2 \cdot h$
U-2	0.16 (0.02)	0.43 (0.05)
U-5 (cut)	0.26 (0.01)	0.40 (0.04)
U-8	0.12 (0.02)	0.40 (0.07)
U-9	0.22 (0.04)	0.50 (0.08)
U-10	0.14 (0.03)	0.45 (0.09)
U-12 (cut)	0.19 (0.01)	0.40 (0.07)

Table 41

Coefficients for ORNL Model

Pressed-wood Product	C	A	$C_{B_{std}}$	B	E
Particleboard Underlayment	9400	0.37	0.36	0.025	0.016
Paneling	6500	0.66	0.41	0.053	0.029
MDF	5000	1.90	0.90	0.090	0.000

Table 42

Results of Prototype-House Tests of Loading of Underlayment

#	Date	n*	Air Exchange Rate*	HCHO Concentration* Outlet	Room 1	Room 2	Inlet
			h^{-1}	ppb	ppb	ppb	ppb
	10/10/84	14	1.2 (0.1)	50.3 (2.1)	-	-	5.1 (2.1)
	10/15/84	3	0.47 (0.01)	106.8 (9.9)	-	-	5.0
	10/17/84 10/19/84	14	0.14 (0.02)	135.6 (13.2)	147.3 (18.1)	153.0 (18.9)	0.8 (5.8)
	11/7/84 11/9/84	23	0.78 (0.07)	60.3 (5.9)	67.5 (4.7)	72.3 (5.9)	1.8 (4.0)
	10/5/84	8	1.28 (0.1)	48.3 (3.0)	-	-	8.9 (0.7)

*Quantities in parentheses are standard deviations.
**n = number of complete measurement cycles

Table 43

Results of Prototype-House Tests of Loading of Underlayment and Paneling

#	Date	n*	Air Exchange Rate*	HCHO Concentration* Outlet	Room 1	Room 2	Inlet
			h^{-1}	ppb	ppb	ppb	ppb
1	11/19/84 11/21/84	34	0.86 (0.04)	70.5 (3.9)	68.3 (6.3)	80.7 (4.9)	1.6 (3.1)
2	11/24/84	14	0.59 (0.02)	138.3 (5.8)	83.9 (6.8)	93.1 (6.6)	2.6 (4.7)
3	11/29/84 12/1/84	36	0.26 (0.02)	107.0 (3.9)	115.9 (5.3)	122.5 (6.4)	-1.9 (2.7)
4	12/12/84 12/14/84	34	0.75 (0.04)	73.1 (3.5)	72.2 (3.4)	82.8 (3.9)	1.4 (3.1)

*Quantities in parentheses are standard deviations.
**n = number of complete measurement cycles

Table 44

Results of Prototype-House Tests of Loading of Underlayment, Paneling and Medium-Density Fiberboard

#	Date	n*	Air Exchange Rate*	HCHO Concentration*			
				Outlet	Room 1	Room 2	Inlet
			h^{-1}	ppb	ppb	ppb	ppb
1	12/20/84 12/21/84	16	0.80 (0.02)	116.1 (14.6)	132.4 (21.7)	142.8 (19.0)	-2.9 (9.0)
2	1/7/85 1/10/85	47	0.58 (0.07)	120.3 (5.5)	121.7 (4.8)	122.2 (3.3)	1.6 (2.3)
3	1/14/85 1/16/85	40	0.27 (0.02)	200.5 (4.8)	222.9 (7.8)	212.2 (7.4)	-1.7 (2.1)
4	1/18/85 1/19/85	11	0.75 (0.01)	123.3 (1.9)	126.1 (7.3)	130.1 (8.3)	-0.9 (1.1)

*Quantities in parentheses are standard deviations.
**n = number of complete measurement cycles

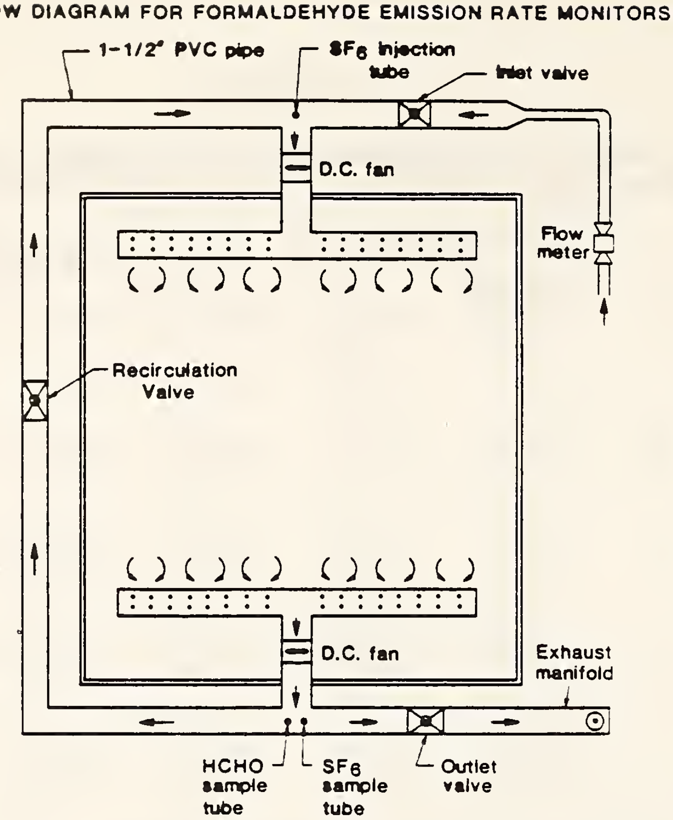


Figure 1. Schematic of Medium-Size Chamber for Measuring HCHO Emission Rates.

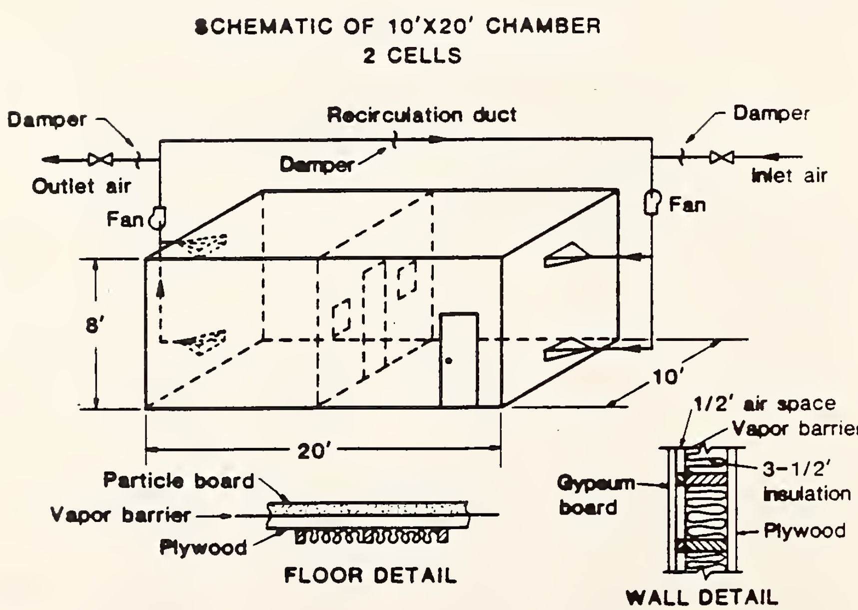


Figure 2. Schematic of Two-Room Prototype House ("Large-Size Chamber").

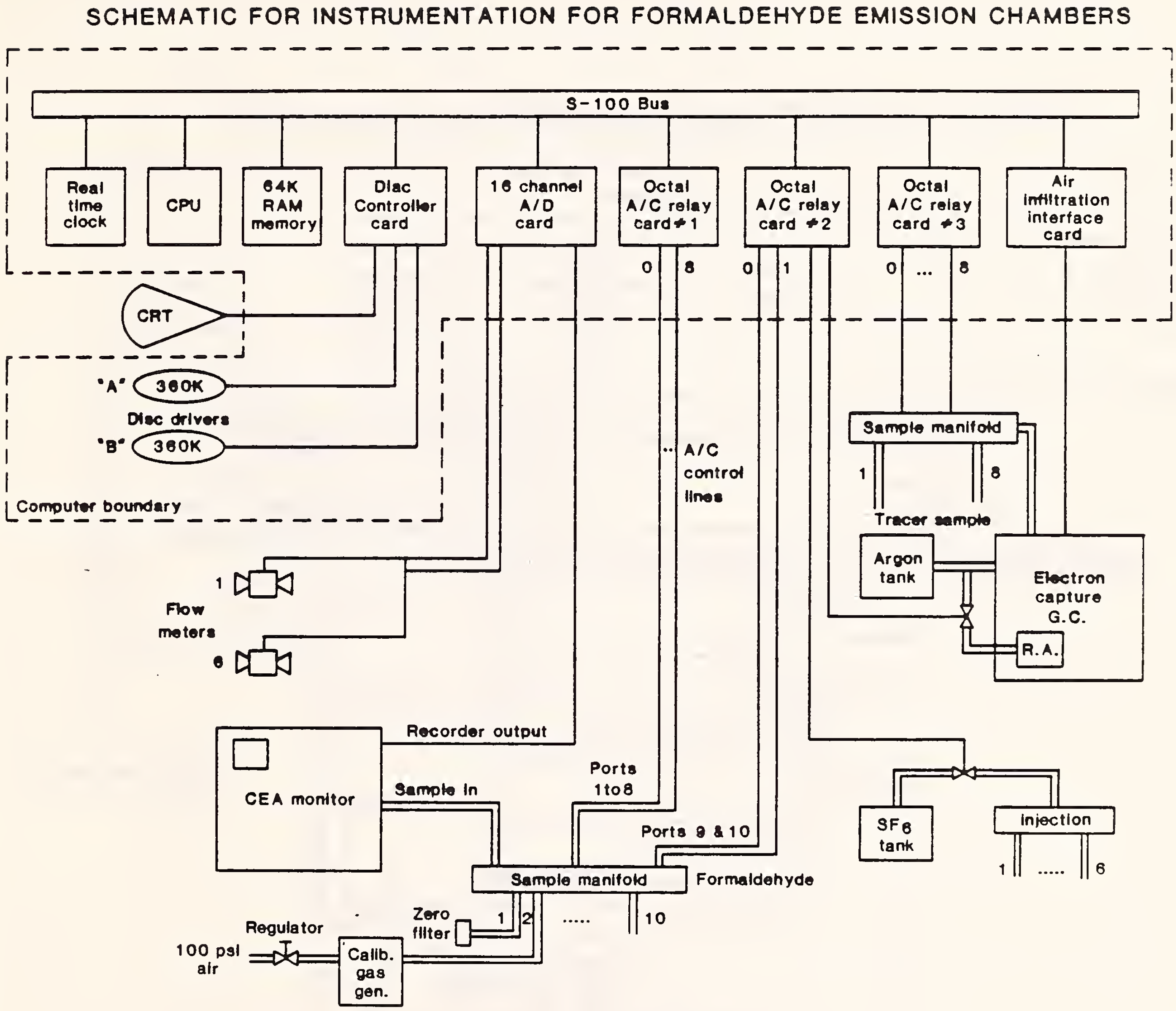


Figure 3. Schematic of Instrumentation for Monitoring Medium-Size Chambers.

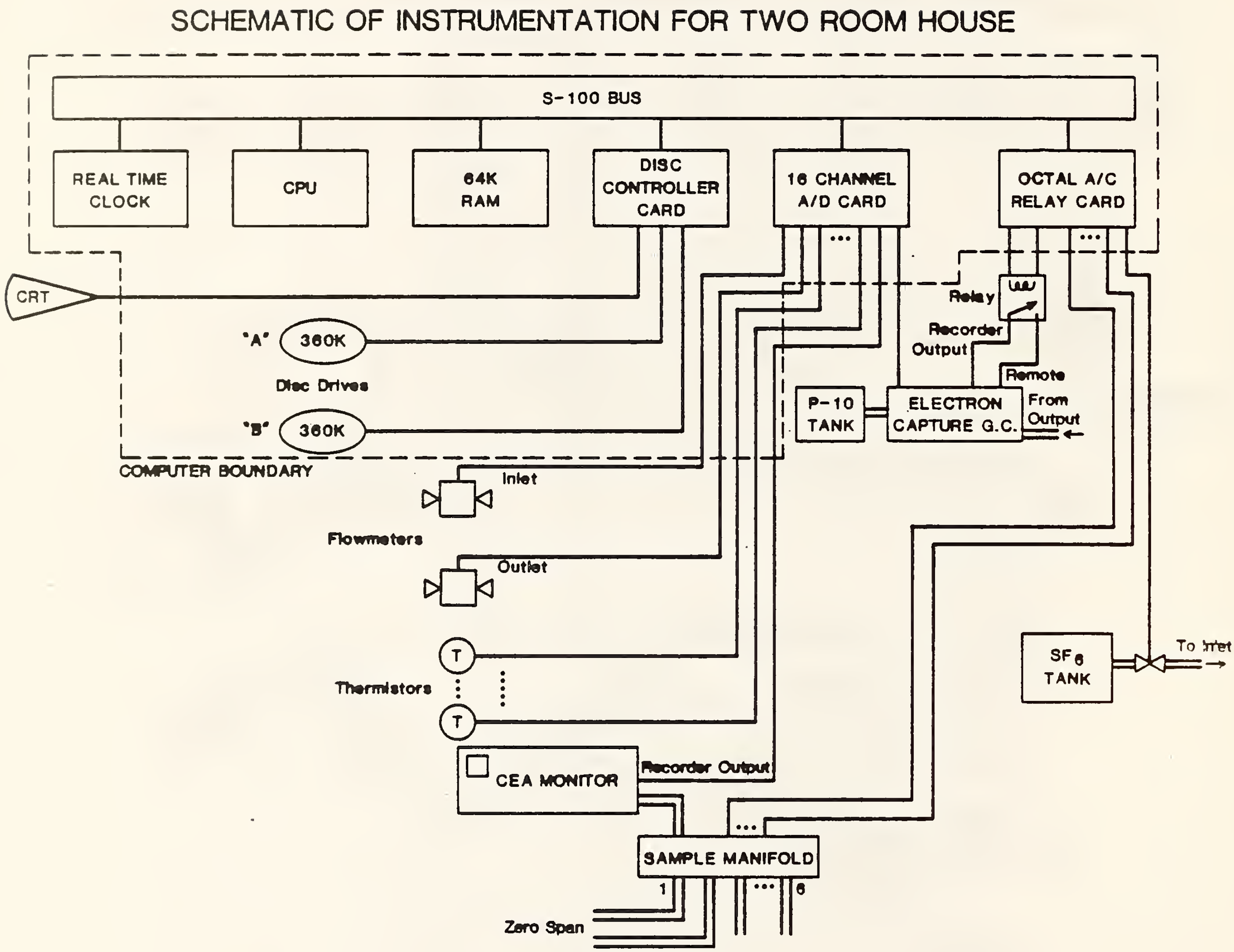


Figure 4. Schematic of Instrumentation for Monitoring Prototype House.

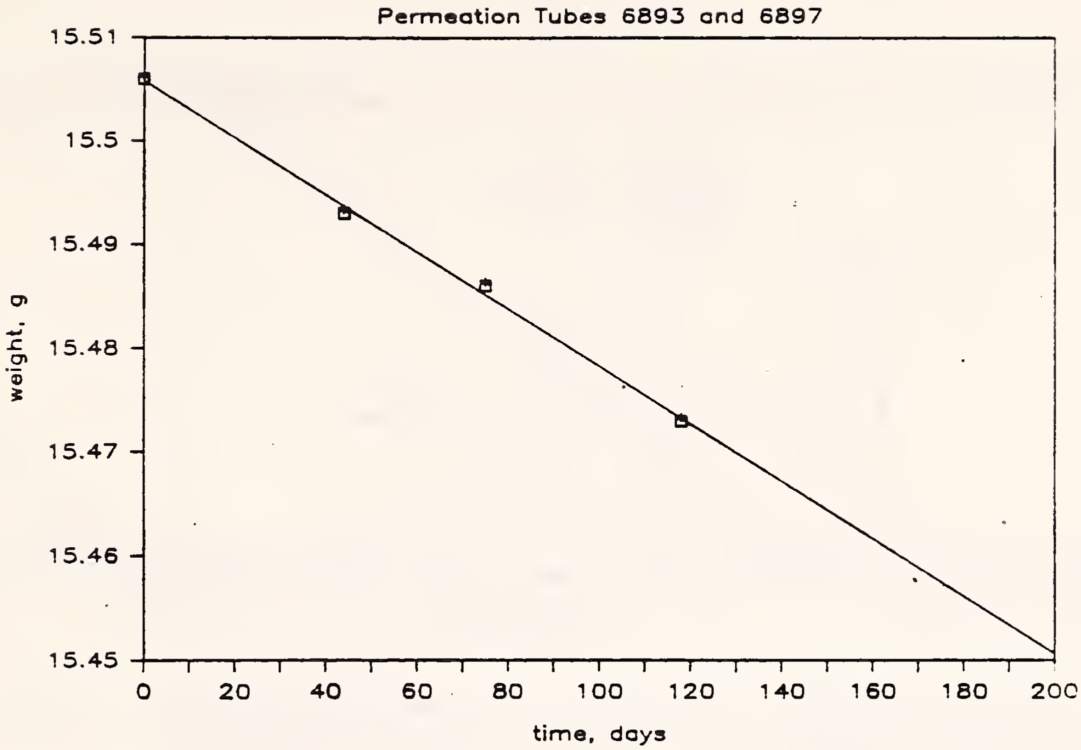


Figure 5. Weight Loss Calibration for Permeation Tubes used for Calibrating HCHO Monitor.

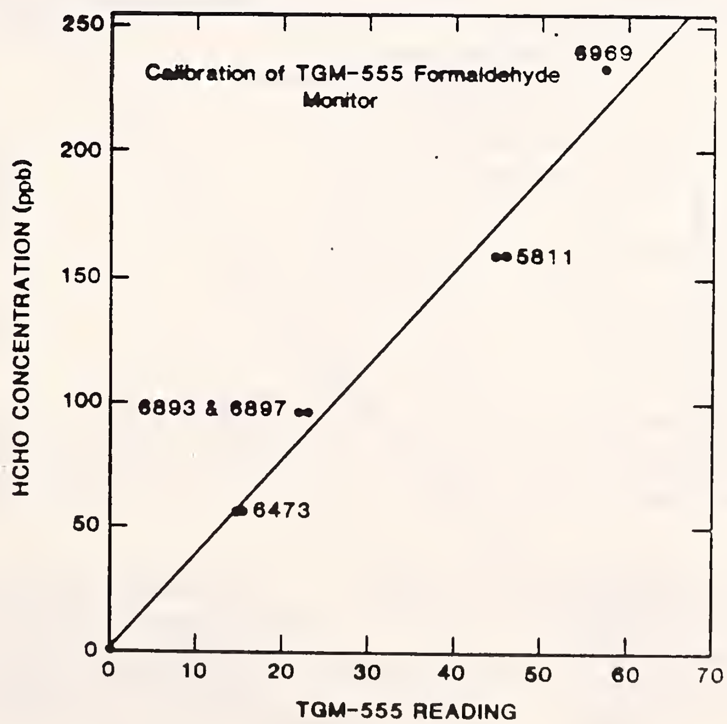


Figure 6. Calibration Curve of the HCHO Concentration Monitor. (The numbers alongside the line are identifying numbers for permeation tubes.)

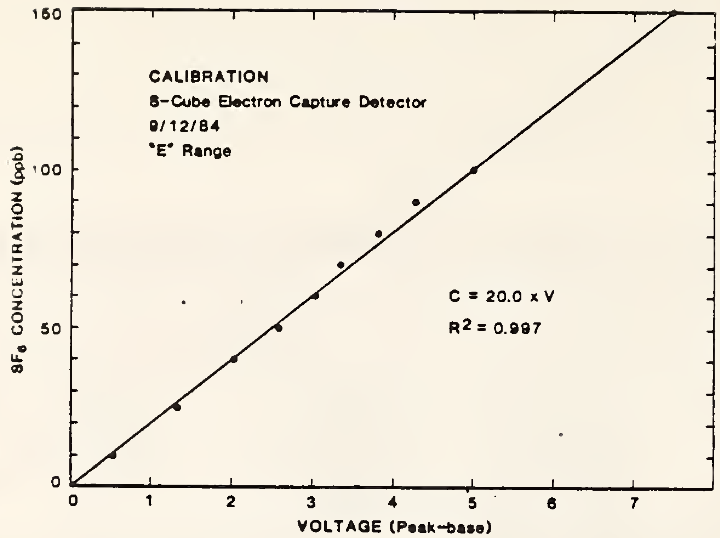


Figure 7. Calibration Curve for S-Cubed Electron-Capture Gas Chromotograph (Prototype-House Unit).

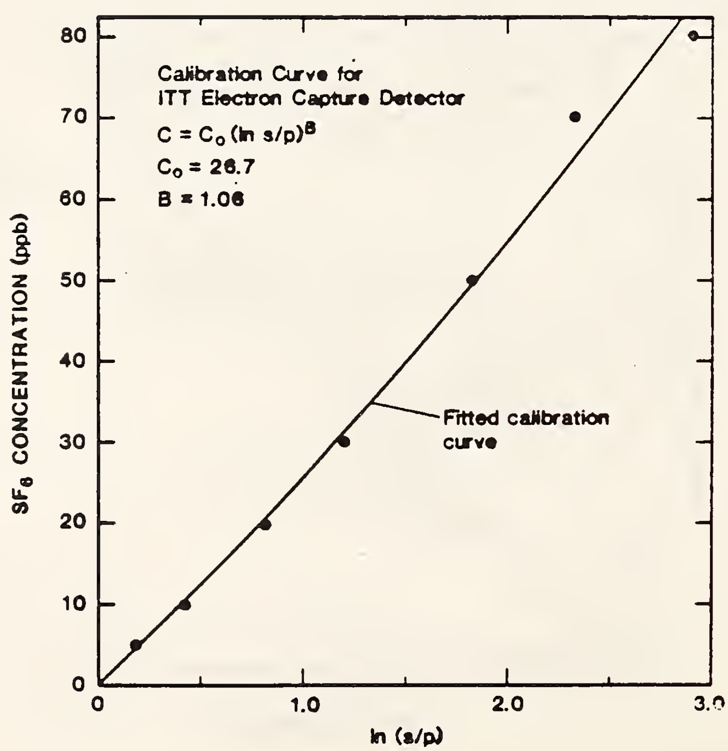


Figure 8. Calibration Curve for ITT Electron-Capture Gas Chromatograph (Medium-Size Chambers).

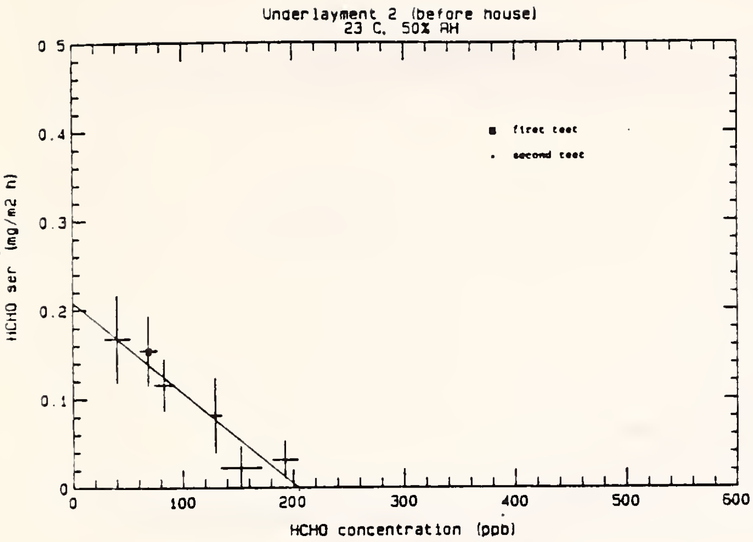


Figure 9. HCHO Emission Rate for Underlayment #2 as a Function of HCHO Concentration (first and second tests).*

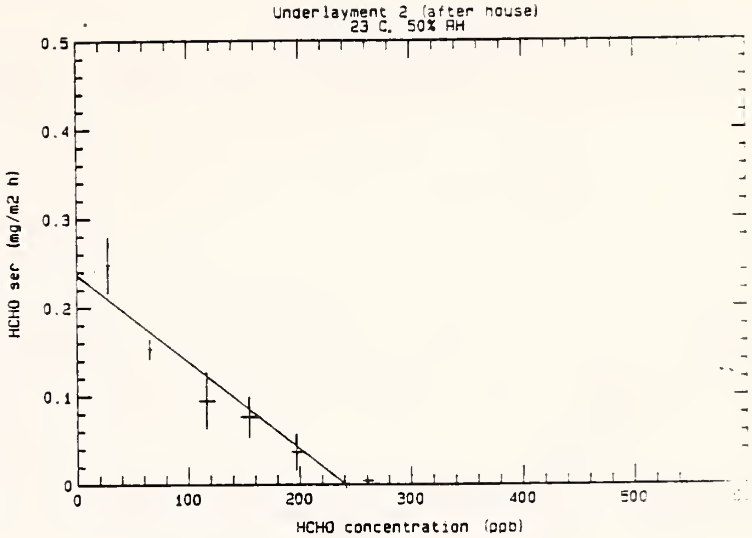


Figure 10. HCHO Emission Rate for Underlayment #2 as a Function of HCHO Concentration (third test.)*

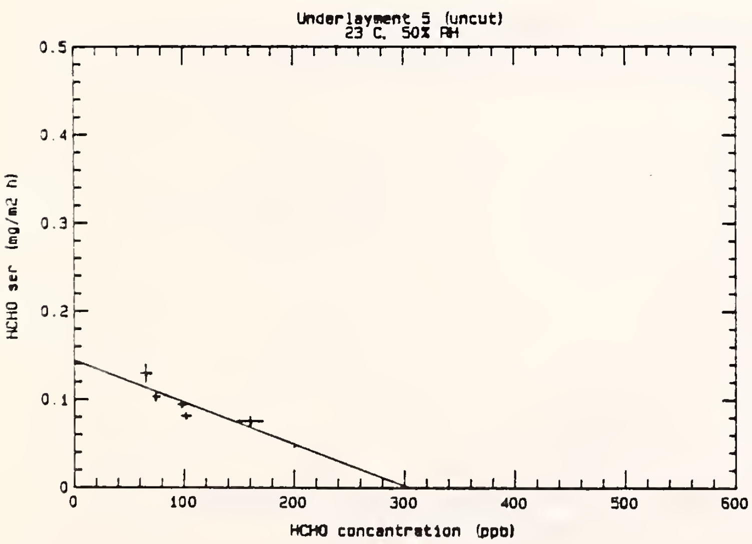


Figure 11. HCHO Emission Rate for Underlayment #5 as a Function of HCHO Concentration (first test).*

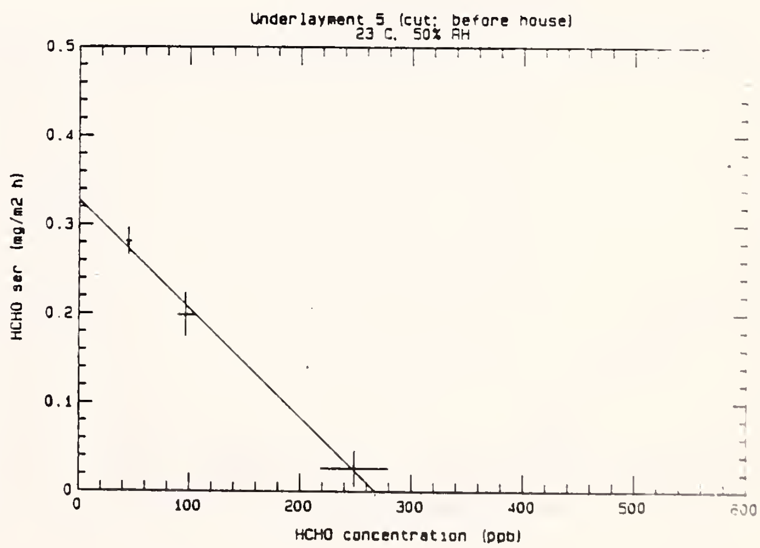


Figure 12. HCHO Emission Rate for Underlayment #5 as a Function of HCHO Concentration (second test).*

*Horizontal bars through data points represent one standard error unit to each side; vertical bars represent one standard deviation unit to each side.

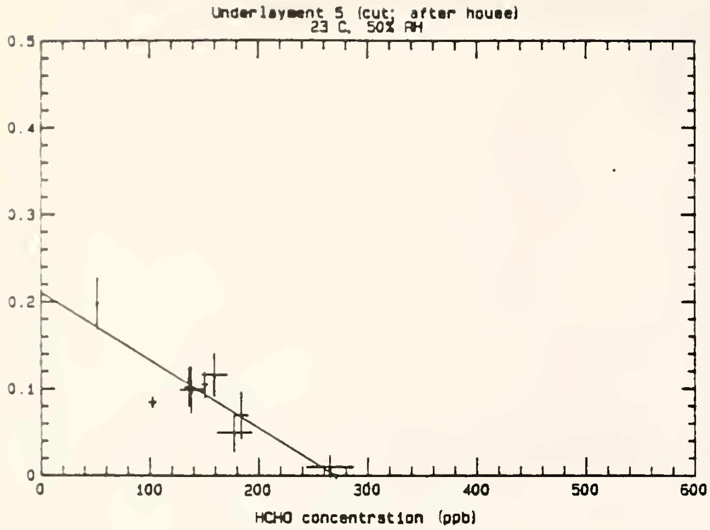


Figure 13. HCHO Emission Rate for Underlayment #5 as a Function of HCHO Concentration (third test).*

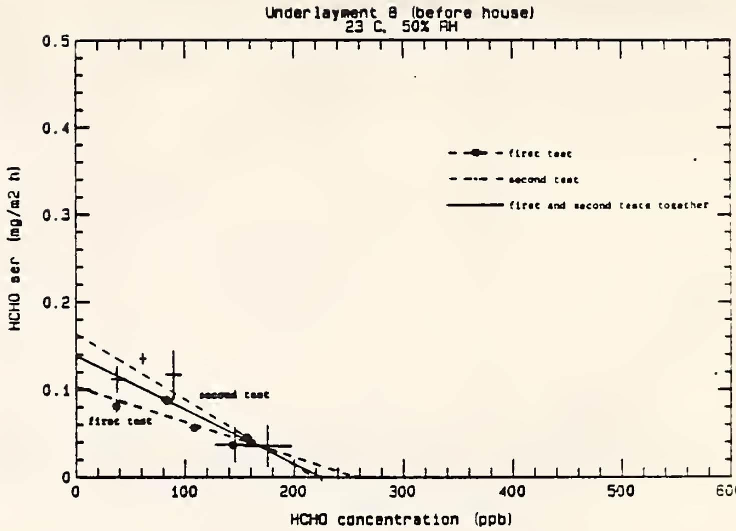


Figure 14. HCHO Emission Rate for Underlayment #8 as a Function of HCHO Concentration (first and second tests.)*

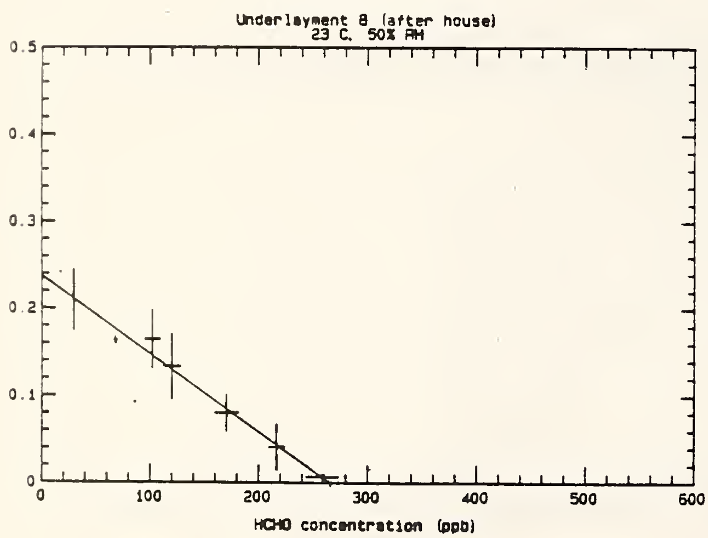


Figure 15. HCHO Emission Rate for Underlayment #8 as a Function of HCHO Concentration (third test).*

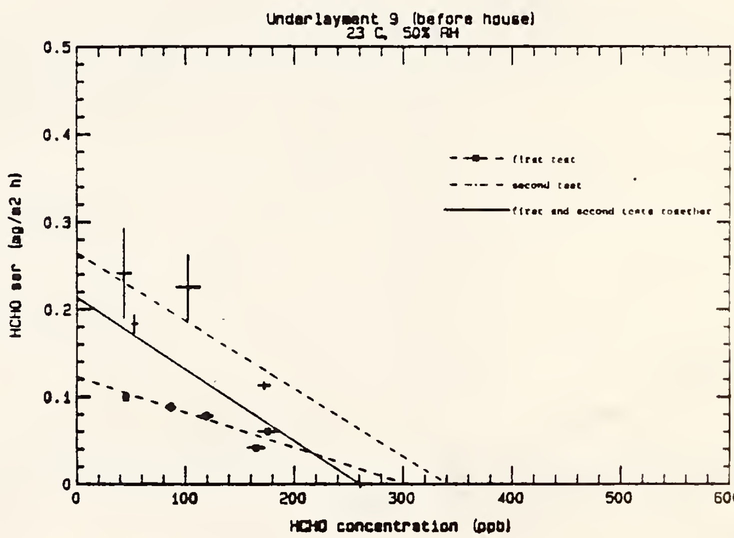


Figure 16. HCHO Emission Rate for Underlayment #9 as a Function of HCHO Concentration (first and second tests).*

*Horizontal bars through data points represent one standard error unit to each side; vertical bars represent one standard deviation unit to each side.

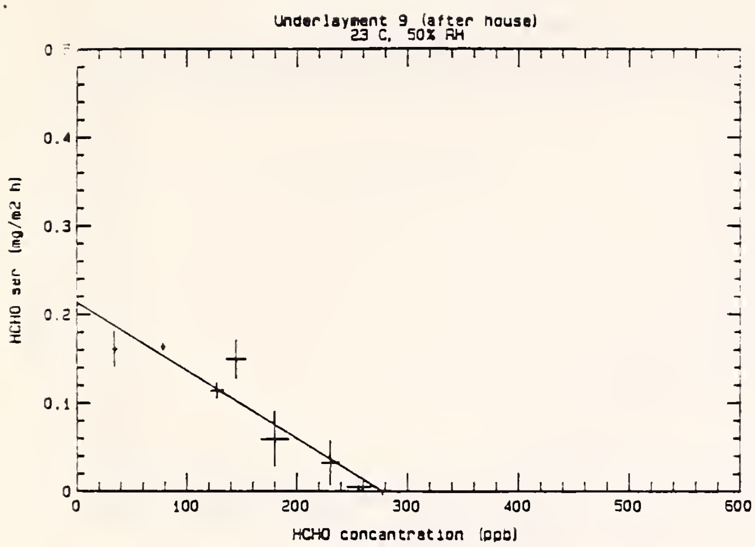


Figure 17. HCHO Emission Rate for Underlayment #9 as a Function of HCHO Concentration (third test).*

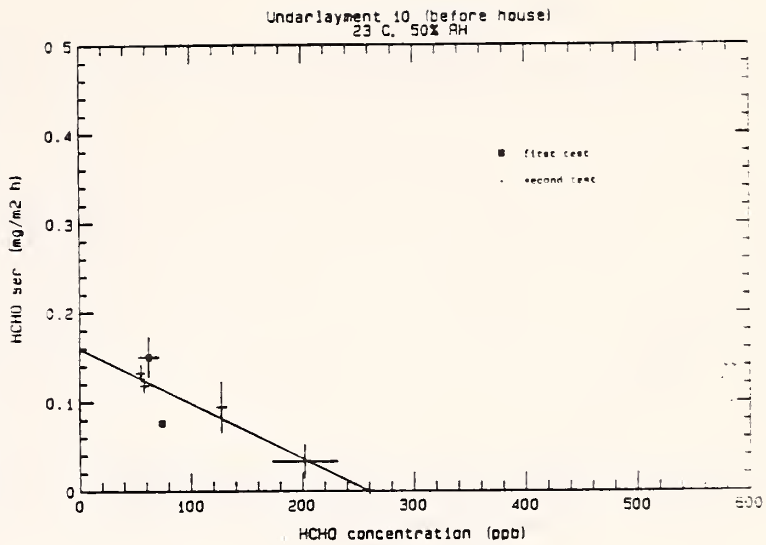


Figure 18. HCHO Emission Rate for Underlayment #10 as a Function of HCHO Concentration (first and second tests.)*

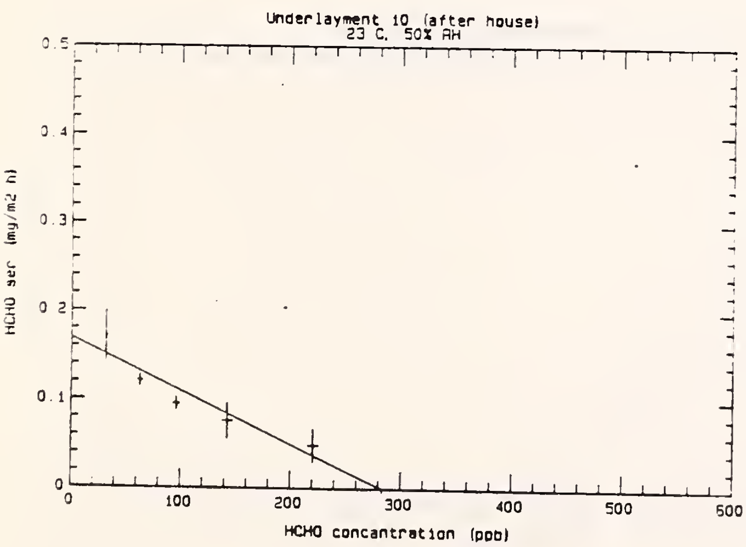


Figure 19. HCHO Emission Rate for Underlayment #10 as a Function of HCHO Concentration (third test).*

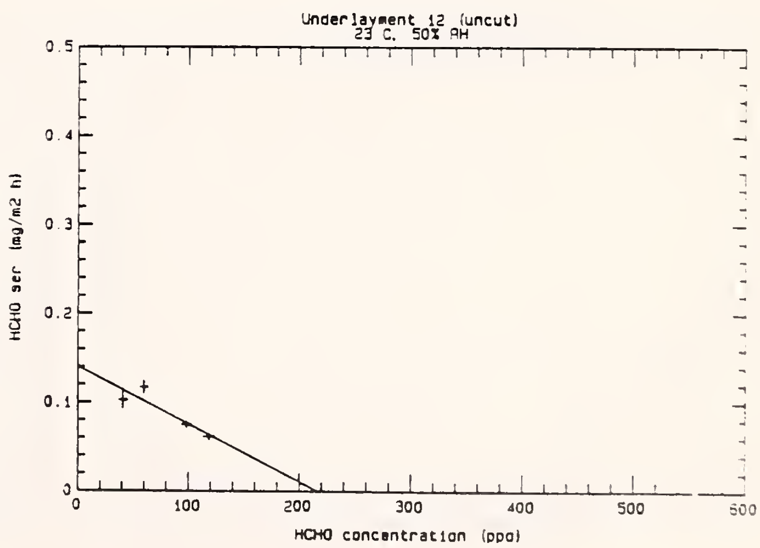


Figure 20. HCHO Emission Rate for Underlayment #12 as a Function of HCHO Concentration (first test).*

*Horizontal bars through data points represent one standard error unit to each side; vertical bars represent one standard deviation unit to each side.

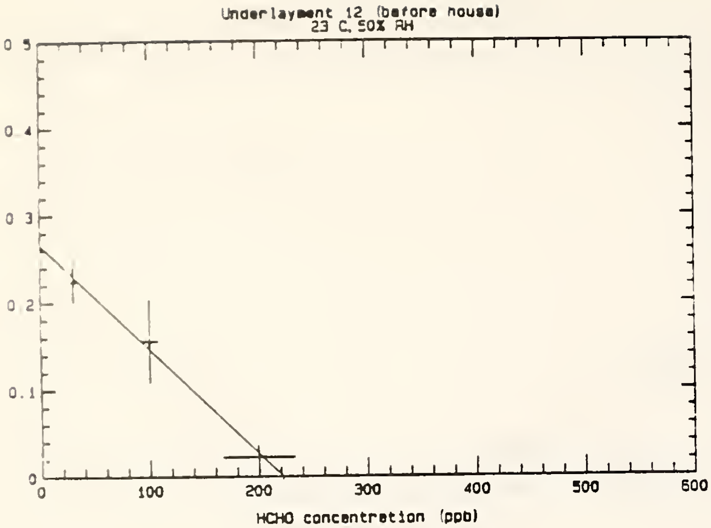


Figure 21. HCHO Emission Rate for Underlayment #12 as a Function of HCHO Concentration (second test).*

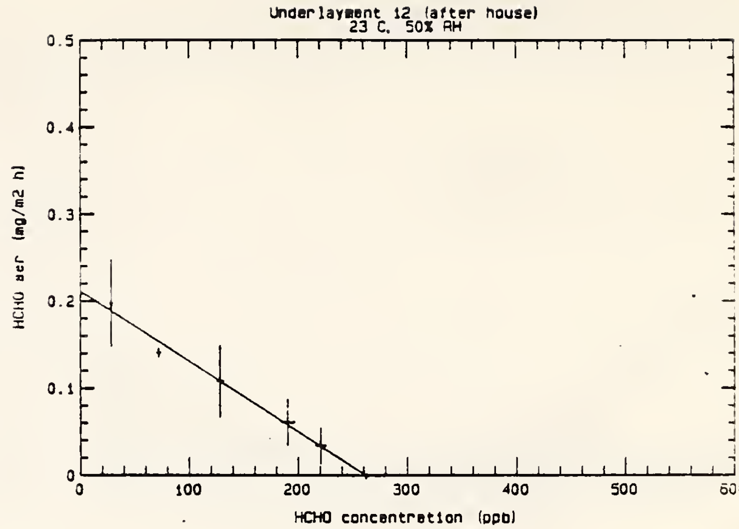


Figure 22. HCHO Emission Rate for Underlayment #12 as a Function of HCHO Concentration (third test.)*

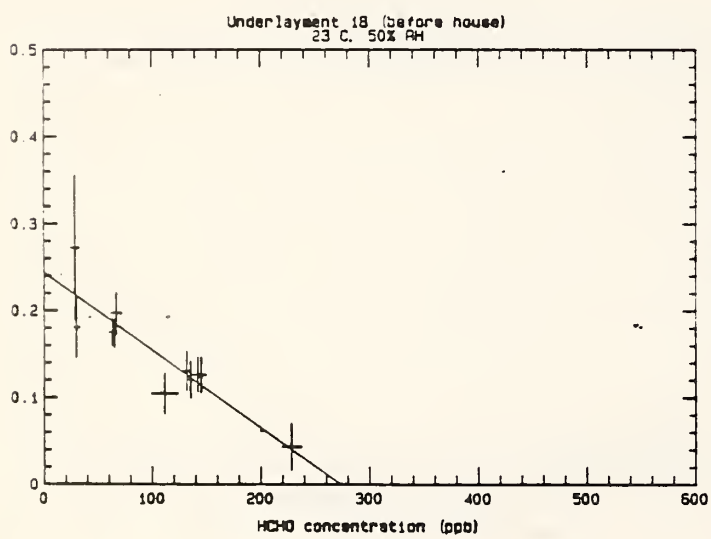


Figure 23. HCHO Emission Rate for Underlayment #18 as a Function of HCHO Concentration (first test).*

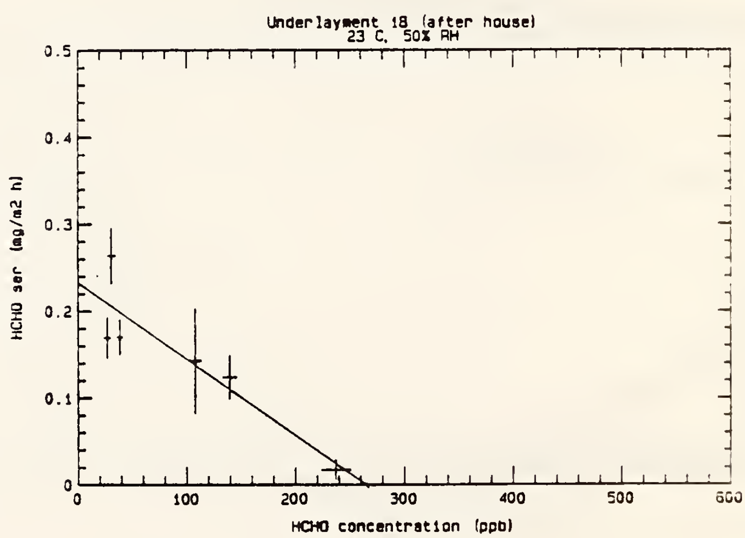
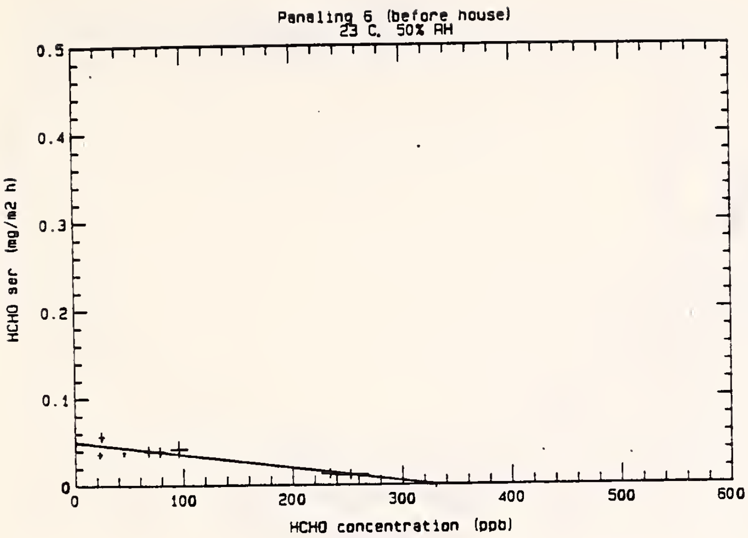


Figure 24. HCHO Emission Rate for Underlayment #18 as a Function of HCHO Concentration (second test).*

*Horizontal bars through data points represent one standard error unit to each side; vertical bars represent one standard deviation unit to each side.



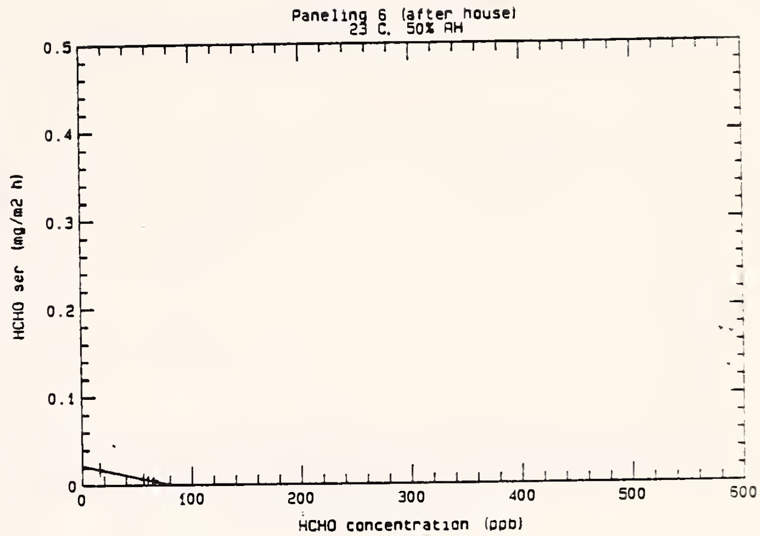
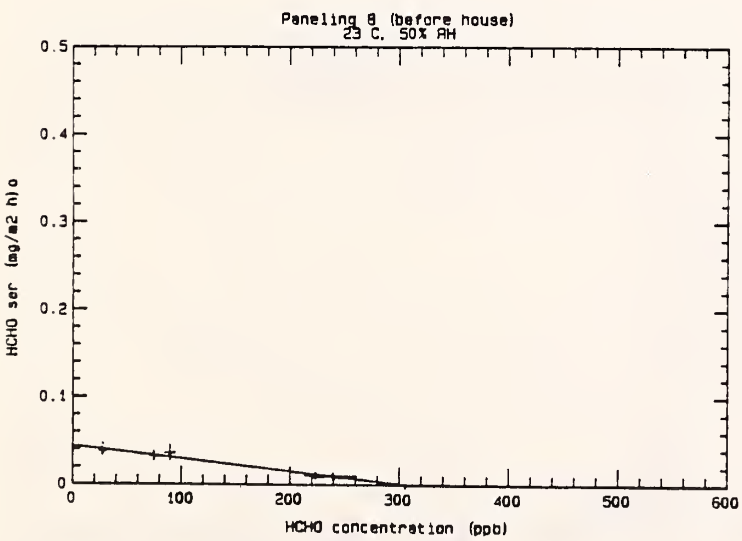


Figure 25. HCHO Emission Rate for Paneling #6 as a Function of HCHO Concentration (first test).*

Figure 26. HCHO Emission Rate for Paneling #6 as a Function of HCHO Concentration (second test.)*



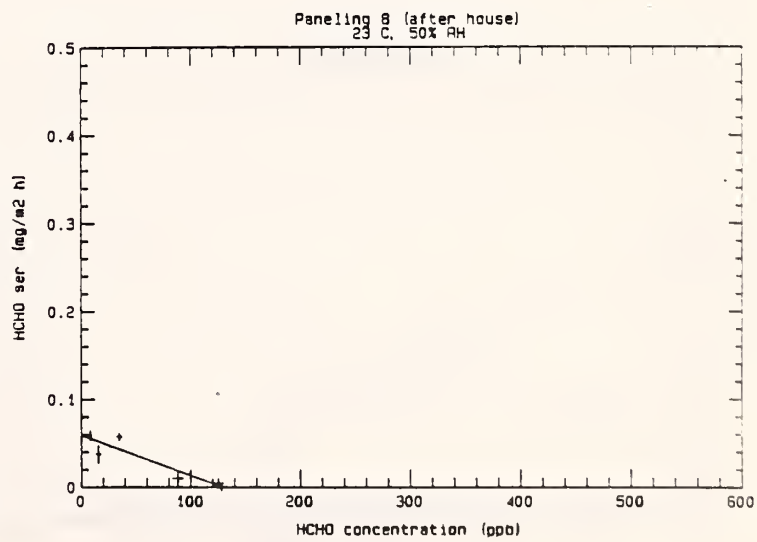


Figure 27. HCHO Emission Rate for Paneling #8 as a Function of HCHO Concentration (first test).*

Figure 28. HCHO Emission Rate for Paneling #8 as a Function of HCHO Concentration (second test.)*

*Horizontal bars through data points represent one standard error unit to each side; vertical bars represent one standard deviation unit to each side.

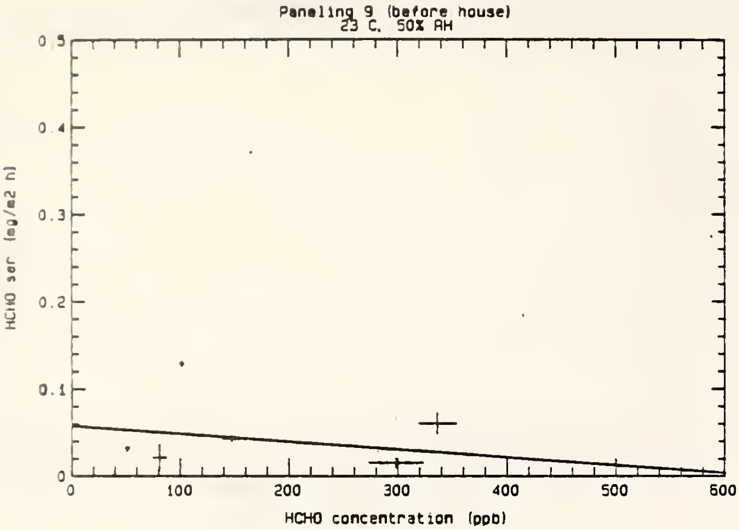


Figure 29. HCHO Emission Rate for Paneling #9 as a Function of HCHO Concentration (first test).*

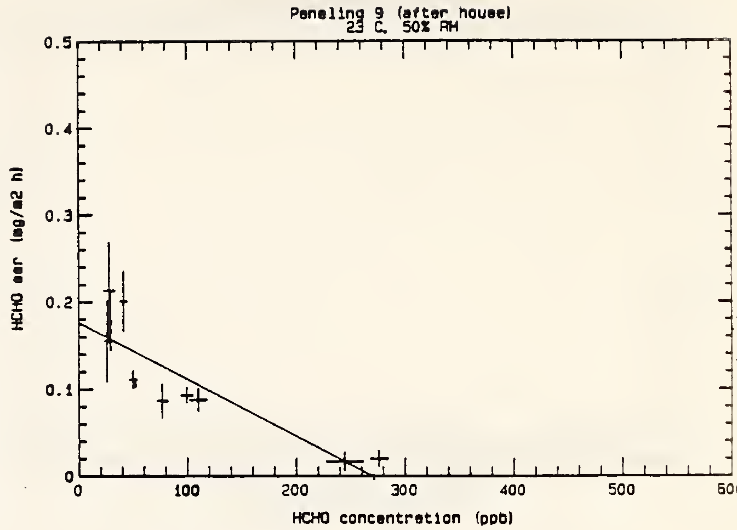


Figure 30. HCHO Emission Rate for Paneling #9 as a Function of HCHO Concentration (second test.)*

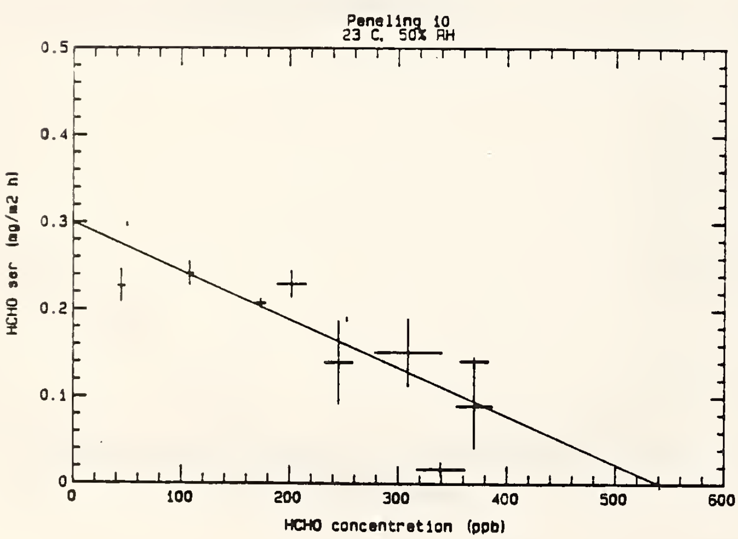


Figure 31. HCHO Emission Rate for Paneling #10 as a Function of HCHO Concentration.*

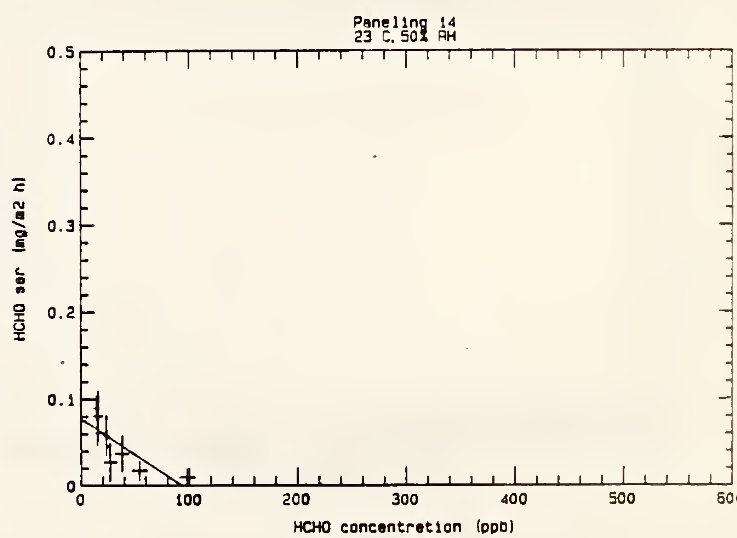


Figure 32. HCHO Emission Rate for Paneling #14 as a Function of HCHO Concentration.*

*Horizontal bars through data points represent one standard error unit to each side; vertical bars represent one standard deviation unit to each side.

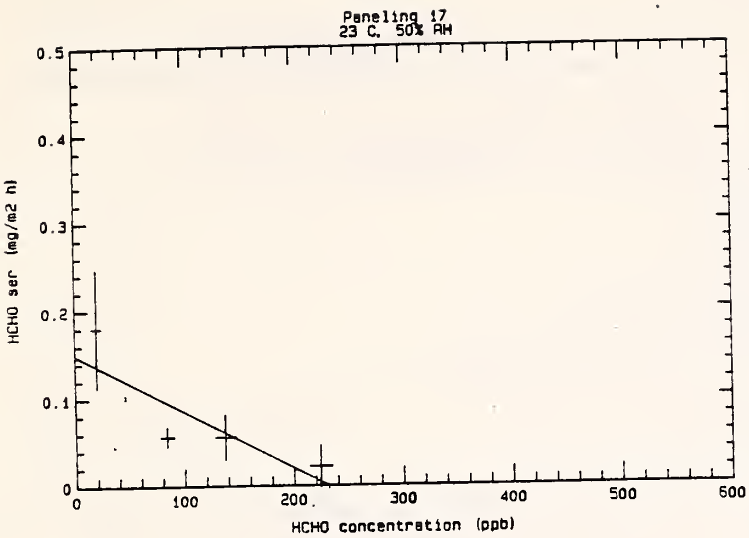


Figure 33. HCHO Emission Rate for Paneling #17 as a Function of HCHO Concentration.*

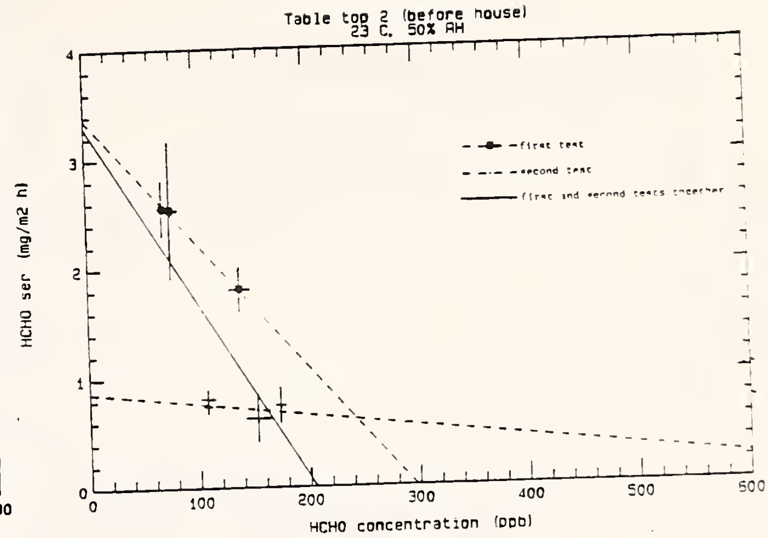


Figure 34. HCHO Emission Rate for MDF Table Top #2 as a Function of HCHO Concentration (first and second tests.)*

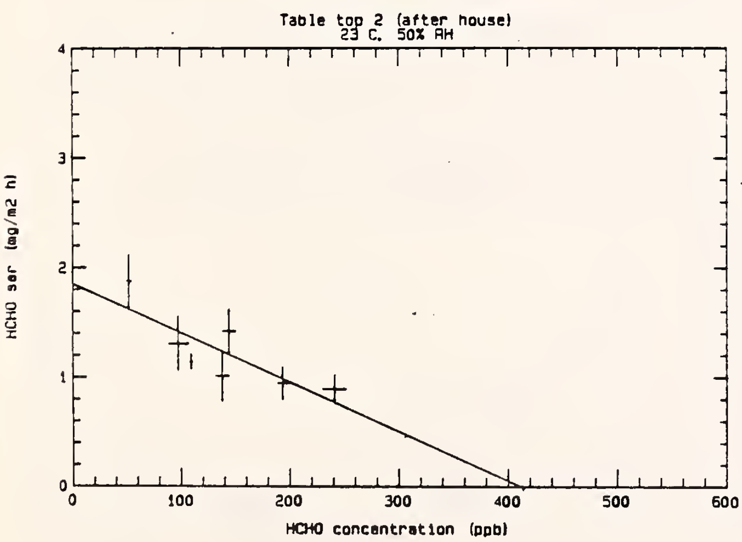


Figure 35. HCHO Emission Rate for MDF Table Top #2 as a Function of HCHO Concentration (third test.)*

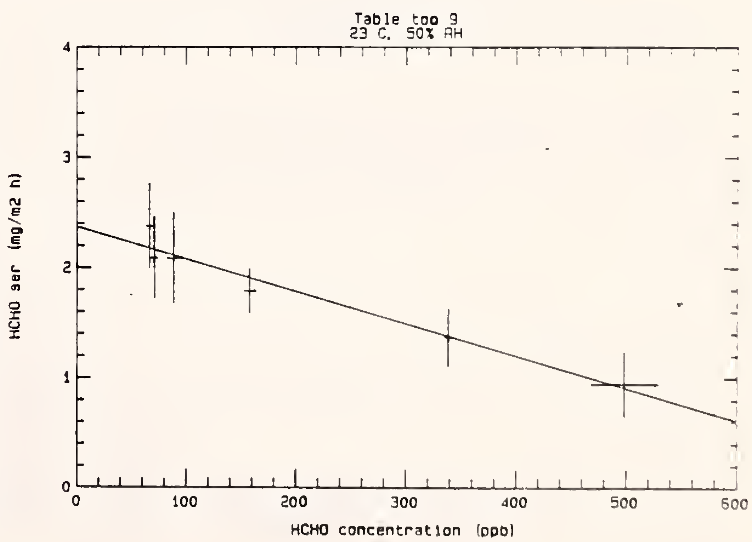


Figure 36. HCHO Emission Rate for MDF Table Top #9 as a Function of HCHO Concentration.*

*Horizontal bars through data points represent one standard error unit to each side; vertical bars represent one standard deviation unit to each side.

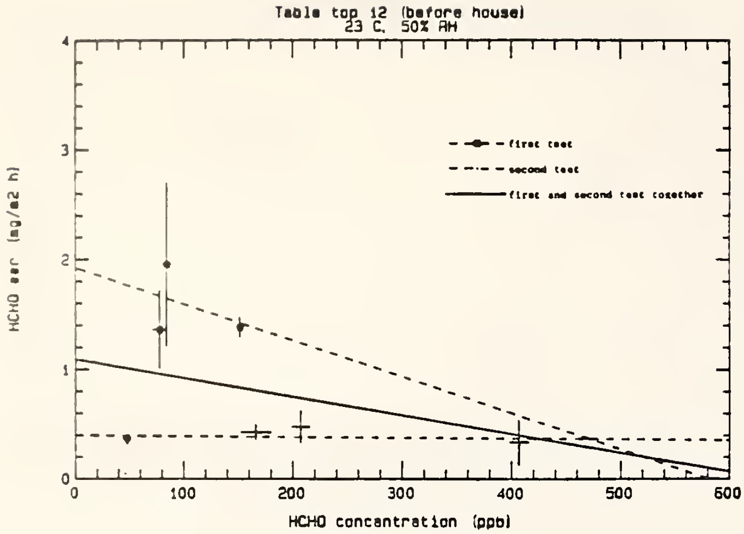


Figure 37. HCHO Emission Rate for MDF Table Top #12 as a Function of HCHO Concentration (first and second tests.)*

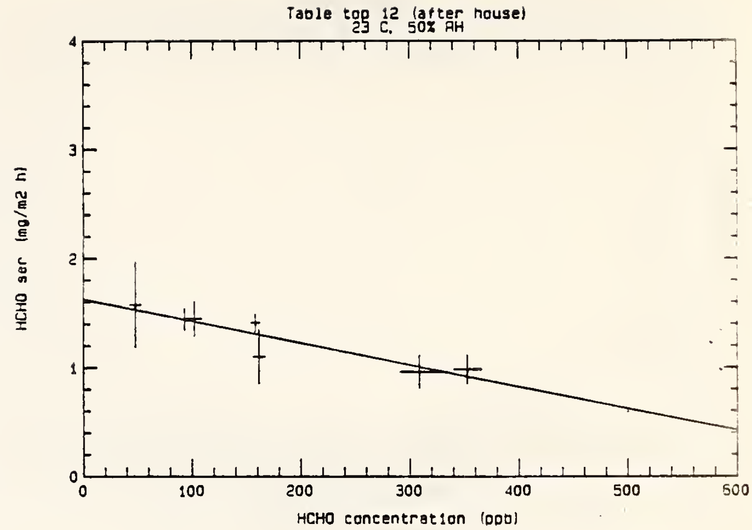


Figure 38. HCHO Emission Rate for MDF Table Top #12 a Function of HCHO Concentration (third test.)*

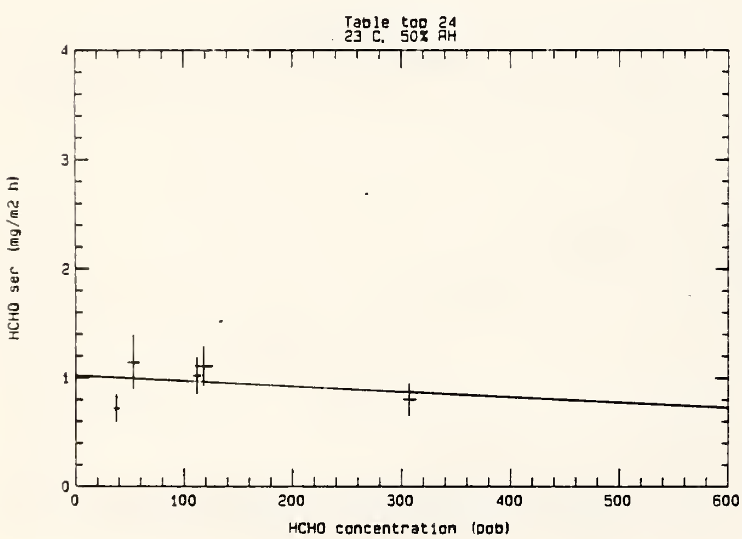


Figure 39. HCHO Emission Rate for MDF Table Top #24 as a Function of HCHO Concentration.*

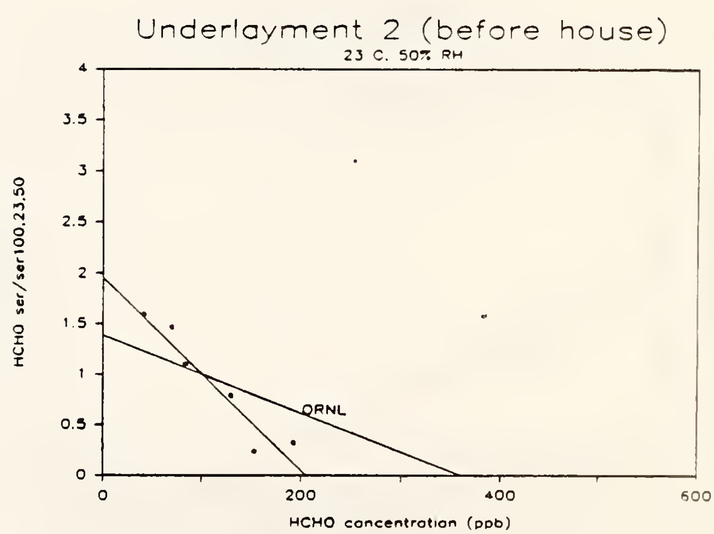


Figure 40. Comparison of Normalized HCHO Emission Rates for Underlayment #2 (first and second tests combined) to those Predicted by ORNL Emission Model.

*Horizontal bars through data points represent one standard error unit to each side; vertical bars represent one standard deviation unit to each side.

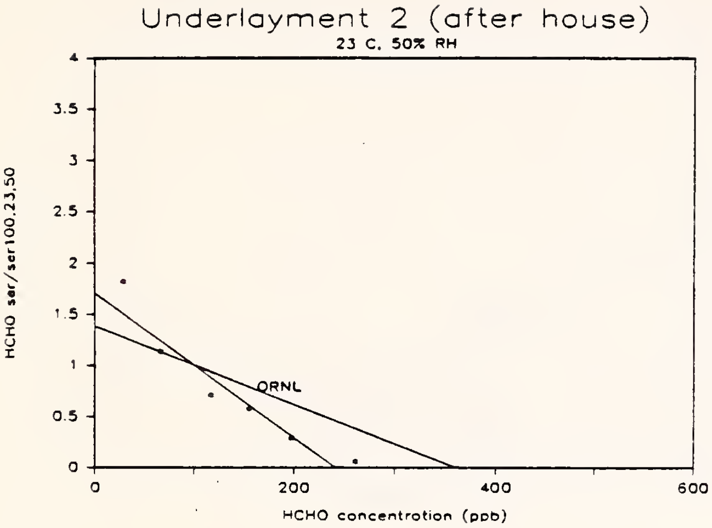


Figure 41. Comparison of Normalized HCHO Emission Rates for Underlayment #2 (third test) to those Predicted by ORNL Emission Model.

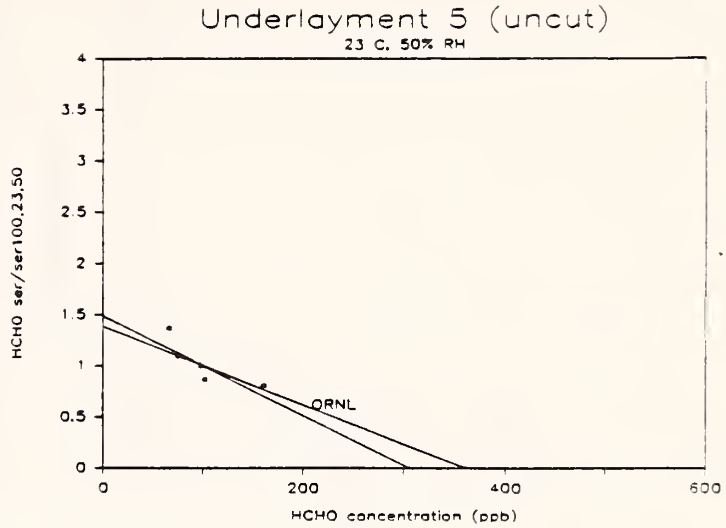


Figure 42. Comparison of Normalized HCHO Emission Rates for Underlayment #5 (first test) to those Predicted by ORNL Emission Model.

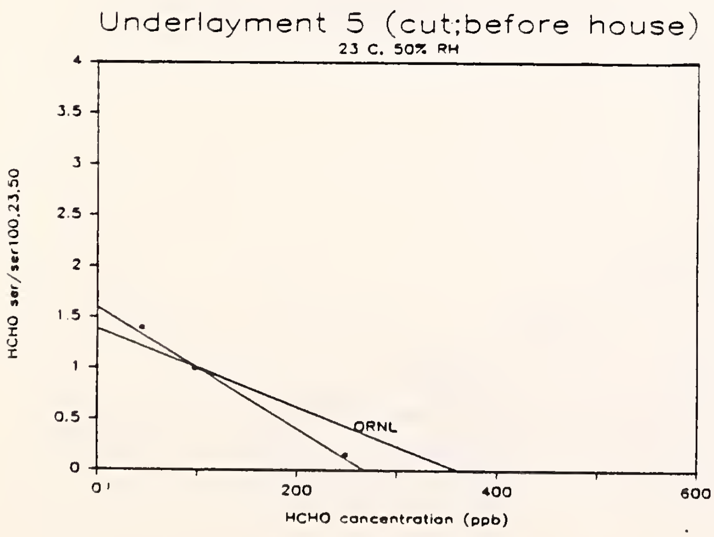


Figure 43. Comparison of Normalized HCHO Emission Rates for Underlayment #5 (second test) to those Predicted by ORNL Emission Model.

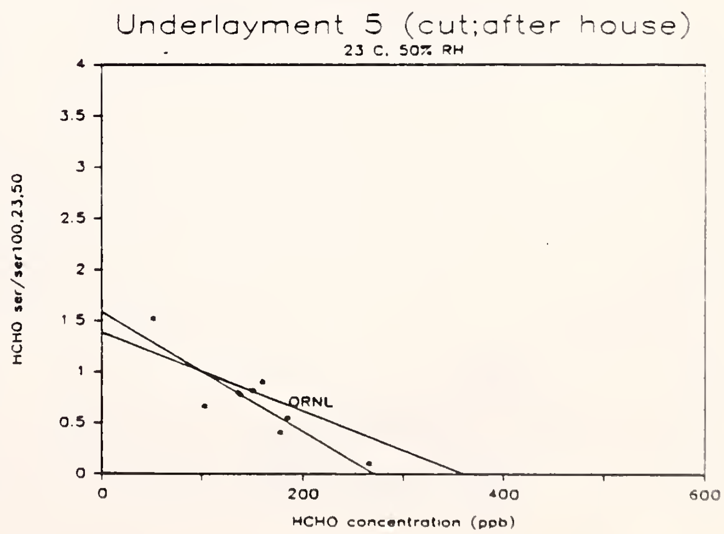


Figure 44. Comparison of Normalized HCHO Emission Rates for Underlayment #5 (third test) to those Predicted by ORNL Emission Model.

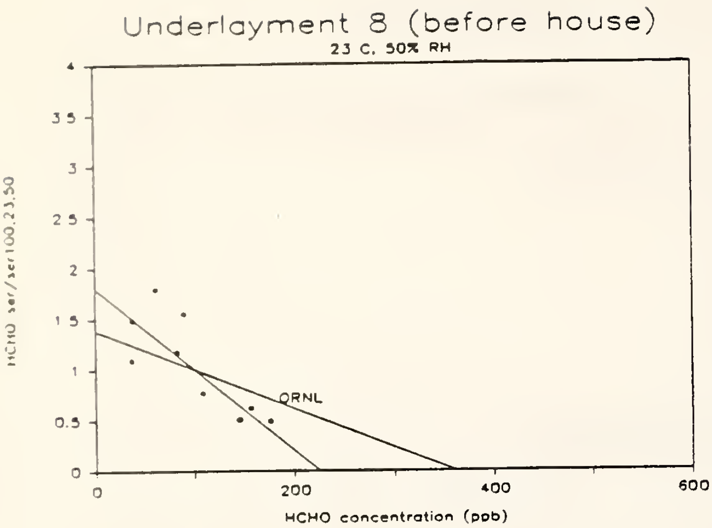


Figure 45. Comparison of Normalized HCHO Emission Rates for Underlayment #8 (first and second tests combined) to those Predicted by ORNL Emission Model.

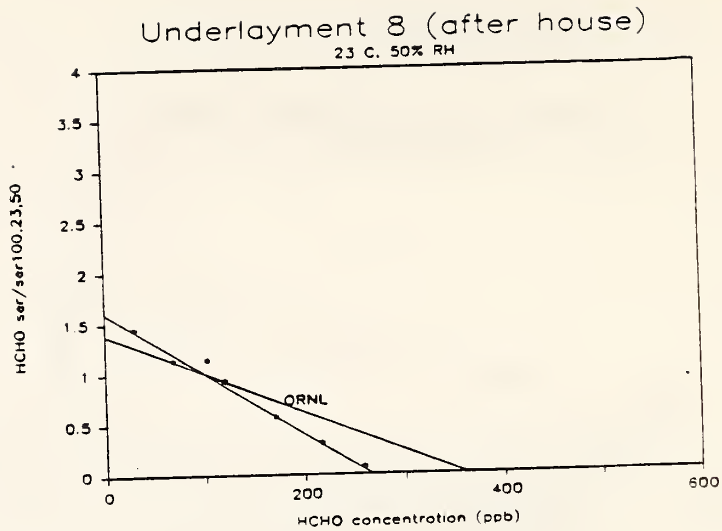


Figure 46. Comparison of Normalized HCHO Emission Rates for Underlayment #8 (third test) to those Predicted by ORNL Emission Model.

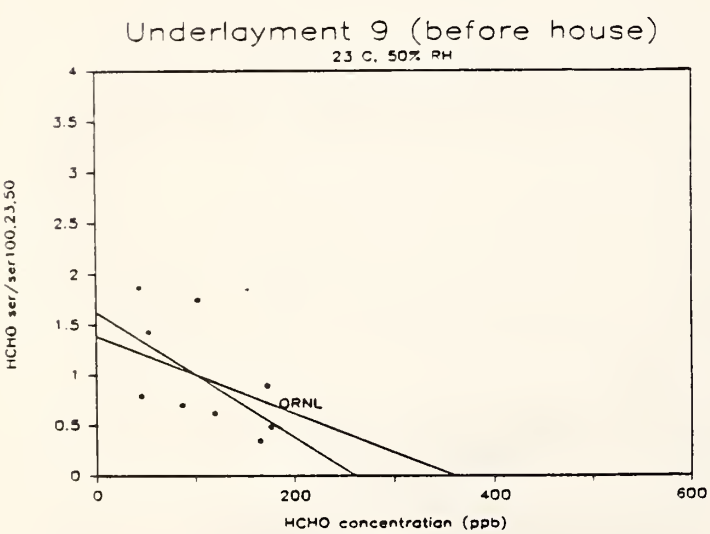


Figure 47. Comparison of Normalized HCHO Emission Rates for Underlayment #9 (first and second tests combined) to those Predicted by ORNL Emission Model.

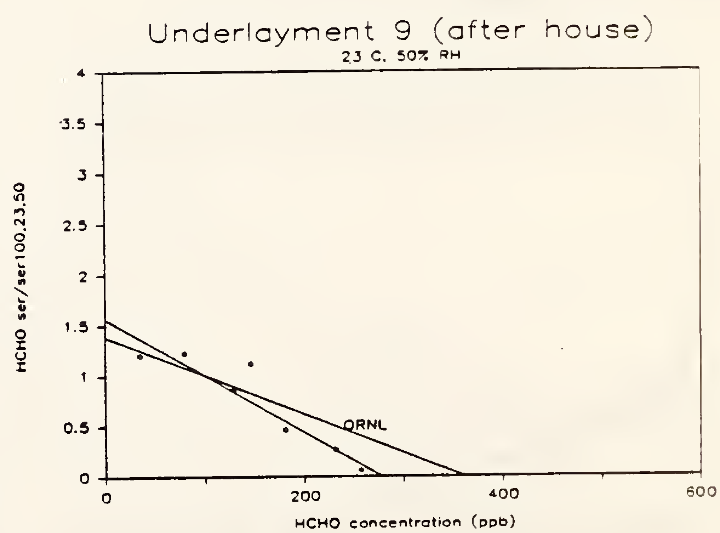


Figure 48. Comparison of Normalized HCHO Emission Rates for Underlayment #9 (third test) to those Predicted by ORNL Emission Model.

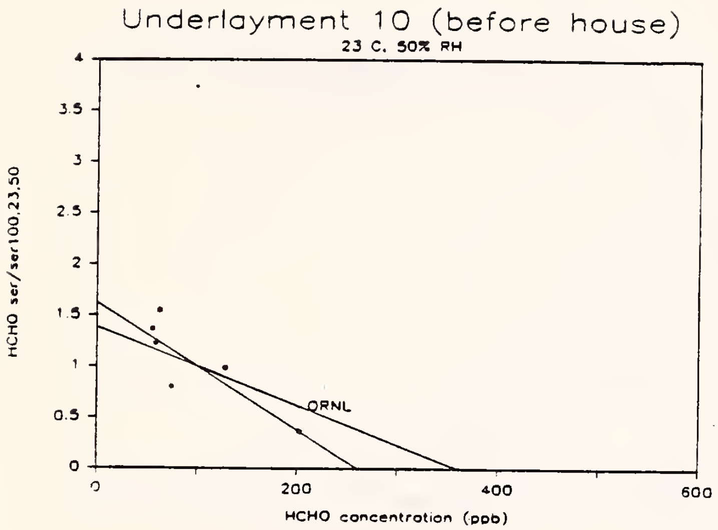


Figure 49. Comparison of Normalized HCHO Emission Rates for Underlayment #10 (first and second tests combined) to those Predicted by ORNL Emission Model.

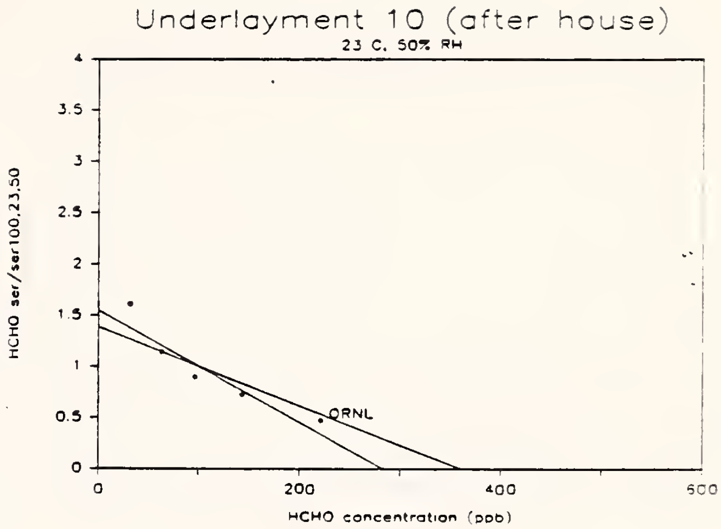


Figure 50. Comparison of Normalized HCHO Emission Rates for Underlayment #10 (third test) to those Predicted by ORNL Emission Model.

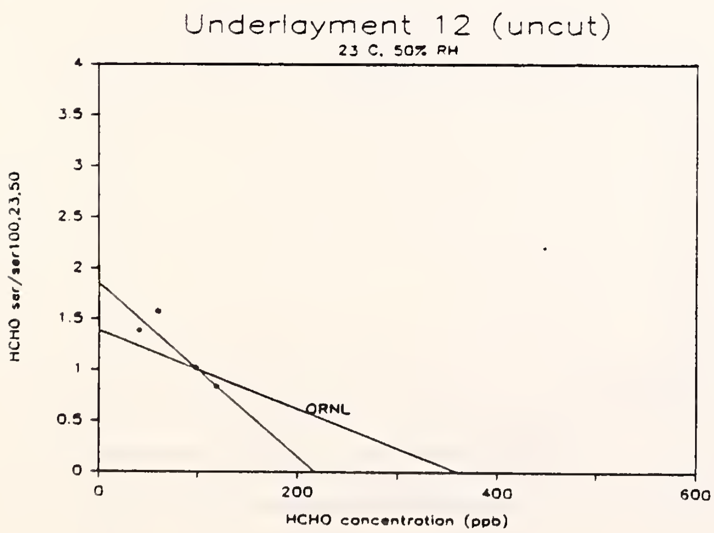


Figure 51. Comparison of Normalized HCHO Emission Rates for Underlayment #12 (first test) to those Predicted by ORNL Emission Model.

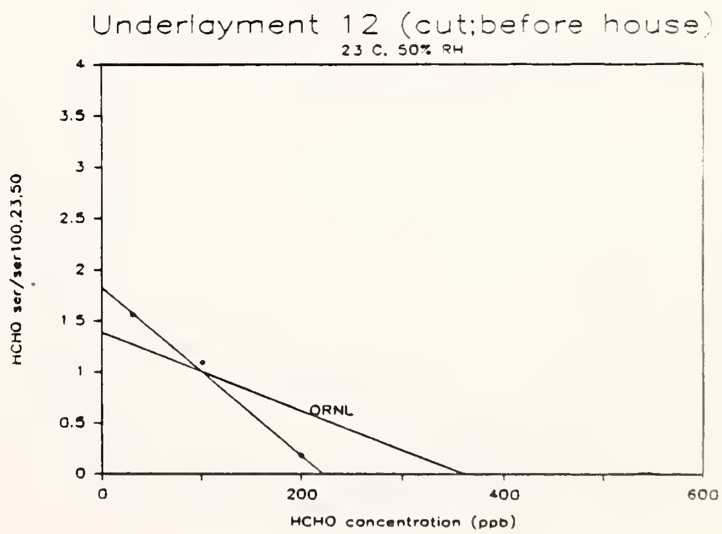
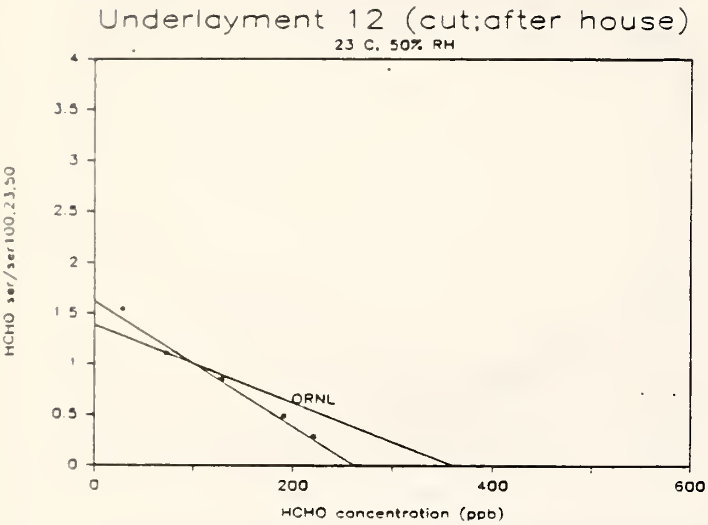


Figure 52. Comparison of Normalized HCHO Emission Rates for Underlayment #12 (second test) to those Predicted by ORNL Emission Model.



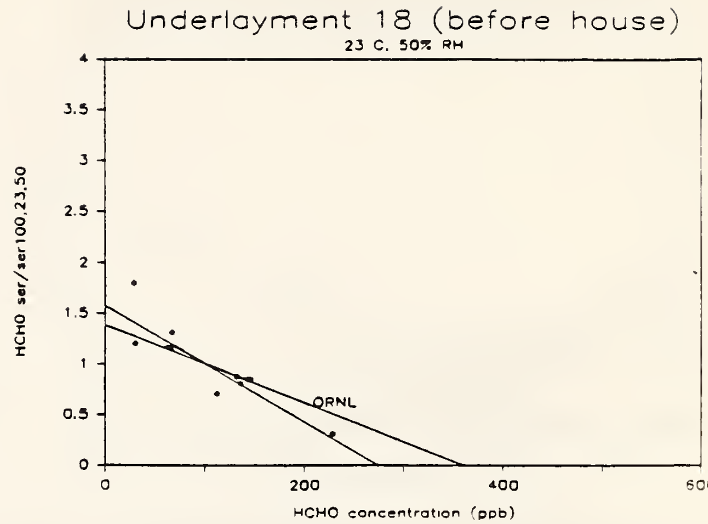
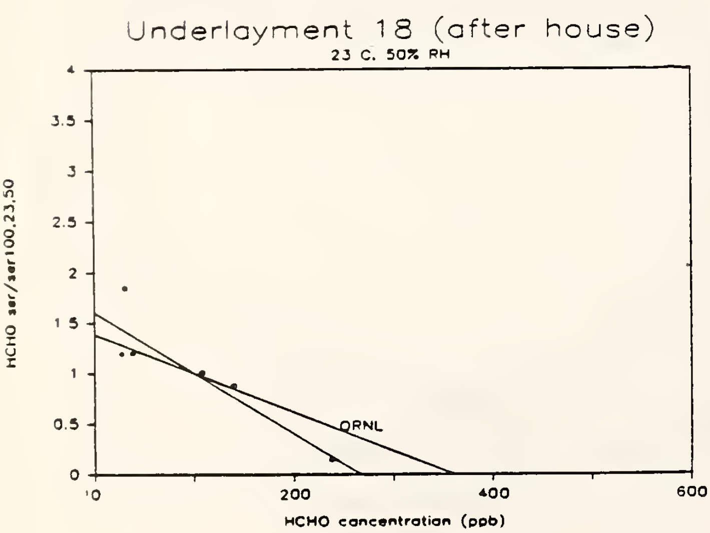


Figure 53. Comparison of Normalized HCHO Emission Rates for Underlayment #12 (third test) to those Predicted by ORNL Emission Model.

Figure 54. Comparison of Normalized HCHO Emission Rates for Underlayment #18 (first test) to those Predicted by ORNL Emission Model.



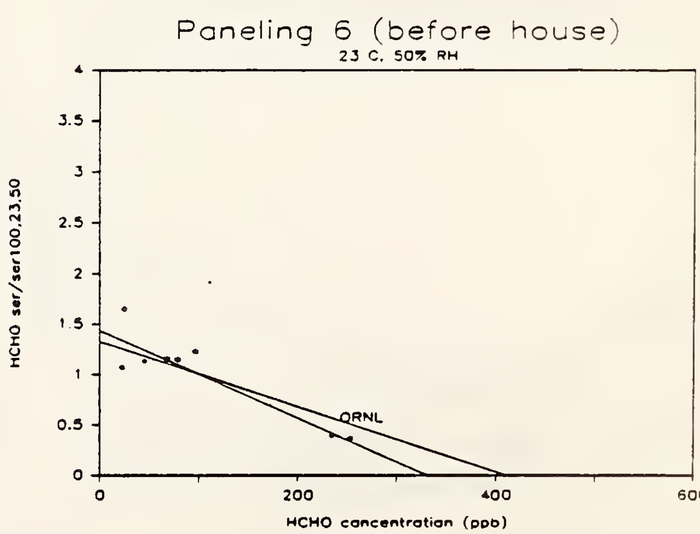


Figure 55. Comparison of Normalized HCHO Emission Rates for Underlayment #18 (second test) to those Predicted by ORNL Emission Model.

Figure 56. Comparison of Normalized HCHO Emission Rates for Paneling #6 (first test) to those Predicted by ORNL Emission Model.

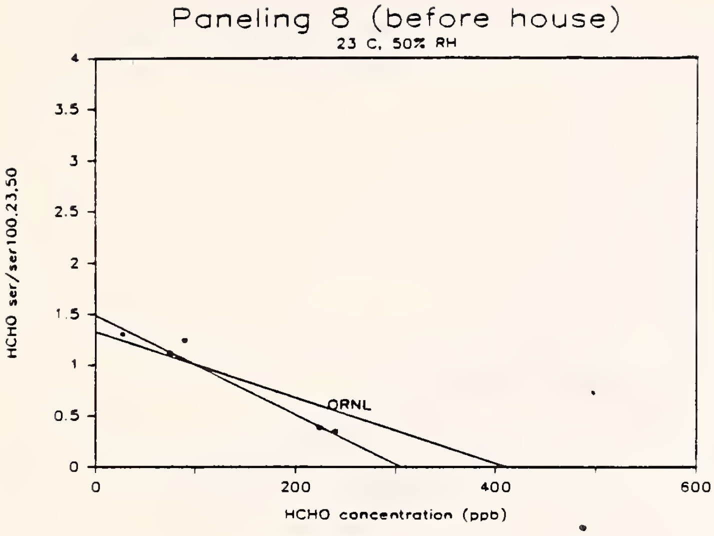


Figure 57. Comparison of Normalized HCHO Emission Rates for Paneling #8 (first test) to those Predicted by ORNL Emission Model.

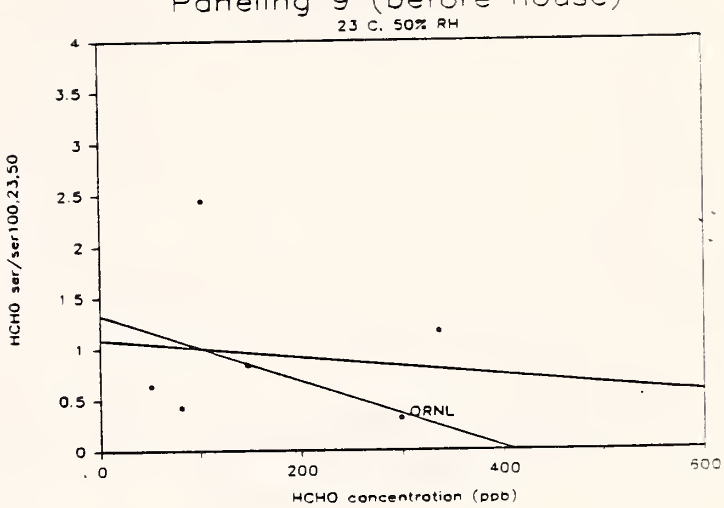


Figure 58. Comparison of Normalized HCHO Emission Rates for Paneling #9 (first test) to those Predicted by ORNL Emission Model.

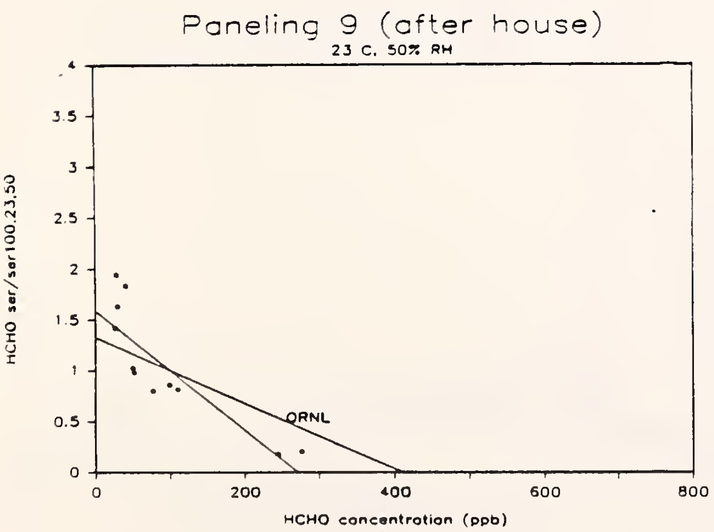


Figure 59. Comparison of Normalized HCHO Emission Rates for Paneling #9 (second test) to those Predicted by by ORNL Emission Model.

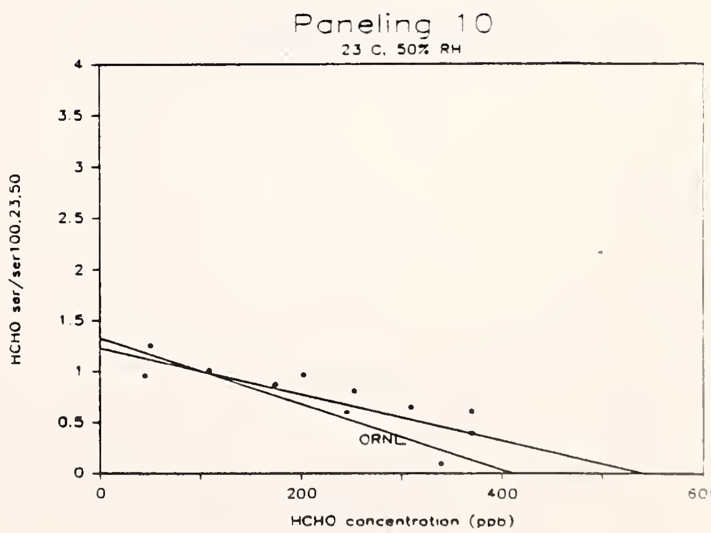


Figure 60. Comparison of Normalized HCHO Emission Rates for Paneling #10 to those Predicted by ORNL Emission Model.

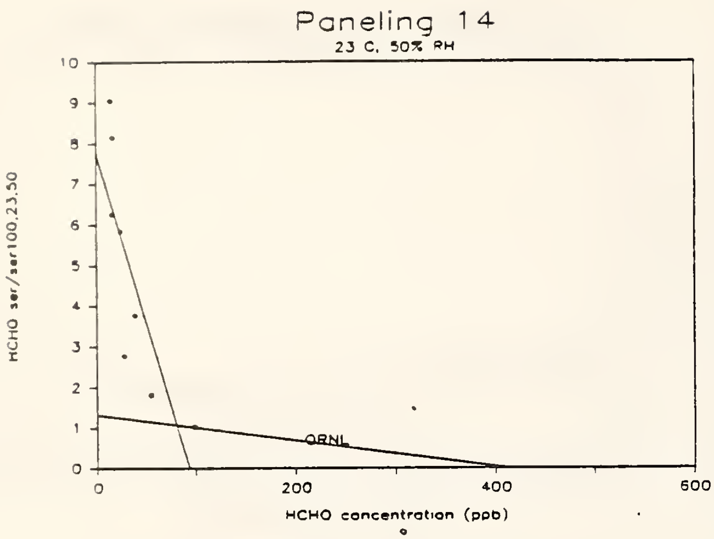


Figure 61. Comparison of Normalized HCHO Emission Rates for Paneling #14 to those Predicted by ORNL Emission Model.

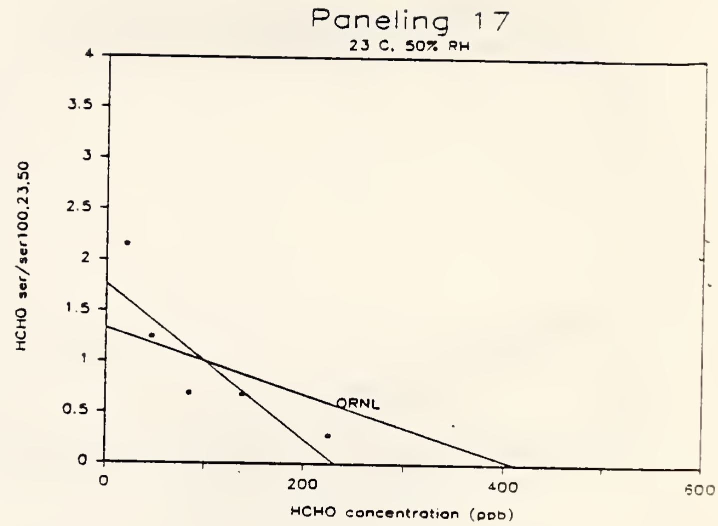


Figure 62. Comparison of Normalized HCHO Emission Rates for Paneling #17 to those Predicted by ORNL Emission Model.

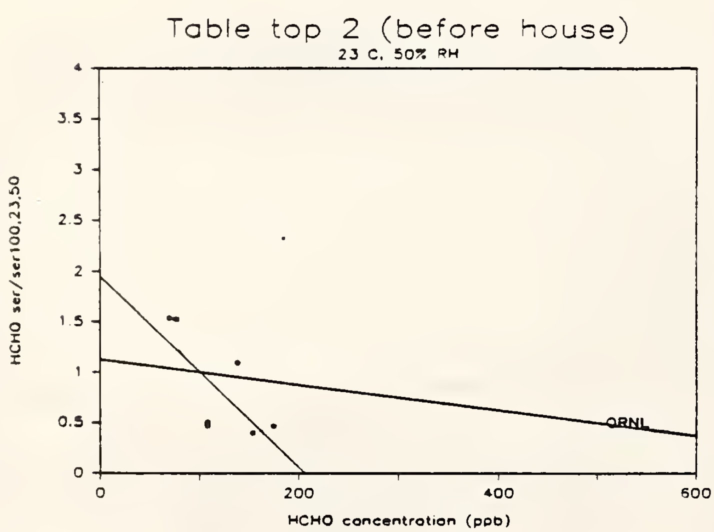


Figure 63. Comparison of Normalized HCHO Emission Rates for MDF Table Top #2 (first and second tests combined) to those Predicted by ORNL Emission Model.

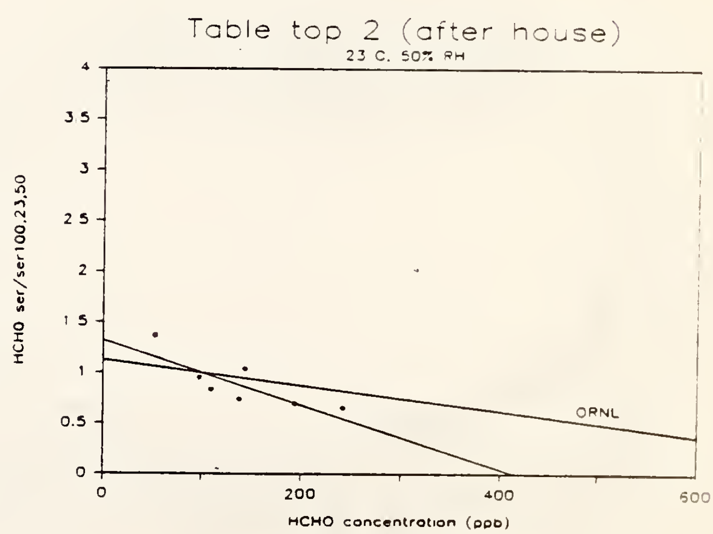


Figure 64. Comparison of Normalized HCHO Emission Rates for MDF Table Top #2 (third test) to those Predicted by ORNL Emission Model.

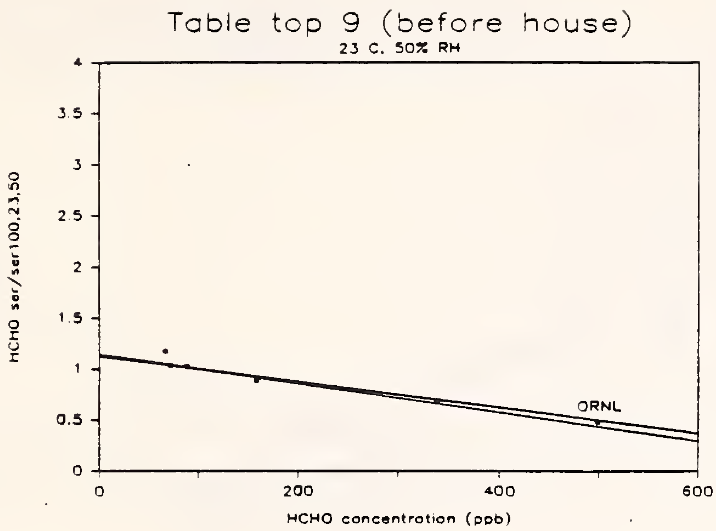


Figure 65. Comparison of Normalized HCHO Emission Rates for MDF Table Top #9 to those Predicted by ORNL Emission Model.

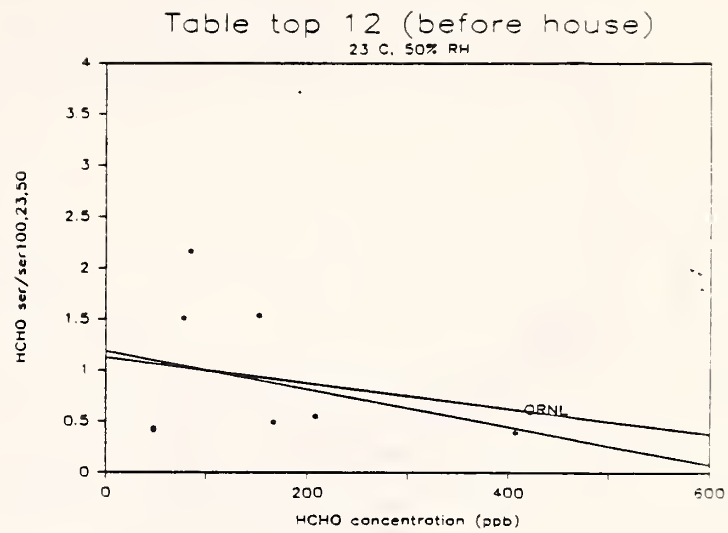


Figure 66. Comparison of Normalized HCHO Emission Rates for MDF Table Top #12 (first and second tests combined) to those Predicted by ORNL Emission Model.

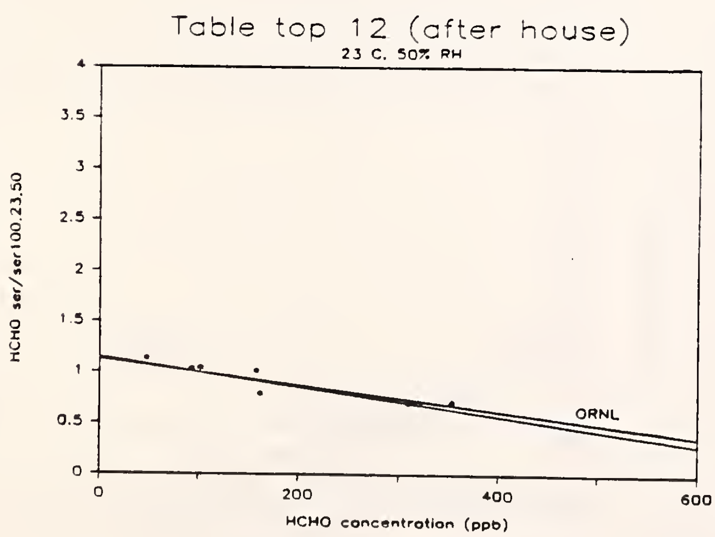


Figure 67. Comparison of Normalized HCHO Emission Rates for MDF Table Top #12 (third test) to those Predicted by ORNL Emission Model.

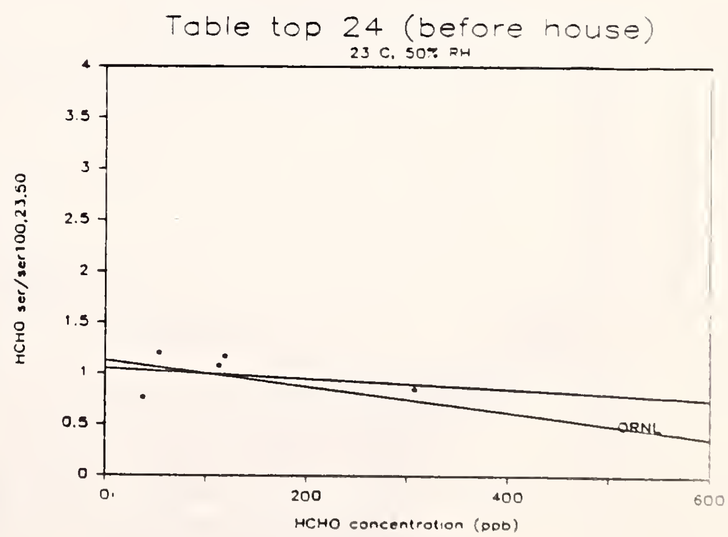


Figure 68. Comparison of Normalized HCHO Emission Rates for MDF Table Top #24 to those Predicted by ORNL Emission Model.

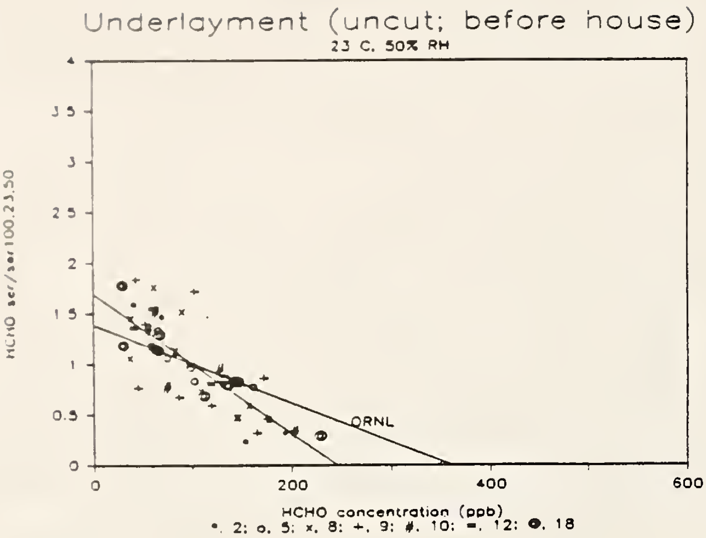


Figure 69. Comparison of Normalized HCHO Emission Rates for Combined Uncut Underlayment (before and during prototype house study) to those Predicted by ORNL Emission Model.

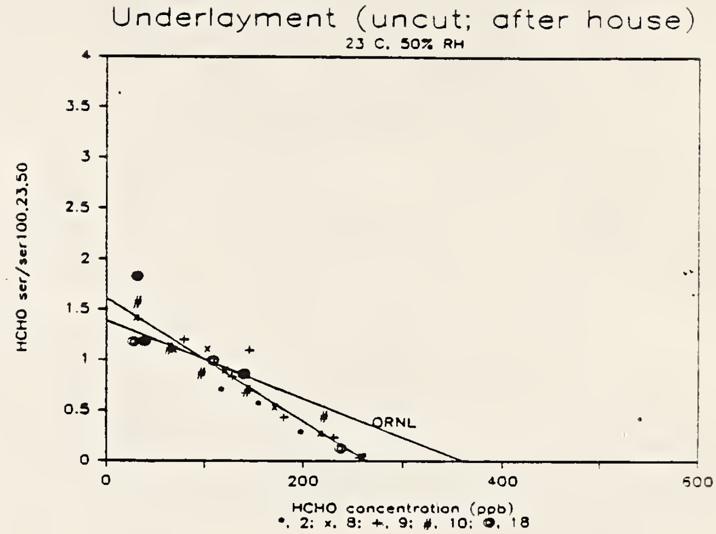


Figure 70. Comparison of Normalized HCHO Emission Rates for Combined Uncut Underlayment (after prototype house study) to those Predicted by ORNL Emission Model.

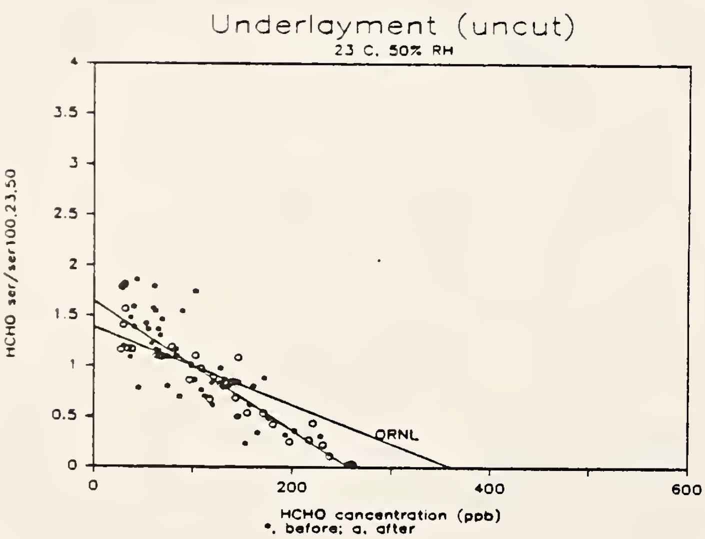


Figure 71. Comparison of Normalized HCHO Emission Rates for Combined Uncut Underlayment to those Predicted by ORNL Emission Model.

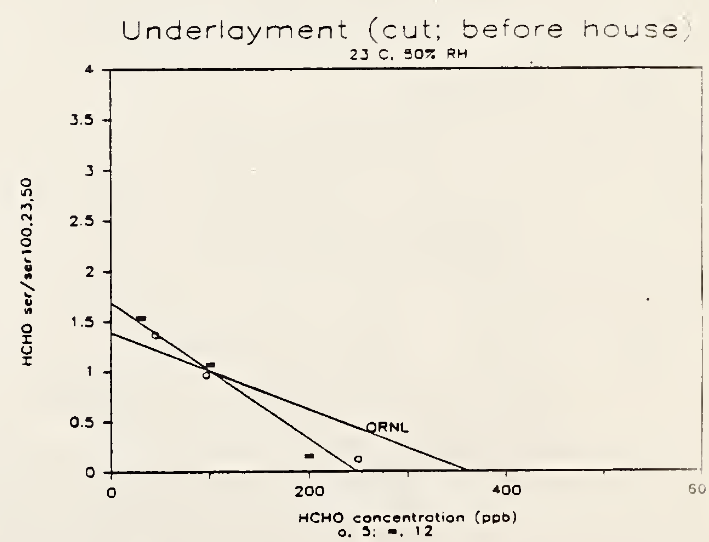


Figure 72. Comparison of Normalized HCHO Emission Rates for Combined Cut Underlayment (during prototype house study) to those Predicted by ORNL Emission Model.

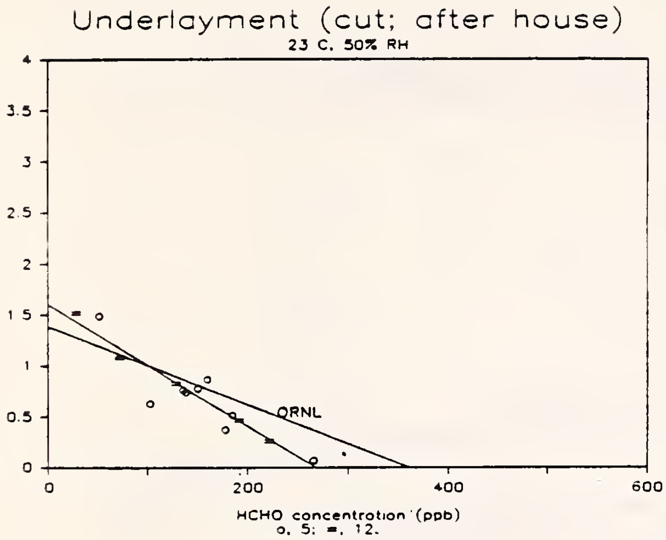


Figure 73. Comparison of Normalized HCHO Emission Rates for Combined Cut Underlayment (after prototype house study) to those Predicted by ORNL Emission Model.

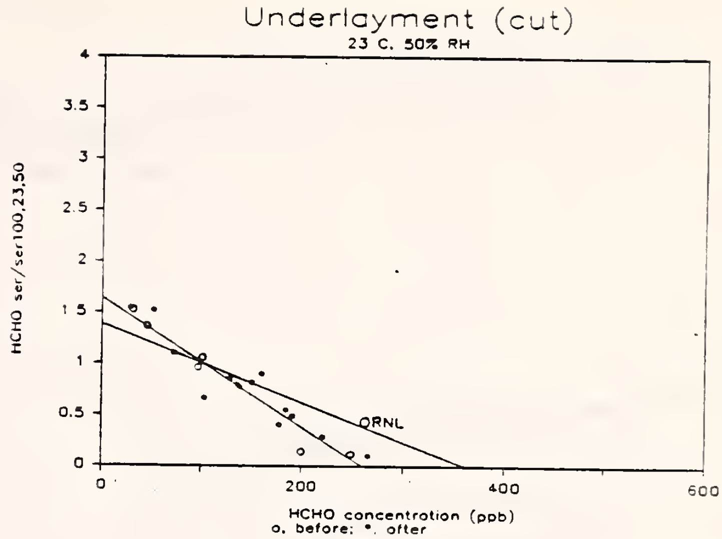


Figure 74. Comparison of Normalized HCHO Emission Rates for Combined Cut Underlayment to those Predicted by ORNL Emission Model.

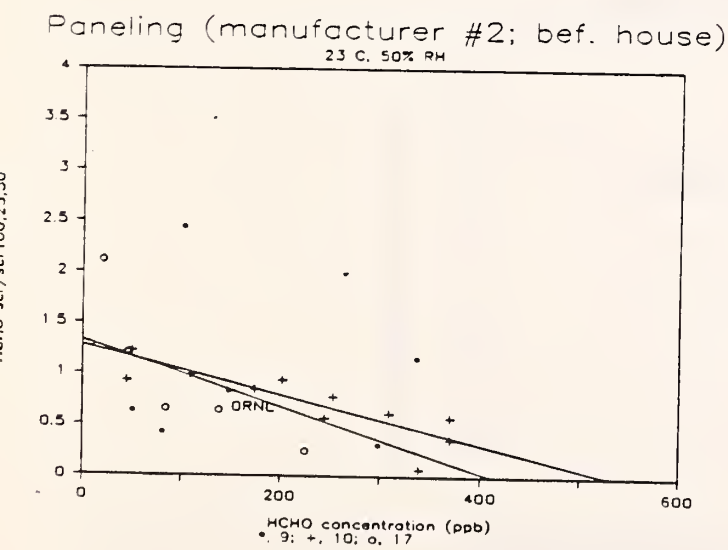


Figure 75. Comparison of Normalized HCHO Emission Rates for Combined Paneling from manufacturer #2 (before prototype house study) to those Predicted by ORNL Emission Model.

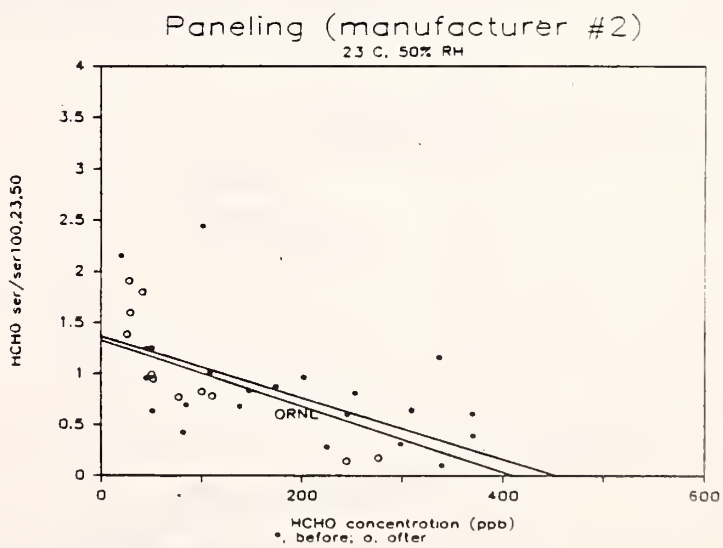


Figure 76. Comparison of Normalized HCHO Emission Rates for Combined Paneling from manufacturer #2 to those Predicted by ORNL Emission Model.

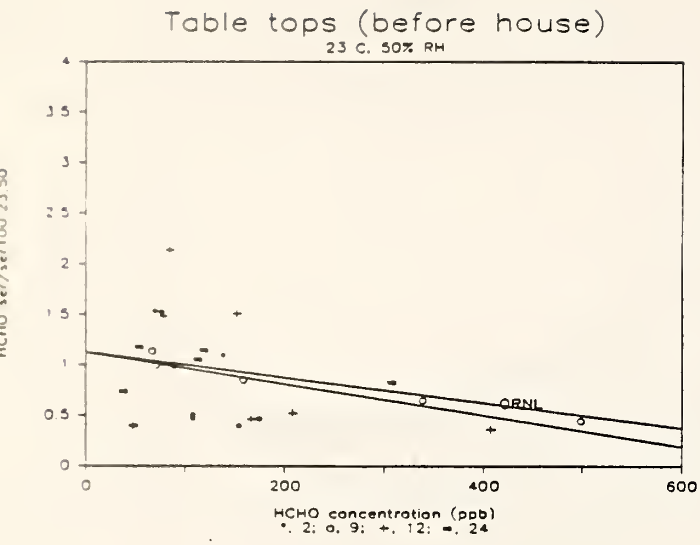


Figure 77. Comparison of Normalized HCHO Emission Rates for Combined MDF Table Tops (before and during prototype house study) to those Predicted by ORNL Emission Model.

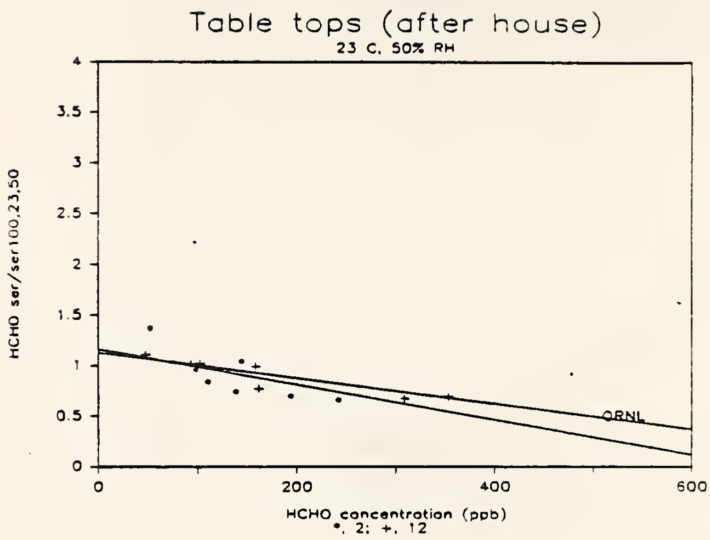


Figure 78. Comparison of Normalized HCHO Emission Rates for Combined MDF Table Tops (after prototype house study) to those Predicted by ORNL Emission Model.

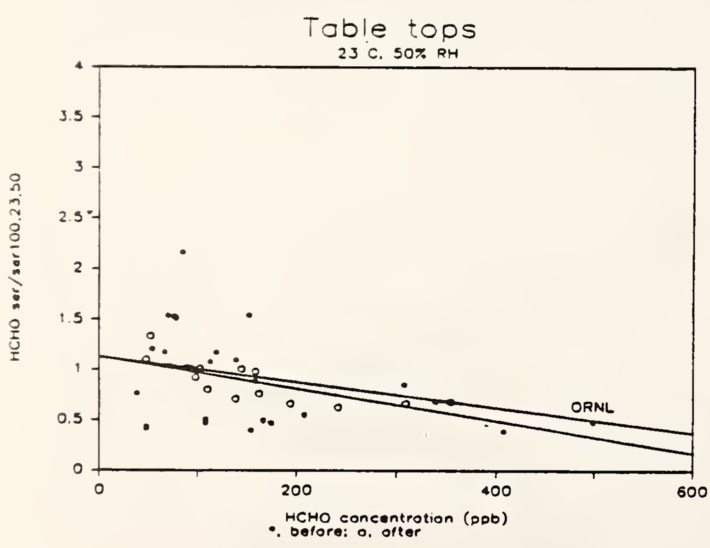


Figure 79. Comparison of Normalized HCHO Emission Rates for Combined MDF Table Tops to those Predicted by ORNL Emission Model.

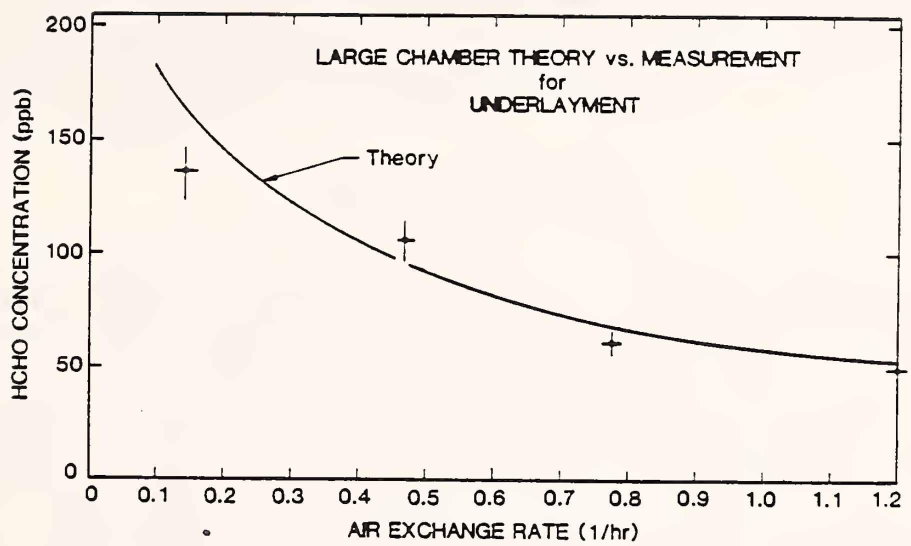


Figure 80. Comparison of Measurements (points) and Predictions of Equation 8 (curve) for Prototype-House Loading of Underlayment.*

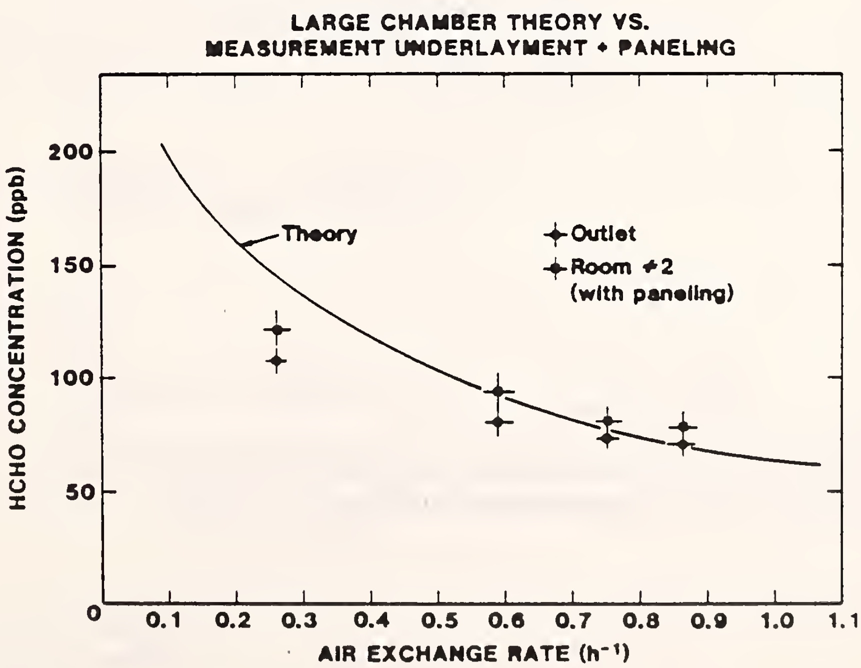


Figure 81. Comparison of Measurements (points) and Predictions of Equation 8 (curve) for Prototype-House Loading of Underlayment and Paneling.*

*Horizontal and vertical bars through data points represent one standard error unit to each side.

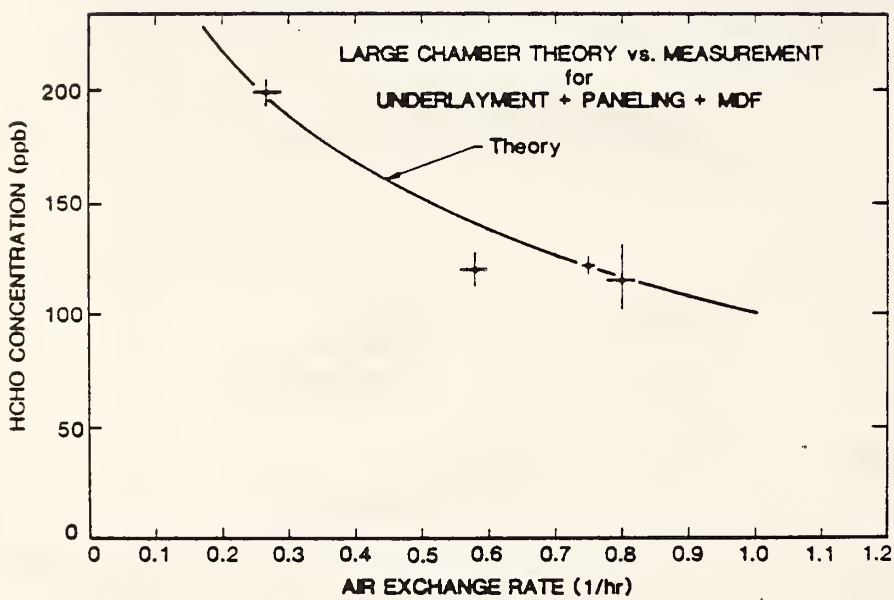


Figure 82. Comparison of Measurements (points) and Predictions of Equation 8 (curve) for Prototype-House Loading of Underlayment, Paneling and MDF.*

*Horizontal and vertical bars through data points represent one standard error unit to each side.

Appendix A

Plan for Testing Model for HCHO Emissions from Pressed Wood Products

The test for evaluating the HCHO emission model from pressed wood products will be carried out in a two cell 10′ x 20′ x 8′ room. Measurements will be made of 1.) HCHO level at various heights in each cell, 2.) temperature in each cell, 3.) humidity in each cell, and 4.) total air infiltration rate in the chamber.

Design of the Chamber

The test chamber will be a 10′ x 20′ x 8′ two cell room. It will be constructed on 2"x4" framing 16" on center. The floor of the chamber will be made 3/4" exterior plywood. The floor and the inside surface will be covered with an air tight continuous vapor barrier sheet over lapped at the edges. Over this will be applied sheet rock to the walls and ceiling. The wall between the two cells will contain a doorway and two 2′ x 2′ removable panels which can at a later time be used to simulate various resistances between the two cells. For the present series of tests the doorway will be left open. The chamber will have two supply registers, one low and one high, at each end and two return registers, one low and one high at the other end. The test chamber will be installed in an NBS environmental chamber which will control the temperature and humidity.

Measurements

1.) Temperature:
- cell 1 at height of 2′, 4′, 6′ at center
- cell 2 at height of 2′, 4′, 6′ at center

2.) Humidity:
- cell 1 at height of 4′ in center
- cell 2 at height of 4′ in center

3.) HCHO
- supply air
- return air
- cell 1 in center at heights of 0, 2, 4 and 6 feet
- cell 2 in center at heights of 0, 2, 4 and 6 feet

4.) Air Infiltration: per ASTM E741-83 by sampling SF_6 at same points as sampling HCHO using electron capture gas chromatograph.

5.) Airflow
- fresh air intake
- spill air outlet

Calibration of HCHO Monitor

Method 1. Permeation tubes containing polyoxymethylene

Calibration will be done at about ten concentrations in the range 0 to 500 ppb, using a polyoxymethylene permeation tube emitting formaldehyde at nominal rates of 66 ng/min at 80°C, and 350 ng/min at 100°C. (A permeation rate of 750 mg/ml is required to produce a formaldehyde concentration of 1 ppm.) The permeation tube output will be diluted with ultra-zero air to get the proper concentrations.

Method 2. Formalin

Dilute formalin is injected into a heated airstream using a syringe pump in order to obtain the desired concentrations of formaldehyde in the range 0-500 ppb. The relative humidity of the airstream will be controlled by bubbling a portion of it through a temperature-controlled water bubble. A mixing chamber will be used to smooth out the formaldehyde concentration fluctuations. This method is described by Matthews et al. in Environment International 8, 143-151, 1982.

Method 3. Check of formaldehyde accuracy

The Center for Analytical Chemistry of NBS will prepare and calibrate the formaldehyde emission for an unknown permeation tube procured and calibrated by their staff. The permeation tube will be conditioned in a 25°C ct.

Testing Sequence

1.) 23°C at 50% RH with air infiltration at 0.2, 0.5 and 1. ACH

   a.) particle board only
   b.) add paneling
   c.) add MDF

2.) 26°C at 60% RH with air infiltration at 0.2, 0.5 and 1. ACH

   a.) particle board only
   b.) add paneling
   c.) add MDF

3.) 20°C at 30% RH with air infiltration at 0.2, 0.5 and 1. ACH

   a.) particle board only
   b.) add paneling
   c.) add MDF

ct.

Testing Sequence

1.) 23°C at 50% RH with air infiltration at 0.2, 0.5 and 1. ACH

a.) particle board only
b.) add paneling
c.) add MDF

2.) 26°C at 60% RH with air infiltration at 0.2, 0.5 and 1. ACH

a.) particle board only
b.) add paneling
c.) add MDF

3.) 20°C at 30% RH with air infiltration at 0.2, 0.5 and 1. ACH

a.) particle board only
b.) add paneling
c.) add MDF

Surface Emission Rate Measurement

1.) Using FESM technology per ORNL protocol.

2.) Using 4′ x 8′ teflon lined chamber.

3.) Per manufacturers specifications.

Pressed Wood Products for Loading Chamber

12 sheets 4′ x 8′ particle board underlayment, 5/8" with emission rate of 0.3 to 0.6 mg/m^2 h

5 sheets 4′ x 8′ industrial particle board, 3/4" with emission rates of 0.25 to .5 mg/m^2 h

10 hardwood plywood paneling 4′ x 8′, 1/8" with emission rate of 0.3 to 0.5 mg/m^2 h

5 MDF 4′ x 8′, 3/4" with emission rates 1 to 2 mg/m^2 h

Schedule

```
                            June  July  Aug   Sept  Oct   Nov
                            1234  1234  1234  1234  1234  1234

Design of 10x20 Chamber     x-x
Construct 10x20 Chamber        x----x
Calibrate CEA               x-------x
FSEM Qualification             x
Design 4x8 Chamber           xx
Building 4x8 Chamber           x----x
Calibrate 4x8 Chambers               x
Calibrate 10x20 Chamber                  x
Conditioning
  Underlayment                       x---x
  Paneling                              x-x
  MDF                                    x-x
Emission Rates
  4x8 Chamber
    Underlayment                           x
    Paneling                                  x
    MDF                                        x
  FSEM
    Underlayment                           x
    Paneling                                  x
    MDF                                        x
Chamber Tests
  23°C 50% RH
    Underlayment                              x
    + Paneling                                 x
    + MDF                                       x

  26°C 60% RH
    Underlayment                                 x
    + Paneling                                      x
    + MDF                                            x

  20°C 30% RH
    Underlayment                                      x
    + Paneling                                         x
    + MDF                                                x

Data Reduction                             x---------------x
Modeling Predictions                    x---------------x

                            1234  1234  1234  1234  1234  1234
                            June  July  Aug   Sept  Oct   Nov
```

Appendix B

Instrumentation System for Formaldehyde Emission-Rate Chambers

The major components of the instrumentation system for the formaldehyde emission rate chambers (FERC) are:

a.) An S-100 bus microcomputer consisting of::
Z-80 CPU Card
Cromemco 16FDC disk-controller card
64K-static RAM memory card
16-channel programmable-gain A/D converter card (Tecmar)
Air infiltration interface card (NBS design)
3 S-100-bus octal A/C relay cards (NBS design)
100,000-day real-time clock (Mountain Hardware)
2 360K double-density, double-sided 5 1/4" disk drives

b.) 2 ten-valve sample manifolds (NBS design)

c.) ITT model 555 electron-capture gas chromatograph

d.) CEA TGM-555 formaldehyde monitor

e.) Tracer-gas (SF_6) injection unit (NBS design)

f.) Kintek calibration gas standard generator (shared with two-room prototype-house system)

g.) 4 Datametric hot-wire air-flow meters

h.) Power unit for chamber exhaust and supply fans

The numbers on the SF_6 and HCHO sample tubes are the same as the medium-size chamber numbers (1 to 12); similarly for the injection tubes, which also carry the letter "I". The exhaust and supply fans on each chamber can be turned off or on by the corresponding numbered switch on the power control unit. There are also 12 potentiometers for regulating the voltage to the fans. This voltage can be displayed on the digital panel meter on the power-control unit by turning the 12-position rotary switch to the corresponding number of the chamber. The sample port and analog connections for the chambers are given in tables B.1 to B.3.

Table B.1. Port Assignments for Formaldehyde Emission-Rate Chambers for the Formaldehyde Manifold

Port #	Description
1	zero gas
2	span gas
3	environmental chamber background
4	FERC #1
5	FERC #2
6	FERC #3
7	not used
8	not used
9	not used
10	not used

Table B.2. Port Assignment for Formaldehyde Emission-Rate Chambers for the SF_6 Sample Manifold

Port #	Description
1	environmental chamber background
2	FERC #1
3	FERC #2
4	FERC #3
5	not used
6	not used
7	not used
8	not used
9	--------
10	--------

Table B.3. Analog Connections for Formaldehyde Emission Rate Chambers

Binding Post #	Description
1	zero
2	-----
3	-----
4	-----
5	-----
6	-----
7	-----
8	-----
9	-----
10	-----
11	-----
12	air-flow meter FERC #3
13	air-flow meter FERC #2
14	air-flow meter FERC #1
15	-----
16	CEA TGM-555 recorder output

Appendix C

Instrumentation System for Two-Room Prototype House

The major components of the instrumentation system for the two-room prototype house are:

a.) An S-100 bus microcomputer consisting of:
Z-80 CPU card
Cromemco 16FDC disk-controller card
64K static RAM memory card
16-channel programmable gain A/D card (Tecmar)
S-100 bus octal A/C relay card (NBS design)
100,000-day real-time clock (Mountain Hardware)
2 360K double-sided, double-density 5 1/4" disk drives

b.) Ten-value sample manifold (NBS design)

c.) S-Cubed electron-capture gas chromatograph

d.) CEA TGM-555 formaldehyde monitor

e.) Tracer gas (SF_6) injection unit (NBS design)

f.) Kintek calibration gas standard generator (shared with medium-size chambers)

g.) 2 Datametric air-flow meters

h.) 10 YSI thermilinear thermistors

The wiring and tubing connections are given in tables C.1 to C.4.

Table C.1. Analog Data Channels for Two-Room Prototype House

Channel #	Binding #	Description
0	1	zero voltage
1	2	thermistor reference voltage (1.2 volts)
2	3	thermistor, inlet air
3	4	thermistor, outlet air
4	5	dew-point sensor thermistor
5	6	thermistor, room 1, 6-foot level
6	7	thermistor, room 1, 2-foot level
7	8	not used
8	9	thermistor, room 1, 0-foot level
9	10	thermistor, room 2, 6-foot level
10	11	thermistor, room 2, 2-foot level
11	12	thermistor, room 2, 0-foot level
12	13	air-flow meter, inlet
13	14	air-flow meter, outlet
14	15	S-Cube elect.-capt. GC recorder output
15	16	CEA TGM-555 recorder output

Table C.2. Formaldehyde Sample-Line Numbers for Two-Room Prototype House

Line #	Description
1	zero filter
2	Kintek calibration gas standard generator
3	inlet air
4	outlet air
5	room 1, 4-foot level
6	room 2, 4-foot level
7	room 1, 6-foot level
8	room 2, 6-foot level
9	room 1, 2-foot level
10	room 2, 2-foot level
11	room 1, 0-foot level
12	room 2, 0-foot level

Table C.3. Sample-Manifold Assignment for Two-Room Prototype House

Port #	Line #	Description
1	1	zero filter
2	2	HCHO Reference Standard, Kintek
3	3	inlet air
4	4	outlet air
5	5	room 1, 4-foot level
6	6	room 2, 4-foot level
7		not used
8		not used
9		not used
10		not used

Table C.4. Two-Room Prototype House Octal A/C Relay Assignment

Bit #	Description
1	sample-manifold solenoid Port #1
2	sample-manifold solenoid Port #2
3	sample-manifold solenoid Port #3
4	sample-manifold solenoid Port #4
5	sample-manifold solenoid Port #5
6	sample-manifold solenoid Port #6
7	SF_6 injection-unit solenoid
8	relay for remote control of GC sample

Appendix D

Experimental Protocols

A. Conditioning Pressed Wood Products

1. Build a rack in a well-ventilated part of a controlled temperature and humidity chamber to store pressed wood products, preferably near a large exhaust fan.

2. Store upright the pressed wood products well separated from each other (by at least 6" (15 cm).

B. Calibrating HCHO Perameation Tubes

Note: Since it takes several months to calibrate HCHO permeation tubes, obtain certified polyoxymethylene permeation tubes so that the approximate emission rate is known. HCHO concentrations and surface emission rates may have to be modified after the permeation tubes are calibrated, but data may at least be collected during calibration.

1. Ensure that the permeation tube is kept at the temperature it is used (80°C in the experiments reported here) at all times.

2. Weigh the tubes each month at the same time of day for at least 4 months.

3. Fit weight in grams to time in days by linear regression analysis.

4. Divide the negative of the slope by 1.44×10^{-6} to get the emission rate in ng/min.

C. Running the HCHO Concentration Monitor and Gas Standards Generator

1. Change the tubing of the HCHO concentration monitor according to the instructions of the manufacturer given in reference 6 in order to analyze HCHO by a modification of the pararosaniline procedure.

2. Obtain 0.2% stock solution of pararosaniline in 1 N HCl, purified by n-butanol extraction.

3. Dilute the stock solution 5-fold in distilled water to obtain a concentration of 0.04% in 0.2 N HCl. Fill a 4-L plastic bottle with this solution, and connect it to the appropriate HCHO concentration monitor tube. This solution may be used indefinitely.

4. Dissolve sodium sulfite (Na_2SO_3) in distilled water to a concentration of 0.5 g/L (4 mM). Fill a 4-L plastic bottle with the solution, and connect it to the appropriate HCHO concentration monitor tube. This solution may be used for three days at a temperature up to 26°C. It should be kept away from any heat sources because Na_2SO_3 degrades with time, and heat speeds degradation. In particular, it should be never be stored inside the HCHO concentration monitor.

5. Fill a 4-L plastic bottle with distilled water, and connect it to the

appropriate HCHO concentration monitor tube.

6. Set the formaldehyde concentration monitor air flow meter to pump air at a flow rate between 0.5 and 1 L/min. The exact flow rate is not critical as long as it remains constant for all sampling ports.

7. The automated system will calibrate itself every measurement cycle. For this it requires "span gas" and "zero air". Prepare span gas as follows:

a. Pass pressurized air through a 15-m long 5/8" (16-mm) O.D. copper column filled with potassium permanganate pellets followed by a regulator that supplies air at 350 kPa (50 psig) pressure difference

b. Turn off the bypass air stream in the gas standards generator. Adjust the air flow rate through the sealed bottle containing permeation tubes in the oven, to about 0.1 L/min.

c. The outlet of the gas standards generator should branch into a number of tubes 1 greater than the number of HCHO concentration monitors. The extra line is for exhaust to the atmosphere. Connect the remaining lines to the HCHO concentration monitors.

d. Ensure that the total air flow rate out of the oven is greater than the sum of the air flow rates to all the HCHO concentration monitors by running them all simultaneously with their span gas ports open, submerging the span gas exhaust tube under water, and adjusting the valve controlling the bypass air until air is bubbling vigorously through the water.

e. Determine the air flow rate out of the gas standards generator with a wet test meter or a gas meter.

f. Calculate the span gas concentration by the following equation:

$$C_s=(V_g/MW_{HCHO})\cdot e/F \qquad (D1)$$

where

MW_{HCHO} = molecular weight of HCHO, 30.03
V_g = volume occupied by 1 kg-mole of HCHO at 25°C, 24.45 m^3
e = emission rate of HCHO from permeation tube, ng/min
F = air flow rate through gas standards generator, l/min

g. When not monitoring HCHO the air flow rate of the air stream bypassing the oven may be turned off. The oven should never be turned off so that the weight loss of the permeation tube at 80° can be determined as described in section above, and air should always be supplied to it at about 0.1 l/min.

7. Prepare "zero air" by filtering room air through a Mine Safety Appliances chemical cartridge against formaldehyde vapor.

D. Calibrating the Electron-Capture Gas Chromatograph SF_6 Detector

1. Inject a known quantity of either 1-ppm or 25-ppm primary standard SF_6 gas into a 10-L variable-volume cylinder.

2. Place the mixture into 10-L air sample bags.

3. Dilute the standard gas to obtain 5 to 10 known concentrations in the range from 5 ppb to 300 ppb.

4. Measure the concentration of the gas in each bag with the electron-capture gas chromatograph SF_6 detector.

5. Fit the readings vs. SF_6 concentration by a curve of the form:

$$C = C_0 \cdot R^B \qquad (D2)$$

where

C = SF_6 concentration, ppb
R = reading
C_0 and B are constants to be fit

E. Running the Automated HCHO Emission Monitor

1. Run the program "SETPARMF" to establish the parameter file "HCHOCHAM.PAR" required for the HCHO emission rate programs "CHAMBER" for the prototype house, and "SCHAMBER" for the medium-size dynamic measuring chambers, .

2. Select of the following parameters (typical values are given in parentheses): C_0 and B, the calibration constants of the electron capture gas chromatograph; the HCHO concentration of the span gas in ppb; the delay time in minutes between sampling air and obtaining a HCHO concentration (about 15 min); the length of the averaging interval in minutes for the HCHO readings (about 5 min), the SF_6 injection flow rate in cm^3/min (15 cm^3/min for the prototype house and 0.15 cm^3/min for the medium-size dynamic measuring chamber), the title for the test, and the disk drive used for data storage.

3. Start the program CHAMBER or SCHAMBER, whichever is appropriate.

F. Data Collection -- HCHO Concentration

1. Connect zero air, span gas, chamber background, and each chamber to its own formaldehyde monitoring port as described above.

2. Connect solenoids to each port; program the computer to switch each solenoid on for 15 minutes in sequence, permitting air to enter a sampling manifold. This sequence comprises a "measurement cycle," lasting 45 + 15n minutes for n chambers.

3. Connect the sampling manifold to the formaldehyde concentration monitor. Because of the time it takes for air to reach the monitor and then for the formaldehyde to react in the color reaction, readings for a particular sampling

port begin approximately 10 minutes after the port is opened.

4. Determine a measuring period during which data will be collected. The measuring period should be a subinterval of the time during which the readings for a a particular port are stable. A suitable measuring period was found to be from 16 to 20 minutes after port change.

5. Set the zero so that the formaldehyde monitor reads approximately 0 for zero gas.

6. Set the span so that even with upward drift, the formaldehyde reading at any port will not exceed about 350. The formaldehyde monitor cannot give readings above about 400. It was found that for a span gas concentration of 66 ppb and a maximum span setting of 1000, the span reading started out at about 60-80 units above zero gas.

7. Read the HCHO monitor each second; average 60 readings each minute and record the average.

8. A "HCHO concentration" is the average of all readings during a measuremnt cycle.

G. Data Collection -- SF_6 Concentration

1. Connect the environment and each chamber to its own SF_6 monitoring port.

2. Connect a solenoid to each port and all ports to a sampling manifold, and program the computer to sample each location once every minute, thus comprising a SF_6 measurement cycle that is equal in duration to the HCHO measurement cycle. The number of samplings per cycle is pre determined by the HCHO measurement cycle and is equal to $(45 + 15n)/(1 + n)$ for n chambers.

3. Connect the SF_6 sampling manifold to a tracer gas decay monitor and computer which calculates air exchange rate by fitting log (SF_6 concentration) against time by linear regression analysis. The air exchange rate in h^{-1} is the negative of the slope divided by 60.

H. Adjusting Air Exchange Rates

1. As a minimum for each specimen, collect sufficient (as defined in step 2 below) HCHO and SF_6 concentrations under each of the following conditions in sequence:

a. Open the inlet and outlet valves completely and close the recirculation valve.

b. Leaving the inlet and outlet open, open the recirculation valve completely.

c. For at least three flow settings before step d, adjust the inlet and outlet so as to decrease the flow by approximately one half each time. This can be done by using a flow meter at the inlet, closing the inlet valve until the flow is down to half of the previous flow, and then closing the outlet valve until the flow just begins to decrease, so as to keep the chamber pressure just above that of the environment.

An alternate method is to close the inlet and outlet in increments of 1/4 to 1/2 turns for each new setting.

d. Close completely both the inlet and outlet.

2. Each of the above settings should be maintained approximately one day or until at least four air exchange rates and formaldehyde concentrations have been obtained which are constant to within 10% of their average.

I. Data Analysis -- HCHO Concentrations

1. Discard an entire cycle of formaldehyde concentrations when zero and span readings are found to be defective, as described below.

a. Zero and span were found to rise slowly. For example, the drift was typically 3 units per 90 minute cycle for a span setting of 1000. Discard data for an entire cycle if the zero and span deviated markedly from the apparent pattern (say by more than 10 units from the reading expected from the pattern).

b. The difference between zero and span slowly decrease over time. Discard data for an entire cycle if the zero and span are not sufficiently apart. We discarded data when the difference between zero and span was less than 20 units for a span gas concentration of 66 ppb and a span setting of 1000, or proportionately less for lower span settings.

c. Readings for zero gas, span gas, or environmental background are unstable, that is their range is greater than 5% of the difference between zero gas and span gas.

d. Environmental background concentration is above about 15 ppb.

2. Discard readings for only a chamber if readings during its measurement period are unstable, using the same criterion as in 1.c. above.

J. Data Analysis -- Air Exchange Rates

1. For air exchange rates greater than about 0.05 h^{-1}, there should be a steady decline in SF_6 concentration over time.

2. At lower air exchange rates the data may be scattered to the extent of about 5% between the maximum and minimum SF_6 concentrations.

3. The background concentration of SF_6 should be less than 10% of the chamber SF_6 concentration at any time. If it is higher discard the air exchange rate for that chamber.

4. The initial SF_6 concentration (below saturation) should not be below 10 ppb.

5. For air exchange rates of 2 h^{-1} or less, there should be at least 8 SF_6 concentrations. For rates between 2 h^{-1} and 5 h^{-1}, at least 4 concentrations should be used. Three concentrations are acceptable only for air exchange rates grater than 5 h^{-1}.

K. Calculations

1. The following calculations should be done for each chamber for each set of data for a particular inlet, outlet, and recirculation valve setting:

   a. Average HCHO concentration and standard deviation

   b. Average air exchange rate and standard deviation

   c. Surface emission rate and its error

2. The following calculations should be done for individual specimens after a complete measurement sequence:

   a. Best fit regression line (ser = a + b*conc)

   b. Standard error of estimate, r^2

L. Graphs

1. Surface emission rate vs. concentration

   a. Show error and standard deviation bars respectively.

   b. Draw lines determined by linear regression analysis.

2. Normalized surface emission rate vs. concentrations

   a. Plot SER/SER_{100} against concentration.

   b. Draw lines determined by linear regression analysis.

   c. Draw lines predicted by ORNL according to equation 4 in the text.

Appendix E

Listing of Programs for Monitoring the Formaldehyde Emission Rates Using the Medium-Size Chambers

```
C
C     SCHAMBER.FOR
C
C   PROGRAM FOR MONITORING HCHO EMISSION RATES FROM
C   PRESSED WOOD PRODUCTS USING THE MEDIUM SIZE CHAMBERS
C
C   THIS PROGRAM MONITORS THREE CHAMBERS
C
      INTEGER*1 ROW,COL,JD(6),ICTRL,JJD(6),IJD(6),NPORT,JKD(6)
     *,LABEL(40),IBYTE,MPORT,IGAIN,JINJ(6),ICTRL
      DIMENSION CC(6),CCSF6(4,18),CCHCHO(6,15),V(16),AV(12),AI(3)
     *  ,ER(3),FLOW(3),CINT(4),INJTIM(5),ICHAM(3)
      COMMON /AVERG/ AV,NV
      COMMON /CALIB/ CO,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,NDISC,LABEL
      COMMON /BOXDTA/ ICHAM
      COMMON /CNTRL/ICTRL,JINJ,INJTIM
      IGAIN=1
      ICTRL=0
      CALL OUT(Z'93',Z'00')
      CALL IAD212
      CALL SETGN(IGAIN)
      NPORT=1
      CALL PORTA(NPORT)
      CALL PORT(NPORT)
      DO 31 KK=1,5
31    INJTIM(KK) = 0
      ROW=0
      COL=0
      CALL CURSOR(COL,ROW)
      CALL CLOCK(JD)
      CALL CLOCK(JINJ)
      WRITE(5,100)
  100 FORMAT(//,5X,'PROGRAM SCHAMBER.FOR')
      CALL PARMF
      CLEVEL=CO*1.5
      CMIN = CO*0.1
      KDELAY=0
      IF(JDELAY.GT.15) KDELAY=1
      IF(JDELAY.GT.15) JDELAY=JDELAY-15
      JZERO=JDELAY-1
      IF(JZERO.EQ.0) JZERO=15
      NFIRST=0
      IF(JAVER.LT.JDELAY) KDELAY=1
      WRITE(5,101)
  101 FORMAT(5X,'Load data disc and type any character ')
      CALL CLOCK(JD)
      CALL PRTCLK(JD)
      CALL SEC(ID)
    1 CALL SEC(KD)
      CALL PRTSEC(KD)
```

```
      IF(KD.EQ.ID) GO TO 1
    2 CALL CONSOL(IBYTE)
      IF(IBYTE.NE.0) GO TO 3
      CALL SEC(KD)
      IF(KD.NE.ID) GO TO 2
  3   CONTINUE
      IF(IBYTE.NE.0) CALL RCRT(IBYTE)
      ROW=0
      COL=0
      CALL CURSOR(COL,ROW)
      CALL CLOCK(JD)
      WRITE(5,4)
  4   FORMAT(1X,,//,5X,'INPUT THE NUMBERS OF THE 3 BOXES (XX,XX,XX): ')
      READ(5,5) (ICHAM(J),J=1,3)
5     FORMAT( 3(I2,1X) )
      CALL FOPEN(NREC,JREC,KREC,NDISC)
      COL=1
      ROW=15
      CALL CURSOR(COL,ROW)
      WRITE(5,102) NREC,JREC,KREC
  102 FORMAT(5X,'File HCHO.DTA has',I6, ' Records',
     */,5X,'File  CONSF6.DTA  has',I6,' Records',/,5X,
     * 'FILE CONHCHO.DTA HAS ',I6,' RECORDS',/)
      ENDFILE 6
      ENDFILE 7
      ENDFILE 8
      VOL=5.43E6
      FINJ=FINJ/(VOL*60)
      FINJ=FINJ*1.0E9
      K=1
      CALL FMASK(CSPAN,LABEL)
      CALL ADCONV(V)
      CALL CONVRT(V)
      CALL PRTFLW(V)
      FLOW(1)=V(14)
      FLOW(2)=V(13)
      FLOW(3)=V(12)
      CALL CLOCK(JD)
      CALL PRTCLK(JD)
      JTOTAL=NREC+JREC+KREC
      CALL PRTREC(JTOTAL)
      MSF6=0
C
      DO 10 L = 1, 15
        MSF6 = 0
        IF (L.LE.4) MSF6=1
          CALL SCAN (CHCHO,CSF6,MSF6,L)
          IF (L.LE.4) CINT(L) = CSF6
          IF (MSF6.EQ.1) CALL PRTSF6(CSF6,L,1)
          CALL PRTCEA (CHCHO,K,L)
          CALL CONSOL (IBYTE)
          IF (IBYTE.EQ.0) GO TO 60
          CALL RCRT(IBYTE)
          IF (IBYTE.EQ.3) GO TO 99
60        CONTINUE
```

```
          IF(L.NE.4) GO TO 10
          JEC = 0
          CM = CINT(1)
          DO 30 KK=2,4
             IF (CINT(KK).GT.CM) CM = CINT(KK)
30        CONTINUE
          TINJ = (CLEVEL-CM)/FINJ
          INJTIM(1) = TINJ
          IF (INJTIM(1).GT.600) INJTIM(1) = 600
          IF (INJTIM(1).LT.0) INJTIM(1)=0
          IF (INJTIM(1).NE.0) JEC=1
          CALL CLOCK(JINJ)
          CALL TSTINJ
10    CONTINUE
C
C
11    CALL FMASK (CSPAN, LABEL)
C
C      ZERO CCSF6 ARRAY
C
      DO 133 NUM=1,4
        DO 144 NUM2 = 1,18
            CCSF6(NUM,NUM2) = 0.0
144     CONTINUE
133   CONTINUE
      JTOTAL = NREC + KREC + JREC
      CALL PRTREC (JTOTAL)
      CALL ADCONV ( V)
      CALL CONVRT (V)
      CALL PRTFLW (V)
      CALL CLOCK (JD)
      CALL PRTCLK (JD)
      CALL ZERO
      IF (NFIRST.EQ.0) GO TO 13
      DO 32 K=1,3
        CALL PRTAI (AI(K),K)
        IF(KDELAY.EQ.1.AND.K.EQ.3) GO TO 32
        CALL PRTER(ER(K),K)
32    CONTINUE
C
C
      NII=5
      IF(KDELAY.EQ.0) NII=6
      DO 12 K = 1, NII
         CALL PRTF (CC(K),K)
12    CONTINUE
13    CONTINUE
      CALL CLOCK (JJD)
      IF (NFIRST.EQ.0) CALL CLOCK(JKD)
      IF (KDELAY.EQ.0) CALL CLOCK(JKD)
C
C
      DO 17 K=  1,  6
      NPORT=K
      CALL PORT(NPORT)
```

```
      DO 16 L = 1, 15
         MSF6 = 0
         LL = L - (L/5)*5
         IF (LL.NE.0.AND.LL.LE.4) MSF6=1
         CALL SCAN (CHCHO,CSF6,MSF6,LL)
         CALL CONSOL (IBYTE)
         IF (IBYTE.EQ.0) GO TO 555
         CALL RCRT (IBYTE)
         IF (IBYTE.EQ.3) GO TO 99
 555     CONTINUE
         CCHCHO (K,L) = CHCHO
         CALL ADCONV (V)
         CALL CONVRT(V)
         CALL ACCUM(V)
         CALL PRTFLW (V)
         CALL PRTCEA (CHCHO,K,L)
         IF (MSF6.EQ.0) GO TO 14
         KM = 3 * (K-1) + 1 + L/5
         CCSF6(LL,KM) = CSF6
         CALL PRTSF6 (CSF6,LL,KM)
         IF(KM.NE.18) GO TO 14
         CALL AIRINF(CCSF6,AI,JEC,LL)
         LL1=LL-1
         IF (LL.NE.1) CALL PRTAI(AI(LL1),LL1)
         IF (LL.EQ.1) GO TO 14
         CL=CSF6*EXP(-1.5*AI(LL1))
         IF(LL.EQ.2) CIMAX=CL
         IF(LL.EQ.2) CIMIN=CL
         IF(LL.EQ.2) CLEV=CSF6
         IF (CL.GT.CIMAX) CLEV = CSF6
         IF (CL.GT.CIMAX) CIMAX = CL
         IF (CL.LT.CIMIN) CIMIN=CL
         IF (LL.NE.4) GO TO 14
         JEC=0
         IF(CIMIN.GT.CMIN) GO TO 14
         TINJ=(CLEVEL-CLEV)/FINJ
         INJTIM(1)=TINJ
         IF(INJTIM(1).GT.600) INJTIM(1)=600.
         IF(INJTIM(1).LE.0) INJTIM(1)=0
         JEC=1
         IF(INJTIM(1).EQ.0) JEC=0
         IF(JEC.EQ.0) GO TO 14
         CALL CLOCK(JINJ)
         CALL TSTINJ
 14      CONTINUE
         IF (L.EQ.JZERO) ACHCHO = 0.0
         IF ((JAVER.LT.JDELAY).AND.(L.GT.JDELAY.OR.L.LE.JAVER))
     *                    ACHCHO = ACHCHO + CHCHO
         IF ((JAVER.GT.JDELAY).AND.(L.GT.JDELAY.AND.L.LE.JAVER))
     *                    ACHCHO = ACHCHO + CHCHO
         IF (L.NE.JAVER) GO TO 15
         KL = K
         IF (KDELAY.EQ.1) KL = K - 1
         IF (KL.EQ.0) KL = 6
         IF (KDELAY.EQ.1.AND.KL.EQ.6.AND.NFIRST.EQ.0) GO TO 15
```

```
      CC (KL) = ACHCHO/FAVER
      IF (KL.LE.2)  CALL PRTF(CC(KL),KL)
      IF (KL.LE.2)  GO TO 15
      CC (KL) = CC(KL) - CC(1)
      IF (CC(2).GT.CC(1))   CC(KL) = CSPAN*(CC(KL))/(CC(2)-CC(1))
      CALL PRTF(CC(KL),KL)
      IF(KL.EQ.3) GO TO 15
      KLL = KL - 3
      KKL=KLL+1
      IF(KDELAY.NE.1) CALL AIRINF(CCSF6,AI,JEC,KKL)
      IF(KDELAY.EQ.1.AND.KL.NE.6)
     *   CALL AIRINF(CCSF6,AI,JEC,KKL)
      CALL PRTAI(AI(KLL),KLL)
      ER(KLL)=(0.7487E-3)*AI(KLL)*(CC(KL)-CC(3) )
      IF(AI(KLL).LT.0.01) ER(KLL)=(0.723E-3)*FLOW(KLL)*(CC(KL)-
     *   CC(3))
      CALL PRTER (ER(KLL),KLL)
      IF (KL.NE.6) GO TO 15
      IF(KDELAY.EQ.0) GO TO 15
      DO 40 KK=1,3
      JK=KK+3
      ER(KK)=(0.7487E-3)*AI(KK)*(CC(JK)-CC(3))
      IF(AI(KK).LT.0.01) ER(KK)=(0.723E-3)*FLOW(KK)*(CC(JK)-CC(3))
40    CONTINUE
      CALL FOPEN (NREC,JREC,KREC,NDISC)
      NREC = NREC + 1
      WRITE (6,200,REC = NREC) (JKD(KK),KK=1,5), CC,AI,ER,FLOW
 200  FORMAT(1X,I2,'/',I2,'/',I2,2X,I2,':',I2,3X,6F7.1,3F7.2,
     *        3F7.3,3F7.2)
      WRITE (6,201, REC = 1) NREC,LABEL,ICHAM
 201  FORMAT(I5,10X,40A1,10X,3(I2,2X))
      JTOTAL = NREC + JREC + KREC
      CALL PRTREC (JTOTAL)
      ENDFILE 6
      ENDFILE 7
      ENDFILE 8
 15   CONTINUE
      CALL CONSOL (IBYTE)
      IF (IBYTE.EQ.0) GO TO 16
      CALL RCRT(IBYTE)
      IF (IBYTE.EQ.3) GO TO 99
16    CONTINUE
      CALL FOPEN(NREC,JREC,KREC,NDISC)
      KREC = KREC + 1
      IF(K.EQ.1)
     *WRITE (8,204,REC = KREC) (JJD(KK),KK=1,5),(CCHCHO(1,LL),LL=1,15)
204   FORMAT(1X,I2,'/',I2,'/',I2,2X,I2,':',I2,3X,15F6.1)
      IF(K.NE.1) WRITE (8,205,REC=KREC)  K, (CCHCHO(K,LL),LL=1,15)
205   FORMAT(5X,I1,5X,15F6.1)
      WRITE (8,201,REC=1) KREC,LABEL,ICHAM
      JTOTAL = NREC + JREC + KREC
      CALL PRTREC (JTOTAL)
      ENDFILE 6
      ENDFILE 7
      ENDFILE 8
```

```
17        CONTINUE
C
C
C
      CALL FOPEN (NREC,JREC,KREC,NDISC)
      CALL AVER
      DO 20 KK=1,3
          KKK = 13-KK
          FLOW(KK) = AV(KKK)
20    CONTINUE
      IF(KDELAY.EQ.1) GO TO 70
      DO 80 KK=1,3
      JK=KK+3
      ER(KK)=(0.7487E-3)*AI(KK)*(CC(JK)-CC(3))
      IF(AI(KK).LT.0.01) ER(KK)=(0.723E-3)*FLOW(KK)*(CC(JK)-CC(3))
80    CONTINUE
      NREC=NREC+1
      WRITE(6,200,REC=NREC) (JKD(KK),KK=1,5),CC,AI,ER,FLOW
      WRITE(6,201,REC=1) NREC,LABEL,ICHAM
70    CONTINUE
      JREC = JREC + 1
      WRITE (7,203,REC=JREC) (JJD(KK),KK=1,5),(CCSF6(1,MM),MM=1,18)
203   FORMAT(1X,I2,'/',I2,'/',I2,2X,I2,':',I2,3X,18F6.1)
      DO 33 KK=2,4
        JREC = JREC + 1
        WRITE(7,206,REC=JREC) KK,(CCSF6(KK,MM),MM=1,18)
206   FORMAT(5X,I1,5X,18F6.1)
33    CONTINUE
      WRITE(7,201,REC=1) JREC,LABEL,ICHAM
      JTOTAL = NREC + JREC + KREC
      CALL PRTREC (JTOTAL)
C
C
      DO  18 KK = 1, 6
         JKD(KK) = JJD(KK)
18    CONTINUE
C
C
      ENDFILE 6
      ENDFILE 7
      ENDFILE 8
      NFIRST=NFIRST+1
      GO TO 11
99    ROW = 0
      COL = 0
      CALL CURSOR (COL, ROW)
      IBYTE = 1
      CALL OUT (Z'83',IBYTE)
      CALL PORT (IBYTE)
      CALL OUT (Z'93',Z'00')
      END
```

```
      SUBROUTINE ACCUM(V)
C
C    ACCUM2.FOR
C
      DIMENSION V(16),AV(12)
      COMMON /AVERG/ AV,NV
      NV=NV+1
      DO 10 K=3,14
      KK=K-2
      AV(KK)=AV(KK)+V(K)
   10 CONTINUE
      RETURN
      END


      SUBROUTINE ADCONV(V)
C
C ADCONV2.FOR
C
      INTEGER*1 NCHAN
      DIMENSION V(16)
      DO 1 K=1,16
      NCHAN=K-1
      CALL ANALOG(NDATA,NCHAN)
      V(K)=NDATA
      V(K)=5.0*V(K)/2048.
    1 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE AIRINF(C,AI,JEC,K)
C
C       AIRINF2.FOR
C
C THIS SUBROUTINE CALCULATES THE AIR INFILTRATION RATE OF THE K-TH SAMPLE
C PORT USING A LEAST SQUARES METHOD
C
      INTEGER*1 LABEL(40)
      DIMENSION C(4,18),AI(3)
      COMMON /CALIB/C0,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,NDISC,LABEL
C
C DEFAULT VALUE OF THE AIR INFILTRATION RATE IS 0.00
C
      IF(K.EQ.1) RETURN
      KK=K-1
      AI(KK)=0.0
      CMAX=2.5*C0
      CMIN=0.1*C0
      L1=4
      IF(JEC.EQ.0) L1=1
C
C INITIALIZE AVERAGES AND MOMENTS
C
      N=0
      XM=0.0
      YM=0.0
      XS=0.0
      YS=0.0
      XY=0.0
C
C CALCULATE NUMBER OF VALID DATA POINTS, AVERAGES AND MOMEMTS
C THE FIRST DATA POINTS TAKEN DURING THE TWENTY MINUTE INTERVAL
C AFTER THE PERIOD OF INJECTION IS IGNORED
C
      DO 1 L=L1,18
C CHECK FOR OVERSATURATION
      IF(C(K,L).GT.CMAX) GO TO 1
C CHECK FOR INSUFFICIENT TRACER GAS
      IF(C(K,L).LT.CMIN) GO TO 1
      N=N+1
C TIME OF THE L-TH SAMPLE ON THE K-TH PORT
      X=5.0*(L-1)
      X=X/60.0
C LOG OF THE CONCENTRATION
      Y=ALOG(C(K,L))
      XM=XM+X
      YM=YM+Y
      XY=XY+X*Y
      YS=YS+Y*Y
      XS=XS+X*X
    1 CONTINUE
C CHECK FOR SUFFICIENT NUMBER OF VALID DATA POINTS
      IF(N.LT.2) RETURN
      FN=N
C THE AVERAGE AIR INFILTRATION RATE IS THE LEAST SQUARE SLOPE OF THE
```

```
C LOG(C) VS. TIME
      AI(KK)=-(XY-YM*XM/FN)/(XS-XM*XM/FN)
      RETURN
      END


      SUBROUTINE AVER
C
C   AVER2.FOR
C
      DIMENSION AV(12)
      COMMON /AVERG/ AV,NV
      IF(NV.LE.0) RETURN
      FN=NV
      DO 10 K=1,12
      AV(K)=AV(K)/FN
   10 CONTINUE
      RETURN
      END


      SUBROUTINE CONVRT(V)
C
C  CONVRT2.FOR
C
      DIMENSION V(16)
      DATA CT203/0.65107/,BT203/6.7966E-3/
      DO 1 K=2,16
      V(K)=V(K)-V(1)
    1 CONTINUE
      DO 2 K=11,14
      V(K)=1.5*V(K)
    2 CONTINUE
      DO 3 K=9,10
      V(K)=5.0*V(K)
    3 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FMASK (CSPAN,LABEL)
C
C FMASK2.FOR
C
      INTEGER*1 ROW,COL,LABEL(40),JD(6)
      DIMENSION ICHAM(3)
      COMMON /BOXDTA/ ICHAM
      ROW = 0
      COL = 0
      CALL CURSOR (COL,ROW)
      CALL CLOCK(JD)
      CALL CLOCK(JD)
      CALL CLOCK(JD)
      WRITE (5,100) LABEL
100   FORMAT(1H+,5X,'RECORDS  ',15X,40A1,/)
      WRITE(5,101) CSPAN
101   FORMAT(4X,'CEA Zero = ',8X,'CEA Span (',F5.1,') = ',9X,
     * 'Background = ',7X, ' ppb',/)
      WRITE (5,102)
102   FORMAT(1X,'Chamber',5X,'HCHO',6X,'Air Flow',5X,'Air Exchange'
     *,5X, 'Emission Rate')
      DO 10 K = 1 , 3
      WRITE(5,103) ICHAM(K)
103   FORMAT(2X,'CHAM',1X,I2,9X,'ppb',10X,'CFM',10X,'/hr',14X,
     * 'mg/hr*m**2')
10    CONTINUE
      WRITE(5,104)
104   FORMAT(/28X,'TRACER CONCENTRATIONS')
      WRITE(5,105)
105   FORMAT(8X,'1',3X,'2',3X,'3',3X,'4',3X,'5',3X,'6',3X,'7',3X,
     *'8',3X,'9',2X,'10',2X,'11',2X,'12',2X,'13',2X,'14',2X,'15',
     *2X,'16',2X,'17',2X,'18')
      WRITE(5,106)
106   FORMAT(1X,'ENVIR')
      DO 40 J = 1,3
          WRITE(5,107) ICHAM(J)
107       FORMAT(1X,'CH ',I2)
40    CONTINUE
      WRITE (5,108)
108   FORMAT(1X,/,28X,'CEA READINGS')
      WRITE(5,115)
115   FORMAT(9X,'1',4X,'2',4X,'3',4X,'4',4X,'5',4X,'6',4X,'7',4X,
     *'8',4X,'9',3X,'10',3X,'11',3X,'12',3X,'13',3X,'14',3X,'15')
      WRITE(5,109)
109   FORMAT(2X,'ZERO',/,2X,'SPAN',/,1X,'ENVIR')
      DO 60 J = 1 , 3
           WRITE (5,110) ICHAM(J)
110        FORMAT(1X,'CH ',I2)
60    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FOPEN(NREC,JREC,KREC,NDISC)
C
C   FOPEN2.FOR
C
      CALL LOGOFF
      CALL OPEN(6,'HCHO    DTA',NDISC)
      READ(6,100,REC=1,END=10) NREC
  100 FORMAT(I5)
      GO TO 13
   10 NREC=1
      WRITE(6,100,REC=1) NREC
   13 CALL OPEN(7,'CONSF6  DTA',NDISC)
      READ(7,100,REC=1,END=14) JREC
      GO TO 15
   14 JREC=1
      WRITE(7,100,REC=1) JREC
   15 CALL OPEN(8,'CONHCHO DTA',NDISC)
      READ(8,100,REC=1,END=16) KREC
      GO TO 17
   16 KREC=1
      WRITE(8,100,REC=1) KREC
   17 RETURN
      END

      SUBROUTINE ON
C
C  ACTIVATES THE ROTARY ACTUATOR ON THE G.C.
C
      INTEGER*1 ICTRL,JINJ(6)
      DIMENSION INJTIM(5)
      COMMON /CNTRL/ ICTRL,JINJ,INJTIM
      ICTRL=ICTRL.OR.Z'80'
      CALL OUT(Z'93',ICTRL)
      RETURN
      END

      SUBROUTINE OFF
C
C  RELEASES THE ROTARY ACTUATOR ON THE G.C.
C
      INTEGER*1 ICTRL,JINJ(6)
      DIMENSION INJTIM(5)
      COMMON /CNTRL/ ICTRL,JINJ,INJTIM
      ICTRL=ICTRL.AND.Z'7F'
      CALL OUT(Z'93',ICTRL)
      RETURN
      END
```

```
      SUBROUTINE PARMF
C
C READS THE PARAMETER FILES IF IT EXISTS
C IF THE PARAMETER FILE "HCHOCHAM.PAR" DOES NOT EXIST,
C THEN IT IS CREATED AND STORED ON THE CURRENT DISK DRIVE
C
      INTEGER*1 LABEL (40)
      COMMON /CALIB/ C0,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,NDISC,LABEL
C
C
      CALL OPEN (6,'HCHOCHAMPAR',0)
      READ (6,100, END = 10) C0,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,
     *                        NDISC,LABEL
100   FORMAT(1X,4F10.3,2I5,F10.3,I5,2X,40A1)
      WRITE (5,101) LABEL
101   FORMAT(5X,'TEST LABEL: ',40A1,/)
      WRITE (5,102) C0,B
102   FORMAT(10X,'ELECTRONIC CAPTURE GC PARAMETERS'/10X,'C0 = ',
     *       F6.1,' ppb',10X,'B = ',F5.3/)
      WRITE (5,202) FINJ
202   FORMAT (5X,'INJECTION FLOW RATE = ',F10.3, ' CC/MIN')
      WRITE(5,103) JDELAY,JAVER
103   FORMAT(10X,'CEA AVERAGING INTERVAL FROM ',I3,' TO',I3,
     *       ' MINUTES AFTER PORT CHANGE'/)
C
C
C
      IF (NDISC.EQ.0) WRITE (5,104)
      IF (NDISC.EQ.1) WRITE (5,105)
      IF (NDISC.EQ.2) WRITE (5,106)
104   FORMAT(10X,'DATA DISC DRIVE IS CURRENT DRIVE')
105   FORMAT(10X,'DATA DISC DRIVE IS DRIVE "A"')
106   FORMAT(10X,'DATA DISC DRIVE IS DRIVE "B"')
C
C
      ENDFILE 6
      RETURN
10    ENDFILE 6
      CALL OPEN(6,'HCHOCHAMPAR',0)
      WRITE (5,107)
107   FORMAT(5X,'INPUT TEST LABEL (MAX 40 CHARACTERS): ' )
      READ (5,108) LABEL
108   FORMAT(40A1)
      WRITE (5,109)
109   FORMAT(5X,'INPUT ELECTRON CAPTURE GC PARAMETERS ',/,5X,
     * 'C0 = (ppb): ')
      READ (5,110) C0
110   FORMAT(F7.0)
      WRITE(5,111)
111   FORMAT(5X,' B = ')
      READ (5,110) B
      WRITE (5,211)
211   FORMAT(5X,'INPUT INJECTION FLOW RATE (cc/min): ')
      READ (5,110) FINJ
```

```
      WRITE (5,112)
112   FORMAT (5X,'INPUT DELAY IN MINUTES FOR CEA TO READ HCHO (NN): ')
      READ (5,113) JDELAY
113   FORMAT(I2)
      WRITE (5,114)
114   FORMAT(5X,'INPUT AVERAGING TIME IN MINUTES (NN): ')
      READ (5,113) JAVER
C
      FAVER = JAVER
      JAVER = JAVER + JDELAY
      IF (JAVER.GT.15) JAVER = JAVER - 15
C
      WRITE(5,115)
115   FORMAT(5X,' INPUT SPAN GAS LEVEL (ppb): ')
      READ (5,110) CSPAN
      WRITE (5,116)
116   FORMAT(5X,'INPUT DRIVE FOR DATA (1 = A, 2 = B, 0 = CURRENT: ')
      READ (5,117) NDISC
117   FORMAT (I1)
      WRITE (6,100) CO,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,NDISC,LABEL
      ENDFILE 6
      RETURN
      END


      SUBROUTINE PORT(NPORT)
C
C  OPENS THE "NPORT" HCHO SAMPLE PORT
C
      INTEGER*1 ICTRL,NPORT,JINJ(6),IPORT(10),IBYTE
      DIMENSION INJTIM(5)
      COMMON /CNTRL/ICTRL,JINJ,INJTIM
      DATA IPORT/1,2,4,8,16,32,64,128,1,2/
      K=NPORT
      IF(K.GT.10) RETURN
      IF(K.LT.1) RETURN
      IF(K.GT.8) GO TO 1
      ICTRL=ICTRL.AND.Z'FC'
      IBYTE=IPORT(K)
      CALL OUT(Z'92',IBYTE)
      CALL OUT(Z'93',ICTRL)
      RETURN
    1 ICTRL=ICTRL.AND.Z'FC'
      ICTRL=ICTRL.OR.IPORT(K)
      CALL OUT(Z'93',ICTRL)
      CALL OUT(Z'92',Z'00')
      RETURN
      END
```

```
      SUBROUTINE PORTA(NPORT)
C
C OPENS THE "NPORT" SF6 SAMPLE PORT
C
      INTEGER*1 NPORT,JPORT(8),IBYTE
      DATA JPORT/1,2,4,8,16,32,64,128/
      IF(NPORT.LE.0) RETURN
      IF(NPORT.GT.8) RETURN
      K=NPORT
      IBYTE=JPORT(K)
      CALL OUT(Z´83´,IBYTE)
      RETURN
      END


      SUBROUTINE PRTAI (AI,K)
C
C PRTAI2.FOR
C
C PRINTS THE KTH AIR INFILTRATION VALUE TO THE SCREEN
C
      INTEGER*1 COL, ROW, IDATA(10)
      ROW = K + 5
      COL = 38
      CALL CURSOR (COL, ROW)
      IF (AI.GT.99.99) AI = 99.99
      IF (AI.LT.-9.99) AI = -9.99
      ENCODE(IDATA,100) AI
100   FORMAT(F5.2,´$´)
      CALL PRT (IDATA)
      RETURN
      END


      SUBROUTINE PRTCEA (CHCHO,K,L)
C
C PRINTS THE LTH CEA READINGS OF THE KTH SAMPLE PORT
C
      INTEGER*1 ROW,COL,IDATA(10)
      ROW = 18 + K
      COL = 2 + 5*L
      CALL CURSOR (COL,ROW)
      NC = CHCHO
      IF (NC.GT.9999) NC = 9999
      IF (NC.LT.-999) NC = -999
      ENCODE (IDATA, 100) NC
100   FORMAT(I4,´$´)
      CALL PRT (IDATA)
      RETURN
      END
```

```
      SUBROUTINE PRTF ( C, K)
C
C PRTF2.FOR
C
C PRINTS THE KTH HCHO VALUE TO THE SCREEN
C
      INTEGER*1 ROW,COL,IROW(6),ICOL(6),IDATA(10)
      DATA IROW /3,3,3,6,7,8/
      DATA ICOL /15,43,65,12,12,12/
      ROW = IROW (K)
      COL = ICOL (K)
      CALL CURSOR (COL,ROW)
      X = C
      IF (X.GT.999.9) X = 999.9
      IF (X.LT.-99.9) X = -99.9
      ENCODE (IDATA,100) X
100   FORMAT(F5.1,'$')
      CALL PRT(IDATA)
      RETURN
      END


      SUBROUTINE PRTFLW (V)
C
C PRTFLW2.FOR
C
C PRINTS THE AIR FLOW METER READINGS TO THE SCREE
C
      INTEGER*1 COL,ROW,IDATA(10)
      DIMENSION V(16),ICHAN(3)
      DATA ICHAN /14,13,12/
C
      COL = 25
      DO 10 K=1,3
      ROW = K + 5
      CALL CURSOR (COL,ROW)
      I = ICHAN(K)
      FF = V(I)
      IF (FF.GT.99.99) FF = 99.99
      IF (FF.LT.-9.99) FF = -9.99
      ENCODE (IDATA,100) FF
100   FORMAT(F5.2,'$')
      CALL PRT(IDATA)
10    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRTREC(NREC)
C
C PRINTS THE NUMBER OF RECORDS USED FOR DATA STORAGE TO SCREEN
C
      INTEGER*1 COL,ROW,IDATA(10)
      ROW=1
      COL=14
      CALL CURSOR(COL,ROW)
      ENCODE(IDATA,100) NREC
  100 FORMAT(I5,'$')
      CALL PRT(IDATA)
      RETURN
      END


      SUBROUTINE PRTSF6 (C, K, L)
C
C PRTSF62.FOR
C
C PRINTS THE LTH SF6 CONCENTRATION OF THE KTH SAMPLE PORT
C TO THE SCREEN
C
      INTEGER*1 ROW, COL, IDATA(10)
      ROW = 11 + K
      COL = 3 + 4*L
      CALL CURSOR (COL,ROW)
      IF(C.GT.999.9) C=999.9
      IF(C.LT.0) C=0.0
      NC = C
      IF (NC.GT.999) NC = 999
      IF (NC.LT.0)  NC = 0
      ENCODE (IDATA,100) NC
100   FORMAT(I3,'$')
      CALL PRT(IDATA)
      RETURN
      END
```

```
      SUBROUTINE SCAN (CHCHO,CSF6,MSF6,L)
C
C                              SCAN2
C
C CONTROLS THE SCANNING OF THE OUTPUT OF THE G.C TO DETERMINE
C THE SF6 PEAK AND THE SF6 CONCENTRATION
C READS THE CEA MONITOR AND CALCULATES A 50 SECOND AVERAGE OF
C THE READINGS
C
C IF MSF6 = 0 ; THEN NO THERE IS NO SF6 READING
C
C
C TESTS FOR INJECTION OF SF6
C
C PERFORMS AVERAGING OF ANALOG VALUES
C
C IF SATURATION OF G.C. ; THE CSF6 = 999.9
C
     INTEGER*1 ID,LABEL(40),JD(6),NCHAN,NPORT
      DIMENSION V(16)
      COMMON /CALIB/ CO,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,NDISC,LABEL
      CSF6=999.9
      NCHAN=15
      CV=0.0
      NN=0
    1 CALL SEC(ID)
      CALL PRTSEC(ID)
      CALL TSTINJ
      IF(ID.NE.0) GO TO 1
      CALL CLOCK(JD)
      CALL PRTCLK(JD)
      IF(MSF6.EQ.0) GO TO 2
      CALL STAND (ISTAND)
      IPEAK = ISTAND
      IF (ISTAND.LT.100) MSF6 = 0
      IF (ISTAND.LT.100) GO TO 5
      CALL ON
6     CALL SEC (ID)
      CALL PRTSEC(ID)
      CALL TSTINJ
      IF (ID.LT.3) GO TO 6
      CALL OFF
   5  LL = L + 1
      IF (LL.GT.4) LL = 1
      NPORT = LL
      CALL PORTA (NPORT)
      PEAK=BASE
    2 CALL SEC(ID)
      CALL PRTSEC(ID)
      CALL ANALOG(NDATA,NCHAN)
      VV=NDATA
      VV=5.0*VV/2048.
      CV=CV+VV
      NN=NN+1
      CALL ADCONV(V)
```

```
      CALL CONVRT(V)
      CALL ACCUM(V)
      CALL TSTINJ
      IF(ID.LT.20) GO TO 2
    3 CALL SEC(ID)
      CALL PRTSEC(ID)
      CALL ANALOG(NDATA,NCHAN)
      VV=NDATA
      VV=5.0*VV/2048.
      CV=CV+VV
      NN=NN+1
      CALL ADCONV(V)
      CALL CONVRT(V)
      CALL ACCUM(V)
      IF(MSF6.EQ.0) GO TO 4
      CALL STAND (ICURR)
      IF(ICURR.LT.IPEAK) IPEAK=ICURR
    4 CONTINUE
      CALL TSTINJ
      IF(ID.LE.45) GO TO 3
      FN=NN
      CV=CV/FN
      CHCHO=100.*CV
      IF(MSF6.EQ.0) RETURN
      IF (IPEAK.LE.5) CSF6 = 999.9
      IF (IPEAK.LE.5) RETURN
      IF (IPEAK.GT.ISTAND) IPEAK = ISTAND
      RATIO = FLOAT(ISTAND)/FLOAT(IPEAK)
      IF(RATIO.LE.0.0) CSF6=999.9
      IF(RATIO.LE.0.0) RETURN
      RATIO = ALOG(RATIO)
      CSF6 = C0* (RATIO ** B)
      CMAX=C0*2.5
      IF(CSF6.GT.CMAX) CSF6=999.9
      IF(CSF6.LT.0.0) CSF6=0.0
      RETURN
      END
```

```
      SUBROUTINE TSTINJ
C
C TSTINJ2.FOR
C
C CONTROLS THE INJECTION OF TRACER GAS INTO THE CHAMBERS
C
      INTEGER*1 ICTRL,JD(6),JINJ(6),INJ(5)
      DIMENSION INJTIM(5)
      COMMON /CNTRL/ ICTRL,JINJ,INJTIM
      DATA INJ/Z'04',Z'08',Z'10',Z'20',Z'40'/
      CALL CLOCK(JD)
      NHOUR=0
      IF(JD(4).NE.JINJ(4)) NHOUR=1
      ITIM=JD(6)-JINJ(6)+60*(JD(5)-JINJ(5))
      ITIM=ITIM+3600*NHOUR
      ICTRL=ICTRL.AND.Z'83'
      DO 10 K=1,5
      IF(INJTIM(K).GT.0) GO TO 11
   10 CONTINUE
      GO TO 13
   11 CONTINUE
      DO 12 K=1,5
      IF(ITIM.GE.INJTIM(K)) INJTIM(K)=0
      IF(INJTIM(K).EQ.0) GO TO 12
      ICTRL=ICTRL.OR.INJ(K)
   12 CONTINUE
   13 CALL OUT(Z'93',ICTRL)
      RETURN
      END


      SUBROUTINE ZERO
C
C  ZERO2.FOR
C
C  SET TO ZERO THE ANALOG ACCUMUATED VALUES
C
      DIMENSION AV(12)
      COMMON /AVERG/ AV,NV
      NV=0
      DO 10 K=1,12
   10 AV(K)=0.0
      RETURN
      END
```

Appendix F

Listing of Programs for Large-Chamber Monitoring and Data Analysis

```
C
C CHAMBER.FOR
C
C PROGRAM FOR MONITORING TWO-ROOM HOUSE
C
C LAST REVISION 11-17-84
C
      INTEGER*1 ROW,COL,IGAIN,JD(6),ICTRL,JJD(6),IJD(6),NPORT,JKD(6)
     *,LABEL(40),IBYTE
      DIMENSION CC(6),CCSF6(18),CCHCHO(6,15),V(16),AV(11)
      COMMON /CNTRL/ICTRL
      COMMON /AVERG/ AV,NV
      COMMON /CALIB/ CO,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,NDISC,LABEL
      COMMON /INJEC/ IJD,INJTIM
      CALL IAD212
      IGAIN=0
      ICTRL=1
      CALL SETGN(IGAIN)
      NPORT=1
      CALL PORT(NPORT)
      ROW=0
      COL=0
      CALL CURSOR(COL,ROW)
      CALL CLOCK(JD)
      CALL CLOCK(IJD)
      INJTIM=0
      WRITE(5,100)
  100 FORMAT(//,5X,'PROGRAM CHAMBER.FOR')
      CALL PARMF
      KDELAY=0
      IF(JDELAY.GT.15) KDELAY=1
      IF(JDELAY.GT.15) JDELAY=JDELAY-15
      JZERO=JDELAY-1
      IF(JZERO.EQ.0) JZERO=15
      NFIRST=0
      IF(JAVER.LT.JDELAY) KDELAY=1
      WRITE(5,101)
  101 FORMAT(5X,'Load data disc and type any character ')
      CALL CLOCK(JD)
      CALL PRTCLK(JD)
      CALL SEC(ID)
    1 CALL SEC(KD)
      CALL PRTSEC(KD)
      IF(KD.EQ.ID) GO TO 1
    2 CALL CONSOL(IBYTE)
      IF(IBYTE.NE.0) GO TO 3
      CALL SEC(KD)
      IF(KD.NE.ID) GO TO 2
    3 CALL FOPEN(NREC,MREC,JREC,KREC,NDISC)
      COL=1
      ROW=15
```

```
      CALL CURSOR(COL,ROW)
      WRITE(5,102) NREC,MREC,JREC,KREC
  102 FORMAT(5X,'File HCHOLARG.DTA has',I6, ' Records',
     */,5X,'File  ANALOG.DTA  has',I6,' Records',
     */,5X,'File  CONSF6.DTA  has',I6,' Records',
     */,5X,'File CONHCHO.DTA  has',I6,' Records',/)
      ENDFILE 6
      ENDFILE 7
      ENDFILE 8
      ENDFILE 9
      MSF6=1
      VOL=1600.*2.8E4
      FINJ=FINJ/(VOL*60)
      FINJ=FINJ*1.0E9
      INJTIM=0
      CALL CLOCK(IJD)
      CALL SCAN(CHCHO,CSF6,MSF6)
      TINJ=(300.-CSF6)/FINJ
      INJTIM=TINJ
      IF(INJTIM.LT.0) INJTIM=0
      IF(INJTIM.GT.600) INJTIM=600
      JEC=1
      IF(INJTIM.EQ.0) JEC=0
      CALL CLOCK(IJD)
      CALL TSTINJ
      K=1
      CALL FMASK(CSPAN,LABEL)
      CALL ADCONV(V,IGAIN)
      CALL CONVRT(V)
      CALL PRTVOL(V)
      CALL PRTSF6(CSF6,1)
      CALL CLOCK(JD)
      CALL PRTCLK(JD)
      JTOTAL=NREC+MREC+JREC+KREC
      CALL PRTREC(JTOTAL)
      MSF6=0
C
      DO 10 L = 1, 15
          CALL SCAN (CHCHO,CSF6,MSF6)
          CALL PRTCEA (CHCHO,K,L)
          CALL CONSOL (IBYTE)
          IF (IBYTE.EQ.0) GO TO 10
          CALL RCRT(IBYTE)
          IF (IBYTE.EQ.3) GO TO 99
10    CONTINUE
C
C
11    CALL FMASK (CSPAN, LABEL)
      JTOTAL = NREC + MREC + KREC + JREC
      CALL PRTREC (JTOTAL)
      CALL ADCONV ( V,IGAIN)
      CALL CONVRT (V)
      CALL PRTVOL (V)
      CALL CLOCK (JD)
      CALL PRTCLK (JD)
```

```
      CALL ZERO
      IF (NFIRST.EQ.0) GO TO 13
      CALL PRTAI (AI)
C
C
      DO 12 K = 1, 5
         CALL PRTF (CC(K),K)
12    CONTINUE
13    CONTINUE
      CALL CLOCK (JJD)
      IF (NFIRST.EQ.0) CALL CLOCK(JKD)
      IF (KDELAY.EQ.0) CALL CLOCK(JKD)
C
C
      DO 17 K=  1,  6
      NPORT=K
      CALL PORT(NPORT)
      DO 16 L = 1, 15
         MSF6 = 0
         IF (L.EQ.1.OR.L.EQ.6.OR.L.EQ.11) MSF6 = 1
         CALL SCAN (CHCHO,CSF6,MSF6)
         CALL CONSOL (IBYTE)
         IF (IBYTE.EQ.0) GO TO 555
         CALL RCRT (IBYTE)
         IF (IBYTE.EQ.3) GO TO 99
 555     CONTINUE
         CCHCHO (K,L) = CHCHO
         CALL ADCONV (V,IGAIN)
         CALL CONVRT(V)
         CALL ACCUM(V)
         CALL PRTVOL (V)
         CALL PRTCEA (CHCHO,K,L)
         IF (MSF6.EQ.0) GO TO 14
         KM = 3 * (K-1) + 1 + L/5
         CCSF6(KM) = CSF6
         CALL PRTSF6 (CSF6,KM)
         IF(KM.NE.18) GO TO 14
         CALL AIRINF(CCSF6,AI,JEC)
         CALL PRTAI(AI)
         CL=CSF6*EXP(-1.5*AI)
         JEC=0
         IF(CL.GT.50.) GO TO 14
         TINJ=(300.-CSF6)/FINJ
         INJTIM=TINJ
         IF(INJTIM.GT.600) INJTIM=600.
         IF(INJTIM.LE.0) INJTIM=0
         CALL CLOCK(IJD)
         JEC=1
         IF(INJTIM.EQ.0) JEC=0
         CALL TSTINJ
14       CONTINUE
         IF (L.EQ.JZERO) ACHCHO = 0.0
         IF ((JAVER.LT.JDELAY).AND.(L.GT.JDELAY.OR.L.LE.JAVER))
     *                     ACHCHO = ACHCHO + CHCHO
         IF ((JAVER.GT.JDELAY).AND.(L.GT.JDELAY.AND.L.LE.JAVER))
```

```
*                         ACHCHO = ACHCHO + CHCHO
        IF (L.NE.JAVER) GO TO 15
        KL = K
        IF (KDELAY.EQ.1) KL = K - 1
        IF (KL.EQ.0) KL = 6
        IF (KDELAY.EQ.1.AND.KL.EQ.6.AND.NFIRST.EQ.0) GO TO 15
        CC (KL) = ACHCHO/FAVER
        IF (KL.LE.2)  CALL PRTF(CC(KL),KL)
        IF (KL.LE.2)  GO TO 15
        CC (KL) = CC(KL) - CC(1)
        IF (CC(2).GT.CC(1))   CC(KL) = CSPAN*(CC(KL))/(CC(2)-CC(1))
        CALL PRTF(CC(KL),KL)
        IF (KL.NE.6) GO TO 15
        CALL FOPEN (NREC,MREC,JREC,KREC,NDISC)
        NREC = NREC + 1
        WRITE (6,200,REC = NREC) (JKD(KK),KK=1,5), CC,AI
 200    FORMAT(1X,I2,'/',I2,'/',I2,2X,I2,':',I2,3X,6F10.1,F7.2)
        WRITE (6,201, REC = 1) NREC,ILABEL
 201    FORMAT(I5,10X,40A1)
        JTOTAL = NREC + MREC + JREC + KREC
        CALL PRTREC (JTOTAL)
        ENDFILE 6
        ENDFILE 7
        ENDFILE 8
        ENDFILE 9
 15     CONTINUE
        CALL CONSOL (IBYTE)
        IF (IBYTE.EQ.0) GO TO 16
        CALL RCRT(IBYTE)
        IF (IBYTE.EQ.3) GO TO 99
16      CONTINUE
      CALL FOPEN(NREC,MREC,JREC,KREC,NDISC)
      KREC = KREC + 1
      IF(K.EQ.1)
     *WRITE (9,204,REC = KREC) (JJD(KK),KK=1,5),(CCHCHO(1,LL),LL=1,15)
204   FORMAT(1X,I2,'/',I2,'/',I2,2X,I2,':',I2,3X,15F6.1)
      IF(K.NE.1) WRITE (9,205,REC=KREC)  K, (CCHCHO(K,LL),LL=1,15)
205   FORMAT(5X,I1,5X,15F6.1)
      WRITE (9,201,REC=1) KREC,LABEL
      JTOTAL=NREC+MREC+JREC+KREC
      CALL PRTREC(JTOTAL)
      ENDFILE 6
      ENDFILE 7
      ENDFILE 8
      ENDFILE 9
17      CONTINUE
C
C
C
      CALL FOPEN (NREC,MREC,JREC,KREC,NDISC)
      MREC = MREC + 1
      CALL AVER
      WRITE (7,202, REC = MREC) (JJD(KK),KK=1,5), AV
202   FORMAT(1X,I2,'/',I2,'/',I2,2X,I2,':',I2,3X,11F6.1)
      WRITE (7,201, REC = 1) MREC,LABEL
```

```
      JREC = JREC + 1
      WRITE (8,203,REC = JREC) (JJD(KK),KK=1,5), CCSF6
203   FORMAT(1X,I2,'/',I2,'/',I2,2X,I2,':',I2,3X,18F6.1)
      WRITE (8,201, REC = 1) JREC,LABEL
      JTOTAL=NREC+MREC+KREC+JREC
      CALL PRTREC(JTOTAL)
C
C
      DO  18 KK = 1, 6
         JKD(KK) = JJD(KK)
18    CONTINUE
C
C
      ENDFILE 6
      ENDFILE 7
      ENDFILE 8
      ENDFILE 9
      NFIRST=NFIRST+1
      GO TO 11
99    ROW = 0
      COL = 0
      CALL CURSOR (COL, ROW)
      IBYTE = 1
      CALL OUT (Z'93',IBYTE)
      END



      SUBROUTINE ACCUM(V)
C
C SUBROUTINE FOR ACCUMULATING ANALOG VOLTAGES
C
      DIMENSION V(16),AV(11)
      COMMON /AVERG/ AV,NV
      NV=NV+1
      DO 10 K=3,7
      KK=K-2
      AV(KK)=AV(KK)+V(K)
   10 CONTINUE
      DO 11 K=9,14
      KK=K-3
      AV(KK)=AV(KK)+V(K)
   11 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ADCONV(V,IGAIN)
C
C SUBROUTINE FOR READING ALL 16 CHANNELS OF A/D CARD
C
      INTEGER*1 NCHAN,IGAIN
      DIMENSION V(16),GAIN(4)
      DATA GAIN/10.,5.,1.25,0.1/
      L=IGAIN+1
      DO 1 K=1,16
      NCHAN=K-1
      CALL ANALOG(NDATA,NCHAN)
      V(K)=NDATA
      V(K)=GAIN(L)*V(K)/2048.
    1 CONTINUE
      RETURN
      END


      SUBROUTINE AIRINF(C,AI,JEC)
C
C THIS SUBROUTINE CALCULATES THE AIR INFILTRATION RATE
C USING A LEAST SQUARES METHOD
C
      DIMENSION C(18)
C
C DEFAULT VALUE OF THE AIR INFILTRATION RATE IS 0.00
C
      AI=0.0
      CMAX=300.
      CMIN=10.
      L1=4
      IF(JEC.EQ.0) L1=1
C
C INITIALIZE AVERAGES AND MOMENTS
C
      N=0
      XM=0.0
      YM=0.0
      XS=0.0
      YS=0.0
      XY=0.0
C
C CALCULATE NUMBER OF VALID DATA POINTS, AVERAGES AND MOMEMTS
C THE FIRST DATA POINTS TAKEN DURING THE TWENTY MINUTE INTERVAL
C AFTER THE PERIOD OF INJECTION IS IGNORED
C
      DO 1 L=L1,18
C CHECK FOR OVERSATURATION
      IF(C(L).GT.CMAX) GO TO 1
C CHECK FOR INSUFFICIENT TRACER GAS
      IF(C(L).LT.CMIN) GO TO 1
      N=N+1
C TIME OF THE L-TH SAMPLE ON THE K-TH PORT
      X=5.0*(L-1)
```

```
      X=X/60.0
C LOG OF THE CONCENTRATION
      Y=ALOG(C(L))
      XM=XM+X
      YM=YM+Y
      XY=XY+X*Y
      YS=YS+Y*Y
      XS=XS+X*X
    1 CONTINUE
C CHECK FOR SUFFICIENT NUMBER OF VALID DATA POINTS
      IF(N.LT.2) RETURN
      FN=N
C THE AVERAGE AIR INFILTRATION RATE IS THE LEAST SQUARE SLOPE OF THE
C LOG(C) VS. TIME
      AI=-(XY-YM*XM/FN)/(XS-XM*XM/FN)
      RETURN
      END


      SUBROUTINE AVER
C
C SUBROUTINE OF OBTAINING AVERAGE OF ANALOG READINGS
C      DIMENSION AV(11)
      COMMON /AVERG/ AV,NV
      IF(NV.LE.0) RETURN
      FN=NV
      DO 10 K=1,11
      AV(K)=AV(K)/FN
   10 CONTINUE
      RETURN
      END


      SUBROUTINE CONVRT(V)
C
C SUBROUTINE FOR CONVERTING ANALOG VOLTAGES TO PHYSICAL UNITS
C
      DIMENSION V(16)
      DATA CT203/0.65107/,BT203/6.7966E-3/
C
C CHANNEL 7 (V(8)) NOT WORKING -- THUS SKIPPED
C
C SUBTRACT ZERO VOLTAGE
C
      DO 1 K=2,16
      V(K)=V(K)-V(1)
    1 CONTINUE
C
C CONVERT FLOW METER TO CFM
C
      V(14)=15.0*V(14)
      V(13)=15.0*V(13)
C
C CHECK REFERENCE VOLTAGE FOR THERMISTORS
```

```
C
      IF(V(2).LT.1.0) GO TO 3
C
C CONVERT THERMISTOR READINGS TO DEGREES CELCIUS
C
      DO 2 K=3,12
      V(K)=(CT203-V(K)/V(1))/BT203
    2 CONTINUE
C
C CONVERT DEW POINT
C
      V(5)=DEWPT(V(5))
      RETURN
    3 CONTINUE
      DO 4 K=3,12
      V(K)=99.9
    4 CONTINUE
      RETURN
      END


      SUBROUTINE CURREN(STCURR)
C
C SUBROUTINE CURREN.FOR FOR READING THE CURRENT OF THE S-CUBE
C ELECTRON CAPTURE DETECTOR
C
      INTEGER*1 NCHAN
      DATA NCHAN/14/
      STCURR=0.0
      DO 10 K=1,10
      CALL ANALOG(NDATA,NCHAN)
      VOLT=NDATA
      VOLT=10.0*NDATA/2048.
      STCURR=STCURR+VOLT
   10 CONTINUE
      STCURR=STCURR/10.
      RETURN
      END
```

```
      SUBROUTINE DEWPT(V)
C
C CONVERTS DEW POINT TEMPERATURE FROM BOBBIN TEMPERATURE
C
      DIMENSION B(10)
      DATA B/-26.020030,0.72157332,0.5797266E-4,0.81653144E-6,
     *0.12259521E-5,-0.65969899E-8,-0.14720739E-8,0.38216241E-10,
     *-0.36454188E-12,0.12371531E-14/
      DP=B(1)
      DO 1 J=1,9
      JJ=J+1
      DP=DP+B(JJ)*V**J
    1 CONTINUE
      DP=V
      RETURN
      END
```

```
      SUBROUTINE FMASK (CSPAN,LABEL)
C
C SUBROUTINE FOR PRINTING SCREEN MASK FOR LARGE CHAMBER
C
C LAST REVISION 11-17-84
C
      INTEGER*1 ROW,COL,JD(6),LABEL(40)
      ROW = 0
      COL = 0
      CALL CURSOR(COL,ROW)
      CALL CLOCK (JD)
      COL = 1
      ROW = 1
      CALL CURSOR(COL, ROW)
C
C
      WRITE(5,100) LABEL
100   FORMAT(1H+,5X,'RECORDS',15X,40A1,/)
      WRITE(5,101)
101   FORMAT(12X,'ZERO = ',7X,'VOLTS',15X,'REFERENCE = ',7X,'VOLTS')
      WRITE(5,102)
102   FORMAT(7X,'INLET TEMP = ',5X,'C',7X,'OUTLET TEMP =',5X,
     * ' C',6X,'DEW POINT = ',5X,'C')
      WRITE(5,103)
103   FORMAT(1X,'ROOM 1 6 FT TEMP = ',5X,'C',9X,'2 FT TEMP = ',5X,
     *'C',4X,' FLOOR TEMP = ',5X, 'C')
      WRITE (5,104)
104   FORMAT(1X,'ROOM 2 6 FT TEMP = ',5X,'C',9X,'2 FT TEMP = ',5X,
     *'C',4X,' FLOOR TEMP = ',5X, 'C')
      WRITE (5,105)
105   FORMAT(3X,'INLET FLOW = ',6X,'CFM',2X,'OUTLET FLOW = ',6X,'CFM',
     *2X,'AIR EXCHANGE = ',6X,'/HR'/)
      WRITE (5,106) CSPAN
106   FORMAT(8X,'CEA ZERO = ',29X,'CEA SPAN (',F5.1,' PPB) = '/)
      WRITE(5,107)
107   FORMAT(26X,'FORMALDEHYDE CONCENTRATIONS')
      WRITE (5,108)
108   FORMAT(2X,'INLET',7X,'PPB',5X,'OUTLET',7X,'PPB',3X,'ROOM 1',
     *7X,'PPB',4X,'ROOM 2',7X,'PPB'/)
      WRITE (5,109)
109   FORMAT(28X,' TRACER CONCENTRATIONS (PPB)')
      WRITE(5,110)
110   FORMAT(8X,'1',3X,'2',3X,'3',3X,'4',3X,'5',3X,'6',3X,'7',3X,'8',
     *3X,'9',2X,'10',2X,'11',2X,'12',2X,'13',2X,'14',2X,'15',2X,'16',
     *2X,'17',2X,'18',/)
      WRITE(5,111)
111   FORMAT(38X,'CEA READINGS')
      WRITE(5,112)
112   FORMAT(9X,'1',4X,'2',4X,'3',4X,'4',4X,'5',4X,'6',4X,'7',
     *4X,'8',4X,'9',3X,'10',3X,'11',3X,'12',3X,'13',3X,'14',3X,'15')
      WRITE (5,113)
113   FORMAT(1X,'ZERO',/,1X,'SPAN',/,1X'INLET',/,1X,'OUTLET',/,
     *1X,'RM 1',/,1X,'RM 2')
      RETURN
```

```
      END


      SUBROUTINE FOPEN(NREC,MREC,JREC,KREC,NDISC)
C
C  THIS SUBROUTINE OPENS THE DATA FILES ON DISK "NDISC"
C
      CALL LOGOFF
      CALL OPEN(6,'HCHOLARGDTA',NDISC)
      READ(6,100,REC=1,END=10) NREC
  100 FORMAT(I5)
      GO TO 11
   10 NREC=1
      WRITE(6,100,REC=1) NREC
   11 CALL OPEN(7,'ANALOG  DTA',NDISC)
      READ(7,100,REC=1,END=12) MREC
      GO TO 13
   12 MREC=1
      WRITE(7,100,REC=1) MREC
   13 CALL OPEN(8,'CONSF6  DTA',NDISC)
      READ(8,100,REC=1,END=14) JREC
      GO TO 15
   14 JREC=1
      WRITE(8,100,REC=1) JREC
   15 CALL OPEN(9,'CONHCHO DTA',NDISC)
      READ(9,100,REC=1,END=16) KREC
      GO TO 17
   16 KREC=1
      WRITE(9,100,REC=1) KREC
   17 RETURN
      END
```

```
      SUBROUTINE ON
C
C THIS SUBROUTINE ACTUATES THE S-CUBE ELECTRON CAPTURE DETECTOR
C REMOTE START
C
      INTEGER*1 ID,KD,ICTRL
      COMMON /CNTRL/ICTRL
      CALL SEC(ID)
    1 CALL SEC(KD)
      IF(ID.EQ.KD) GO TO 1
      ICTRL=ICTRL.OR.Z'80'
      CALL OUT(Z'93',ICTRL)
    2 CALL SEC(ID)
      IF(ID.EQ.KD) GO TO 2
      ICTRL=ICTRL.AND.Z'7F'
      CALL OUT(Z'93',ICTRL)
      RETURN
      END

      SUBROUTINE PARMF
C
C THIS SUBROUTINE READS OR CREATES THE PARAMETER FILE FOR THE
C  LARGE CHAMBER PROGRAM
C
      INTEGER*1 LABEL (40)
      COMMON /CALIB/ C0,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,NDISC,LABEL
C
C
      CALL OPEN (6,'HCHOCHAMPAR',0)
      READ (6,100, END = 10) C0,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,
     *                       NDISC,LABEL
100   FORMAT(1X,4F10.3,2I5,F10.3,I5,40A1)
      WRITE (5,101) LABEL
101   FORMAT(5X,'TEST LABEL: ',40A1,/)
      WRITE (5,102) C0,B
102   FORMAT(10X,'ELECTRONIC CAPTURE GC PARAMETERS'/10X,'C0 = ',
     *      F6.1,' ppb',10X,'B = ',F5.3/)
      WRITE (5,202) FINJ
202   FORMAT (5X,'INJECTION FLOW RATE = ',F10.3, ' CC/MIN')
      WRITE(5,103) JDELAY,JAVER
103   FORMAT(10X,'CEA AVERAGING INTERVAL FROM ',I3,' TO',I3,
     *       ' MINUTES AFTER PORT CHANGE'/)
C
C
C
      IF (NDISC.EQ.0) WRITE (5,104)
      IF (NDISC.EQ.1) WRITE (5,105)
      IF (NDISC.EQ.2) WRITE (5,106)
104   FORMAT(10X,'DATA DISC DRIVE IS CURRENT DRIVE')
105   FORMAT(10X,'DATA DISC DRIVE IS DRIVE "A"')
106   FORMAT(10X,'DATA DISC DRIVE IS DRIVE "B"')
C
C
      ENDFILE 6
```

```
      RETURN
10    ENDFILE 6
      CALL OPEN(6,'HCHOCHAMPAR',0)
      WRITE (5,107)
107   FORMAT(5X,'INPUT TEST LABEL (MAX 40 CHARACTERS): ' )
      READ (5,108) LABEL
108   FORMAT(40A1)
      WRITE (5,109)
109   FORMAT(5X,'INPUT ELECTRON CAPTURE GC PARAMETERS ',/,5X,
     * 'C0 = (ppb): ')
      READ (5,100) C0
110   FORMAT(F7.0)
      WRITE(5,111)
111   FORMAT(5X,' B = ')
      READ (5,110) B
      WRITE (5,211)
211   FORMAT(5X,'INPUT INJECTION FLOW RATE (cc/min): ')
      READ (5,110) FINJ
      WRITE (5,112)
112   FORMAT (5X,'INPUT DELAY IN MINUTES FOR CEA TO READ HCHO (NN): ')
      READ (5,113) JDELAY
113   FORMAT(I2)
      WRITE (5,114)
114   FORMAT(5X,'INPUT AVERAGING TIME IN MINUTES (NN): ')
      READ (5,113) JAVER
C
      FAVER = JAVER
      JAVER = JAVER + JDELAY
      IF (JAVER.GT.15) JAVER = JAVER - 15
C
      WRITE(5,115)
115   FORMAT(5X,' INPUT SPAN GAS LEVEL (ppb): ')
      READ (5,110) CSPAN
      WRITE (5,116)
116   FORMAT(5X,'INPUT DRIVE FOR DATA (1 = A, 2 = B, 0 = CURRENT: ')
      READ (5,117)
117   FORMAT (I1)
      WRITE (6,100) C0,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,NDISC,LABEL
      ENDFILE 6
      RETURN
      END
```

```
      SUBROUTINE PORT(NPORT)
C
C THIS SUBROUTINE CHANGES SAMPLE PORT
C
      INTEGER*1 NPORT,JPORT(8),IBYTE,ICTRL
      COMMON /CNTRL/ ICTRL
      DATA JPORT/1,2,4,8,16,32,64,128/
      IF(NPORT.LE.0) RETURN
      IF(NPORT.GT.6) RETURN
      K=NPORT
      IBYTE=JPORT(K)
      ICTRL=ICTRL.AND.Z'C0'
      ICTRL=ICTRL.OR.IBYTE
      CALL OUT(Z'93',ICTRL)
      RETURN
      END
```

```
      SUBROUTINE PRTAI (AI)
C
C PRINTS THE AIR EXCHANGE RATE ON SCREEN
C
      INTEGER*1 COL, ROW, IDATA(10)
      ROW = 7
      COL = 67
      CALL CURSOR (COL, ROW)
      IF (AI.GT.99.99) AI = 99.99
      IF (AI.LT.-9.99) AI = -9.99
      ENCODE(IDATA,100) AI
100   FORMAT(F5.2,'$')
      CALL PRT (IDATA)
      RETURN
      END


      SUBROUTINE PRTCEA (CHCHO,K,L)
C
C THIS SUBROUTINE PRINTS TO THE SCREEN THE CEA READINGS
C
      INTEGER*1 ROW,COL,IDATA(10)
      ROW = 18 + K
      COL = 2 + 5*L
      CALL CURSOR (COL,ROW)
      NC = CHCHO
      IF (NC.GT.9999) NC = 9999
      IF (NC.LT.-999) NC = -999
      ENCODE (IDATA, 100) NC
100   FORMAT(I4,'$')
      CALL PRT (IDATA)
      RETURN
      END


      SUBROUTINE PRTF ( C, K)
C
C THIS SUBROUTINE PRINTS THE ZERO, SPAN AND HCHO VALUES TO
C  THE SCREEN
C
      INTEGER*1 ROW,COL,IROW(6),ICOL(6),IDATA(10)
      DATA IROW /9,9,12,12,12,12/
      DATA ICOL /19,70,8,29,48,68/
      ROW = IROW (K)
      COL = ICOL (K)
      CALL CURSOR (COL,ROW)
      X = C
      IF (X.GT.999.9) X = 999.9
      IF (X.LT.-99.9) X = -99.9
      ENCODE (IDATA,100) X
100   FORMAT(F5.1,'$')
      CALL PRT(IDATA)
      RETURN
      END
```

```
      SUBROUTINE PRTREC(NREC)
C
C THIS SUBROUTINE PRINTS THE RECORD COUNT TO THE SCREEN
C
      INTEGER*1 COL,ROW,IDATA(10)
      ROW=1
      COL=14
      CALL CURSOR(COL,ROW)
      ENCODE(IDATA,100) NREC
  100 FORMAT(I5,'$')
      CALL PRT(IDATA)
      RETURN
      END


      SUBROUTINE PRTSF6 (C, L)
C
C THIS SUBROUTINE PRINTS THE SF6 CONCENTRATIONS TO THE SCREEN
C
      INTEGER*1 ROW, COL, IDATA(10)
      ROW = 16
      COL = 3 + 4*L
      CALL CURSOR (COL,ROW)
      NC = C
      IF (NC.GT.999) NC = 999
      IF (NC.LT.0)  NC = 0
      ENCODE (IDATA,100) NC
100   FORMAT(I3,'$')
      CALL PRT(IDATA)
      RETURN
      END
```

```
      SUBROUTINE PRTVOL (V)
C
C THIS SUBROUTINE PRINTS THE ANALOG VALUES TO THE SCREEN
C
      INTEGER*1 COL,ROW,IDATA(10),ICOL(3)
      DIMENSION V(16)
      DATA ICOL/20,47,71/
C
C  LAST REVISION 11-17-84
C
      ROW = 3
      COL = 19
      CALL CURSOR(COL,ROW)
      ENCODE (IDATA,100) V(1)
 100  FORMAT(F6.3,'$')
      CALL PRT (IDATA)
      COL = 57
      CALL CURSOR (COL, ROW)
      ENCODE (IDATA, 100) V(2)
      CALL PRT (IDATA)
      DO 10 K = 1 , 3
           ROW = 3 + K
                DO 10  L = 1, 3
                   COL = ICOL(L)
                   CALL CURSOR (COL, ROW)
                   MK = 3 * (K-1) + L + 2
                   IF (MK.GE.8) MK = MK + 1
                   IF (V(MK).GT.99.9) V(MK) = 99.91
                   IF (V(MK).LT.-9.9) V(MK) = -9.9
C
                   ENCODE (IDATA, 101) V(MK)
101                FORMAT(F4.1,'$')
                   CALL PRT (IDATA)
10      CONTINUE
C
C
      ROW = 7
      COL = 16
      CALL CURSOR (COL,ROW)
      ENCODE (IDATA,102) V(13)
102   FORMAT(F5.1,'$')
      CALL PRT (IDATA)
      COL = 41
      CALL CURSOR (COL, ROW)
      ENCODE (IDATA,102) V(14)
      CALL PRT (IDATA)
      RETURN
      END
```

```
      SUBROUTINE SCAN (CHCHO,CSF6,MSF6)
C
C LAST REVISION 11-17-84
C
C THIS SUBROUTINE DETERMINES THE AVERAGE CEA READING FOR A PERIOD
C OF 45 SECONDS
C
C IF MSF6 =1 , THEN THE SF6 CONCENTRATION IS DETERMINED BY
C FINDING THE PEAK CURRENT OCCURRING BETWEEN 20 AND 50 SECONDS
C
      INTEGER*1 ID,IGAIN,LABEL(40),JD(6),NCHAN
      DIMENSION V(16)
      COMMON /CALIB/ C0,B,CSPAN,FINJ,JDELAY,JAVER,FAVER,NDISC,LABEL
      CSF6=999.9
      NCHAN=15
      ISEC=45
      IF(MSF6.EQ.1) ISEC=50
      IGAIN=0
      CV=0.0
      NN=0
    1 CALL SEC(ID)
      CALL PRTSEC(ID)
      CALL TSTINJ
      IF(ID.GT.2) GO TO 1
      CALL CLOCK(JD)
      CALL PRTCLK(JD)
      IF(MSF6.EQ.0) GO TO 2
      CALL CURREN(BASE)
      CALL ON
      PEAK=BASE
    2 CALL SEC(ID)
      CALL PRTSEC(ID)
      CALL TSTINJ
      CALL ANALOG(NDATA,NCHAN)
      VV=NDATA
      VV=10.0*VV/2048.
      CV=CV+VV
      NN=NN+1
      CALL ADCONV(V,IGAIN)
      CALL CONVRT(V)
      CALL ACCUM(V)
      IF(ID.LT.15) GO TO 2
      CALL CURREN(PCURR)
    3 CALL SEC(ID)
      CALL PRTSEC(ID)
      CALL ANALOG(NDATA,NCHAN)
      VV=NDATA
      VV=10.0*VV/2048.
      CV=CV+VV
      NN=NN+1
      CALL ADCONV(V,IGAIN)
      CALL CONVRT(V)
      CALL ACCUM(V)
      CALL TSTINJ
      IF(MSF6.EQ.0) GO TO 4
```

```
      CALL CURREN(CURR)
      IF(PCURR.GT.PEAK.AND.PCURR.GE.CURR) PEAK=PCURR
      PCURR=CURR
    4 CONTINUE
      IF(ID.LE.ISEC) GO TO 3
      FN=NN
      CV=CV/FN
      CHCHO=100.*CV
      IF(MSF6.EQ.0) RETURN
      IF(PEAK.GT.9.9) RETURN
      PEAK=PEAK-BASE
      IF(PEAK.GT.0.0) CSF6=C0*(PEAK**B)
      IF(PEAK.LE.0.0) CSF6=0.0
      IF(CSF6.GT.999.9) CSF6=999.9
      RETURN
      END


      SUBROUTINE TSTINJ
C
C THIS SUBROUTINE CONTROLS THE INJECTION PORT
C
      INTEGER*1 ICTRL,JD(6),IJD(6)
      COMMON /CNTRL/ ICTRL
      COMMON /INJEC/ IJD,INJTIM
      IF(INJTIM.LE.0) RETURN
      CALL CLOCK(JD)
      NHOUR=0
      IF(JD(4).NE.IJD(4)) NHOUR=1
      ITIM=JD(6)-IJD(6)+60*(JD(5)-IJD(5))
      ITIM=ITIM+3600*NHOUR
      IF(ITIM.GE.INJTIM) GO TO 10
      ICTRL=ICTRL.OR.Z'40'
      CALL OUT(Z'93',ICTRL)
      RETURN
   10 INJTIM=0
      ICTRL=(ICTRL.AND.Z'BF')
      CALL OUT(Z'93',ICTRL)
      RETURN
      END


      SUBROUTINE ZERO
C
C THIS SUBROUTINE SETS THE ANALOG ACCUMULATORS TO ZERO
C
      DIMENSION AV(11)
      COMMON /AVERG/ AV,NV
      NV=0
      DO 10 K=1,11
   10 AV(K)=0.0
      RETURN
      END
```

Appendix G

Listing of Program for Predicting HCHO Concentrations in Two-Room Prototype House

```
C
C PROGRAM HCHOLEV.FOR
C
C PROGRAM FOR  PREDICTING HCHO LEVELS IN A HOUSE USING
C OAKRIDGE MODELS FOR HCHO EMISSION RATES AS A FUNCTION OF
C TEMPERATURE AND HUMIDITY

      CHARACTER*15 FHOUSE
      CHARACTER*15 FDATA
      CHARACTER*15 FEMIT
      INTEGER*1 LABEL(40)
      DIMENSION NTYPE(40),AREA(40),ERSTD(40),CBSTD(40),A(40),B(40),
     1C(40),E(40)
      DATA FHOUSE/"HOUSE.DTA"/
      DATA FEMIT/"EMITTERS.DTA"/
      DATA FDATA/"HCHO.DTA"/
      COMMON /EMIT/ERSTD,CBSTD,A,B,C,E
      WRITE(1,100)
  100 FORMAT(//,10X,'PROGRAM HCHOLEV',//)
      IF(IOREAD(6,2,0,FHOUSE)) GO TO 12
      WRITE(1,101)
  101 FORMAT(5X,'READING HOUSE DATA',/)
      READ(6,1200) LABEL
  200 FORMAT(1H1,40A1)
 1200 FORMAT(40A1)
      READ(6,1201) VOL,NUM
  201 FORMAT(1H1,F10.2,I3)
 1201 FORMAT(F10.2,I3)
      DO 10 K=1,NUM
      READ(6,1202) NTYPE(K),AREA(K)
  202 FORMAT(1H1,I2,F10.2)
 1202 FORMAT(I2,F10.2)
   10 CONTINUE
C      WRITE(1,203) LABEL
  203 FORMAT(//,1H1,5X'HOUSE DATA READ',//,5X,'LABEL IS ',5X,40A1)
      WRITE(1,204) VOL
  204 FORMAT(1H1,/,5X,'VOLUME = ',F10.2,' m**2',/)
      WRITE(1,1204) NUM
 1204 FORMAT(1H1,5X,'NUMBER OF EMITTERS IS',I3,/)
      DO 11 K=1,NUM
      WRITE(1,205) K,NTYPE(K),AREA(K)
  205 FORMAT(1H1,1X,'EMITTER #',I2,' IS TYPE ',I2,' WITH AREA OF',
     1F10.2,' m**2')
   11 CONTINUE
      GO TO 14
   12 IF(IOWRIT(6,2,0,FHOUSE)) GO TO 99
      WRITE(1,206)
  206 FORMAT(/,5X,'INPUT HOUSE DATA',/,5X,'LABEL = '$
      READ(1,200) LABEL
```

```
      WRITE(6,200) LABEL
      WRITE(1,207)
  207 FORMAT(5X,'VOLUME (M**3) = '$
      READ(1,208) VOL
  208 FORMAT(F10.0)
      WRITE(1,209)
  209 FORMAT(5X,'NUMBER OF EMITTERS = (NN) '$
      READ(1,210) NUM
  210 FORMAT(I2)
      WRITE(6,201) VOL,NUM
      DO 13 K=1,NUM
      WRITE(1,211) K
  211 FORMAT(5X,'EMITTER #',I2,' IS TYPE (NN) : '$
      READ(1,210) NTYPE(K)
      WRITE(1,212) K
  212 FORMAT(5X,'EMITTER #',I2,' AREA  (M**2) = : '$
      READ(1,208) AREA(K)
      WRITE(6,202) NTYPE(K),AREA(K)
   13 CONTINUE
      IF(IOCLOS(6)) GO TO 98
   14 CONTINUE
      IF(IOREAD(7,2,0,FEMIT)) GO TO 16
      WRITE(1,250)
  250 FORMAT(1H1,//,5X,'INPUTTING EMITTERS DATA')
      READ(7,1300) NEMIT
  300 FORMAT(1H1,I3)
 1300 FORMAT(I3)
      WRITE(1,251) NEMIT
  251 FORMAT(1H1,//,5X,'EMITTER FILE HAS ',I2,' ENTRIES')
      DO 15 K=1,NEMIT
      READ(7,1301) ERSTD(K),CBSTD(K),A(K),B(K),C(K),E(K)
  301 FORMAT(1H1,6F10.3)
 1301 FORMAT(6F10.0)
      WRITE(1,252) K,ERSTD(K),CBSTD(K),A(K),B(K),C(K),E(K)
  252 FORMAT(1H1,/,5X,'ENTRY #',I2,/,10X,'ERSTD = ',F10.3,
     1' mg/m**2*hr',
     1/,10X,'CBSTD = ',F10.0,' ppb',/,10X,'    A = ',F10.3,/,10X,
     1'    B = ',F10.3,/,10X,'    C = ',F10.3,/,10X,'    E = ',F10.3)
   15 CONTINUE
      GO TO 18
   16 CONTINUE
      IF(IOWRIT(7,2,0,FEMIT)) GO TO 97
      WRITE(1,260)
  260 FORMAT(5X,'INPUT EMITTER DATA',/,10X,'NUMBER OF EMITTERS = (NN) '
     1,':'$
      READ(1,210) NEMIT
      WRITE(7,300) NEMIT
      DO 17 K=1,NEMIT
      WRITE(1,261) K
  261 FORMAT(5X,'EMITTER #',I2)
      WRITE(1,262)
  262 FORMAT(10X,'ERSTD (mg/m**2*hr) = '$
      READ(1,208) ERSTD(K)
      WRITE(1,263)
  263 FORMAT(10X,'CBSTD (ppb) = '$
```

```
      READ(1,208) CBSTD(K)
      WRITE(1,264)
  264 FORMAT(10X,'A = '$
      READ(1,208) A(K)
      WRITE(1,265)
  265 FORMAT(10X,'B = '$
      READ(1,208) B(K)
      WRITE(1,266)
  266 FORMAT(10X,'C = '$
      READ(1,208) C(K)
      WRITE(1,267)
  267 FORMAT(10X,'E = '$)
      READ(1,208) E(K)
      WRITE(7,301) ERSTD(K),CBSTD(K),A(K),B(K),C(K),E(K)
   17 CONTINUE
      IF(IOCLOS(7)) GO TO 96
   18 CONTINUE
      IF(IOWRIT(8,2,0,FDATA)) GO TO 95
      WRITE(1,268)
  268 FORMAT(1H1,/,10X,'DATA FILE OPENED',/)
  269 FORMAT(1H1,5X,'TEMP.      RH          AI        HCHO',/,6X,
     1'  C          %          /hr        ppb')
      DO 20 L=1,6
      T=20.0+1.0*(L-1)
      DO 20 M=1,5
      RH=20.0+10.0*(M-1)
      SA=0.0
      SB=0.0
      WRITE(1,702) T,RH
  702 FORMAT(1H1,5X,'TEMP. = ',F5.1,' C',5X,'RH = ',F5.1,' %',/)
      WRITE(1,701)
  701 FORMAT(1H1,5X,' N NT    ALPHA     BETA')
      WRITE(8,702) T,RH
      WRITE(8,701)
      CMAX=0.0
      CMIN=99999.
      DO 21 K=1,NUM
      KK=NTYPE(K)
      CALL ER(ALPHA,BETA,T,RH,KK)
      CC=ALPHA/BETA
      IF(CC.GE.CMAX) CMAX=CC
      IF(CC.LT.CMIN) CMIN=CC
      WRITE(1,700) K,KK,ALPHA,BETA
      WRITE(8,700) K,KK,ALPHA,BETA
  700 FORMAT(5X,I2,I3,F10.4,F10.7)
      SA=SA+AREA(K)*ALPHA
      SB=SB+AREA(K)*BETA
   21 CONTINUE
      WRITE(1,269)
      WRITE(8,269)
      SA=819.*SA/VOL
      SB=819.*SB/VOL
      DO 22 N=1,10
      AI=0.1*N
      CHCHO=SA/(AI+SB)
```

```
      IF(CHCHO.GE.CMAX) CHCHO=CMAX
      IF(CHCHO.GE.CMAX) GO TO 26
      IF(CHCHO.LT.CMIN) GO TO 26
   23 ICHCHO=CHCHO
      SA=0.0
      SB=0.0
      DO 24 K=1,NUM
      KK=NTYPE(K)
      CALL ER(ALPHA,BETA,T,RH,KK)
      FER=ALPHA-BETA*CHCHO
      IF(FER.LE.0.0) GO TO 24
      SA=SA+AREA(K)*ALPHA
      SB=SB+AREA(K)*BETA
   24 CONTINUE
      SA=819.*SA/VOL
      SB=819.*SB/VOL
      CHCHO=SA/(AI+SB)
      IF(CHCHO.GE.CMAX) CHCHO=CMAX
      IF(CHCHO.GE.CMAX) GO TO 26
      JCHCHO=CHCHO
      IF(JCHCHO.NE.AX) CHCHO=CMAX
      IF(CHCHO.GE.CMAX) GO TO 26
      IF(CHCHO.LT.CMIN) GO TO 26
   23 ICHCHO=CHCHO
      SA=0.0
      SB=0.0
      DO 24 K=1,NUM
      KK=NTYPE(K)
      CALL ER(ALPHA,BETA,T,RH,KK)
      FER=ALPHA-BETA*CHCHO
      IF(FER.LE.0.0) GO TO 24
      SA=SA+AREA(K)*ALPHA
      SB=SB+AREA(K)*BETA
   24 CONTINUE
      SA=819.*SA/VOL
      SB=819.*SB/VOL
      CHCHO=SA/(AI+SB)
      IF(CHCHO.GE.CMAX) CHCHO=CMAX
      IF(CHCHO.GE.CMAX) GO TO 26
      JCHCHO=CHCHO
      IF(JCHCHO.NE.TA')
      STOP
   97 WRITE(1,503)
  503 FORMAT(10X,'ERROR IN OPENING FILE EMITTERS.DTA')
      STOP
   98 WRITE(1,504)
  504 FORMAT(10X,'ERROR IN CLOSING FILE HOUSE.DTA')
      STOP
   99 WRITE(1,505)
  505 FORMAT(10X,'ERROR IN OPENING FILE HOUSE.DTA')
      STOP
      END
```

```
      SUBROUTINE ER(ALPHA,BETA,T,RH,N)
C
C SUBROUTINE FOR CALCULATING THE HCHO EMISSION RATE AS A FUNCTION
C OF TEMPERATURE, HUMIDITY AND HCHO CONCENTRATION
C
C THIS SUBROUTINE USE THE OAKRIDGE MODEL II
C
C       ER=ALPHA(T,RH,N)-BETA(T,RH,N)*C
C
C           WHERE:
C                   T    IS THE TEMPERATURE IN DEGREES CELSIUS
C                  RH    IS THE RELATIVE HUMIDITY
C                   C    IS THE HCHO CONCENTRATION IN ppb
C                   N    IS THE INDEX OF THE HCHO EMITTER
C
C IN THIS MODEL THE COEFFICIENTS HAVE THE MEANING
C
C       ERSTD(N)    THE EMISSION RATE AT STANDARD CONDITION
C                      23 DEGREES CELSIUS, 50% RH, 100 ppb
C       CBSTD(N)    CUTOFF CONCENTRATION IN ppb AT 23 DEGREES & 50% RH
C       A(N)        OAKRIDGE HUMDITY EXPONENT
C       B(N)        OAKRIDGE TEMPERATURE COEFFICIENT
C       C(N)        OAKRIDGE TEMPERATURE COEFFICIENT DIVIDED BY 296*273
C       E(N)        OAK RIDGE HUMIDITY COEFFICIENT
C
C       THE EMISSION RATE IS GIVEN IN mg/m**2*hr
C
      DIMENSION ERSTD(40),A(40),B(40),C(40),E(40),CBSTD(40)
      COMMON /EMIT/ ERSTD,CBSTD,A,B,C,E
      F=ERSTD(N)*(1.0+B(N)*(T-23.0))*(1.0+E(N)*(RH-50.0))
      BETA=F/(CBSTD(N)-100.0)
      ALPHA=F*EXP(-C(N)*(23.0-T)/(1.0+T/273.0))*CBSTD(N)/
     1(CBSTD(N)-100.0)
      ALPHA=ALPHA*EXP(A(N)*ALOG(RH/50.0))
      RETURN
      END
```

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5. AUTHOR(S)

Richard A. Grot, Samuel Silberstein, Kunimichi Ishiguro

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This interim report describes procedures and presents results of the first phase of a laboratory project undertaken at the National Bureau of Standards for the Consumer Product Safety Commission (CPSC). The purpose of the ongoing project is to assess the accuracy of emission and indoor air quality models to be used by CPSC in predicting formaldehyde (HCHO) concentrations in residences due to pressed-wood products made with urea-formaldehyde bonding resins, namely particleboard underlayment, hardwood-plywood paneling and medium-density fiberboard (MDF). In phase I, these products were characterized in "medium-size" dynamic measuring chambers by measuring their HCHO surface emission rates over a range of HCHO concentrations, at 23°C and 50% RH. They were then installed in a two-room prototype house and the equilibrium HCHO concentrations were monitored as a function of air exchange rate. Excellent agreement was obtained between measured HCHO concentrations and those predicted by a mass-balance indoor air quality model. In the next phase, the study will be repeated at various different temperatures and relative humidities so that models predicting HCHO surface emission rate as a function of temperature and humidity can be tested.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Formaldehyde; indoor air quality; modeling; paneling; particleboard; plywood; tracer gas; underlayment.

13. AVAILABILITY

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