INVESTIGATION OF EMISSIONS FROM PLYWOOD VENEER DRYERS

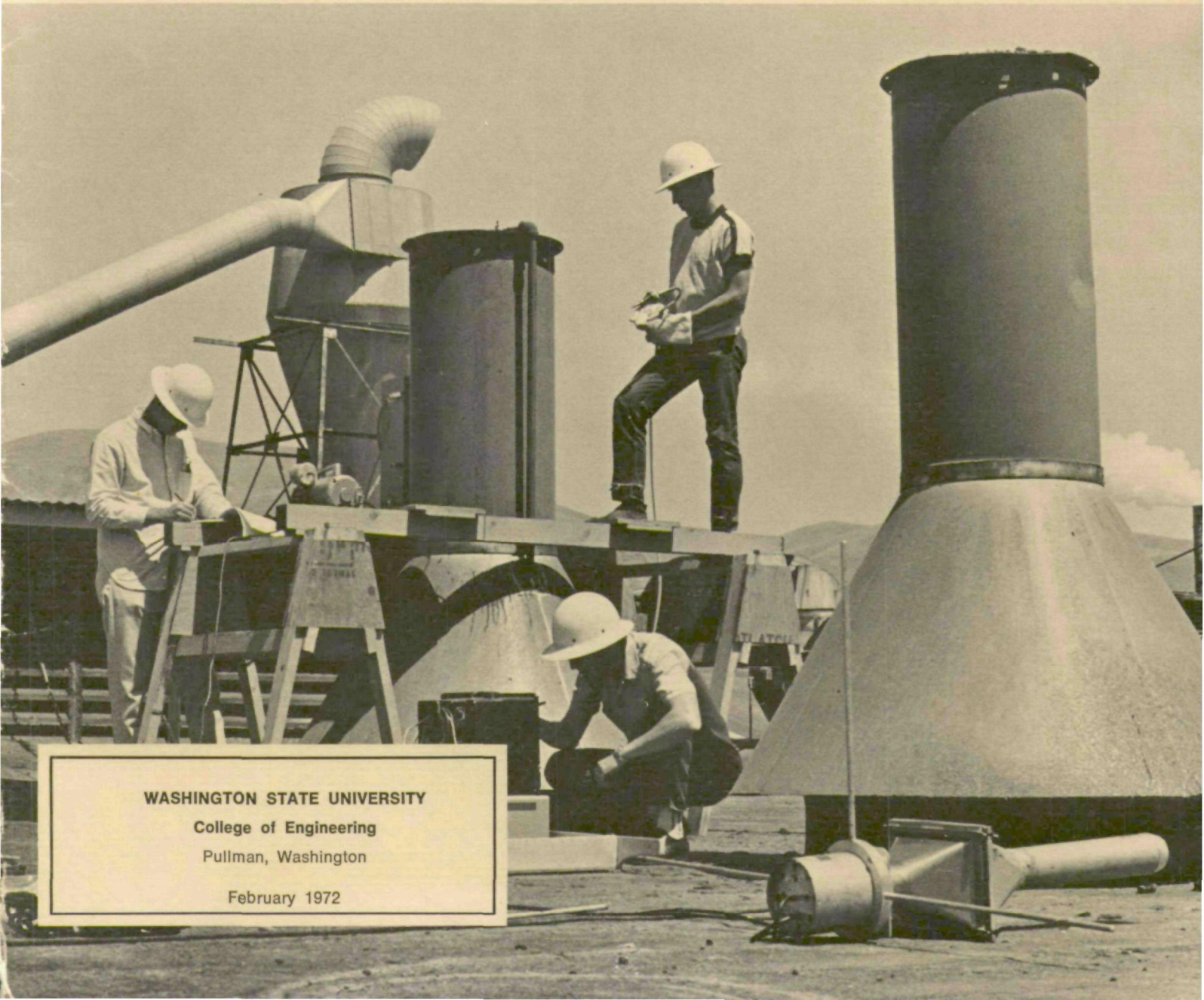
Revised Final Report

Prepared for

PLYWOOD RESEARCH FOUNDATION
7011 South 19th
Tacoma, Washington 98466

with matching support under Contract No. CPA-70-138

ENVIRONMENTAL PROTECTION AGENCY
Air Pollution Control Office
Durham, North Carolina 27701



WASHINGTON STATE UNIVERSITY
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INVESTIGATION OF EMISSIONS FROM PLYWOOD VENEER DRYERS

FINAL REPORT

SUMMARY

[Subsequent to the completion of the 13-mill study conducted under the joint sponsorship of the Plywood Research Foundation and the Environmental Protection Agency (contract CPA-70-138) questions were raised concerning the comparability or equivalence between (a) the condenser source sampling technique and the Rinco rotary evaporator analytical procedure used to develop the 13-mill veneer dryer condensable organic emission data herein reported, and (b) the Research Appliance Company "Staksamplr" and an organic solvent extraction analysis technique. Appendix B reports a series of studies of limited scope designed to delineate possible errors in the reported data for the 13-mill study and to indicate the possible range of correction factors which might be applied to these data to provide a more realistic measure of the rate of emission of condensable organic material from typical veneer dryers and wood species.]

Eight Pacific Northwest and five southern plywood veneer dryers were tested for emission rates and process variables. Gas- and steam-heated, longitudinal and jet dryers were studied drying ten wood species types. Wood particles in concentrations of less than 0.002 gr/ std dry ft^3 were the only significant particulate found at stack temperatures. The visible blue-haze plume consists of hydrocarbon materials that condense after the plume cools below stack temperature. Douglas fir and ponderosa pine produced the most visible plume. Some dryers have visible water plumes. Total hydrocarbon emissions from the stacks averaged 5.7 lbs/10,000 ft^2 of 3/8" plywood produced, of which 3.6 lbs represented the condensable fraction. These condensable hydrocarbons consisted largely of wood resins, resin acids and wood sugars. The other fraction, termed volatile hydrocarbons, consisted of terpenes only in steam-heated dryers, and terpenes and natural gas components in gas-fired dryers.

INVESTIGATION OF EMISSIONS FROM PLYWOOD VENEER DRYERS

FINAL REPORT

INTRODUCTION

The emissions from thirteen plywood dryers drying ten different specie types were studied: Douglas fir heart, Douglas fir sap, Douglas fir white speck, Englemann spruce, ponderosa pine, Western hemlock, Western larch, Western white pine, and southern pine. Four different types of dryers were included in the study: steam-heated longitudinal, gas-heated longitudinal, steam-heated jet, and a three-zone, steam-heated jet with a gas-heated first zone.

The objectives of this study included the determination of the physical and chemical nature of the emissions from these dryers during the drying of various veneer species under normal conditions of operation and the evaluation of process differences which might account for the observed differences in visual emissions. Determinations were made of the volatile and condensable hycrocarbon emissions in pounds per hour and pounds per 10,000 ft^2 of 3/8" plywood produced. Gas velocities, flow rates, and wet and dry bulb temperatures were measured concurrently. Most of the dryers were operated at about 360°F, but a wide variation in exhausted stack gas flow was observed. Visual observations of the equivalent opacity of the stack emissions were also made. Process and materials variables were documented to attempt to determine causes for the variations in hydrocarbon emissions.

EXPERIMENTAL METHODS

1. Gas Velocities and Flow Rates

   Stack gas velocities and flow rates were measured and calculated according to the Standardized Method of the Industrial Gas Cleaning Institute (IGCI). This procedure requires the measurement of barometric pressure, wet and dry bulb temperatures, O_2 and CO_2 percentage by volume, static and velocity pressure, and diameter of the stack. Barometric pressures were measured using an aneroid barometer at the site. The barometric readings were

compared with radio and television weather reports and then corrected to actual altitude to give actual barometric pressures for use in gas volume flow calculations.

The water content of the stack gas was determined by wet and dry bulb temperature measurements taken at the top of the stack with a mercury in glass thermometer. The bulb of the wet bulb thermometer was encased in a thin layer of cotton cloth and dampened with water, as required, forcing water through a Teflon tube.

O_2 and CO_2 percentages by volume were measured with a Bacharach Fyrite O_2-CO_2 analyzer.

Static and velocity pressures were obtained with an Ellison Inclined Draft gauge using a manometric fluid with a specific gravity of 0.834.

Stack sampling locations were determined using the method described in Western Precipitation Bulletin WP-50. Eight sampling points representing equal cross-sectional areas of the stacks were used in most cases. Sixteen sampling points were used in stacks with diameters in excess of 24 inches.

2. Quantitative Measurement of Hydrocarbons

a. Collection of Condensed Hydrocarbons

A sampling train was developed for the collection of the condensable fraction of the hydrocarbon emissions. The sampling probe for this system consisted of a glass tube with a fritted glass filter at the inlet end. The glass tube led from the stack into a glass condenser which was kept in an ice-water bath. The condenser was designed to provide a long contact time with the heat exchanger and a large reservoir for collecting the water. The condenser was cooled in an ice water bath to collect the portion of the hydrocarbons which for purposes of this study were termed "condensable" hydrocarbons. A vacuum pump, a rotameter, and a vacuum gauge completed the sampling train. Acetone was used to facilitate quantitative transfer of the sample into sample bottles in

the field. The sample bottles contained a mixture of wash acetone and condensed water and hydrocarbons. Sampling time, usually about 2 hours, varied from 27 minutes to 6 hours. Sufficient amounts of water condensed in the ice water bath that no further drying of the sample gas was necessary for proper operation of the THA.

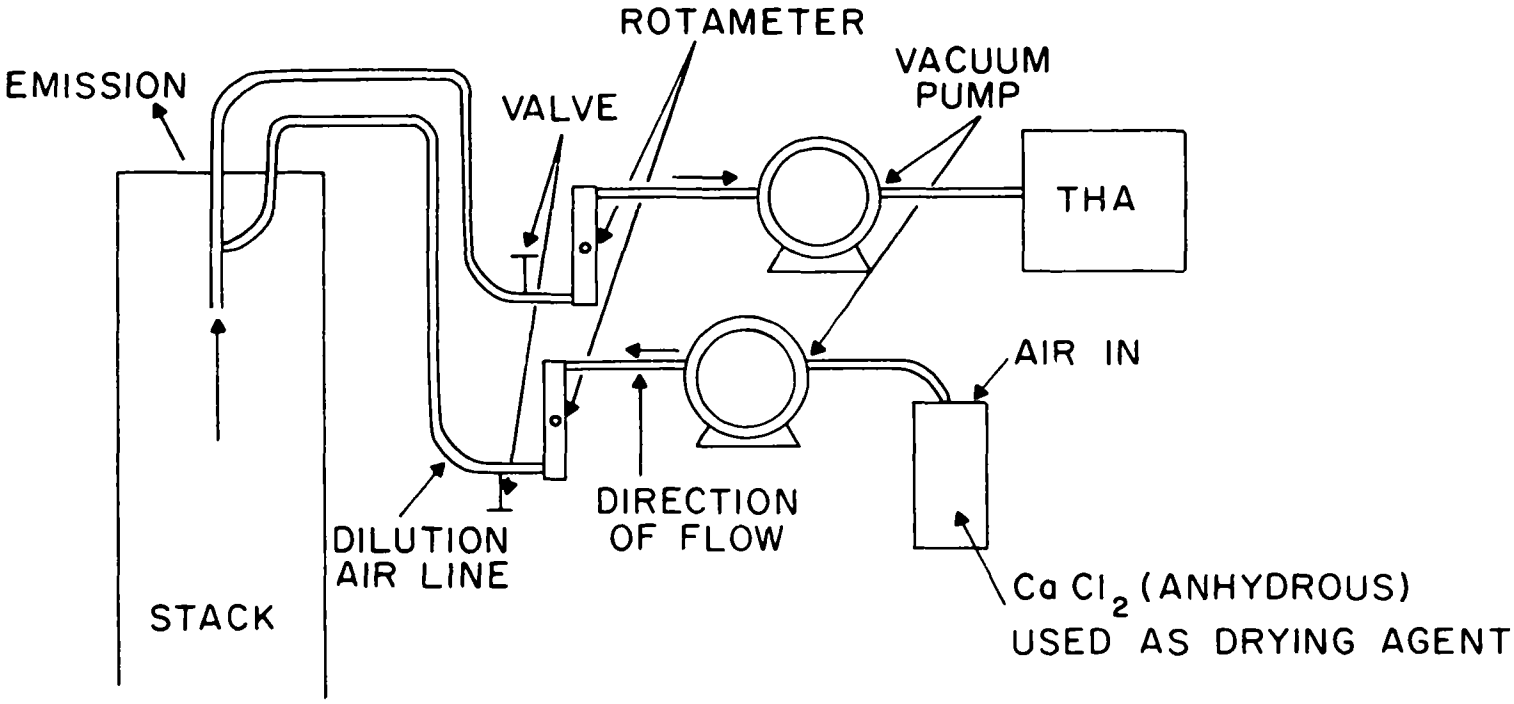
b. Volatile Hydrocarbons

(1) Dilution System

During the first phase of the study, a sample gas dilution system was used to deliver a sample of stack gas to the total hydrocarbon analyzer (THA) (see schematic). The use of this sampling system was discontinued in favor of the previously described condenser method because of the desirability of collecting the condensable hydrocarbon in a glassware condenser. With the dilution system, the condensable hydrocarbons appeared as varnish-like droplets along the sample line. The purpose of the sample gas dilution system configuration was primarily to prevent condensed water from interfering with the operation of the THA. Ambient air, used as a diluent, was dried by passing it through anhydrous calcium chloride. The dry air was then delivered to a tee connector in the stack where measured (with rotameters) volumes of dry air and stack gas were mixed. The volume of air required to dilute the stack gas below its dewpoint, after the gas is cooled to ambient temperature, was determined from the wet/dry bulb temperatures of the diluted gas. The ratio of dry air to stack gas in the sampling train was determined with two rotameters--the first measured the flow of dry air and the second measured the total flow of dry air plus sample gas. The flow of sample gas was determined from the difference in rotameter readings.

Diagram 1

SCHEMATIC OF DILUTION PROBE SAMPLING TRAIN USED EARLY IN PROJECT



The diluted and cooled sample gas was conducted from the mixing tee in the stack through a 6 ft x 3/16 in. O.D. Teflon^{R} tube to the sampling ports where samples were obtained for determination of volatile hydrocarbons, particle size distribution, and total hydrocarbons.

(2) Condensing System

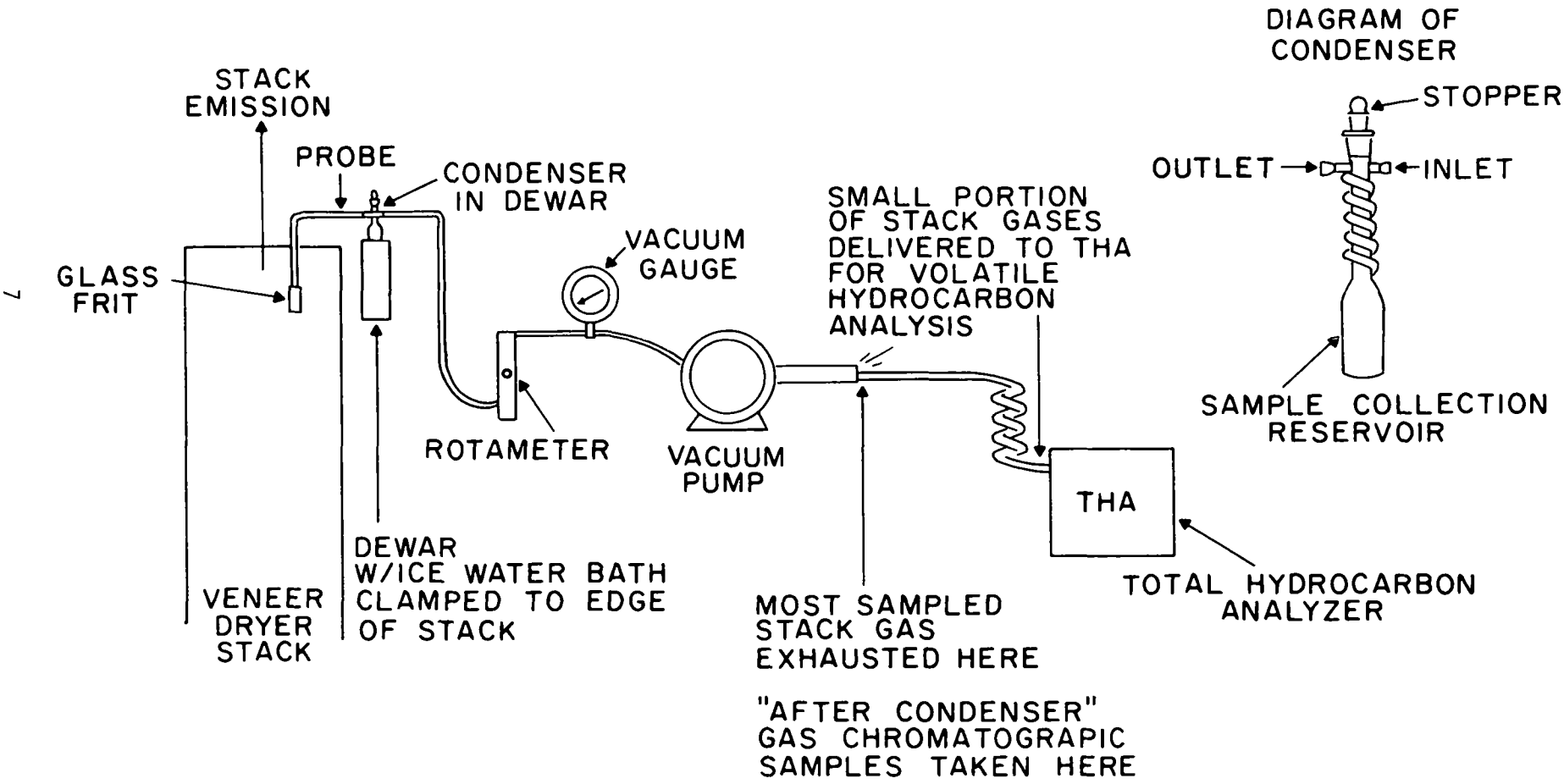
Later in the study the previously described condensing system was utilized instead of the dilution probe. A portion of the sampled stack gas, after the condensible hydrocarbons were removed, was fed to a Wilkins gas chromatograph equipped with a hydrogen flame ionization detector (FID) through the vacuum pump. This gas-chromatograph was operated without a column in a continuous mode as a total hydrocarbon analyzer. The THA was calibrated with hexane. A calibration gas cylinder containing 262 ppm hexane was also used in the field to determine THA response. The hydrocarbons that were not collected in the condenser went through the carbon-vane-vacuum pump and produced a response on the THA are termed "volatile" hydrocarbons. The output of the THA was continuously recorded with a Model H Leeds and Northrup strip chart recorder at a chart speed of 8 minutes per inch. Significant events relating to dryer operating conditions and stack sampling data were also noted on the chart. The items most frequently recorded included stack wet and dry bulb temperatures, times when gas chromatographic samples were taken and whether or not the dryer was operating.

c. Rinco Evaporating Apparatus

A Rinco evaporating apparatus was used to evaporate water and acetone from the condensed hydrocarbon samples. The rotating flask of the apparatus was maintained at 40°C $\pm$5° in a water bath heated with a electrical hot plate under 27-28"

Diagram 2

SCHEMATIC OF CONDENSER SAMPLING TRAIN FOR VENEER DRYER STUDY



Hg. vacuum pressure until the water and acetone had evaporated leaving a pitchy, resinous, varnish-like residue. The total weight was taken after a 3-hour stabilization period. This weight was used along with data from rotameter readings and sample times to determine the amount of condensed hydrocarbons emitted from the stack in units of pounds per hour, lb per 10,000 ft^2 of 3/8" plywood produced, and lb per 10,000 ft^2 of plywood per 1000 CFM exhausted from the dryer.

3. Qualitative Analyses of Major Hydrocarbon Components

a. Sampling Technique

(1) Volatile Hydrocarbons

All stack gas samples for analysis on the Carle 9000 gas chromatograph were taken in Pressure-lok^R gas-tight syringes. All samples were of 1 ml volume, except where otherwise noted. This small volume was used because (1) sufficient volatile hydrocarbon material was in the sample for optimum resolution on the low substrate level Carbowax column used in the study; (2) many samples could be injected into the GC before the accumulation of higher hydrocarbon components began to generate spurious signal noise; (3) the 1 ml sample did not need prepressurization for optimum resolution; and (4) the metal nose piece and front barrel ring of the Pressure-lok syringe remained hot until injection a few minutes after the sample was drawn from the stack. These metal parts of the syringe enclose much of the 1 ml volume in the syringe.

Samples drawn into the syringe were routinely taken by holding the syringe 4-6 inches below the rim of the stack. The syringe was held in the hot stack gases for a minute before drawing in the sample, using an asbestos glove to protect the hand. The syringe was flushed twice with the hot stack gas before closing the valve. The

syringe was immediately placed in the styrofoam insulated packing box for delivery to the GC in the trailer. Reproducible GC analyses of paired samples were obtained using this method.

(2) Condensed Hydrocarbons

Gas chromatographic, thin-layer chromatographic, and infrared spectroscopic techniques were utilized to determine the qualitative characteristics of the condensed material discussed in section 2c above.

(3) Headspace Analysis

The analysis of the volatile components in the air above and around an enclosed material is termed "headspace analysis." This technique was used to study different types of wood veneer placed in 500 ml flasks each fitted with a septum sampling port. Gas samples of 1 ml volume were taken through the septum-sealed sampling port and analyzed on the Carle 9000 gas chromatograph. The same conditions of analysis were used as described for the analysis of the stack gases. The concentration of the volatile monoterpenes from the enclosed veneers usually reached equilibrium with the air in 4 hours at room temperature.

(4) Cryocondenser

A new environmental sampler, with a unique concentration mechanism, has been developed at this laboratory to study qualitatively and quantitatively the different types of trace organics gases present in the atmosphere. This cryogenic sampler (cryocondenser) employs a multiple column heat exchanger to pump ambient air into the concentrator. The sampling rate of 2.2 l/min is controlled by a critical orifice with a repeatibility of $\pm$2%. The liquid air sample with its contaminants obtained in the

cryocondenser was distilled at -78°C (dry ice). A retention efficiency of 95% and higher for C_5 - C_{10} compounds is obtained using this procedure. Gas samples were taken from the valved sample port and analyzed by isothermal and programmed temperature gas chromatography. This equipment was used at several of the study sites to obtain enriched collections of C_1 through C_{10} compounds in the stack emissions.

(5) Carboy-Irradiation Studies

The photochemical reactivity of the volatile hydrocarbons (monoterpenes) in the veneer dryer emissions was determined using a simulated atmospheric irradiation reactor. An evacuated borosilicate glass carboy (5 gal) with a 30 inch 3/16" O.D. stainless steel tube was used to sample the stack emission. The ambient temperature of the sampling probe effectively removed the "blue haze" fraction of the emission by thermal deposition. The pressure of the final sample in the carboy was the same as the barometric pressure at the time of sampling. Gas chromatographic analyses of the stack emissions and the hydrocarbon fractions in the carboy were made at the time of sampling. These analyses established baseline data for determining the accuracy of the monoterpene composition in the carboy compared to the stack emission during the sampling period. These data also provided the time zero analyses for reference to the chemical changes that would occur in the simulated atmospheric irradiation of the carboy as well as a measure of any loss of the hydrocarbons in the carboy because of thermal deposition on the glass walls.

Access to the carboy is through two stainless steel fittings with septums and a stainless steel packless vacuum valve. Twelve "blacklight" (Sylvania F 15T8-BL)

fluorescent lamps (15 watts each) are mounted in a framework as a vertical cylinder large enough to contain one of the carboys. This irradiation system is an established method for studying the reactivity of hydrocarbons that participate in the formation of smog.

b. Analytical Techniques and Conditions

(1) Gas Chromatography of Volatile Hydrocarbons

The basic gas chromatographic (GC) conditions used in this study were established earlier during the laboratory studies of the different veneer wood types and veneer dryer gases obtained from the Potlatch Forests Industries, Inc., plant in St. Maries, Idaho. The conditions of those earlier studies were modified slightly for these field studies.

Instrument: Carle, model 9000 gas chromatograph, with dual columns, isothermal oven, and dual flame ionization detectors. Sensitivity of 1×10^{-11} AFS.

Columns: One 6-ft column, 1/8 in. O.D., #304, S.S., 4% Carbowax 20M on 60-80 mesh Chromosorb W HP (Supelco). One 3-ft column, 1/8 in. O.D., #304, S.S., Porapak Q, 80-100 mesh.

Mode of Operation: Isothermal at 72-76°C; signal noise from column bleed compensated for through the use of a Mofet dual channel electrometer. Gas pressures were He, 16 psi; H_2, 22 psi; and air, 21 psi. Signal output was recorded on a Hewlett Packard model 680 option 141, 5 in. recorder, at a chart speed of 1/2 in./min.

(2) Identification of Volatile Hydrocarbons

The identification of the monoterpene components was based on relative retention times. For greater accuracy the retention times were measured in millimeters (mm). This was necessary due to the very close elution times of the terpene hydrocarbons.

The following elution sequence was determined for the Carbowax column (74°C) used:

isoprene	(7 mm)	myrcene	(31 mm)
α pinene	(13 mm)	α terpinene	(34 mm)
camphene	(17 mm)	limonene	(39 mm)
β pinene	(22 mm)	β phellandrene	(41 mm)
Δ^3 carene	(29 mm)	γ terpinene	(53 mm)
		α terpinolene	(67 mm)

(3) Gas Chromatography of Condensed Hydrocarbons

Analyses of the varnish-like condensate residues resolubilized in acetone at concentrations of 1.2 - 2.8% were made on a Perkin Elmer model 990 programmed temperature, dual column, FID gas chromatograph. Diethylphthlate, odorless grade, was used as an internal standard to determine the percentage of the residue eluted from the SE 30 column. This instrument, with the appropriate column pair, has the capability of resolving components from -70°C to 400°C. After initial studies showed very small traces of α pinene, limonene, and α terpineol in the residues, analyses were restricted to those components eluted between 100 to 350°C.

Columns: Matched pair of 6 ft, 1/8 in. O.D., #304, S.S. tubing packed with 2% SE 30 GC grade on 60-80 mesh Chromosorb W HP. Helium flow was 35 ml/min.

(4) Thin-Layer Chromatography of Condensed Hydrocarbons

Thin-layer chromatographic (TLC) analysis of the residues from stack #1 and stack #2 at Dryer #2 were made on 10 x 20 cm glass slides coated with Silica Gel G, 250 microns thick. The residues were resolubilized in acetone at concentrations of 1.2% for stack #1 and 2.8% for stack #2. Twenty microliters were spotted on the plates and partitioned in three different single-phase

solvent systems. The three solvents selected from the eluotropic series were benzene (#4), chloroform (#6), and acetone (#9). The plates were developed by spraying with a 50% H_2SO_4 solution containing 5% $K_2Cr_2O_7$ and charred at 140°C.

(5) Infrared Analysis of Condensed Hydrocarbons

A Perkin Elmer model 621 infrared spectrophotometer was used to analyze the condensates. The infrared (IR) spectra were obtained from amorphous thin films of the residues on NaCl plates.

4. Particulates and Aerosols

In the early stages of the study, particulate sampling for total solid mass loading was accomplished with a Hi-Vol sampler modified to accept iso-kinetic nozzles. The Hi-Vol unit was positioned in the stack with its nozzle about two feet below the rim of the stack. Sampling at stack temperature was accomplished in this way. The hot stack gas passing over the Hi-Vol melted the motor's wire insulation, however, causing an electrical short after approximately an hour of use. To prevent further motor failures, the sampler was redesigned so that the motor was outside the stack.

Particulate matter was collected on two types of filter media -- a standard fiberglass filter and wire mesh. Difficulties were encountered with the use of the fiberglass filter because the light wood chips and splinters blew off the filter easily, making it difficult to obtain a valid sample. The wire screen support filter inside the apparatus was used separately because the visible deposit of the fiberglass filter was primarily wood fibers and splinters of a large size. The wire mesh had a grid of 30 wires per inch with square "pore" sizes of approximately 1/32 inches on a side. The fiberglass filters were tared following equilibration in a constant humidity chamber. They were allowed

to equilibrate after sampling in the chamber also. The use of the Hi-Vol sampler was discontinued because the wood particle emission was below 0.003 gr/std ft^3 of stack gas.

A Unico cascade impactor was used to sample aerosol in the stack gas for determination of particle size distribution. Samples were obtained from two different locations: (a) from the diluted stack gas in the sampling train and (b) from the blue-haze portion of the stack gas plume at one and three feet above the stack.

Aerosol samples were also taken by holding clean glass slides in the blue-haze portion of the stack plume for 30 seconds. The aerosols collected on the impactor plates were counted and sized by visual observation at 100 x magnification. An American Optical microscope equipped with a reticle with 100 squares, each seventy microns on a side, was used to make these measurements. The smallest particle size visible with the optical microscope in these conditions was about 1 micron in diameter.

Equivalent opacity readings were made of the plume throughout the sampling period. These data were a part of the data set as shown on Table #1, Sample Data form.

The shape of the condensing plume was mapped photographically using a dark-field strobe-light illumination technique with an ordinary electronic flash unit. The vertical, oblique, and horizontal cross-sections of the plume were illuminated in the dark by a flat light beam from a slitted mask placed over the face of the electronic flash gun. The shape of the developing plume was determined using this technique.

5. Veneer Dryer Operation

The operating conditions of the dryers were noted on the data sheets. The most frequently variable condition was drying time, that is, residence time of a sheet of veneer in the dryer. The drying time was measured with a stopwatch by determining the time required for a point on a sheet of veneer to travel

TABLE I
SAMPLE DATA FORM

Dryer code _____ (2,0) _____

Species code _____ (2,0) _____

Stack number _____ (2,0) _____

Date _____ (6,0) _____

Production _____ (8,1) _____

Emission _____ (3,0) _____

Barometric pressure ("Hg) _____ (4,2) _____

Static pressure ("Hg) _____ (4,2) _____

Water vapor pressure ("Hg) _____ (5,3) _____

Dry bulb temperature (^{o}F) _____ (3,0) _____

Wet bulb temperature (^{o}F) _____ (3,0) _____

Percent CO_2 (%) _____ (4,1) _____

Percent O_2 (%) _____ (4,1) _____

Duct temperature (^{o}F) _____ (3,0) _____

Velocity pressure in water gage (") :

Point Number	Velocity Pressure	$\sqrt{VP}$
A1		
A2		
A3		
A4		
B1		
B2		
B3		
B4		

Sum _____ Ave _____ (5,4) _____

Duct diameter (") _____ (5,3) _____

HC PPM _____ (5,0) _____

the distance of one section. On longitudinal dryers this distance, called section size, was usually 63 inches. On some dryers, however, it was 72 inches. On all jet dryers observed, this length was 72 inches. An allowance was made in the production and drying time calculations for the different section sizes.

Veneer moisture contents were determined by weighing selected sheets of veneer three times -- before being dried, after being dried, and after being dried a second time. The assumption was made that after the second pass through the dryer the water content of the veneer sheet would be 0% by weight. The validity of this assumption was spot checked occasionally and was found to be sufficiently accurate.

Other information regarding the dryers was recorded, such as number of stacks, zones, sections, decks, and drying temperature within the dryer.

6. Data Analysis

Fortran and PL-1 programs were developed for use on an IBM 360-67 computer to calculate many of the intermediate and final results contained in this report. An example of a program that produced intermediate results was one that used rotameter vacuum gauge readings, length of sample time, and barometric pressure readings to calculate the volume of stack gas sampled. Standard temperature was assumed since sampling was done at ambient temperature and an error of 5°F would only affect the results by a factor of 468/473 or about 1%.

An error analysis was performed using typical data sets for a longitudinal and a jet dryer. Each datum was decreased by its expected negative range of error and used to calculate a complete set of results. The percentage change in the results was then reported as a plus or minus percentage error. Single and multiple variable analyses were run. For example, a typical data set was taken from Table III. The estimated amount of error for each datum was subtracted from the complete

data set. The resulting data set was then calculated using the formulas in the appendix. The differences between the actual results and the results from the "reduced" data set was then reported as a percentage error of the actual results.

In addition, opacity readings were treated separately in two ways. Linear correlations were run between opacity and volatile, condensable, and total hydrocarbons on production basis only and on a production basis normalized for SCFM exhausted from a dryer. (See key in Appendix for species code and abbreviations.)

RESULTS

1. Gas Velocities and Flow Rates

A listing of stack analysis data is contained in Table III (15 pages), Individual Measurements for Computation of Emissions. Species codes are listed after the table.

Gas velocities and flow rates did not vary greatly within any stack on a day-to-day basis. However, there was a large variation between various stacks and between dryers. This variation depends upon the damper setting within the stack, which was controlled by the dryer tenders. The range of average air volumes from all stacks measured varied from a minimum of 171.8 SCFM to a maximum of 31,627 SCFM. The minimum and maximum occurred on different dryers drying southern pine.

Stacks which had a very high velocity emission had typically clean inside walls and low plume opacities. Those stacks with lower velocities generally had blue plumes developing at varying distances above the stacks. Those with the lowest velocities typically had a steam or water plume developing from the stack.

2. Quantitation of Volatile Hydrocarbons

Typical volatile hydrocarbon emissions on the THA ranged from 10 to 200 parts per million as hexane. Hemlock and white

TABLE II. DESCRIPTION OF DRYERS AND AVERAGES OF VENEER MOISTURE CONTENT.

DRYER CODE	TYPE	SECT	ZONE	DECK	NUM OF STKS	SECT SIZE IN.	DRYING TEMP F DEG	STACK WET END	TEMP DRY END	SPECIES	AVE PERCENT H2O (VENEER DRY BASIS) NUM	GREEN	DRY	DRYING TIME MIN
9	STEAM LONG	13	2	5	2	63	375.	316.	349.	D FIR SAP	6	45.05	0.39	11.2
12	STEAM LONG	14	2	5	2	63	350.	278.	329.	D FIR SAP	6	91.94	0.69	39.3
12	STEAM LONG	14	2	5	2	63	350.	283.	329.	SPRUCE	9	125.86	0.83	41.0
15	STEAM LONG	12	1	6	1	72	375.	0.	327.	D FIR HRT	6	38.08	3.05	6.6
15	STEAM LONG	12	1	6	1	72	375.	0.	330.	D FIR SAP	6	85.96	1.64	10.1
15	STEAM LONG	12	1	6	1	72	375.	0.	325.	P PINE	8	132.06	0.17	11.3
15	STEAM LONG	12	1	6	1	72	375.	0.	328.	LARCH	6	45.52	1.59	10.5
15	STEAM LONG	12	1	6	1	72	375.	0.	325.	W PINE	8	70.49	1.01	9.5
19	STEAM LONG	16	2	5	2	63	375.	317.	348.	D FIR HRT	4	36.02	4.48	5.5
19	STEAM LONG	16	2	5	2	63	375.	315.	348.	D FIR SAP	5	84.56	0.27	13.7
23	GAS LONG	12	1	4	3	72	375.	0.	273.	D FIR SAP	4	45.82	2.54	12.3
24	23 AT 300F	12	1	4	2	72	300.	0.	225.	D FIR SAP	0	0.0	0.0	13.0
25	23 AT 390F	12	1	4	2	72	390.	0.	277.	D FIR SAP	0	0.0	0.0	11.5
26	GAS LONG	8	1	4	3	72	375.	0.	281.	D FIR WSK	0	0.0	0.0	7.5
27	STEAM JET	11	3	4	3	72	375.	298.	351.	WHITE FIR	4	88.87	0.07	20.9
28	STEAM JET	10	3	4	3	72	360.	324.	360.	D FIR HRT	4	34.06	0.18	4.9
31	STEAM JET	17	6	4	6	72	365.	267.	334.	S PINE	13	82.87	1.79	9.8
32	MIXED JET	23	3	4	4	72	360.	314.	290.	S PINE	0	0.0	0.0	8.9
35	STEAM LONG	18	2	6	2	72	320.	256.	279.	S PINE	7	76.59	0.10	15.8
36	STEAM JET	20	5	4	5	72	330.	198.	316.	S PINE	14	108.53	0.13	12.7
37	STEAM LONG	21	2	6	2	72	320.	265.	292.	S PINE	9	121.08	0.72	20.2

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS

DRYER CODE*	SPECIE CODE**	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
9	1	1	70770	13230	40	30.09	311	137	0.0	21.5	0.4610	24
9	1	1	70870	13230	20	29.92	318	131	0.0	21.5	0.4721	24
9	1	2	70770	13230	40	30.09	330	138	0.0	21.5	0.0180	24
9	1	2	70870	13230	20	29.92	334	147	0.0	21.5	0.0237	24
9	2	1	70870	7216	10	29.95	309	142	0.0	21.5	0.4720	24
9	2	1	70970	7216	20	29.92	309	143	0.0	21.5	0.4738	24
9	2	1	101570	6750	40	30.08	308	143	0.0	21.5	0.4608	24
9	2	1	101570	6750	40	30.08	310	143	0.0	21.5	0.4608	24
9	2	1	101570	6750	40	30.08	316	148	0.0	21.5	0.4608	24
9	2	1	101570	6750	40	30.08	318	154	0.0	21.5	0.4608	24
9	2	1	101570	5476	60	30.08	320	162	0.0	21.5	0.1816	24
9	2	1	101570	5476	60	30.08	321	158	0.0	21.5	0.1816	24
9	2	1	101570	5476	60	30.08	321	156	0.0	21.5	0.1816	24
9	2	1	101570	5476	60	30.08	323	152	0.0	21.5	0.1816	24
9	2	2	70870	7216	10	29.95	326	145	0.0	21.5	0.0193	24
9	2	2	70970	7216	20	29.92	326	144	0.0	21.5	0.0180	24
9	2	2	101570	6750	80	30.08	352	153	0.0	21.5	0.1292	24
9	2	2	101570	6750	80	30.08	352	144	0.0	21.5	0.1292	24
9	2	2	101570	6750	100	30.08	357	150	0.0	21.5	0.0295	24
9	2	2	101570	6750	100	30.08	356	151	0.0	21.5	0.0295	24
9	2	2	101570	6750	100	30.08	352	155	0.0	21.5	0.0295	24
9	2	2	101570	6750	100	30.08	357	159	0.0	21.5	0.0295	24
9	2	2	101570	6750	100	30.08	360	146	0.0	21.5	0.0295	24
9	6	1	71070	5292	80	29.92	308	144	0.0	21.5	0.4753	24
9	6	2	71070	5292	80	29.92	340	137	0.0	21.5	0.0152	24
12	1	1	71470	9621	10	30.05	290	148	0.0	21.5	0.5055	18
12	1	1	71470	9621	10	30.05	272	149	0.0	21.5	0.2556	18
12	1	1	71470	9621	10	30.05	273	153	0.0	21.5	0.2556	18
12	1	1	71470	9621	10	30.05	275	140	0.0	21.5	0.2556	18
12	1	1	71470	9621	10	30.05	276	128	0.0	21.5	0.2556	18
12	1	1	71470	9621	10	30.05	276	145	0.0	21.5	0.2556	18
12	1	1	71470	9621	10	30.05	275	140	0.0	21.5	0.2556	18
12	1	1	71470	9621	10	30.05	290	148	0.0	21.5	0.2556	18

* See Table II
** See key, page 111

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H20	STK DIA IN.
12	1	1	71570	9621	10	29.90	292	146	0.0	21.5	0.4998	18
12	1	1	71570	9621	10	29.90	290	136	0.0	21.5	0.4998	18
12	1	1	71570	9621	10	29.90	278	140	0.0	21.5	0.4998	18
12	1	1	71570	9621	10	29.90	294	128	0.0	21.5	0.4998	18
12	1	1	71570	9621	10	29.90	300	135	0.0	21.5	0.4998	18
12	1	2	71470	9621	10	30.05	322	143	0.0	21.5	0.9139	18
12	1	2	71470	9621	10	30.05	324	138	0.0	21.5	0.9139	18
12	1	2	71470	9621	10	30.05	322	136	0.0	21.5	0.9139	18
12	1	2	71470	9621	10	30.05	322	145	0.0	21.5	0.9139	18
12	1	2	71470	9621	10	30.05	326	136	0.0	21.5	0.9139	18
12	1	2	71470	9621	10	30.05	340	124	0.0	21.5	0.9139	18
12	1	2	71470	9621	10	30.05	324	159	0.0	21.5	0.9139	18
12	1	2	71470	9621	10	30.05	320	131	0.0	21.5	0.9139	18
12	1	2	71470	9621	10	30.05	320	134	0.0	21.5	0.9139	18
12	1	2	71470	9621	10	30.05	322	143	0.0	21.5	0.9139	18
12	1	2	71570	9621	10	29.90	324	142	0.0	21.5	0.8649	18
12	1	2	71570	9621	10	29.90	324	133	0.0	21.5	0.8649	18
12	2	1	101370	2975	0	30.24	292	134	0.0	21.5	0.4558	18
12	2	1	101370	2975	0	30.24	285	134	0.0	21.5	0.4558	18
12	2	1	101370	3720	0	30.24	273	143	0.0	21.5	0.4558	18
12	2	1	101370	3720	0	30.24	269	135	0.0	21.5	0.4558	18
12	2	1	101370	3720	0	30.24	269	140	0.0	21.5	0.4558	18
12	2	1	101370	3570	0	30.24	279	136	0.0	21.5	0.4558	18
12	2	1	101370	3570	0	30.24	280	135	0.0	21.5	0.4558	18
12	2	1	101370	3570	0	30.24	280	136	0.0	21.5	0.4558	18
12	2	2	101370	2975	0	30.24	330	131	0.0	21.5	0.9912	18
12	2	2	101370	2975	0	30.24	330	131	0.0	21.5	0.9912	18
12	2	2	101370	3570	0	30.24	330	136	0.0	21.5	0.9912	18
12	2	2	101370	3570	0	30.24	329	135	0.0	21.5	0.9912	18
12	2	2	101370	3570	0	30.24	328	134	0.0	21.5	0.9912	18
12	2	2	101370	3720	0	30.24	325	136	0.0	21.5	0.9912	18
12	2	2	101370	3720	0	30.24	324	137	0.0	21.5	0.9912	18
12	2	2	101370	3570	0	30.24	331	134	0.0	21.5	0.9912	18

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HP 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
12	2	2	101370	3570	0	30.24	330	136	0.0	21.5	0.9912	18
12	11	1	71370	7441	0	30.16	284	134	0.0	21.5	0.5152	18
12	11	1	71570	2480	0	29.90	284	136	0.0	21.5	0.4998	18
12	11	2	71370	7441	0	30.16	324	140	0.0	21.5	0.9686	18
12	11	2	71570	2480	0	29.90	326	149	0.0	21.5	0.8649	18
12	29	1	101370	3550	0	30.24	293	131	0.0	21.5	0.4732	18
12	29	1	101370	3550	0	30.24	294	132	0.0	21.5	0.4732	18
12	29	1	101470	3825	0	30.12	280	139	0.0	21.5	0.4532	18
12	29	1	101470	3825	0	30.12	274	135	0.0	21.5	0.4532	18
12	29	1	101470	4040	0	30.12	275	134	0.0	21.5	0.4532	18
12	29	1	101470	4040	0	30.12	274	135	0.0	21.5	0.4532	18
12	29	1	101470	4040	0	30.12	284	136	0.0	21.5	0.4532	18
12	29	1	101470	4040	0	30.12	290	130	0.0	21.5	0.4532	18
12	29	1	101470	4040	0	30.12	286	135	0.0	21.5	0.4532	18
12	29	1	101470	4040	0	30.12	280	136	0.0	21.5	0.4532	18
12	29	1	101470	4040	0	30.12	280	134	0.0	21.5	0.4532	18
12	29	2	101370	3550	0	30.24	330	129	0.0	21.5	0.9872	18
12	29	2	101370	3550	0	30.24	330	129	0.0	21.5	0.9872	18
12	29	2	101470	3825	0	30.12	329	137	0.0	21.5	0.9176	18
12	29	2	101470	3825	0	30.12	324	133	0.0	21.5	0.9176	18
12	29	2	101470	4040	0	30.12	326	130	0.0	21.5	0.9176	18
12	29	2	101470	4040	0	30.12	327	133	0.0	21.5	0.9176	18
12	29	2	101470	4040	0	30.12	328	132	0.0	21.5	0.9176	18
12	29	2	101470	4040	0	30.12	332	135	0.0	21.5	0.9176	18
12	29	2	101470	4040	0	30.12	332	132	0.0	21.5	0.9176	18
12	29	2	101470	4040	0	30.12	332	131	0.0	21.5	0.9176	18
12	29	2	101470	4040	0	30.12	328	131	0.0	21.5	0.9176	18
15	1	1	100770	18650	80	29.11	326	147	0.0	21.5	0.0454	47
15	1	1	100770	18650	80	29.11	312	143	0.0	21.5	0.0454	47
15	1	1	100970	11970	70	28.77	330	145	0.0	21.5	0.0779	47
15	1	1	100970	11970	70	28.77	331	146	0.0	21.5	0.0779	47
15	1	1	100970	11970	70	28.77	331	145	0.0	21.5	0.0779	47
15	1	1	100970	11970	70	28.77	334	147	0.0	21.5	0.0779	47

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN.H2O	STK DIA IN.
15	2	1	100770	9860	15	29.11	329	145	0.0	21.5	0.0454	47
15	2	1	100770	9860	15	29.11	328	144	0.0	21.5	0.0454	47
15	2	1	100770	9860	15	29.11	332	144	0.0	21.5	0.0454	47
15	2	1	100870	8970	35	29.08	329	148	0.0	21.5	0.0454	47
15	2	1	100870	8970	35	29.08	328	146	0.0	21.5	0.0454	47
15	2	1	100870	8970	35	29.08	331	147	0.0	21.5	0.0454	47
15	2	1	100870	8970	35	29.08	330	148	0.0	21.5	0.0454	47
15	2	1	100870	8970	35	29.08	331	147	0.0	21.5	0.0454	47
15	2	1	100870	8970	35	29.08	332	146	0.0	21.5	0.0454	47
15	5	1	100970	8245	100	28.77	326	147	0.0	21.5	0.0779	47
15	5	1	100970	8245	100	28.77	320	151	0.0	21.5	0.0779	47
15	5	1	100970	8245	70	28.77	329	151	0.0	21.5	0.0779	47
15	5	1	100970	8245	70	28.77	328	151	0.0	21.5	0.0779	47
15	5	1	100970	8245	70	28.77	323	147	0.0	21.5	0.0779	47
15	6	1	100970	19100	80	28.77	322	130	0.0	21.5	0.2948	47
15	6	1	100970	19100	80	28.77	320	128	0.0	21.5	0.2948	47
15	8	1	100670	9060	10	28.94	315	144	0.0	21.5	0.0396	47
15	8	1	100670	9060	10	28.94	331	146	0.0	21.5	0.0396	47
15	8	1	100670	9060	10	28.94	330	151	0.0	21.5	0.0396	47
15	8	1	100670	9060	10	28.94	332	151	0.0	21.5	0.0396	47
15	8	1	100670	9060	10	28.94	328	149	0.0	21.5	0.0396	47
15	8	1	100670	9060	10	28.94	332	146	0.0	21.5	0.0396	47
15	13	1	100670	8130	25	28.94	325	152	0.0	21.5	0.0396	47
15	13	1	100670	8130	25	28.94	331	145	0.0	21.5	0.0396	47
15	13	1	100670	8130	25	28.94	334	146	0.0	21.5	0.0396	47
15	13	1	100670	8130	25	28.94	328	140	0.0	21.5	0.0396	47
15	13	1	100770	9500	0	29.11	325	144	0.0	21.5	0.0454	47
15	13	1	100770	9500	0	29.11	326	148	0.0	21.5	0.0454	47
15	13	1	100770	9500	0	29.11	328	145	0.0	21.5	0.0454	47
15	13	1	100870	9130	20	29.08	330	147	0.0	21.5	0.0454	47
15	13	1	100870	9130	20	29.08	329	143	0.0	21.5	0.1201	47
15	13	1	100870	9130	20	29.08	324	140	0.0	21.5	0.1201	47
15	13	1	100870	9130	20	29.08	328	144	0.0	21.5	0.1201	47

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIF CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
15	26	1	100770	9860	40	29.11	323	144	0.0	21.5	0.1942	47
15	26	1	100770	9860	40	29.11	328	147	0.0	21.5	0.1942	47
15	26	1	100770	9860	40	29.11	325	138	0.0	21.5	0.1942	47
15	26	1	100770	9860	40	29.11	322	137	0.0	21.5	0.1942	47
19	1	1	91670	17388	30	28.87	320	142	0.0	21.5	0.3946	24
19	1	1	91670	17388	30	28.87	317	139	0.0	21.5	0.3946	24
19	1	1	91670	17388	30	28.87	321	143	0.0	21.5	0.3946	24
19	1	1	91770	14958	0	28.80	312	137	0.0	21.5	0.3946	24
19	1	1	91770	14958	0	28.80	315	143	0.0	21.5	0.3946	24
19	1	1	91770	14958	0	28.80	325	123	0.0	21.5	0.3946	24
19	1	1	91770	14958	0	28.80	321	137	0.0	21.5	0.3946	24
19	1	1	91870	17010	30	28.76	319	139	0.0	21.5	0.3946	24
19	1	1	91870	17010	30	28.76	310	139	0.0	21.5	0.3946	24
19	1	1	91870	17010	30	28.76	311	139	0.0	21.5	0.3946	24
19	1	1	91870	17010	30	28.76	311	149	0.0	21.5	0.3946	24
19	1	2	91670	17388	30	28.87	341	146	0.0	21.5	0.3231	24
19	1	2	91670	17388	30	28.87	352	139	0.0	21.5	0.3231	24
19	1	2	91770	14958	25	28.80	349	128	0.0	21.5	0.3231	24
19	1	2	91770	14958	25	28.80	353	139	0.0	21.5	0.3231	24
19	1	2	91770	14958	25	28.80	356	131	0.0	21.5	0.3231	24
19	1	2	91870	17010	35	28.76	348	145	0.0	21.5	0.3231	24
19	1	2	91870	17010	35	28.76	340	145	0.0	21.5	0.3231	24
19	1	2	91870	17010	35	28.76	344	136	0.0	21.5	0.3231	24
19	1	2	91870	17010	35	28.76	351	144	0.0	21.5	0.3231	24
19	2	1	91670	6804	30	28.87	312	150	0.0	21.5	0.3904	24
19	2	1	91670	6804	30	28.87	310	132	0.0	21.5	0.3904	24
19	2	1	91670	6804	30	28.87	311	150	0.0	21.5	0.3904	24
19	2	1	91670	6804	30	28.87	310	148	0.0	21.5	0.3904	24
19	2	1	91770	6183	30	28.80	317	141	0.0	21.5	0.3904	24
19	2	1	91770	6183	30	28.80	314	144	0.0	21.5	0.3904	24
19	2	1	91770	6183	30	28.80	331	128	0.0	21.5	0.3904	24
19	2	1	91770	6183	30	28.80	311	146	0.0	21.5	0.3904	24
19	2	1	91870	6939	0	28.76	315	147	0.0	21.5	0.3114	24

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HP 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
19	2	1	91870	6939	0	28.76	312	147	0.0	21.5	0.3114	24
19	2	1	91870	6939	0	28.76	317	143	0.0	21.5	0.3114	24
19	2	2	91670	6804	30	28.87	352	134	0.0	21.5	0.3175	24
19	2	2	91670	6804	30	28.87	340	149	0.0	21.5	0.3175	24
19	2	2	91670	6804	30	28.87	348	144	0.0	21.5	0.3175	24
19	2	2	91670	6804	30	28.87	354	142	0.0	21.5	0.3175	24
19	2	2	91770	6183	30	28.80	346	142	0.0	21.5	0.3175	24
19	2	2	91770	6183	30	28.80	346	149	0.0	21.5	0.3175	24
19	2	2	91770	6183	30	28.80	354	140	0.0	21.5	0.3175	24
19	2	2	91870	6939	0	28.76	347	148	0.0	21.5	0.3108	24
19	2	2	91870	6939	0	28.76	346	143	0.0	21.5	0.3108	24
19	2	2	91870	6939	0	28.76	344	136	0.0	21.5	0.3108	24
23	2	1	91970	5400	15	28.72	265	140	0.9	19.0	0.5715	18
23	2	1	91970	5400	15	28.72	274	138	0.9	19.0	0.5715	18
23	2	1	91970	5400	15	28.72	262	137	0.9	19.0	0.5715	18
23	2	1	91970	5400	15	28.72	262	137	0.9	19.0	0.5715	18
23	2	1	91970	5400	15	28.72	256	139	0.9	19.0	0.5715	18
23	2	1	92070	3833	30	28.82	256	139	0.5	21.0	0.4485	18
23	2	1	92070	5192	30	28.82	270	135	0.5	21.0	0.4412	18
23	2	1	92070	5192	30	28.82	272	139	0.5	21.0	0.4412	18
23	2	1	92270	4775	0	28.78	254	141	0.5	21.0	0.5149	18
23	2	1	92270	4775	0	28.78	247	140	0.5	21.0	0.5149	18
23	2	1	92270	4775	0	28.78	254	143	0.5	21.0	0.5149	18
23	2	2	91970	5400	20	28.72	281	143	1.0	19.0	0.3279	18
23	2	2	91970	5400	20	28.72	279	139	1.0	19.0	0.3279	18
23	2	2	91970	5400	20	28.72	271	139	1.0	19.0	0.3279	18
23	2	2	91970	5400	20	28.72	270	139	1.0	19.0	0.3279	18
23	2	2	91970	5400	20	28.72	262	141	1.0	19.0	0.3279	18
23	2	2	92070	3833	30	28.82	262	141	0.5	21.0	0.6284	18
23	2	2	92070	5192	30	28.82	279	137	0.5	21.0	0.3441	18
23	2	2	92070	5192	30	28.82	274	139	0.5	21.0	0.3441	18
23	2	2	92270	4775	0	28.78	260	143	0.5	21.0	0.3495	18
23	2	2	92270	4775	0	28.78	252	141	0.5	21.0	0.3495	18

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
23	2	2	92270	4775	0	28.78	264	145	0.5	21.0	0.3495	18
23	2	3	91970	5400	10	28.72	195	107	0.0	21.0	0.1468	23
23	2	3	91970	5400	10	28.72	199	102	0.0	21.0	0.1468	23
23	2	3	91970	5400	10	28.72	201	102	0.0	21.0	0.1468	23
23	2	3	91970	5400	10	28.72	205	108	0.0	21.0	0.1468	23
23	2	3	91970	5400	10	28.72	190	103	0.0	21.0	0.1468	23
23	2	3	92070	3933	25	28.82	202	112	0.5	21.0	0.1275	23
23	2	3	92070	5192	25	28.82	208	111	0.0	21.5	0.1275	23
23	2	3	92270	4775	0	28.78	210	111	0.0	21.5	0.1468	23
23	2	3	92270	4775	0	28.78	210	113	0.0	21.5	0.1468	23
24	2	1	92270	4775	0	28.78	216	132	0.5	21.0	0.5149	18
24	2	1	92270	4775	0	28.78	219	128	0.5	21.0	0.5149	18
24	2	1	92270	4775	0	28.78	221	130	0.5	21.0	0.5149	18
24	2	2	92270	4775	0	28.78	225	141	0.5	21.0	0.3495	18
24	2	2	92270	4775	0	28.78	224	129	0.5	21.0	0.3495	18
24	2	2	92270	4775	0	28.78	225	132	0.5	21.0	0.3495	18
24	2	3	92270	4775	0	28.78	161	99	0.0	21.5	0.1468	23
24	2	3	92270	4775	0	28.78	167	100	0.0	21.5	0.1468	23
24	2	3	92270	4775	0	28.78	178	105	0.0	21.5	0.1468	23
25	2	1	92170	5432	0	28.96	268	139	1.4	17.6	0.4453	18
25	2	1	92170	5432	0	28.96	278	141	1.4	17.6	0.4453	18
25	2	1	92170	5432	0	28.96	272	143	1.4	17.6	0.4453	18
25	2	1	92170	5432	0	28.96	256	141	1.4	17.6	0.4453	18
25	2	1	92170	5432	0	28.96	256	140	1.4	17.6	0.4453	18
25	2	2	92170	5432	0	28.96	279	143	1.1	18.0	0.3530	18
25	2	2	92170	5432	0	28.96	289	145	1.1	18.0	0.3530	18
25	2	2	92170	5432	0	28.96	282	146	1.1	18.0	0.3530	18
25	2	2	92170	5432	0	28.96	267	143	1.1	18.0	0.3530	18
25	2	2	92170	5432	0	28.96	267	141	1.1	18.0	0.3530	18
25	2	3	92170	5432	0	28.96	202	111	0.0	21.5	0.1468	23
25	2	3	92170	5432	0	28.96	220	112	0.0	21.5	0.1468	23
25	2	3	92170	5432	0	28.96	207	112	0.0	21.5	0.1468	23
25	2	3	92170	5432	0	28.96	210	112	0.0	21.5	0.1468	23

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
25	2	3	92170	5432	0	28.96	216	112	0.0	21.5	0.1468	23
26	1	1	91970	5184	0	28.72	264	128	1.2	20.0	0.7081	22
26	1	1	91970	5184	0	28.72	276	129	1.2	20.0	0.7081	22
26	1	1	91970	5184	0	28.72	287	128	1.2	20.0	0.7081	22
26	1	1	91970	5184	0	28.72	284	129	1.2	20.0	0.7081	22
26	1	1	91970	5184	0	28.72	289	136	1.2	20.0	0.7081	22
26	1	1	92170	5791	0	28.96	315	122	0.5	21.0	0.3744	22
26	1	1	92170	5791	0	28.96	311	128	0.5	21.0	0.3744	22
26	1	1	92170	5791	0	28.96	261	136	0.5	21.0	0.3744	22
26	1	1	92170	5791	0	28.96	273	130	0.5	21.0	0.3744	22
26	1	1	92170	5791	0	28.96	292	137	0.5	21.0	0.3744	22
26	1	1	92170	6185	0	28.96	294	141	0.5	21.0	0.3744	22
26	1	1	92170	6185	0	28.96	286	140	0.5	21.0	0.3744	22
26	1	1	92170	6185	0	28.96	277	141	0.5	21.0	0.3744	22
26	1	1	92170	6185	0	28.96	276	130	0.5	21.0	0.3744	22
26	1	1	92270	5497	0	28.78	241	124	1.5	20.0	0.3744	22
26	1	1	92270	5497	0	28.78	281	130	1.5	20.0	0.3744	22
26	1	1	92270	5497	0	28.78	295	142	1.5	20.0	0.3744	22
26	1	1	92270	5497	0	28.78	281	138	1.5	20.0	0.3744	22
26	1	1	92270	5497	0	28.78	251	128	1.5	20.0	0.3744	22
26	1	2	92170	5791	10	28.96	218	108	0.0	21.5	0.0916	19
26	1	2	92170	5791	10	28.96	220	113	0.0	21.5	0.0916	19
26	1	2	92170	5791	10	28.96	222	112	0.0	21.5	0.0916	19
26	1	2	92170	5791	10	28.96	210	126	0.0	21.5	0.0916	19
26	1	2	92170	5791	10	28.96	220	132	0.0	21.5	0.0916	19
26	1	2	92170	5791	10	28.96	210	110	0.0	21.5	0.0916	19
26	1	2	92270	5497	0	28.78	214	114	0.0	21.5	0.0916	19
26	1	2	92270	5497	0	28.78	271	133	0.0	21.5	0.0916	19
26	1	2	92270	5497	0	28.78	195	116	0.0	21.5	0.0916	19
26	1	2	92270	5497	0	28.78	213	120	0.0	21.5	0.0916	19
26	1	3	92170	5791	10	28.96	211	107	0.0	21.5	0.1150	19
26	1	3	92170	5791	10	28.96	205	104	0.0	21.5	0.1150	19
26	1	3	92170	5791	10	28.96	224	116	0.0	21.5	0.1150	19

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
26	1	3	92270	5497	0	28.78	225	115	0.0	21.5	0.1150	19
26	1	3	92270	5497	0	28.78	274	130	0.0	21.5	0.1150	19
26	1	3	92270	5497	0	28.78	215	113	0.0	21.5	0.1150	19
26	1	3	92270	5497	0	28.78	225	123	0.0	21.5	0.1150	19
26	1	3	92270	5497	0	28.78	275	131	0.0	21.5	0.1150	19
26	1	3	92270	5497	0	28.78	255	130	0.0	21.5	0.1150	19
26	3	1	92070	5037	0	28.82	284	129	0.5	21.0	0.4586	22
26	3	1	92070	5037	0	28.82	285	134	0.5	21.0	0.4586	22
26	3	1	92070	5037	0	28.82	290	131	0.5	21.0	0.4586	22
26	3	1	92070	5037	0	28.82	285	128	0.5	21.0	0.4586	22
26	3	2	92070	5037	10	28.82	212	108	0.0	21.5	0.0916	19
26	3	3	92070	5037	10	28.82	209	108	0.0	21.5	0.1150	19
27	2	1	82670	8670	20	29.96	300	159	0.0	21.5	0.0361	18
27	2	2	82670	8760	25	29.96	300	164	0.0	21.5	0.0174	18
27	2	3	82670	8760	40	29.96	340	165	0.0	21.5	0.0635	18
27	11	1	82770	6570	20	29.94	292	161	0.0	21.5	0.0299	18
27	11	1	82770	5910	0	29.94	296	162	0.0	21.5	0.0353	18
27	11	1	82870	6150	0	29.92	307	158	0.0	21.5	0.0328	18
27	11	1	82870	6240	0	29.92	297	163	0.0	21.5	0.0328	18
27	11	2	82770	6570	40	29.94	309	163	0.0	21.5	0.0110	18
27	11	2	82770	5910	0	29.94	302	168	0.0	21.5	0.0151	18
27	11	2	82870	6150	0	29.92	309	166	0.0	21.5	0.0135	18
27	11	2	82870	6240	0	29.92	300	167	0.0	21.5	0.0064	18
27	11	3	82770	6570	40	29.94	355	159	0.0	21.5	0.0600	18
27	11	3	82770	5910	0	29.94	351	158	0.0	21.5	0.0676	18
27	11	3	82870	6150	0	29.92	351	159	0.0	21.5	0.0605	18
27	11	3	82870	6240	0	29.92	345	164	0.0	21.5	0.0471	18
28	1	1	83170	10200	20	29.90	325	174	0.0	21.5	0.0458	19
28	1	1	83170	10200	20	29.90	331	190	0.0	21.5	0.0458	19
28	1	1	83170	10200	20	29.90	295	185	0.0	21.5	0.0458	19
28	1	1	83170	10200	20	29.90	333	174	0.0	21.5	0.0458	19
28	1	1	90170	10800	40	29.98	332	170	0.0	21.5	0.0510	19
28	1	1	90170	10800	40	29.98	330	189	0.0	21.5	0.0510	19

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
28	1	1	90170	10800	40	29.98	324	178	0.0	21.5	0.0510	19
28	1	2	83170	10200	60	29.90	354	177	0.0	21.5	0.0433	19
28	1	2	83170	10200	60	29.90	340	190	0.0	21.5	0.0433	19
28	1	2	83170	10200	60	29.90	337	190	0.0	21.5	0.0433	19
28	1	2	83170	10200	60	29.90	351	177	0.0	21.5	0.0433	19
28	1	2	90170	10800	100	29.98	340	190	0.0	21.5	0.0435	19
28	1	2	90170	10800	100	29.98	337	184	0.0	21.5	0.0435	19
28	1	2	90170	10800	100	29.98	342	192	0.0	21.5	0.0435	19
28	1	2	90170	10800	100	29.98	351	179	0.0	21.5	0.0435	19
28	1	3	83170	10200	40	29.90	368	154	0.0	21.5	0.0538	19
28	1	3	83170	10200	40	29.90	360	178	0.0	21.5	0.0538	19
28	1	3	83170	10200	40	29.90	352	179	0.0	21.5	0.0538	19
28	1	3	83170	10200	40	29.90	364	168	0.0	21.5	0.0538	19
28	1	3	83170	10200	40	29.90	352	171	0.0	21.5	0.0538	19
28	1	3	90170	10800	100	29.98	358	171	0.0	21.5	0.0427	19
28	1	3	90170	10800	100	29.98	365	150	0.0	21.5	0.0427	19
28	1	3	90170	10800	100	29.98	359	168	0.0	21.5	0.0427	19
28	1	3	90170	10800	100	29.98	366	163	0.0	21.5	0.0427	19
28	2	1	82870	6020	40	29.92	323	191	0.0	21.5	0.0686	19
28	2	1	83070	6480	40	29.78	336	173	0.0	21.5	0.0527	19
28	2	1	83070	6480	40	29.78	332	175	0.0	21.5	0.0527	19
28	2	1	83070	6480	40	29.78	338	172	0.0	21.5	0.0527	19
28	2	1	83070	6480	30	29.78	322	182	0.0	21.5	0.0543	19
28	2	1	83070	6480	30	29.78	329	182	0.0	21.5	0.0543	19
28	2	1	83070	6480	30	29.78	326	176	0.0	21.5	0.0543	19
28	2	1	83070	6480	30	29.78	324	173	0.0	21.5	0.0543	19
28	2	1	90170	6480	30	29.98	326	186	0.0	21.5	0.0538	19
28	2	1	90170	6480	30	29.98	318	191	0.0	21.5	0.0538	19
28	2	1	90170	6480	30	29.98	316	178	0.0	21.5	0.0538	19
28	2	2	82870	6020	80	29.92	320	188	0.0	21.5	0.0239	19
28	2	2	83070	6480	80	29.78	361	178	0.0	21.5	0.0497	19
28	2	2	83070	6480	80	29.78	358	175	0.0	21.5	0.0497	19
28	2	2	83070	6480	80	29.78	364	170	0.0	21.5	0.0497	19

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
28	2	2	83070	6480	60	29.78	346	180	0.0	21.5	0.0468	19
28	2	2	83070	6480	60	29.78	342	181	0.0	21.5	0.0468	19
28	2	2	83070	6480	60	29.78	338	180	0.0	21.5	0.0468	19
28	2	2	83070	6480	60	29.78	344	174	0.0	21.5	0.0468	19
28	2	2	90170	6480	80	29.98	350	186	0.0	21.5	0.0435	19
28	2	2	90170	6480	80	29.98	342	192	0.0	21.5	0.0435	19
28	2	2	90170	6480	80	29.98	344	178	0.0	21.5	0.0435	19
28	2	3	82870	6020	80	29.92	353	154	0.0	21.5	0.0269	19
28	2	3	83070	6480	80	29.78	370	171	0.0	21.5	0.0449	19
28	2	3	83070	6480	80	29.78	366	164	0.0	21.5	0.0449	19
28	2	3	83070	6480	80	29.78	368	149	0.0	21.5	0.0449	19
28	2	3	83070	6480	80	29.78	369	158	0.0	21.5	0.0449	19
28	2	3	83070	6480	60	29.78	356	164	0.0	21.5	0.0506	19
28	2	3	83070	6480	60	29.78	354	160	0.0	21.5	0.0506	19
28	2	3	83070	6480	60	29.78	352	172	0.0	21.5	0.0506	19
28	2	3	83070	6480	60	29.78	349	160	0.0	21.5	0.0506	19
28	2	3	90170	6480	80	29.98	357	175	0.0	21.5	0.0427	19
28	2	3	90170	6480	80	29.98	348	176	0.0	21.5	0.0427	19
28	2	3	90170	6480	80	29.98	359	172	0.0	21.5	0.0427	19
31	17	1	102870	9070	0	29.94	234	133	0.0	21.5	0.0039	17
31	17	1	102870	9070	0	29.94	244	130	0.0	21.5	0.0039	17
31	17	1	102870	9070	0	29.94	224	136	0.0	21.5	0.0039	17
31	17	1	102870	9070	0	29.94	237	138	0.0	21.5	0.0039	17
31	17	1	102970	8740	0	30.00	237	139	0.0	21.5	0.0030	17
31	17	1	102970	8740	0	30.00	231	138	0.0	21.5	0.0030	17
31	17	1	102970	8740	0	30.00	247	138	0.0	21.5	0.0030	17
31	17	1	102970	8740	0	30.00	242	138	0.0	21.5	0.0030	17
31	17	1	103070	9400	0	30.00	243	135	0.0	21.5	0.0030	17
31	17	1	103070	9400	0	30.00	241	140	0.0	21.5	0.0030	17
31	17	2	102870	9070	10	29.94	257	162	0.0	21.5	0.0058	17
31	17	2	102870	9070	10	29.94	270	154	0.0	21.5	0.0058	17
31	17	2	102870	9070	10	29.94	250	158	0.0	21.5	0.0058	17
31	17	2	102870	9070	10	29.94	264	159	0.0	21.5	0.0058	17

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
31	17	2	102970	8740	10	30.00	271	160	0.0	21.5	0.0020	17
31	17	2	102970	8740	10	30.00	270	158	0.0	21.5	0.0020	17
31	17	2	102970	8740	10	30.00	274	162	0.0	21.5	0.0020	17
31	17	2	102970	8740	10	30.00	274	163	0.0	21.5	0.0020	17
31	17	2	103070	9400	10	30.00	271	165	0.0	21.5	0.0020	17
31	17	2	103070	9400	10	30.00	271	162	0.0	21.5	0.0020	17
31	17	3	102870	9070	10	29.94	301	170	0.0	21.5	0.0146	17
31	17	3	102870	9070	10	29.94	302	161	0.0	21.5	0.0146	17
31	17	3	102870	9070	10	29.94	290	172	0.0	21.5	0.0146	17
31	17	3	102870	9070	10	29.94	290	168	0.0	21.5	0.0146	17
31	17	3	102970	8740	10	30.00	294	171	0.0	21.5	0.0159	17
31	17	3	102970	8740	10	30.00	290	168	0.0	21.5	0.0159	17
31	17	3	102970	8740	10	30.00	293	168	0.0	21.5	0.0159	17
31	17	3	102970	8740	10	30.00	293	171	0.0	21.5	0.0159	17
31	17	3	103070	9400	10	30.00	290	172	0.0	21.5	0.0159	17
31	17	3	103070	9400	10	30.00	305	160	0.0	21.5	0.0159	17
31	17	4	102870	9070	15	29.94	301	168	0.0	21.5	0.0139	17
31	17	4	102870	9070	15	29.94	302	164	0.0	21.5	0.0139	17
31	17	4	102870	9070	15	29.94	295	169	0.0	21.5	0.0139	17
31	17	4	102870	9070	15	29.94	293	171	0.0	21.5	0.0139	17
31	17	4	102970	8740	15	30.00	295	172	0.0	21.5	0.0122	17
31	17	4	102970	8740	15	30.00	293	166	0.0	21.5	0.0122	17
31	17	4	102970	8740	15	30.00	295	164	0.0	21.5	0.0122	17
31	17	4	102970	8740	15	30.00	290	169	0.0	21.5	0.0122	17
31	17	4	103070	9400	15	30.00	291	169	0.0	21.5	0.0122	17
31	17	4	103070	9400	15	30.00	302	163	0.0	21.5	0.0122	17
31	17	5	102870	9070	20	29.94	326	160	0.0	21.5	0.1249	24
31	17	5	102870	9070	20	29.94	328	168	0.0	21.5	0.1249	24
31	17	5	102870	9070	20	29.94	318	171	0.0	21.5	0.1249	24
31	17	5	102870	9070	20	29.94	319	165	0.0	21.5	0.1249	24
31	17	5	102970	8740	30	30.00	321	166	0.0	21.5	0.0543	24
31	17	5	102970	8740	30	30.00	329	163	0.0	21.5	0.0543	24
31	17	5	102970	8740	30	30.00	328	166	0.0	21.5	0.0543	24

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN.H2O	STK DIA IN.
31	17	5	102970	8740	30	30.00	324	168	0.0	21.5	0.0543	24
31	17	5	103070	9400	30	30.00	318	171	0.0	21.5	0.0543	24
31	17	5	103070	9400	30	30.00	330	164	0.0	21.5	0.0543	24
31	17	6	102870	9070	20	29.94	340	154	0.0	21.5	0.1614	24
31	17	6	102870	9070	20	29.94	342	156	0.0	21.5	0.1614	24
31	17	6	102870	9070	20	29.94	328	152	0.0	21.5	0.1614	24
31	17	6	102870	9070	20	29.94	329	150	0.0	21.5	0.1614	24
31	17	6	102970	8740	30	30.00	332	156	0.0	21.5	0.1579	24
31	17	6	102970	8740	30	30.00	337	148	0.0	21.5	0.1579	24
31	17	6	102970	8740	30	30.00	335	139	0.0	21.5	0.1579	24
31	17	6	102970	8740	30	30.00	331	151	0.0	21.5	0.1579	24
31	17	6	103070	9400	30	30.00	331	142	0.0	21.5	0.1579	24
31	17	6	103070	9400	30	30.00	339	146	0.0	21.5	0.1579	24
32	17	1	103070	13400	0	30.00	320	186	5.7	15.8	0.0206	23
32	17	1	103070	13400	0	30.00	316	178	5.7	15.8	0.0206	23
32	17	1	103070	13400	0	30.00	306	186	5.7	15.8	0.0206	23
32	17	2	103070	13400	20	30.00	317	197	3.4	18.1	0.0267	23
32	17	2	103070	13400	20	30.00	323	191	3.4	18.1	0.0267	23
32	17	2	103070	13400	20	30.00	314	200	3.4	18.1	0.0267	23
32	17	3	103070	13400	30	30.00	285	194	1.1	20.4	0.0253	23
32	17	3	103070	13400	30	30.00	293	184	1.1	20.4	0.0253	23
32	17	3	103070	13400	30	30.00	293	191	1.1	20.4	0.0253	23
32	17	4	103070	13400	10	30.00	151	127	0.0	21.5	0.3842	23
32	17	4	103070	13400	10	30.00	141	114	0.0	21.5	0.3842	23
32	17	4	103070	13400	10	30.00	140	119	0.0	21.5	0.3842	23
35	17	1	110270	8900	0	29.74	257	131	0.0	21.5	0.5975	49
35	17	1	110270	8900	0	29.74	257	130	0.0	21.5	0.5975	49
35	17	1	110270	8900	0	29.74	255	130	0.0	21.5	0.5975	49
35	17	1	110270	8900	0	29.74	252	130	0.0	21.5	0.5975	49
35	17	1	110370	8700	0	29.74	256	130	0.0	21.5	0.5975	49
35	17	1	110370	8700	0	29.74	258	130	0.0	21.5	0.5975	49
35	17	2	110270	8900	0	29.74	281	126	0.0	21.5	0.0846	49
35	17	2	110270	8900	0	29.74	285	124	0.0	21.5	0.0846	49

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
35	17	2	110270	8900	0	29.74	279	124	0.0	21.5	0.0846	49
35	17	2	110270	8900	0	29.74	275	126	0.0	21.5	0.0846	49
35	17	2	110370	8700	0	29.74	277	124	0.0	21.5	0.0846	49
35	17	2	110370	8700	0	29.74	277	124	0.0	21.5	0.0846	49
36	17	1	110470	6670	0	29.76	189	167	0.0	21.5	0.0023	24
36	17	1	110470	6670	0	29.76	191	167	0.0	21.5	0.0023	24
36	17	1	110470	9720	0	29.76	208	170	0.0	21.5	0.0023	24
36	17	1	110470	9720	0	29.76	202	168	0.0	21.5	0.0023	24
36	17	2	110470	6670	0	29.76	198	185	0.0	21.5	0.0011	24
36	17	2	110470	6670	0	29.76	209	181	0.0	21.5	0.0011	24
36	17	2	110470	9720	0	29.76	213	185	0.0	21.5	0.0011	24
36	17	2	110470	9720	0	29.76	210	181	0.0	21.5	0.0011	24
36	17	3	110470	6670	0	29.76	238	190	0.0	21.5	0.0012	24
36	17	3	110470	6670	0	29.76	247	188	0.0	21.5	0.0012	24
36	17	3	110470	9720	0	29.76	251	168	0.0	21.5	0.0012	24
36	17	3	110470	9720	0	29.76	242	192	0.0	21.5	0.0012	24
36	17	4	110470	6670	0	29.76	273	178	0.0	21.5	0.0038	24
36	17	4	110470	6670	0	29.76	268	182	0.0	21.5	0.0038	24
36	17	4	110470	9720	0	29.76	271	191	0.0	21.5	0.0038	24
36	17	4	110470	9720	0	29.76	271	190	0.0	21.5	0.0038	24
36	17	5	110470	6670	25	29.76	320	174	0.0	21.5	0.0667	24
36	17	5	110470	6670	25	29.76	317	179	0.0	21.5	0.0667	24
36	17	5	110470	9720	25	29.76	309	185	0.0	21.5	0.0667	24
36	17	5	110470	9720	25	29.76	316	174	0.0	21.5	0.0667	24
37	17	1	110470	10100	0	29.76	266	143	0.0	21.5	0.1628	48
37	17	1	110470	10100	0	29.76	265	142	0.0	21.5	0.1628	48
37	17	1	110470	10100	0	29.76	265	140	0.0	21.5	0.1628	48
37	17	1	110470	10100	0	29.76	264	140	0.0	21.5	0.1628	48
37	17	1	110470	10100	0	29.76	265	140	0.0	21.5	0.1628	48
37	17	1	110470	10100	0	29.76	266	139	0.0	21.5	0.1628	48
37	17	1	110470	10100	0	29.76	266	141	0.0	21.5	0.1628	48
37	17	2	110470	10100	10	29.76	293	139	0.0	21.5	0.0965	48
37	17	2	110470	10100	10	29.76	291	140	0.0	21.5	0.0965	48

TABLE III. INDIVIDUAL MEASUREMENTS FOR COMPUTATION OF EMISSIONS (Contd)

DRYER CODE	SPECIE CODE	STK NUM	DATE	PRODUCTION SQ FT/HR 3/8 VENEER	OPACITY PERCENT	BARO PRESS IN.HG	STK TEMP DRY DEG F	STK TEMP WET DEG F	CO2 PERCENT BY VOL	O2 PERCENT BY VOL	VELOCITY PRESS IN,H2O	STK DIA IN.
37	17	2	110470	10100	10	29.76	291	139	0.0	21.5	0.0965	48
37	17	2	110470	10100	10	29.76	288	137	0.0	21.5	0.0965	48
37	17	2	110470	10100	10	29.76	295	140	0.0	21.5	0.0965	48
37	17	2	110470	10100	10	29.76	291	140	0.0	21.5	0.0965	48
37	17	2	110470	10100	10	29.76	292	140	0.0	21.5	0.0965	48

TABLE IV
HYDROCARBON EMISSIONS FROM STEAM-HEATED DRYERS.

DRYER CODE	STK NUM	SPECIES CODE	PRODUCTION SQ FT/HR 3/8 VENEER	AIR VOLUME SCFM	OPACITY PERCENT AVERAGE	VOLATILE HC LB/HR	COND HC LB/HR	H2O LB/MIN STK	HYDROCARBONS LB/1000,PROD VOL	COND	TOT
9	1	DFRS	6580	5980	43	--	2.24	68.2			
9	2	DFRS	6580	819	76	--	1.14	14.1			
									--	5.13	5.13
12	1	DFRS	3474	3611	0	--	0.42	38.3			
12	2	DFRS	3474	5352	0	--	0.73	43.5			
									--	3.29	3.29
12	1	SPRC	3911	3680	0	--	0.67	35.3			
12	2	SPRC	3911	5214	0	--	0.68	36.2			
									--	3.43	3.43
15	1	DFRH	11970	9217	73	2.22	4.17	147.7			
									1.85	3.48	5.34
15	1	DFRS	9266	7049	28	0.69	4.21	108.4			
									0.74	4.54	5.29
15	1	PPNE	8245	9105	82	2.43	6.61	151.1			
									2.95	8.02	10.97
15	1	HMLK	9060	6420	10	0.35	1.03	113.5			
									0.39	1.14	1.53
15	1	LRCH	8867	6595	17	0.30	3.02	165.7			
									0.34	3.40	3.74
15	1	WPNE	9860	14812	40	1.07	6.05	213.0			
									1.09	6.13	7.22
19	1	DFRH	16386	5655	20	0.40	1.52	68.4			
19	2	DFRH	16386	5046	30	0.23	2.48	55.0			
									0.38	2.44	2.83
19	1	DFRS	6635	4894	23	0.16	1.20	69.4			
19	2	DFRS	6635	4838	22	0.26	2.60	64.8			
									0.63	5.73	6.36
27	1	WFIR	--	--	--	--	--	--			
27	2	WFIR	6217	484	12	0.01	0.10	11.5			
27	3	WFIR	6217	1092	12	0.01	0.22	26.1			
									0.03	0.51	0.54
28	1	DFRH	10475	873	28	0.11	1.05	45.8			
28	2	DFRH	10475	705	28	0.09	2.00	47.7			

TABLE IV
HYDROCARBON EMISSIONS FROM STEAM-HEATED DRYERS. (Contd)

DRYER CODE	STK NUM	SPECIES CODE	PRODUCTION SQ FT/HR 3/8 VENEER	AIR VOLUME SCFM	OPACITY PERCENT AVERAGE	VOLATILE HC LB/HR	COND HC LB/HR	H2O LB/MIN STK	HYDROCARBONS LB/10000,PROD VOL	COND	TOT
28	3	DFRH	10475	1033	66	0.18	0.85	31.5			
									0.36	3.72	4.09
28	1	DFRS	6439	820	33	0.11	0.66	51.6			
28	2	DFRS	6439	791	72	0.13	1.23	45.4			
28	3	DFRS	6439	987	73	0.09	1.03	31.0			
									0.51	4.54	5.05
31	1	SPNE	9004	317	0	0.07	0.12	3.5			
31	2	SPNE	9004	195	10	0.15	0.03	5.4			
31	3	SPNE	9004	473	10	0.20	0.10	17.9			
31	4	SPNE	9004	434	15	0.21	0.22	15.2			
31	5	SPNE	9004	1727	26	0.72	1.15	55.9			
31	6	SPNE	9004	3454	26	1.02	1.21	54.4			
									2.63	3.13	5.76
32	1	SPNE	13400	678	0	0.27	0.42	51.4			
32	2	SPNE	13400	506	20	0.36	2.77	72.3			
32	3	SPNE	13400	650	30	0.37	5.15	64.0			
32	4	SPNE	13400	6173	10	1.21	0.13	51.6			
									1.65	6.33	7.98
35	1	SPNE	8833	31627	0	3.18	1.22	281.9			
35	2	SPNE	8833	12062	0	1.09	1.17	74.8			
									4.83	2.71	7.55
36	1	SPNE	8195	357	0	0.17	0.01	14.2			
36	2	SPNE	8195	199	0	0.12	0.22	13.0			
36	3	SPNE	8195	171	0	0.10	0.12	15.1			
36	4	SPNE	8195	350	0	0.22	0.22	23.0			
36	5	SPNE	8195	1549	25	0.72	2.74	86.4			
									1.62	4.05	5.67
37	1	SPNE	10100	15037	0	2.63	0.71	206.4			
37	2	SPNE	10100	11516	10	1.40	1.58	144.0			
									3.99	2.26	6.25

TABLE V
HYDROCARBON EMISSIONS BY TYPE FROM STEAM-HEATED DRYERS
LB/10000 PRODUCTION BY SPECIES

SPECIES	LOW	HIGH	AVERAGE	DRYERS
TOTAL				
DFRH	2.83	5.34	4.08	3
DFRS	3.29	6.36	5.02	5
PPNE	10.97	10.97	10.97	1
HMLK	1.53	1.53	1.53	1
WFIR	0.54	0.54	0.54	1
LRCH	3.74	3.74	3.74	1
SPNE	5.67	7.98	6.64	5
WPNE	7.22	7.22	7.22	1
SPRC	3.43	3.43	3.43	1
VOLATILE				
DFRH	0.36	1.85	0.87	3
DFRS	0.51	0.74	0.62	5
PPNE	2.95	2.95	2.95	1
HMLK	0.39	0.39	0.39	1
WFIR	0.03	0.03	0.03	1
LRCH	0.34	0.34	0.34	1
SPNE	1.62	4.83	2.95	5
WPNE	1.09	1.09	1.09	1
CONDENSED				
DFRH	2.44	3.72	3.22	3
DFRS	3.29	5.73	4.65	5
PPNE	8.02	8.02	8.02	1
HMLK	1.14	1.14	1.14	1
WFIR	0.51	0.51	0.51	1
LRCH	3.40	3.40	3.40	1
SPNE	2.26	6.33	3.70	5
WPNE	6.13	6.13	6.13	1
SPRC	3.43	3.43	3.43	1

TABLE VI
HYDROCARBON EMISSIONS FROM GAS-HEATED DRYERS

DRYER CODE	STK NUM	SPECIES CODE	PRODUCTION SQ FT/HR 3/8 VENEER	AIR VOLUME SCFM	OPACITY PERCENT AVERAGE	VOLATILE HC LB/HR	COND HC LB/HR	H2O LB/MIN STK	HYDROCARBONS LB/10000,PROD VOL	COND	TOT
23	1	DFRS	5053	3465	15	2.50	0.91	53.5			
23	2	DFRS	5053	2909	17	2.06	0.92	45.3			
23	3	DFRS	5053	3713	11	0.68	0.22	14.8			
									10.37	4.05	14.41
24	1	DFRS	4775	3940	0	3.55	0.27	41.0			
									7.43	0.56	7.99
25	1	DFRS	5432	3393	0	1.36	0.82	50.3			
25	2	DFRS	5432	2995	0	1.25	0.54	47.2			
									4.80	2.50	7.31
26	1	DFRW	5037	5378	0	0.90	0.61	47.6			
26	2	DFRW	5037	2024	10	0.12	0.17	8.8			
									2.02	1.54	3.57

TABLE VII
HYDROCARBON EMISSIONS BY TYPE FROM GAS-HEATED DRYERS
LB/10000 PRODUCTION BY SPECIES

SPECIES	LOW	HIGH	AVERAGE	DRYERS
TOTAL				
DFRS	7.31	14.41	9.90	3
DFRW	3.57	3.57	3.57	1
VOLATILE				
DFRS	4.80	10.37	7.54	3
DFRW	2.02	2.02	2.02	1
CONDENSED				
DFRS	0.56	4.05	2.37	3
DFRW	1.54	1.54	1.54	1

TABLE VIII
VARIABILITY OF DUPLICATE HYDROCARBON SAMPLES ON STEAM-HEATED DRYERS

DRYER CODE	STK NUM	SPECIES CODE	PRODUCTION SQ FT/HR 3/8 VENEER	AIR VOLUME SCFM	OPACITY PERCENT AVERAGE	VOLATILE HC LB/HR	COND HC LB/HR	H2O LB/MIN STK	HYDROCARBONS LB/10000,PROD VOL	COND	TOT
15	1	DFRS	8970	6995	35	0.36	5.92	112.4			
									0.40	6.60	7.01
15	1	DFRS	9860	7127	15	0.29	2.33	100.8			
									0.29	2.36	2.66
15	1	DFRS	8970	6995	35	0.36	3.57	112.4			
									0.40	3.98	4.38
15	1	LRCH	9500	7072	0	0.25	2.72	105.4			
									0.26	2.86	3.12
15	1	LRCH	8130	6557	25	0.17	4.29	101.2			
									0.21	5.28	5.49
15	1	LRCH	9130	10554	20	0.10	3.92	165.7			
									0.11	4.29	4.40
19	1	DFRH	14958	5746	0	0.31	1.57	61.4			
19	2	DFRH	14958	5206	25	0.17	2.78	37.1			
									0.32	2.91	3.23
19	1	DFRH	17388	5574	30	0.25	1.48	74.6			
19	2	DFRH	17010	4945	35	0.20	2.23	67.8			
									0.26	2.16	2.42
28	1	DFRH	10200	771	20	1.60	0.67	52.0			
28	2	DFRH	10200	698	60	0.89	1.99	54.0			
28	3	DFRH	10200	995	40	0.69	0.82	38.6			
									3.12	3.41	6.53
28	1	DFRH	10800	843	40	0.50	1.69	45.8			
28	2	DFRH	10800	703	100	0.55	2.57	47.7			
28	3	DFRH	--	--	--	--	--	--			
									0.97	3.94	4.91

TABLE IX

VARIABILITY OF DUPLICATE HYDROCARBON SAMPLES ON STEAM-HEATED DRYERS

LB/10000 PRODUCTION BY SPECIES

SPECIES	LOW	HIGH	AVERAGE	DRYERS
TOTAL				
DFRH	2.42	6.53	4.27	4
DFRS	2.66	7.01	4.68	3
LRCH	3.12	5.49	4.34	3
VOLATILE				
DFRH	0.26	3.12	1.17	4
DFRS	0.29	0.40	0.37	3
LRCH	0.11	0.26	0.19	3
CONDENSED				
DFRH	2.16	3.94	3.10	4
DFRS	2.36	6.60	4.32	3
LRCH	2.86	5.28	4.14	3

fir had very low volatile hydrocarbon emission, for example, while ponderosa pine, Douglas fir, and white pine had comparatively high values. Tables IV, V, VI, VII, VIII summarize hydrocarbon emission values for steam- and gas-heated dryers. Tables IV, VI, and VIII give hydrocarbon emission figures on a dryer basis. Tables V, VII, and IX give the figures on a species-type basis.

3. Qualitative Analysis of Major Hydrocarbon Components

a. Volatile Hydrocarbons

(1) Representative GC Profiles of Emissions

A selection of representative gas chromatograms of the veneer dryer monoterpene emissions is shown in Figures 1-8. These chromatograms were selected from 747 gas chromatographic analyses of the stack emissions made in the field using the Carle 9000 gas chromatograph housed in the trailer. The chromatograms (Figures 1-17) show the following:

1. Concentrations of methane and C_2 to C_5 compounds were less than 5 ppm in the stack gases in steam dryers whereas in gas fired dryers concentrations of these compounds ranged from 30 to 175 ppm (hexane).
2. Minor traces of unidentified (U) C_6 to C_9 compounds were eluted before α pinene (α) in the stack gas during the drying of Douglas fir, southern pine, and ponderosa pine veneer. The amount of light hydrocarbon (LHC) components in the stack gas was higher during the drying of ponderosa pine than during the drying of Douglas fir or southern pine.
3. The volatile hydrocarbon emission was predominantly of reactive hydrocarbon types (monoterpenes = olefin

structure). Studies to determine its relative reactivity compared to ethylene, isobutene and 1-butene are in progress.

4. The percentage distribution of these volatile terpenes was characteristic of the wood species.
5. The composition of monoterpenes emitted from all stacks in a dryer during the drying of a single wood species was similar.
6. The concentration of the volatile hydrocarbons was different for each stack on a dryer and usually was characteristic of the dryer.
7. In the diluted stack gas going to the THA, α pinene was almost 100% of the monoterpene fraction.
8. A wide range in the concentration of volatile hydrocarbons (monoterpenes) was measured in the stack gases studied.
9. The day-to-day character of the emissions for a given species of wood was similar at any plant but the concentrations of the stack emissions were variable.

Although Douglas fir veneer was the major wood type dried at the four plants in the Pacific Northwest, three other wood types (ponderosa pine, western hemlock, and white fir) were dried during the study period. Figure 4 shows three chromatograms of the volatile hydrocarbons analyzed in the stack gas at Dryer #09 on 10 July 1970 during the drying of ponderosa pine veneer. The chromatogram on the left is attenuated in the usual fashion, 2X, 5X, 2X. It shows a small (10% of scale at 10X) α pinene peak compared to the average 60 to 80% of scale peak at 10X for Douglas fir.

The measurements of the amount of α pinene in the stack gas indicate that ponderosa pine veneer releases only 20 to 30% as much α pinene as Douglas fir. These

TABLE X. HYDROCARBON EMISSION NORMALIZED FOR SCFM.

DRYER CODE	STK NUM	SPECIES CODE	PRODUCTION SQ FT/HR 3/8 VENEER	AIR VOLUME SCFM	CPACITY PERCENT AVERAGE	HYDROCARBONS LB/10000 SQ FT PROD/1000 SCFM VOLATILE	CONC	TOTAL
9	1	DFRS	6580	5980	43			
9	2	DFRS	6580	819	76			
						--	2.680	2.680
12	1	DFRS	3474	3611	0			
12	2	DFRS	3474	5352	0			
						--	0.723	0.723
12	1	SPRC	3911	3680	0			
12	2	SPRC	3911	5214	0			
						--	0.796	0.796
15	1	DFRH	11970	9217	73			
						0.201	0.378	0.579
15	1	DFRS	9266	7049	28			
						0.105	0.644	0.750
15	1	PPNE	8245	9105	82			
						0.324	0.881	1.205
15	1	HMLK	5060	6420	10			
						0.061	0.178	0.238
15	1	LRCH	9867	6595	17			
						0.052	0.515	0.567
15	1	WPNE	9860	14812	40			
						0.074	0.414	0.487
19	1	DFRH	16386	5655	20			
19	2	DFRH	16386	5046	30			
						0.070	0.466	0.536
19	1	DFRS	6635	4894	23			
19	2	DFRS	6635	4838	22			
						0.130	1.180	1.310
23	1	DFRS	5053	3465	15			
23	2	DFRS	5053	2909	17			
23	3	DFRS	5053	3713	11			
						3.194	1.261	4.449
24	1	DFRS	4775	3940	0			
						1.886	0.142	2.028

TABLE X. HYDROCARBON EMISSION NORMALIZED FOR SCFM. (Contd)

DRYER CODE	STK NUM	SPECIES CODE	PRODUCTION SQ FT/HR 3/8 VENEER	AIR VOLUME SCFM	OPACITY PERCENT AVERAGE	HYDROCARBONS LB/10000 SQ FT PROD/1000 SCFM VOLATILE	CONC	TOTAL
25	1	DFRS	5432	3393	0			
25	2	DFRS	5432	2995	0			
						1.505	0.779	2.283
26	1	DFRW	5037	5378	0			
26	2	DFRW	5037	2024	10			
						0.451	0.388	0.839
27	1	WFIR	--	--	--			
27	2	WFIR	6217	484	12			
27	3	WFIR	6217	1092	12			
						0.060	0.651	0.690
28	1	DFRH	10475	873	28			
28	2	DFRH	10475	705	28			
28	3	DFRH	10475	1033	66			
						0.418	4.633	5.051
28	1	DFRS	6439	820	33			
28	2	DFRS	6439	791	72			
28	3	DFRS	6439	987	73			
						0.602	5.290	5.991
31	1	SPNE	9004	317	0			
31	2	SPNE	9004	195	10			
31	3	SPNE	9004	473	10			
31	4	SPNE	9004	434	15			
31	5	SPNE	9004	1727	26			
31	6	SPNE	9004	3454	26			
						2.905	2.474	5.403
32	1	SPNE	13400	678	0			
32	2	SPNE	13400	506	20			
32	3	SPNE	13400	650	30			
32	4	SPNE	13400	6173	10			
						1.404	10.464	11.868
35	1	SPNE	8833	31627	0			
35	2	SPNE	8833	12062	0			
						0.216	0.154	0.370

TABLE X. HYDROCARBON EMISSION NORMALIZED FOR SCFM. (Contd)

DRYER CODE	STK NUM	SPECIES CODE	PRODUCTION SQ FT/HR 3/8 VENEER	AIR VOLUME SCFM	CPACITY PERCENT AVERAGE	HYDROCARBONS LB/10000 SQ FT PROD/1000 SCFM VOLATILE	COND	TOTAL
36	1	SPNE	8195	357	0			
36	2	SPNE	8195	199	0			
36	3	SPNE	8195	171	0			
36	4	SPNE	8195	350	0			
36	5	SPNE	8195	1549	25			
						3.377	5.188	8.559
37	1	SPNE	10100	15037	0			
37	2	SPNE	10100	11516	10			
						0.294	0.182	0.476

percentages agree favorably with the reported 10 to 20% figures for the amount of extractive α pinene in ponderosa pine wood compared to Douglas fir.

The middle chromatogram in figure 4 is attenuated throughout the profile at 2X. It presents a picture of the undistorted proportions of the eight monoterpene and three light hydrocarbon peaks resolved in the analysis of the volatile hydrocarbons in stack #1. The chromatograms (left and middle) are analyses of paired samples, i.e. samples taken simultaneously. The peaks heights of α pinene are 215 vs. 214 mm; the two GC profiles are identical within the limits of analytical error.

The chromatogram on the right in figure 4 is an analysis of the diluted stack gas going to the THA. Alpha pinene is essentially the sole component measured.

Figures 5 and 6 (Dryer #12) show the similar day-to-day character of the volatile hydrocarbon emissions from the same wood species as well as the significant difference in actual hydrocarbon concentrations in these emissions. Figures 7, 8, and 9 (Dryer #28) show the constancy of the composition of the monoterpenes in the stack gas and the distribution in the concentrations related to the stack number for three consecutive days during the drying of Douglas fir. Figure 10 (Dryer #19) and 11 (Dryer #15) show the characteristic composition of the monoterpenes for Douglas fir veneer as well as the relative concentrations between sapwood and heartwood.

Figures 12, 13, and 14 (Dryer #31) show the

1. characteristic composition of volatile monoterpene in the veneer dryer emissions for southern pine;
2. the constancy of composition and relative concentration of the monoterpene emissions in stacks 1 to 6;

3. the repeatibility of the gas chromatographic analyses for three simultaneous samples taken from stack #4.

Figure 15 (Dryer #35) and 16 and 17 (Dryer #36) show a lower percentage of α pinene in the monoterpene emissions of southern pine. This difference is most likely due to a different species of pine being studied under the general description of "southern pine." These analyses show essentially the same thing as shown in Figure 13.

To determine if the condenser used to collect the condensed hydrocarbon fraction of the stack gas affected the concentration of volatile hydrocarbons delivered to the total hydrocarbon analyzer, gas chromatographic analyses were made before and after the condenser. Figures 18 and 19 representing southern pine show no differences for the analyses made before and after the condenser. Figure 19 includes two ways of calculating the percentage distribution: one, not including the LHC from the gas fired dryer and the second one including the LHC fraction with the monoterpene composition. Figures 20 and 21 also show that the condenser did not affect the concentration or composition of the volatile hydrocarbons fed to the total hydrocarbon analyzer.

At several of the plywood plants analyses were made of the stack emissions while veneers from tree species recognized not to be monoterpene sources were dried. Chromatograms for these analyses show very low concentrations of monoterpenes in the stack gases. Figure 22 shows the composition and the concentrations measured for western hemlock, western larch, and western white pine compared to the ponderosa pine. All of the analyses were made from the same dryer (#15) within three days of each other. Figure 23 shows the low concentration

of α pinene in the stack gases for Dryer #27 during the drying of western white fir.

(2) Comparison of Volatiles from Green and Dried Veneer

The volatile monoterpenes released from green veneers of Douglas fir and ponderosa pine at room temperature were determined for several wood samples obtained from the feed stock source of dryer #09. The percentage distribution of the volatile monoterpenes (by headspace analysis) compared favorably with the monoterpene composition measured in the stack gas. Figure 24 shows the volatiles from green ponderosa pine veneer. The GC profiles for green and dried Douglas fir veneers are shown in Figure 25. The green veneer produced approximately nine times greater concentration of volatiles than did the dried veneer. As expected, a greater number of monoterpene components were measured in the hot stack gas than in the headspace.

(3) Quantitative Identification of Volatile Hydrocarbons

Seven to twelve components were usually resolved in the 1 ml samples of the stack gas. Three to four of these were light hydrocarbons and five to eight were monoterpene hydrocarbons. Five of the monoterpene peaks were identified by relative retention times; in order of elution they are: α pinene (α), camphene (C), β pinene (β), Δ^3 carene (Δ^3), and limonene (L). No attempt was made to identify the light hydrocarbon peaks C_7, C_8, and C_9. The C_1-C_5 compounds eluted with the air peak. Isoprene (I) was determined not to be in the stack gas at a concentration above 1 ppm. Analyses below 1 ppm were not attempted.

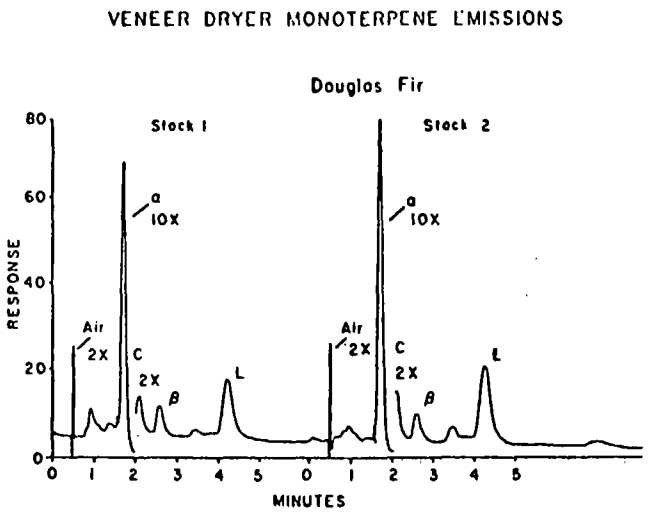


Figure 1 Dryer #09
7 July 1970, 1705 hrs.

	#1	#2
α	81.2%	81.7%
C	3.3	3.5
β	3.0	2.6
L	6.8	7.9

Total ppm (hexane):
57.3 64.0

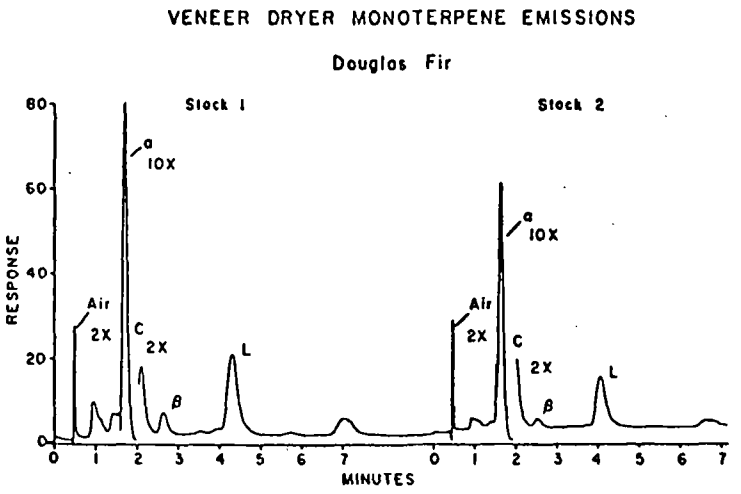


Figure 2 Dryer #09
8 July 1970, 1521 hrs.

	#1
α	77.3%
C	3.7
β	1.6
L	8.4

Total ppm (hexane):
79.3

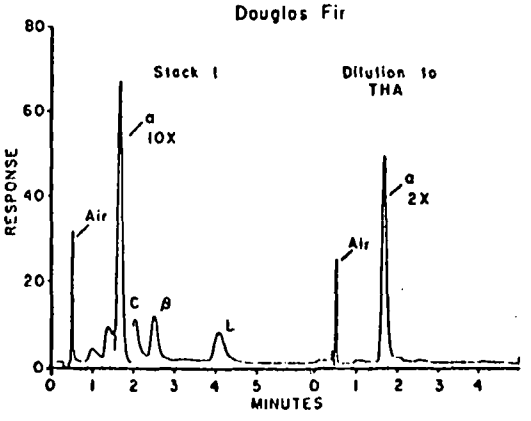


Figure 3 Dryer #09
9 July 1970, 1155 hrs.

	#1
α	82.3%
C	3.4
β	3.9
L	5.4

Total ppm (hexane):
56.2

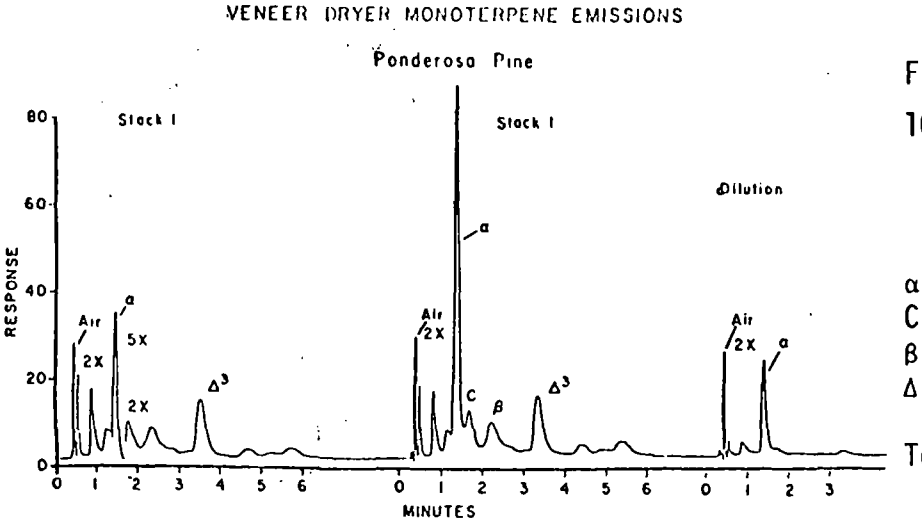


Figure 4 Dryer #09
10 July 1970, 1125 hrs

	#1
α	41.6%
C	7.1
β	7.5
Δ^3	14.3

Total ppm (hexane):
27.5

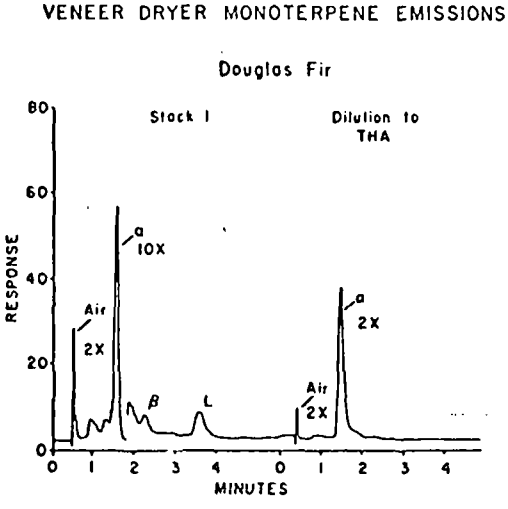


Figure 5 Dryer #12
14 July 1970, 1452 hrs.

	#1
α	84.1%
C	3.7
β	3.1
L	4.2

Total ppm (hexane);
43.5

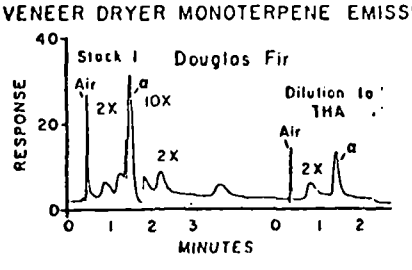


Figure 6 Dryer #12
15 July 1970, 1125 hrs.

Total ppm (hexane):
25.6

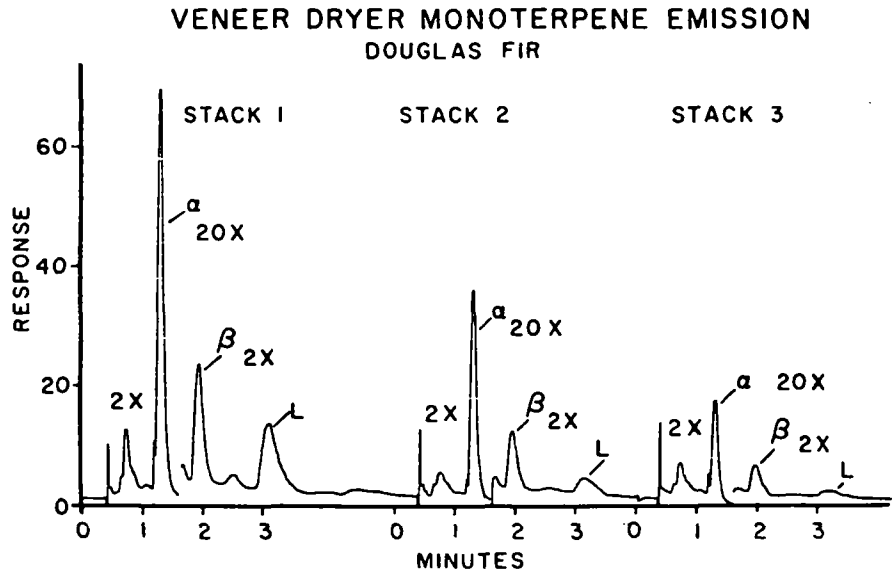


Figure 7 Dryer #28

30 August 1970 1215 hrs

	Stack 1	Stack 2	Stack 3
U	1.4%	1.0	3.0
α	88.9	90.7	90.6
C	.8	1.4	1.2
β	3.8	3.8	3.4
M	.8	.8	--
L	4.1	2.2	1.7
Total ppm (hexane) per 1/2 ml	96.3	48.4	23.1

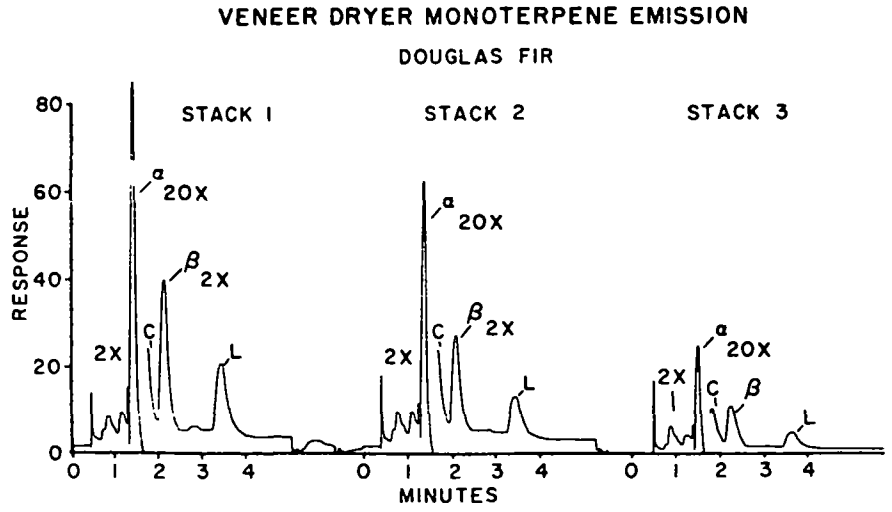


Figure 8 Dryer #28

31 August 1970 1105 hrs

	Stack 1	Stack 2	Stack 3
U	.5%	.8	1.6
U	.5	.8	.8
α	87.5	87.1	87.0
C	2.8	3.8	4.0
β	4.8	4.4	2.2
M	.5	.4	2.2
L	3.4	2.8	--
Total ppm (hexane) per 1/2 ml	123.3	91.8	36.8

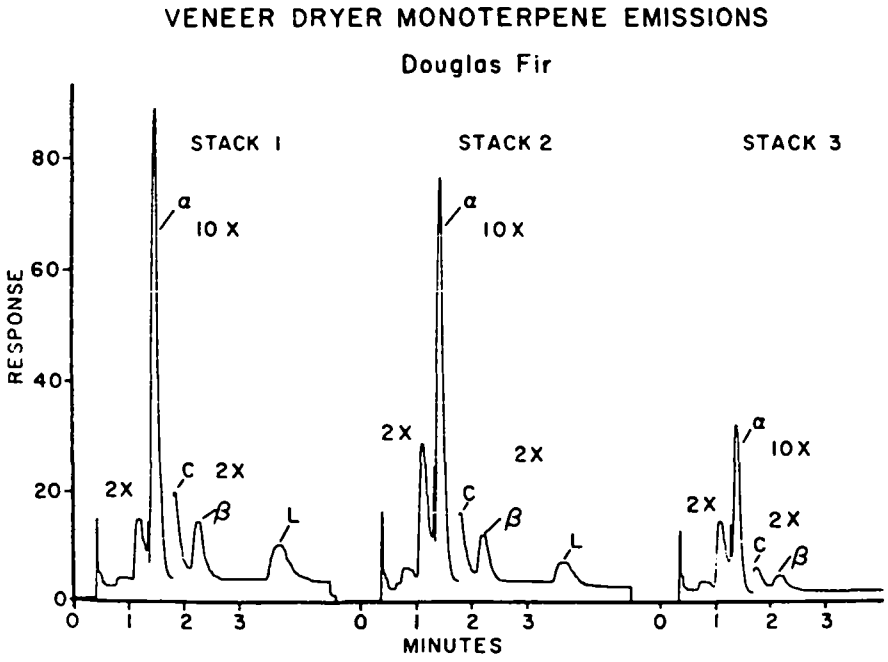


Figure 9 Dryer #28

1 September 1970 1005 hrs

	Stack 1	Stack 2	Stack 3
U	.2%	.5	.8
U	3.0	7.6	9.0
α	86.4	83.2	84.5
C	4.5	4.0	3.4
β	3.0	2.6	2.3
L	3.0	2.2	--
Total ppm (hexane) per 1/2 ml			
	63	55.8	23.7

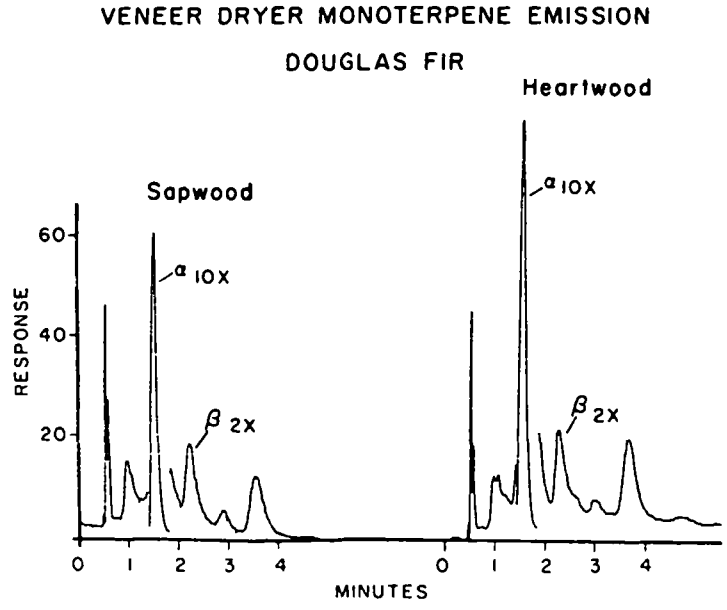


Figure 10 Dryer #19

16 September 1970

	1135 hrs Sap	1609 hrs Heart
U	1.6%	0.8
U	3.6	2.0
α	80.0	78.9
C	3.2	3.6
β	6.9	5.7
M	1.8	1.6
L	6.4	6.7
Total ppm (hexane)		
	66.5	87.8

VENEER DRYER MONOTERPENE EMISSIONS

DOUGLAS FIR

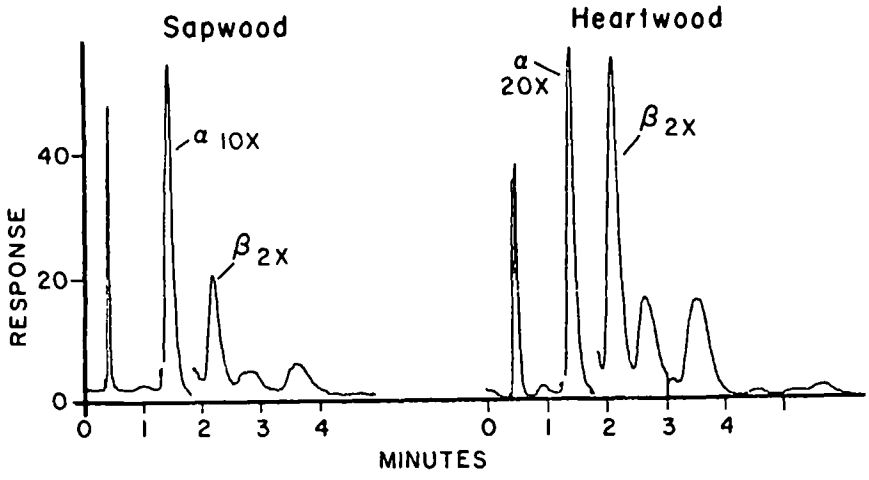


Figure 11 Dryer #15

7 October 1970

1145 hrs Sap		1501 hrs Heart	
U	.2%	U	1.5
α	82.5	α	74.6
C	1.5	C	1.0
β	9.1	β	10.9
M	3.0	M	5.4
L	3.6	L	5.4

Total ppm (hexane)	
55	130.5

VENEER DRYER MONOTERPENE EMISSIONS

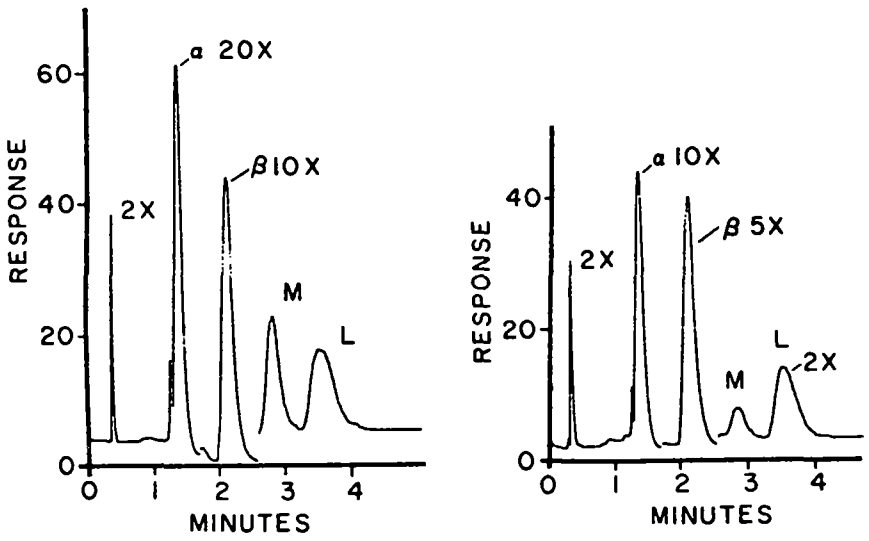
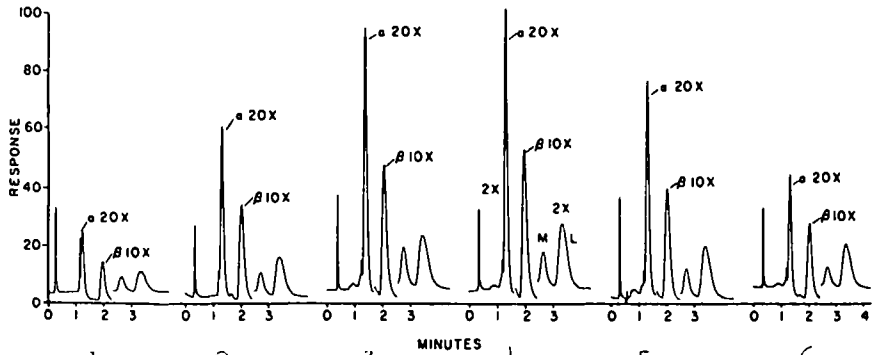


Figure 12 Dryer 31

Southern Pine Sapwood

	28 October 1970 1542 hrs	30 October 1970 1159 hrs
U	---	.3%
α	67.7%	56.0
C	1.2	.5
β	28.0	33.2
M	3.0	2.1
L	4.9	7.7
Total ppm (hexane) per 1/2 ml	121.2	47.7

STACK DISTRIBUTION
OF VENEER DRYER MONOTERPENE EMISSIONS



Stacks 1 2 3 4 5 6

1505 hrs 1512 hrs 1520 hrs

Figure 13 Dryer 31

29 October 1970 Southern Pine

Stacks	1	2	3	4	5	6
U	---	.1	.2	.1	.3	.3
α	65.1%	67.9	69.7	68.9	68.7	64.9
C	1.1	1.4	1.2	1.1	1.1	.6
β	26.0	24.8	23.4	24.4	23.9	26.5
M	2.5	1.5	1.7	1.4	1.6	1.6
L	5.2	4.3	3.7	4.0	4.5	6.1

Total ppm (hexane) per 1/2 ml

46	110.4	165	179.1	136.8	83.1

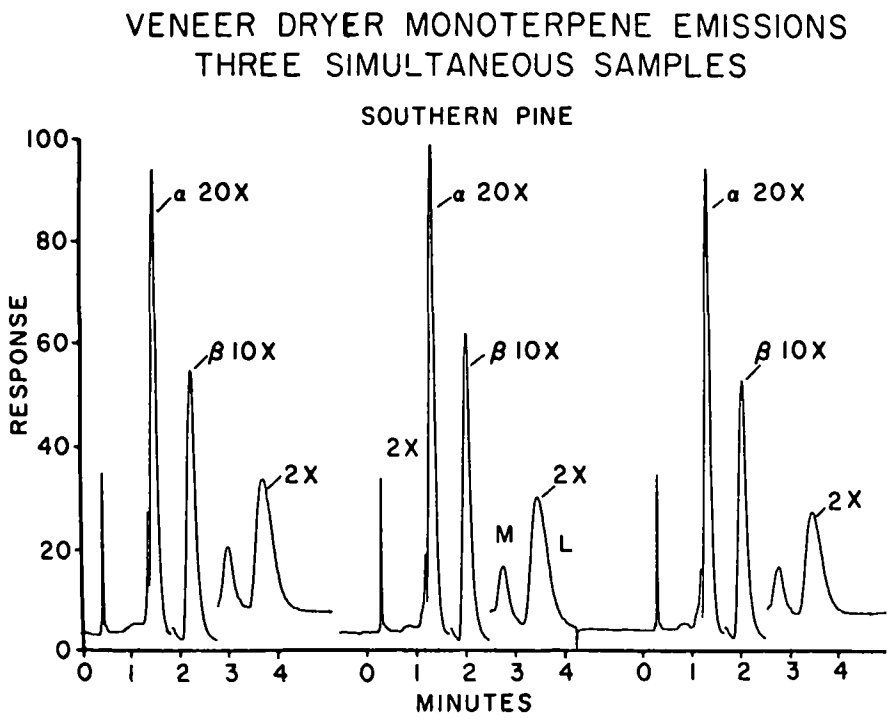


Figure 14 Dryer 31

29 October 1970 1059 hrs

Southern Pine
Stack #4

U	.1%	.1%	.1%
α	61.5	60.3	62.0
C	1.6	1.0	1.1
β	29.9	31.8	30.9
M	1.6	1.5	1.3
L	5.9	5.4	4.7

Total ppm (hexane) per 1/2 ml

187.5 200 185.3

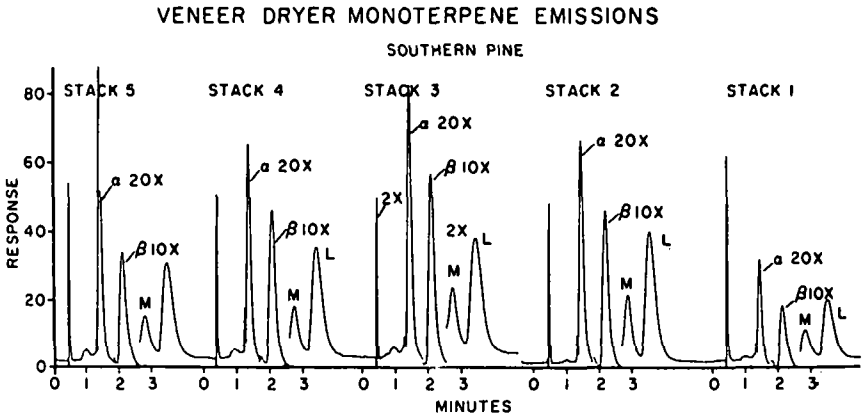


Figure 15 Dryer #35

3 November 1970 0940 hrs

Stack	5	4	3	2	1
U	.6%	.3%	.2%	.2%	.4%
α	56.1	55.5	56.7	54.6	57.4
C	1.8	1.4	1.1	1.3	1.9
β	30.7	33.1	33.1	32.2	28.7
M	2.5	2.2	2.5	3.2	2.9
L	8.4	7.5	6.4	8.6	8.8

Total ppm (hexane) per 1 ml

113.4	145.8	177.6	152.0	67.5

VENEER DRYER MONOTERPENE EMISSIONS

SOUTHERN PINE

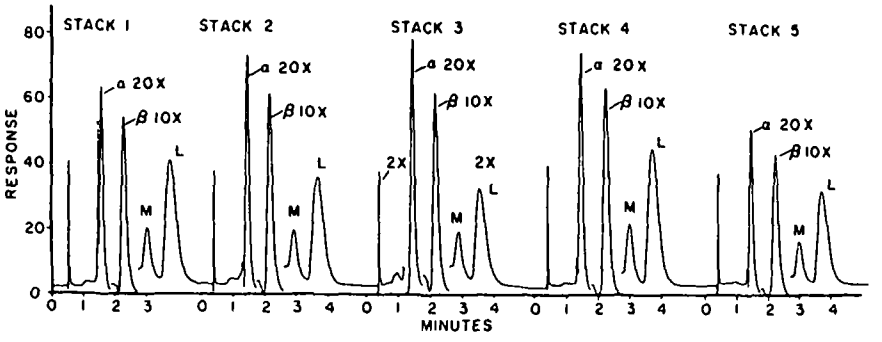


Figure 16 Dryer #36

4 November 1970 1637 hrs

Stack	1	2	3	4	5
U	.2%	.2%	.3%	.1%	.1%
α	51.1	52.0	53.5	50.9	51.0
C	1.3	1.9	2.2	1.5	1.6
β	36.6	37.2	36.2	36.9	37.2
M	2.6	2.3	2.0	2.5	2.5
L	8.3	6.4	5.8	8.0	7.6

Total ppm (hexane) per 1/2 ml

153.8	174.5	179.1	180.3	124.0

VENEER DRYER MONOTERPENE EMISSIONS

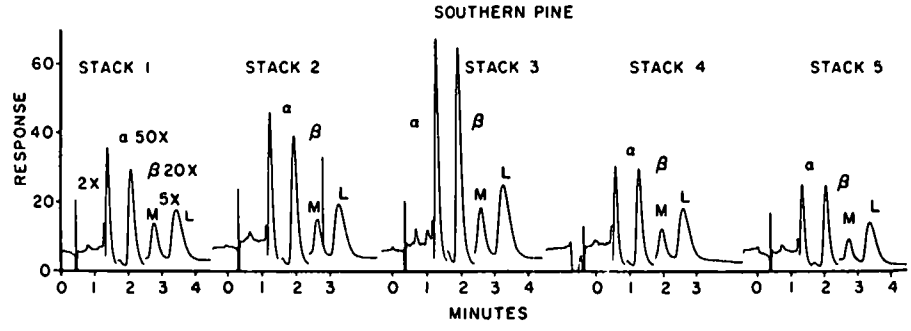


Figure 17 Dryer #36

5 November 1970 1304 hrs

Stack	1	2	3	4	5
U	.1%	.1	.2	.1	.1
α	57.6	57.2	55.7	52.6	52.9
C	1.4	1.6	1.4	1.6	1.9
β	31.0	32.7	35.6	35.1	35.2
M	3.5	2.9	2.3	3.2	2.8
L	6.4	5.4	4.8	7.4	7.0

Total ppm (hexane) per 1/2 ml

188.1	244.6	373.5	171	141.8

EFFECT OF CONDENSER ON CONCENTRATION OF VENEER DRYER MONOTERPENE EMISSIONS

SOUTHERN PINE

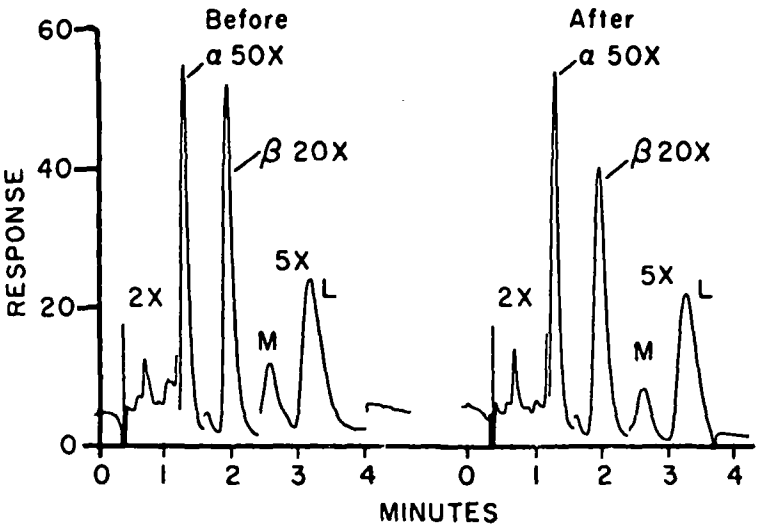


Figure 18 Dryer #36

5 November 1970 1137 hrs

	Before	After
U	.2%	.3%
U	.1	.07
α	58.9	59.3
C	1.9	1.9
β	30.5	29.9
M	1.9	1.8
L	6.6	6.7

Total ppm (hexane) per 1/2 ml

284.4	278.1

CONDENSER EFFECT ON MONOTERPENE EMISSIONS

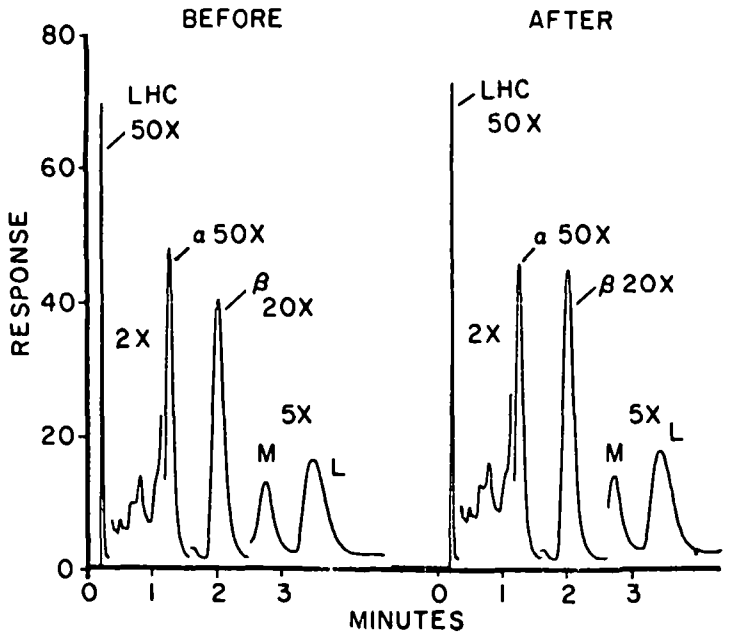


Figure 19 Dryer #32

30 October 1970 1404 hrs

	Before		After	
	1	2	1	2
LHC	---	22.2%	---	22.2%
U	.08%	.06	.05%	--
U	.5	.4	.6	.4
U	.3	.2	.2	.1
α	57.7	44.9	54.4	42.3
C	1.0	.8	1.0	.8
β	31.7	24.7	35.4	27.6
M	2.5	2.0	2.7	2.1
L	6.2	4.8	5.7	4.4

Total ppm (hexane) per 1/2 ml

257.2 263.2

Column 1, LHC not included in calculations
Column 2, LHC included in calculations

VENEER DRYER MONOTERPENE EMISSIONS

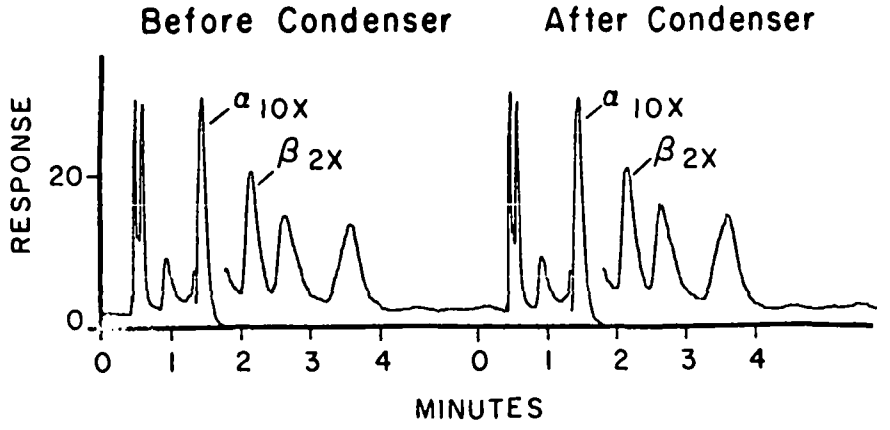


Figure 20 Dryer #15

7 October 1970 White pine

1636 hrs

Before		After
U	5.3%	5.2%
U	2.6	2.8
α	58.8	57.2
C	2.0	2.0
β	10.8	10.5
M	9.8	10.6
L	10.8	11.9
Total ppm (hexane) per 1 ml		
46.8		47.7

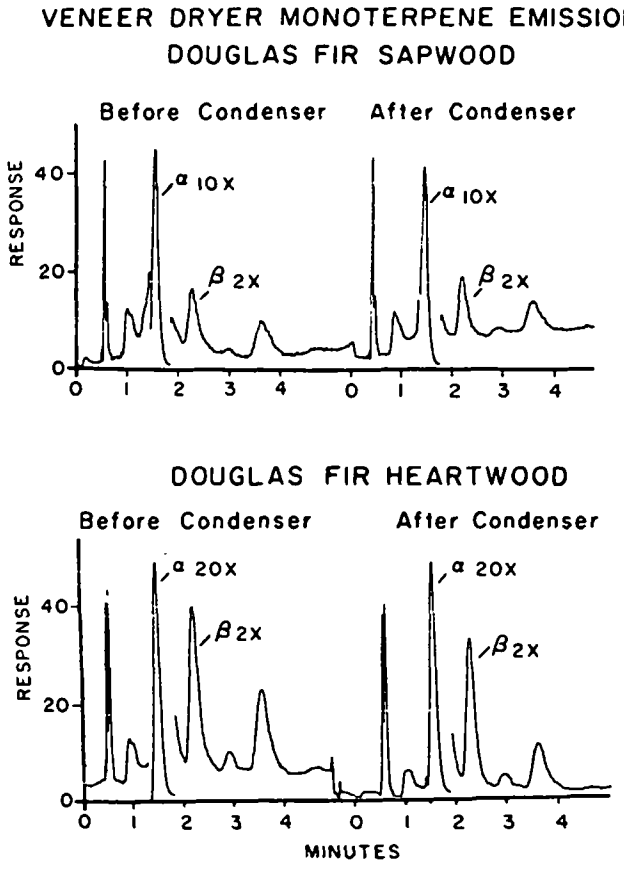


Figure 21 Dryer #19

17 September 1970 1512 hrs

Before		After
U	3.9	4.3
α	80.6	80.6
C	2.6	2.0
β	7.2	7.6
M	0.6	0.6
L	5.1	5.1

Total ppm (hexane) per 1 ml

47 42.3

18 September 1970 1320 hrs

Before		After
U	3.0	2.7
α	79.5	82.4
C	2.0	2.2
β	8.5	8.3
M	1.0	1.0
L	5.8	3.5

Total ppm (hexane) per 1 ml

100.6 98.6

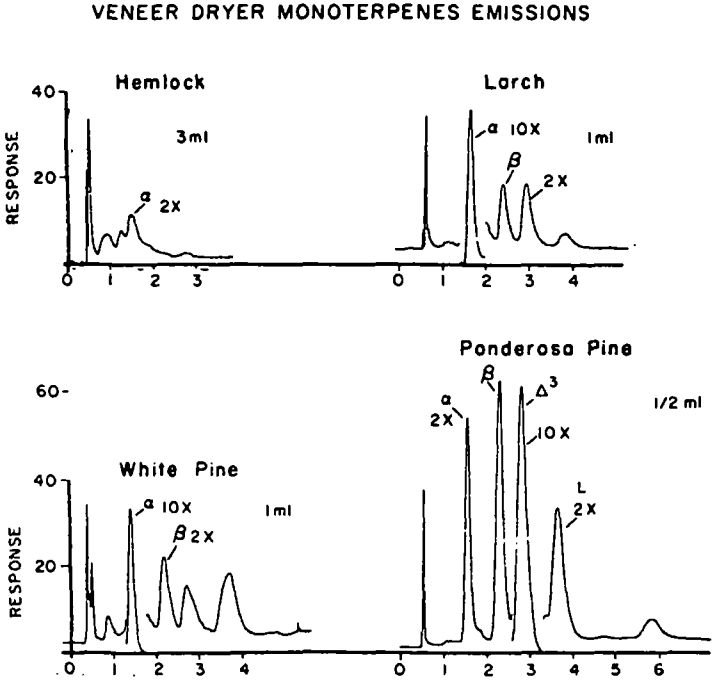


Figure 22 Dryer #15

6 October 1970

1100 hrs Hemlock		1427 hrs Larch	
U	27.5	α	74.3
U	18.8	C	2.4
U	16.1	β	9.6
α	26.2	M	9.6
U	11.4	L	3.4
Total ppm (hexane)			
	9.9		39.6

7 October 1970

1540 hrs White Pine	
U	2.0
U	1.4
α	76.9
C	1.2
β	6.3
M	5.6
L	7.9
Total ppm (hexane)	
	38

9 October 1970

1007 hrs Ponderosa Pine	
α	7.9
C	0.4
β	9.1
Δ^3	70.9
L	9.5
U	2.1
	112.3

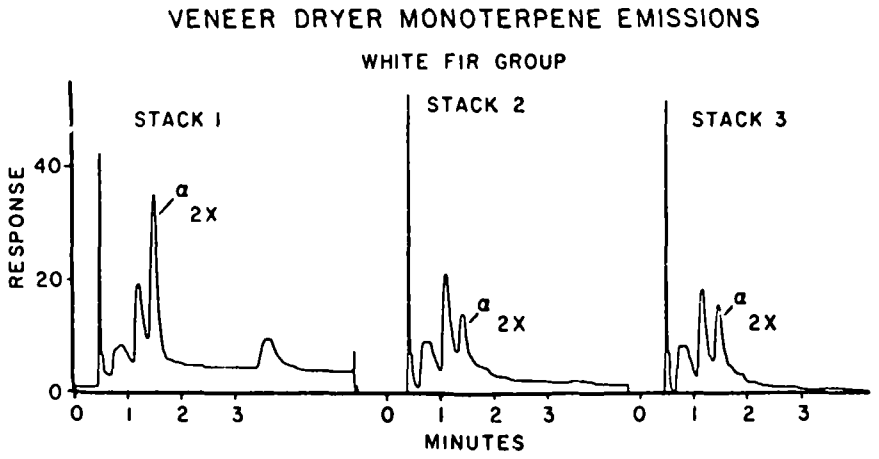


Figure 23 Dryer #27

27 August 1970 1635 hours

Stack 1	Stack 2	Stack 3
U 8.0%	18.4	17.0
U 25.5	49.0	44.7
α 52.4	32.6	38.3
L 14.1	--	--
Total ppm (hexane) per 1 ml		
9.9	6.5	6.1

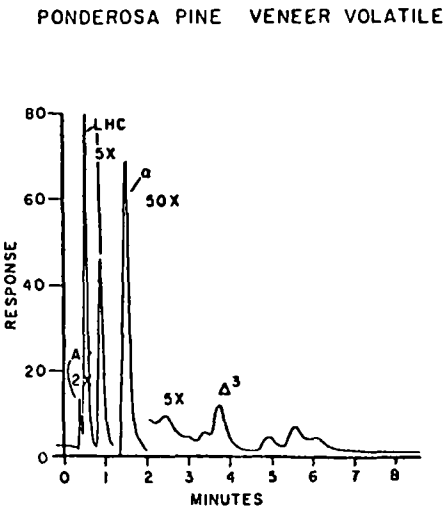


Figure 24 Dryer #09
10 July 1970, 5½ hrs.

LHC	4.7%
IHC	3.7
α	82.8
C	0.6
β	1.2
Δ^3	2.2

Total ppm (hexane):
457

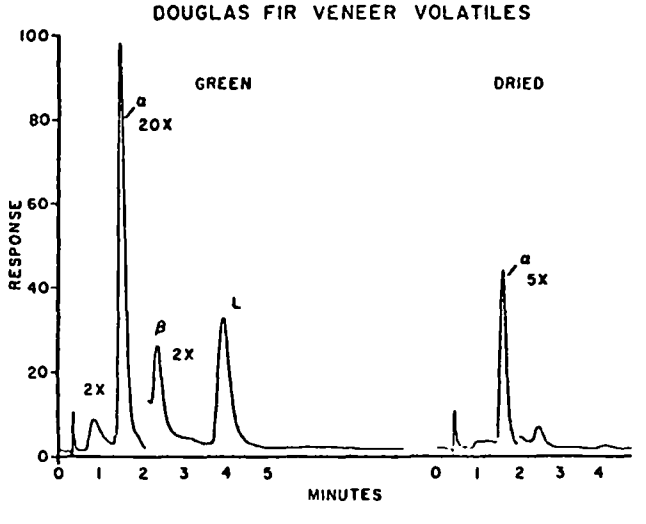


Figure 25 Dryer #09
10 July 1970, 56 hrs.

	Green
α	88.1%
C	1.1
β	3.6
L	5.1

Total ppm (hexane):
219

(4) Comparison of α Pinene Concentrations as Measured by the THA and GC

On 9 July 1970 at Dryer #09, the times of nine samples taken for separate GC analyses were identified on the THA chart for comparison with the GC analyses. The data shown in Figure 26 are expressed in equivalent parts per million of hexane. The THA records a higher concentration of volatile hydrocarbons than that measured for the single α pinene peak. This is to be expected. However, it was not expected that α pinene would represent only 50 to 60% of the THA response when α pinene compound is 75-80% of the monoterpenes in the volatile hydrocarbon fraction. In Figure 26 the average of the differences in concentrations is 20 to 25 ppm.

The plot of the nine paired measurements shows a very strong parallel structure. This correlation indicates that the response of the THA is strongly influenced by fluctuations in the concentration of α pinene. The continuous daily recordings of the THA are presented in Figures 27-31. These THA records have been corrected for background, baseline drift, dilution ratio, and attenuation. The points on the graphs represent the average concentration for each 4-minute time interval.

(5) Cryocondenser

In Figure 32 a comparison between the analyses of monoterpenes in the cryocondenser and those in the stack gas at the time of sampling is shown. The analyses indicate that no changes occurred in the percentage distribution of the monoterpenes collected in the cryocondenser. Figure 33 shows a programmed temperature gas chromatographic analyses of the same sample. The analysis was performed to see if any oxygenated

Figure 26

9 July 1970

Dryer #9

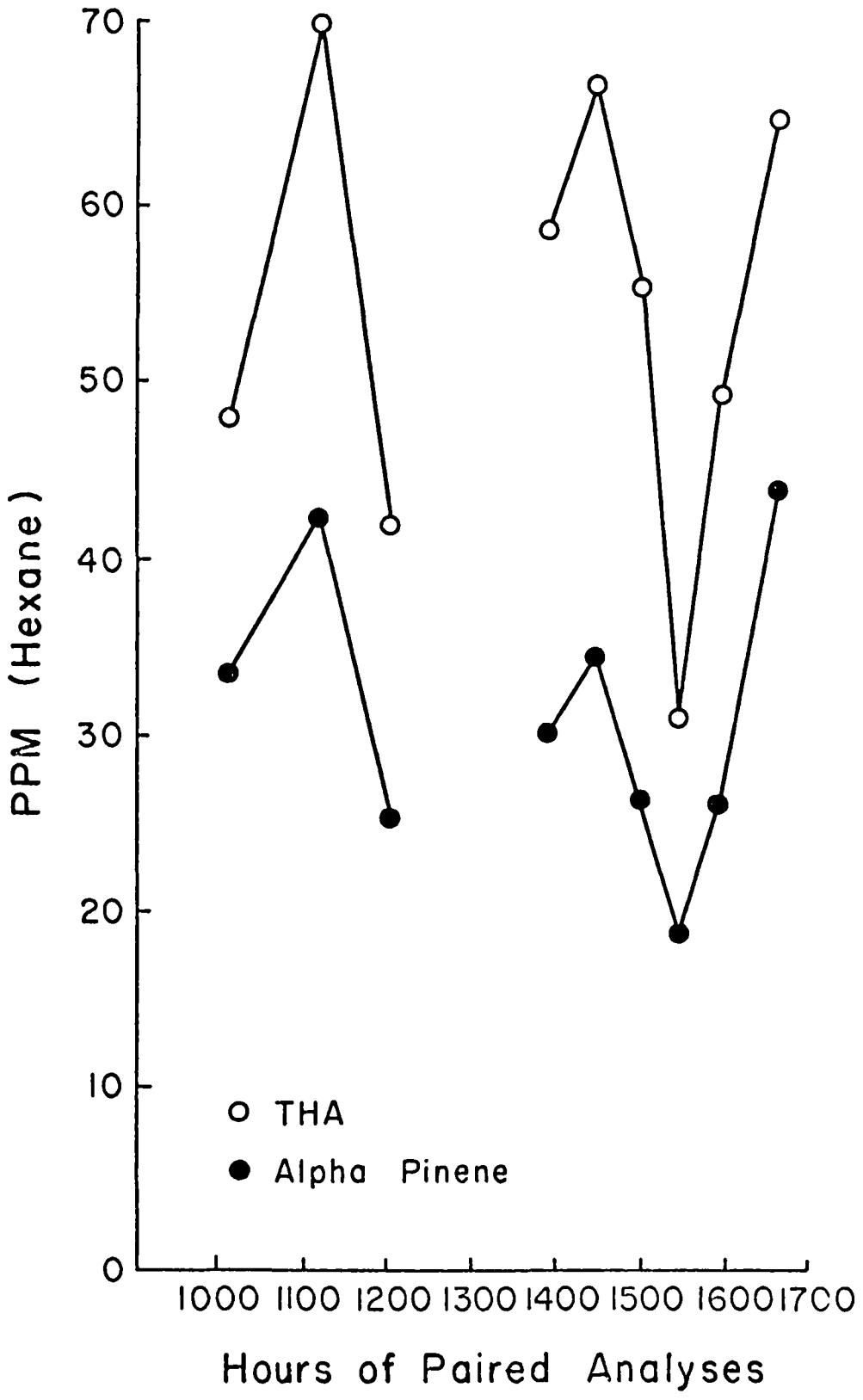


Figure 27

9 July 1970
Dryer #09
Stack #1

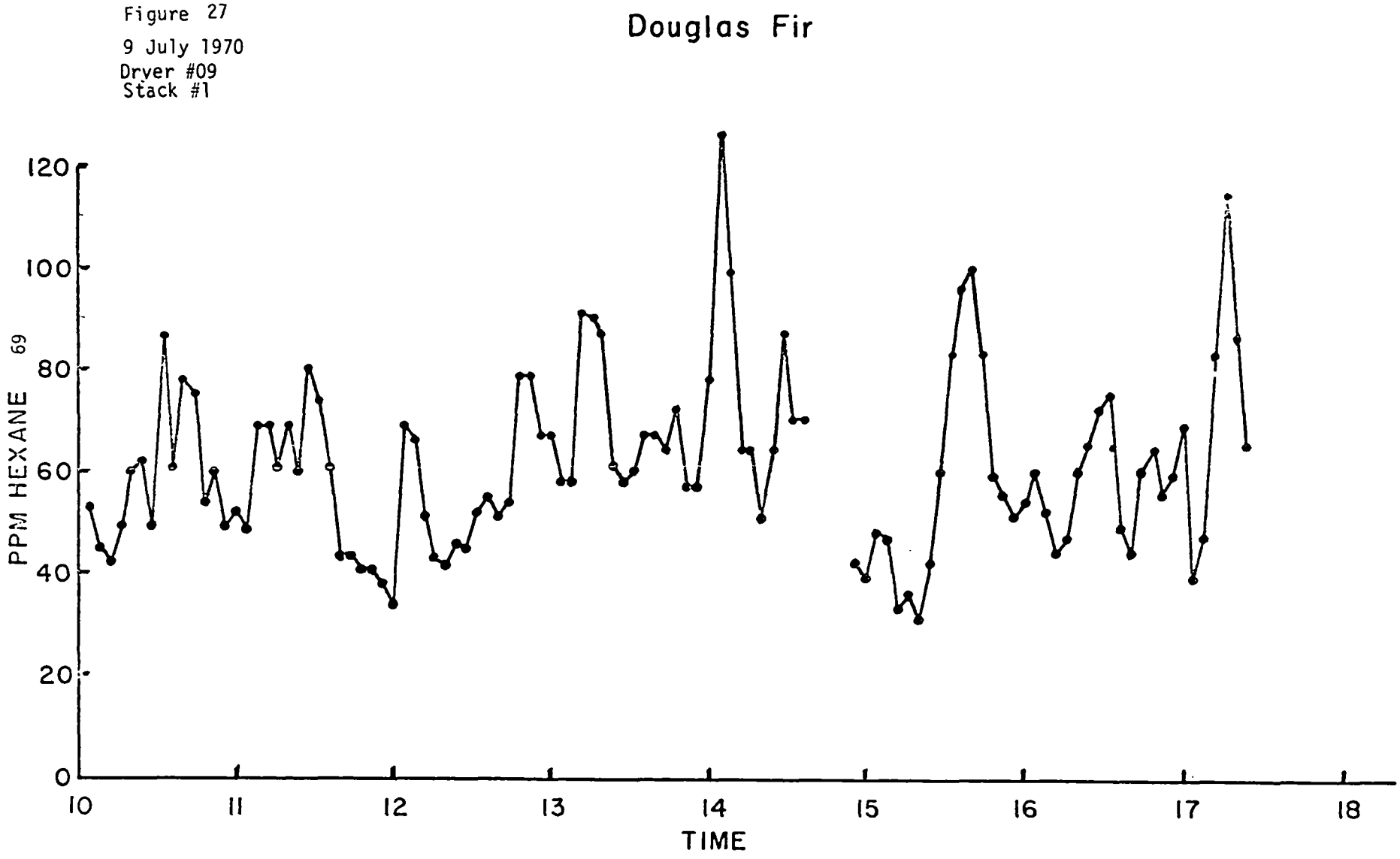
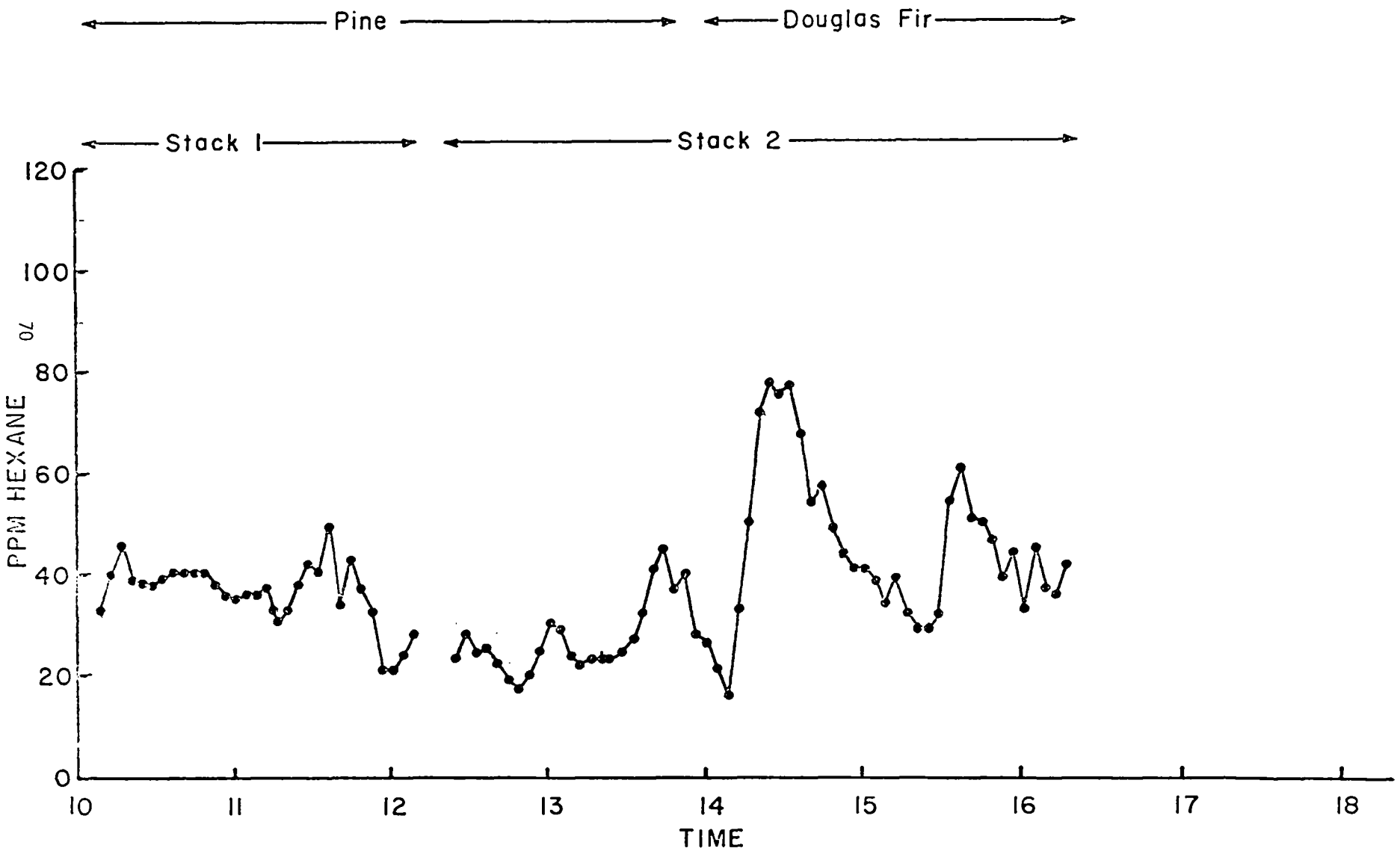


Figure 28

10 July 1970
Dryer #09



Hemlock

Stack 1 ← → ← Stack 2 →

Figure 29
13 July 1970
Drver #12

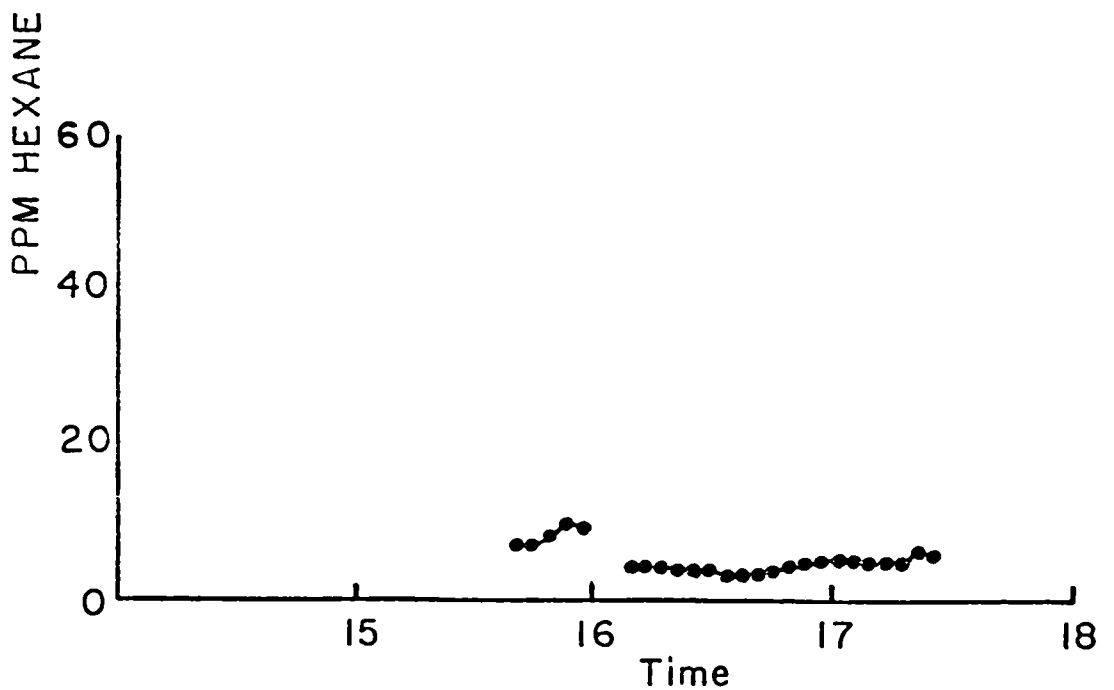


Figure 30

14 July 1970
Dryer #12

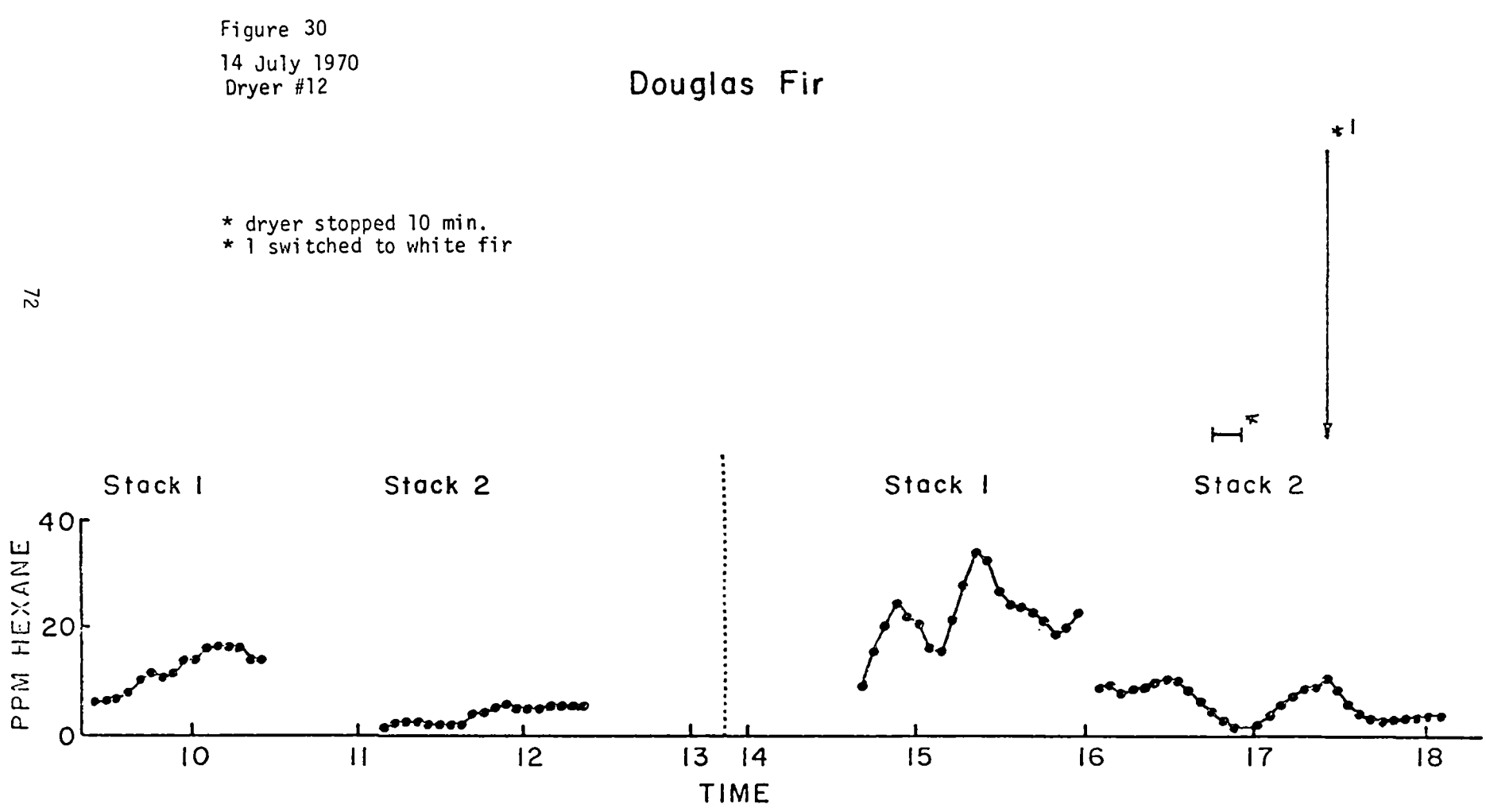
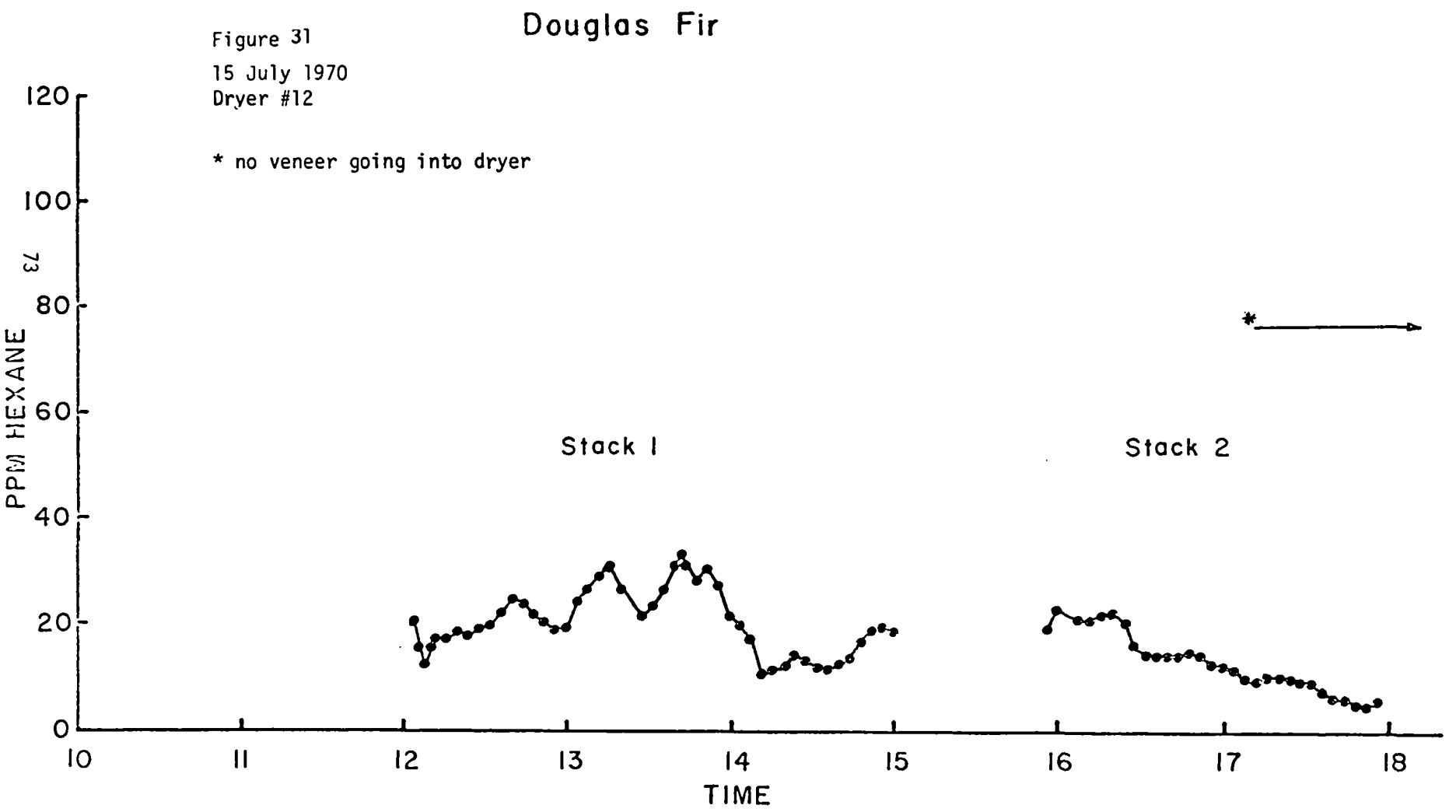


Figure 31

15 July 1970
Dryer #12

* no veneer going into dryer



terpenes or sesquiterpene (C_{15}) components could be resolved in the collection. The cryocondenser was heated to 60°C and a 5 ml pressurized gas sample taken for analysis. The elution of α terpineol is indicated on the chromatogram by *T. The sesquiterpenes and other oxygenated terpenes eluted before and after this component at 30 minutes.

Figure 34 shows a gas chromatographic analysis of a cryocondenser enriched sample of the stack emission from a gas-fired dryer (#05). The analysis shows a range of C_1 through C_5 hydrocarbon with several photochemically reactive olefins: ethylene, propylene, and butene. The concentrations of these olefins in the stack emission is in the order of 10 ppm as measured in a 1 ml sample. The cryogenic collection was necessary in order to collect sufficient material for precise identification of these combustion products in the exhaust gases of the veneer dryer (see section Discussion 3 for more information regarding these gases).

(6) Carboy-Irradiation Studies

In Figure 35 the photochemical reactivity of the monoterpenes (conjugated olefins) is shown in two parts. The first two analyses demonstrate the stability and minimal thermal deposition of the monoterpenes onto the walls of the carboy. The carboy was wrapped in black polyethylene plastic, kept in a cardboard box, and stored at room temperature for 26 days (9 July to 4 August). The difference in concentrations is within the error of analysis. The irradiation was begun after the sample was taken on 4 August. By 17 August a 85% decrease in the concentration of the monoterpenes in the carboy had occurred. An interesting observation in the photochemically induced

VENEER DRYER MONOTERPENE EMISSIONS

DOUGLAS FIR

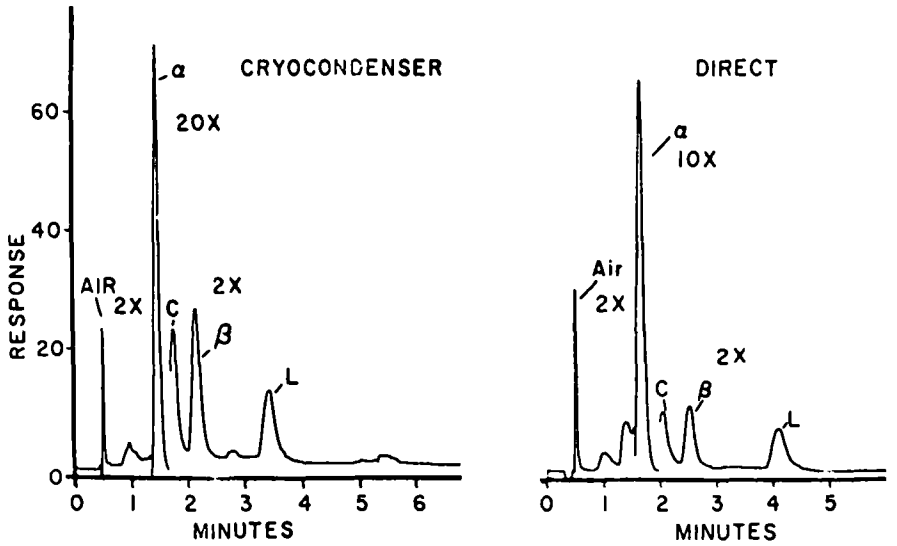


Figure 32 Dryer #09

9 July 1970 1500 hrs

	0.2 ml	1 ml
U	.3%	.8%
U	---	1.8
	84.1	84.7
C	4.0	2.9
	6.0	4.7
M	.5	.4
L	4.4	4.2
U	.7	.5
Total ppm (hexane)		
	72.9	50.0

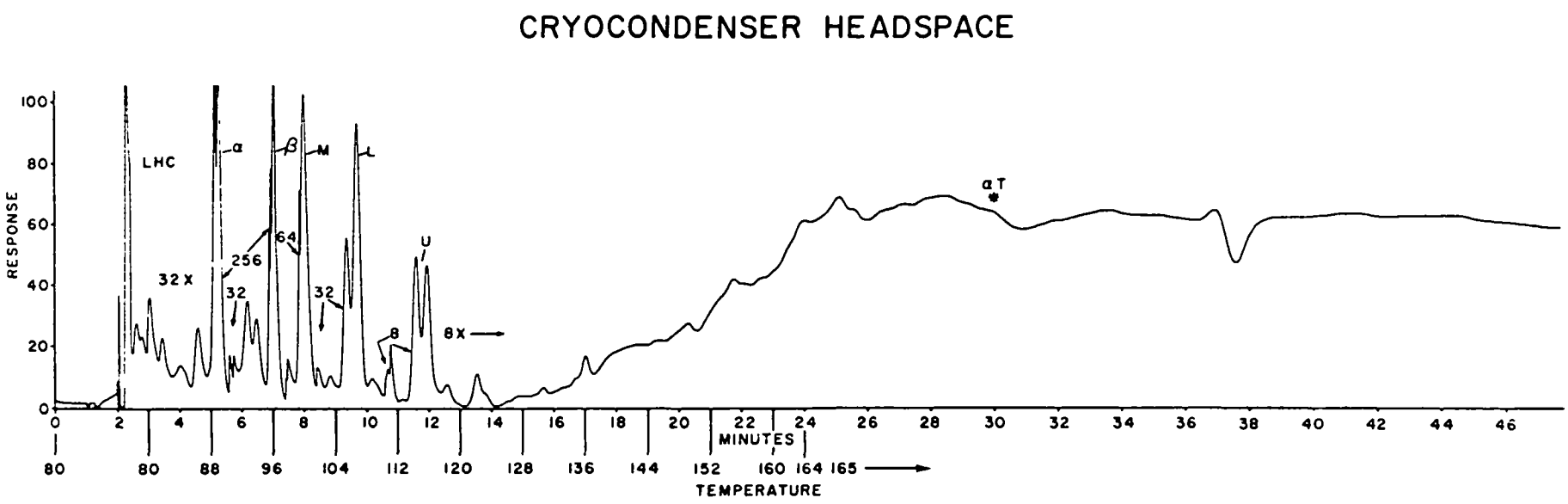


Figure 33 Enriched Terpene Sample

VENEER DRYER LIGHT HYDROCARBON EMISSION

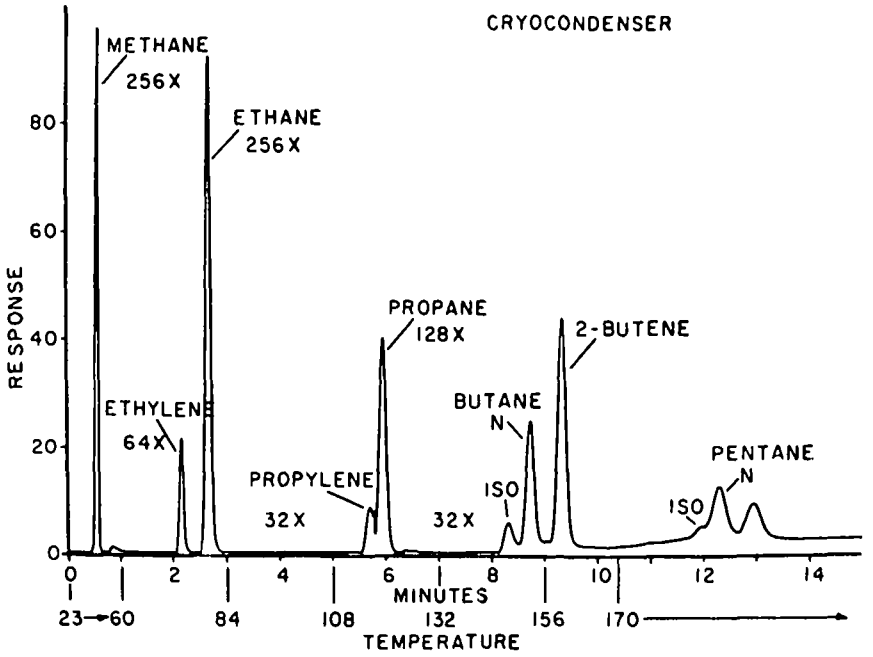


Figure 34 Dryer #05

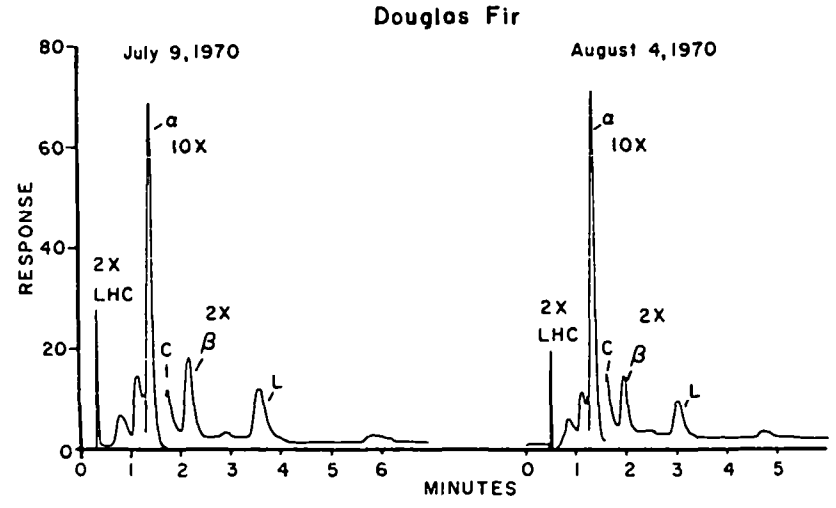
24 June 1970 1515 hrs

Corrected Percent Distribution

M	47.9%
E	1.3
E	35.6
P	.7
P	12.5
i-B	.14
n-B	.5
B	.9
i-P	.03
n-P	.18
P	.14

Total ppm (hexane) 3,299.5 per 0.4 ml sample from the cryo-condenser.

STABILITY OF VENEER DRYER EMISSIONS STORED IN THE CARBOY



IRRADIATED DOUGLAS FIR VENEER EMISSION

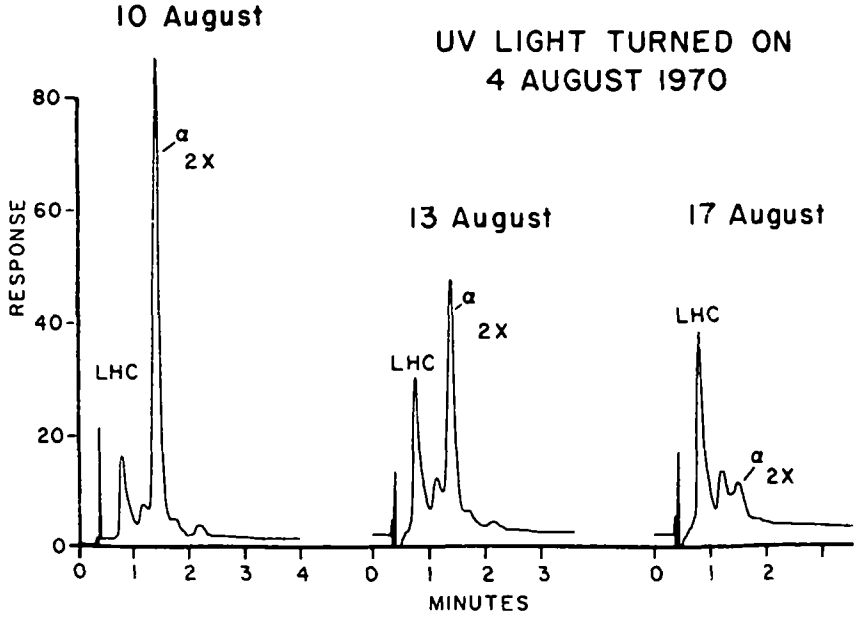


Figure 35 Dryer #09

	9 July 1970	4 August 1970
U	1.6%	1.4%
U	4.0	3.0
	77.7	78.3
C	3.3	3.8
	6.2	3.8
M	.5	.5
L	5.8	4.1
U	.9	.9
Total ppm (hexane)	56.6	55.9

	10 August	13 August	17 August
U	16.3%	34.7	65.2
U	6.8	12.9	17.4
	70.0	43.1	14.5
C	4.3	5.0	2.9
	2.6	4.5	---
M	---	---	---
L	---	---	---
U	---	---	---
Total ppm (hexane)	15.6	13.5	9.2

STABILITY OF VENEER DRYER EMISSIONS STORED IN CARBOY

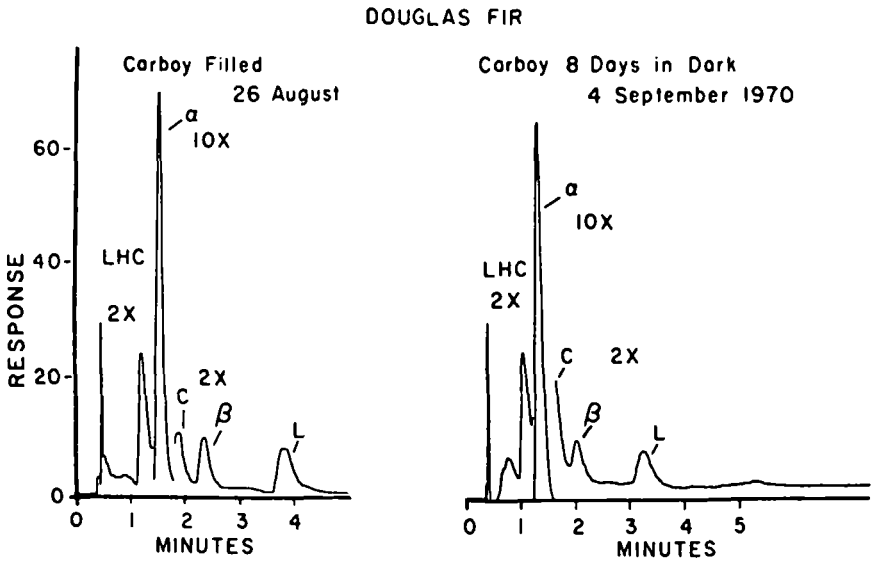


Figure 36 Dryer #28

	26 August	4 September
U	.4%	.6%
U	5.4	5.3
	82.3	79.6
C	2.7	6.0
	3.7	3.1
M	.4	.4
L	5.0	4.5
U	---	.5
Total ppm (hexane)	53.4	53.2

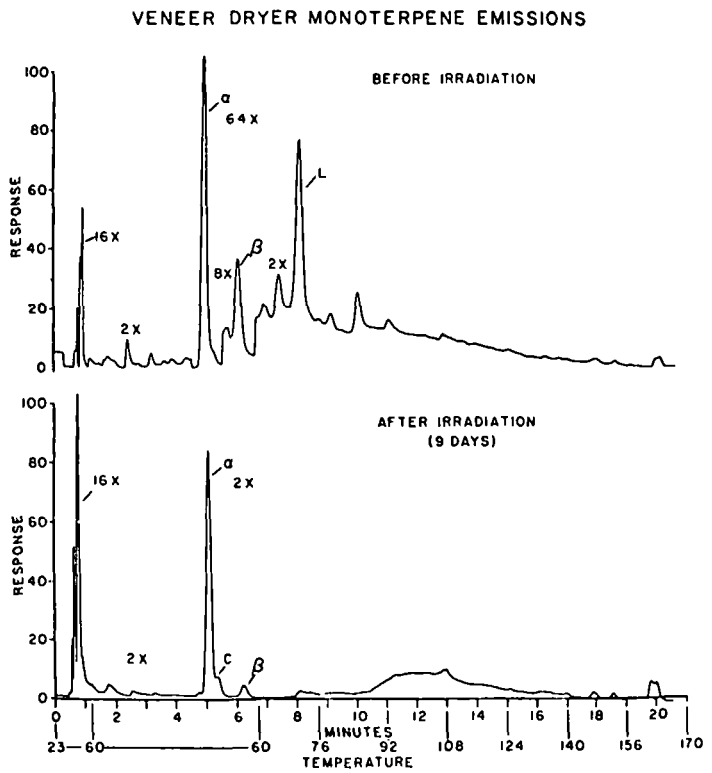


Figure 37 Dryer #28

4 September 1970

Shows:

1. Loss of terpenes
2. Increase in LHC
3. NO increase in higher boiling materials

disappearance of α pinene and the other monoterpenes is the appearance of the light hydrocarbon peaks.

Figure 36 shows a similar study made on the emissions from Dryer #28. The thermal deposition of the monoterpenes was again neglible for eight days storage period.

Figure 37 shows a programmed temperature analysis of the monoterpenes in the carboy (Dryer #28) before irradiation and after nine days of irradiation. The photochemical reactivity of the monoterpenes is evident in the 45-fold decrease in the concentration of these chemicals. The increase in light hydrocarbon compounds is similar to that observed in the analyses shown in Figure 35 for Dryer #09. The programmed temperature analysis did not resolve any significant increase in higher molecular weight materials.

b. Condensed Hydrocarbons

(1) Analysis by Gravimetry

The condensate residues obtained in the Rinco evaporating flasks had an odor similar to slightly charred wood. The odor was the same as that surrounding the stacks. The residue appeared to be a yellowish emulsion mixed with a clear liquid which had a yellow to amber color. The rotating flask gained appreciable weight after it was taken off the Rinco apparatus and no longer under vacuum. The most probable cause for this gain is the absorption of atmospheric water vapor since the gain was reversible; that is, if the flask was put on the Rinco and evaporated again under original vacuum conditions, the original weights would be obtained at the start, and the observed weight gain would occur again. For this reason the flasks were allowed to sit within the laboratory for a period of time (3 hours or more) to

reach an equilibrium point so that the weight reported had a constant value. The gain was generally less than 2%.

Tables III through X summarize results for condensable hydrocarbons. Table IX gives results for replicate samples. Table X contains values for hydrocarbon emissions normalized for 1000 SCFM at standard conditions.

(2) Representative GC Profiles of Condensed Hydrocarbons

The GC analysis of the condensate residues (Dryer #12) from stack #1 and stack #2 are shown in Figures 3 and 39. The retention times at which α pinene and α terpineol should be eluted are marked in these figures. It can be seen that these two terpenes were not detected in these analyses.

Figure 38 shows the analysis of 1 μl volume of a 1.2% solution of the residue from stack #1 in acetone. The chromatogram is dominated by one peak, resolved at 240°C, attenuated to 128X, range 10. The identity of this compound is unknown, but it is believed to be a hydrocarbon. This peak represents 70% of the components resolved. Based on the use of the internal standard (diethylphthlate), the peaks eluted in this chromatogram of the residue from stack #1 account for only 35% of sample injected.

Figure 39 presents the analysis of 1 μl of a 2.8% solution of the residue from stack #2 in acetone. This chromatogram is strikingly different from Figure 38 in that (1) many more components are resolved, (2) the chromatogram is not dominated by one peak but rather by three peaks resolved between 226 to 244°C, and (3) these peaks are attenuated to 64X, range 10.

The identity of these compounds is unknown. This group of peaks represents 54% of the composition resolved; and from the internal standard, only 39% of the sample is

eluted from the column. The inability to elute 60 to 65% of the residue from the low level silicone oil GC column (2% SE-30) prompted TLC and IR analyses.

(3) TLC of Condensed Hydrocarbon

Benzene was the best solvent for the TLC analysis, chloroform the next best, and acetone the least. No differences were observed between stack #1 and stack #2 residues.

The plates run in benzene separated the residue from stack #1 and stack #2 into four components (Figure 40). The bulk of the material was separated into two components, one of which remained at the origin, the other moved 30% of the distance of the solvent front and tailed badly. The third component moved 50% of the distance of the solvent front and appeared as a weak, diffuse spot. The fourth component moved close to the solvent front as a strong and coherent spot.

The separations obtained in chloroform were similar to those obtained in benzene with the exception that the spots were less well resolved. In acetone (Figure 40) the residue moved as a cohesive spot close to the solvent front but showed considerable tailing.

(4) IR Analysis of Condensed Hydrocarbon.

The spectra obtained for the residues from stacks #1 and #2 (Figure 41) were similar to the Sadtler spectrum #D1173 of pitch, a mixture of residue and oils from treatment of pine wood. These spectra also resembled the spectrum of abietic acid (Sadtler #3963) also shown in Figure 41 for comparison. However, both residue spectra have considerably more structure between 8-15 microns than either of the two reference spectra.

VENEER DRYER CONDENSED TERPENIC EMISSIONS

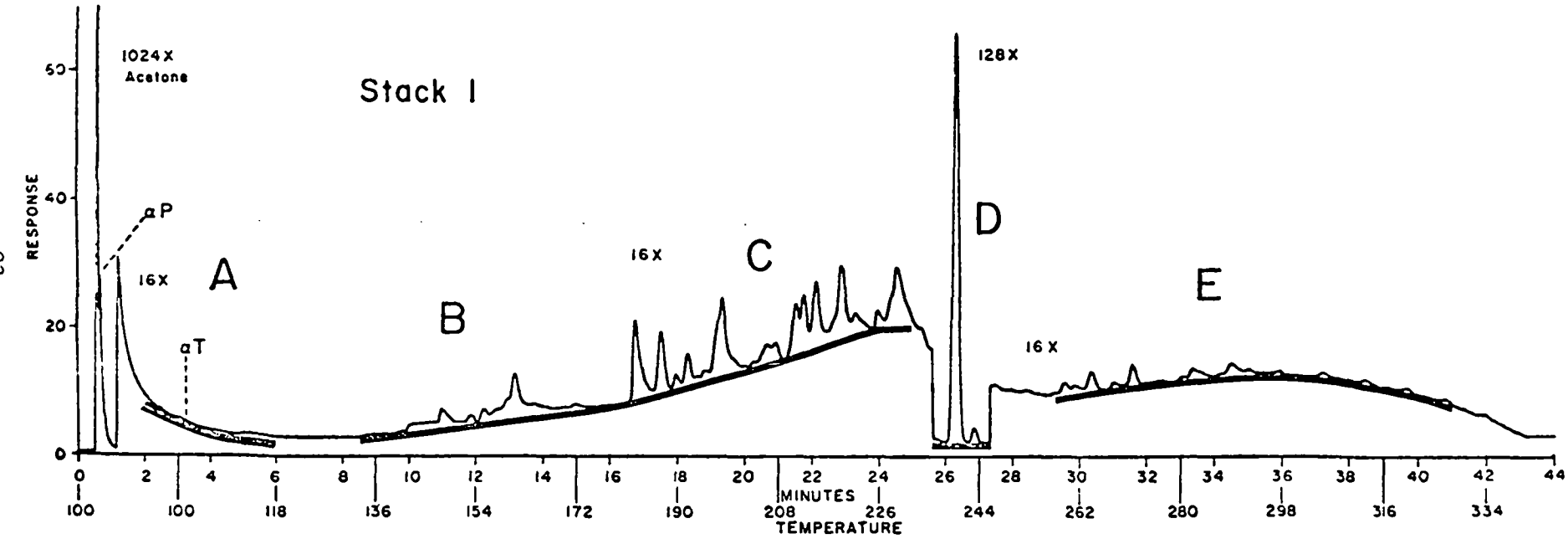


Figure 38
15 July 1970
Dryer #12

A = 1.4%
B = 8.4
C = 16.7
D = 70.1
E = 3.5

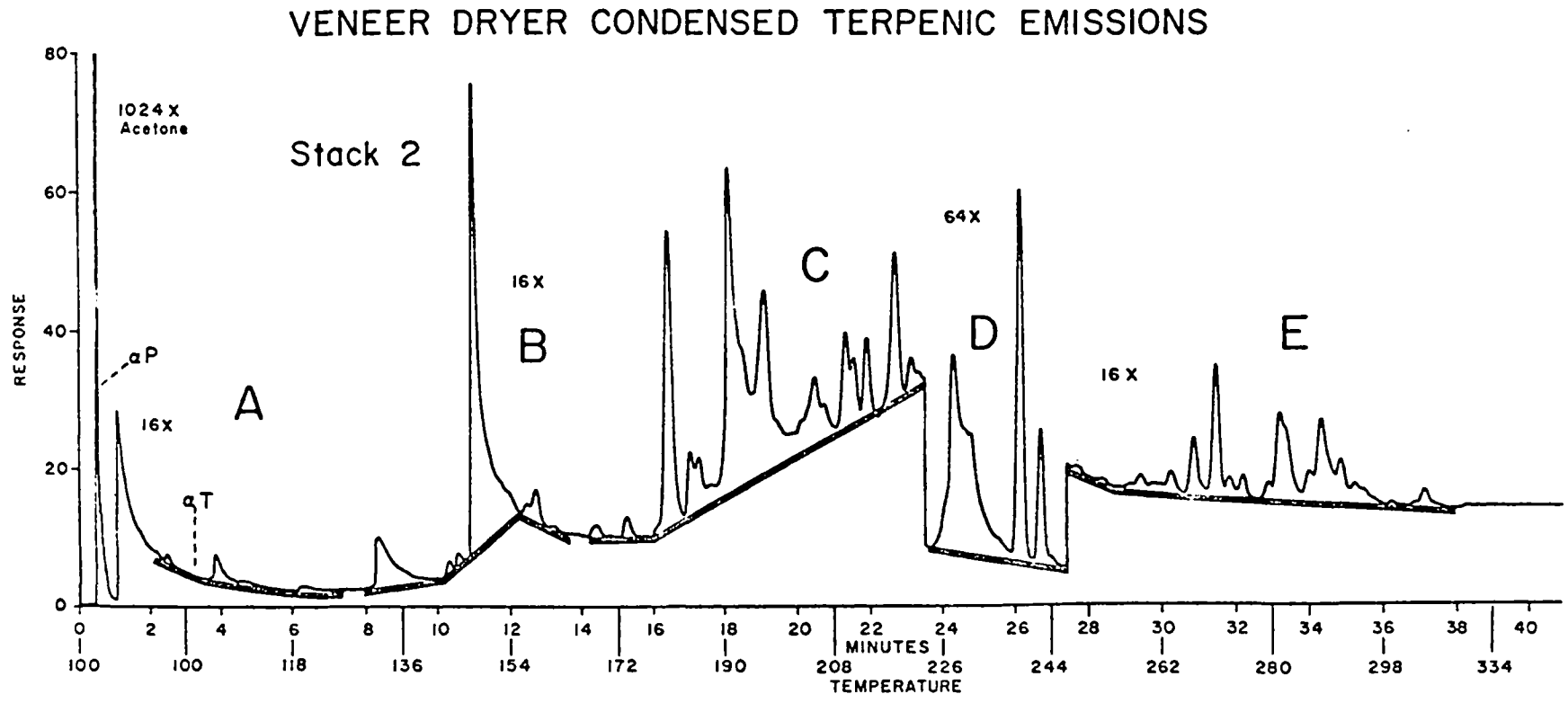


Figure 39

15 July 1970
Dryer #12

A = 2.3%
B = 9.9
C = 23.9
D = 54.1
E = 9.7

Figure 40
15 July 1970
Dryer #12

TLC OF STACK 2 RESIDUE

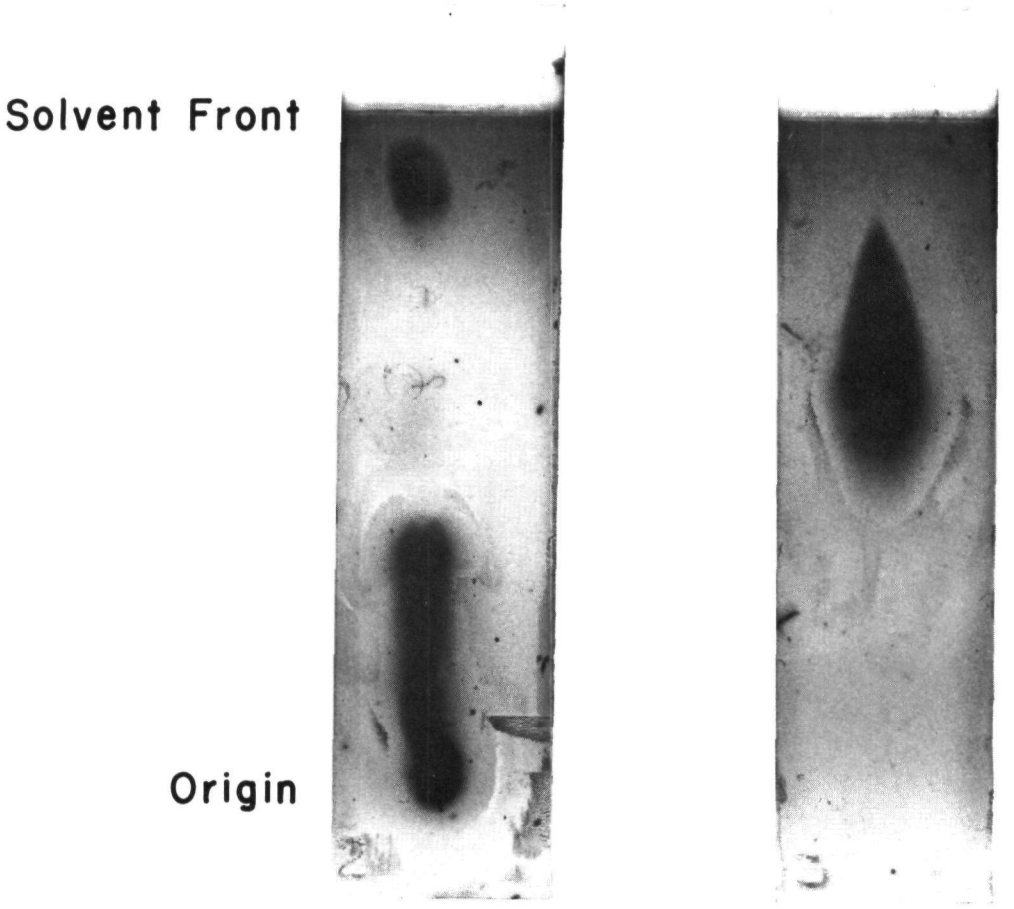
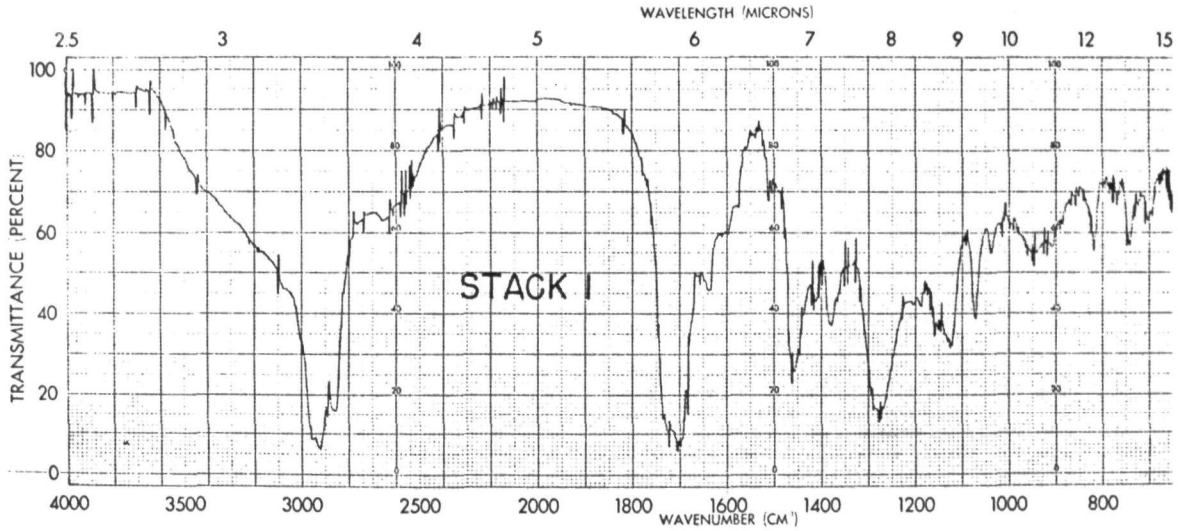
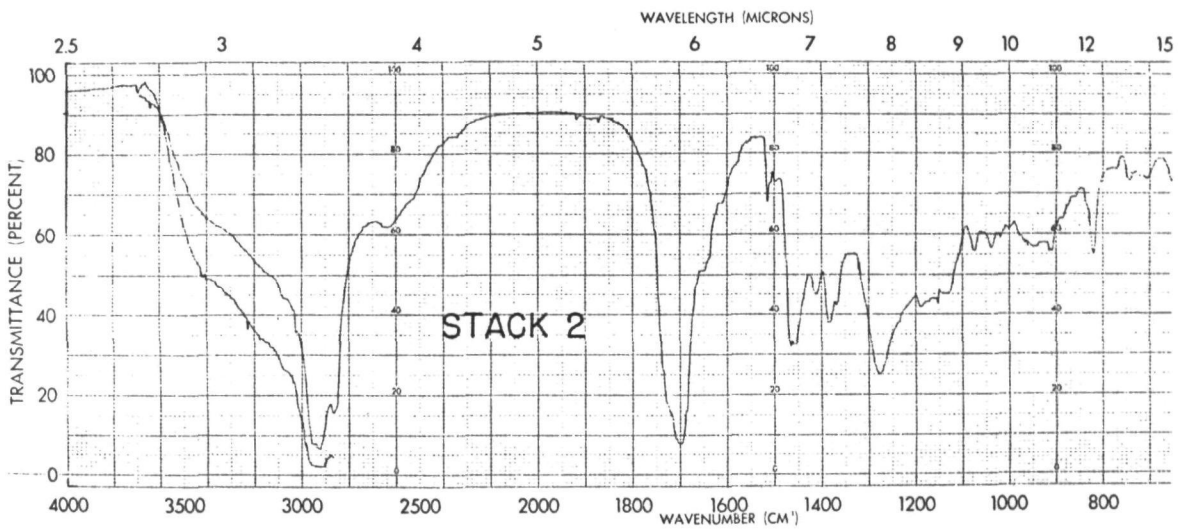


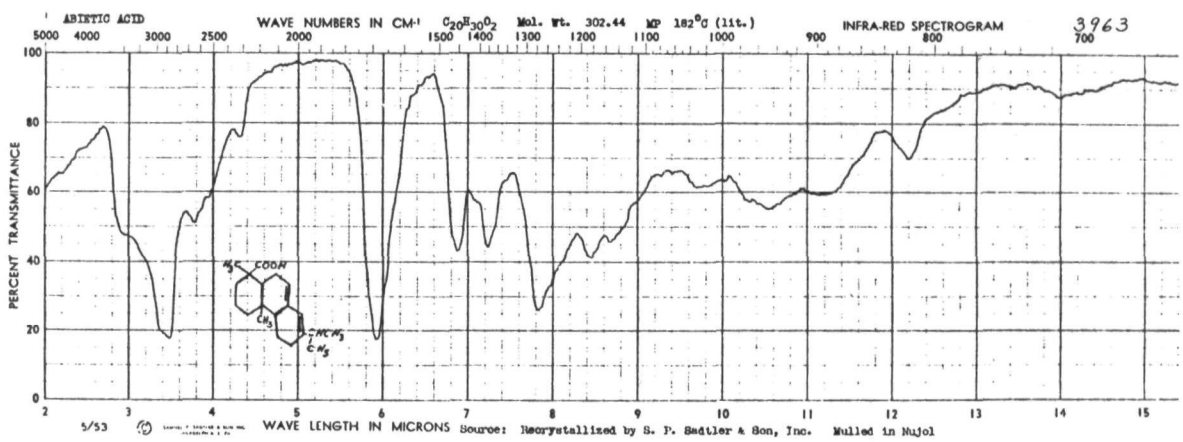
Figure 41

15 July 1970

Dryer #12







Minor differences between the spectra for stacks #1 and #2 were also observed. The spectrum for the residue form stack #1 had slightly more hydrocarbon structure than the spectrum for stack #2 between 8-15 microns. Also the spectrum for stack #1 had a more intense double bond absorption band at 6.1 mccrons. However, the hydroxyl absorption at 2.8 - 3.1 microns was more intense in the spectrum for stack #2. The spectra obtained are appropriate for a 60-65% concentration of abietic acid in a mixture of various sesquiterpene hydrocarbon components. The finer hydrocarbon structure between 8-15 microns approximates this level of associated composition. Therefore, the tentative identification of the bulk of the residue as a type of abietic acid (a resin acid, $C_{20}H_{32}O_2$) is warranted by the close similarity of the IR spectra.

4. Particulates

Wood splinters were the primary solid particulate collected on the Hi-Vol filters at stack temperatures. No condensed hydrocarbons were evident on the filters. Particulate concentrations in grains/dry standard cubic feet were calculated from the particulate weight collected at stack temperatures. Stack #1 of dryer 09 yielded concentrations from 0.00122 to 0.00236 gr/dry std ft^3 (see Table XI).

Size distribution was determined for particles collected from diluted stack gas at 70-75°F in the dilute gas sampling train using a Unico impactor. Twenty-minute samples were taken at a flow of 0.3 CFM. These impactor plates showed about 5-10,000 particles in the 1-10μ range, 5-10 particles in the 50-400μ range, and a few particles larger than 400μ. The particles were generally spots of a clear oil, a clear yellow resin, small black spots, wood and wood fibers (see Table XII). The particle size measurements obtained from the Unico impactor

TABLE XI

HI-VOL DATA ON DRYER #9

Stack	Sampling Point	Nozzle Size Inches	Sample Time Min.	Rotameter Reading Maintained CFM	Air Sampled Ft^3	Air Sampled Dry, Std Ft^3	Filter Wt. Gain Grams	Concentration Grains/ Std Ft^3
1	A1	1.5	30	40	1200	739.33	0.0825	0.00172
1	A1	1.5	30	40	1200	724.80	0.0574	0.00122
1	A1	1.5	8:10	40	326.4	188.24	0.0288	0.00236
1	B3	3.25	60	*	10400	5934.14	0.7679	0.00199
1	B3	3.25	60	*	12000	6839.40	0.7679	0.00173
2	A3	3.0	30	33	990	582.12	0.0339	0.000898
2	A4	3.0	30	32	960	536.84	0.0240	0.000703

* No Hi-Vol motor used and no Hi-Vol filter used.
Sample collected directly on screen support (for filter).
Flow due to jet velocity of stack.
One collection, calculated for measured flow through screen and for stack flow.

TABLE XII

PARTICLE SIZE DISTRIBUTION
WITH UNICO SAMPLER IN SAMPLING TRAIN

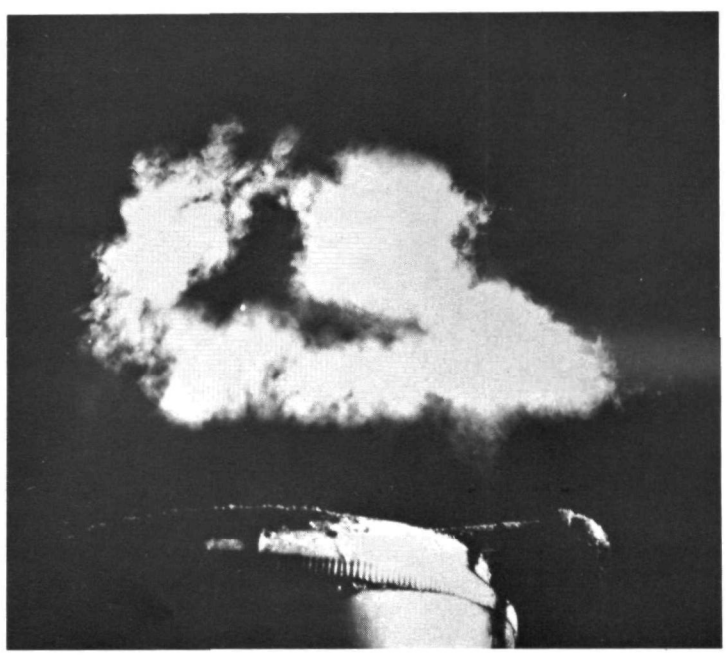
Location	Species	Stack	1-10μ	10-50μ	50-400μ	400+μ	Appearance
#12	fir	1	47	30	1	0	Clear yellow resin & wood.
	fir	2	365	52	4	0	Clear resin & wood.
9	fir	1	3791	1	0	0	Clear yellow resin & wood.
	fir	1	6483	11	8	0	Clear resin & wood.
	fir	1	3972	77	2	2	Clear yellow resin & wood.
	fir	1	8325	32	1	0	Opaque black spots & yellow resin.
	fir	1	7740	58	4	1	Clear yellow resin & wood.
	fir	1	12560	251	7	0	Clear yellow resin & wood.
	fir	2	2758	13	1	0	Clear yellow resin & wood.
	fir	2	12638	148	8	2	Clear resin & wood.
	pine	2	81	17	6	1	Clear resin & wood.

VENEER DRYER STACKS
ON DRYER #9
USING STROBE-LIGHT PHOTOGRAPHY

Picture #1: Direct lighting,
No Mask.
Stack #1.

Picture #2: Mask used,
Slit vertical.
Stack #1.

Picture #3: Mask used,
Slit vertical.
Stack #2.



Picture #4: Mask used,
Slit horizontal.
Stack #2.

samples obtained from the gas dilution system used earlier are of doubtful value in view of the apparent collection of more than 90% of the "total" hydrocarbons on the interior wall of the gas dilution system tubing.

The strobe light pictures clearly show the structure of the developing plume (see Pictures 1-4). The stack gases were clear (except for a few wood particles) as they left the stack. Initial particulate development (condensation) began at the extreme outer edge of the gas stream. The pictures taken with the slit held horizontally show very clear ring-like or doughnut shapes. The clear volume in the center of the developing plume was conical. Vertical cross sections show the cone which extends 3 to 5 ft above the stack (24 in. diameter). A stronger side scatter effect than back scatter was observed in the plume. The emission had the general appearance of a bunsen burner flame with the clear cone of hot stack gas analogous to a bunsen burner's reducing flame.

5. Veneer Dryer Operations

Dryer operations were held essentially constant except for drying time and veneer type. The following average production figures are calculated using measured drying times. The maximum average production figure was observed on dryer #19, drying Douglas fir heart at 16,410 ft^2/hr of 3/8" plywood. The minimum was observed on dryer #12, species Douglas fir sap, producing 3,474 ft^2 of 3/8" plywood. Average production figures were generally constant on a daily basis and were characteristic of the species type being dried.

The weight loss of veneers being dried was usually less than 10g on the third run. Douglas fir heartwood veneers usually weighed about 2,000 grams and Douglas fir sapwood about 4,000 grams. After the third pass, both heart and sap usually weighed about 1,500 grams. Each dryer and

species combination was checked (two exceptions) for percentage moisture through the dryer. Most veneers weighed were 27" x 100" x 0.1" in size.

One of the dryers tested was modified by project personnel with a barometric-type, trap-door damper made of plywood. The dryer tender agreed that the modification allowed him to operate the dryer at higher than usual production rates.

Table II, Description of Dryers and Averages of Veneer Moisture Content, summarizes information describing the dryer type, size, number of stacks, etc., and gives average values for veneer moisture contents along with average drying time figures for the species type as dried in a particular dryer.

6. Error Analyses

Error of input datum for the longitudinal dryer was estimated to be: ±2.2% for production, ±0.2% for barometric pressure, ±0.3% for dry bulb temperature, ±0.7% for wet bulb temperature, ±2.5% for CO_2 and O_2 concentrations, ±1.5% for the square root of the velocity pressure, ±0.8% for stack diameter measurements, and ±5.0% for the representative volatile hydrocarbon values. Using these figures the error of the results of the stack analysis program is estimated to be: ±3.3% for H_2O percent, ±0.2% for gas density, ±1.3% for stack gas velocity, ±2.0% ft^3/min actual volume flow, ±2.6% ft^3/min standard volume flow, ±6.4% for H_2O emission in lb/min, and ±7.6% for volatile hydrocarbon emission. Values for jet dryers showed smaller error than reported for the longitudinal dryers above. All error for jet dryers was within ±2.0% except for H_2O lb/min at ±3.8% and volatile hydrocarbons at ±3.1%. Overall error in the measurement of condensed hydrocarbons is estimated to be ±8.9%

The error in the volume of stack gas sampled is estimated to be as high as ±8.4%, allowing ±2.8% error in rotameter

readings due to calibration and reading errors, ±1% in sampling time, and ±3% in the pressure correction factor which combines error from barometric readings and the vacuum gauge. The error of weight gain (due to atmospheric water) of the condensable sample after the completion of evaporation is assumed to be ±0% by the method used because the weights were allowed to stabilize (the method used would be repeatable if identical techniques were used).

The average hydrocarbon emission from all veneer dryers tested was 5.70 lbs of hydrocarbons per 10,000 ft^2 of 3/8" plywood produced per dryer (production basis) of which on the average 3.59 lbs were condensable and 2.43 lbs were volatile. (These two figures do not total 5.70 lbs because three more samples of condensables were taken than of volatiles see Table IV, Steam Dryers). The averages for steam-heated dryers were 5.16 lbs of total hydrocarobns consisting of 2.16 lbs of condensables and 6.16 lbs of volatiles. These figures are all given on a production basis. Averages on a species basis are given in Tables V, VII, IX.

7. Condensation Temperature of Plume

Attempts were made to determine the temperature of the condensing plume using an infrared optical thermometer. However, an unknown emissivity of the plume precluded an accurate measurement. Estimations of the emissivity were made with a steam plume with a known temperature of 209°F, and it was determined that the emissivity of a veneer dryer plume may approximate 0.4. This value, however, was at the low end of the scale of the instrument. It is difficult to determine whether a correct value for emissivity was actually determined. Using this value, however, and aiming the device at the densest portion of the plume, at night, a temperature reading of about 180°F was obtained. This temperature is perhaps approximately the temperature at which a large portion of the hydrocarbons that form the blue haze condensed.

DISCUSSION

1. Gas Velocities and Flow Rates

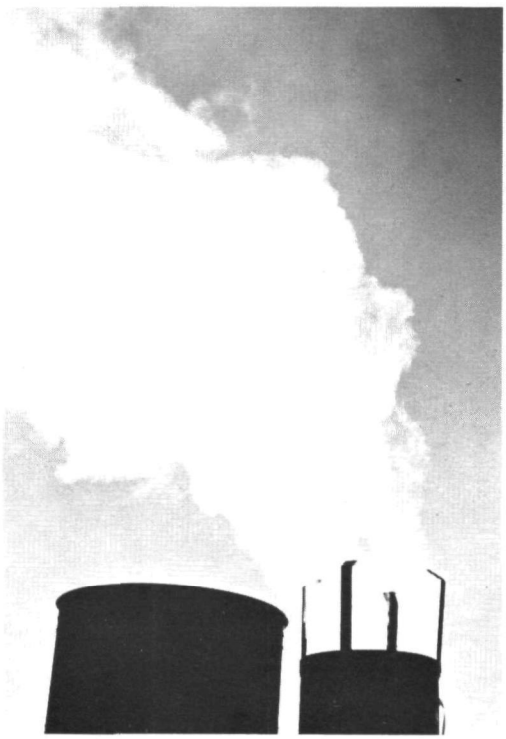
The average stack velocities observed in dryer stacks varied depending on the damper setting. The stacks with the highest stack velocity generally had emissions with less opacity than stacks with a low velocity. Low velocity stacks generally had a very obvious blue-haze plume. Jet dryer stacks usually had the lowest velocities (1000 ft/min or less) and most commonly had visible steam plumes also. No dryer that had a high stack velocity (2000 ft/min and higher) had a steam plume evident and generally very little blue haze. See Pictures 5-19.

Total volume flow out the dryer was calculated from stack cross-sectional area and stack velocity. The total volume flow varied as did velocity with stack damper setting. Increased volume flow out the stack would indicate a higher number of air exchanges within the dryer per unit time with a corresponding lessening of water and hydrocarbon concentrations in the stack emission. Equivalent opacity of the stack plumes can be greatly reduced by opening stack dampers and increasing stack flow, but process costs increase because of increased heat losses.

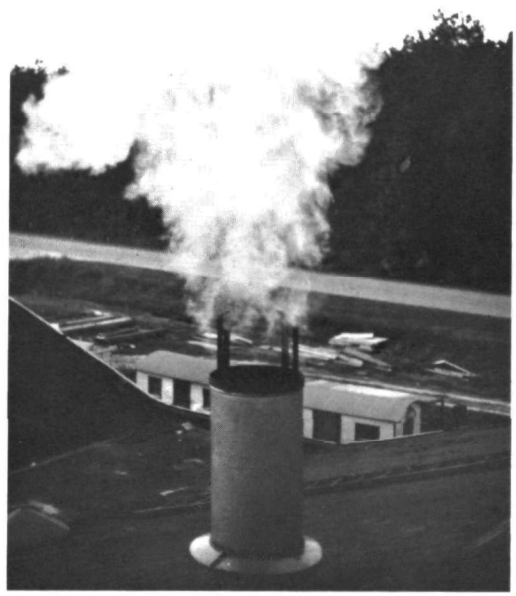
In terms of production of high quality plywood, however, it is desirable to maintain the highest concentration of water vapor within the dryer as possible, for two reasons: (1) the specific heat of water vapor is about twice that of air and (2) the equilibrium moisture content of wood, in 100% moisture (live steam) is 1% by weight, dry-basis, above 350°F.

Heat is used to dry wood veneers because raising the temperature results in faster drying rates. Increased heat is desirable to attain maximum production levels. Increased temperature and increased specific heat of the dryer gases would provide the desired heat. The upper limit for temperature is approximately 360°F since case hardening and surface inactivation effects begin to be troublesome in the gluing process. The other and most desirable method of increasing heat in a dryer is by

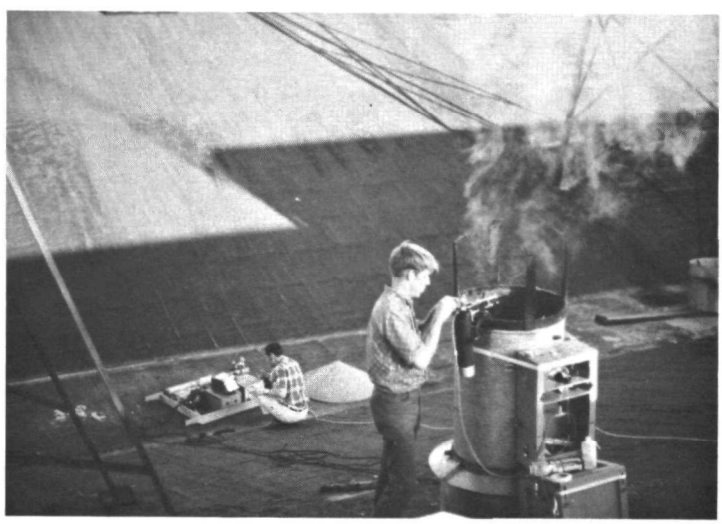
VISIBLE EMISSIONS, MOSTLY WATER VAPOR, FROM DRYER #32



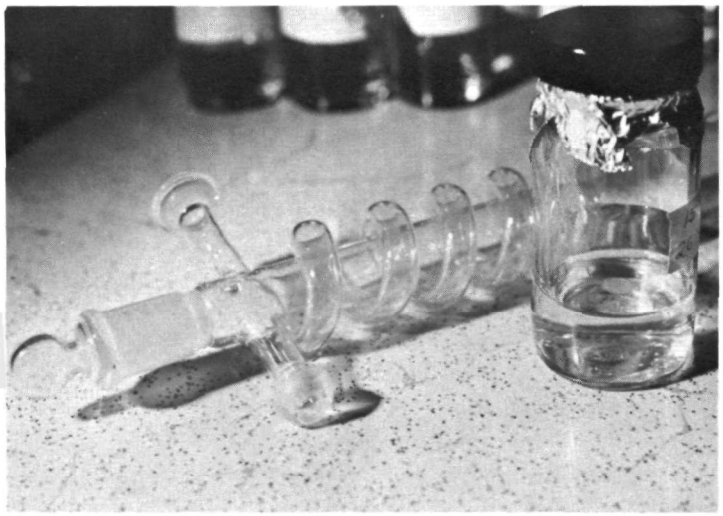
Picture #5. Backlighted with sky as background.



Picture #6. Sidelighted with dark trees and sky as background.

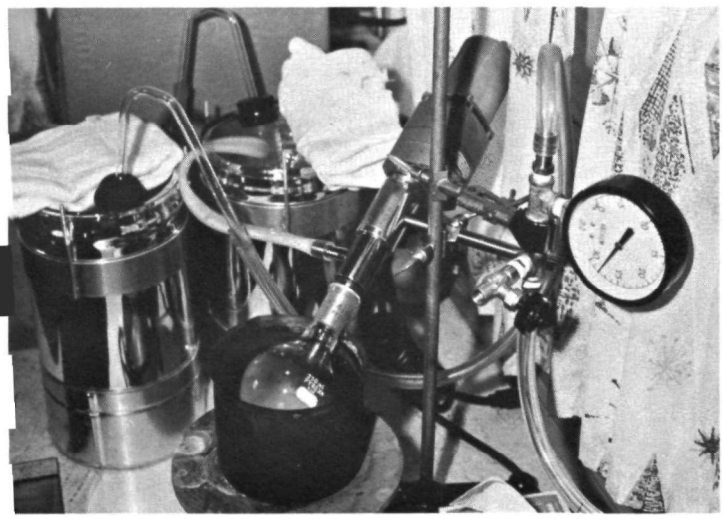


Picture #7. Forelighted with plant roof as background.



Picture #8. Top of glass condenser used in sampling train and sample bottle. Sample entered through glass coil.

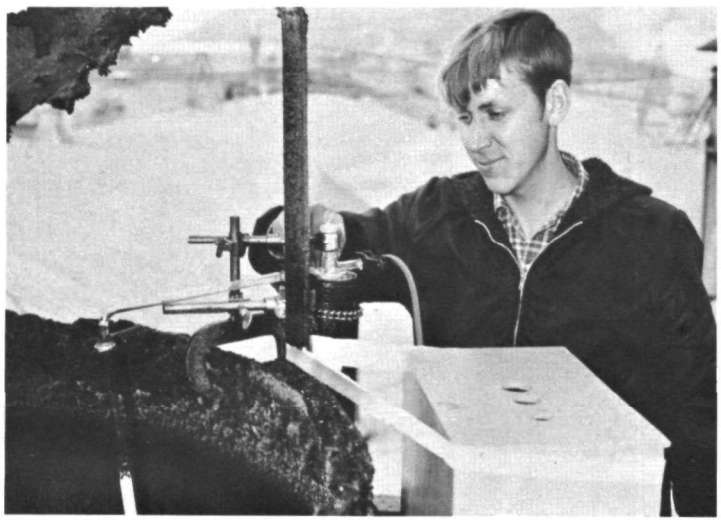
Picture #9. Collection reservoir of glass condenser and a sample bottle.



Picture #10. Rinco evaporating apparatus.

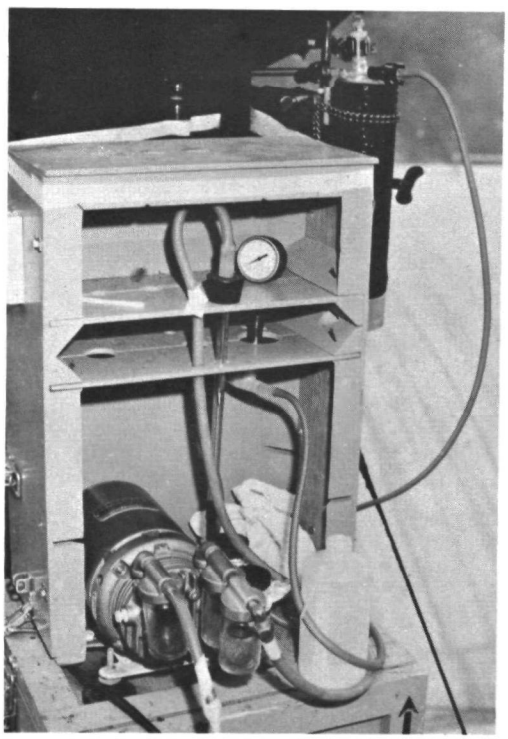
Picture #11. Close up of rotating flask on Rinco apparatus, showing milky mix of condensable hydrocarbons and water.

DETAILS OF STACK SAMPLING TRAIN WITH CONDENSER

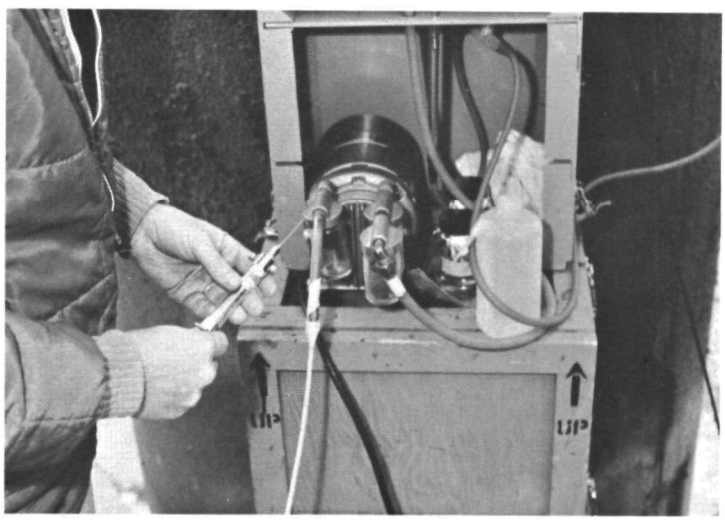


Picture #12. Fritted glass sampling probe.

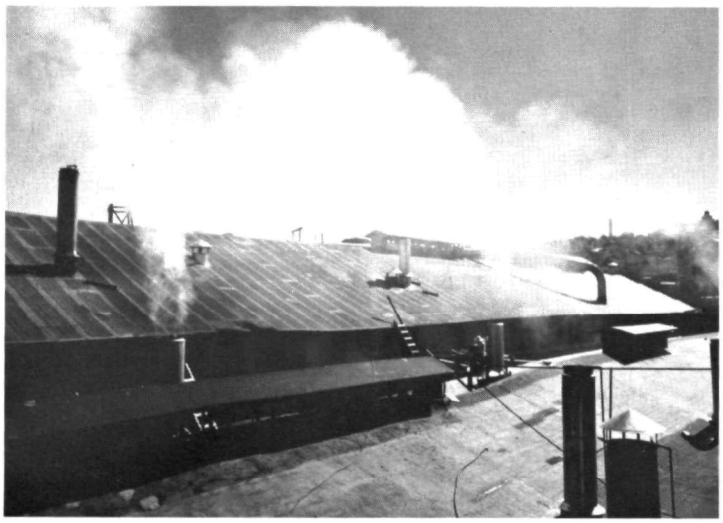
Picture #13. Glass condenser on stack in ice-water bath.



Picture #14. Vacuum guage, rotameter & vacuum pump.



Picture #15. Volatile samples taken for gas chromatograph at outlet of pump.



Picture #16. View of visible emissions from Dryer #9.

Picture #17. Method used to obtain wet-bulb temperatures.

Picture #18. Total Hydrocarbon Analyzer

Picture #19. Gas chromatograph in field laboratory.

concentrating the water content of the gases within the dryer by operating it with the dampers closed as far as possible. Since the equilibrium moisture content of wood in 100% moisture (live steam) is 1%, above 350°F it would appear that the wood can be dried most effectively with maximum moisture content within the dryer. The data generally indicate that increased moisture concentration in stack gases will increase production.

The purpose of veneer dryer stacks appears to have very little to do with proper operation of the dryer as long as the dampers are closed. Their prime purpose appears to be to rapidly cool the interior of the dryer should it be necessary to gain access to the inside of the dryer during a work shift (under plug-up conditions, for example). It was observed in the field that many dryer tenders have the misconception that the dampers should be kept open at least partially and that the inside of the dryer should be kept as dry as possible to obtain optimum drying conditions.

2. Hydrocarbons

During the earlier phases of the project, hydrocarbon materials were seen condensing on the outside of objects placed in the stack and on the inside of sampling lines. This condensate was presumed to be responsible for the bulk of the condensing blue haze emission. It condensed very quickly outside the stack after being cooled below stack temperature as revealed by the immediate appearance of the emission from the stack. Visual evidence indicated that the emission would condense into yellow resinous droplets similar to those observed later in the Rinco evaporating flask. It is estimated that these materials condensed at a temperature above 100°F, perhaps as high as 180°F.

When veneer species were switched from Douglas fir to ponderosa pine on two dryers, the observed increase in visible

emissions was not accompanied by a corresponding increase in volatile hydrocarbon emission. This fact provides further evidence that the visible emissions are related to hydrocarbons which have temperatures of condensation above 100°F. Douglas fir heart, ponderosa pine, and white pine generally produced the most visible emission. Hemlock and white fir generally produced the least blue haze. Volatile hydrocarbon levels from the hemlock and white fir were also very low.

3. Qualitative Analysis of the Major Hydrocarbon Components

In addition to carbohydrate (cellulose), lignin, and water, wood contains smaller amounts of other substances. Some of these substances are volatile; others are characterized by their solubility. The fresh limpid oleoresin exudate on the surface of the veneer peels is a solution of resin acids and neutral bodies in turpentine. During the drying process, the distillation of the volatile terpenes, terpene alcohols, sesquiterpenes, resin acids, fatty acids (free and combined), resin esters, waxes, and resin alcohols is expected.

In the analysis of the hydrocarbons in the stack gas, two fractions were encountered: a volatile terpene component and a condensed hydrocarbon fraction. The volatile terpenes were expected. The GC conditions for their analysis were determined in the preliminary study. These conditions were the only GC conditions used in the *in situ* analyses at the eight plants studied. In the preliminary study, gas samples were taken from the dryer through a partially opened door. Both direct syringe samples and freezeout collections were made. The GC analyses showed only monoterpene compounds even though a considerable effort was made to detect oxygenated monoterpenes and sesquiterpenes in the cryocondenser samples with the Perkin Elmer 990 GC. The analyses showed very low levels of these higher boiling materials.

There are several possible reasons for not detecting these higher boiling materials. (1) Most of the material condensed in the sampling line (a 6 ft, 3/16 in. O.D., #304, S.S. tube). (2) The material that did condense in the cryocondenser did not volatilize to an appreciable concentration at the 50 and 100°C temperatures used for sampling the headspace. (3) The condensate in the cryocondenser cannot be analyzed unless removed with a solvent such as acetone. A scheme of analysis involving each of the above considerations should provide a balanced analysis of the volatile and condensed hydrocarbon fractions in the stack gas.

On 24 and 25 June 1970, further studies were made of the #4 stack of dryer #05. Both direct syringe samples and freeze-out collections were analyzed. The analyses made of 1 ml vol samples on the Carle 9000 GC at the site showed only volatile hydrocarbons (Figure 42) methane, ethylene, ethane, and propane at 100-130 ppm (hexane). The presence of these compounds is undoubtedly related to the natural gas used to fuel the gas-fired dryer. The concentrations of monoterpene hydrocarbons (Figures 42 and 43) emitted during the drying of Douglas fir ranged from 7 to 15 ppm (hexane). A second series of gas chromatographic analyses were made on another gas-fired dryer (#23) with similar results (Figure 44).

Analyses of the emissions of Dryer #09 for methane, ethylene, ethane, and propane showed very low levels of these gases (less than 4 ppm). Figures 1-8 show that the volatile hydrocarbons in the stack gas are almost entirely composed of five monoterpene hydrocarbons, α pinene, camphene, β pinene, Δ^3 carene, and limonene at concentrations of 5 to 748 ppm (hexane) as measured in a 1 ml sample. Programmed temperature GC analyses of 5 ml volume gas syringe samples and freezeout collections obtained at several dryers did not show any significant concentration of terpene alcohols or sesquiterpene hydrocarbons (Dryers 05, 09, 12 and 28).

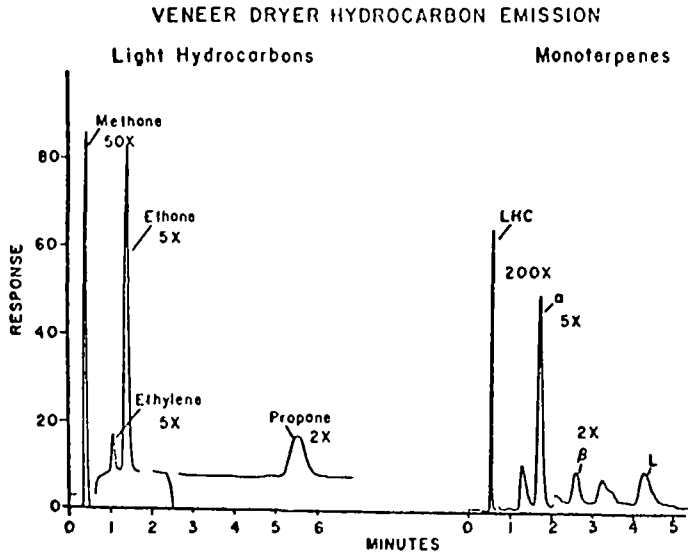


Figure 42

25 June 1970

Drver #05

	LHC		Terpenes
M	84.4%	α	63.8%
E	1.6	C	1.4
E	12.1	β	5.0
P	1.9	L	8.1

Total ppm (hexane)

125.6 14.8

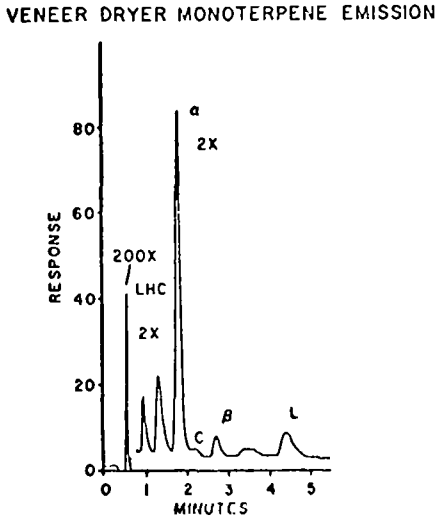


Figure 43

24 June 1970

Drver #05

α	42.0
C	1.6
β	6.2
L	16.3

Total ppm (hexane)

7.4

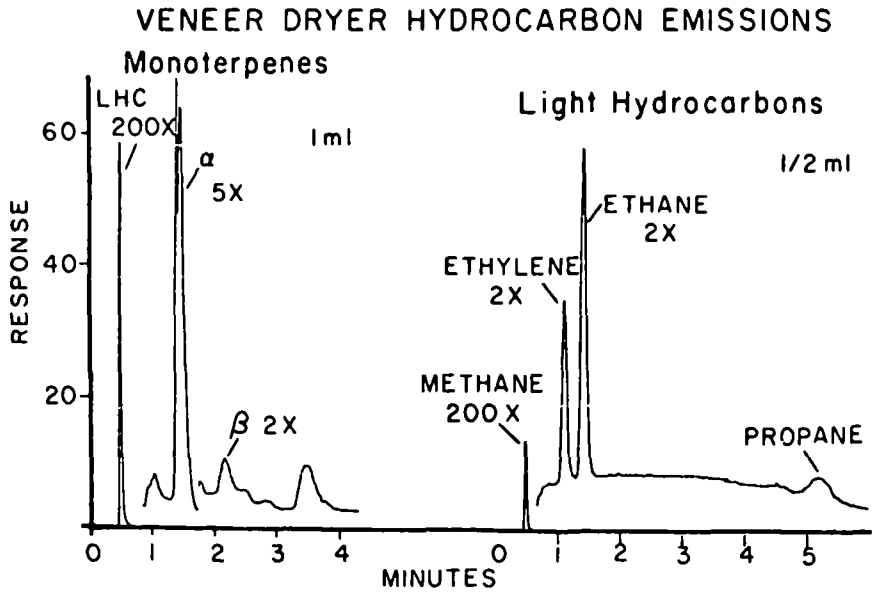


Figure 44 Dryer #23

21 September 1970 1315 hrs

	Monoterpenes		Light Hydrocarbons	
	1	2		
LHC	----	88.0%	M	87.0%
U	2.8%	.3	E	3.5
α	77.8	9.3	E	6.3
C	2.4	.3	P	.8
β	6.5	.8	P	2.4
U	2.4	.3		
M	1.2	.2		
L	7.1	.8		
Total ppm (hexane)				
	34	102.1		34.1

Column 1, LHC not included in calculations
Column 2, LHC included in calculations

At present the Carle 9000 used for on-site GC analyses is limited to the resolution of volatile hydrocarbons at the existing stack concentrations. However, the Carbowax 20M column operated isothermally between 71 to 78°C will elute terpenic compounds out to and beyond α terpineol (56.4 minutes); but in order to be resolved as distinct peaks, compounds with retention times greater than that of α terpinolene (5.3 ±.1 minutes) must be at concentrations greater than 10 ppm.

The heavy components distilled from the oleoresin in the veneer peels are believed to be the condensate recovered in the acetone washings. This same condensate is also believed to be the source of the blue-haze plume emitted by the veneer dryer.

The GC data from the analyses of the residues indicated that 60-65% of the sample injected would not elute from the column. This is to be expected if the residue consists primarily of resin and fatty acids.

The TLC data suggested that the bulk of the residue is acidic as evidenced by the strong tailing of the separation. Also a major portion is highly polar as indicated by the material which remained at the origin (in benzene and chloroform). A minor fraction of the residue is moderately nonpolar and moves with or close to the solvent front (in benzene and chloroform).

The single, cohesive, strongly tailing spot obtained in the acetone solvent system supports the interpretation that the bulk of the residue is a highly polar acidic material.

The IR spectra indicate that a mixture of the isomers of abietic and pimaric acids may be the major portion of the residue. Abietic acid is an oxidation product of the diterpenes and has the empirical formula $C_{20}H_{30}O_2$. It is recognized to be the major constituent of coniferous oleoresins.

4. Particulate

The most important particulate in the veneer dryer operations develops outside and above the stack after the emission has cooled

below stack temperatures and consists largely of the hydrocarbon material collected in the condenser.

The only significant particulate in the emission at stack temperature is wood fiber. Gas dryers had a very slight haze within the stack at stack temperatures. The concentrations of wood particles are very low, generally below 0.002 grains per dry standard cubic foot. These values were found to be so low in preliminary investigations that subsequent measurements of these values were not made. Particle counts were made using microscope slides as impactor plates from Unico Cascade impactor.

Significant quantities of hydrocarbons condensed on the inside of the sample dilution system tubing. As much as 90-95% of the condensed hydrocarbons may never have reached the Unico impactor when it was in the sample line; therefore, the reported counts were of questionable value. Impactor samples, taken with the sampler held in the plume, showed an overload of an oil on the microscope slides. Oil droplets had coalesced on the slides after only 30- second exposures making it impossible to count or size particles. Thirty-second exposures of clean slides inserted directly into the plume showed the same coalescence of oil on the slides. Spread factors for this material on glass slides was unknown also.

The strobelight pictures show an especially clear and well-defined plume formation from dryer #9 drying Douglas fir sap. The structure of the plume was not as well defined at other mills, perhaps due to higher stack velocities, which produced turbulence and distortion within the plume, ambient wind velocities, condensable hydrocarbon concentrations, and other factors.

5. Veneer Dryer Operation

Several difficulties were encountered during the sampling program which were beyond our control. The most important problem involved the unexpected switching from species to species and from heart to sap wood. The switching occurred with such

frequency in some cases that no separation of sap or heart wood data was possible. Therefore, the data is reported as sap wood. (A sheet of veneer is typically dried as sap if it contains as little as 5% sap wood). Another problem involved a discrepancy between the drying time as reported by dryer tenders and drying time as measured by survey personnel. Therefore, drying times were measured with a stopwatch on a single section basis and then multiplied times the number of sections in the dryer.

The expertise of dryer tenders appears to vary widely. Often after a species change a different drying time would be required. Sometimes no change in drying time was made for half an hour or so. Occasionally the tender was not aware of the drying time being used. Other tenders knew very accurately what drying time would be required for a species type depending on its source or storage conditions of the wood and made fine adjustments constantly. They would use temperature chart tracings, percentage of veneer marked wet by the moisture meter at the dry end of the dryer, or sometimes they would make corrections on the basis of "how she sounded."

Well-defined relationships between amount of production and water vapor and hydrocarbon emissions from the stack were difficult to make because many variables impinge upon the problem. For example, as stack dampers are increasingly closed, an increased "emission" of dryer gases will occur around the body of the dryer within the mill; along its sides, around the section doors, and at the green end and dry end where the veneer enters and exits from the dryer. Mill personnel generally prefer to leave the stack dampers open at least slightly to reduce this emission within the mill. More efficient seals around section doors are needed to contain the dryer gases. Water vapor figures (reported in pounds per minute) will be similarly affected.

As the data show (Table II), there is a significant over-drying of veneers on all dryers tested. Most veneer weighed contained less than 1% moisture on a dry-weight basis. Some dryer tenders said they should allow up to 8% moisture in the veneer for good gluing properties and to maximize production.

CONCLUSIONS AND OBSERVATIONS

Eight dryers in Pacific Northwest mills and five dryers in southern mills were studied. Steam- and gas-heated longitudinal and jet dryers were studied drying ten different species types.

The nature of veneer dryer emissons varies between species types, heat source, and dryer type. A number of basic similarities exist, however. At stack temperatures the only particulate emission consists of wood particles in concentrations less than 0.002 gr/standard dry cubic feet of stack gas. Outside the stack, however, at cooler than stack temperature, hydrocarbons and water typically condense to form blue haze and/or a water plume or both. Plume opacities of the blue-haze emission ranged from 0% to 100%. Other volatile hydrocarbons do not condense.

The average total hydrocarbon emission from all dryers tested was 5.7 lbs/10000 ft^2 of 3/8" plywood produced. The average condensable hydrocarbon emission was 3.6, same basis.

There were large differences in the operation of veneer dryers. These differences, coupled with the condition of the dryers, combined to give varying results for opacity readings of the stacks, water vapor emitted from the stack, and the total hydrocarbon emitted from the stack. If, for example, a stack was operated with its dampers open, the volume flow of gases out the stack was very high, plume opacity was very low, and the volatile and condensable concentration figures seemed generally to be at the lower values. If, however, the dryer was operated with the dampers closed, production was generally higher, air volume was lower, plume opacity was higher, volatile and condensable hydrocarbon concentrations were higher, and total hydrocarbons on a 10,000 ft^2 (of 3/8" plywood) production basis were also lower. An important factor, therefore, in veneer dryer operation is the

damper setting. Further study is planned to evaluate the effects of dryer operation on the dryer emissions.

Routine GC analyses of the volatile hydrocarbons in the stack gas at the thirteen dryers studied showed that α pinene was the major monoterpene emitted except for ponderosa pine where Δ^3 carene was the major component. Alpha and β pinene are recognized to be potentially reactive hydrocarbons. Studies to determine the relative reactivities of α and β pinene, ethylene, isobutene, and 1-butene are in progress.

During the drying of Douglas fir, α pinene accounted for 75 to 90% of the monoterpene emission; for southernpine, 55 to 65%; and for ponderosa pine, 40 to 50%. The data also showed that the monoterpene composition of the stack gas was characteristic of the wood species being dried. However, the concentrations were not as characteristic as the composition. During the drying of Douglas fir, southern pine, and ponderosa pine, the concentrations were quite variable; whereas the concentrations measured during the drying of western hemlock, larch, and white fir were at the lower limits of sensitivity of the GC used.

The condensed hydrocarbon fraction has been preliminarily studied. A tentative identification of the bulk of the condensate as a mixture of abietic-pimaric acids has been made. The data also indicate the presence of sesquiterpenes, fatty acids, resin esters, and resin alcohols. Analyses to more precisely identify the components in the condensate would require an effort equal to a separate research project and as such is outside the scope of the present project.

APPENDIX A

APPENDIX A

FORMULAS USED FOR CALCULATIONS

Calculation of moisture content:

Moisture content calculated using Carrier's equation from IGCI method.

$$Pp = Pw - \frac{(Pd-Pw)\ (Td-Tw)}{2800 - 1.3\ Tw}$$

Pp = partial pressure of water vapor in gas (in Hg)

Pw = vapor pressure of water at Tw (in Hg)

Pd = absolute pressure in duct (in Hg)

$$\text{Moisture Content (\% by vol)} = \frac{Pp}{Pd} \times 100$$

Total mole fraction of gas calculated by summing all mole fractions.

Σ gas % by volume X molecular wt = Σ mole fractions

Gas density = Dd (lb/ft^3) at standard conditions of 70^oF and 29.92 in Hg pressure

$$Dd = \frac{\text{mole frac}}{386} \times \frac{530}{\text{duct temp} + 460} \times \frac{Pd}{29.92}$$

Average stack velocity:

$$\text{AV velocity (ft/min)} = 1096.5 \sqrt{\frac{Pv}{Dd}}$$

PV = velocity pressure

Gas flow rate at stack conditions:

(round stack)

$$\text{Stack flow } (ft^3/min) = \frac{K\ (r)^2}{144} \times \text{AV velocity}$$

r = radius of stack

Stack flow at dry standard conditions of 70^oF, 29.92 in Hg pressure:

$$\text{Stack flow}_{std}\ (ft^3/min) = \text{FRAC} \times \text{stack flow} \times \frac{530}{\text{duct temp} + 460} \times \frac{Pd}{29.92}$$

$$\text{FRAC} = \frac{100 - \text{percentage of } H_2O \text{ by vol}}{100}$$

Calculation of volume of stack gas sampled through condenser:

(std conditions)

$$VOL = ROTA \times TIME \times \frac{BARO-VAC}{29.92}$$

VOL = ft^3 of stack gas at standard conditions

ROTA = average rotameter reading maintained during sample period (ft^3/min)

TIME = sample time in minutes

BARO = barometric pressure (in Hg)

VAC = vacuum gauge pressure (in Hg)

Calculation of Production (ft^2/hr of 3/8" plywood)

Production = 180 X decks X thickness X in/min = production

decks - number of decks in dryer

thickness - thickness of veneer in decimal inches

in/min - the number of inches of length of veneer fed into the dryer per minute.

$$180 = 162 \times 60 \frac{min}{hr} \times \frac{1}{0.375\ in} \times \frac{1\ ft^2}{144\ in^2}$$

Calculation of condensable hydrocarbon quantities:

$$CONDHC = \frac{0.132 \times SCFM \times WTG \times FAC}{VOL}$$

CONDHC = condensable hydrocarbons (lb/hr)

SCFM = CFM at standard conditions

WTG = weight of condensable hydrocarbons collected

FAC = factor used to compare two laboratory methods used

VOL = volume of stack gas sampled

$$0.132 = \frac{60\ min}{hr} \times \frac{1\ lb}{454\ g}$$

Calculation of hydrocarbons on production basis

$$HCPD = \frac{10000 \times HC}{Production}$$

HC =hydrocarbon value (lb/hr)

HCPD = lb hydrocarbon emission per 10,000 ft^2 of 3/8" plywood produced

This calculation performed for volatile, condensable, and total hydrocarbons and summed for all stacks on a dryer

Calculation of hydrocarbons per production on a SCFM BASIS

$$HCSCFM = \frac{HCPD}{SCFM} \times 1000$$

HCSCFM = lbs hydrocarbons emission per 10,000 ft^2 of 3/8" plywood per 1000 ft^3/min of stack gas flow

This calculation summed for all stacks on a dryer.

KEY

	Species Type	Code No.	Abbreviation
Douglas fir	heart	01	DFRH
	sap	02	DFRS
	other	03	DFRW
Ponderosa pine	sap	05	PPNE
	redry	06	PDRY
Hemlock	sap	08	HMLK
White Fir	sap	11	WFIR
Larch	sap	13	LRCH
Southern Pine	sap	17	SPNE
White Pine	sap	26	WPNE
Spruce	sap	29	SPRC

APPENDIX B

APPENDIX B

EVALUATION OF SAMPLING AND ANALYSIS TECHNIQUES FOR EMISSIONS OF CONDENSABLE ORGANICS FROM VENEER DRYERS

I. WSU-DEQ FIELD COMPARISON

Field teams from Washington State University (WSU) and the Oregon Department of Environmental Quality (DEQ) conducted a joint veneer dryer emission source testing program in June, 1971, at two veneer dryers in Oregon. Both longitudinal dryers were similar, except that dryer #50 was steam-heated and dryer #60 was gas-fired. Significant differences in the emission rates for condensable organics reported by WSU and DEQ for these simultaneously obtained samples raised several fundamental questions which required experimental investigation.

Experimental. The WSU team utilized a condensation technique previously described (1), wherein the source sample was cooled to approximately 60°F in a spiral condenser and the condensate collected. A portion of the sample gas leaving the condenser was then passed through the flame of a total hydrocarbon analyzer (THA) to determine the uncondensed or volatile fraction of the sampled veneer dryer emissions. It was assumed under these conditions that any organic material not collected in the condenser would be burned in the flame of the THA and be recorded. These data were calculated as equivalent hexane. The stack sampling procedure involved sampling at a single point within the stack and was based upon the knowledge that the organic fraction of the dryer emissions was gaseous at stack temperature. Therefore, a "particulate sampling traverse" was not deemed necessary.

The Oregon DEQ team utilized a Research Appliance Company "Staksamplr" (RAC train) using a particulate stack sampling traverse technique, i.e., isokinetic sampling with 16 traverse points representing four concentric, equal areas (2). The usual "NAPCA" sampling train configuration was modified in that the filter, normally located in the fore portion of the train between the heated cyclone and the first impinger,

was placed at the end of the sampling train following the fourth impinger. The purpose of this filter was to collect any particulate material not collected in the fore-part of the train.

Different laboratory techniques were also used by the two groups in the determination of the collected weight of condensed organic material. The WSU team used the "Rinco" method previously used in their 13-mill study (1), wherein the condensed sample weight was obtained after evaporation of the associated water and rinse acetone at 104-113°F under a 27-28" Hg vacuum in Rinco rotary evaporator. Oregon DEQ personnel used a chloroform-ether extraction and evaporated the water and organic solvents from their samples at room temperature and pressure. The sample weights were then obtained after dessication.

Results. Table I shows the comparative emission rates reported by the two laboratories for the simultaneously obtained samples. The significant differences in these comparative data raised several questions which required experimental evaluation. These questions were divided into three areas, ie., (a) the high percentage of the total DEQ collection found in the "heated" RAC probe and cyclone, (b) the proportion of the DEQ collection on the filter following the Greenburg-Smith impingers, and (c) possible losses of condensed organics during separation from condensed water and rinse acetone in the Rinco evaporation apparatus. A fourth associated question was related to the need to follow a particulate sampling traverse protocol when sampling for gases.

As a first approach to answering the above questions, one sample of condensed organic material with its associated water and acetone was split. One half was analyzed at WSU using the Rinco procedure and the other half was analyzed by Oregon DEQ using their room temperature and pressure evaporation procedure. The results obtained from one split sample, i.e., 0.1043 grams (WSU Rinco) vs. 0.0971 grams (DEQ procedure) indicated, under these conditions, that the difference between the two analytical procedures were not the primary source of variance between the two laboratories.

TABLE IB

COMPARISON OF FOUR SIMULTANEOUS SAMPLES

TAKEN BY DEQ AND WSU

Dryer 50

	Stack no.	Probe	Condenser	Filter	Total	gr/scf
DEQ	1	78.7 mg	102.2 mg	88.1mg	269 mg	0.095
	2	44.2	135.7	73.1	253	0.090
WSU	1	--	114.6	--	114.6	0.045
	2	--	145.9	--	145.9	0.056
			Dryer 60			
DEQ	1	110.8	125.5	32.7	269	0.095
	2	95.9	120.2	120.9	337	0.144
WSU	1	--	116.0	--	116.0	0.048
	2	--	144.4	--	144.4	0.076

However, data from one split sample was not considered to be an adequate evalution. Therefore, 17 additional samples previously collected by the WSU team and not yet analyzed were split and subjected to the Rinco and a solvent extraction analytical techniques in the WSU laboratory. The results of this further evaluation of analytical techniques are discussed in the following section.

The remaining differences between the two sampling techniques which required field evaluation included (a) the heated probe and cyclone, and (b) the final filter vs. the THA as indicators of sample fractions not retained in the condenser or Greenburg-Smith impingers, and (c) "particulate traverse" sampling vs. single point gaseous sampling. The WSU field team investigated these latter three questions on dryer #70 on September 22, 1971 by comparing the RAC and the WSU sampling techniques simultaneously. The experimental techniques and data obtained are also described in this report.

II. COMPARISONS OF SAMPLE ANALYSIS PROCEDURES AT WSU.

Each of seventeen veneer dryer emission condensate samples obtained from three dryers in May, June and July, 1971, were split into two equal samples. The condensed organic compounds in one-half of each sample was analyzed with the Rinco rotary evaporator as previously described. (1) The other half of each sample was analyzed by an organophillic extraction method described below.

Extraction Procedure. The samples were first filtered through filter papers which had been previously washed with acetone, dessicated over Drierite (magnesium sulfate) for 24 hours and weighed. The filter papers were then redessicated, weighed and the insoluble weight determined. This insoluble material appeared to be small wood fibers which probably fell into the sample bottles during the transfer of the "condensables" from the sampling train to the sample storage bottles.

The filtrate, containing the dissolved condensable organic fraction, was placed into a separatory funnel with approximately 100 ml 9:1 ether/acetone (volume of ether-acetone euqal to one-half of the sample volume) and the flask shaken. The aqueous phase was separated and the organic layer was placed into a 600 ml beaker. The aqueous layer was subjected to three additional extractions using first another volume of 9:1 ether-acetone, and finally two additional volumes of ether.

These three organic extracts were added to the original ether-acetone extract. Approximately 75 g of 12 mesh[1] anhydrous calcium chloride was added to the combined extracts with stirring. The contents of the beaker was stirred again after about fifteen minutes and allowed to stand for approximately 45 minutes. The liquid was then decanted and placed over approximately 75 g granular, anhydrous potassium sulfate[2]. The calcium chloride residue was washed with anhydrous ethyl ether and the ether wash added to the extract and allowed to stand for an hour.

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[1] 8 mesh $CaCl_2$ formed a hard cake which expanded upon hydration, breaking the sample beaker.

[2] Metallic sodium was tested as the final drying agent. However, it produced condensation reactions among the condensed organic veneer dryer emission products.

A clean, dry 500 ml Florence flask containing a Teflon-covered stirring bar was weighed. The sample was filtered into the tared, dry Florence flask. The flask was then attached to a water cooled condenser connected to an aspirator solvent evaporator (Diagram 1B). The flask was placed into a water bath maintained at approximately 70°F. The magnetic stirrer and aspirator were turned on and the solvent evaporated. When the solvent had been removed, the condenser was washed with anhydrous ether to remove lower boiling material that may have been condensed on the walls of the condenser. The system was again closed to the atmosphere and the ether evaporated. The flask containing the solvent-free sample was removed from the bath and system, dried and the gross weight taken. The increase in weight was reported as the condensable hydrocarbon fraction of the veneer dryer emissions. The extraction procedure is outlined in Diagram 2B.

Results and Discussion. Table II compares the weights of condensed organics obtained by the Rinco evaporation procedure with comparable weights obtained by the solvent extraction procedure. The first 14 paired data sets refer to condensable organics collected at mills #40 and #50. The 400000 series samples were obtained from an eight-section gas-fired jet dryer on Douglas fir and ponderosa pine. The 500000 series samples came from a 20-section, five-deck steam dryer on Douglas fir. The final three 050000 series samples came from a 22-section gas-fired dryer on white fir.

The extraction method applied to Douglas fir condensate gave a recovery of 1.48 ±0.13 times as much condensed organics as the corresponding halves run by the Rinco method. Eleven samples were used to obtain these figures. Within the Douglas fir species, the condensable organics recovery from Douglas fir heart was 1.49 and Douglas fir sap was 1.41 times that obtained by the Rinco method. Three white fir condensate samples averaged 1.80 ±0.20 times as much condensed organics by the extraction procedure than by Rinco evaporation. Two ponderosa pine condensate samples averaged 1.46 times as much condensed organics by the extraction procedure.

Diagram 1B. Schematic of Solvent Removal System

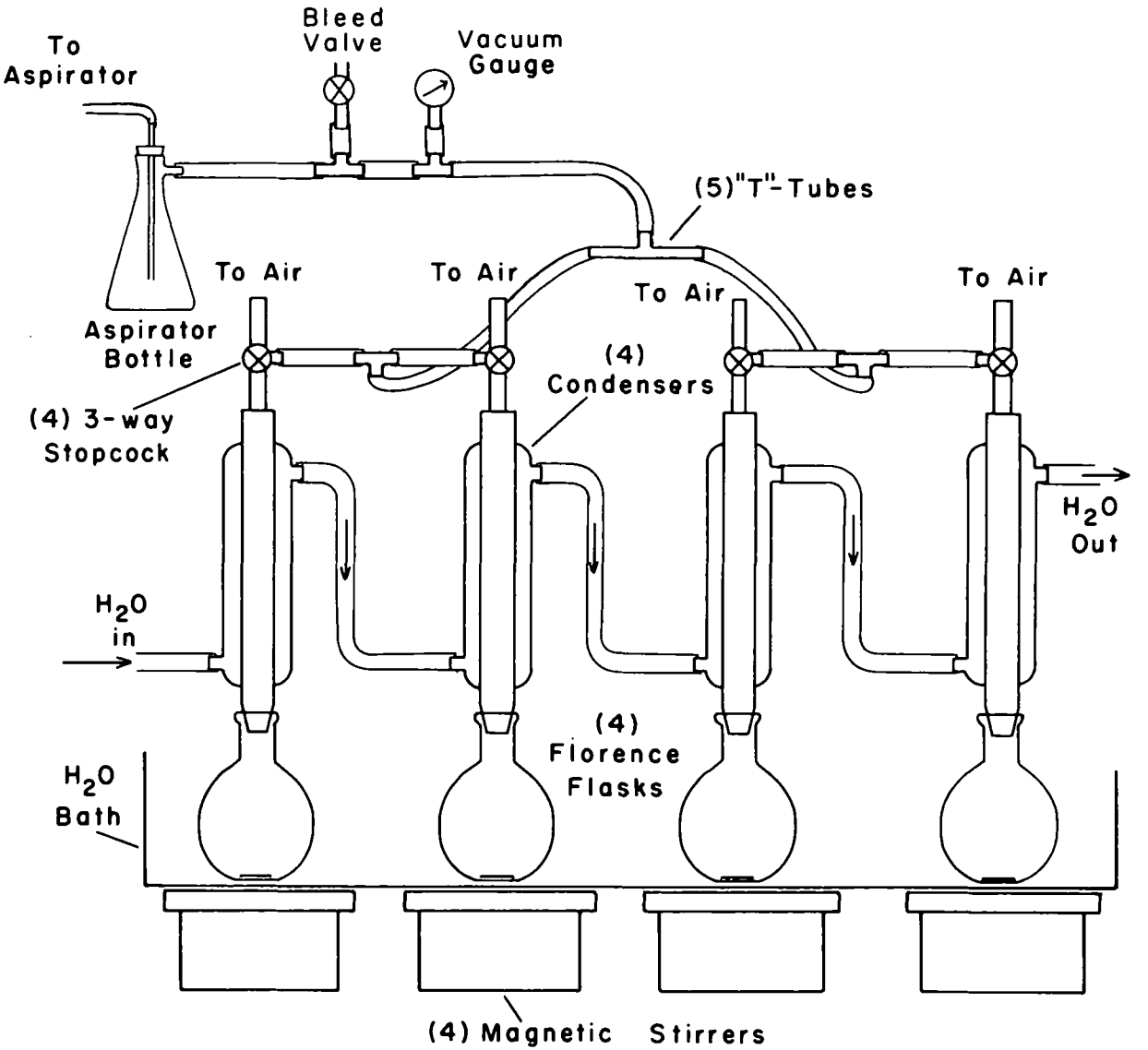

Diagram 2B. Extraction-Separation Procedure

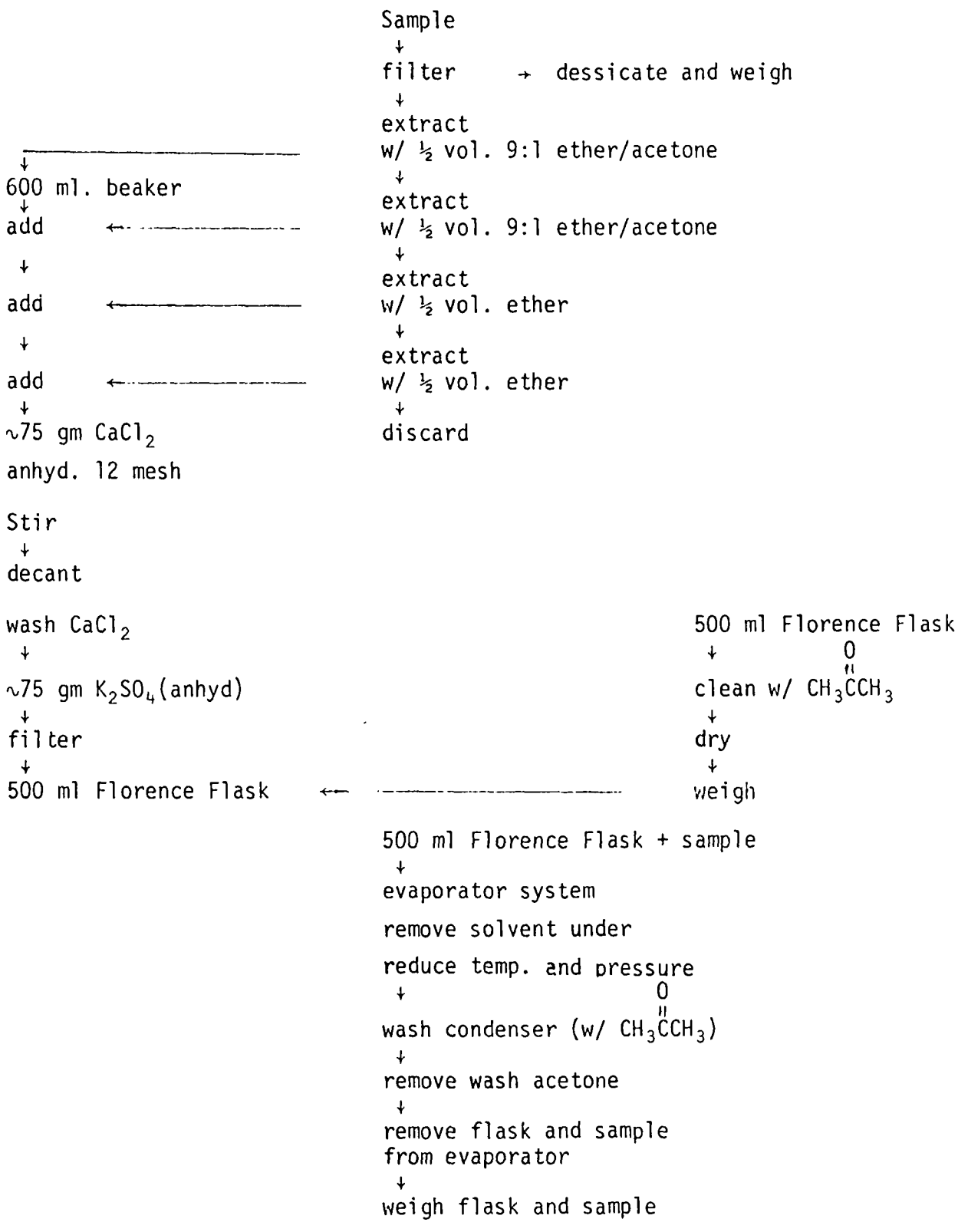

TABLE IIB

COMPARISON OF THE RECOVERY OF CONDENSABLE ORGANICS BY THE RINCO ROTARY EVAPORATION AND ETHER EXTRACTION PROCEDURES

Sample No.	Date	Rinco	Ether Extn.	Ratio Ether/Rinco
400102	5/5/71	279 mg	405 mg	1.45
420101	5/6/71	320	449	1.40
420102	5/6/71	525	876	1.67
420102	5/11/71	471	538	1.14
500101	6/3/71	1460	2577	1.77
500102	6/3/71	2062	3320	1.61
510101	6/4/71	858	1221	1.42
400203	5/5/71	277	403	1.45
410201	5/6/71	653	834	1.28
410202	5/6/71	692	1047	1.51
410212	5/11/71	279	393	1.40
420203	5/6/71	711	1012	1.42
410601	5/14/71	789	1207	1.53
410603	5/14/71	946	1321	1.40
051101	7/14/71	340	558	1.64
051102	7/14/71	456	803	1.76
051103	7/14/71	263	547	2.01

The lower recovery from the Rinco evaporator is attributed to the removal of varying quantities of sample vapor of the lower boiling point compounds at 103-114°F under 28-29" Hg vacuum. From these limited data, there appears to be some species dependency upon the relative condensables recovered from split samples, particularly with reference to white fir. However, the average increase in condensable recovery from Douglas fir heart and sap and ponderosa pine, i.e., 1.49, 1.41, and 1.46 were not significantly different. No extension of these data should be made to other species dried at different temperatures.

III. WSU'S COMPARISON OF "RAC" SAMPLING TRAIN AND THE "WSU" CONDENSER-FILTER TECHNIQUE.

On September 22, 1971, comparative, simultaneous samples were obtained from a longitudinal steam dryer (#70) on Douglas fir. The objective of this limited, one-day study was to compare (a) the "Research Appliance Company Staksamplr" (RAC) which was similar in design to the "NAPCA" train and (b) the "WSU" condenser technique with a filter. In addition, the "WSU" sampling technique was replicated, thus providing two simultaneous samples from the replicated "WSU" trains to evaluate the reproducibility of the WSU sampling technique.

The RAC train was equipped with a five-foot, heated stainless steel probe. Isokinetic conditions were maintained as closely as possible at all times and the stack was traversed on three minute intervals, utilizing eight traverse points across one stack diameter line. Since another sample port at 90° was not available, each point was sampled twice during the total sample period. The "RAC" train as used in this situation embodied one major modification from the usual "NAPCA" train. Normally, a heated glass-fiber filter was placed between the heated glass cyclone collecter and the first of four Greenburg-Smith impingers. For source monitoring of volatile organic compounds in the gaseous state at stack temparature, the filter was placed behind the four Greenburg-Smith impingers to provide for a final collection of particulate close to the 70°F EPA particulate definition temperature. During this comparison study on September 22, 1971,

it was only possible to maintain the exit sample gas temperature at the RAC filter within a temperature range of 86°-103°F while sampling under isokinetic conditions, using 0.25" diameter probe tip.

On the other hand, the exit gas temperature from the WSU condenser was readily held between 60-70°F at all times during the sampling period. These differences in exit gas temperature and the relative ease of holding the lower temperature with the "WSU" condenser appeared to be related to the collector designs, i.e., Greenburg-Smith is an impinger whereas the WSU unit is a condenser. The former was not designed for use as a condenser, whereas the latter was specifically designed to provide a high surface to volume ratio for maximum heat exchange.

Sampling with the replicated WSU sampling train was accomplished at two points 6 inches into the stack separated by approximately 2 inches. Unheated, 12-inch fritted glass tipped probes were coupled to their respective condensers. (Any condensate collected in the unheated probe was transferred with acetone and combined with the sample fraction collected in the condenser.)

The major change in the "WSU" condenser system from that used during the previous studies of 16 veneer dryers (1,3) was the addition of a 2" plastic-filter holder and a glass-fiber filter between the WSU condenser and the sample flow-measuring rotameter. Two tare weights were obtained for each filter prior to use - (a) each glass-fiber filter paper and (b) each filter plus the weight of its protective envelope. After each filter sample was obtained, the filter was replaced in its original envelope. Upon return to the laboratory, the filters and envelopes were dried in a dessicator over Drierite for 36 hours and weighed.

It was fortunate that the filter and envelope were originally weighed together. The organic material collected on the filters was of an oily nature and some of these oily compounds migrated through the inward-folded filters and accumulated on the inner envelope surface during the in-transit storage period. Thus accurate weight gains could not have been obtained from the tared and final filter weights alone.

Results and Discussion. The total condensed organic content in each of the two sets of replicated samples was determined by the organic extraction procedure described above. The comparative data are shown in Table IIIB. From these limited data it appears that there is no clear-cut advantage of one sampling system over the other in terms of collection efficiency.

TABLE IIIB

COMPARISON OF SAMPLING PROCEDURES

WSU Condenser-filter vs. RAC Staksamplr

Mill 70 - September 22, 1971

Sample Train	Sample Vol. scfm	RAC Probe gr/scf	Condenser gr/scf	Filter gr/scf	Total Condensable Organics gr/scf	% Total on filter	Ratio Total/Condenser
WSU-1A	23.8	--	0.15	0.094	0.24	39.2	1.61
WSU-1B	22.4	--	0.18	0.100	0.29	34.6	1.61
RAC-1	35.2	0.033	0.23	0.086	0.35	24.6	1.33
WSU-2A	23.7	--	0.18	0.072	0.25	28.8	1.39
WSU-2B	22.7	--	0.22	0.089	0.31	28.7	1.41
RAC-2	33.9	0.065	0.12	0.084	0.27	31.1	1.46

The variation within each sample set ranged from ±10-15% which is quite reasonable considering the many sources of possible error including non-uniform flow in the stack, the rooftop environment where samples had to be handled and transferred in a quantitative manner, and the difficulty in assuring adequate washing of the RAC probe.

It was also noted that the total liquid volume of sample to be handled in the laboratory, was approximately three times as great from the RAC train. Furthermore, the total sample train surface which must be cleaned up with acetone was also significantly larger.

The organic material collected with the RAC must be separated from 450-600 ml total volume of water as compared with 100-150 ml water from the WSU train. The volume of acetone required to clean the WSU train was approximately 1/3 the quantity required to clean the RAC train (approximately 150 ml vs. 350 ml) because of the significantly different surface areas involved. Hence the field and laboratory sample and sample train manipulations were magnified many-fold through the use of the RAC train as compared with the WSU condenser, thereby increasing the possibility for contamination and sample loss and increasing the laboratory time required to determine the weight of the condensable organic material collected.

It was also observed in the RAC Staksamplr used by WSU in comparative tests run on September 22, 1971, that the manufacturer's temperature controller scale was in error by more than 100°F. It was necessary to set the temperature control to 450°F to achieve a temperature of 325° in the RAC heated cyclone-filter chamber. It is therefore considered possible that the oven temperature controller on the Oregon DEQ RAC staksamplr and probe also may have had a similar calibration error, thus accounting for the relatively high probe loadings reported (2), during the July comparative studies in Oregon, i.e., the DEQ probe may have been well below the stack temperature, thus favoring partial sample condensation in the probe.

Since the two sampling techniques provide similar results, the overall equipment advantage lies with the modified "WSU" sampling train in terms of initial cost, the relative bulk and weight of the equipment involved, the simplicity of the system, the low surface area requiring quantitative cleaning, sample transfer, the lower volume of water in the sample, and the lower total volume of sample to be handled.

IV. ADDITIONAL VENEER DRYER EMISSION DATA OBTAINED WITH THE COMBINATION WSU CONDENSER PLUS GLASS FIBER FILTER.

Three samples of white fir emissions were obtained in July, 1971, from a 22-section, 2 zone gas-fired dryer (#05). Eight additional

samples, four of Douglas fir and four of ponderosa pine, were obtained on dryer #70 on September 20 and 21, 1971. These eleven samples were obtained using WSU condenser followed by a two-inch glass fiber filter.

The weights of the organic matter collected in the condensers and on the filter papers were determined as described above.

Results and Discussion. Table IV shows the relative quantities of condensable organics collected in the condenser and by the filter. No consistent pattern emerged from the data to relate the percentage of condensed organic matter collected on the glass fiber filter following the condenser. The total weights of organic matter collected, as well as the ratios of the total condensable organics to condenser weights appear to be associated with wood species (Tables III and IV). Ponderosa pine showed the highest ratio (1.49-2.19); Douglas fir was second (1.33-1.62 ratio); and white fir had the lowest ratio (1.06-1.19) of the species examined. Filter weights tended to show greater variation than did the condenser weights for these three species. The low 9.1% filter collection for sample 7005018 was probably related to the feed veneer being "re-dry".

Whenever the ratio of condensables collected in the condenser and on the filter remains relatively constant within a species type we can assume that the veneer dryer volatiles have quite similar composition. This would be true for the first three Douglas fir samples obtained on September 20. The total grain loading for these three samples, however varied from approximately 0.16 to 0.40 (gr/scf). These variations might reflect differences in production rate or veneer moisture content. The condenser to filter weight ratio could also be influenced by the condensation temperature maintained in the condenser and to dryer temperature. The condenser temperature, however, seldom varied beyond the 60-70^{o} range, and would not be expected to influence the condenser to filter ratio to the extent shown in Tables III and IV.

In the absence of vapor pressure-temperature relationships for the various fractions of the condensable organics, one can only

TABLE IVB

CONDENSABLE ORGANIC FRACTION COLLECTED BY FILTER

WSU Condenser-filter System

Dryer 70 - September 20-22, 1971

Dryer 05 - July 14, 1971

Sample No.	Species	Sample Time min	Condenser gr/scf	Filter gr/scf	Total Condensable Organics gr/scf	% of Total on Filter	Ratio Total/Condenser
7001011	DFIRH	67	.100	.057	.157	36.3	1.57
7001012	DFIRH	65	.250	.145	.405	35.8	1.62
7002013	DFIRS	59	.184	.105	.290	36.3	1.58
7002014	DFIRS	61	.201	.067	.268	24.9	1.33
7005015	PPINE	60	.143	.158	.301	52.6	2.10
7005016	PPINE	48	.094	.112	.206	54.3	2.19
7005017	PPINE	58	.134	.067	.200	33.0	1.49
7005018	PPINE(RDRY)	62	.192	.019	.212	9.1	1.58
050101	WFIR	61	.056	.0105	.0665	15.8	1.19
050102	WFIR	60	.081	.0096	.0906	10.6	1.12
050103	WFIR	60	.056	.0035	.0595	5.9	1.06

speculate as to the classes of wood volatiles which are collected by the sample condenser or are missed by the condenser and collected on the fiber glass back-up filter. Visually, the fraction collected by the filter appeared as a white fume in the glass sample line between the condenser and the filter.

A specific study would be required to identify the physical characteristics and chemical identity of the wood volatile fractions (a) retained in the condenser and (b) missed by the condenser and collected on the sample train back-up filter.

V. THA RESPONSE TO CONDENSED VENEER DRYER EMISSIONS BEFORE AND AFTER FILTRATION

During the collection of three samples on dryer #70 the total hydrocarbon analyzer (THA) sampling tee was moved for a short period of time from its normal position following the fiberglass filter to a position between the condenser and the filter to provide a comparison of the THA response to the sample stream coming directly from the condenser vs. the same sample stream after filtration through the glass fiber filter. Calculations of the condensed organic matter were appropriately adjusted to compensate for the reduction in flow rate through the filter while a portion of the sample flow was removed for equivalent hexane determination by THA.

Determination of the effect of filtration on the THA response was complicated by the fact that the drying of veneer is by no means a steady state operation. THA recorder traces obtained during all of our previous studies (1,3) showed an almost cyclic rise and fall of the measured hydrocarbons when the dryers were being operated under "normal" loading. More drastic and rapid response was recorded whenever the usual veneer feed rates were upset due to "plug-ups", change in species, inadequate veneer supply to the dryer, etc.

Because of the general cyclic nature of the THA "volatile" measurements, the "before" and "after" the filter THA measurements had to be evaluated by projecting the changes in THA trend lines between each pair of sequential samplings. Table V shows the comparative volatile hydrocarbon response of the THA calculated as equivalent ppm hexane for the three comparisons.

TABLE VB

COMPARATIVE THA RESPONSE BEFORE AND AFTER THE FILTER

		THA LOCATION	
Date	Sample No.	Before	After
9/20/71	7001011	106 ppm	106 ppm
	7002013	140	146
9/21/71	7005017	74	74

From these data it appears that the THA did not show a significant response to the filterable portion of the condensed veneer dryer emissions. Therefore, it will not be possible to adjust any of the previously measured to condensable hydrocarbons through use of the concurrently obtained THA data.

SUMMARY

1. The "Rinco" method for separation of the condensable organic fraction of the veneer dryer emissions from concomitant water and acetone produced a variable loss of the higher vapor pressure fraction of the collected condensate. Comparative data from 14 split Douglas fir samples suggests an analytical correction factor of 1.48 ±.13. Data from three split samples of white fir suggests a white fir correction factor of 1.8 ±0.2. No similar comparative studies have been conducted for the other species previously studied.
2. Significant and variable quantities of condensed organic matter in veneer dryer emissions were retained on glass fiber filters following the WSU condenser maintained at 60-70°F. These variations are probably related to veneer species and condition and to dryer operating variables.
3. Samples obtained simultaneously with the RAC train and the WSU condenser plus glass fiber filter gave comparable, equivalent veneer dryer emission data for two one-hour sampling periods.
4. Samples obtained simultaneously with two replicated WSU condenser-glass fiber filter trains gave comparable, reproducible veneer dryer emission data for two one-hour sampling periods.
5. The total hydrocarbon analyzer (THA) did not show a significant difference in response to the filtered and unfiltered sample gas emerging from the condenser. The THA undoubtedly responds to the volatile, lower molecular weight hydrocarbons, but does not "see" the higher molecular weight, filterable organic aerosols which can be collected on a fiberglass filter.
6. Based upon the data herein reported, it is concluded that the condensable hydrocarbon emission data previously reported for 13 plywood veneer dryers and 10 wood species are low by variable amounts depending upon many factors in the drying operation. The previously reported

"volatile" hydrocarbon emission rates were not influenced by the absence of a filter between the condenser and the THA.

7. A "best approximation" for developing a correction factor for the above noted conditions would involve a two-step procedure. First, the reported weight of condensable hydrocarbons should be multiplied by a factor in the range of 1.1 to 2.0 (depending upon the species and associated dryer conditions) to correct for losses of condensed sample from the Rinco rotary evaporator during the removal of concomitant water and acetone. Second, this calculated weight of condensables (corrected for loss in the Rinco apparatus) should then be multiplied by a second factor in the range of 1.06-2.19 (depending upon the species and associated dryer conditions) to account for the inability of the condenser to trap the shock-cooled, aerosolized organics which were collected on a glass fiber filter following the condenser.

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