

AN ABSTRACT OF THE THESIS OF

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Title: PARTICULATE AND TOTAL GASEOUS HYDROCARBON
EMISSIONS FROM A GAS HEATED VENEER DRYER

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A source test was conducted to determine the particulate and the total gaseous hydrocarbon emissions from a gas heated veneer dryer. Samples were taken on eight separate days from the exhaust stacks while the dryer was processing Douglas fir veneer. Of the eight days, three was used to determine the gaseous hydrocarbon concentration using a flame ionization hydrocarbon detector and five were used to determine gravimetrically the particulate concentration.

Experimental emission rates were 0.87 pounds per hour for particulates and 16.02 pounds per hour for gaseous hydrocarbons.

Particulate and Total Gaseous Hydrocarbon Emissions
from a Gas Heated Veneer Dryer

by

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
Object of Study	2
Scope of Study	2
DESCRIPTION OF THE VENEER PLANT	4
PROCEDURE	8
Experimental Design	8
Sampling Equipment and Procedure	10
RESULTS	18
CONCLUSIONS	21
BIBLIOGRAPHY	24
APPENDIX	26

LIST OF TABLES

Table	Page
1. Drying times for the different types and thicknesses of veneer.	5
2. Control temperatures of the drying zones at the exit end of the air jet tubes.	8
3. Experimental design for gaseous hydrocarbons.	9
4. Experimental design for particulates.	9
5. Gaseous hydrocarbon emission rates (lb/hr).	19
6. Particulate emission rates (lb/hr).	19
7. Analysis of variance for particulates.	20
8. Analysis of variance for hydrocarbons.	21

APPENDIX TABLES

A-1. Types of Douglas fir (1/10 inch) processed during tests.	26
A-2. Operating temperatures (° F) and damper positions.	27
A-3. Stack temperatures (° F).	28
A-4. Effluent moisture contents (percent by volume).	29
A-5. Stack and atmospheric pressures.	29
A-6. Orsat analyses (percent by volume, dry basis).	30
A-7. Effluent flow rates (ft ³ /hr).	31
A-8. Particulate concentrations.	32
A-9. Hydrocarbon concentrations (ppm as hexane).	34
A-10. Moisture contents of veneers.	34
A-11. Particle size distributions.	35

LIST OF FIGURES

Figure	Page
1. Veneer dryer.	4
2. A typical drying zone.	6
3. Vent stacks of the veneer dryer.	6
4. Hydrocarbon detector.	10
5. Modified high volume sampler.	12
6. Arrangement of equal areas and particulate sampling points in the rectangular stack.	14
7. Arrangement of equal areas and particulate sampling points in the circular stacks.	14
8. Arrangement of equal areas and velocity measuring points in the circular stacks.	15

PARTICULATE AND TOTAL GASEOUS HYDROCARBON EMISSIONS FROM A GAS HEATED VENEER DRYER

INTRODUCTION

Surprisingly little is known about the nature of emissions from the drying of veneers, an important step in the manufacturing process of plywood. Yet, there are approximately 280 softwood dryers in the Pacific Northwest (5). Each has its characteristic "blue haze" plume, indicating the possible emissions of terpenes and other volatile hydrocarbons. Besides these softwood dryers in the Pacific Northwest, there are an additional 99 softwood dryers and 324 hardwood dryers in the United States (5).

In the manufacture of plywood the veneers are first peeled from fresh-cut or water stored logs by rotating the logs on a lathe against a knife. The moisture content of the veneers is usually too high for gluing and therefore the veneers must be dried.

The veneers are generally dried in dryers where hot gases are circulated, passing over the surface of the veneers as they are fed through the dryer between steel hold-down rolls. The drying medium circulated by fans is essentially either a mixture of air and water vapor from the wood or combustion gases, air, and water vapor. In most cases, the drying medium is heated by steam coils or by the direct heat of combustion of the fuel. These dryers normally operate

at temperatures of 300-400° F (2).

After the drying process is completed the veneer is glued together and steam pressed to obtain the finished product.

Object of Study

The veneer dryers are vented to the atmosphere to allow evaporated moisture to escape. Along with the vent gases are wood fibers, some of which are charred, and gaseous hydrocarbons from the more volatile components of wood. Whether these pollutants contribute significantly to the air pollution burden of the atmosphere was not known.

The object of this study, therefore, was to determine the average quantity of particulate matter and gaseous hydrocarbons emitted from one of these veneer dryers and to assess its significance as a source of air pollution.

Scope of Study

The gas heated veneer dryer was chosen for this study for several reasons. First, higher temperatures are attainable in gas heated dryers than in steam heated dryers, thus possibly evolving greater amounts of hydrocarbons. Second, higher stack gas velocities are involved, resulting in higher entrainment of the loose wood fibers. Third, the newer dryers are of this type.

For this investigative study only particulates and total gaseous

hydrocarbons were considered. The nitrogen oxides and sulfur oxides were not expected to be much different from the combustion of natural gas. The amount of emissions from this source is well documented in other works (8, p. 13; 13, p. 27).

Samples were taken from the stacks at what was considered as "normal operation." Most veneer plants make few or no changes in their day to day operation (2).

DESCRIPTION OF THE VENEER PLANT

A cross-circulation "UNI-Jet" gas heated dryer was selected for this study. It was comprised of an infeed, one cleaning section, sixteen drying sections, two cooling sections, and an outfeed. There were four decks in the dryer on which the veneers could pass; the speed of each deck was regulated to vary the drying time of the veneers. Figure 1 shows a view of the dryer.



Figure 1. Veneer dryer.

By circulating ambient air, the cleaning section provided for the removal of all loose debris (knots, loose fibers, etc.) before drying. The exhaust stack of this section measured 64 x 44 inches.

A zone is made up of two drying sections. In each drying section, all of which were identical, the hot gases flowed through the

ductwork and impinged on the veneer from both sides. The temperature of each zone was controlled by a pneumatically operated damper in the vent stack. The eight stacks of the eight zones each measured 18.75 inches in diameter. A schematic drawing of a typical zone showing the gas burner, the air jet tubes, the fan, and the vent stack is shown in Figure 2. Figure 3 shows a view of the stacks of the cleaning section and seven of the drying zones.

The cooling sections passed ambient air over the wood and reduced the temperature of the veneer to facilitate handling. An exhaust stack, 128 x 44 inches, was provided for this area.

The drying time depended upon the type of wood--sapwood, white speck, or heartwood--and its thickness, either 1/8 or 1/10 inch. The heartwood, the inner part of the log, and the white speck, a worm eaten wood of ornamental value, did not require as long a drying time as the sapwood. The sapwood, which is the area between the bark and the heartwood, required the longest time because of its higher moisture content. Table 1 gives the drying time of each.

Table 1. Drying times for the different types and thicknesses of veneer.

Type of wood	Thickness	
	1/10"	1/8"
Heartwood	3 1/2 min.	4 1/4 min.
White Speck	4 1/2 min.	5 1/2 min.
Sapwood	7 1/2 min.	9 min.

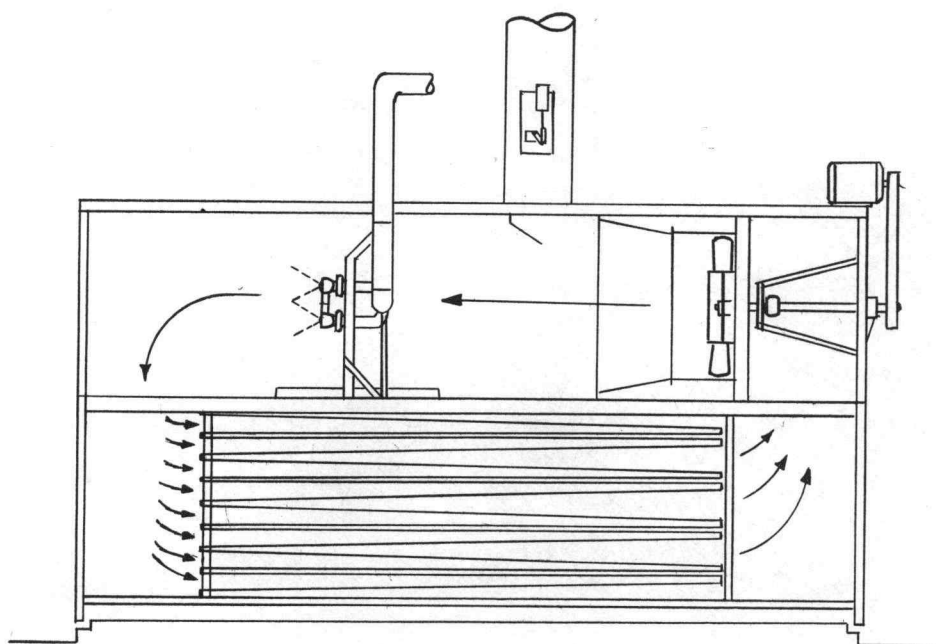


Figure 2. A typical drying zone.



Figure 3. Vent stacks of the veneer dryer.

To obtain veneer of less than 10% moisture, the different types of wood were run through the dryer either separately or in combinations of two and the speed of the decks was varied accordingly.

About 82, 000 square feet (basis of 3/8 inch thick plywood) of veneer was processed each day, with the bulk of the veneer coming from Douglas fir.

The plant operated in three shifts, 24 hours daily, except for weekends when the dryer was shut down for four hours for cleaning and maintenance.

PROCEDURE

Experimental Design

System Variables

The experimental objective of this study was to obtain the mean emission rate for both particulates and gaseous hydrocarbons from a gas heated veneer dryer processing Douglas fir veneer. Since there was no control over the system variables, samples were taken under what was termed as "normal operation."

Usually the system was operated at some predetermined conditions. From day to day the temperature of the various drying zones was held constant as much as possible by means of the pneumatic damper. The control temperatures of the different zones are listed in the table below.

Table 2. Control temperatures of the drying zones at the exit end of the air jet tubes.

Zone	1	2	3	4	5	6	7	8
Temperature, °F	320	350	360	360	360	350	325	300

The actual conditions under which the tests were taken are listed in the Appendix (Tables A-1 and A-2). The only significant variable in the operation was the type of wood (sapwood, heartwood, or white speck) that was processed during the time of the tests.

Number of Stacks

Of the ten stacks of the system, nine were tested. The cooling sections were not included in the tests since preliminary indications showed that emissions were quite low.

Final Experimental Model

A randomized block design shown in Tables 3 and 4 was used for the tests. The days were considered to be random effects and the stacks were considered fixed.

Table 3. Experimental design for gaseous hydrocarbons.

Day	Stack								
	P	1	2	3	4	5	6	7	8
1	3	3	3	3	3	3	3	3	3
2	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3

Table 4. Experimental design for particulates.

Day	Stack								
	P	1	2	3	4	5	6	7	8
4	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1

Separate tests were conducted for the hydrocarbons and the

particulates. Three replications were taken within a day for the gaseous hydrocarbons. One run was made for the particulates due to the length of sampling time required to obtain a measurable sample.

Sampling Equipment and Procedure

Determination of Total Gaseous Hydrocarbon Concentration

The total gaseous hydrocarbon concentrations were determined by using the portable Perkin Elmer Model 213B flame ionization hydrocarbon detector (see Figure 4). This analyzer required that the samples be reasonably dry and that they be supplied under pressure (9, p. 26). However, the preventing of condensation by means of heating the sampling line up to the detector was made impractical by the long tubing of the instrument, some parts of which were teflon.



Figure 4. Hydrocarbon detector.

A sampling train consisting of a fiber glass filter, a water condenser, and a diaphragm pump was used to transport the sample to the detector. It was known that some of the hydrocarbons would condense, however, due to the high vapor pressure of most organics and the low expected concentrations, the loss was considered to be negligible. As an example, α -pinene, the main expected constituent, has a vapor pressure of 1 mm Hg at -1°C (1, p. D-116). Acetic acid, another expected component, has a vapor pressure of 1 mm Hg at -17.2°C (1, p. D-106). A 1 mm Hg vapor pressure at 0°C and 760 mm Hg corresponds to 1316 ppm, whereas the total expected concentration was less than 200 ppm.

Using the assumption that gases tend to mix uniformly, the samples were taken at the center of the stack. Just prior to sampling, the instrument was zeroed and calibrated. Between the samplings of the different stacks, the sampling line was purged with ambient air to reduce any contamination from the previous sample. Any residual reading was recorded and subtracted from the ensuing sample reading.

Although the instrument was calibrated to read the concentration in parts per million as propane, in the final analysis the concentration was converted to parts per million as hexane.

Determination of Particulate Concentration

The liquid and solid particulates were measured by filtering part of the effluent through an 8 x 10 inch fiber glass filter using a high volume sampler and by weighing the filter before and after the sampling period. Because of the low particulate concentration and the large number of stacks, it was essential that the high volume sampler be used. Its use made it possible not only to sample all nine stacks in one day, but also to obtain a measurable amount of sample. The high volume sampler, normally used for atmospheric sampling, was modified to fit a probe, a nozzle, and a flow regulator. A view of the sampler is shown in Figure 5. The orifice at the outlet of the sampler was calibrated so that the rate of flow could be determined for isokinetic sampling conditions.

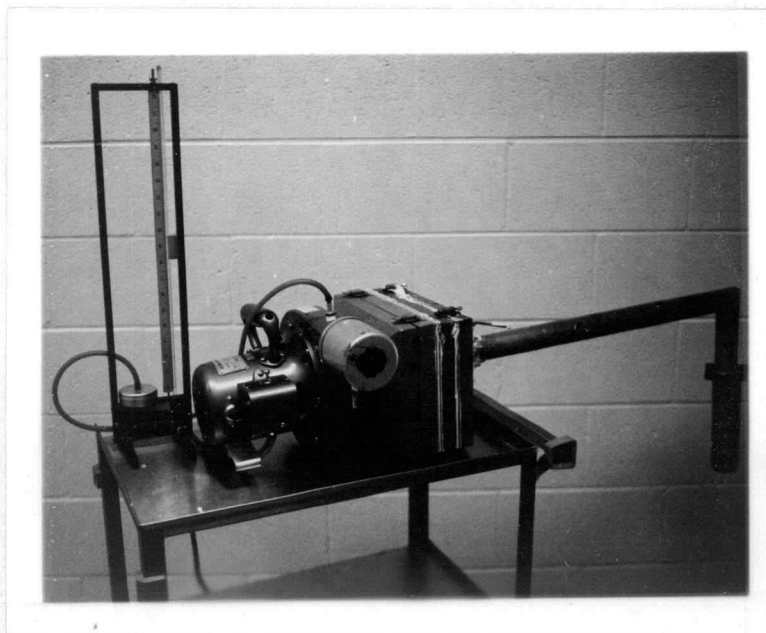


Figure 5. Modified high volume sampler.

Before taking the particulate samples, the cross-section of the stack was first divided into equal areas as suggested in the Los Angeles Source Testing Manual (3, p. 15-16) and in the Western Precipitation Bulletin 50 (14, p. 1-4). The rectangular stack was divided into 12 equal areas. Although six equal areas were recommended for the circular stacks, those stacks were divided into four areas only because the size of the nozzle used would have caused overlapping. Figures 6 and 7 show the equal areas and sampling points of the rectangular and circular stacks, respectively.

After the divisions were made a pitot traverse was conducted at the centroid of each area and the isokinetic sampling rates were determined.

In taking the samples equal lengths of time were allotted for each area. The points in the circular stacks were sampled for five minutes each and those in the rectangular stack for two minutes each.

After each sample was taken the filter was transferred to an envelope and any particulate matter in the probe and filter holder was brushed into the envelope. The filtered samples were allowed to reach constant weight while being maintained at constant humidity before the weight was recorded.

Determination of Effluent Flow Rate

To determine the amount of effluent being discharged from the

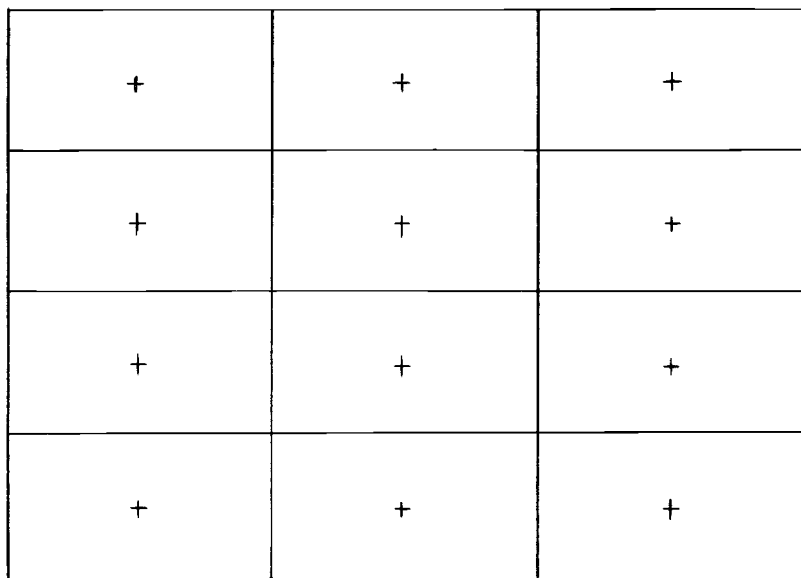


Figure 6. Arrangement of equal areas and particulate sampling points in the rectangular stack.

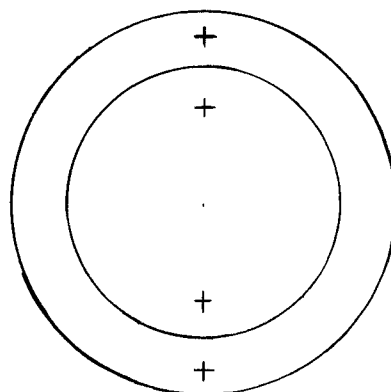


Figure 7. Arrangement of equal areas and particulate sampling points in the circular stacks.

vent stacks, the velocity of the gas and the area of the cross section of each stack were found. In order to calculate the velocity, the following were found:

1. velocity head of the flowing fluid
2. density of the flowing fluid
 - a. temperature
 - b. pressure
 - c. gas composition

With the use of a conventional pitot tube and an inclined manometer, the velocity head was measured. The circular stacks, measuring 18.75 inches in diameter, were divided into 12 areas as suggested in the Los Angeles Source Testing Manual (3, p. 15-16). Figure 8 shows a schematic drawing of the divided circular stack. A traverse, giving a total of 12 readings, was made on perpendicular diameters. Measurements for the rectangular stack were taken at the same points as in the particulate traverse.

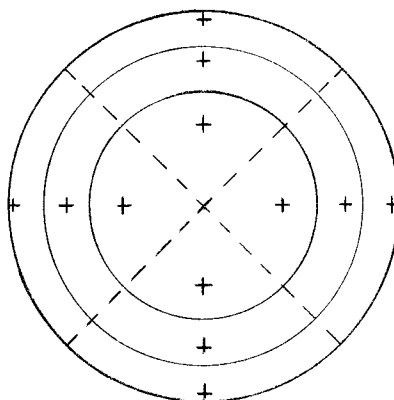


Figure 8. Arrangement of equal areas and velocity measuring points in the circular stacks.

The temperature was measured by a mercury in glass thermometer calibrated at 1°C. The stack pressure was measured by a pressure probe and a water manometer. The dry gas composition was determined from an orsat analysis of carbon dioxide, oxygen, and nitrogen. Carbon monoxide was found to be negligible in a preliminary investigation.

To measure the moisture content of the effluent, the wet bulb-dry bulb temperature technique was used. The following equations (7, p. 365-67) yielded the moisture content,

$$e = e' - 0.000660(1 + 0.00115t')p(t - t')$$

$$B_w = \frac{e}{p}(100)$$

where

t = dry bulb temperature, °C

t' = wet bulb temperature, °C

p = barometric pressure

e = vapor pressure of water in the stack

e' = saturation vapor pressure at t'

B_w = percent moisture by volume

and with e , e' , and p all in the same unit.

The validity of the equations for application at the high stack temperatures was checked by comparing it with the acceptable

consenser technique. Of six tests that were run, the wet bulb-dry bulb temperature technique consistently gave higher results, the difference being 1.2% by volume. Calculations showed that this difference produced only about 0.5% error in the molecular weight. Since the error was insignificant, the wet bulb-dry bulb technique was used.

RESULTS

The pertinent data collected from the tests are given in Tables A-3 through A-11 of the Appendix and the operational data of the veneer dryer during the tests are given in Tables A-1 and A-2. The emission rates for the gaseous hydrocarbons and particulates were calculated and are tabulated in Tables 5 and 6.

An analysis of variance (Tables 7 and 8) of the data revealed the following:

1. Total gaseous hydrocarbons
 - a. Mean emission rate: 16.02 pounds per hour
 - b. Standard deviation
 - 1) One run on any day: 4.09 pounds per hour
 - 2) Average of three runs each day for three days: 2.25 pounds per hour
2. Particulates
 - a. Mean emission rate: 0.87 pounds per hour
 - b. Standard deviation
 - 1) One run on any day: 0.31 pounds per hour
 - 2) Average of one run per day for five days:
0.14 pounds per hour

The day to day variation in hydrocarbons and particulates was found to be significant, as was expected.

Table 5. Gaseous hydrocarbon emission rates (lb/hr).*

Day	Stack									Total
	P	1	2	3	4	5	6	7	8	
1	0	1.5166	4.0590	4.3964	3.2953	1.5212	1.5022	0.2446	0.3498	16.8851
	0.5803	1.6544	4.3582	5.3751	4.5506	1.5329	1.3993	0.2386	0.2998	19.9892
	0.0967	1.4339	4.5265	4.0916	4.7271	1.0414	1.0701	0.1074	0.1874	17.2821
2	0	2.0132	5.9494	7.1886	4.1004	1.1966	0.4522	0.3132	0.2111	21.4247
	0	1.3694	5.6915	5.0206	4.1356	0.9921	0.0740	0.1653	0.1847	18.6332
	0	1.4243	4.0059	4.3848	3.3261	1.0330	0.8479	0.1740	0.1847	15.3807
3	0.1935	0.5979	2.4341	1.8546	2.1263	0.4823	0.5745	0.1585	0.2229	8.6446
	0.0967	1.0644	2.8510	2.8062	3.7514	1.0304	0.6528	0.1585	0.2105	12.6219
	0	1.0644	2.7343	3.4513	3.6131	1.4798	0.5484	0.1744	0.2352	13.3009

*based on hexane

Table 6. Particulate emission rates (lb/hr).

Day	Stack									Total
	P	1	2	3	4	5	6	7	8	
4	0.3290	0.0407	0.0365	0.0418	0.2405	0.2048	0.2501	0.0750	0.0366	1.2550
5	0.2762	0.0167	0.0270	0.0183	0.0257	0.0550	0.4529	0.1740	0.0826	1.1284
6	0.2579	0.0123	0.0144	0.0158	0.0371	0.0201	0.0572	0.0550	0.0406	0.5104
7	0.3509	0.0299	0.0398	0.0304	0.0253	0.0211	0.1419	0.0320	0.0437	0.7150
8	0.2978	0.0324	0.0254	0.0187	0.0368	0.0875	0.1016	0.0865	0.0563	0.7430

Table 7. Analysis of variance for particulates.

Source of variation	Sum of squares	Degrees of freedom	Mean square	Expected mean square
Total	0.5332	44		
Stacks	0.3545	8	0.04431	$\sigma^2 + \frac{5\Sigma S_t^2}{8}$
Days	0.0427	4	0.01068	$\sigma^2 + 9\sigma_d^2$
Residual	0.1360	32	0.00425	σ^2

Table 8. Analysis of variance for hydrocarbons.

Source of variation	Sum of squares	Degrees of freedom	Mean square	Expected mean square
Total	259.7321	80		
Subtotal	245.8632			
Stacks	219.6950	8	27.4619	$\sigma^2 + 3\sigma_{sd}^2 + 9\frac{\Sigma S_t^2}{8}$
Days	10.1356	2	5.0678	$\sigma^2 + 3\sigma_{sd}^2 + 27\sigma_d^2$
Stacks x Days	16.0326	16	1.0020	$\sigma^2 + 3\sigma_{sd}^2$
Residual	13.8689	54	0.2568	σ^2

CONCLUSIONS

The total emission rates averaged 0.87 pounds of particulates per hour with a standard deviation of 0.31 and 16.02 pounds of total gaseous hydrocarbons per hour with a standard deviation of 4.09.

Since these figures are for just one veneer dryer--a gas heated one processing Douglas fir at a given condition--the results should not be assumed for all veneer dryers. Other factors should also be considered. The different species of wood processed would be of great significance, especially for the hydrocarbon emissions. The components of wood include a vast number of organic compounds present in some woods and absent in others. More specifically certain woods contain appreciable quantities of essential oils, fixed oils, resin acids, and sterols. Others contain tannins and coloring matter (15, p. 543). Another important factor is the temperature at which the dryer is operated. Because of the varied boiling points of the vast number of organic compounds, the temperature would have a direct effect on the amount of emissions. Consideration of the effect of steam heated dryers should not be overlooked either.

To determine whether the pollution due to the particulates is significant, a comparison with the emission standards of the County of Los Angeles and the San Francisco Bay Area can be made. Based upon a daily production of 82,000 square feet (basis of 3/8 inch) of

veneer and Douglas fir having a specific gravity of 0.51 (10, p. 23-62), this plant processes 3410 pounds of veneer per hour. According to rules and regulations, the County of Los Angeles allows a maximum weight discharge of 5.44 pounds per hour (12, p. 55-6) and the San Francisco Bay Area allows an emission rate of 5.85 pounds per hour (12, p. 65-8). From those comparisons we can conclude that the emission rate of particulates is not a major problem.

Making a similar comparison for the gaseous hydrocarbons is not as easy, for their emission standards are not available. However, keeping in mind that a dryer processing 3410 pounds of veneer per hour emits 16.02 pounds of hydrocarbons per hour, it would be interesting to compare it with other sources. A typical tepee burning 100 tons of wood waste per day emits 46 pounds of hydrocarbon gases per hour (4, p. 6). A thousand automobiles driving at an average speed of 25 miles per hour emit about 15 pounds per hour (11, Table 4, Appendix). A commercial incinerator with a burning rate of 100 pounds per hour would emit 2.5 pounds of hydrocarbons per hour (8, p. 34) and a dump burning 100 pounds of refuse per hour would emit 14.0 pounds per hour (8, p. 35).

This still does not give an indication whether the veneer dryer is a significant source of air pollution, but it does give an idea of the relative emission rate as compared to other sources.

Further study of individual gaseous hydrocarbons from veneer

dryers is recommended to determine the proportion of reactive species and to estimate an emission factor so that its total contribution can be assessed in an emission inventory.

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APPENDIX

Table A-1. Types of Douglas fir (1/10 inch) processed during tests.

Test no.	Levels	Top levels				Bottom levels			
	Time	8:00	10:00	12:00	2:00	8:00	10:00	12:00	2:00
1	Width	27	27	27	27	Strip	Strip	Strip	Strip
	Type	WS ^a	Heart ^b	Heart	Sap ^c	Sap	Sap	Sap	Sap
	D. T. ^d	4.6	3.5	3.5	7.7	7.5	7.6	7.6	7.6
2	Width	27	27	54	54	27	27	27	27
	Type	Sap	Heart	Heart	Heart	WS	WS	WS	WS
	D. T.	7.7	3.4	3.2	3.2	4.4	4.3	4.4	4.3
3	Width	Strip	Strip	Strip	Strip	27	27	27	27
	Type	Heart	Heart	Heart	Heart	WS	WS	WS	WS
	D. T.	3.2	3.3	3.3	3.4	4.3	4.3	4.3	4.3
4	Width	54	27	27	27	Strip	Strip	Strip	Strip
	Type	Sap	WS	WS	WS	Sap	Sap	Sap	Sap
	D. T.	7.6	4.4	4.4	4.4	7.4	7.4	7.4	7.5
5	Width	27	27	27	27	54	54	54	54
	Type	WS	WS	WS	WS	Heart	Heart	Heart	Heart
	D. T.	4.6	4.6	4.5	4.6	3.2	3.2	3.2	3.0
6	Width	27	54	54	54	Strip	Strip	Strip	Strip
	Type	Sap	Heart	Heart	Heart	Sap	Sap	Sap	Sap
	D. T.	7.6	3.4	3.5	3.3	7.4	7.6	7.6	7.7
7	Width	27	54	54	54	Strip	Strip	Strip	27
	Type	Sap	Heart	Heart	Heart	Sap	Sap	Sap	WS
	D. T.	7.7	3.4	3.3	3.3	7.7	7.7	7.7	4.1
8	Width	27	27	27	27	Strip	Strip	Strip	Strip
	Type	Sap	Heart	Heart	Heart	WS	WS	Sap	Sap
	D. T.	7.7	3.4	3.4	3.3	4.5	4.5	7.5	7.4

^aWS - White speck

^cSap - Sapwood

^bHeart - Heartwood

^dD. T. - Drying time in minutes

Table A-2. Operating temperatures (° F) and damper positions.

Test		Zone							
		1	2	3	4	5	6	7	8
1	D ^a	7	0	0	0	7	7	8	10
	E ^b	460	450	450	400	400	390	360	320
	L ^c	300	350	355	360	350	360	330	300
2	D	7	0	0	0	7	6	7	10
	E	460	450	450	400	400	380	360	330
	L	300	350	355	350	350	360	340	310
3	D	7	0	0	0	7	7&5	7&6	10
	E	460	450	450	410	400	395	360	330
	L	290	360	365	370	370	365	335	310
4	D	7	0	0	0	7	7	8	10
	E	450	450	450	410	390	385	360	330
	L	310	360	360	370	350	355	330	310
5	D	7	0	0	0	7	7	8	10
	E	460	450	440	410	400	380	360	330
	L	295	350	350	360	350	350	330	310
6	D	7	0	0	0	7	7	8	10
	E	450	450	445	410	400	390	360	330
	L	270	350	350	360	350	350	330	310
7	D	8	0	0	0	7	7	8	10
	E	450	450	445	400	400	370	360	330
	L	305	350	350	350	350	350	325	310
8	D	7	0	0	0	7	7	8	10
	E	450	450	450	410	400	380	360	330
	L	310	350	350	360	360	350	330	310

^a Damper position^b Entrance end of air jet tubes^c Exit end of air jet tubes

Note: An average of 313,130 ft³ of natural gas per day was used in the dryers.

Table A-3. Stack temperatures (° F).

Test no.	Stack								
	P	1	2	3	4	5	6	7	8
1a	91	268	369	399	387	372	368	320	300
1b	91	269	379	379	385	---	355	---	295
2a	91	284	379	385	379	363	352	340	307
2b	91	280	361	374	365	360	342	331	302
3a	91	284	392	404	394	379	374	349	306
3b	91	284	376	392	379	374	363	347	309
4a	91	266	363	392	383	370	360	320	307
4b	93	262	374	377	377	361	356	329	293
5a	91	259	358	377	374	367	338	325	315
5b	91	266	365	374	376	372	345	320	304
6a	91	288	365	383	376	360	356	322	302
6b	93	284	361	374	383	361	354	320	297
7a	91	269	361	376	370	374	350	333	302
7b	93	275	369	383	372	365	347	334	300
8a	91	266	360	379	378	369	343	302	318
8b	91	284	361	376	374	374	345	307	289

Table A-4. Effluent moisture contents (percent by volume).

Test no.	Stack								
	P	1	2	3	4	5	6	7	8
1a	2.34	5.54	15.48	22.64	19.13	18.35	12.79	7.40	4.96
1b	2.34	----	19.65	24.92	16.62	-----	13.28	-----	3.61
2a	2.33	6.57	14.44	27.72	24.84	27.01	15.51	6.99	4.98
2b	2.33	7.41	15.71	25.06	32.68	39.52	15.93	11.22	5.19
3a	2.34	6.60	14.00	21.04	24.35	23.45	13.61	7.89	2.05
3b	2.34	6.60	13.54	24.42	24.92	23.66	15.14	7.14	3.65
4a	2.33	6.58	16.21	25.84	34.61	22.30	18.77	8.97	4.32
4b	2.33	6.06	13.54	22.02	26.41	22.66	14.25	7.80	3.65
5a	2.10	5.01	16.51	23.54	29.90	25.44	18.49	8.82	4.74
5b	1.87	5.97	16.23	25.16	29.83	25.23	18.20	9.88	4.50
6a	2.35	7.21	15.15	23.41	31.62	14.25	14.39	9.86	5.26
6b	2.28	6.64	15.29	23.77	24.89	21.48	15.57	9.93	5.47
7a	2.33	7.16	15.21	25.06	28.38	25.13	16.78	12.15	6.61
7b	2.27	7.65	14.93	23.30	28.31	25.49	16.92	12.07	5.97
8a	2.34	8.00	14.16	26.43	28.08	28.44	19.48	10.57	4.59
8b	2.34	5.91	17.54	26.58	33.28	29.86	19.41	12.17	6.38

Table A-5. Stack and atmospheric pressures.

Test no.	1	2	3	4	5	6	7	8
P_s^a	0	0	0	0	0	0	0	0
P_a^b	29.86	29.93	29.86	29.95	29.84	29.76	29.86	29.87

$^a P_s$ = stack pressure, in. Hg gage

$^b P_a$ = atmospheric pressure, in. Hg absolute

Table A-6. Orsat analyses (percent by volume, dry basis).

Test no.	Component	Stack								
		P	1	2	3	4	5	6	7	8
1	CO ₂	0	0.6	1.4	1.8	2.3	2.0	0.4	0.4	0.2
	O ₂	20.9	19.6	17.8	16.7	16.3	16.7	19.0	19.6	20.1
	N ₂	79.1	79.8	80.8	81.5	81.4	81.3	80.6	80.0	79.7
2	CO ₂	0	0.9	1.2	1.8	2.4	1.7	1.0	0.6	0.4
	O ₂	20.9	18.8	17.7	16.7	15.8	17.1	18.4	19.2	19.6
	N ₂	79.1	80.3	81.1	81.5	81.8	81.2	80.6	80.2	80.0
3	CO ₂	0	0.3	1.4	2.0	2.0	1.0	1.0	0.5	0.4
	O ₂	20.9	19.6	17.4	16.5	16.2	17.5	18.4	19.1	19.8
	N ₂	79.1	80.1	81.2	81.5	81.8	81.5	80.6	80.4	79.8
4	CO ₂	0.2	0.4	1.3	1.9	2.1	2.0	1.2	0.4	0.4
	O ₂	20.5	19.9	17.5	16.2	15.8	16.4	18.3	20.0	20.2
	N ₂	79.3	79.7	81.2	81.9	82.1	81.6	80.5	79.6	79.4
5	CO ₂	0	0.6	1.6	2.0	2.8	1.8	1.6	0.6	0.4
	O ₂	20.6	19.2	17.8	16.2	15.2	16.2	18.0	19.0	19.6
	N ₂	79.4	80.2	80.6	81.8	82.0	82.0	80.4	80.4	80.0
6	CO ₂	0	0.5	1.0	2.0	3.0	2.2	1.3	0.7	0.3
	O ₂	20.3	19.1	18.0	16.4	15.1	16.5	18.0	18.3	20.1
	N ₂	79.7	80.4	81.0	81.6	81.9	81.3	80.7	81.0	79.6
7	CO ₂	0	0.3	1.4	1.8	2.4	2.2	1.5	0.6	0.3
	O ₂	20.0	19.5	17.8	16.8	15.6	16.2	17.9	19.1	19.9
	N ₂	80.0	80.2	80.8	81.4	82.0	81.6	80.6	80.3	79.8
8	CO ₂	0	0.6	1.3	2.0	2.4	1.7	1.0	0.7	0.3
	O ₂	20.8	19.4	18.1	16.6	15.6	17.4	18.3	19.3	20.1
	N ₂	79.2	80.0	80.6	81.4	82.0	80.9	80.7	80.0	79.6

Table A-7. Effluent flow rates (ft³/hr).^a

Test no.	Stack								
	P	1	2	3	4	5	6	7	8
1a	---	121,010	186,620	172,260	196,390	117,800	195,250	53,350	109,610
1b	---	---	---	---	---	---	---	---	---
2a	---	121,050	194,740	179,590	203,720	124,220	138,610	77,850	117,000
2b	---	122,890	190,080	181,960	198,670	124,220	137,580	80,520	114,510
3a	---	94,510	138,170	172,350	193,720	114,050	129,530	57,420	109,280
3b	---	117,670	180,750	169,540	181,400	120,670	121,870	84,520	107,970
4a	906,500	123,750	202,590	178,940	199,290	128,580	121,610	53,410	110,820
4b	871,840	117,400	200,880	177,360	188,060	121,160	120,450	84,450	111,470
5a	847,630	122,220	197,610	179,670	198,910	127,240	118,800	53,410	85,320
5b	823,050	117,120	197,610	180,460	193,000	128,920	120,010	52,060	83,630
6a	845,850	118,650	189,050	170,900	193,220	126,340	122,130	58,640	89,234
6b	915,480	112,880	195,180	174,160	186,470	129,080	119,820	52,180	90,840
7a	797,530	79,780	202,350	169,610	193,330	126,570	114,930	53,360	91,750
7b	894,530	88,770	195,750	168,780	190,680	121,970	108,580	53,360	93,320
8a	772,350	91,880	204,070	173,910	197,060	125,970	110,840	52,880	90,710
8b	811,320	80,510	202,700	170,180	199,620	126,550	115,310	54,250	94,600

^a60° F and 30 in. Hg

Table A-8. Particulate concentrations.

Test number	Stack number	Volume of gas samples scf ^a	Particulate weight gm	Concentration lb/ft ³ x 10 ⁻⁶
4	P	1914 ^b	0.3212	0.3700
	1	736 ^c	0.1128	0.3379
	2	1075	0.0882	0.1809
	3	892	0.0973	0.2349
	4	920	0.5184	1.2422
	5	743	0.5529	1.6405
	6	979	0.9176	2.0663
	7	1010	0.4986	1.0883
	8	598	0.0893	0.3292
5	P	1198	0.1797	0.3307
	1	678	0.0428	0.1392
	2	629	0.0390	0.1367
	3	986	0.0455	0.1017
	4	640	0.0380	0.1309
	5	714	0.1392	0.4298
	6	687	1.1820	3.7930
	7	649	0.9715	3.3001
	8	586	0.2599	0.9778
6	P	469 ^d	0.0623	0.2928
	1	626	0.0301	0.1060
	2	612	0.0208	0.0749
	3	567	0.0235	0.0914
	4	649	0.0575	0.1953
	5	687	0.0491	0.1576
	6	676	0.1499	0.4726
	7	565 ^e	0.2543	0.9923
	8	479	0.0979	0.4506
7	P	819 ^d	0.1541	0.4148
	1	1065	0.1712	0.3544
	2	634	0.0575	0.1999
	3	575	0.0469	0.1798
	4	645	0.0386	0.1319
	5	783 ^c	0.0602	0.1695
	6	699	0.4027	1.2701
	7	562	0.1528	0.5994
	8	479	0.1026	0.4722

(Continued)

Table A-8. (Continued).

Test number	Stack number	Volume of gas samples scf ^a	Particulate weight gm	Concentration lb/ft ³ x 10 ⁻⁶
8	P	782 ^d	0.1334	0.3761
	1	534	0.0911	0.3761
	2	621	0.0352	0.1250
	3	559	0.0276	0.1088
	4	637	0.0536	0.1855
	5	738	0.2321	0.6933
	6	633	0.2581	0.8989
	7	495	0.3627	1.6154
	8	455	0.1253	0.6071

^a 60° F and 30 in. Hg^b 48 min. sample^c 22 min. sample^d 20 min. sample^e 21 min. sample

Table A-9. Hydrocarbon concentrations (ppm as hexane).

Test no.	Stack								
	P	1	2	3	4	5	6	7	8
1a	0	55	108.5	137	84	65	36.5	20.5	14
1b	3	60	116.5	162.5	116	65.5	34	20	12
1c	0.5	52	121	127.5	120.5	44.5	26	9	7.5
2a	0	73.5	150	220.5	116.5	58.5	16	18	8
2b	0	50	143.5	154	117.5	48.5	38	9.5	7
2c	0	52	101	134.5	94.5	50.5	30	10	7
3a	1	25	123	57.5	61.5	22	22	10	9
3b	0.5	44.5	135.5	87	108.5	47	25	10	8.5
3c	0	44.5	132	107	104.5	67.5	21	11	9.5

Table A-10. Moisture contents of veneers^a (gm moisture/gm of dry veneer).

Test no.	2	3	4	5	6	7	8
From lathe	25.0	65.1	156	43.9	122	35.9	28.1
	43.0	27.8	161	27.7	26.7	185	27.5
	165	29.0	173	64.5	194	39.0	139
Outfeed	8.2	6.6	4.3	6.4	4.3	5.5	5.0
	6.4	7.3	4.5	6.3	5.6	5.3	5.0
	6.6	7.6	4.9	5.5	4.2	7.6	5.1

^aSamples were oven dried at 103°C

Table A-11. Particle size distributions^a (percent by count).

Size μ	Stack								
	P	1	2	3	4	5	6	7	8
< 3.1	7.5	2.1	5.6	9.2	10.3	15.1	11.1	25.0	13.4
4.4	8.8	4.5	11.5	14.6	15.8	13.0	10.6	25.0	18.5
6.2	11.2	8.9	7.7	11.2	10.3	13.0	17.1	14.5	17.7
8.8	10.9	5.8	5.2	8.3	6.0	8.0	9.7	8.6	11.2
12.5	6.6	8.9	5.2	6.2	4.7	9.2	2.8	3.2	6.5
17.5	8.1	5.2	1.7	5.0	2.1	2.9	5.6	4.5	4.3
25	6.6	2.7	2.1	2.9	0.9	2.9	3.2	1.8	4.3
35	3.4	5.8	8.7	5.4	4.7	4.6	2.8	1.8	3.4
50	2.8	4.5	4.9	5.0	6.8	6.3	6.0	1.8	4.3
70	6.2	5.5	8.0	5.0	5.6	3.4	6.0	1.4	1.7
100	2.8	5.8	5.2	4.2	1.7	4.6	1.9	0.9	2.2
140	9.4	5.8	3.5	2.9	4.7	3.8	1.4	0.9	3.0
200	3.4	5.2	3.8	3.3	5.1	1.7	4.2	0	2.2
> 200	20.6	29.2	26.8	16.7	21.4	11.3	17.6	10.5	7.3

^aSamples were taken using 1 3/4 inch strip of sticky paper. Over 200 particles were counted from the centerline of the strip using light field microscopy. A Porton eyepiece was used and total magnification was 100x.