"The Use of Gas Sampling and Analysis for the Evaluation of Tepee Burners"

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INTRODUCTION

The Bureau of Air Sanitation of the California Department of Public Health has been engaged in a program to improve the operation of wood waste burners. This has been a cooperative program with local county health departments and with individual operators. The major emphasis of this program has been to improve the combustion of the wood waste. This has been accomplished by modification in the burner operation, for instance, better distribution of the underfire and overfire air. A quick evaluation of combustion efficiency can be made by using surface thermometers at various points on the outer shell. A better evaluation of combustion efficiency would be an analysis of the particulate and gaseous effluent from the burner.

Particulate sampling of a tepee is difficult and time consuming and the results are often questionable. Some success has been achieved with greased slides. Gas sampling, on the other hand, is relatively simple and the equipment required is easily transported and set up.

The success of any sampling program finally depends on the ability to analyze the samples. All of the samples reported in this paper were analyzed by the Air and Industrial Hygiene Laboratory of the Department. The analyses were made by gas chromatography and infrared spectroscopy.

TEST PROCEDURE

The sample probe is a quarter inch copper tube which is inserted several feet into the burner at some point above the combustion zone. The sampling heights used in this study ranged from a few feet above the combustion zone to just below the base of the screen. The probe is connected by tygon tubing to a diaphragm pump. The exhaust from the diaphragm pump is collected in an aluminized polyester bag (Scotchpak). Surface contact thermometers are attached to various points on the burner shell. Typical thermometer placement on a 60 foot high burner would be at the 8, 20, 35, and 50 foot level, usually alongside the burner ladder. Shell temperatures used in this discussion are the highest temperatures noted during the sampling time. In every case the highest temperature was at either the 20 or the 35 foot level.

DISCUSSION

Forty-three gas samples were taken from 6 different mills on 13 different days, and analyzed for the C_1 to C_5 hydrocarbons. Six representative analyses are given in Table 1 to show the magnitude of concentrations.

A very wide range of concentrations was found: CO_2 values ranged from 0.11% to 2.8%; CO concentrations from 180 ppm to 3000 ppm; and total hydrocarbons were from 4 ppm to 300 ppm. The concentration ranges for all compounds are given in Table 2. Some compounds were found in only a small number of samples. These are given in separate columns; for example, pentane was detected in only a half dozen samples. On some of the earlier samples the analysis did not include the C_4 and C_5 hydrocarbons. Pentane was checked on 56% of the samples and butane on 75%.

SOME GAS CONCENTRATIONS FOUND IN TEPEE BURNER SAMPLES

Table 1

TEST		38	11	33	2	25	6
Shell Temp.,	°F*	130	180	240	290	300	430
CO_2	%	0.25	0.32	2.5	1.9	2.6	2.2
CO	ppm	645	312	3000	1576	1500	713
Methane	"	64.9	11	99	96	21.2	26.8
Ethane	"	8.05	0.30	10.6	3.8	---	0.26
Ethylene	"	8.1	0.80	2.5	16.8	18.9	2.1
Acetylene	"	0.7	0.90	17.3	5.5	1.1	---
Propane	"	1.3	0.06	0.34	0.37	---	0.03
Propylene	"	5.6	0.3	0.02	1.9	8.6	0.54
Butane	"	0.25	0.02	0.17	0.4	---	0.11
Butenes	"	1.6	0.05	0.85	0.3	0.13	---
Pentane	"	0.15	---	0.42	---	---	---
Isopentane	"	2.1	---	3.9	0.08	---	---

* Maximum measured shell temperature at time of sampling.

RANGE OF GAS CONCENTRATIONS FOUND IN
TEPEE BURNER SAMPLES
Table 2

		HIGH	LOW	MED	ANALYZED	FOUND
CO_2	%	2.8	0.11	0.94		
CO	ppm	3000	180	760		
Methane	"	232	2.4	28.7		
Ethane	"	10.6	0.18	2.2		
Ethylene	"	37	0.28	6		
Acetylene	"	19.6	0.2	4		
Propane	"	5.1	0.01	0.25		
Propylene	"	8.6	0.02	1.0		
Butane	"	0.4	T	0.08	32	32
Butenes	"	1.59	T	0.19	32	28
Pentane	"	0.49	0.03	0.36	24	6
Isopentane	"	5.69	0.08	2.09	24	10
Methylbutene	"	0.87	0.18	0.32	24	12

A carbon balance was run on each sample to calculate the pounds of gas produced per ton of wood waste burned. This weight ratio of product to charge was calculated for carbon monoxide, for total hydrocarbons, and for C_2 to C_5 hydrocarbons. In order to make these calculations the following assumptions were necessary:

1. That the moisture content of the wood was 50%.
2. That 25% of the original fuel was carbon.
3. That all of the combustion products were emitted in a gaseous state. (Other unpublished results have shown from 20 to 80 lbs per ton emitted as particulate matter.)
4. That the weight of total hydrocarbons was 1.3 times the weight of the carbon in these hydrocarbons. $1.3 \times 12 = 15.6 \cong CH_4$
5. That the weight of the C_2 to C_5 hydrocarbons was 1.2 times the weight of the carbon in these hydrocarbons.

If all the hydrocarbons are converted to ppm C in equivalent hydrocarbon, then the pounds of gas produced per ton burned are given by the following equations:

for CO 1. $$\frac{\text{lbs CO}}{\text{ton burned}} = \frac{1166 \times (\text{ppm CO})}{\%\ CO_2 \times 10^4 + \text{ppm CO} + \text{ppm C equiv.}}$$

for total hydrocarbons 2. $$\frac{\text{lbs HC}}{\text{ton burned}} = \frac{650 \times (\text{ppm C equiv.})}{\%\ CO_2 \times 10^4 + \text{ppm CO} + \text{ppm C equiv.}}$$

for C_2 to C_5 hydrocarbons 3. $$\frac{\text{lbs } C_2\text{-}C_5 \text{ HC}}{\text{ton burned}} = \frac{600\ (\text{ppm C equiv.} - \text{ppm methane})}{\%\ CO_2 \times 10^4 + \text{ppm CO} + \text{ppm C equiv.}}$$

The C_2 to C_5 hydrocarbons have been calculated in accordance with Regulation 2 of the Bay Area Air Pollution Control District. This Regulation limits hydrocarbon emissions to 50 ppm when volumes are corrected to 6% oxygen. The BAAPCD has found that multiple chamber incinerators designed

TABLE 3

Sample	Shell Temp.	CO_2	CO	CH_4	Total HC	Equiv. HC
	°F	%	ppm	ppm	ppm	ppm
W- 1	290	0.93	935	97	124	154
W- 2	290	1.9	1576	96	126	164
W- 3	310	1.4	1449	116	146	183
W- 4	340	2.8	720	47	54	66
W- 5	410	1.95	1576	19	21	25
W- 6	430	2.23	713	27	30	34
T- 7	200 - 50	0.13	260	18.5	32	46
T- 8	200 - 50	0.16	320	24	34	44
T- 9	200 - 50	0.36	610	56	79	103
S-10	190	0.38	305	7.6	9.6	10.8
S-11	180	0.32	312	11.2	13.6	16.5
S-12	140	0.44	400	26	33	40
V-13	250	0.50	1300	141	175	211
V-14	260	0.46	1200	232	297	366
V-15	270	0.44	868	197	254	315
V-16	150 - 200	0.22	740	110	139	170
V-17	150 - 200	0.38	1500	204	229	258
V-18	150 - 200	0.42	1800	220	277	336
A-19	400 - 50	1.63	855	14.4	31	49
A-20	400 - 50	2.05	1195	15.4	40	65
A-21	400 - 50	1.97	1175	17.2	35	64
A-22	400 - 50	1.16	688	12.2	23	35
A-23	420	0.54	250	2.4	4.1	6.9
A-24	300	2.6	1500	21	50	87
A-25	210	0.51	270	9.5	16.4	24.5
A-26	240	0.28	225	8.6	15	23
A-27	270	0.37	210	7.5	12.5	18.7
D-28	170	1.4	1500	24	33	46
D-29	170	1.4	1030	24	31	43
D-30	90	0.14	290	29	31	36
D-31	280	1.6	2000	94	148	225
D-32	320	2.5	3000	157	219	303
D-33	240	2.3	2000	99	140	196
D-34	300	1.7	2000	62	117	196
D-35	265	1.3	1200	34	66	117
D-36	130	0.25	645	65	93	138
D-37	350	1.0	565	28	39	53
D-38	330	2.2	1050	62	73	85
D-39	250	0.94	760	14.1	28	46
D-40	150	0.11	180	17.3	25	35
D-41	210	0.74	565	12.6	20	29
D-42	180	0.92	725	32	46	63
D-43	160	0.66	600	31	44	60
		Average 1.06%	955		80.0	107

GAS CONCENTRATIONS OF TEPEE BURNER EFFLUENT

TABLE 4

Sample	Shell Temp.	LBS. CO / Ton	LBS. HC / Ton	LBS C_{2+} / Ton	REG. 2 C_{2+}
	°F				ppm
W- 1	290	110	10.1	3.5	364
W- 2	290	92	5.4	2.1	204
W- 3	310	113	7.9	2.6	334
W- 4	340	30	1.5	0.41	38
W- 5	410	94	0.8	0.17	13
W- 6	430	37	0.97	0.19	19
T- 7	200 - 50	205	20.3	11.2	1140
T- 8	200 - 50	207	15.9	6.7	660
T- 9	200 - 50	195	16.8	7.2	730
S-10	190	87	1.8	0.46	68
S-11	180	105	3.2	0.94	95
S-12	140	98	4.2	1.3	195
V-13	250	268	23.4	7.2	670
V-14	260	250	43.1	14.5	1360
V-15	270	153	39.8	13.8	1400
V-16	150 - 200	302	40.5	13.2	1170
V-17	150 - 200	364	35.1	6.8	560
V-18	150 - 200	387	40.5	12.9	1090
A-19	400 - 50	59	1.9	1.2	140
A-20	400 - 50	66	2.0	1.4	157
A-21	400 - 50	67	1.7	1.1	121
A-22	400 - 50	67	1.9	1.1	127
A-23	420	44	0.68	0.4	43
A-24	300	65	2.1	1.5	148
A-25	210	60	3.0	1.7	184
A-26	240	90	5.1	3.0	295
A-27	270	62	3.05	1.7	182
D-28	170	60	2.0	0.87	71
D-29	170	90	1.9	0.8	67
D-30	90	213	15.0	2.8	202
D-31	280	161	8.5	4.6	409
D-32	320	130	7.35	3.3	300
D-33	240	97	5.3	2.4	224
D-34	300	128	7.0	4.5	390
D-35	265	102	5.6	3.6	311
D-36	130	273	32.5	15.9	1325
D-37	350	64	3.5	1.5	154
D-38	330	54	2.45	0.63	70
D-39	250	87	2.9	1.85	188
D-40	150	171	18.4	8.6	730
D-41	210	85	2.4	1.2	125
D-42	180	89	4.3	1.9	188
D-43	160	103	5.6	2.5	247

in accordance with Los Angeles County Air Pollution Control District standards can meet this limit. This gives another basis for comparison of the samples.

These values have been calculated for all samples and tabulated in Tables 3 and 4. The range of gaseous emissions in Table 4 and the arithmetic average are given below:

	pounds gas emitted per ton burned	average
CO	30.0 - 360.0	130
Total hydrocarbons	0.8 - 43.0	11
C_2^+ hydrocarbons	0.2 - 14.5	4

These averages indicate that a typical tepee burning 100 tons per day of wood waste will emit daily: 13,000 pounds of CO, 1100 pounds of hydrocarbon gases, and 400 pounds of C_2 to C_5 hydrocarbon gases. The wide range of values leads to some hope that these emissions can be substantially reduced. By grouping the samples within ranges of shell temperature and taking average emission values within these temperature ranges, the effect of better combustion can be shown. Table 5 indicates that when the highest measured shell temperature exceeds 400°F, hydrocarbons emissions are reduced by better than 80% and CO emissions are reduced by more than 50% over the average value.

An example of the change that can occur when higher temperatures are achieved can be seen by comparing tests W-1 and W-2 with tests W-5 and W-6. The principal change was a reduction in the volume of the overfire air. The shell temperature has been raised 130°F. CO values have decreased 40%; and the C_2 and higher hydrocarbons have been reduced from an average 2.8 lbs/ton to less than 0.2 lbs/ton.

AVERAGE EMISSIONS OF TEPEE BURNERS
Table 5

RANGE TEMP. F	SAMPLES	AVE LBS GAS PER TON BURNED CO	Total HC	C_2^+	Reg.2 C_2^+ppm*
90-150	30, 36, 12 40	189	17.5	7.2	613
160-200	43, 28, 29 42, 11, 10 16, 17, 18	176	15.0	4.5	395
210-250	25, 41, 26 33, 13, 39 7, 8, 9	144	10.6	4.7	468
260-300	14, 35, 27 15, 31, 1 2, 24, 34	125	13.8	5.5	287
310-350	3, 32, 38 4, 37	78	4.5	1.7	179
410-450	5, 23, 6 19, 20, 21 22	62	1.4	0.5	89

* Volumes corrected to 6% O_2

CONCLUSION

Gas sampling offers a relatively simple way to evaluate combustion efficiency in a tepee burner. When the highest measured shell temperature is greater than 400°F, gaseous emissions may be reduced by 80% or more over average operation of a tepee burner. However, below 400°F the correlation between shell temperatures and gaseous emissions is not clearcut. There are at least three reasons for this lack of correlation:

1. Shell temperature changes will lag combustion changes and this time lag will vary from one burner to another.
2. Air may enter through bottom openings or leak into the shell, and pass directly up the side of the burner without entering the combustion zone, thus reducing the shell temperature without a corresponding effect on burning characteristics.
3. There is a large variation in the relationship of the size of the burner to the size of the burning pile.

At this time most of the work has been with redwood plus some pine and fir. The project is continuing on other burners and for other compounds, such as aldehydes. Further reports will be made as data is accumulated.

REFERENCES

1. Regulation 2, Bay Area Air Pollution Control District, May 1960.
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3. H. Droege, H. C. Johnson, L. Clayton, T. McEwen, "Performance Characteristics and Emission Concentrations from Various Type Incinerators." Information Bulletin 1-63, Bay Area Air Pollution Control District, February 1963.

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