STUDY OF ABATEMENT METHODS AND METEOROLOGICAL CONDITIONS FOR OPTIMIUM DISPERSION OF PARTICULATES FROM FIELD BURNING OF RICE STRAW

SPRING OPEN FIELD BURNING TRIALS

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PRINCIPAL INVESTIGATORS

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ABSTRACT

This project was initiated to obtain information on the effect of meteorological conditions and management techniques on particulate emissions from spring open field burning of rice field residue. Two fire management practices were employed: single line backfire, and single line headfire. Three residue management techniques were studied: spread straw, windrowed straw, and raked spread straw. In addition, measurements were taken of air temperature, relative humidity, absolute humidity, wind speed and direction, residue moisture content, residue loading (Kg/m^2), fire temperature, rate of flame spread, CO_2 emission, particulate production and particulate size distribution. The data analysis showed that particulate emissions could be minimized by burning at low moisture contents and using a backfire instead of a headfire ignition technique. Laboratory simulations confirmed the advantages of low residue moisture and backfiring in reducing particulate emissions. The laboratory tests also showed that increased fuel loading (Kg/m^2) may help to decrease particulate emissions. Laboratory and field data showed that the particulate emissions were generally of a submicron size and a significant amount of the particulates were chloroform-soluble organic compounds. Studies were conducted with several large open field burns where the practicality of selected fire and residue management techniques were tested. The estimated costs per acre of the various techniques were confirmed in the large open field burns.

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* Statewide Air Pollution Research Center, University of California, Riverside

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CONCLUSIONS

Field and laboratory studies have shown that fire managment and rice residue management techniques can be used to minimize particulate emissions from spring open field burning. Single line backfiring reduced particulate emissions by approximately 50% over single line head firing. Moisture content of the rice residue was found to be the primary field condition variable controlling particulate emissions. Head firing with the residue at 10% moisture content (wet basis) will produce approximately 5 kilograms of particulates per metric ton of fuel burned (10 lb/ton) while residue at 25% moisture content will produce approximately 18 kilograms of particulates per metric ton of fuel burned (36 lb/ton). Laboratory burn data indicated a tendency for decreased emissions with increased fuel loading (Kg/m^2). However, improved drying characteristics of low fuel loading more than offsets this possible benefit under field conditions. Other independent variables considered but for which no significant effect on particulate emissions could be found were: air temperature, relative humidity, absolute humidity, and wind speed.

Field residue drying studies indicated the effect of atmospheric conditions and residue placement techniques on drying. The minimum moisture content the straw reached at any time during the day was strongly related to relative humidity. Solar radiation, air temperature, relative humidity, wind speed, residue loading, and residue placement all affected the rate at which the residue reached the minimum moisture level. Minimum moisture level for the day in spread straw was generally reached between 2 p.m. and 3 p.m. when the relative humidity was at the low point for the day. If the straw was spread uniformly on standing stubble, two clear days would dry the straw to an equilibrium moisture level. If the straw were left in rows and placed on short or lodged stubble close to wet soil, the straw might not be at equilibrium moisture content after 10 clear days.

Particulate size distribution data gave mass median diameters in the range of $.1\mu$ to $.3\mu$. Particulates in this size range remain in the atmosphere for extended periods. Approximately 50% of the particulates were soluble in chloroform with the soluble particulates having a smaller mass median diameter than the insoluble particulates. Particulate samples from backfires had a smaller percentage of soluble particulates than from headfires. Small chloroform soluble particles having vapor pressures greater than 10^{-5} Torr can be expected to evaporate rapidly.

CONCLUSIONS (Cont'd)

Cost studies of various burning techniques indicate a cost of \$.47 per hectare (19¢/ac) for head fires, \$1.61 per hectare (65¢/ac) for backfires, \$.62 per hectare (25¢/ac) for into-the-wind striplighting.

RECOMMENDATIONS

The laboratory and field results have identified the major residue and fire management factors that effect particulate emissions from open field burning of rice residue. Moisture content of the residue is the most significant residue management variable. Residue burned at higher moisture content produces more particulate emissions than residue burned at lower moisture content. Field ignition technique is the most significant fire management factor. Single line backfires (burning against the wind) product 50% less emissions than single line head fires (burning with the wind). Sidefiring and into-the-wind-strip firing appear to be similar to backfires in particulate production while covering a field at, or near, the speed of a headfire.

On the basis of the above findings the following recommendations are made:

Residue Management

1. The residue should be burned on permissive burn days when it has reached a reasonably low moisture level (less than 12% wet basis). The residue will generally be less than 12% moisture if one or more of the following requirements is met:

   A. Hand held residue samples, representative of the whole field, produce an audible crackle when bent sharply.

   B. The relative humidity is less than 60% in spread straw supported on stubble after one clear day and on a clear day.

   C. Representative field samples tested with a calibrated moisture meter (wood type) show the residue to be less than 12% moisture.

The above requirements will most often be met between the hours of 11 a.m. to 6 p.m. and will only be met when the relative humidity is less than 60%.

2. Spread the straw behind the harvester whenever possible. Spread straw dries faster than windrowed straw. Therefore, spread straw will require fewer days to dry than windrowed straw, it is likely to be drier than windrowed straw during burning hours, and it will be at an acceptably low moisture content for more hours during the day than windrowed straw. Uniformly spread straw also provides more even fuel distribution for better fire spread and disease control. Straw may be left in windrows if it is to be raked before spring burning.

3. Mow the unharvested rice and weeds on the checks or levees to provide continuity of fuel for good fire spread and disease control.

4. During harvest minimize bankout wagon haul road areas, wherever possible and practical, to maintain good straw placement on standing stubble.

Fire Management

5. Burn as soon as straw is dry in the fall following harvest, whenever possible or practical. This will distribute emissions from burning more uniformly over the entire burning season utilizing permissable burn days to the maximum extent and provide for combustion when the straw placement on the stubble is optimum. Over-wintering compacts residue which tends to impede drying in the spring.

6. Utilize backfires, sidefires, or into-the-wind-strip-light fires (with caution - preparing for possible accidents) whenever feasible or practical. Reserve the use of head fires and peripheral light fires for those conditions where they are the only method(s) that will produce an effective burn (i.e. low residue loading). To minimize particulate emissions head fires and peripheral light fires should only be used under very dry residue conditions.

Other Recommendations

7. Studies should be conducted to:
   (a) Further characterize smoke from rice straw burning.
   (b) Management and machinery systems to improve drying rates and achieve reduced particulate emissions under adverse conditions.
   (c) Develop models for predicting moisture content of residues as affected by atmospheric and meteorological variables under various field conditions.

PART I INTRODUCTION

One hundred thousand to two hundred thousand hectares (1/4 - 1/2 million acres) of rice are grown in the Sacramento and San Joaquin valleys in California[6]. Each hectare of rice has about 7 metric tons (3 tons/acre) of residue left in the field after the fall harvest. The residue from this production ranges from 0.7 to 1.5 million metric tons that must be disposed of each year before the next crop can be planted in the following Spring. The predominant practice is to burn the residue and prepare the soil with conventional tillage implements. For most seasons there is sufficient dry weather after harvest to burn most of the residue in fall but an early onset of rain will require much of the residue to be burned in the following spring. The condition of the residue at this time is much different after it has been in the field during the winter months. During the fall, except in high alkali areas, the rice stubble is green but the straw and chaff cut by the combine will dry and be burnable. In the spring the straw has undergone some decomposition, the stubble has died and in some cases both the straw and stubble have been compacted on the surface of the wet soil by rain, flooding, and migratory water fowl. In addition, the spring burning conditions are different from the fall because better atmospheric dispersion potentials normally exist in the spring. For these reasons spring rice field residue burning was investigated to supplement information obtained in fall burning studies.

The goal of the study was to determine the nature and amount of particulates in rice residue smoke and to evaluate methods of fire and fuel management that would reduce the particulate emissions. Little reported research was found in this area. Work done by Boubel[1,2] showed average emissions from grass seed stubble and straw fires but showed no statistically significant effect of fire conditions, fuel conditions and atmospheric conditions on particulate emissions. Open field burning has been utilized for years in California rice fields to facilitate tillage operations, aid in disease, pest and weed control and improve stand establishment and productivity for the following crop. No prescribed methods of burning to minimize emissions could be found.

The first phase of the project was a series of burning trials designed to determine the relationship of fuel, fire and atmospheric conditions to particulate emissions. Trials were conducted both in the field and in the laboratory. The second phase, straw drying experiments, was designed to determine the effects of residue and atmospheric conditions on straw drying rates in the field. The third phase consisted of large field burning trials designed to test the practicality of various proposed management methods and determine costs of these methods.

PART II. MATERIALS AND METHODS

Phase 1: Burning Trials

Part A: Field Plot Trials

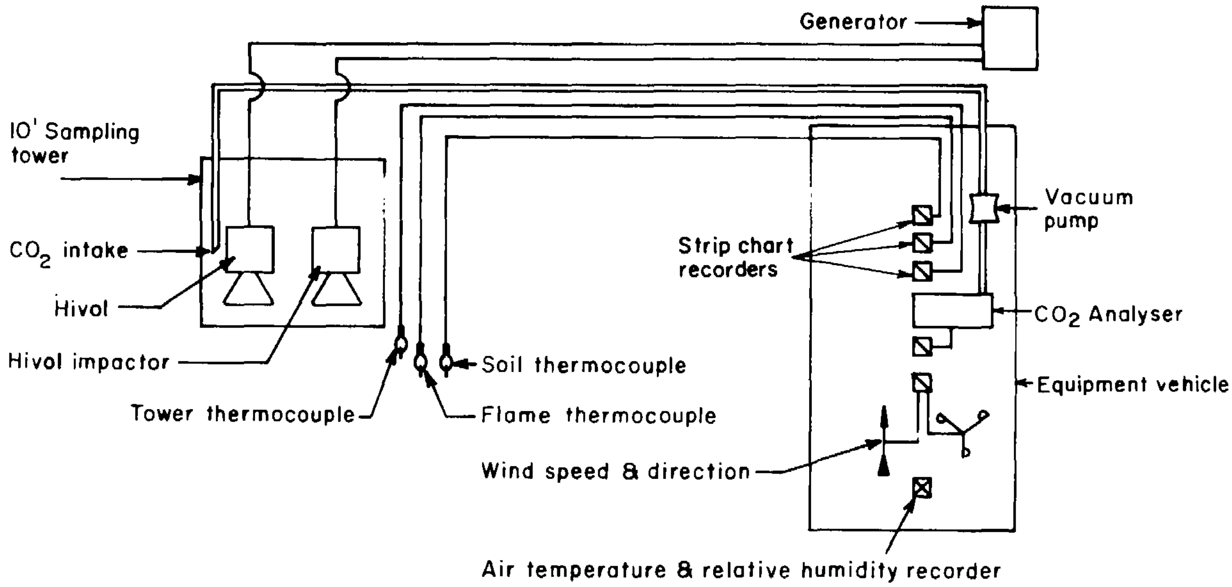
The field tests were conducted on 1/4 hectare (1/2 ac) plots. The plots were burned under typical residue and atmospheric conditions found in the spring. A sampling platform elevated 3 meters (10 feet) above the ground was set up prior to the burn. (see figure 1). The platform contained the following instruments:

1. Gelman Hurricane high volume sampler with 20 cm x 25 cm (8" x 10") type A glass fiber filter.
2. Gelman Hurricane high volume sampler with a six stage Weathermeasure high-volume cascade particulate impactor.
3. Chromel-alumel thermocouples for measuring temperatures at the platform, and in the fire.
4. CO_2 gas sample intake.

A 37 meter (120 feet) cable carried the temperature and gas information to a four wheel drive instrument vehicle and supplied power to the sampling equipment. The instrument vehicle contained the following:

1. 2 strip chart recorders for temperature recording.
2. A Beckman non-dispersive infra-red gas analyser for CO_2 analysis and a strip chart recorder.
3. Wind speed and direction recording aparatus.
4. Ambient air temperature and relative humidity sensors.

For these trials straw and chaff are defined as the material cut by the combine. Stubble is that portion of the plant not cut by the combine.



SCHEMATIC OF FIELD SAMPLING EQUIPMENT

Figure 1

Prior to each burn straw and stubble quantity and moisture content samples were taken along with stubble height measurements. After the burn, unburned straw and stubble quantity and moisture samples were collected as well as ash samples to determine ash quantity and carbon content. Flame advance measurements were made on a number of the trials. Laboratory analysis of field collections included: chloroform extraction of high volume particulate samples using Soxhlet extraction apparatus; carbon content analysis of rice straw and post burn ash using an induction oven, dry chemical CO_2 absorption method; and air oven moisture content determinations of the straw and stubble samples. (See Appendix A for sample calculations for particulates.) Three residue management techniques and two fire management tehcniques were studied in the field trials. The straw was left in windrows as it was dropped behind the harvester, spread uniformly over the stubble by a combine straw spreader attachment or two rakewidths of spread straw were raked together after several days of drying. The two fire techniques were: lighting a single line fire perpendicular to the wind on the leeward edge of the plot allowing the flame to progress into the wind (backfire), or on the windward edge of the plot (head fire). Fires were not monitored unless the windspeed was greater than 4 miles per hour to avoid the difficulty of defining the fire type under light and variable winds. Despite this precaution, some fires changed type and this undoubtedly contributed to some of the variability of field data results.

Part B: Burning Tower Simulations at the Statewide Air Pollution Research Center, University of California, Riverside

This work was done in conjunction with agricultural burning trials funded by PCA-6 project[9]. The laboratory setup is fully described in the PCA-6 report. (See Figure 2 for summary of the laboratory setup).

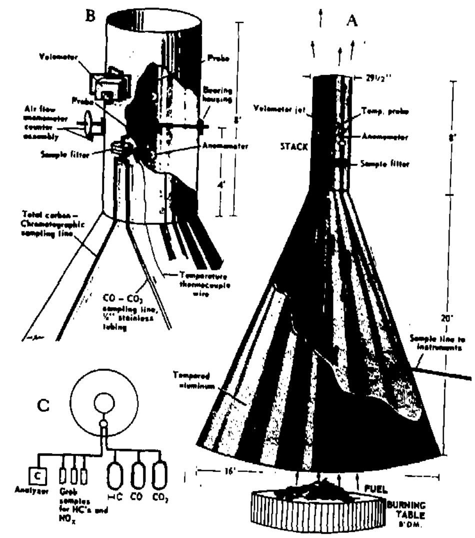
Phase II: Residue Property Experiments

Part A: Rice Straw Drying Rate Studies

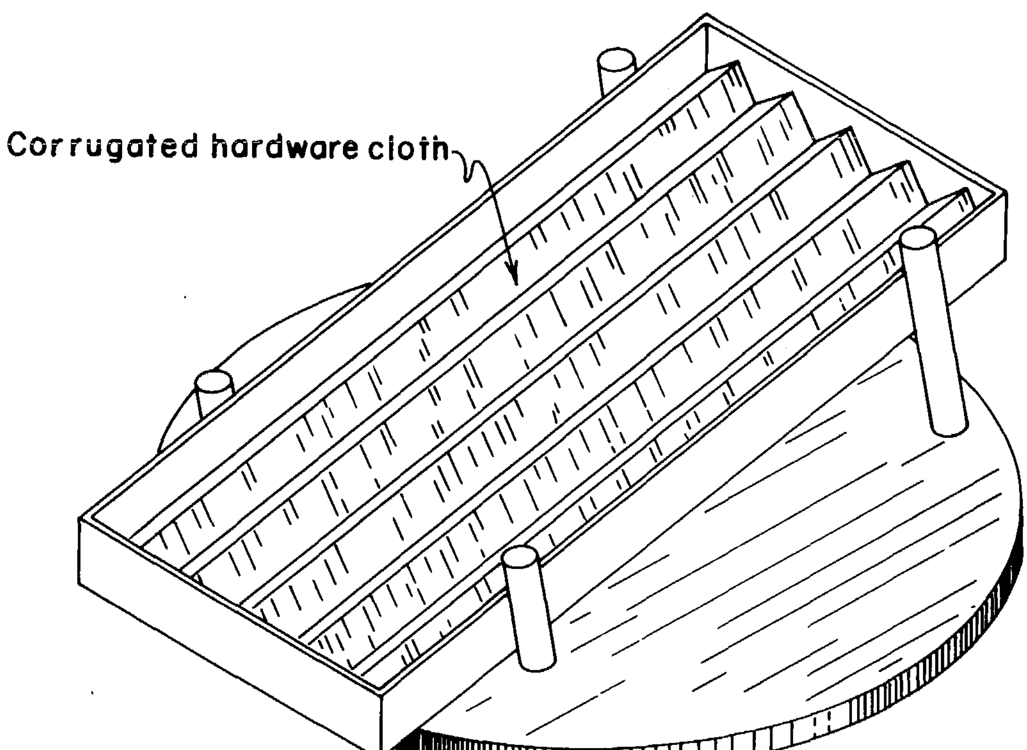
These studies were conducted in field plots at the UCD Rice Research Facility beginning in the late fall of 1972 and ending in the spring of 1973. Immediately following harvest a 1.2m x 2.5m (4' x 8') area of spread straw or a 1.2m (4') section of windrowed straw was carefully lifted from the field and placed on a 1.2m x 2.5 m (4' x 8') steel tubing framed, volleyball net tray. The tray was then placed in the area where the straw was removed. The moisture content and dry weight of the material used to make the tray sample was determined at the beginning of the experiment. At regular intervals the tray was weighed to determine changes in moisture content. After the test the final dry weight and moisture content were determined. Coninuous records were kept of air temperature, relative humidity and rainfall. Evaporation was measured daily using a standard U.S. Weather Bureau 1.2m (4 ft) diameter evaporation pan. The evaporation is a measure of the combined effect of solar radiation, air temperature, relative humidity, and windspeed. Soil moisture was determined periodically from air oven dried samples.

Part B: Decomposition Trials

The amount of decomposition was determined by measuring the dry weight of the whole sample on the tray at the beginning, and at various stages of the test. After 27 days eight of the sixteen trays were removed from the field and taken to a drying room and kept at a temperature of 38°C (100°F). The samples were allowed to reach an equilibrium moisture content, then weighted and bottled moisture sample was taken to determine the dry weight of the sample on the tray. These samples were then removed from the experiment. The remaining eight trays were similarly processed



Drawing of tower used in burning straw. (A) Complete unit showing relative position of fuel bed and sampling sites. Burning table is mounted on scales. (B) Detail of instrumentation and probes at sampling site in stack of tower. (C) Schematic relationships of tower and analytical instruments in shed next to tower.



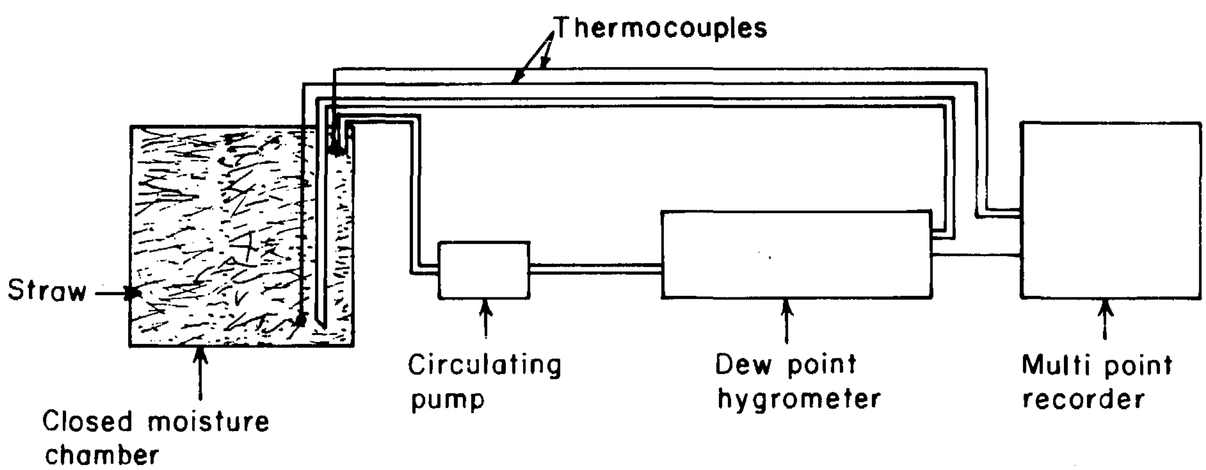
Inclined tray set on burning table to simulate head and back fires

Figure 2. SAPRC Laboratory Set-up

after 107 days but were returned to the field for 43 more days. After 150 days the dry weight was again determined and the experiment terminated.

Part C: Equilibrium Moisture Trials

These tests determined the equilibrium moisture content of weathered straw at various relative humidities. A weighed charge of high moisture straw was placed in a sealed system and allowed to reach equilibrium by circulating the air inside the system with a small diaphram pump. (see Figure 3). The equilibrium condition was considered to have been reached when difference between dry bulb temperature and dewpoint temperature remained constant for a period of 2 hours and when the temperatures at the inlet and outlet of the sealed container were equal. The relative humidity was then determined with a recording dew point hygrometer. A series of equilibrium points were obtained by drying or hydrating the straw to various levels.



SCHEMATIC OF EQUILIBRIUM MOISTURE TRIALS

Figure 3

Phase III: Cost Analysis

The cost figures were determined primarily on the basis of the rate of flame propogation for the various fire management techniques. Rate of flame propogation was measured on many of the field plot trials. Several average sized rice fields, approximately 40 ha (100 ac) were burned to verify the total time required to burn a field calculated on the basis of the plot data. The large field trials were also used to evaluate the practicality of the proposed fire and residue management techniques.

PART III - DISCUSSION OF RESULTS

Phase 1: Field Burning Trials

Analyses were performed to determine what fire and fuel management variables had a statistically significant effect on particulate emission. In the analyses of the field data, fall and spring open field burning data were combined to give a broader range of some of the independent variables. The following dependent and independent variables were considered.

Dependent variable	Independent variables
particulate emissions	direction of burn (head fires vs. backfires)
	residue moisture content
	(residue moisture content)^{2}*
	(residue moisture content)^{3}
	fuel loading
	absolute humidity
	(absolute humidity)^{2}
	relative humidity
	log (relative humidity)
	air temperature
	wind speed

*NOTE: $(\ )^{n}$ where n indicates the exponent of the variable enclosed in the parentheses.

The direction of burn variable is discreet, therefore, the correlation and regression analyses were performed separately on head fire burns and backfire burns. No significant difference could be found in particulate production by grouping the data by fuel management technique. The effect of spread, windrowed, and raked straw was represented by the moisture content and fuel loading variables.

The correlation analysis indicated that as fuel loading and moisture content increased particulate production increased but the high positive correlation between fuel loading and moisture content overshadowed the real effect of fuel loading. (Tests at the SAPRC Riverside laboratory, where the field correlation between fuel loading and residue moisture did not exist, indicate that as fuel loading increases, particulate production decreases. The relationship between fuel loading and residue moisture content will be discussed further in the residue drying experiment.)

Table 1

Correlation Analysis

Field Data

independent variables vs. particulate production

<u>independent variables</u>:	<u>Head fire</u> r	<u>Backfire</u> r
residue moisture content	.548	.743
(residue moisture content)^2	.536	.766
(residue moisture content)^3	.503	.776
fuel loading	.538	.675
relative humidity	.275	.417
log (relative humidity)	.281	.405
absolute humidity	.198	.159
(absolute humidity)^2	.174	.143
air temperature	-.103	-.218
wind speed	.066	-.208
<u>significant correlations between independent variables</u>:		
moisture content vs. fuel loading	.649	.748

A regression analysis of the data verified the significance of residue moisture content and showed the difference between head firing and backfiring. A stepwise regression package developed at the Health Sciences Computing Facility at UCLA was used.[3] Using a 10% significance level the regression chose residue moisture content in head fires and (residue moisture content)^3 in backfires as being the significant variables affecting particulate production. The head fire and backfire regression equations are significantly different at the 1% level.

Table 2

Regression Analysis

Field Data

	Independent Variable Selected	Coefficient Metric	% of Variability Explained
Headfire	residue moisture content	.76 (1.52)	30
	[constant -3.78 (-7.55)]		
	multiple r = .548		
Backfire	$\begin{bmatrix}\text{residue}\\ \text{moisture}\\ \text{content}\end{bmatrix}^3$	.00068 (.00135)	60
	[constant 1.37 (2.74)]		
	multiple r = .776		

Figure 4 (field data) shows what the statistics imply. Firstly, particulate emissions decrease with decreasing residue moisture in both head fires and backfires. Secondly, backfiring reduces particulate emissions over head firing.

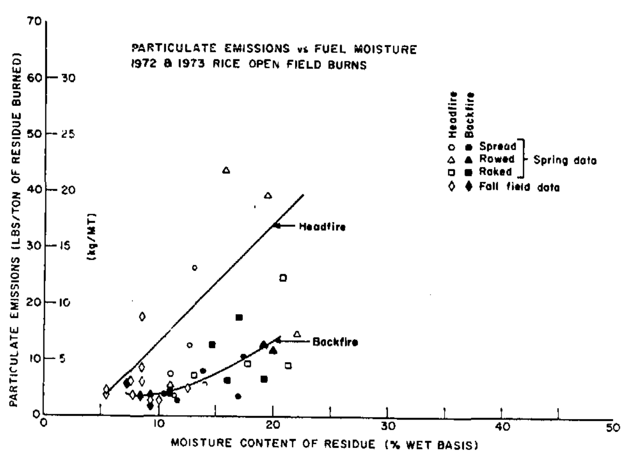


Figure 4

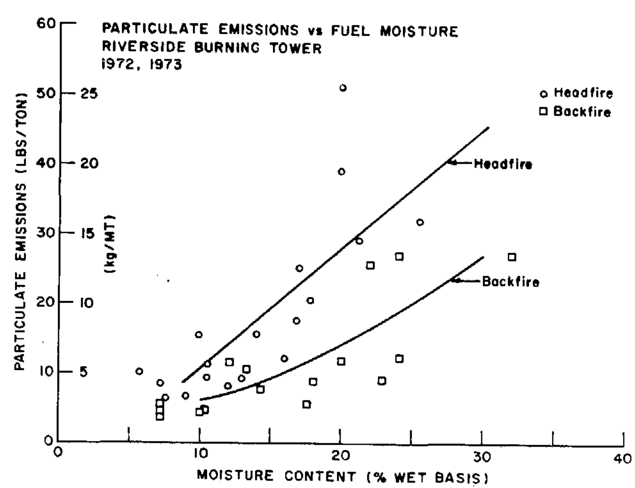


Figure 5

Although the other independent variables were not found to be statistically significant in determining particulate production this does not imply that they do not have any effect. The variation in the data could easily obscure the effects of these other variables. This variation arises from several sources. The residue is rarely in a uniform condition in the field. Even in a field that appears to be very uniform there may be variations in residue moisture content as high as 50% about the mean value. Fuel loading will also vary by as much as 50% about the mean value, because of differences in plant populations in the field, straw spreader performance, and harvester patterns in the field. The smoke sampling technique only measures the particulates produced from .07 kg (.15 lbs) of fuel or less. Unless a uniform mixing of the particulate emissions takes place between the fire and the sampler the emissions measured may not be fully representative of the entire plot.

Recognition of the variability in field data led to the laboratory work at Riverside. It was expected that under the laboratory situation variables could be better controlled and measured with greater reliability. A series of forty trials was conducted with rice straw. The same statistical analyses used on the field trial data were performed on the laboratory test data. The correlation analysis showed that residue moisture content and fuel loading were the most significant variables affecting particulate emissions. There was not a significant correlation between straw loading and residue moisture content because the residue samples were not allowed to be affected by meteorological factors before ignition. Straw loading showed a negative correlation with particulate production. This result was in agreement with trends observed in piled straw burns. The stepwise regression, using a 10% significance level, chose residue moisture content and fuel loading in head fires and (residue moisture content)^2 in backfires as being the significant variables affecting particulate production.

Table 3

Correlation Analysis

SAPRC Riverside Laboratory Data

Independent variable	Head fire r	Backfire r
residue moisture content	.785	.726
(residue moisture content)^2	.779	.738
(residue moisture content)^3	.745	.738
fuel loading	-.248	-.242
air temperature	-.202	-.096
(absolute humidity)^2	-.153	-.226
log (relative humidity)	.137	.122
absolute humidity	-.133	-.200
relative humidity	.087	.068
windspeed	held constant in trials	

No significant correlations between independent variables.

Table 4

Regression Analysis

SAPRC Riverside Laboratory Data

	Independent Variable Selected	Coefficient Metric	% of Variability Explained
Headfire	residue moisture content	.87 (1.74)	61
	straw loading	-3.66 (-35.6)	7
	[constant .51 (1.02)]		
	multiple r = .826		
Backfire	$\begin{bmatrix}\text{residue}\\ \text{moisture}\\ \text{content}\end{bmatrix}^2$	.013 (.026)	55
	[constant 1.54 (3.08)]		
	multiple r = .738		

The head fire data were significantly different from the backfire data at the 5% level.

Riverside and field data were statistically compared to determine the correlation between laboratory and field tests. Field and Riverside data were segregated according to moisture content and type of burn and then the difference between laboratory and field particulate emission data was calculated at each moisture level and for each type of burn. The following table was calculated using a significance level of 5% and 5 lbs/ton was selected as the minimum detectable difference between means.

Table 5

Comparison of Riverside and Field Data

	average of differences	std. deviation of differences	d	probability of acceptin[g] false hypothesis
Head fire	1.52	7.85	.64	7%
Backfire	- .04	4.40	1.1	2%

Table 5 indicates that there is only a 7% chance of erroneously concluding that the Riverside head fire data is the same as the field head fire data. Similarly, there is only a 2% chance of erroneously concluding that the Riverside backfire data is the same as the field data. Thus it is reasonable to conclude that the Riverside laboratory trials accurately simulated field trials.

The Riverside data confirmed the effects of direction of burn and residue moisture content (see Figure 5). A reduction in residue moisture content from 25% (wet basis) to 10% can reduce particulate emissions from 18 kg/MT (36 lb/ton) to 5 kg/MT (10 lb/ton) in head fires. Backfire burning additionally reduces particulate production nearly 50% over head fire burning at moisture levels between 10% and 25%. Increased straw loadings tended to reduce emissions in head fires but not in backfires.

The effectiveness of a backfire in reducing particulate emissions can be inferred from the nature of the fire. A backfire burn is characterized by a low flame which progresses across the field at a slow rate. The slow rate of burn results in a longer local flame residence time as the flame front advances into unburned residue. Thermocouple recordings of a backfire flame front show that a typical backfire maintains a high temperature two to three times longer than a head fire and that the peak temperature in a backfire is usually slightly higher than a head fire peak temperature (see Figure 6).

The longer residence time and the higher flame temperature in a backfire exposes the unburned fuel adjacent to the flame front to greater heating and drying as the front progresses toward this fuel. As a result of this, more fuel burns without smoldering. The higher peak temperature in a backfire is probably due to the greater oxygen supply and drier fuel in the slow speed front moving against the wind. The relative velocity of the wind (oxygen supply) to the flame front on a backfire is the sum of the wind velocity plus the rate of flame spread. The relative velocity of the wind (oxygen supply) to the flame front on a head fire is the difference between the wind velocity and the rate of flame spread.

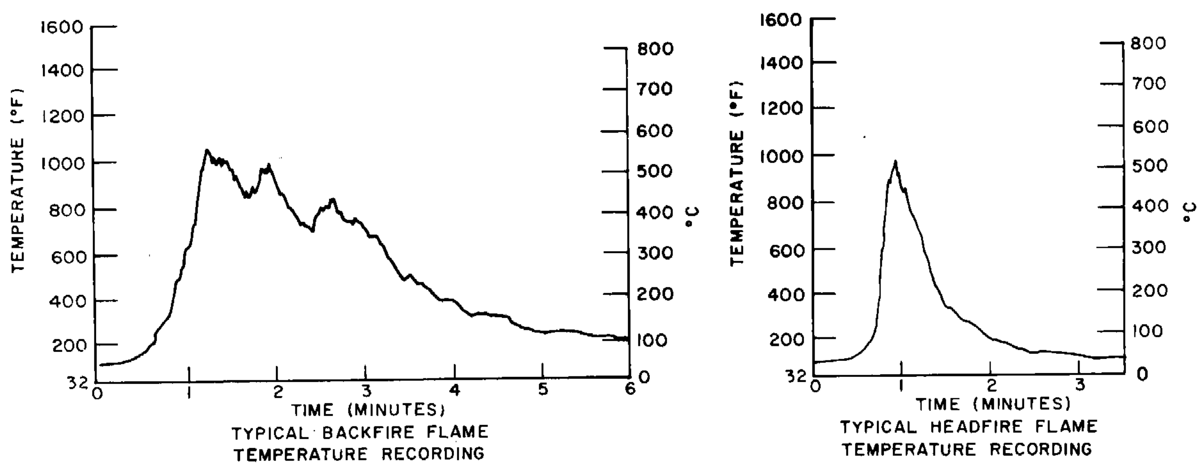


Figure 6

A backfire also has the property of consuming substantial quantities of the combustibles contained in the white smoke associated with smoldering combustion. The slow rate of flame spread in a backfire causes most of the distilled volatile organic compounds and gaseous hydrocarbons to be released upwind from the flame. These are then carried by the wind into the flame area of the fire and largely consumed. The flame area of a headfire passes quickly over the surface of the residue heating unburned or partially burned material enough to drive off volatile compounds and gases. With a wind of 4 miles per hour or more the flame of a head fire does not remain in contact with the fuel and volatiles long enough to consume as much of these combustibles. As the unburned volatiles leave the heat source (flaming and smoldering combustion areas), they are cooled and some condense forming thick white or brown smoke behind the flame front (see Figures 7 and 8).

Greater residue moisture tends to increase particulate production for two reasons. The water vapor coming out of the residue tends to smother the fire. For higher moisture contents, especially associated with wet pockets of straw, the vapor pressure of the water may almost equal the atmospheric pressure.[5] Under this extreme condition oxygen is nearly excluded from the area near the fire. With insufficient oxygen the residue will not flame but will only smolder. Increased moisture in the residue also requires a greater heat energy flux to dry the residue enough to burn. As the moisture increases more of the residue will not be dry enough to burn while the flame is nearby. However, there will be enough residual heat to cause smoldering of the incompletely burned residue.

In both field and laboratory work effort has been made to determine some of the properties of the particulate emissions. Microscopic examinations of particulate collections revealed two main types of particles: spherical and angular. The spherical particles were assumed to be liquid and potentially soluble in an organic solvent. The angular particles were assumed to be fly ash, carbon particles and possibly some crystalline forms of organic materials. The crystalline forms may also be soluble. The high volume filter samples were extracted with chloroform to determine the actual quantities of the two types of particles produced. (Benzene was also tested as a solvent but typically dissolved less material). The field data revealed that from 15% to 83% of the weight collected on the filters was extractable in chloroform. Backfire burns averaged 49% extractable particulates and head fires averaged 68% extractable particulates. The extractant from the filters is a thick brown liquid which has lead to the speculation that the soluble particles are liquid aerosols of organic compounds. These compounds are the major constituents of the thick white (or brownish yellow) smoke often seen in open field burns. These organic compounds have not been identified in this study but work done by Tebbins et. al. indicates that the soluble particulates from the combustion of cellulosic fuels are a complex mixture of perhaps hundreds of organic species[4]. These particles are associated with the pungent odor of the smoke from open field burning.

The particulates proved to be of a very small size. Hivol cascade impactor data showed the mass median diameter for head fires was .13μ and .11μ for backfires (See Figure 9). Both head fires and backfires had a definite difference between the size of soluble and insoluble particulate fractions.

Figure 7 Spring Backfire Burn

Figure 8 Spring Head Fire Burn

The head fire data showed a mass median diameter of .10μ for the soluble particulates and .25μ for the insoluble particulates. The backfires showed a similar trend with a mass median diameter of .025μ for the soluble particulates and .25 for the insoluble particulates. The reduced size of the chloroform soluble particulates in backfires may be due to reduced plume density and a corresponding reduction in potential for condensation and agglomeration. The reduced plume density is due to the slower burning rate of the backfire and lower emission level. Particles from backfires are in the plume longer between the fire and sampler which provides more time for evaporation of volatile components which may further reduce particle size. The fact that all mass median diameters are small shows that very few of the particulates will fall out of the plume. Figure 12 indicates that particles less than 10μ in size cannot be expected to fall more than 210 meters per day (700 feet per day). Except on windy days open field burn plumes will rise at least 210 meters. The size distribution indicates that perhaps 1-2% of the particles are larger than 10μ. Only particles less than 10μ are significantly affected by gravitational settling. Thus, most of the particulates have the potential to remain in atmosphere for an extended period of time unless removed by the often infrequent precipitation or the slow process of coagulation and subsequent gravitational settling.

Although most of the particulates have the potential to remain in the atmosphere for extended periods of time, not all are going to affect visibility. Visibility degradation is associated primarily with particles larger than .4μ. 10% of the particulates in open field burning emissions are smaller than .4μ. This means that only 30% of the total mass of particulates will contribute significantly to visibility degradation.

The above statement demonstrates that merely measuring the quantity of particulate emissions without considering the nature of them can lead to an incorrect evaluation of the magnitude of their effect. A further example of this can be seen in the chloroform extraction data. It showed that about half the particulate production is soluble in chloroform. It is probable that a substantial portion of the soluble particles can be expected to evaporate at atmospheric temperatures. It has been shown that organic compounds with vapor pressures as low as 10^{-5} Torr (mm of Hg) can evaporate quite rapidly when they are in an aerosol form with a large surface to volume ratio[8]. Aircraft sampling of particulates by Carrol[7] confirms the fact that some of the particulates evaporate. Carrol's data leads to the conclusion that within a few hours enough evaporation has taken place to significantly decrease the size of many of the particles.

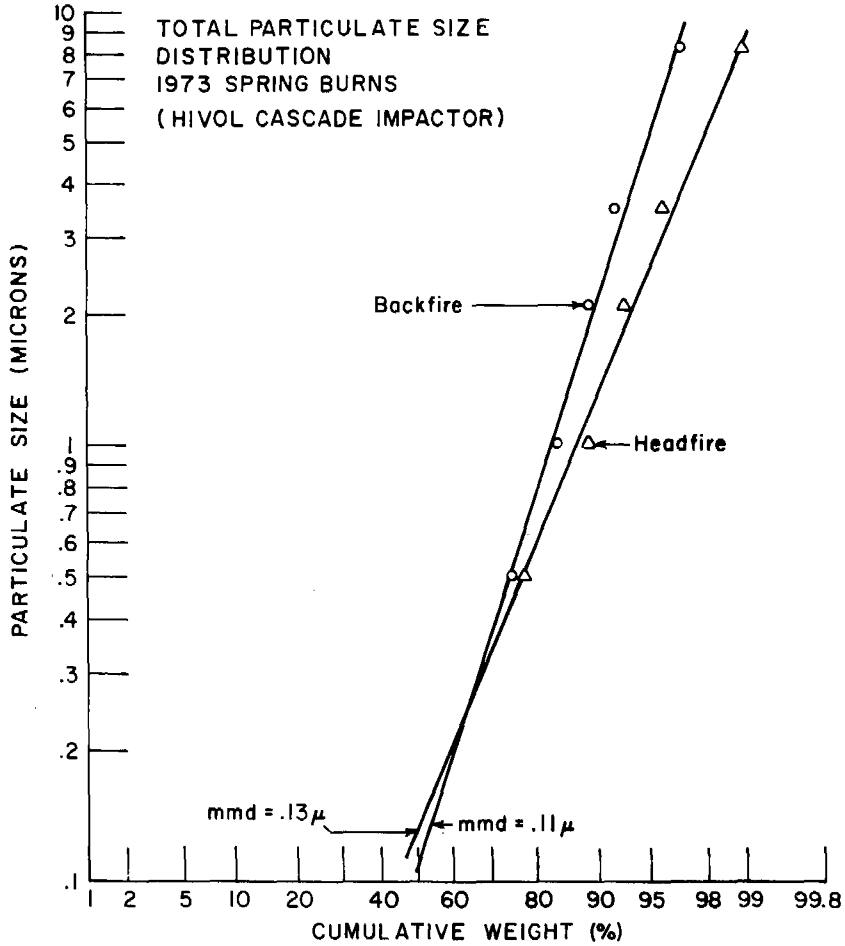

TOTAL PARTICULATE SIZE
DISTRIBUTION
1973 SPRING BURNS
(HIVOL CASCADE IMPACTOR)
PARTICULATE SIZE (MICRONS)
CUMULATIVE WEIGHT (%)
Backfire
Headfire
mmd = .13μ
mmd = .11μ
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
1
2
5
10
20
40
60
80
90
95
98
99
99.8

Figure 9

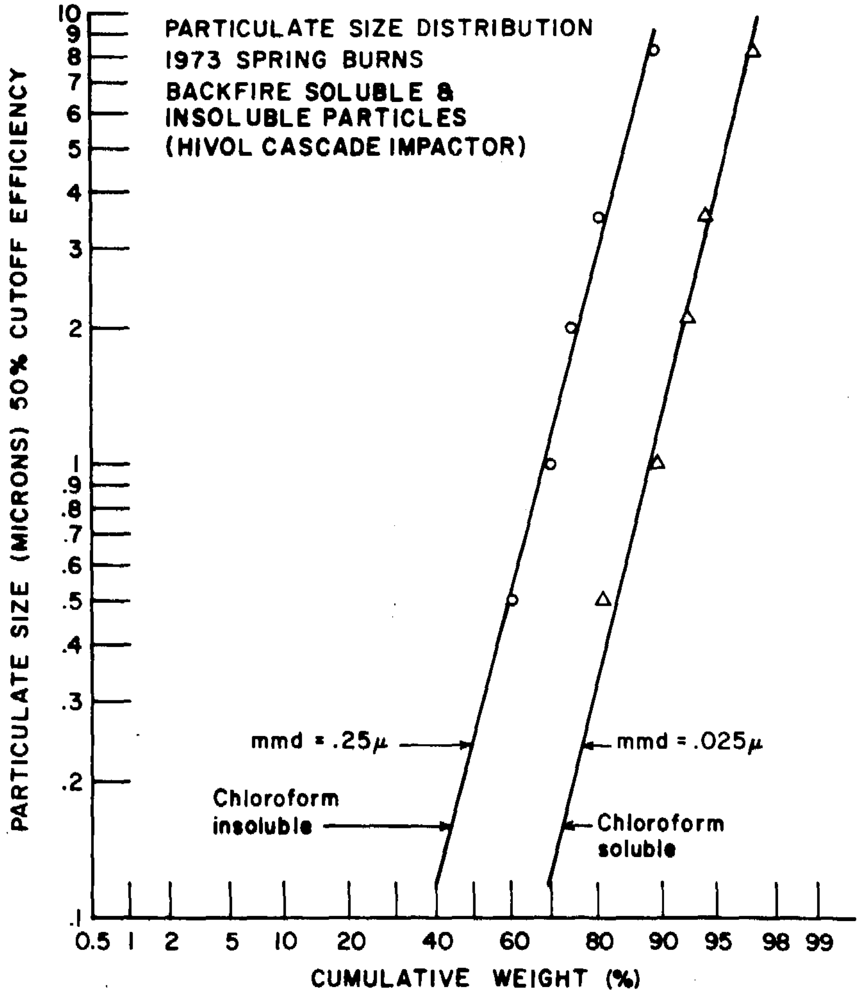


Figure 10

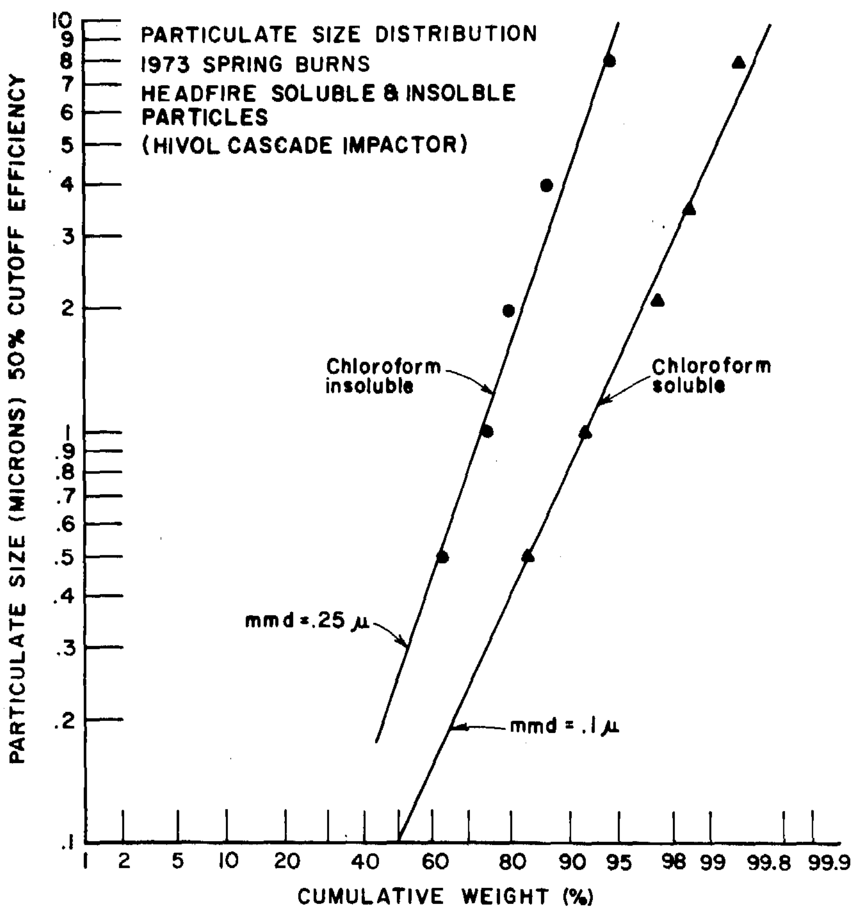


Figure 11

Thus within a few hours the chloroform soluble particulate fraction (approx. 50% of total mass) may be small enough to have significantly different physical characteristics than they had when initially emitted from the fire. The data in this report can reveal only glimpses of the picture of the fate of open field burning particulates. More work needs to be done to discover the processes that effect the particulates in the atmosphere.

Phase II Drying and Deterioration Trials

The field residue drying process was seen to be controlled by two main factors: equilibrium moisture content at any relative humidity and moisture removal rate. The equilibrium moisture relationship determines the lowest possible moisture that the residue can reach at any given relative humidity. Figure 13 shows the results of the equilibrium moisture experiment. Although relative humidity is the most important factor controlling equilibrium moisture, air temperature can shift the line slightly. Temperatures above 22°C (72°F) will move the line slightly downward and temperatures less than 22°C (72°F) will move the line slightly upward.

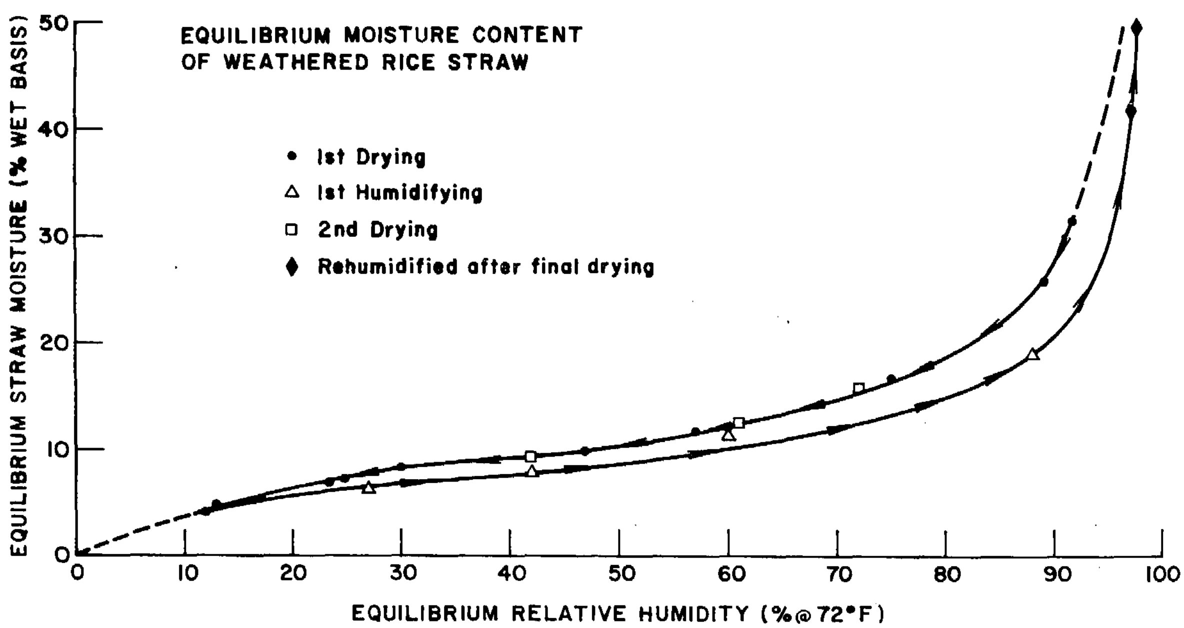


Figure 13

Relative humidity is usually the limiting atmospheric factor controlling residue moisture content. For example, Figure 13 shows that the straw cannot be less than 10% moisture (wet basis) unless the relative humidity is less than 50%. Solar radiant heating can raise the temperature of the straw above the surrounding air temperature. This allows the relative humidity in the immediate vicinity of the straw material, and the moisture content, to drop below predictions based on air relative humidity measured close by, but not at, the outer layer of the straw. The light residue loading shows this effect on 3/24 and 3/25 on Figure 14. 10% moisture can even be reached in the winter months as long as there are several clear days when the relative humidity is less than 50% and the residue is not in contact with the wet soil or water.

The moisture removal rate is determined by solar radiation, air temperature, relative humidity, wind speed, residue loading, and residue placement. The exact relationship between these variables and moisture removal rate has not been determined, but some important observations have been made. An increase in solar radiation, an increase in temperature, a decrease in relative humidity and an increase in wind speed will increase the drying rate but most clear days will provide sufficient drying potential so that none of these factors will be limiting. On clear days residue loading and placement will usually be the limiting factors affecting moisture removal rate. A high residue loading (i.e. windrowed straw) on short stubble close to the wet soil will retard the moisture removal rate. For example, Figure 14 shows that a light residue loading (spread straw) can approach the equilibrium moisture curve in two days. The high residue loading, (windrowed straw) did not approach this curve after three days and instances have been observed where it took considerably longer. Residue in standing water or on wet soil will dry very little. Residue supported above the ground by standing stubble will dry even if there is water in the field.

Several cultural recommendations to minimize particulate emissions from open field burning of rice field residues in the spring can be made from the above findings. The straw should be allowed to dry in the field for a sufficient number of days following a substantial rain. Spreading the residue from the harvester will reduce drying time compared to leaving the residue in windrows. The residue should not be burned in the morning or late evening hours when the relative humidity and the residue moisture content are high.

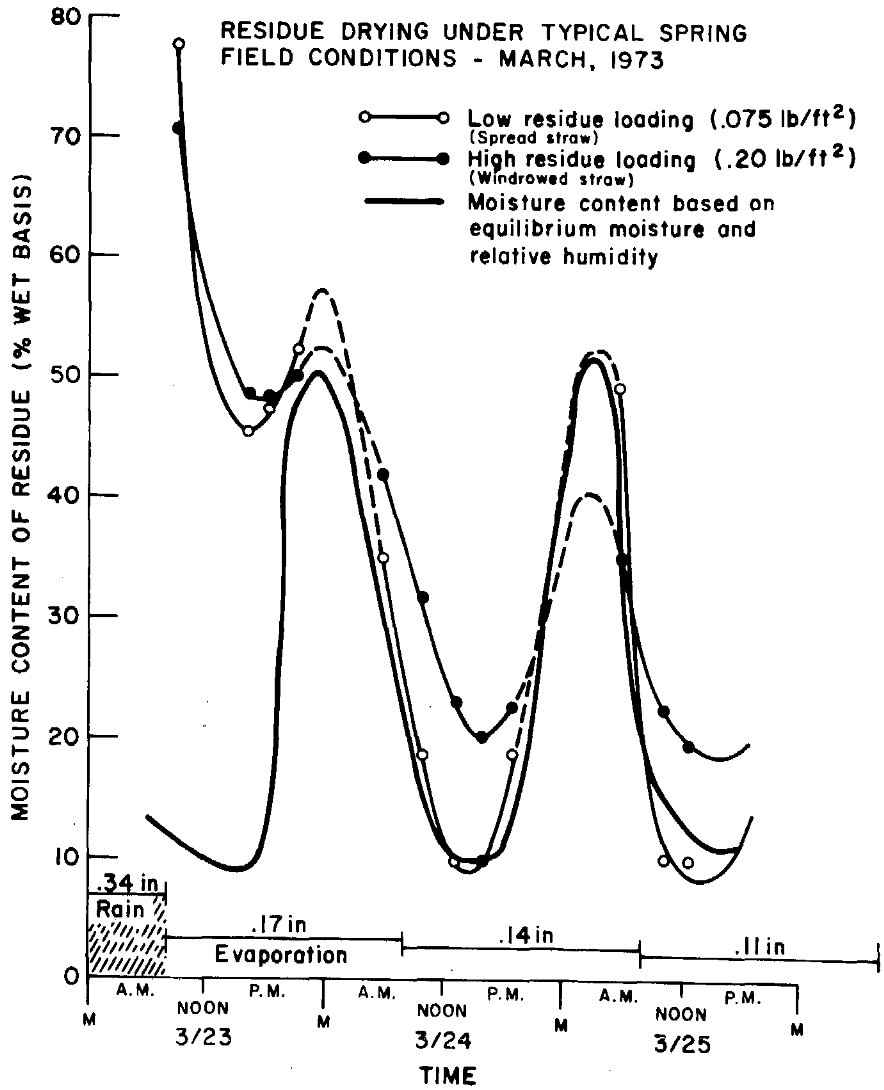


Figure 14

Using the residue moisture content for 3/24 graphed in Figure 14, Figure 15 shows that after nearly two days of drying following a substantial rain, a head fire burn on a light fuel loading (spread straw) would produce 16 kg. of particulates per MT (32 lb/ton) at 9:00 in the morning, 7 kg. of particulates per MT (14 lb/ton) at 12 noon, and 4.5 kg. of particulates per MT (9 lb/ton) at 3 o'clock. If burning had been delayed until low relative humidity was reached in mid afternoon particulate emissions would have been reduced by 72%. Figure 16 clearly shows that the windrowed straw needs more time to dry as a head fire would produce 14 kg. of particulates per metric ton (28 lbs/ton) even when the windrowed straw is at its minimum moisture content. Both Figures 15 and 16 confirm the advantage of backfiring. In fact, Figure 15 shows that a backfire on spread straw produces less particulates than the 2 o'clock head fire minimum from 11 a.m. to 6 p.m. This would allow a backfire six more hours of burning time at lower emissions levels than head fires.

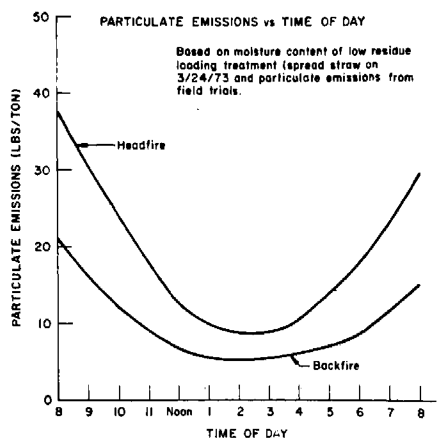


Figure 15

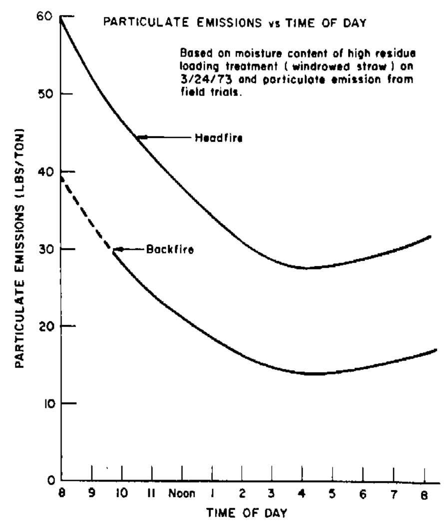


Figure 16

The deterioration trials conducted in the field showed that residue loading and time were the most significant factors controlling deterioration. The effect of ambient air temperature, a factor which cannot be controlled, did not appear to be significant in these trials. Figure 17 shows deterioration increases with time. Also, the amount of straw that deteriorates increases with decreasing straw loading. In these tests spread straw left in the field from November to March, five months, lost about 50% of its dry weight. At first glance this would lead to the conclusion that all burning should be done in the spring when there is perhaps half as much fuel left to be burned. However, in the fall it is largely the material cut above the rice plant crown, i.e. the straw, that will burn. If the rice were cut at 32% of its height [33 cm (13") stubble on 100 cm (40") rice - see Figure 18] only about 50%

of the material would be straw and burned in the fall. So practically the same amount of residue would be burned in the fall or spring. Winter decomposition would significantly decrease the amount of residue burned only if the crop was down and cut close to the ground surface.

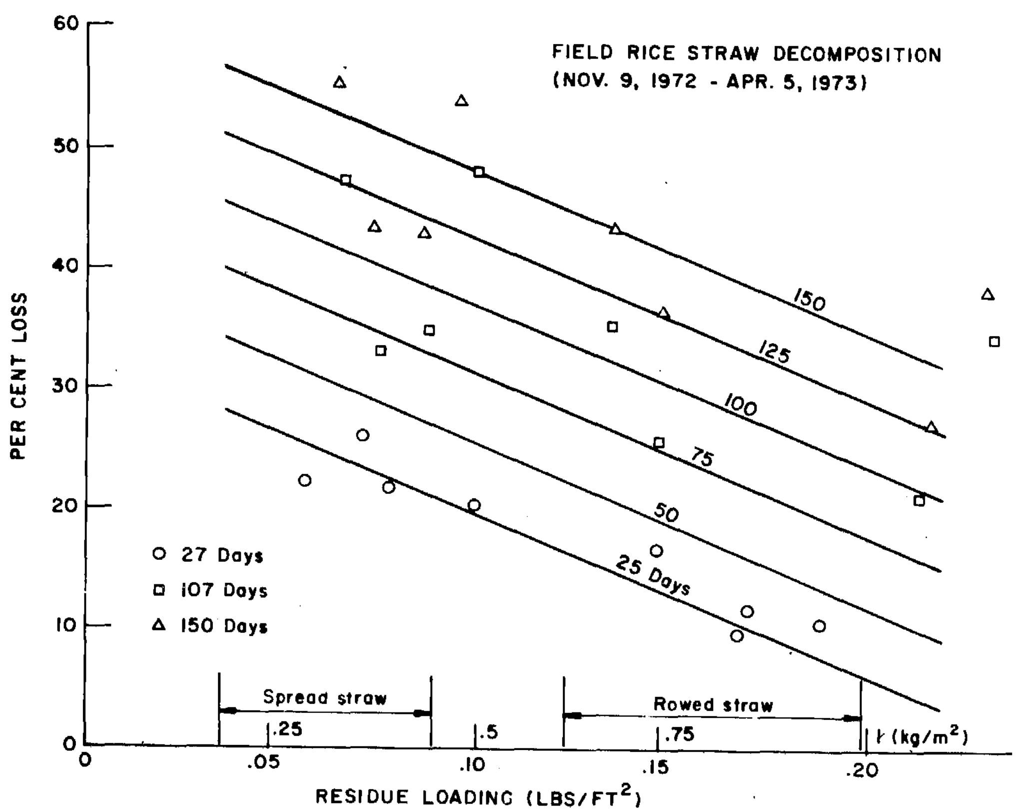


Figure 17

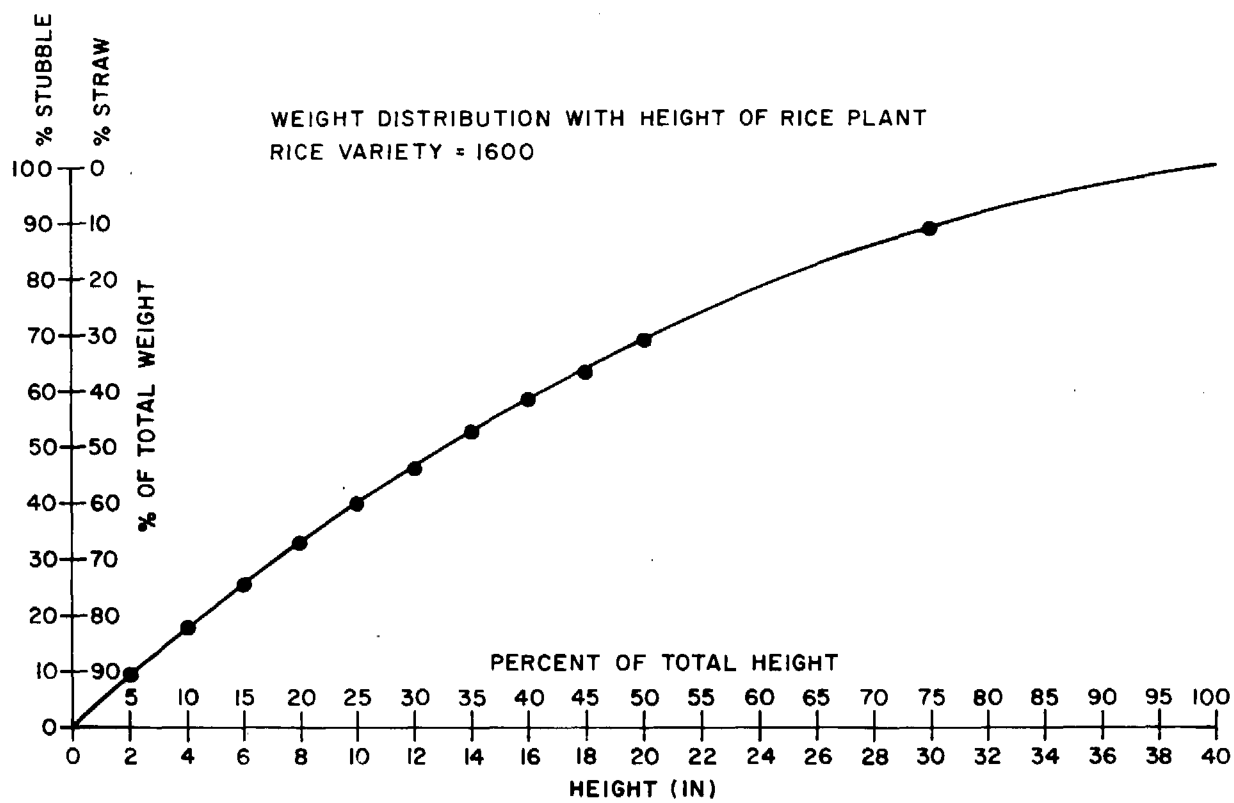


Figure 18

Phase III Cost Analysis and Large Field Burning Trials

The difference in cost between head fires and backfires is due mainly to the length of time each method requires to burn an entire field. Rate of flame propagation was used to estimate total burn time. Backfires consistently progressed across the field at a rate of about 1 meter/min (3 ft/min). The rate of flame propagation for head fire burns was more dependent on wind speed, residue moisture and residue condition. Propagation ranged from 2 to 21 m/min (8 to 70 ft/min). A rate of 4.8 m/min (15.7 ft/min) was an average for head fires under spring burning conditions. Spring backfire burning would cost \$1.61/ha (\$.65/ac) and spring head fire burning would cost \$.47/ha (\$.19/ac). (For complete cost analysis see appendix B). Raking the straw to facilitate drying would add approximately \$4.94/ha (\$2.00/acre) to both fire management techniques.

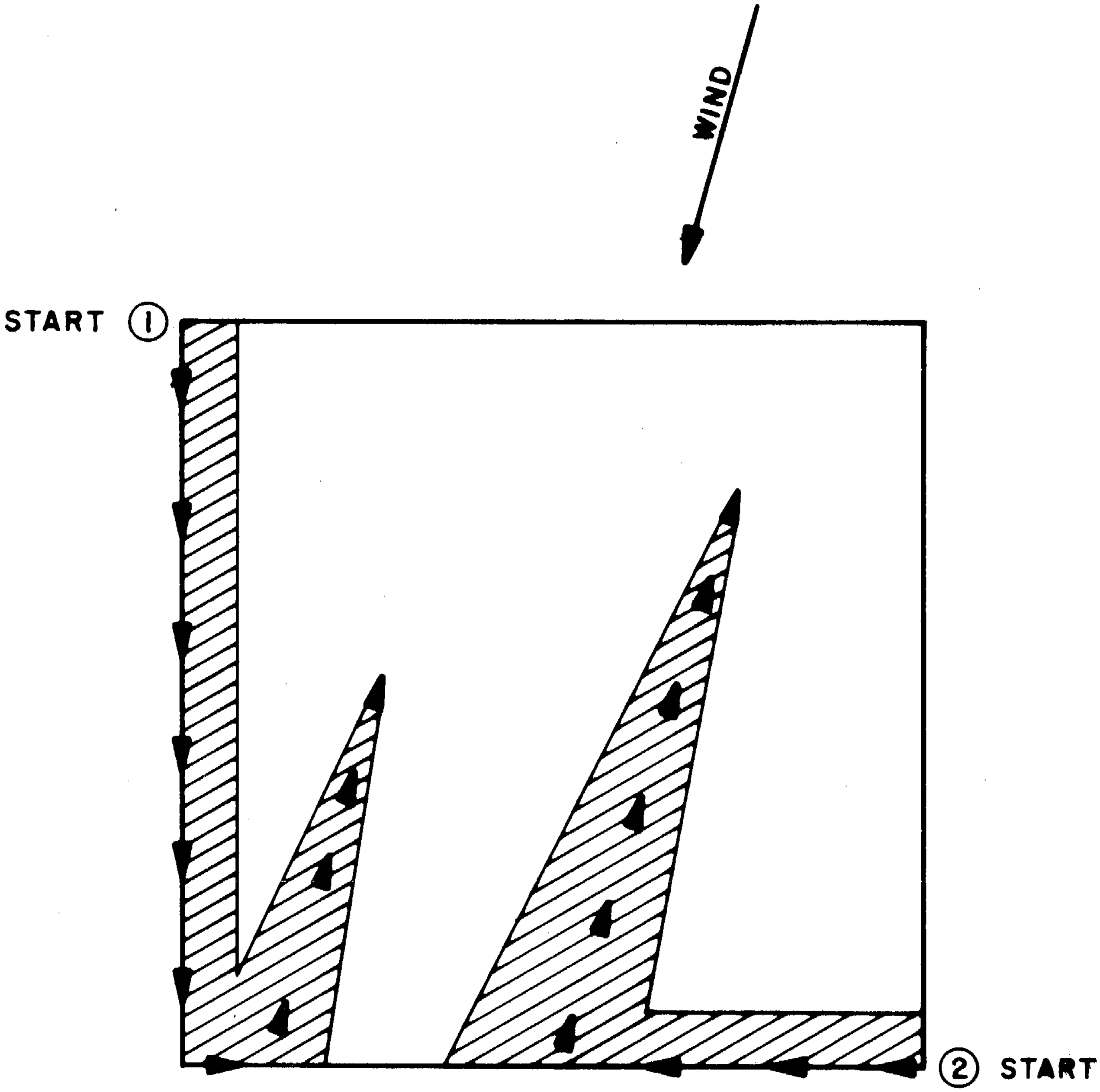
The evaluation of the practicality of the fire management techniques showed that backfiring cannot be used under as varied conditions as head fires.

The low intensity flame (in terms of cal/m^2/min, not temperature) of a backfire has poorer fire propagation potential than a head fire flame. For example, a backfire burn requires a higher fuel density to maintain a fire front than a head fire and head fires will continue to propagate under higher residue moisture conditions than backfires. The higher fuel loading requirement may restrict the use of backfiring in the spring if the rice stubble had been cut high and the straw spread. Deterioration would have removed approximately 50% of the straw and there may be insufficient fuel to maintain a backfire. Under these circumstances it would be necessary to use a head fire and to burn the field when the residue has dried to less than 10-12% moisture content. The lower residue moisture content requirement should not effect the usefulness of backfiring. If a backfire will not stay lighted because of high residue moisture the residue is too wet to burn and neither a backfire nor a head fire should be used. In this case, the field should be given more time to dry, or if straw is in windrows raked to shorten drying time, if urgency requires it.

The evaluation of the practicality of residue management techniques under favorable harvesting conditions showed that straw spreading is superior to leaving the straw in windrows. Straw spreading reduces emission production by enhancing the drying rate and providing a greater chance for drier straw. Straw spreading places a continuous bed of fuel over the field providing good fire coverage and consequently better disease control. Straw left in rows from the combine appears to offer little advantage over spread straw, except possibly where residue loading is very light which makes fire maintenance difficult. Raking straw rows can be of use in the spring to turn and fluff the straw. This would facilitate faster drying and allow the residue to be burned sooner, but with substantial additional cost and poor overall field sanitation.

Several methods for moisture determination have been investigated which are suitable for field use. A common test used in hay baling operations is the "crackle test". This test is performed by gathering a handful of straw and while holding the straw in both hands bending it sharply. If the rice straw makes a crackling or popping noise it has dried to less than 10-12% moisture content. If the straw makes a "shhhush" sound, or no sound at all, it has not dried to 10-12% moisture content. Representative sampling must be done to make this a valid test. Laboratory studies of weathered straw equilibrium moisture show that there is a relationship between ambient air relative humidity and the straw moisture content. On the basis of this work another test has been developed for spread straw supported on stubble following one or more clear days. When the relative humidity in the field is 50% or less on succeeding clear days the average residue moisture should be about 10% or less. Hand held wood moisture meters have also been used to determine the moisture content of the straw. They can be easily calibrated for straw, but have the inherent limitation of measuring the moisture of only a very few stems at one time. Extensive sampling must be done to get a representative sample.

After the completion of the 1973 spring field trials, a third fire management technique called "into-the-wind strip-lighting" was developed. This technique consists of backfiring the downwind side of the field and having several men spaced 100 m (300 ft) to 200 m (600 ft) apart igniting the residue as they walk toward the windward side of the field directly into the wind. An observer in the air would see long adjacent wedges of flame front progressing across the field into the wind (see Figure 19). This technique combines the slow movement of the fire front of the backfire with a greatly increased length of flame front. Optimally, this will combine the low particulate emissions of a backfire with the speed of head fire burns. Field particulate emission tests are difficult to perform with this technique but limited laboratory simulations indicate that the emission levels will be somewhere between backfires and head fires, generally approaching backfire levels. Changes in wind direction have a tendency to make portions of the flame front into head fires. With normal variation in wind direction, approximately 20-30% of the area of a field would be burned with a head fire type burn. The remaining portion of the field would be burned with a fire that approaches a backfire. However, before this ignition technique can be recommended, a personnel safety scheme must be devised. If a person lighting a fire through the field were immobilized (i.e. by a broken leg, heart attack, seizure, etc.), he would be subject to further injury by the oncoming fire. Personnel for this work should be selected for good health to minimize the potential for accidents. A buddy system or special supervision with an all-purpose vehicle with water tank and pump have been suggested as possible solutions, however, at this point no completely satisfactory method has been developed and thoroughly investigated.



LIGHTING PATTERN FOR INTO-THE-WIND-STRIPLIGHT
(TWO MEN LIGHTING FIELD)

Figure 19

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Appendix A

PARTICULATE LEVEL CALCULATIONS

Theory of Calculation -

A high volume air sampler measures basically the weight of particulates in a known volume of air, usually expressed as μg of particulates per m^3 of air. This figure can be converted into lbs. of particulates produced per ton of fuel burned if the CO_2 level is measured at the high volume air sampler. The conversion is made by calculating the amount of fuel that was burned to produce the particles in the sample volume. The fuel amount is assumed to be directly proportional to the CO_2 level in the sample volume (eg. 100 lbs. of residue @36% C will produce 132 lbs. of CO_2 if completely burned).

Sample Calculation - using typical field data:

A. Assumptions made in the calculation:

1. Negligible amount of CO produced
2. Negligible amount of hydro carbons produced
3. Insignificant amount of carbon in particulates

B. Carbon balance:

Carbon content of residue = 36%

Carbon content of ash = 15%

Lbs. of ash produced per lb. of fuel burned = .25

Carbon consumed per lb. of fuel =

(1 lb fuel) (.36) - (1 lb fuel) (.25) (.15) =

.36 - .038 = .322 lbs C/lb fuel

C. Fuel burned to produce CO_2 level in sample volume:

cfm = average hi-vol flow rate = 80 cfm [a]

temp = average temperature of sampled air = 180°F [b]

CO_2 = average CO_2 level of sampled air = .50%

time = duration of sampling = 3 minutes

$$(\text{cfm}) \cdot \left(\frac{\text{std. temp.}}{\text{temp.}}\right)^{c} \cdot (\text{time}) \cdot \left(\frac{CO_2}{100}\right) \cdot (K_1)^{d} = \text{liters } CO_2$$

$$\left(\frac{80 \text{ ft}^3}{\text{min.}}\right) \left(\frac{530^{\circ}R}{640^{\circ}R}\right) \cdot \left(\frac{3 \text{ min.}}{1}\right) \cdot \left(\frac{.005 \text{ ft}^3 CO_2}{\text{ft}^3 \text{ air}}\right) \cdot \left(\frac{28.32 \text{ liters}}{\text{ft}^3}\right) = 28.2 \text{ liters of } CO_2$$

then: $$(\text{liters } CO_2) \cdot (K_2) \cdot (K_3) \cdot (K_4) \cdot \left(\frac{1}{\text{lbs C/lb fuel}}\right) = \text{g fuel burned}$$

$$\left(\frac{282 \text{ liter } CO_2}{1}\right) \cdot \left(\frac{1 \text{ mol } CO_2}{22.4 \text{ liter } CO_2}\right) \cdot \left(\frac{44 \text{ g } CO_2}{\text{mole } CO_2}\right) \cdot \left(\frac{12\text{g C}}{44\text{g } CO_2}\right) \cdot$$

$$\left(\frac{1\text{g fuel}}{322 \text{ g C}}\right) = 46.8 \text{ g fuel burned}$$

D. Particulate level:

amount of particulates collected = .1400 g

$$\left(\frac{\text{g particulate collected}}{\text{g fuel burned}}\right) \cdot (K_5) = \text{lbs/ton}$$

$$\left(\frac{.1400 \text{ g particulate}}{46.8 \text{ g fuel}}\right) \left(\frac{2000 \text{ lb}}{\text{ton}}\right) = 5.98 \text{ lb/ton}$$

NOTES:

a The calibration curve for the hi-vol sampler must be used in determining the average flow rate.

b The time base for the CO_2 average is the sum of the periods where the CO_2 level is above the ambient level. This time base is the duration of sampling and is also used in the average temperature calculation.

c Standard conditions: $70^{o}F$ or $530^{o}R$ and 29.92" Hg barometric pressure

d Conversion Factors:

K_1 = 1 ft^3 = 28.32 liters @ S.T.P.

K_2 = 1 gram mole of a gas = 22.4 liters

K_3 = 1 gram mole of CO_2 = 44 g

K_4 = 1 gram mole of CO_2 has 12 g of C

K_5 = 1 ton = 2000 lbs.

Appendix B

COST ANALYSIS

Spring and Fall Rice Straw Burns

Rates of burn in feet per minute.

HEAD FIRE			BACKFIRE
Fall 1972, 1971	Spring 1973		Spring 1973, 1972
37.5	18.0	24.0	
66.4	13.0	24.0	4.75
70.0	14.0	11.0	2.3
50.0	22.0	8.0	3.1
29.0	12.0	8.0	10.0*
50.0	18.0	8.0	2.7
50.0	26.0	11.0	2.9
50.0	17.0	8.0	3.3
40.0	26.0	9.0	4.15 average
49.2 average	22.0		*3.2 without 10.0
	15.7 average		

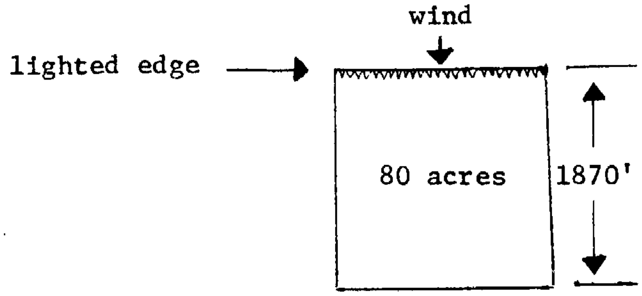
A. Head fire Burning:

The speed of the flame front in head fire burns varies significantly with wind speed, moisture content and fuel loading. Rates have been recorded as high as 70 fpm on a field with little residue compaction and dry straw and stubble. (Note: summer barley may reach rates as high as 150 fpm). On the other hand, rates as low as 8 fpm have been recorded on fields where the residue is severely compacted as a result of a long winter with much flooding and animal traffic. This analysis will use two flame front speeds: (1) 50 fpm; corresponding to a spring burn on a field with dry straw and stubble (10% wb), moderate wind speeds (8 to 12 mph) and little fuel compaction, (2) 16 fpm: corresponding to a spring burn on a field with wet stubble (20% wb), dry straw (10% wb), compacted fuel and low wind speeds (4 to 5 mph).

A square 80-acre field would burn in:

1. (1,870 ft) · [1/(50 ft/min)] · [1/(60 min/hr)] = .6 hrs
2. (1,870 ft) · [1/(16 ft/min)] · [1/(60 min/hr)] = 1.9 hrs

A. Head fire (cont'd) COST ANALYSIS



Headfire (speed of flame front = 50 fpm)

Cost based on 400 acres in rice per year. Fire is lighted along one edge only and requires no relighting.

	cost	use	total
field labor (1 man operation)	2.25/hr.	.6 hr.	1.35
equipment:			
pickup	2.00/hr.	.6 hr.	1.20
small tools, drip can,			
etc. $50/2 years	.0375/acre	80 acres	5.00
lighting fuel	.0005/ft.	1,870 ft.	.94
			8.49
overhead and supervision(10% of subtotal)			.85
TOTAL COST PER 80 ACRES			$9.34
cost per acre			$ .12
cost per hectare			$ .30

Headfire (speed of flame front = 16 fpm)

Based on 400 acres in rice per year

	cost	use	total
field labor(1 man operation)	2.25/hr.	1.9 hr.	4.28
equipment:			
pickup	2.00/hr.	1.9 hr.	3.80
small tools, drip can,			
etc. $50/2 years	.0375/ac.	80 acres	5.00
lighting fuel	.0005 ft.	1,870 ft.	.94
			14.02
overhead and supervision (10% of subtotal)			1.40
TOTAL COST PER 80 ACRES			$15.42
cost per acre			$ .19
cost per hectare			$ .47

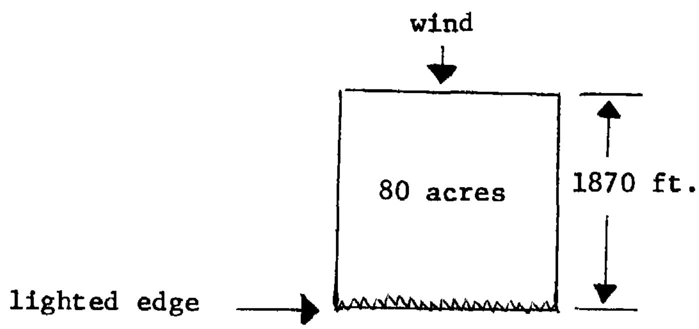
COST ANALYSIS

B. Backfire Burning:

Data from rice residue burning consistently indicates a rate (speed of flame front) of flame advance (progression) between 2.7 to 4.8 ft/minute. An average rate of 3.25 fpm will be used in the cost analysis.

A square, 80-acre field would completely burn in:

(1,870 ft.) (1/3.25 ft/min) (1/60 min/hr) = 9.6 hr



Cost based on 400 acres in rice per year and field tended throughout entire timetime of burn.

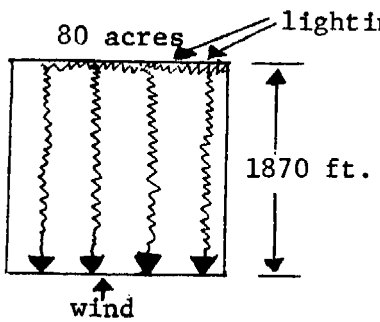
	cost	use	total
field labor (1 man operation)	2.25/hr.	9.6 hr.	21.60
equipment:			
pickup	2.00/hr.	9.6 hr.	19.20
small tools, drip can,			
etc. $50/2 years	.0375/ac	80 acres	5.00
lighting fuel	.0005/ft.	1,870 ft.	.94
			46.74
overhead and supervision	(10% of subtotal)		4.67
TOTAL COST/80 ACRES			$51.41
cost per acre			$ .65
cost per hectare			$ 1.61

COST ANALYSIS

C. Into-the-wind-Strip-lighting

The rate of flame front advance with the into-the-wind-strip-light technique is comparable to backfire burning. The advantage of this technique is that more than just one edge of the field can be ignited. Although the rate of flame front advance is the same as a backfire burn, the fire front is much longer, and is moving in two directions at once plus the rate of lighting is equivalent to a fast head fire (@ 2 mph = 176 fpm), thereby covering the field faster.

Using the following lighting pattern:



		Man Hrs.
lighting	$\frac{2290}{176} \times \frac{1}{60}$ = .22 hrs x 4 men =	.88
standby	$\frac{1870}{8} \cdot \frac{1}{200}$ = 1.13 hrs x 1 man =	1.12
		2.00 hrs.

1/4 hour at two miles per hour and fire advances 200 ft/hr.

Cost based on 400 acres in rice per year:

	cost	use	total
field labor (4 men operation)	2.25/hr.	2 hrs.	4.50
equipment:			
pickup	2.00/hr.	2 hrs.	4.00
small tools, drip can,			
etc. $50/2 years	.0375/ac	80 acres	5.00
lighting fuel	.0005/ft.	9,350 ft.	4.70
			18.20
overhead and supervision	(10% of subtotal)		1.82
TOTAL COST/80 ACRES			$20.02
cost per acre			$ .25
cost per hectare			$ .62

Field Data (original units)

Date and Burn No.	Time of Burn	Brief Description of Burn	Wt. of Straw Samples Taken in the Field (kg)			Moisture Content of Samples Taken in the Field (% wet basis)			Sample Area (M²)	Straw Quantity (kg/ha)	Wt. of Stubble Samples As Taken in the Field (kg)			Moisture Content of Sample Taken in the Field (% wet basis)			Sample Area (m²)	Stubble Quantity (kg/ha)	Total Fuel Quantity (kg/ha)	Moisture Content of Straw at Time of Burn (% wet basis)			Avg. Straw Moisture (% wet basis)	Moisture Content of Stubble at Time of Burn (% wet basis)			Avg. Stubble Moisture (% wet basis)	Cumulative Moisture Content (% wet basis)	Fuel Consolidation (kg/m²)	Weight of Post-burn Stubble as taken in the field (kg)			Moisture Content of Samples Taken in the Field (% wet basis)			Sample Area (ft²)	Post Burn Stubble Quantity (kg/ha)	Percent of Fuel Burned (%)	Weight of Ash Sample as Taken in the Field (kg) (4)			Ash Quantity (kg/ha)	Carbon Content of Ash (%)	Ambient Temperature (°C)	Relative Humidity (%)	Wind Speed
3/15 #2	12:06	head	1.45	.86	.79	4.10	4.67	4.78	1.49	6654	1.75	.65	.59	22.2	14.1	16.0	1.49	5411	12,065	(2)	6.20	4.41	5.3	25.59	22.44	19.39	22.5	13.1	1.169	.118	0	0	51.32	--	--	1.5	385	96.8	.65	.28	.43	3056	13.4	26	35	[illegible]
3/15 #4	2:38	fire	1.21	.95	.62	5.47	4.27	4.57	1.49	5929	1.74	.41	.48	26.7	18.9	13.7	1.49	4571	10,501	5.73	6.61	4.91	5.8	17.36	26.39	11.05	18.4	11.3	1.072	0	0	0	--	--	--	1.5	0	100.0	(2)	(2)	(2)	2684	15.2	28	30	[illegible]
3/21 #4	3:30	spread	1.64	1.09	.82	7.96	9.22	7.90	1.49	7286	.39	.27	.44	31.2	28.1	26.9	1.49	1877	9,163	7.96	9.22	7.90	8.4	31.17	25.35	26.90	29.0	12.6	.925	0	0	0	--	--	--	1.5	0	100.0	.27	.37	.45	2436	17.0	24	42	[illegible]
3/15 #1	11:46	back-	1.06	.62	.85	6.36	5.48	4.34	1.49	5345	1.03	.44	.77	10.0	9.1	26.7	1.49	4259	9,605	7.29	6.65	8.15	7.4	10.88	23.93	35.25	29.6	17.2	.974	0	0	0	--	--	--	1.5	0	100	(2)	(2)	(2)	2166	17.9	25	37	[illegible]
3/15 #3	1:49	fire	1.24	.	.84	6.25	4.70	5.65	1.49	7426	.54	.53	.41	13.5	13.6	14.6	1.49	2860	10,287	5.33	7.58	6.84	6.6	9.34	19.21	26.29	22.8	11.1	.974	.113	0	.06	19.06	-- --	20.86	1.5	476	95	.34	.52	.30	2619	19.0	27	32	[illegible]
3/15 #5	3:17	spread	.31	.85	.50	5.48	5.00	5.62	1.49	4574	.54	.39	.45	21.6	16.8	14.9	1.49	2554	7,128	(2)	5.47	6.32	5.9	25.68	29.82	18.37	21.5	11.5	.731	0	0	0	--	--	--	1.5	0	100	.42	.23	.37	2263	20.0	27	29	[illegible]
3/15 #6	4:23		1.34	1.04	1.32	6.67	5.98	6.00	1.49	8202	.62	.43	.72	22.1	22.6	18.6	1.49	3135	11,337	10.24	28.01	7.15	8.7	51.67	12.45	24.90	38.2	16.9	1.120	0	0	0	--	--	--	1.5	0	100	.39	.23	(2)	2086	17.1	29	28	[illegible]
3/21 #5	4:32		(2)	(2)	(2)	(2)	(2)	(2)	1.49	6487	(2)	(2)	(2)	(2)	(2)	(2)	1.49	3502	10,012	7.85	8.14	7.83	7.9	15.17	22.79	17.11	15.0	10.4	.779	0	0	0	--	--	--	1.5	0	100	.22	.34	.20	1696	15.4	23	43	[illegible]
3/9 #1	3:50	head	3.53	4.76	1.67	8.39	(2)	8.87	5.81	4096	1.12	3.64	.42	40.3	70.0	15.8	1.49	4740	8,836	13.74	12.53	(2)	13.1	25.95	(2)	(2)	26.0	15.4	1.946	.123	5.45	1.608	58.7	63.3	56.7	1.5	1573	70	.91	1.24	.93	2426	15.4	16	56	[illegible]
3/10 #2	5:00	fire	5.95	5.27	6.41	-2-	12.50	9.83	5.58	9319	.82	.81	(1)	41.37	38.98	40.59	1.49	3269	12,589	28.71	16.55	(2)	22.6	61.91	33.49	49.13	41.1	22.0	3.312	.258	.462	5.749	50.2	39.3	58.7	1.5	1667	84	1.41	.69	1.20	2667	7.8	19	43	[illegible]
3/13 #3	3:22	rowed	7.97	4.49	5.23	11.35	17.81	18.40	6.08	8194	.36	.33	1.21	58.91	45.67	45.61	1.49	3276	11,470	8.03	9.97	14.9	10.9	44.16	39.26	52.97	45.4	19.4	3.458	.408	.458	.100	15.3	57.7	20.3	1.5	339	96	(2)	(2)	(2)	2547	13.4	23	40	[illegible]
3/13 #1	1:35		(2)	2.15	2.96	9.42	11.81	15.33	5.95	3698	.36	.57	.58	67.80	21.61	21.47	1.49	2641	6,340	11.96	10.93	15.1	12.67	56.14	25.70	36.31	39.55	23.2	1.997	.068	.027	0	61.24	8.10	-	1.5	106	99	1.22	.87	1.06	2418	13.8	23	40	[illegible]
3/9 #2	5:20	back-	7.44	5.31	5.14	9.30	13.74	16.80	5.45	9548	.98	.86	.62	38.7	57.8	49.0	1.49	2869	12,418	11.33	(2)	(2)	11.3	48.36	(2)	(2)	48.38	19.9	3.897	0	(2)	(2)	--	13.95	63.7	1.5	0	100	1.43	.58	.82	2622	12.2	16	57	[illegible]
3/10 #1	3:00	fire	4.58	4.77	3.66	10.14	5.80	10.07	5.95	6664	.74	.60	.56	39.51	26.11	25.19	1.49	2903	9,567	7.50	18.77	(2)	13.1	17.18	42.17	(2)	29.7	18.1	3.02	0	1.300	.430	--	56.8	13.6	1.5	0	100	1.21	1.05	.51	2304	13.7	20	47	[illegible]
3/12 #2	2:05	rowed	3.99	2.31	2.91	13.34	10.38	18.98	5.08	5179	.55	.96	.57	22.47	30.79	27.49	1.49	3377	8,557	6.89	8.48	6.95	7.4	17.96	39.44	15.66	39.4	19.0	2.435	0	.222	0	--	52.4	--	1.5	210	97	.61	.81	1.05	2269	11.5	24	38	[illegible]
3/30 #1	1:35		3.99	3.65	2.12	8.24	9.26	7.81	5.86	5076	.54	.48	.31	18.20	25.68	17.02	1.49	2353	7,430	5.98	7.48	6.02	6.5	40.22	30.37	31.65	34.08	14.7	2.338	.113	0	0	58.07	--	--	1.5	106	99	.87	.48	.31	944	11.6	(2)	(4)	[illegible]
3/17 #2	3:45	head	4.16	5.17	4.64	5.64	5.77	5.36	6.45	6808	.64	.67	.54	31.85	34.79	20.72	1.49	2113	9,721	6.41	6.81	6.70	6.6	34.16	26.16	29.17	29.8	13.1	3.312	.204	0	0	45.8	--	--	1.5	143	98	1.88	.72	.95	1292	9.5	29	35	[illegible]
3/17 #4	5:00	fire raked	4.79	3.31	3.21	9.77	13.66	8.11	6.65	5078	.59	.65	.83	27.88	25.16	18.66	1.49	3549	8,627	9.50	13.46	9.50	10.8	24.73	30.90	20.76	27.8	17.8	2.971	(2)	(2)	(2)	(2)	(2)	(2)	1.5	0	100	.70	1.23	1.06	1496	9.3	27	33	[illegible]
3/21 #1	11:22		5.42	4.51	3.06	9.77	13.30	9.09	6.58	5786	.43	.59	.66	33.80	33.66	16.79	1.49	2747	8,556	15.04	11.54	11.88	12.8	35.13	43.48	34.02	37.5	20.8	2.971	(2)	(2)	(2)	(2)	(2)	(2)	1.5	0	100	.49	.94	.96	1208	12.7	21	52	[illegible]
3/21 #3	1:21		5.33	3.52	5.55	8.51	13.08	15.55	7.21	5842	.44	.49	1.06	38.89	24.66	18.49	1.49	3371	9,213	18.01	10.00	12.14	13.4	38.05	22.18	34.38	36.2	21.2	3.117	(2)	(2)	.127	(2)	(2)	16.08	1.5	147	98	1.37	1.30	1.53	1941	12.7	24	43	[illegible]
3/17 #1	2:59	back-	3.30	2.94	7.14	6.13	6.15	7.22	6.45	6741	.59	.53	.52	33.5	32.5	44.5	1.49	2319	9,060	8.56	7.43	6.64	7.5	36.71	19.00	17.88	36.7	14.7	3.117	.104	.005	.100	23.2	15.9	33.7	1.5	77	99	1.32	.69	.88	1490	10.1	28	35	[illegible]
3/17 #3	4:27	fire	3.13	5.69	4.09	5.95	5.57	6.83	6.14	6687	.49	.63	.65	30.14	17.00	14.58	1.49	3192	9,880	(2)	6.45	7.66	7.3	35.81	33.67	19.53	34.6	16.5	3.410	(2)	(2)	(2)	(2)	(4)	(2)	1.5	0	100	.49	1.36	.92	1508	10.3	28	34	[illegible]
3/20 #1		raked	3.63	3.34	3.36	(2)	8.39	12.13	7.14	4920	.73	.59	.57	(2)	63.88	32.80	1.49	2010	6,930	12.41	8.91	6.43	9.3	11.24	35.79	11.36	35.8	17.0	2.387	(2)	(2)	(2)	(2)	(2)	(2)	1.5	0	100	1.17	1.20	1.21	1817	12.0	21	45	[illegible]
3/21 #2	12:17		3.58	4.30	3.26	8.82	14.18	9.59	5.58	5919	.49	.45	.68	30.92	29.22	30.35	1.49	2540	8,459	9.09	13.81	15.44	12.8	39.72	31.35	31.31	34.2	19.2	2.923	(2)	(2)	.131	(2)	(2)	37.7	1.5	0	100	.81	.72	.61	1277	14.8	21	48	[illegible]
1973		spread												1973																																
3/29 #1	11:58	back	(10)						1.49	1441	(10)			(10)			1.49	3051	4,493	(10)			13.0	(10)			14	14	.448	0	0	0	(10)			1.5	0	100	.181	.169	(2)	1173	16.2	13	43	[illegible]
3/29 #2	12:01	head							1.49	1441							1.49	3051	4,493				10.0				12	11	.448	0	0	0				1.5	0	100	.167	.144	(2)	1043	16.2	17	34	[illegible]
3/29 #3	3:15	back							1.49	1441							1.49	3051	4,493				10.0				12	11	.448	0	0	0				1.5	0	100	.209	.163	.150	1034	16.2	18	34	[illegible]
3/29 #4	4:14	head							1.49	1441							1.49	3051	4,493				10.0				12	11	.446	0	0	0				1.5	0	100	.181	.150	.122	1016	16.2	18	24	[illegible]
4/4 #1	8:46	back							5.58	1485							1.49	2696	9,774				9.0				15	11	.862	0	0	0	-	-		1.5	0	64	.459	.564	.511	858	16.2	21	40	[illegible]
4/5 #2	10:07	head rowed							5.58	1485							1.49	2696	9,774				13.0				16	14	.862	0	0	0	-	-		1.5	0	64	.459	.564	.511	858	16.2	23	38	[illegible]

Date and Number of Burn	Chloroform Soluble Particulate Production Level (kg/mt) (Cont)	Chloroform Insoluble Particulate Production Level (kg/mt)	Average Fire Temperature (°C)	Maximum Fire Temperature (°C)	Maximum Tower Temp. (°C above amb.) (Cont)	Maximum Tower Temp. (CO_2) (°C above amb.)	Chloroform Soluble Particulate Concentration (Cont) µg/m³ x 10^6	Chloroform Insoluble Particulate Concentration (Cont) µg/m³ x 10^6	Lb. Fuel Represented by Particulates Sampled lb x 10^{-2}	Avg. CO_2 Level (%) (Cont)	Average CO_2 Level (%) (CO_2)	Particulate Production Level (kg/mt) (Cont)	Particulate Production Level (kg/mt) (CO_2)	Particulate Production Level (kg/ha) (Cont)	Particulate Production Level (kg/ha) (CO_2)	Part. Concentration at Sampler (µg/m³ x 10^6) (Cont)	Part. Concentration at Sampler (µg/m³ x 10^6) (CO_2)	Part. Concentration at Fire (µg/m³ x 10^6) (Cont)	Part. Concentration at Fire (µg/m³ x 10^6) (CO_2)	% Chloroform Extractables (%) (Cont)	Wind Direction	Final Wt. of HiVol Filters (gms) (Cont)	Initial Wt. of HiVol Filters (gms)	Wt. of Particulates (gm) (cont)	Final Wt. of HiVol Filters (gms) (CO_2)	Initial Wt. of HiVol Filter (gms)	Wt. of Particulates (gms) (CO_2)	Average HiVol Sampling Rate (M³/Min) (Cont)	Calibration Corrected Flow (M³/Min) (Cont)	Average Sampling Rate (M³/Min) (CO_2)	Calibration Corrected Flow (M³/Min) (CO_2)	Duration of Sampling (Min) (Cont)	Duration of Sampling (Min) (CO_2)	CO_2 Area (% - sec.) (Cont) (9)	CO_2 Area (% - sec) (CO_2) (9)	Tower Temp. (°K) (Cont) (11)	Tower Temp. (°K) (CO_2)	Net Fuel Burned (kg)
3/15 #2	12.29	3.10	(2)	(2)	53	53	.012	.003	4.09	.0617	.0924	15.38	10.79	100.00	70.24	.015	.016	2.99	2.10	80	NNE	4.3090	4.0230	.2860	4.2001	4.0711	.1290	2.46	2.22	2.55	2.26	8.85	3.80	5.25	3.38	308	314	4741
3/15 #4	1.65	1.16	64	318	169	169	.0053	.0037	4.23	.1987	.4940	2.81	.85	18.90	5.73	.009	.006	.553	.167	59	NNE	4.0552	4.0011	.0541	4.0269	4.0160	.0109	2.48	2.23	2.58	2.28	3.25	1.00	6.21	4.75	359	423	4262
3/21 #4	4.45 6.14	1.30 2.02	173	424	106	106	.0065	.0025	5.44	.0849	.1310	6.24	6.19	41.94	41.72	.009	.014	1.25	1.25	72	SW	4.1386	3.9840	.1546	4.0351	3.9971	.0380	2.53	2.29	2.52	2.24	6.55	1.35	5.35	1.70	307	316	3719
3/15 #1	.70	5.09	(2)	(2)	48	48	.0011	.0059	5.86	.0716	.0829	5.79	4.78	38.92	32.10	.007	.007	1.14	.945	15	N	4.1853	4.0310	.1543	4.0520	3.9960	.0560	2.46	2.22	2.53	2.25	10.6	4.0	7.30	3.19	304	307	3898
3/15 #3	.50	1.80	(2)	(2)	36	36	.0010	.002	1.71	.0716	.0851	2.30	1.50	14.76	9.57	.003	.002	.470	.306	36	NE	4.0749	4.0181	.0568	4.0383	4.0280	.0103	2.48	2.23	2.58	2.28	9.56	2.20	6.59	1.80	308	309	3982
3/15 #5	.36	1.53	166	616	59	59	.0005	.0015	6.22	.0663	.1242	1.89	1.49	12.64	10.02	.002	.003	.401	.318	24	E	4.0585	4.0051	.0534	4.0343	4.0221	.0122	2.48	2.22	2.55	2.26	11.25	1.75	7.17	2.09	303	312	2893
3/15 #6	.55	1.32	287	678	56	56	.0013	.0027	7.59	.1243	.1456	1.87	1.66	12.53	11.17	.004	.039	.359	.320	32	SSE	4.0405	3.9761	.0644	4.0609	4.0250	.0359	2.51	2.26	2.58	2.28	8.20	4.45	9.84	6.23	312	321	4602
3/21 #5	(2)	(2)	163	485	31	31	(2)	(2)	2.19	.0573	.0900	1.63	2.54	10.93	17.09	.002	.037	.315	.493	-	SW	4.0882	4.0263	.0619	3.9842	3.9668	.0174	2.53	2.29	2.55	2.26	18.23	2.15	10.05	1.86	297	302	3075
3/9 #1	19.28	6.39	(2)	(2)	(2)	(2)	.020	.007	5.12	.0621	.1088	25.67	17.83	120.80	83.89	.027	.032	5.12	3.56	75	(2)	4.6023	4.0050	.5973	4.2560	3.9891	.2669	2.86	2.53	2.88	2.60	8.98	3.25	5.36	3.40	295	299	2511
3/10 #2	4.69	2.65	(2)	(2)	31	31	.0026	.0014	15.63	.0367	.0531	7.34	7.49	41.50	42.17	.004	.006	1.38	1.41	64	S	4.5937	4.0720	.5217	4.1897	4.0121	.1776	2.90	2.59	2.97	2.69	48.03	10.90	16.94	5.57	294	300	4292
3/13 #3	12.89	5.54	206	588	51	30	.0098	.0042	3.73	.0452	.0411	18.43	20.93	118.56	135.34	.014	.014	3.63	4.12	70	NNW	4.2848	3.9721	.3127	4.0720	4.0040	.0686	2.56	2.32	2.63	2.25	10.15	2.2	4.76	.87	301	297	4470
3/13 #1										.0867	.0763	6.54	(2)	43.73	(2)	.009	(2)	1.35	(2)	70	NW	4.1452	4.0300	.1152	4.1020	4.0640	.0380	2.52	2.28	2.60	2.31	4.7	2.1	3.92	1.54	303	255	2547
3/9 #2	4.20	2.40	108	281	(2)	(2)	.0045	.0025	12.48	.0653	.0838	6.59	5.19	44.18	35.01	.007	.007	1.26	1.00	64	W	4.3931	4.0191	.3740	4.1411	3.9781	.1630	2.84	2.55	2.91	2.63	21.5	8.95	13.50	7.21	294	295	5040
3/10 #1	(2)	(2)	76	197	53	43	(2)	(2)	(2)	.0396	.0486	40.01	(2)	268.44	(2)	.025	(2)	7.72	(2)	64	N	4.5656	4.0011	.5645	4.3907	4.0101	.3806	2.95	2.65	3.00	2.73	8.5	6.10	17.00	2.85	297	300	3883
3/13 #2	2.10	3.30	178	231	31	31	.0012	.0018	0.31	.0375	.0512	5.39	7.14	35.23	46.64	.003	.0061	1.09	1.44	39	S	4.0981	4.0210	.0771	4.0123	3.9820	.0303	2.55	2.30	2.62	2.32	10.15	2.2	6.02	2.98	301	302	3125
3/30 #1										(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	83	-	3.3627	3.2618	.1009	(2)	(2)	(2)	2.49	2.25	(2)	(2)	4.4	(2)	(2)	(2)	(2)	(2)	2988
3/17 #2	4.15	2.00	141	530	85	85	.0068	.0082	4.50	.1560	.2153	6.14	.95	40.38	6.27	.015	.0031	1.13	.175	68	W	4.0909	3.9654	.1255	4.0137	3.0909	.0228	2.51	2.26	2.58	2.29	4.13	3.55	8.25	7.35	319	327	3867
3/17 #4	3.60	2.55	(2)	(2)	142	114	.0088	.0062	7.29	.1525	.2773	6.14	3.03	41.16	20.36	.015	.013	1.15	.569	59	S	4.1481	3.9445	.2036	3.9647	3.8931	.0516	2.49	2.25	2.56	2.27	7.05	2.10	10.3	5.60	332	355	3502
3/21 #4	13.83	2.85	409	205	37	33	.015	.003	4.73	.0703	.1094	16.68	6.84	111.85	45.97	.018	.0117	3.13	1.29	83	SSE	4.2787	3.9202	.3585	3.9449	3.8799	.0650	2.51	2.26	2.56	2.27	8.8	2.5	5.95	2.63	298	299	3464
3/21 #3	2.65	2.85	341	702	55	55	.0038	.0042	3.63	.0920	.1403	5.49	3.36	36.13	22.03	.008	.0077	1.08	.659	48	W	4.1409	4.0502	.0907	4.0476	3.9997	.0479	2.49	2.25	2.55	2.26	5.2	2.95	4.60	3.98	311	314	3665
3/17 #1	6.24	4.00	113	452	72	72	.0092	.0058	3.02	.0952	.1137	10.24	2.58	68.23	17.23	.015	.004	1.91	.480	61	W	4.1507	4.0103	.1404	3.9476	3.9191	.0285	2.51	2.25	2.55	2.26	4.50	3.10	6.73	3.39	319	327	3641
3/17 #3	2.10	1.50	399	783	60	31	.0029	.0021	7.37	.0809	.0789	3.6	2.65	30.98	17.78	.005	.003	.672	.494	58	W	4.0027	3.8823	.1204	3.9835	3.9565	.0270	2.51	2.26	2.58	2.28	12.55	3.85	9.76	2.92	312	309	4010
3/20 #1	3.30	4.94	481	817	55	104	.004	.006	3.72	.0731	.1560	8.24	9.24	55.48	61.97	.010	.023	1.63	1.82	40	E	4.1567	4.0173	.1394	4.0277	3.9611	.0666	2.49	2.25	2.56	2.27	6.5	1.3	5.95	2.63	304	307	2513
3/21 #2	(2)	(2)	526	759	38	38	(2)	(2)	8.46	.0509	.0840	1.25	5.49	8.39	37.02	.001	.007	.238	1.05	(2)	SSE	4.1421	3.9941	.0480	3.9634	3.9269	.0365	2.48	2.23	2.55	2.26	21.7	2.25	10.63	2.06	298	299	3435
1973	1973									Cont	Impact	Cont	Impact	Cont	Impact	Cont	Impact	Cont	Impact	Impact Cont		1973 -Cont-					Impactor									Cont	Impact	
3/29 #1	2.10	1.55	114	246	4	(2)	.001	.001	4.5	.0382	.0382	3.65	4.25	24.61	28.63	.002	.002	.727	.847	67 58	NE	3.5671	3.4932	.0739	(14)		.0469	2.31	2.04	1.12	1.12	15.5	15.5	(14)		290	290	1824
3/29 #2	2.15	1.10	263	731	34	(2)	(2)	(2)	2.6	.2536	.2536	3.25	4.15	21.92	27.96	.013	.017	.638	.815	- 66	NE	3.7083	3.6704	.0379			.0260	2.34	2.07	1.12	1.12	1.5	1.5			323	323	1824
3/29 #3	1.40	1.10	(2)	(2)	2	(2)	.008	.005	2.7	.0324	.0324	2.40	2.20	15.32	14.09	.001	.001	.468	.429	63 59	NE	3.7204	3.6919	.0379			.0144	2.31	2.04	1.12	1.12	11.1	11.1			294	294	1824
3/29 #4	1.10	.30	(2)	(2)	12	(2)	.002	.001	4.5	.1059	.1059	1.90	3.10	12.30	20.13	.003	.005	.375	.613	66 59	NE	3.3957	3.3575	.0379			.0315	2.45	2.21	1.12	1.12	5.4	5.4			304	304	1824
4/5 #1	(2)	(2)	(2)	(2)	2	(2)	.010	.009	.1	.0333	.0333	(2)	31.47	(2)	226.73	(2)	.019	(2)	6.90	55 (2)	S	(2)	(2)	(2)			.0190	(2)	(2)	1.12	1.12	12.9	12.9			297	297	1052
4/5 #2	1.25	.45	276	732	5	(2)	.0006	.0004	5.2	.0490	.0490	1.70	3.60	5.82	13.53	.001	.002	.349	.740	58 74	S	3.5344	3.4988	.0356			.0940	2.39	2.14	1.12	1.12	12.0	12.0			301	301	1052

(1) Mud in sample
(2) No data available
(3) Doubtful data
(4) Basis for calculation ℄ to ℄ distance = 15.75 and row width = 5'
(5) Basis for calculation ℄ to ℄ distance = 17.35 and row width = 5'
(6) Estimated from data for other burns
(7) Figures in this column are estimated on the basis of the other Hivol, particulate collections and three known values for the CO_2 Hivol.
(8) Actual value
(9) Vertical scale 10 inches = 2.08%, horizontal scale 1 = 1/2 minute
(10) A different method of moisture and fuel quantity was used.
(11) Tower temperature calculated by adding average °F above back round line to ambient temperature at U.C.D. weather station.
(12) Samples to 3/17 #1 were taken only in quadrat, not a four foot section.
(13) Estimated from one piece of data
(14) 1973 trials used only one Hivol sampler

Field Data (Meteric units)

Date and Burn No.	Time of Burn	Brief Description of Burn	Wt. of Straw Samples Taken in the Field (lbs.)			Moisture Content of Samples Taken in the Field (% wet basis)			Sample Area (ft²)	Straw Quantity (lb/ac)	Wt. of Stubble Samples As Taken in the Field (lbs.)		
3/[illegible]	12:05	head	3.21	3.90	1.75	4.10	4.67	4.78	16	5969	3.86	1.44	1.20
3/[illegible]	2:30	fire	2.62	2.10	1.37	5.47	4.27	4.57	16	5301	3.84	.90	1.06
3/21 [illegible]	1:20	spread	3.61	2.41	1.61	7.96	9.22	7.90	16	6514	.85	.60	1.14
3/15 [illegible]	11:40	back-	2.33	1.36	1.53	6.36	5.48	4.34	16	4779	2.28	.98	1.71
3/15 [illegible]	1:43	fire	2.73	1.16	1.[illegible]3	6.25	4.70	5.65	16	6640	1.20	1.16	.91
3/15 [illegible]	3:[illegible]	spread	1.79	1.87	1.[illegible]0	5.48	5.00	5.62	16	4090	1.20	.87	1.00
3/15 [illegible]	4:13		3.43	2.29	2.92	6.67	5.98	6.00	16	7333	1.37	.95	1.58
3/21 [illegible]	4:32		(2)	(2)	(2)	(2)	(2)	(2)	16	5900[6]	(2)	(2)	(2)
3/9 [illegible]1	3:53	head	7.80	10.52	3.49	8.39	(2)	8.87	62.5	3662	2.47	8.04	.93
3/1[illegible]	3:[illegible]	fire	13.20	11.02	16.16	(2)	12.30	9.83	69.0	4352	1.59	1.79	(2)
3/13 [illegible]	[illegible]	roved	17.[illegible]	9.92	11.54	12.35	17.81	18.40	65.4	7336	1.90	1.83	2.07
3/[illegible] 1³	1:25		(2)	4.74	6.54	9.42	11.81	15.33	64.0	3307	1.89	1.23	1.29
[illegible] 2	5:20	back-	16.42	12.73	11.35	9.30	13.74	16.60	58.6	5537	2.17	1.89	1.37
3/1[illegible] 1³	3:00	fire	10.10	16.53	8.03	10.14	5.80	10.07	64.0	5058	1.63	1.23	1.24
3/1 [illegible]2	2:03	roved	8.61	5.10	6.4[illegible]	13.34	10.35	13.98	59.6[6]	4631	1.22	2.13	1.25
3/[illegible] 1³	1:35		5.80	8.06	4.67	8.24	9.26	7.31	63.0[6]	4539	1.19	1.05	.68
3/17 [illegible]2	3:45	head	9.18	11.42	10.24	5.64	5.77	5.36	69.4[6]	6087[6]	1.42	1.47	1.19
3/17 [illegible]4	5:[illegible]	fire raked	10.38	7.30	7.03	9.77	13.66	8.11	71.5	4540	1.30	1.43	1.83
3/21 #1	11:22		11.97	9.55	6.76	9.77	13.30	9.09	70.8	5173	.95	1.30	1.46
3/21 #3	1:21		11.77	7.77	12.26	3.51	13.03	15.55	77.5	5223	.97	1.09	2.34
3/17 #1	2:59	back-	8.62	6.49	15.76	6.13	6.15	7.22	69.4[6]	6027	1.3	1.16	1.15
3/17 #3	4:27	fire	7.34	12.57	9.02	5.95	5.57	6.83	66.0	5979	1.09	1.40	1.43
3/20 #1		raked	8.01	7.39	8.53	(2)	3.39	12.13	70.8	4399	1.62	1.31	1.26
3/21 #2	12:17		7.91	9.50	7.29	6.62	14.18	9.59	60.0	5292	1.09	1.00	1.51
1973		spread											
3/29 #1	11:53	back	(10)						16	1289	(10)		
3/29 #2	12:01	head							16	1289			
3/29 #3	3:15	back							16	1289			
3/29 #4	4:14								16	1289			
4/4 #1	[illegible]:46	back							60	1328			
4/5 #2	10:07	head roved							60	1328			

Date and Burn No.	Moisture Content of Sample Taken in the Field (% wet basis)			Sample Area (ft²)	Stubble Quantity (lb/ac)	Total Fuel Quantity (lb/ac)	Moisture Content of Straw at Time of Burn (% wet basis)			Avg. Straw Moisture (% wet basis)	Moisture Content of Stubble at Time of Burn (% wet basis)			Avg. Stubble Moisture (% wet basis)	Cumulative Moisture Content (% wet basis)	Fuel Consolidation (lb/ft²)
3/[illegible]	22.2	14.1	16.0	16	4838	10,787	(2)	6.20	4.41	5.3	25.59	12.44	19.39	22.5	13.1	.240
3/[illegible]	26.7	18.9	13.7	16	4087	9,388	5.73	6.61	4.91	5.8	17.38	26.99	11.05	18.4	11.3	.22
3/21 [illegible]	31.2	28.1	26.9	16	1678	8,192	7.96	9.22	7.90	8.4	31.17	28.85	26.90	29.0	12.6	.19
3/15 [illegible]	10.0	9.1	26.7	16	3808	8,587	7.29	6.65	8.15	7.4	10.88	23.93	35.25	29.6	17.2	.20
3/15 [illegible]	13.5	13.6	14.6	16	2557	9,397	5.33	7.58	6.84	6.6	9.54	19.21	26.29	22.8	11.1	.20
3/15 [illegible]	21.6	16.8	14.9	16	2283	6,378	(2)	5.47	6.32	5.9	25.68	19.82	18.97	21.5	11.5	.15
3/15 [illegible]	22.1	22.6	18.6	16	2803	10,136	10.24	28.01	7.15	8.7	51.67	11.45	24.90	38.2	16.9	.23
3/21 [illegible]	(2)	(2)	(2)	16	3151[6]	8,951[6]	7.85	8.14	7.83	7.9	15.17	12.79	17.11	15.0	10.4	.16
3/9 [illegible]1	40.3	70.0	15.8	16	4238	7,900	13.74	12.53	(2)	13.1	25.95	(2)	(2)	26.0	15.4	.40[4]
3/1[illegible]	41.37	38.98	40.59	16	2923	11,255	28.71	16.55	(2)	22.6	61.91	33.49	49.10	41.1	22.0	.68[4]
3/13 [illegible]	58.91	45.67	45.61	16	2929	10,255	8.03	9.97	14.9	10.9	44.16	39.16	52.97	45.4	19.4	.71[4]
3/[illegible] 1³	67.80	21.61	21.47	16	2361	5,668	11.96	10.93	15.1	12.67	56.14	25.70	36.81	39.55	23.2	.41[4]
[illegible] 2	38.7	57.8	49.0	16	2565	11,102	11.33	(2)	(2)	11.3	48.38	(2)	(2)	48.38	19.9	.80[4]
3/1[illegible] 1³	39.51	26.11	25.19	16	2595	8,553	7.50	18.77	(2)	13.1	17.18	42.17	(2)	29.7	18.1	.62[4]
3/1 [illegible]2	22.47	30.79	27.49	16	3019	7,650	6.89	8.48	6.95	7.4	17.96	39.44	15.66	39.4	19.0	.50[4]
3/[illegible] 1³	18.20	25.68	17.02	16	2104	6,643	5.98	7.48	6.02	6.5	40.22	30.37	31.65	34.08	14.7	.48[4]
3/17 [illegible]2	31.85	34.79	20.72	16	2604	8,691	6.41	6.81	6.70	6.6	34.16	26.16	29.17	29.8	13.1	.68[5]
3/17 [illegible]4	27.88	25.16	18.66	16	3173	7,713	9.50	13.46	9.50	10.8	24.73	30.90	20.76	27.8	17.8	.61[5]
3/21 #1	33.80	33.66	16.79	16	2456	7,629	15.04	11.54	11.88	12.8	35.13	43.48	34.02	37.5	20.8	.61[5]
3/21 #3	38.89	24.66	18.49	16	3014	8,237	18.01	10.00	12.14	13.4	38.05	21.18	34.38	36.2	21.2	.64[5]
3/17 #1	33.5	32.5	44.5	16	2073	8,100	8.56	7.43	6.64	7.5	36.71	19.00	17.88	36.7	14.7	.64[5]
3/17 #3	30.14	17.00	14.58	16	2854	8,833	(2)	6.85	7.66	7.3	35.81	33.67	19.53	34.6	16.2	.70[5]
3/20 #1	(2)	63.88	32.80	16	1797	6,196	12.41	8.91	6.43	9.3	11.24	35.79	11.96	35.8	17.0	.49[5]
3/21 #2	30.92	29.22	30.35	16	2271	7,563	9.09	13.81	15.44	12.8	39.72	31.95	31.01	34.2	19.2	.60[5]
1973																
3/29 #1	(10)			16	2728	4,017	(10)			13.0	(10)			14	14	.092
3/29 #2				16	2728	4,017				10				12	11	.092
3/29 #3				16	2728	4,017				10				12	11	.092
3/29 #4				16	2728	4,017				10				12	11	.092
4/4 #1				16	2410	3,738				9				15	11	.177
4/5 #2				16	2410	3,738				13				16	14	.177

Date and Burn No.	Weight of Post-burn Stubble as taken in the field (lb)			Moisture Content of Samples Taken in the Field (% wet basis)			Sample Area (ft²)	Post Burn Stubble Quantity (lb/ac)	Percent of Fuel Burned (%)	Weight of Ash Sample as Taken in the Field (lbs) (4)			Ash Quantity (lb/ac)	Carbon Content of Ash	Ambient Temperature (°F)	Relative Humidity (%)	Wind Speed (mph)
3/[illegible]	.26	0	0	51.32	--	--	16	344.6	96.8	1.44	.62	.95	2732	13.4	76	35	4.5
3/[illegible]	0	0	0	--	--	--	16	0	100.0	(2)	(2)	(2)	2400[6]	15.2[6]	83	30	[illegible]
3/21 [illegible]	0	0	0	--	--	--	16	0	100.0	.60	.82	1.0	2196	17.0	76	42	4.5
3/15 [illegible]	0	0	0	--	--	--	16	0	100	(2)	(2)	(2)	1936[6]	17.9[6]	77	37	2.5
3/15 [illegible]	.25	0	0.14	19.06	--	20.86	16	426	95	.76	1.15	.67	2341	19.0	80	32	5.0
3/15 [illegible]	0	0	0	--	--	--	16	0	100	.92	.50	.81	2023	20.0	81	29	4.5
3/15 [illegible]	0	0	0	--	--	--	16	0	100	.86	.51	(2)	1865	17.1	84	26	5.0
3/21 [illegible]	0	0	0	--	--	--	16	0	100	.48	.75	.441	1516	15.4	74	43	6.5
3/9 [illegible]1	.25	12.03	3.55	58.7	63.3	56.7	16	1406	70	2.01	2.74	2.05	2169	13.4	60	56	(2)
3/1[illegible]	.37	1.04	11.69	50.2	39.3	58.7	16	1490	84	3.12	1.52	2.56	2364	7.8	66	49	5.0
3/13 [illegible]	.90	1.01	.22	15.3	57.7	20.3	16	303	96	(2)	(2)	(2)	2277	13.4	74	40	9.5
3/[illegible] 1³	.15	.06	0	61.24	8.10	-	16	95	99	2.70	1.93	2.35	2162	13.9	74	40	5.5
[illegible] 2	0	(2)	(2)	--	13.95	63.7	16	0	100	3.15	1.55	1.81	2344	12.2	61	57	7.5
3/1[illegible] 1³	0	2.87	.95	--	56.8	13.6	16	0	100	2.68	2.31	1.13	2060	13.7	68	47	2.5
3/1 [illegible]2	0	.49	0	--	52.4	--	16	188	97	1.34	1.78	2.31	2118	11.5	75	38	5.0
3/[illegible] 1³	.25	0	0	58.07	--	--	16	95	99	1.93	1.25	.63	644	11.6	(2)	(2)	(2)
3/17 [illegible]2	.45	0	0	45.8	--	--	16	128	98	4.15	1.59	2.09	1155	9.5	84	35	5.0
3/17 [illegible]4	(2)	(2)	(2)	(2)	(2)	(2)	16	0	100	1.54	2.71	2.33	1337	9.3	81	33	6.5
3/21 #1	(2)	(2)	(2)	(2)	(2)	(2)	16	0	100	1.08	2.08	2.11	1080	12.7	69	52	8.5
3/21 #3	(2)	(2)	.28	(2)	(2)	16.08	16	132	98	3.02	2.87	3.37	1735	12.7	73	43	6.5
3/17 #1	.23	.01	.22	23.2	15.9	33.7	16	69	99	2.90	1.52	1.95	1332	10.1	82	35	2.5
3/17 #3	(2)	(2)	(2)	(2)	(2)	(2)	16	0	100	1.09	3.00	2.04	1348	10.3	83	34	6.0
3/20 #1	(2)	(2)	(2)	(2)	(2)	(2)	16	0	100	2.59	2.66	2.67	1624	12.0	70	45	2.5
3/21 #2	(2)	(2)	.29	(2)	(2)	37.7	16	0	100	1.78	1.60	1.34	1142	14.5	70	46	5.0
1973										grams							(mph)
3/29 #1	0	0	0	(10)			16	0	100	181	169	(2)	1049	16.2[6]	56	43	7.5
3/29 #2	0	0	0				16	0	100	167	144	(2)	932	16.2	63	34	9.0
3/29 #3	0	0	0				16	0	100	209	163	150	924	16.2	65	24	7.0
3/29 #4	0	0	0				16	0	100	181	150	122	908	16.2	65	24	4.5
4/4 #1	0	0	0				16	0	64	459	564	511	767	16.2	70	40	6.5
4/5 #2	0	0	0				16	0	64	459	564	511	767	16.2	74	38	8.0

Date and Number of Burn	Chloroform Soluble Particulate Production Level (lbs/ton) (Cont)	Chloroform Insoluble Particulate Production Level (lbs/ton)	Average Fire Temperature (°F)	Maximum Fire Temperature (°F)	Maximum Tower Temp. (°F above amb.) (Cont)	Maximum Tower Temp. (CO_2) (°F above amb.)	Chloroform Soluble Particulate Concentration (Cont) $\mu g/m^3 \times 10^6$	Chloroform Insoluble Particulate Concentration (Cont) $\mu g/m^3 \times 10^6$	Lb. Fuel Represented by Particulates Sampled lb $\times 10^{-2}$	Avg. CO_2 Level (%) (Cont)	Average CO_2 Level (%) (CO_2)	Particulate Production Level (lbs/ton) (Cont)	Particulate Production Level (lbs/ton) (CO_2)	Particulate Production Level (lbs/std ac.) (Cont)	Particulate Production Level (lbs/std ac.) (CO_2)	Part. Concentration at Sampler ($\mu g/m^3 \times 10^6$) (Cont)	Part. Concentration at Sampler ($\mu g/m^3 \times 10^6$) (CO_2)	Part. Concentration at Fire ($\mu g/m^3 \times 10^6$) (Cont)	Part. Concentration at Fire ($\mu g/m^3 \times 10^6$) (CO_2)	% Chloroform Extractable (%) (Cont)	Wind Direction
3/15 #2	24.6	6.2	(2)	(2)	95	95	.012	.003	4.09	.0617	.0924	30.8	21.6	89.4	62.8	.015	.016	2.99	2.10	80	NNE
3/15 #4	3.3	2.33	148	607	305	305	.0053	.0037	4.23	.1987	.4940	5.63	1.71	16.9	5.12	.009	.006	.553	.167	59	NNE
3/21 #4	8.9	3.6	343	795	191	191	.0065	.0025	5.44	.0849	.1310	12.5	12.4	37.5	37.3	.009	.014	1.25	1.25	72	SW
	12.3	4.05																			
3/15 #1	1.4	10.2³	(2)	(2)	86	86	.0011	.0059	5.86	.0716	.0829	11.6	9.58	34.8	26.7	.007	.007	1.14	.945	15	N
3/15 #3	1.0	3.6	(2)	(2)	64	64	.0010	.002	1.71	.0716	.0851	4.6	3.00	13.2	8.56	.003	.002	.470	.306	36	NE
3/15 #5	.72	3.06	530	1141	105	105	.0005	.0015	6.22	.0663	.1242	3.78	2.99	11.3	8.96	.002	.003	.401	.318	24	E
3/15 #6	1.1	2.64	548	1252	101	101	.0013	.0027	7.59	.1243	.1456	3.74	3.33	11.2	9.99	.004	.039	.359	.320	32	SSE
3/21 #5	(2)	(2)	325	905	55	55	(2)	(2)	2.19	.0573	.0900	3.26	5.09	9.77	15.28	.002	.037	.315	.493	(2)	SW
3/9 #1	38.6	12.8	(2)	(2)	(2)	(2)	.020	.007	5.12	.0621	.1088	51.4	35.7	108	75.0	.027	.032	5.12	3.56	75	(2)
3/10 #2	9.4	5.3	(2)	(2)	55	55	.0026	.0014	15.63	.0367	.0531	14.7	15.0	37.1	37.7	.004	.006	1.38	1.41	64	S
3/13 #3	25.8	11.1	402	1091	91	53	.0098	.0042	3.73	.0452	.0411	36.9	41.9	106	121.0	.014	.014	3.63	4.12	70	NNW
3/13 #1³										.0367	.0763	13.1	(2)	39.1	(2)	.009	(2)	1.35	(2)	70	NW
3/9 #2	8.4	4.8	227	537	(2)	(2)	.0045	.0025	12.48	.0653	.0838	13.2	10.4	39.5	31.3	.007	.007	1.26	1.00	64	W
3/10 #1	(2)	(2)	169	387	95	77	(2)	(2)	(2)	.0396	.0486	80.1	(2)	240.0	(2)	.025	(2)	7.72	(2)	64	N
3/1 #2	4.2	6.6	352	448	55	55	.0012	.0018	0.31	.0375	.0512	10.8	14.3	31.5	41.7	.003	.0061	1.09	1.44	39	S
3/30 #1³										(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2).	83	–
3/17 #2	8.3	4.0	285	1022	152	152	.0068	.0082	4.50	.1560	.2153	12.3[6]	1.90	36.1	5.61	.015	.0031	1.13	.175	68	W
3/17 #4	7.2	5.1	(2)	(2)	256	204	.0088	.0062	7.29	.1525	.2773	12.3[6]	6.07	36.8	18.2	.015	.013	1.15	.569	59	S
3/21 #1	27.7	5.7	769	401	67	59	.015	.003	4.73	.0703	.1094	33.4	13.7	100.0	41.1	.018	.0117	3.13	1.29	83	SSE SSE
3/21 #3	5.3	5.7	645	1295	99	99	.0038	.0042	3.63	.0920	.1403	11.0	6.72	32.3	19.7	.008	.0077	1.08	.659	48	W
3/17 #1	12.5	8.0	235	846	130	130	.0092	.0058	3.02	.0952	.1137	20.5	5.17	61.0	15.4	.015	.004	1.91	.480	61	W
3/17 #3	4.2	3.0	750	1441	108	55	.0029	.0021	7.37	.0809	.0789	7.2	5.31	27.7	15.9	.005	.003	.672	.494	58	W
3/20 #1	6.6	9.9	898	1503	98	86	.004	.006	3.72	.0731	.1560	16.5	18.5	49.6	55.4	.010	.023	1.63	1.82	40	E
3/21 #2	(2)	(2)	978	1398	50	50	(2)	(2)	8.46	.0509	.0840	2.50	11.0	7.5	33.1	.001	.007	.238	1.05	(2)	SSE
1973	1973									Cont	Impact	Cont	Impact	Cont	Impact	Conc	Impact	Cont	Impact	Impact Cont	
3/29 #1	4.2	3.1	238	475	6[7]	(2)	.001	.001	4.5	.0382	.0382	7.3	8.5	22.0	25.6	.002	.002	.727	.847	67 58	NE
3/29 #2	4.3	2.2	506	1348	61	(2)	(2)	(2)	2.6	.2536	.2536	6.5	8.3	19.6	25.0	.013	.017	.638	.815	– 66	NE
3/29 #3	2.8	2.0	(2)	(2)	4	(2)	.008	.005	2.7	.0324	.0324	4.8	4.4	13.7	12.6	.001	.001	.468	.429	63 59	NE
3/29 #4	2.2	1.6	(2)	(2)	22	(2)	.002	.001	4.5	.1059	.1059	3.8	6.2	11.0	18.0	.003	.005	.375	.613	66 59	NE
4/4 #1	(2)	(2)	(2)	(2)	4	(2)	.010	.009	.1	.0333	.0333	(2)	63.0	(2)	113.3	(2)	.019	(2)	6.90	55 (2)	S
4/5 #2	2.5	.9	528	1350	8	(2)	.0006	.0004	5.2	.0490	.0490	3.4	7.2	5.7	12.1	.001	.002	.349	.740	58 74	S

Date and Number of Burn	Final Wt. of HiVol Filters (gms) (Cont)	Initial Wt. of HiVol Filters (gms)	Wt. of Particulates (gm) (cont)	Final Wt. of HiVol Filters (gms) (CO_2)	Initial Wt. of HiVol Filter (gms)	Wt. of Particulates (gms) (CO_2)	Average HiVol Sampling Rate (CFM) (Cont)	Calibration Corrected Flow (CFM) (Cont)	Average Sampling Rate (CFM) (CO_2)	Calibration Corrected Flow (CFM) (CO_2)	Duration of Sampling (Min) (Cont)	Duration of Sampling (Min) (CO_2)	CO_2 Area (% - sec.) (Cont) (9)	CO_2 Area (% - sec) (CO_2) (9)	Tower Temp. (°R) (Cont) (11)	Tower Temp. (°R) (CO_2)	Net Fuel Burned (lbs)
3/15 #2	4.3090	4.0230	.2860	4.2001	4.0711	.1290	88	79.2	91[7]	80.8	3.85	3.80	5.25	3.38	554	566	10443
3/15 #4	4.0552	4.0011	.0541	4.0269	4.0160	.0109	88.5	79.8	92	81.6	3.25	1.00	6.21	4.75	646	760	[illegible]
3/21 #4	4.1386	3.9840	.1546	4.0351	3.9971	.0380	90.5	81.9	90[6]	80.0	6.55	1.35	5.35	1.70	553	569	[illegible]
3/15 #1	4.1853	4.0310	.1543	4.0520	3.9960	.0560	88[13]	79.2	90.5	80.4	10.6	4.0	7.30	3.19	547	552	[illegible]
3/15 #3	4.0749	4.0181	.0568	4.0383	4.0280	.0103	88.5	79.8	92	81.6	9.36	2.20	6.59	1.80	555	557	[illegible]
3/15 #5	4.0585	4.0051	.0534	4.0343	4.0221	.0122	88[13]	79.2	91	80.8	11.25	1.75	7.17	2.09	545	561	[illegible]
3/15 #6	4.0405	3.9761	.0644	4.0609	4.0250	.0359	89.5[13]	80.8	92	81.6	8.20	4.45	9.84	6.23	562	578	10136
3/21 #5	4.0882	4.0263	.0619	3.9842	3.9668	.0174	90.5	81.9	91	80.8	18.23	2.15	10.05	1.86	535	544	6773
3/9 #1	4.6023	4.0050	.5973	4.2560	3.9891	.2669	102	90.5	103	93	8.98	3.25	5.36	3.40	531	538	[illegible]
3/10 #2	4.5937	4.0720	.5217	4.1597	4.0121	.1776	103.5	92.4	106	96	48.03	10.90	16.94	5.57	530	540	[illegible]
3/13 #3	4.2848	3.9721	.3127	4.0720	4.0040	.0686	91.5	82.9	94	80.34	10.15	2.2	4.76	.87	542[8]	535	[illegible]
3/13 #1³	4.1452	4.0300	.1152	4.1020	4.0640	.0380	90	81.3	93	82.5	4.7	2.1	3.92	1.54	546	460	[illegible]
3/9 #2	4.3931	4.0191	.3740	4.1411	3.9781	.1630	101.5[13]	91.2	104	94	21.5	8.95	13.50	7.21	530	531	[illegible]
3/10 #1	4.5655	4.0011	.5645	4.3907	4.0101	.3806	105.5	94.5	107	97.5	2.5	6.10	17.00	2.85	534	540	[illegible]
3/1 #2	4.0981	4.0210	.0771	4.0123	3.9820	.0303	91	82.3	93.5	83	10.15	2.2	6.02	2.98	542	544	[illegible]
3/30 #1³	3.3627	3.2618	.1009	(2)	(2)	(2)	89	80.4	(2)	(2)	4.4	(2)	(2)	(2)	(2)	(2)	[illegible]
3/17 #2	4.0909	3.9654	.1255	4.0137	3.0909	.0228	89.5	80.8	92	81.7	4.13	3.55	8.25	7.35	574	589	[illegible]
3/17 #4	4.1481	3.9445	.2036	3.9647	3.8931	.0516	89[13]	80.3	91.5	81.2	7.05	2.10	10.3	5.60	598	640	7713
3/21 #1	4.2787	3.9202	.3585	3.9449	3.8799	.0650	89.5	80.8	91.5	81.2	3.8	2.5	5.95	2.63	536	539	7629
3/21 #3	4.1409	4.0502	.0907	4.0476	3.9997	.0479	89[6]	80.3	91[8]	80.8	5.2	2.95	4.60	3.98	560	565	[illegible]
3/17 #1	4.1507	4.0103	.1404	3.9476	3.9191	.0285	89	80.3	91	80.8	4.50	3.10	6.73	3.39	574	589	[illegible]
3/17 #3	4.0027	3.8823	.1204	3.9835	3.9565	.0270	89.5	80.8	92	81.6	12.55	3.85	9.76	2.92	562	556	[illegible]
3/20 #1	4.1567	4.0173	.1394	4.0277	3.9611	.0666	89[6]	80.3	91.5	81.2	6.5	1.3	5.95	2.63	548	553	6196
3/21 #2	4.1421	3.9941	.0480	3.9634	3.9269	.0365	88.5[6]	79.8	91	80.8	21.7	2.25	10.63	2.06	536	539	7563
1973	1973 -Cont-						Impactor								Cont	Impact	
3/29 #1	3.5671	3.4932	.0739	(14)		.0469	82.5	73.0	40	40	15.5	15.5	(14)		522	522	4017
3/29 #2	3.7063	3.6704	.0379			.0260	83.5	74.0	40	40	1.5	1.5			582	582	4017
3/29 #3	3.7204	3.6919	.0379			.0144	82.5	73.0	40	40	11.1	11.1			529	529	4017
3/29 #4	3.3957	3.3575	.0379			.0315	87.5	78.8	40	40	5.4	5.4			547	547	4017
4/4 #1	(2)	(2)	(2)			.0190	(2)	(2)	40	40	12.9	12.9			534	534	[illegible]
4/5 #2	3.5344	3.4988	.0356			.0940	85.5	76.5	40	40	12.0	12.0			542	542	[illegible]

(1) Mud in sample
(2) No data available
(3) Doubtful data
(4) Basis for calculation ℄ to ℄ distance = 15.75 and row width = 5'
(5) Basis for calculation ℄ to ℄ distance = 17.35 and row width = 5'
(6) Estimated from data for other burns
(7) Figures in this column are estimated on the basis of the other Hivol, particulate collections and three known values for the CO_2 Hivol.
(8) Actual value
(9) Vertical scale 10 inches = 2.08%, horizontal scale 1 = 1/2 minute
(10) A different method of moisture and fuel quantity was used.
(11) Tower temperature calculated by adding average °F above back round line to ambient temperature at U.C.D. weather station.
(12) Samples to 3/17 #1 were taken only in quadrat, not a four foot section.
(13) Estimated from one piece of data
(14) 1973 trials used only one Hivol sampler