Background Report Reference

AP-42 Section Number: 9.12.2

Background Chapter: 4

Reference Number: 3

Title: Evaluation Test to Measure Ethanol Emission From a 106,000 Gallon Fermentation Tank

California Air Resources Board

California Air Resources Board

October 1980

Ref 3

AP-42 Section 9.12.2
Reference
Report Sect. 4
Reference 3

STATE OF CALIFORNIA
AIR RESOURCES BOARD

EVALUATION TEST TO MEASURE ETHANOL EMISSIONS FROM A 106,000 GALLON FERMENTATION TANK

Stationary Source Control Division

ENGINEERING EVALUATION BRANCH

REPORT NO. C-80-071

OCTOBER 1980

PETER OUCHIDA

Project Engineer

Approved:

FRANCIS R. PERRY, Chief

Engineering Evaluation Branch

Approved:

HARMON WONG-WOO, Chief

Stationary Source Control Division

SUMMARY

A 106,000 gallon fermentation tank filled with 90,000 gallons of must to produce a white blending wine was tested for 159 hours during which ethanol emissions were continuously monitored. Carbon dioxide (CO_2), oxygen (O_2), temperature, and exhaust gas volumes were also measured.

Fermentation exhaust gas temperatures were a constant 53°F.

The average ethanol concentration was 3,640 parts per million (ppm). Based on this concentration and a total measured gas volume of 310,060 ft^3, the estimated mass of ethanol emitted to atmosphere was 137 lbs in 159 hours. This corresponds to a mass emission rate of approximately 0.86 lbs/hr. or, when expressed in terms of gallons of wine juice fermented, 1.52 lbs/10^3 gal.

Other exhaust gas components and their determined concentrations are:

CO_2	99.6%
H_2S	1.1 ppm
SO_2	<.2 ppm
CH_3SH	<.006 ppm

No oxygen was detected in the exhaust gas.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

I. Introduction

The Air Resources Board staff conducted an evaluation test on a wine fermentation tank owned by United Vintners, Inc and located at its facility on 2916 South Reed Avenue, P.O. Box 709, Reedley, California, 93654. The objective of the test was to determine an ethanol emission rate from the tank during one complete fermentation cycle.

The capacity of the stainless steel fermentation tank is 106,000 gallons. For the test, the tank was filled with 90,000 gallons of must pressed from approximately 487 tons of St. Emillion grapes. A dry, white bending wine was the intended product from this fermentation.

ARB personnel were assisted at the winery by: Ronald S. Niino, Plant Manager; Adrienne Iwata, Winemaker; and Max Day. A list of witnesses to the evaluation test is presented in Table I.

TABLE I

EVALUATION TEST WITNESSES

NAME	TITLE	AFFILIATION
PETER OUCHIDA	PROJECT ENGINEER	AIR RESOURCES BOARD
DAVID CRAFT	AIR POLLUTION SPECIALIST	AIR RESOURCES BOARD
RONALD NIINO	PLANT MANAGER	UNITED VINTNERS
ADRIENNE IWATA	WINEMAKER	UNITED VINTNERS
MAX DAY	————	UNITED VINTNERS
JACK LABRUE	INSTRUMENT TECHNICIAN	AIR RESOURCES BOARD
DON FITZEL	INSTRUMENT TECHNICIAN	AIR RESOURCES BOARD
A. SUE PINKERTON	ENVIRONMENTAL ENGINEER	FRESNO COUNTY APCD
GENE DAVIS	ENVIRONMENTAL ENGINEER	FRESNO COUNTY APCD
DON VARTABEDIAN	ENVIRONMENTAL ENGINEER	FRESNO COUNTY APCD

II. Process Description

United Vintners, Inc. operates a winery situated off of state route 65, just north of Reedley, California. This facility processes approximately 75,000 tons of grapes per crushing season.

Harvested grapes are shipped from the vineyard to this winery via trucks and are off loaded directly into a crusher/stemmer for initial processing. The crusher/stemmer consists of a cylindrical drum with slots or holes large enough to pass the berry but not the stem. The cylinder rotates about an axle at a speed of approximately 500 r.p.m. or more. Attached to the axle are paddles that are also rotating, but at a slower rate; approximately 25 r.p.m. The action of the paddles forcing the berries off the stem and through the holes of the rotating cylinder is vigorous enough to crush the berries. The crushed grape mass, called must, is caught in a stationary cylinder that surrounds the first and is drained into a sump for storage before transfer to the next operation. The dry stems amount to an average of 80 pounds per ton of grapes crushed and, depending on the grape variety involved, can range from 40 to 150 pounds per ton.

Sulfur dioxide gas is usually metered into the must as it is being transfered from the storage sump to the next operation. Sulfur dioxide serves three functions: it inhibits the growth of undesirable microorganism, it denatures the browning enzymes, and prevents oxidative reactions from occurring by keeping the must in a reducing environment.

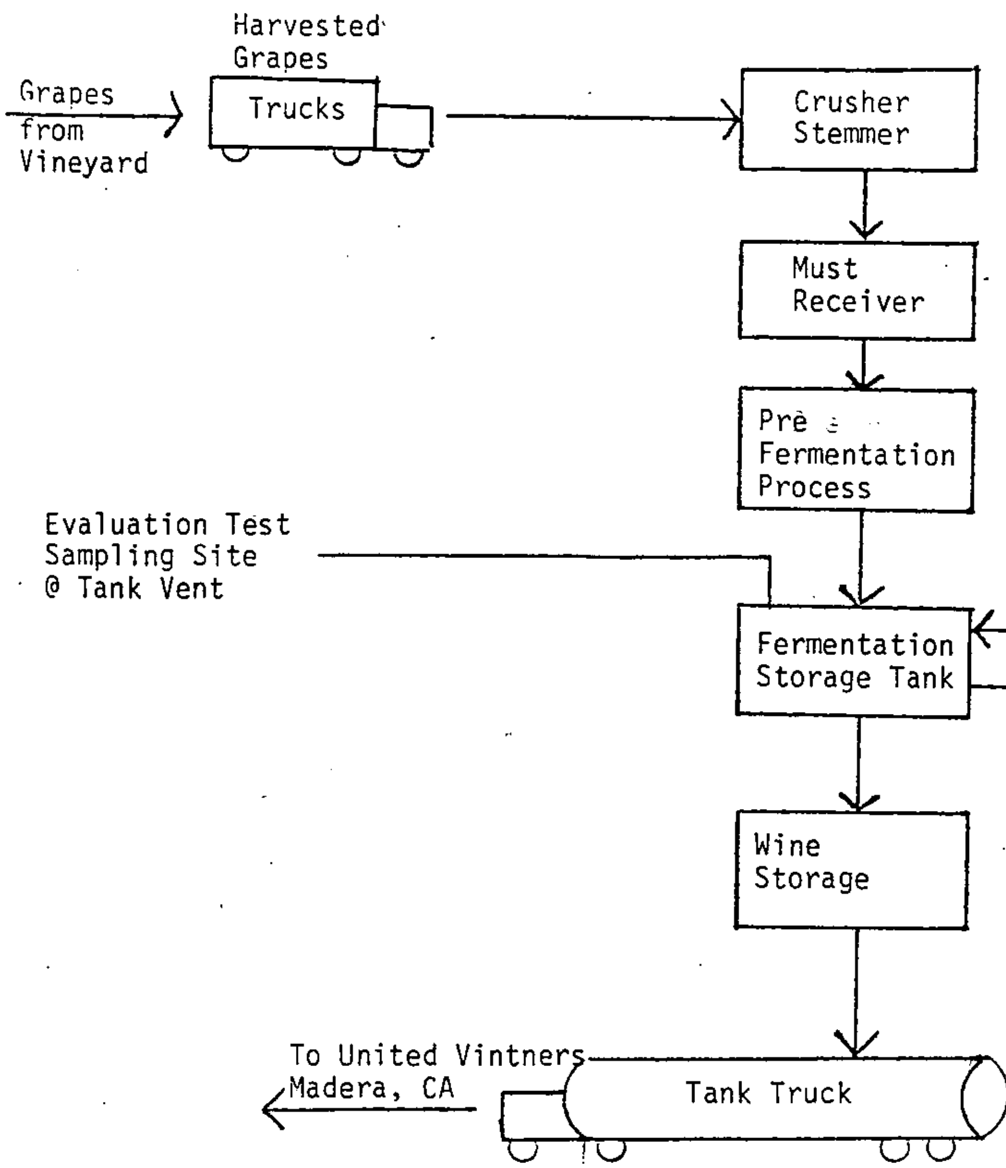
After the addition of the sulfur dioxide gas, the must is ready for processing. This involves seperating the fluid must, or juice, from the solids called pomace. Seeds, skin, and part of the pulp comprise the pomace. The juice that is divorced from the pomace is called the free run and is used to make higher quality wines. The juice obtained from compressing the pomace is called the press run and goes into making the lower-quality grade wines and blending wines. For white wine production, the juice and pomace are separated before fermentation in contrast to red wine production, where this step occurs during fermentation.

Fermentation of the juice for white wines and the total crushed grape mass for red wines follows the pressing operation. The must is pumped into a stainless steel tank and the inoculum of white yeast added. The must is temperature controlled during the fermentation process by circulating it through a heat exchanger that is connected to a mechanical refrigeration system.

After several days the fermentation is complete and the resulting wine is stored. From storage tanks, the wine is loaded into tanker trucks and transported to the United Vintners facility in Madera, California for blending and/or bottling.

FIGURE I

PROCESS SCHEMATIC



III. The Effects of Temperature on Fermentation

Fermentation temperatures can significantly influence the quality of the wine and special attention is given to its control. The recommended fermentation temperature for the making of white table wines is in the range of 50 to 60° F. At warmer temperatures, a loss of grape aroma and the development of "hot fermentation" off flavors will occur (1).

A linear relationship exists between fermentation rate and temperature over the range of 50 to 91° F. At temperatures above 70° F, the growth of yeast cells begins almost immediately and their rate of multiplication is rapid, reaching steady state after approximately 25 hours. At temperatures below 70° F the growth is delayed. This is illustrated in Figure 2. Between the temperatures of 50 to 80° F, the following equation approximates the effects of temperature on delay in starting a fermentation:

$$\frac{1}{H} = k\,T$$

where
H= time
T= temperature
K= constant

The constant, k, will vary for each must, yeast type and, in general, other conditions that affect yeast multiplication. (2)

With white musts, the maximum yeast cell count appears to be reached when the degree Brix drops to between 10^{o} and 3^{o} (about 6 to 9 percent alcohol by volume produced). During the initial cell multiplication period, the yeast population increases exponentially, but after fermentation starts, the multiplication rate is slower, and either gradually stops, or reaches an equilibrium with dying cells. The rate of cell growth and the rate of fermentation are independent, but both react to temperature; therefore, the conversion of sugar to alcohol will depend to some degree on the temperature effects on both rates. As more yeast cells are produced, the overall fermentation rates increase. The overall fermentation rates (disappearance of sugar) are, however, inhibited by sugar, alcohol and pH, and are limited by the amount of thiamine and other micronutrients present in the juice. (2)

By utilizing multiple regression techniques, C.S. OUGH correlated the effects of three must variables on the fermentation rates at different temperatures. The three musts variables were ammonia (NH_3), initial Brix, and initial pH. About 80 per cent of the rate variations were accounted for in this study and the result is illustrated in Figure 3. (2), (4).

Premature stopping, or sticking, of the fermentation can occur at excessively high or low fermentation temperatures. At high temperatures, the metabolic functions of the yeast cells are inhibited or the cells killed. At low temperatures, the enzymatic reactions proceed slowly, eventually causing the yeast cell to die.

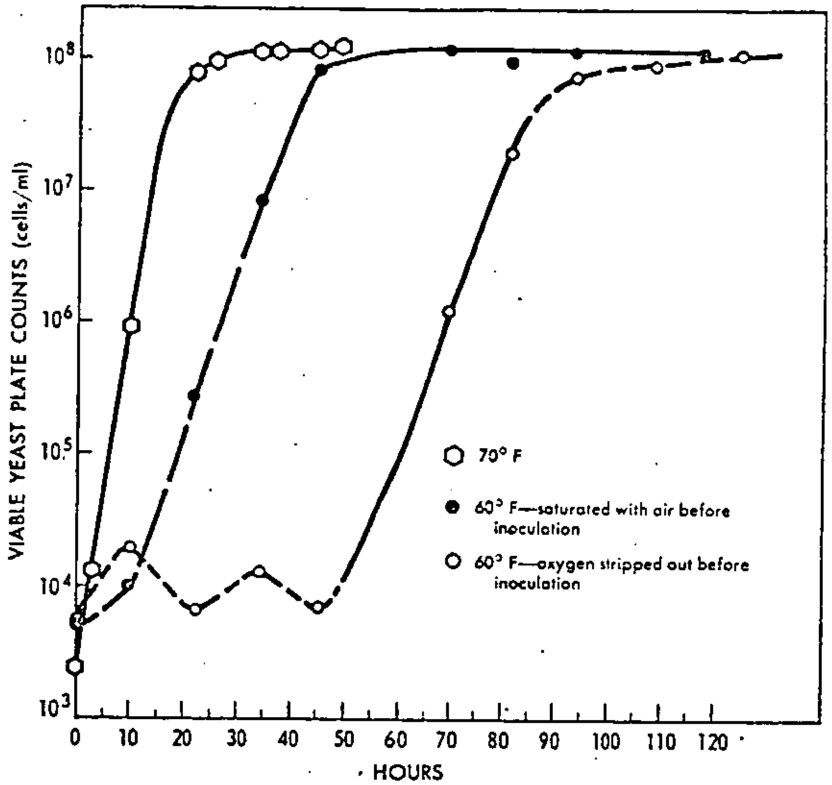


Fig. 2 Yeast growth curves showing the effect of two temperatures and absence of air on starting time and growth rate. Counts were made in duplicate or triplicate at each point.

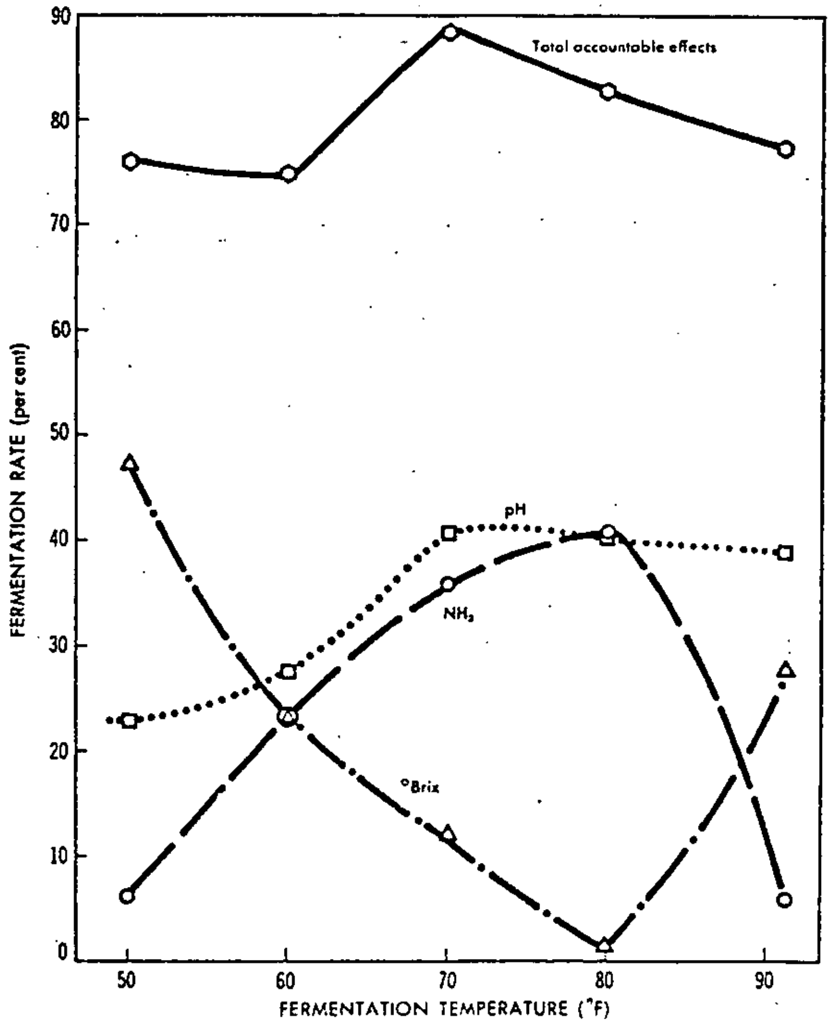


Fig. 3. Effect of three must variables on rates of fermentation at different temperatures.

IV. TEST METHODOLOGY & EQUIPMENT

All emission measurements were taken at the fermentation tank vent hatch. The hatch was fitted with an adaptor to which a turbine meter was attached. Ports on the adaptor accomodated (1) the sample line for continuous gaseous measurements, (2) a thermocouple for exhaust gas temperature measurements, and (3) a pitot tube for velocity pressure measurements. Exhaust gas volume was metered through the turbine and the volumetric rate determined by dividing the exhaust gas volume by the corresponding time interval during which the volume was measured. This was cross checked by pitot tube measurements and ARB Method 1-2, "Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)." Oxygen (O_2), carbon dioxide (CO_2), and ethanol (C_2H_5OH) concentrations were continuously measured by analyzers located inside a mobile van parked at the base of the fermentation tank. A heated sample line was used to prevent condensation as the sampled gas was being drawn from the vent hatch to the van.

The evaluation test equipment used and the sampling site where the measurements were taken are identified in Figure 4. The arrangement of the turbine meter and the adaptor is illustrated in Figure 5.

The parameters monitored and the measurement methods used are listed below:

Total Hydrocarbons: A Beckman Model 400 continuous analyzer measured hydrocarbon concentrations with a flame ionization detector (FID). The analyzer was calibrated with propane and a response factor to ethanol was determined.

Oxygen: Oxygen was measured with a Beckman Model F-3 continuous O_2 analyzer equipped with a paramagnetic detection system.

Carbon Dioxide: An Anarad Model 500 analyzer with a nondispersive infrared detector (NDIR) continuously monitored CO_2 concentrations.

Grab Samples: Grab samples of the exhaust gas were taken in 2 liter glass flasks and analyzed for total hydrocarbon, ethanol, CO_2, O_2, sulfur dioxide (SO_2), hydrogen sulfide (H_2S), and methyl mercaptan.

FIGURE 4

SOURCE TEST EQUIPMENT
AND
SAMPLING SITES

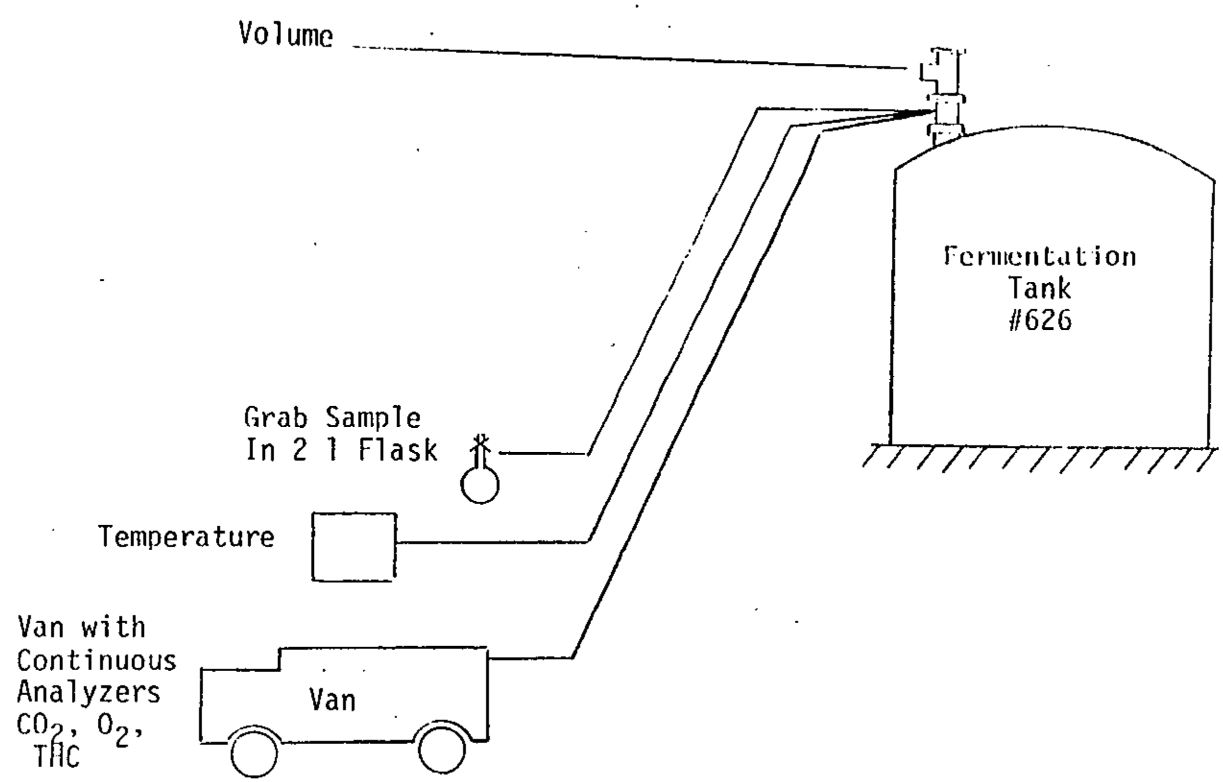
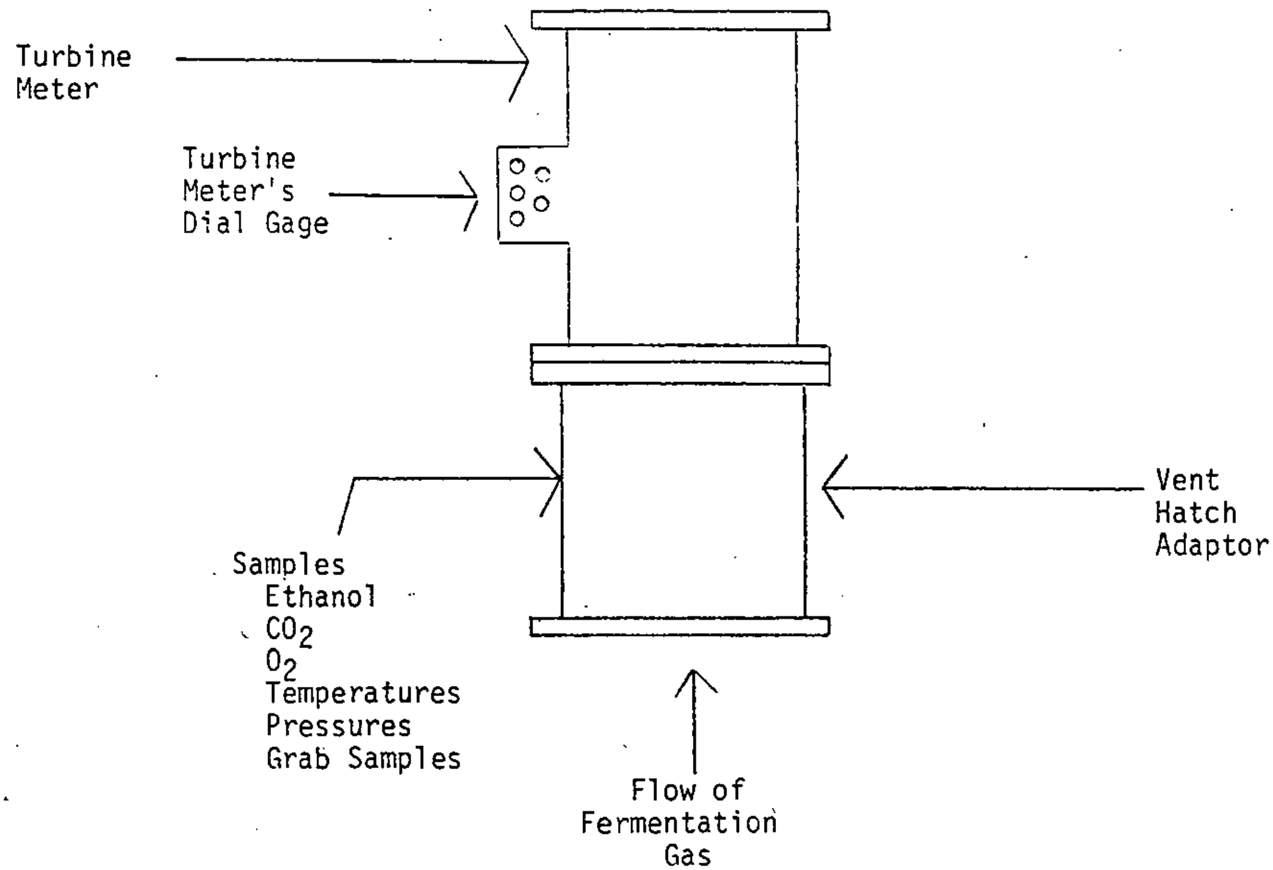


FIGURE 5

VENT HATCH ADAPTOR
&
TURBINE METER



V. DISCUSSION OF RESULTS

The fermentation of 90,000 gallons of St. Emillion grape juice took 216.5 hours, starting on October 13, 1980 at 7:30 a.m. and ending on October 22, 1980 at 8:00 a.m. The fermentation process was initiated by the inoculation of the grape juice with yeast. The degrees Brix measured with a hygrometer at the time of inoculation was 20.5. The Brix scale is a measure of the concentration of sugar in solution as grams of sucrose per 100 grams of liquid. Two methods are typically used for making this determination: the hygrometer procedure and the refractometer procedure. The methodology involved with both procedures is presented in Appendix II. The fermentation was judged to be complete by United Vintner's winemaker when the degrees Brix was reduced to 2.

The ARB evaluation test began on October 15 at 5:00 p.m., 57.5 hours after the inoculum was introduced into the tanks. The duration of the evaluation test was 159 hours, representing data collection for 73 percent of the fermentation process. During the test period, the following parameters were monitored: CO_2, O_2, and ethanol concentrations in the exhaust gas; ambient and exhaust gas temperatures; exhaust gas volumetric flow rate.

The exhaust gas was predominantely composed of carbon dioxide and ethanol, with trace amounts of hydrogen sulfide, sulfur dioxide and mercaptans. As expected from an anerobic process, measurable amounts of oxygen were not present. Table II lists the exhaust gas components in descending order with respect to their measured concentrations averaged over the test period.

TABLE II

FERMENTATION TANK EXHAUST GAS COMPONENTS

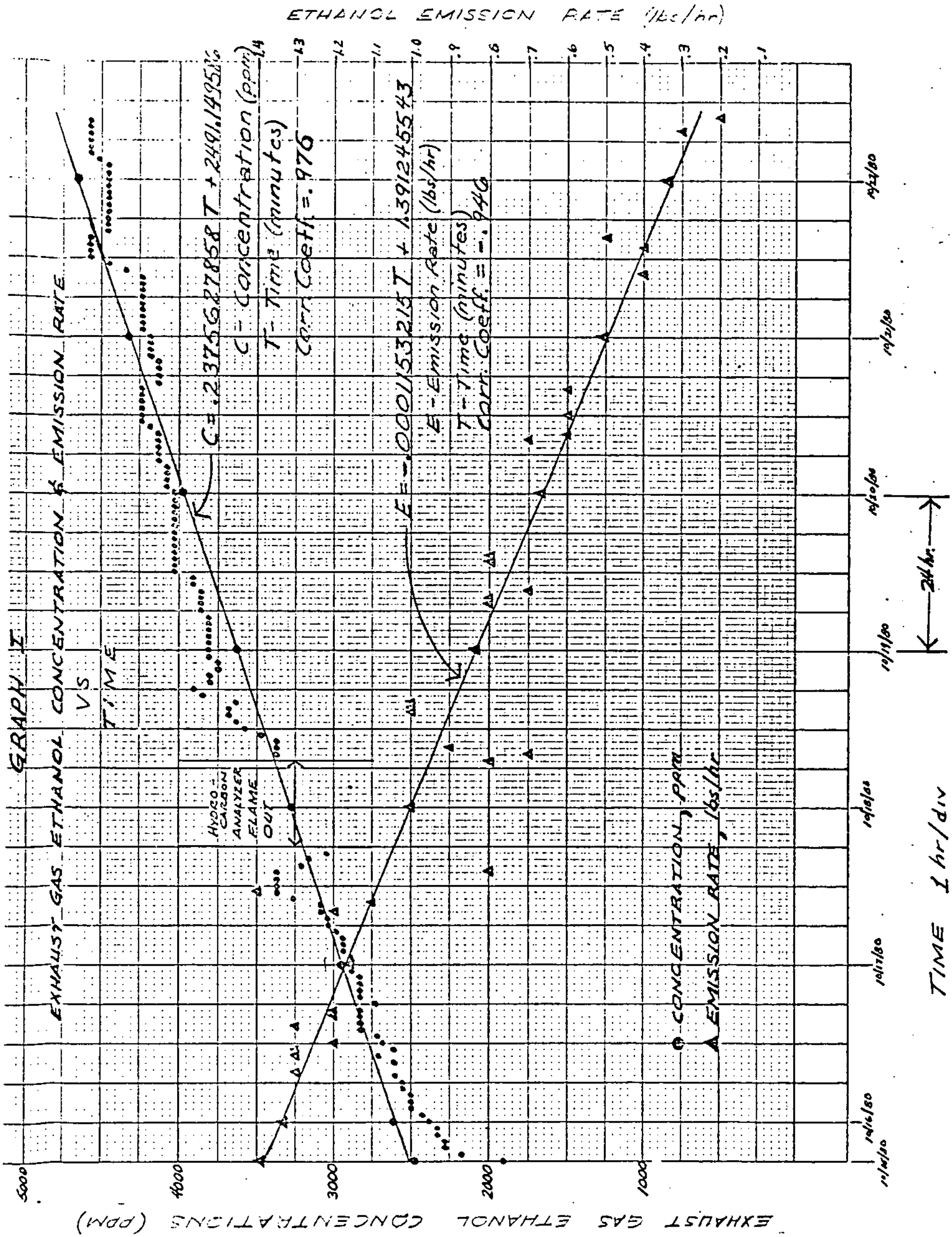
Exhaust Gas Component	Concentration
CO_2	99.6%
C_2H_5OH	0.4%
H_2S	1.1 ppm
SO_2	< .2 ppm
CH_3SH	< .006 ppm

Analysis of the exhaust gas by continuous analyzers showed ethanol concentrations to increase steadily with respect to time while CO_2 remained constant. The ethanol concentration increased from 1,902 parts per million at the beginning of the test to 4,565 ppm at the end of the test. The end of the ARB's evaluation test coincided with the completion of the fermentation process. The average ethanol concentration over the 159 hour test period was approximately 3,640 ppm. Measured values of CO_2 concentration remained at over 99 percent throughout the test period while, in contrast, no oxygen was detected.

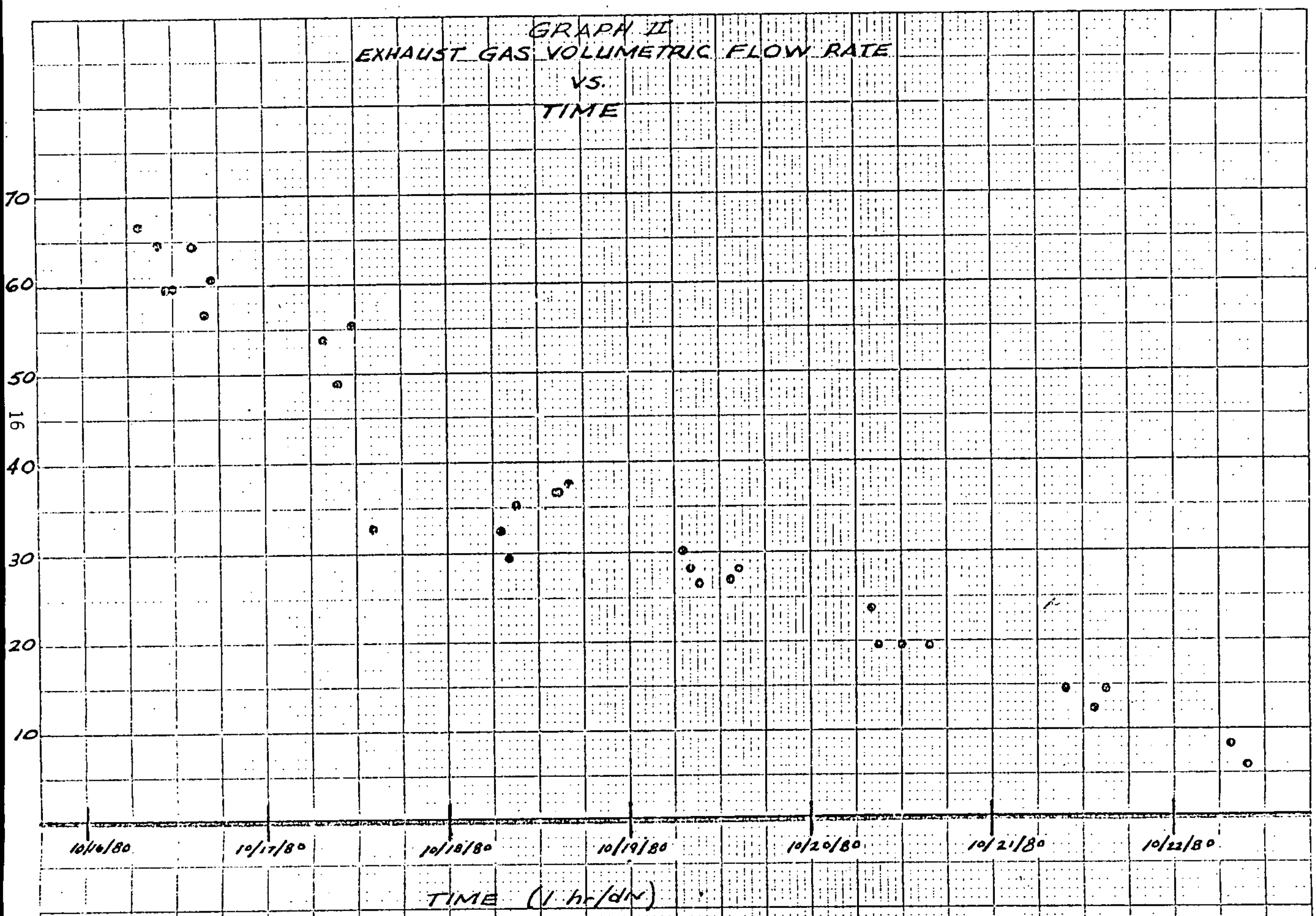
Based on an averaged ethanol concentration value of 3,640 ppm and a total measured exhaust gas volume of 310,060 ft^3, the estimated mass of ethanol emitted to atmosphere during the fermentation process was 137 pounds (lbs) in 159 hours. This corresponds to a mass emission rate of approximately 0.86 lbs/hr. Alternatively, when expressed in terms of gallons of wine juice fermented, the emission rate is approximately 1.52 lbs/10^3 gal. This compared closely with an ethanol emission factor of 1.45 lbs/10^3 gal. calculated per an equation cited in the Environmental Protection Agencies' publication entitled, "Compilation of Air Pollutant Emission Factors", commonly referred to as AP-42. The calculation and AP-42 equation are presented in Appendix III.

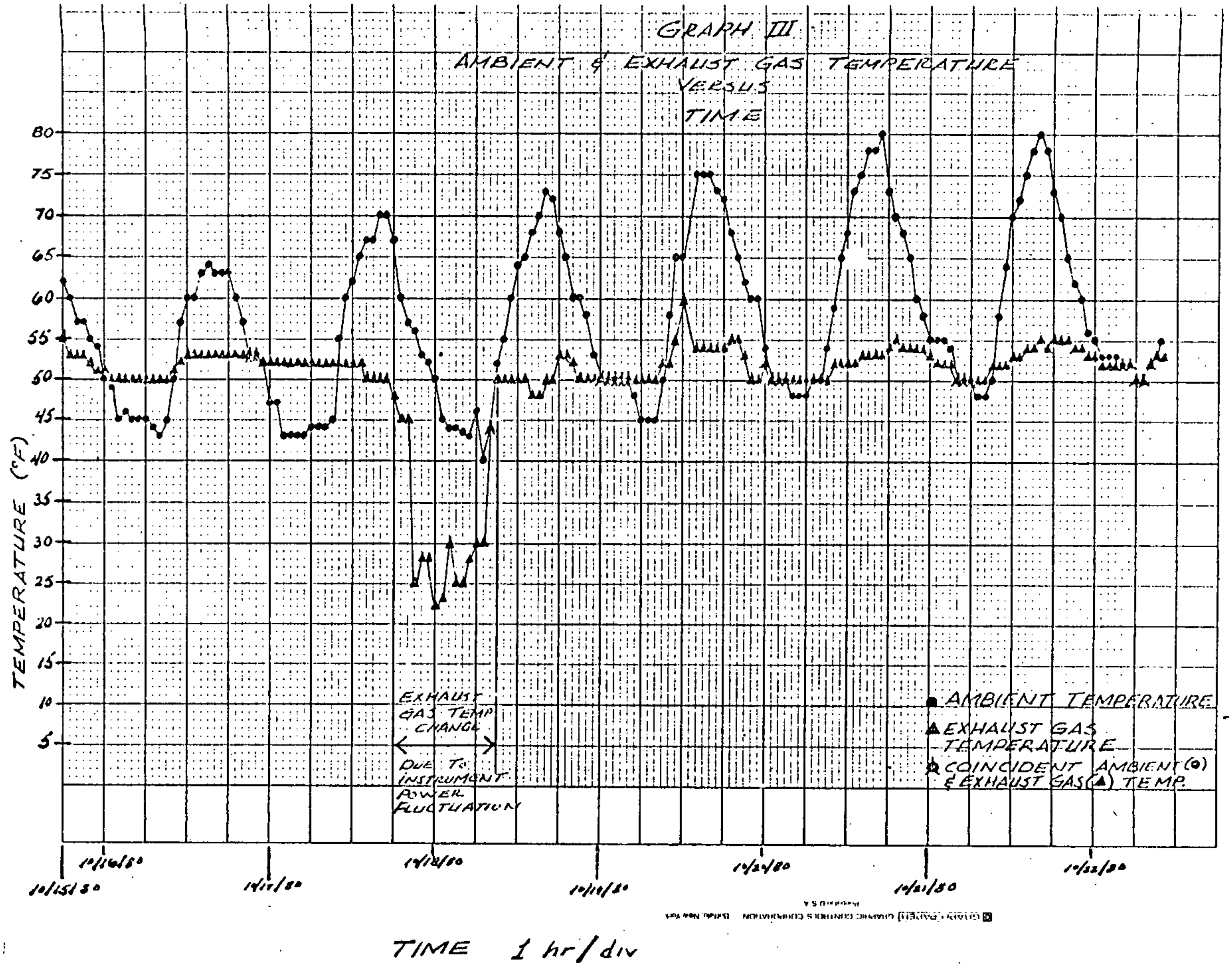
A composite plot of ethanol concentration and emission rate versus time is presented in Graph I. As previously mentioned, exhaust gas ethanol concentrations steadily increased during the test. Correspondingly, ethanol emission rates were decreasing. The diminishing emission rates were attributed to the dominance of declining exhaust gas volumetric flow over increasing concentrations as the fermentation process approached completion. Graph II illustrates the change in flow rates with respect to time.

Ambient and exhaust gas temperatures are plotted on Graph III. Ambient temperatures varied diurnally while the exhaust gas temperatures remained relatively constant. Exhaust gas temperatures reflected the constant tank temperatures to which the fermenting must was subjected.



GRAPH I
EXHAUST GAS ETHANOL CONCENTRATION & EMISSION RATE
VS
TIME
ETHANOL EMISSION RATE (lbs/hr)
EXHAUST GAS ETHANOL CONCENTRATIONS (PPM)
C = .2375627858 T + 2491.14958
C - Concentration (ppm)
T - Time (minutes)
Corr. Coeff. = .976
E = -.000153215 T + 1.391245543
E - Emission Rate (lbs/hr)
T - Time (minutes)
Corr. Coeff. = -.946
HYDRO-CARBON ANALYZER FLAME OUT
CONCENTRATION, PPM
EMISSION RATE, lbs/hr
24 hr.
TIME 1 hr/div


GRAPH II
EXHAUST GAS VOLUMETRIC FLOW RATE
VS.
TIME
70
60
50
40
30
20
10
10/16/80
10/17/80
10/18/80
10/19/80
10/20/80
10/21/80
10/22/80
TIME (1 hr/div)


GRAPH III
AMBIENT & EXHAUST GAS TEMPERATURE
VERSUS
TIME
TEMPERATURE (°F)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
EXHAUST GAS TEMP CHANGE
DUE TO INSTRUMENT POWER FLUCTUATION
AMBIENT TEMPERATURE
EXHAUST GAS TEMPERATURE
COINCIDENT AMBIENT (●) & EXHAUST GAS (▲) TEMP.
10/15/80
10/16/80
10/17/80
10/18/80
10/19/80
10/20/80
10/21/80
10/22/80
TIME 1 hr/div

The abrupt change in exhaust gas temperatures from 50°F to approximately 28°F on October 10 was due to suspected fluctuation in the power source that affected the temperature, recorder as well as the continuous analyzers.

APPENDIX I

DATA SHEETS

TURBINE METER READINGS

"UNITED VINTNERS INC
2916 REED AVENUE
P.O. BOX 709
REEDLEY, CA. 93654
(209) 638-3511

DATE	TIME	TURBINE METER	VAPOR TEMP (°F)	AMBIENT TEMP (°F) DRY WET	BARO. PRESS (in Hg)	PITOT PRESS in H_2O
10/15	1700	00916900				
10/16	0730	00974900				
	1000	00984590		61 53		
	1100	00988170		61 53	29.61	
	1200	00991760				
	[illegible]	01001390	54		[illegible]	[illegible]
	[illegible]	[illegible]500	[illegible]		29.57	[illegible]
	1700	01010130	54	64 54	29.57	.005
10/17	0740	01057420	54	59 —	29.72	
	0830	01062800	54	62 52	29.75	[illegible] INOP
	[illegible]5	01068720	54		29.76	
	1400	01074100	54	69 58	29.72	
		[illegible]7000	54	70 58	29.71	
10/18	0700	01106950	56 [illegible]	48 46	29.83	
	0900	01108710	[illegible]		29.84	
	[illegible]	01110820	[illegible]		[illegible]	
	1450	01122960	5[illegible]	67 62	29.78	
	1500	01124040		67 62	29.77	
	1600	01126300			29.77	
[illegible]	[illegible]	[illegible]	[illegible]		29.78	
	08[illegible]	0115[illegible]	[illegible]	50 46	29.79	
	[illegible]	01156640			29.80	
	[illegible]	01157910	55	[illegible]	29.7[illegible]	
	[illegible]	[illegible]600	55		[illegible]	

UNITED VINTNERS INC
2916 S. REED AVE.
P.O. BOX 709
REEDLEY, CA. 93654
(209) 638-3511

DATE	TIME	TURBINE METER	VAPOR TEMP (°F)	AMBIENT TEMP (°F) DRY WET	BARO PRESS (in Hg)	PITOT PRESS (in H_2O)
[illegible]	[illegible]	01190120	[illegible]		29.77?	
	0900	01191300			29.78	
	1200	011948[illegible]	[illegible]		[illegible]	
		01199200			[illegible]	
[illegible]	0030?	01214110	[illegible]		29.71	
	1330?	01217000?	55		29.65?	
	1700	01218290	55		29.60	
[illegible]	[illegible]	[illegible]26350	55		29.63	
	[illegible]	01226960	55		29.65	

APPENDIX II

SUMMARY OF DATA

&

CALCULATIONS

EXHAUST GAS CONCENTRATIONS

C-80-071

1/6

FERMENTATION TANK

CONTINUOUS THC, CO_2, & O_2

correct factor 2.17

DATE	CLOCK TIME		MINUTES	THC CONC (ppm)	THC CORRECT (ppm)	CLOCK TIME		MINUTES	CO_2 (%)	CO_2 CORRECT (%)	O_2 (%)	
12/15/80	1700	1800	60	875	1902	1700	1715	15			0	
	1800	1900	60	1000	2174	1715	1721	6	Flow off	Flow off	Flow off	comp uter ck.
	1900	2000	60	1050	2283	1721	1800	39		~49	0.	
	2000	2100	60	1050	2283	1800	1900	60			0	
	2100	2200	60	1075	2337	1900	2000	60			0 drift	
	2200	2300	60	1075	2337	2000	2100	60			0 zd	
	2300	2400	60	1100	2391	2100	2400	180			0 zd	
12/16/80	0000	0100	60	1113	2420	0000	0100	60			0 zd	
	0100	0200	60	1150	2500							
	0200	0300	60	1150	2500							
	0300	0400	60	1150	2500							
	0400	0500	60	1175	2554							
	0500	0600	60	1175	2554							
	0600	0700	60	1200	2609							
	0700	0800	60	—	—							
	0800	0900	60	1200	2609							
	0900	0924	24	1225	2663							
	0924	0939	15	SPAN CHECK	—							
	0939	1000	21	1250	2717							
	1000	1100	60	1200	2609							
	1100	1200	60	1238	2691							
	1200	1215	15	BLOW DOWN	—							
	1215	1300	45	1250	2717							
	1300	1400	60	1300	2826							
	1400	1500	60	1300	2826							
	1500	1600	60	1300	2826							
	1600	1639	39	1300	2826							
	1639	1700	21	SPAN & BLOW DOWN	—							
	1700	1800	60	1250	2717							

FERMENTATION TANK

CONTINUOUS THC, CO_2 & O_2

correct. factor 2.17

Date	Clock Time		Minutes	THC (ppm)	THC Correct (ppm)
	1900	2000	60	1300	2820
	2000	2100	60	1300	2820
	2100	2200	60	1300	2820
	2200	2300	60	1325	2880
	2300	2400	60	1325	2880
10/17/80	0000	0100	60	1325	2880
	0100	0200	60	1350	2935
	0200	0300	60	1350	2935
	0300	0400	60	1350	2935
	0400	0500	60	1375	2989
	0500	0600	60	1400	3043
	0600	0700	60	1400	3043
	0700	0730	30	1425	3098
	0730	0800	30	Z-S CHECK & BLOW DOWN	—
	0800	0900	60	1425	3098
	0900	1000	60	1500	3261
	1000	1100	60	1550	3370
	1100	1200	60	1550	3370
	1200	1300	60	1550	3370
	1300	1400	60	1550	3370
	1400	1424	24	1500	3261
	1424	1430	6	SPAN ZERO	—
	1430	1500	30	1475	3207
	1500	1533	33	1450	3152
	1533	1600	27	S & Z BLOW DOWN	—
	1600	1657	57	1400	3043
	1657	2400	423	FLAME OUT	—
10/18/80	0000	0703	423	FLAME OUT	—
	0703	0736	33	S & Z, LIGHT UP BLOW DN	—

Clock Time		Minutes	CO_2 (%)	CO_2 Correct (%)	O_2 (%)
			[illegible]	[illegible]	[illegible]

FERMENTATION TANK

CONTINUOUS THC, CO_2 & O_2

3/6

correct. factor 2.17

DATE	CLOCK TIME		MINUTES	THC (ppm)	THC Correct (PPM)
	0800	0900	60	1550	3370
	0900	1000	60	1550	3370
	1000	1100	60	1600	3475
	1100	1200	60	1650	3587
	1200	1300	60	1675	3641
	1300	1400	60	1700	3696
	1400	1418	18	1725	3750
	1418	1424	6	ZERO SPAN	—
	1424	1500	36	1700	3696
	1500	1533	33	1750	3804
	1533	1545	12	SPAN ZERO BLOW DN	—
	1545	1600	15	1675	3641
	1600	1700	60	1775	3859
	1700	1800	60	1800	3913
	1800	1900	60	1750	3804
	1900	2000	60	1750	3804
	2000	2100	60	1725	3750
	2100	2200	60	1725	3750
	2200	2300	60	1750	3804
	2300	2400	60	1750	3804
11/15/80	0000	0100	60	1750	3804
	0100	0200	60	1750	3804
	0200	0300	60	1750	3804
	0300	0400	60	1750	3804
	0400	0500	60	1750	3804
	0500	0600	60	1775	3859
	0600	0700	60	1775	3859
	0700	0724	24	SPAN ZERO BLOW DN	—
	0724	0748	24	OUTPUT "DITHER"	—
	[illegible]	[illegible]	[illegible]	Trouble	

CLOCK TIME		MINUTES	CO_2 (%)	CO_2 Correct (%)	O_2 (%)
				??	

FERMENTATION TANK

CONTINUOUS THC, CO_2 & O_2

4/6

DATE	CLOCK TIME		MINUTES	THC (PPM)	THC CORRECT (PPM)
	0806	0900	54	1775	3357
	0900	1000	60	1800	3913
	1000	1100	60	1800	3913
	1100	1200	60	1850	4022
	1200	1300	60	1850	4022
	1300	1333	33	1850	4022
	1333	1345	12	SPAN ZERO	—
	1345	1400	15	1850	4022
	1400	1418	18	1850	4022
	1418	1424	6	BLOW DOWN	—
	1424	1500	36	1850	4022
	1500	1600	60	1850	4022
	1600	1700	60	1850	4022
	1700	1800	60	1850	4022
	1800	1900	60	1850	4022
	1900	2000	60	1850	4022
	2000	2100	60	1850	4022
	2100	2200	60	1850	4022
	2200	2300	60	1850	4022
	2300	2400	60	1850	4022
11/20/80	0000	0100	60	1875	4076
	0100	0200	60	1875	4076
	0200	0300	60	1875	4076
	0300	0400	60	1875	4076
	0400	0500	60	1900	4133
	0500	0600	60	1900	4133
	0600	0700	60	1900	4133
	0700	0800	60	1900	4133
	0800	0803	3	1900	4133
	[illegible]	[illegible]	[illegible]	SPAN ZERO	—

CLOCK TIME		MINUTES	CO_2 (%)	CO_2 CORRECT (%)	O_2 (%)
				79	0

FERMENTATION TANK

CONTINUOUS THC, CO_2 & O_2

5/6

DATE	CLOCK TIME		MINUTES	THC (PPM)	THC CORRECT. (PPM)
	0830	0900	30	1900	4130
	0900	1000	60	1925	4185
	1000	1100	60	1950	4239
	1100	1200	60	1950	4239
	1200	1300	60	1950	4239
	1300	1400	60	1950	4239
	1400	1500	60	1950	4239
	1500	1527	27	1950	4239
	1527	1551	24	SPAN ZERO BLOWDN	—
	1551	1600	9	1900	4130
	1600	1700	60	1900	4130
	1700	1800	60	1900	4130
	1800	1900	60	1900	4130
	1900	2000	60	1900	4130
	2000	2100	60	1925	4185
	2100	2200	60	1925	4185
	2200	2300	60	1925	4185
	2300	2400	60	1925	4185
10/21/80	0000	0100	60	1950	4239
	0100	0200	60	1950	4239
	0200	0300	60	1950	4239
	0300	0400	60	1950	4239
	0400	0500	60	1950	4239
	0500	0600	60	1950	4239
	0600	0700	60	1950	4239
	0700	0800	60	1950	4239
	0800	0900	60	1950	4239
	0900	0927	27	1950	4239
	0927	0945	18	SPAN ZERO	—
	0945	1000	15	2000	[illegible]

CLOCK TIME		MINUTES	CO_2 (%)	CO_2 CORRECT (%)	O_2 (%)

FERMENTATION TANK

CONTINUOUS THC, CO_2 & O_2

6/6

DATE	CLOCK TIME		MINUTES	THC (ppm)	THC CORRECT (ppm)
	1000	1100	60	2050	4457
	1100	1200	60	2100	4565
	1200	1300	60	2100	4565
	1300	1400	60	2100	4565
	1400	1448	48	2100	4565
	1448	1506	18	SPAN ZERO BLOW DN	—
	1506	1600	54	2050	4457
	1600	1700	60	2050	4457
	1700	1800	60	2050	4457
	1800	1900	60	2050	4457
	1900	2000	60	2050	4457
	2000	2100	60	2050	4457
	2100	2200	60	2050	4457
	2200	2300	60	2050	4457
	2300	2400	60	2050	4457
10/22/80	0000	0100	60	2050	4457
	0100	0200	60	2050	4457
	0200	0300	60	2075	4511
	0300	0400	60	2100	4565
	0400	0500	60	2100	4565
	0500	0600	60	2100	4565
	0600	0700	60	2100	4565
	0700	0800	60	2100	4565
	0800	0900	60	2100	4565
	0900	0930	30	SPAN ZERO BLOW DN.	—

CLOCK TIME		MINUTES	CO_2 (%)	CO_2 (corr) (%)	O_2 (%)

VOLUMETRIC FLOW

FERMENTATION TANK
[illegible] Flow

1/2

DATE	CLOCK TIME		MINUTE	Volume (ft)^3	Flow Rate ft^3/min	
10/15/80	1700					
10/16/80		0730	870	58000	66.67	
	0730	1000	150	9690	64.60	
	1000	1100	60	3580	59.67	
	1100	1200	60	3590	59.83	
	1200	1430	150	9630	64.20	
	1430	1600	90	5110	56.78	
	1600	1700	60	3630	60.50	
10/16/80	1700					
10/17/80		0740	880	47290	53.74	
	0740	0930	110	5380	48.91	
	0930	1115	105	5920	56.38	
	1115	1400	165	5380	32.61	
10/17/80	1400					
10/18/80		0700	1020	32850	32.21	
	0700	0800	60	1760	29.33	
	0800	0900	60	2110	35.17	
	0900	1430	330	12140	36.79	
	1430	1500	30	1080	36.00	
	1500	1600	60	2260	37.67	
10/18/80	1600					
10/19/80		0700	900	27090	30.1	
	0700	0800	60	1680	28.00	
	0800	0900	60	1570	26.17	
	0900	1330	270	7270	26.93	
	1330	1430	60	1680	28.00	
10/19/80	1430					
10/20/80		0800	1050	24530	23.36	

FERMENTATION TANK

Volumetric Flow

Date	Clock Time		Minutes	Volume (ft)³	Flow Rate ft³/min
	0900	1200	180	3500	19.44
	1200	1545	225	4400	19.56
11/20/80	1545				
11/21/80		0930	1035	14910	14.41
	0930	1330	240	2890	12.04
	1330	1500	90	1290	14.33
11/21/80	1500				
11/22/80		0745	1005	8060	8.02
	0745	0930	105	610	5.81

AMBIENT & EXHAUST GAS TEMPERATURES

FERMENTATION TANK

TEMP - Ambient & Exhaust Gas

1 hr Avg

Date	Clock Time		Minutes	Amb. Temp (°F)	Exh Gas Temp (°F)
	0220	0300	40	45	25
	0300	0330	30	45	52
	0330	0400	30	42	25
	0400	0410	10	42	25
	0410	0500	60	44	26
	0500	0600	60	46	30
	0600	0700	60	40	30
	0700	0800	60	44	44
	0800	0830	30	READJUST STRIP	CHART PAPER
	0830	0900	30	52	50
	0900	1000	60	55	50
	1000	1100	60	60	50
	1100	1200	60	64	50
	1200	1300	60	65	50
	1300	1400	60	68	48
	1400	1500	60	70	48
	1500	1600	60	73	50
	1600	1700	60	72	50
	1700	1800	60	68	53
	1800	1900	60	65	53
	1900	2000	60	60	52
	2000	2100	60	60	50
	2100	2200	60	58	50
	2200	2300	60	53	50
	2300	2400	60	50	50
10/19/80	0000	0100	60	50	50
	0100	0200	60	50	50
	0200	0300	60	50	50
	0300	0400	60	50	50
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Date	Clock Time		Minutes	Amb. Temp (°F)	Exh. Gas Temp. (°F)
	0500	0600	60	45	50
	0600	0700	60	45	50
	0700	0800	60	45	50
	0800	0900	60	50	52
	0900	1000	60	58	52
	1000	1100	60	65	55
	1100	1200	60	65	60
	1200	1330	90	Paper Jam in Roller	Repair
	1330	1400	30	75	54
	1400	1500	60	75	54
	1500	1600	60	75	54
	1600	1700	60	73	54
	1700	1800	60	72	54
	1800	1900	60	68	55
	1900	2000	60	65	55
	2000	2100	60	62	53
	2100	2200	60	60	50
	2200	2300	60	60	50
	2300	2400	60	54	52
10/20/80	0000	0100	60	50	50
	0100	0200	60	50	50
	0200	0300	60	50	50
	0300	0400	60	48	50
	0400	0500	60	48	50
	0500	0600	60	48	50
	0600	0700	60	50	50
	0700	0800	60	50	50
	0800	0900	60	54	50
	0900	1000	60	59	52
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

LIUC - [illegible]
red - [illegible] Temp.

1/3

FERMENTATION TANK

TEMP. - Ambient & Exhaust Gas

1-hr. Avg

Date	Clock Time		Minutes	Amb. Temp (°F)	Exh. Gas Temp (°F)
11/13/80	1700	1800	60	62	55
	1800	1900	60	60	53
	1900	2000	60	57	53
	2000	2100	60	57	53
	2100	2200	60	55	52
	2200	2300	60	54	51
	2300	2400	60	50	51
11/14/80	0000	0100	60	49	50
	0100	0200	60	45	50
	0200	0300	60	46	50
	0300	0400	60	45	50
	0400	0500	60	45	50
	0500	0600	60	45	50
	0600	0700	60	44	50
	0700	0800	60	43	50
	0800	0900	60	45	50
	0900	1000	60	50	51
	1000	1100	60	57	52
	1100	1200	60	60	53
	1200	1300	60	60	53
	1300	1400	60	63	53
	1400	1500	60	64	53
	1500	1600	60	63	53
	1600	1700	60	63	53
	1700	1800	60	63	53
	1800	1900	60	60	53
	1900	2000	60	57	53
	2000	2100	60	53	53
	2100	2200	60	53	53
	[illegible]	[illegible]	60	[illegible]	[illegible]

Date	Clock Time		Minutes	Amb. Temp (°F)	Exh. Gas Temp (°F)
	2300	2400	60	47	52
11/15/80	0000	0100	60	47	52
	0100	0200	60	43	52
	0200	0300	60	43	52
	0300	0400	60	43	52
	0400	0500	60	43	52
	0500	0600	60	44	52
	0600	0700	60	44	52
	0700	0800	60	44	52
	0800	0900	60	45	52
	0900	1000	60	55	52
	1000	1100	60	60	52
	1100	1200	60	62	52
	1200	1300	60	65	52
	1300	1400	60	67	50
	1400	1500	60	67	50
	1500	1600	60	70	50
	1600	1700	60	70	50
	1700	1800	60	67	48
	1800	1900	60	60	45
	1900	2000	60	57	45
	2000	2050	50	56	45
	2050	2100	10	53	25
	2100	2200	60	52	28
	2200	2300	60	50	28
	2300	2400	60	48	22
11/16/80	0000	0100	60	45	23
	0100	0120	20	45	23
	0120	0200	40	43	30
	0200	0220	20	43	30

FERMENTATION TANK
TEMP. – Ambient &
EXHAUST GAS

Date	Clock Time		Minutes	Amb. Temp. (°F)	Exh. Gas Temp. (°F)
	1100	1200	60	68	52
	1200	1300	60	73	52
	1300	1400	60	75	53
	1400	1500	60	78	53
	1500	1600	60	78	53
	1600	1700	60	80	53
	1700	1800	60	73	54
	1800	1900	60	70	55
	1900	2000	60	66	54
	2000	2100	60	65	54
	2100	2200	60	60	54
	2200	2300	60	58	54
	2300	2400	60	55	53
10/21/80	0000	0100	60	55	52
	0100	0200	60	55	52
	0200	0300	60	54	52
	0300	0400	60	50	50
	0400	0500	60	50	50
	0500	0600	60	50	50
	0600	0700	60	48	50
	0700	0800	60	48	50
	0800	0900	60	50	52
	0900	1000	60	58	52
	1000	1100	60	64	52
	1100	1200	60	70	53
	1200	1300	60	72	53
	1300	1400	60	75	54
	1400	1500	60	78	54
	1500	1600	60	80	55
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1700	1800	60	73	55
	1800	1900	60	70	55
	1900	2000	60	65	55
	2000	2100	60	62	54
	2100	2200	60	60	54
	2200	2300	60	56	53
	2300	2400	60	55	53
10/22/80	0000	0100	60	53	52
	0100	0200	60	53	52
	0200	0300	60	53	52
	0300	0400	60	52	52
	0400	0500	60	52	52
	0500	0600	60	50	50
	0600	0700	60	50	50
	0700	0800	60	52	52
	0800	0900	60	53	53
	0900	0930	30	55	53

CALCULATIONS BASED ON
ARB DATA

$V = 310060\ ft^3$

$T = 9600\ mins\ \frac{hr}{60\ mins}$

$= 160\ hrs$

3. Measurement in the exhaust gas:

$C = 3637.7\ ppm$

4. $m_{etoh} = \left(\frac{3637.7}{10^6}\frac{l}{l}\right)\left(\frac{mol}{23.7\ l}\right)\left(\frac{46\ gm}{mol}\right)\left(\frac{lbs}{454\ gm}\right)\left(\frac{28.32\ l}{ft^3}\right)(310060\ ft^3)$

$= 136.6\ lbs$ in $160\ hrs$

5. $\dot{m}_{etoh} = \frac{136.6\ lbs}{160\ hrs} = .853\ \frac{lbs}{hr}$

APPENDIX III

HYGROMETER AND REFRACTOMETER BRIX DETERMINATION

Soluble Solids Content

Of the total soluble solids dissolved in the must of ripe grapes the sugars constitute approximately 90 to 94 per cent. For this reason measuring the total soluble solids content gives a fairly good indication of the sugar content of the must and hence of the maturity of the grapes. However, if an accurate determination of the sugar content of the must is desired one of the chemical procedures recommended for wines should be used (p. 24). The non-sugar portion of the soluble solids consists of acids, salts, tannin, coloring materials, pectins, etc.

A knowledge of the soluble solids content of the must is useful as (1) a measure of the maturity of the grapes and hence as an indication of the proper time of harvesting, (2) a partial guide to the rational utilization of the grapes for producing the most appropriate type of wine, (3) an indication of the amount of amelioration needed by over- and under-ripe grapes, and (4) an approximate basis for calculating the alcohol yield.

The two most common procedures for determining the total soluble solids content of musts are: hydrometry and refractometry. A hydrometer is a floating instrument which indicates the specific gravity of the liquid in which it floats. Hydrometers are constructed in varying weights and sizes to float in liquids of different densities. The hydrometers commonly used in wineries in California are of the Brix (usually called Balling) type which are calibrated to indicate grams of sucrose per 100 grams of liquid. The refractive index of musts may also be used as a measure of the total soluble solids. Hand refractometers are often used but accurate laboratory models are required for exact work. Where a check on these two methods is desired a sample of the must may be weighed in a pycnometer of the specific gravity may be determined with a Westphal balance.

Equipment required: hydrometer procedure: hydrometer cylinder, hydrometer (for musts a Brix (of Balling) hydrometer in the range of about 10° to 24° with 0.1° subdivisions is recommended), thermometer; refractometer procedure: hand refractometer preferably calibrated in 0.2° subdivisions or Abbé laboratory refractometer.

Hydrometer procedure: Carefully pour a sample of the clear must into the hydrometer cylinder taking care to create as few bubbles in the liquid during pouring as possible. Then place the Brix hydrometer in the liquid and allow it to come to equilibrium. Make a reading by placing the eye at the level of the liquid surface and reading the hydrometer stem at the bottom of the meniscus. Determine the temperature of the must. Most of the hydrometers are calibrated at 68° F (20° C). To obtain the correct reading (since the temperature of the must will seldom be exactly 68°) refer to table 1. Should this table not be available the approximate correction is +0.033 for each degree Fahrenheit above the calibrated temperature of the hydrometer or +0.06 for each degree Centigrade, and -0.033 and -0.06 respectively for temperatures below the calibrated temperature. Hydrometers are available which have a thermometer enclosed in the bulb or stem and which include a correction scale opposite the enclosed thermometer. It is wise to check the calibration of hydrometers using pure sucrose solutions (grams of sucrose per 100 grams of liquid).

Although the hydrometer procedure is simple there are a number of precautions to be noted for accurate results. The equipment used must be clean. The hydrometer cylinder must be level and the hydrometer must float freely in it. Entrained air also leads to erroneous results. Since most hydrometers, even though calibrated to 0.1°, are accurate to only about +0.1° it is useless to report results past the first decimal place, even though the temperature correction may indicate an intermediate value.

Should a Brix (or Balling) hydrometer not be available an ordinary specific gravity hydrometer for liquids heavier than water may be used. To convert the specific gravity readings to degree Brix (Balling) refer to table 3. In several European countries the Baumé hydrometer is used. This hydrometer reads 0.0° for a density of 1.0 (0.0° Balling) and 16.34° for density of 1.127 (30° Brix). The degree Brix is thus, approximately, 1.8 times the degree Baumé. The Oechsle hydrometer, used in Germany and Austria, is a density hydrometer but omits the decimal point and the figures preceding it. A Oechsle reading of 80 therefore indicates a density of 1.080. To convert Oechsle readings to sugar content divide by 4 and subtract 3. Thus a Oechsle value of 80 = $\frac{80}{4}$ -3 or 17 per cent sugar. If 47 parts of alcohol are produced per 100 parts of sugar 17 per cent sugar will yield 17 x 0.47 or 7.99 per cent by weight of alcohol. Therefore, Oechsle degree x 0.1 gives the approximate alcohol in weight per cent. To convert to per cent by volume multiply by 1.26.

Refractometer procedure: The primary attraction of the refractometer method is its extreme simplicity. A drop of two of liquid is placed on the glass surface of the instrument and the soluble solids content, as grams per 100 gr., is read directly from the scale. The refractive index, however, changes rapidly with temperature and under field conditions large errors may be introduced by failure to take this temperature effect into account. Table 4 gives the corrections for readings made at temperatures other than 68° F. The best hand refreactometers have an attached thermometer. The chief precaution in the use of the refractometer lies in the validity of the sample used. Since only a drop or two of liquid is required some will crush too small a sample. The amount of grapes which must be crushed in the preparation of an adequate sample for the refractometer is no less than for the hydrometer. Furthermore, the sample must be thoroughly mixed. When using an Abbé or other laboratory refreactometer follow the directions supplied with the instrument.

APPENDIX IV

ETHANOL EMISSION FACTOR
CALCULATED FROM AP-42

AP 42

[illegible] Fermentation Temp [illegible]

$EF = [0.[illegible] T - 5.[illegible]] + [(K - [illegible])(T - [illegible])([illegible])] \pm C$

unaccounted [illegible] white wines

$= [0.[illegible](53°F) - 5.[illegible]] + [(61 - [illegible])(53 - 15.[illegible])([illegible])]$

$EF = 1.45 \frac{lbs}{10^3 gal}$

6.5.2 WINE MAKING

6.5.2.1 General[1-4]

Wine is made by the fermentation of the juice of certain fruits, chiefly grapes. The grapes are harvested when the sugar content is right for the desired product, generally around 20 percent sugar by weight. The industry term for grape sugar content is Degrees Brix, with 1 °Brix equal to 1 gram of sugar per 100 grams of juice.

The harvested grapes are stemmed and crushed, and the juice is extracted. Sulfurous acid, potassium metabisulfite or liquefied SO_2 is used to produce 50 to 200 mg of SO_2, which is added to inhibit the growth of undesirable bacteria and yeasts. For the making of a white wine, the skins and solids are removed from the juice before fermentation. For a red wine, the skins and solids, which color the wine, are left in the juice through the fermentation stage. The pulpy mixture of juice, skins and solids is called a "must".

White wine is generally fermented at about 52°F (11°C), and red wine at about 80°F (27°C). Fermentation takes a week to ten days for white wine and about two weeks for red. Fermentation is conducted in tanks ranging in size from several thousand gallons to larger than 500,000 gallons.

The sugar of the fruit juice is converted into ethanol by the reaction:

$$\underset{\text{(sugar)}}{C_6H_{12}O_6} \rightarrow \underset{\text{(ethanol)}}{2\ C_2H_5OH} + 2\ CO_2$$

This process takes place in the presence of a specially cultivated yeast. Theoretically, the yield of ethanol should be 51.1 percent by weight of the initial sugar. The actual yield is found to be around 47 percent. The remaining sugar is lost as alcohol or byproducts of complex chemical mechanisms, or it remains in the wine as the result of incomplete fermentation.

When fermentation is complete, the wine goes through a finishing process for clarification. Common clarification procedures are filtration, fining refrigeration, pasteurization and aging. The wine is then bottled, corked or capped, labeled and cased. The finer red and white table wines are aged in the bottle.

6.5.2.2 Emissions and Controls[1,2]

Large amounts of CO_2 gas are liberated by the fermentation process. The gas is passed into the atmosphere through a vent in the top of the tank. Ethanol losses occur chiefly as a result of entrainment in the

CO_2. Factors which affect the amount of ethanol lost during fermentation are temperature of fermentation, initial sugar content, and whether a juice or a must is being fermented (i.e., a white or red wine being made).

Emission factors for wine making are given in Table 6.5.2-1. These emission factors are for juice fermentation (white wine) with an initial sugar content of 20 °Brix. Emission factors are given for two temperatures commonly used for fermentation.

Table 6.5.2-1. ETHANOL EMISSION FACTORS FOR UNCONTROLLED WINE FERMENTATION

EMISSION FACTOR RATING: B

Fermentation temperature	Ethanol Emissions[a,b] lb/10³ gal fermented	g/kl fermented
52°F (11.1°C)[c]	1.06	127.03
80°F (26.7°C)[c,d]	4.79	574.04
Other conditions	e	e

[a]Due primarily to entrainment in CO_2, not evaporation. H_2S, mercaptans and other componments may be emitted in limited quantities, but no test or other information is available.
[b]C_2H_5OH lost in production.
[c]References 1 and 2. For white wine with initial 20° Brix.
[d]For red wine, add correction term for must fermentation (2.4 lb/10^3 gal or 287.62 g/kl).
[e]See Equation 1.

Emission factors for wines produced under other conditions can be approximated with the following equation:

$$EF = [0.136T - 5.91] + [(B - 20.4)(T - 15.21)(0.00685)] + [C] \quad (1)$$

where: EF = emission factor, pounds of ethanol lost per thousand gallons of wine made

T = fermentation temperature, °F

B = initial sugar content, °Brix

C = correction term, 0 (zero) for white wine or 2.4 lb/10^3 gal for red wine

Although no testing has been done on emissions from wine fermentation without grapes, it is expected that ethanol is also emitted from these operations.

There is potential alcohol loss at various working and storage stages in the production process. Also, fugitive alcohol emissions could occur from disposal of fermentation solids. Ethanol is considered to be a reactive precursor of photochemical oxidants (ozone). Emissions would be highest during the middle of the fermentation season and would taper off towards the end. Since wine facilities are concentrated in certain areas, these areas would be more affected.

Currently, the wine industry uses no means to control the ethanol lost during fermentation.

References for Section 6.5.2

1. Source Test Report and Evaluation on Emissions from a Fermentation Tank at E. & J. Gallo Winery, C-8-050, California Air Resources Board, Sacramento, CA, October 31, 1978.

2. H. W. Zimmerman, et al., "Alcohol Losses from Entrainment in Carbon Dioxide Evolved during Fermentation", American Journal of Enology, 15:63-68, 1964.

3. R. N. Shreve, Chemical Process Industries, 3rd Ed., McGraw-Hill Book Company, New York, 1967, pp. 591-608.

4. M. A. Amerine, "Wine", Kirk-Othmer Encyclopedia of Chemical Technology, Volume 22, John Wiley and Sons, Inc., New York, 1970, pp. 307-334.