

ERRATA SHEET

EXECUTIVE SUMMARY

CHARACTERIZATION OF ETHANOL EMISSIONS FROM WINERIES

Submitted to:

Research Division
California Air Resources Board

on

July 19, 1982

By:

EAL Corporation

Principal Investigators:

Mr. David R. Fielder (Technical Services Manager)
Mr. Philip A. Bumala (Air Program Manager)

Reference:

Mr. Joseph A. Pantalone (Contract Officer)
California Air Resources Board Agreement
No. A0-071-31

EAL Work Order No. 64-6003

<u>Page</u>	<u>Item</u>	<u>Comments/Corrections</u>
12	Table 14	Figure 8 in the main text is the reference for sample locations 1, 2, 5 and 6.
14	Figure 13	All data contained in Figure 13, excluding EAL data was taken directly from California Air Resources Board Report No. C-8-050, Oct. 31, 1978, Section IIB, Figure I, Table I.
15	AP., Supplement 10 Emission Factor Equation	should read: $EF = (0.136T - 5.91) + [(B-20.4)(T-15.21) \\ (0.00085) + C]$
15	solids handling process	<u>Definition:</u> the separation of grape skins and seeds from the fermenting must resulting in the free run juice.
19	nozzels	correct spelling: nozzles
17	Example, stoichiometric calculated cumulative ETOH emissions vs. measured emissions	The calculation began with an initial juice sugar content of 20°Brix (20 grams sugar/100 mls juice). When in reality, 23°Brix could have been more representative. Recalculating the example starting with 23°Brix and ending at 3°Brix results in a value of 769 total cumulative lbs. ETOH emitted vs. 714 lbs. measured. Agreement is within 8% and the lower measured value could be due to draining of the fermentation tank before additional ethanol losses would have occurred.

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Introduction

Wine industry ethanol emission factors have been determined with emphasis on the fermentation process and fugitive emissions. Information has been gained from winery surveys, an extensive literature search, and actual source testing of fermentation exhaust streams and suspected fugitive emission sources. The ethanol emission quantities have been generated for a variety of California wine production in terms of climate/temperature zones, extent of production, and technological state of the art.

Review of Problem

The California Air Resources Board has determined that ethanol emissions from winery production and storage processes may significantly contribute to the formation of ozone through photochemical smog reactions. The primary source of these emissions is ethanol entrainment by carbon dioxide during the fermentation process. However, emissions will occur from any other process or situation where wine is exposed to the air, such as in transferring or racking, blending, and storage utilizing porous materials. Factors affecting the degree of ethanol emissions include fermenting parameters, process equipment design, and handling techniques and temperatures.

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STUDY APPROACH

The project objectives were:

- To perform an ethanol survey of selected wineries and blending and storage facilities.
- To determine the effect on ethanol emission rate and amount of the type of wine being produced, the type of yeast utilized, fermentation time and temperature, and the fermenting equipment design.
- To perform source and fugitive emission tests at selected wine industry facilities to obtain actual emission data per ton of fermentation feed stock and per unit of fermentation time.
- To determine the ethanol emissions from storage involving porous materials, and handling operations including transfer, blending and bottling.
- To review and discuss potentially applicable control technology for the reduction of ethanol emissions from industry processes.

In order to meet these objectives, a technical plan was followed beginning with consultation with experts in the wine industry. The exchange of information greatly assisted the subsequent literature search. The literature search formed the basis from which a winery survey was conducted. Detailed inspections of facilities and a continued dialogue with winemakers and plant managers eventually led to decisions on sampling locations.

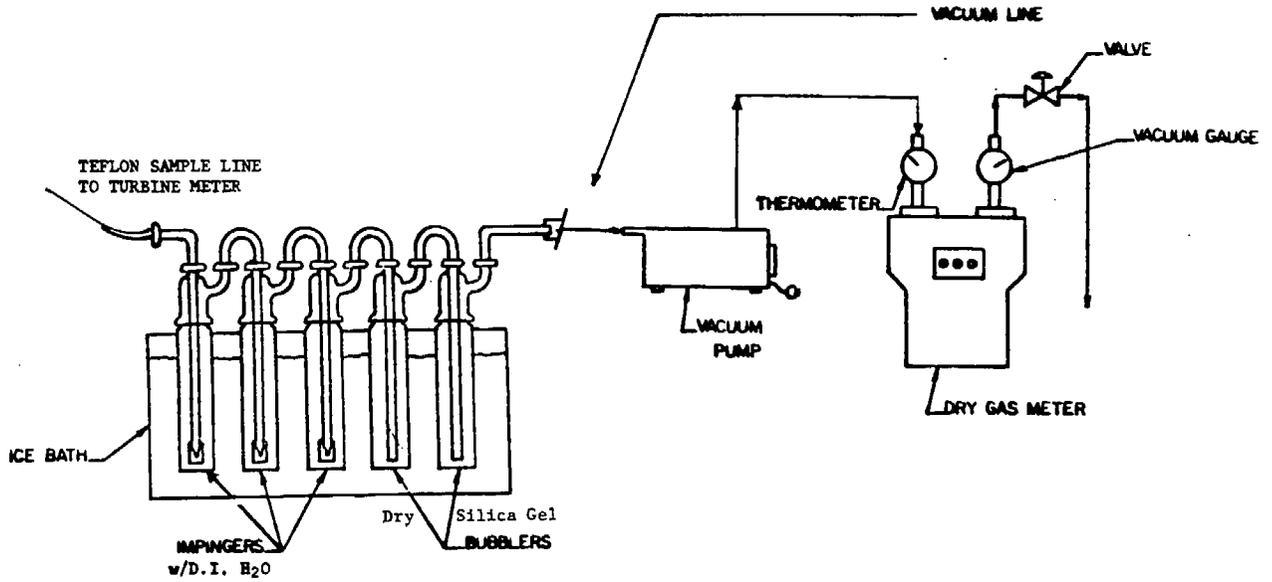
METHODS

Sample Collection

An extraction method was employed in which a known volume of gas, withdrawn from the fermentation exhaust stream, was bubbled through a series of three large Greenburg-Smith impingers. The first two impinger collections were separated from the third in order to verify an acceptable collection efficiency. A sample interface and all connections were made of glass and teflon. A thorough leak-check of the collection train was performed prior to each test at a 10" Hg vacuum for sixty seconds with a maximum tolerance of 0.02 ft³ of volume change. The sampling rate (cubic feet/min, cfm) test duration and dry gas meter conditions were carefully monitored (Ref. Figure 1). All the procedural items considered, the collection method had the advantage of simplicity, proximity to the source (minimizing ethanol wall losses and chances of leaks with a long sample line), and virtually no problem with entrained moisture.

FIGURE 1

ETHANOL GAS SAMPLING TRAIN



SAMPLE COLLECTION FIELD DATA

Date: _____		Analyte: _____					
Client: _____		Collection Medium: _____					
Location: _____		Ambient Temp.: _____					
Process Operation: _____		Ambient Pressure: _____					
Collected By: _____							
Run Number	Time	Sample Volume	Temp. Met.	Pressure Met.	Sampling Rate	Duration (min.)	Comments

Ethanol Analysis

The determination of ethanol concentrations (ppm v/v (aq)) in the impinger collections was accomplished by gas chromatography. An aliquot was directly injected onto an FFAP column and ethanol was quantified with a flame ionization detector operating at a lower detection limit of 5 ppm by weight. This lower detection limit corresponds to a 0.4 ppm by volume concentration in the gaseous phase.

Fermentation Exhaust Volumetric Flow Rate

The fermentation exhaust flow rates for the red and white wine tanks were measured with a turbine meter (totalizer) provided by the California Air Resources Board (CARB). Hourly readings were taken throughout the duration of the fermentation periods.

Fugitive Emissions

Samples were collected for fugitive ethanol emissions using the same impinger train illustrated in Figure 1, omitting the sample line and locating the train in selected sites for area sampling.

Analytical procedures were identical to those mentioned for source sampling.

A number of process handling procedures were evaluated and ethanol fugitive emissions estimated based on building ventilation and production activity during testing.

Example of a Fermentation Tank Source Test

The following pages (6-9), are an example of EAL results from ethanol emissions testing of a complete fermentation period. Table and Figure numbers have been kept identical to those in the main report.

TABLE 2
PHYSICAL PARAMETERS
Tank #576
White Wine Fermentation

Tank Material: Stainless Steel

Fermentation Tank Dimensions

12 inch bottom cone

24 inch top cone

480 inch shell (height)

Gallons per inch = 711.4

Total tank capacity = 350,110 gallons

Actual capacity = 280,000 gallons

Temperature Control

Chiller temperature set point (°F) = 57 in/56 out

Fermentation Period

Beginning September 9, 1981 ... through September 16, 1981

Total Hours = 172

Total volumetric exhaust flow = 1,549,940 actual cubic feet @ turbine meter.

TABLE 3

White Wine Fermentation Exhaust Ethanol Emissions

Run	Time (Day/hrs)	Exhaust Flow (acfm)	Ethanol ppm-vol	Ethanol Emissions (lbs/hr)	Cumulative (lbs)	Run	Time (Day/hrs)	Exhaust Flow (acfm)	Ethanol ppm-vol	Ethanol Emissions (lbs/hr)	Cumulative (lbs)
1	1/0800	0.0	-- (1)	--	0	26	4/2009	243.7	3625	6.2	183.6
2	1/1123	0.0	27	0.0	0	27	4/2304	233.9	3882	6.3	205.6
3	1/1500	0.0	12	0.0	0	28	5/0200	225.9	3632	5.8	234.4
4	1/1730	0.0	36	0.0	0	29	5/0909	210.0	3582	5.3	255.5
5	1/2010	0.0	70	0.0	0	30	5/1030	223.2	3409	5.3	266.2
6	2/0019	0.0	152	0.0	0	31	5/1306	218.5	3886	5.9	283.9
7	2/0213	6.3	37 (1)	0.0	0	32	5/1600	223.8	3891	5.8	307.2
8	2/0800	44.5	735	0.2	0.2	33	5/2052	209.8	3891	5.7	327.0
9	2/1000	61.2	563	0.2	0.8	34	5/2300	208.6	3775	5.5	338.0
10	2/1300	70.7	768	0.4	1.9	35	6/0200	182.6	3918	5.1	263.3
11	2/1600	82.5	745	0.4	3.4	36	6/0834	198.3	4256	4.8	394.6
12	2/2020	93.9	822	0.5	5.3	37	6/1214	186.0	3796	4.9	406.9
13	2/2300	118.7	1065	0.9	8.0	38	6/1341	209.2	5416	7.8	418.6
14	3/0200	138.1	1156	1.1	13.0	39	6/1600	216.0	5847	8.8	457.8
15	3/0800	156.6	1346	1.5	19.7	40	6/2000	247.0	5662	9.7	486.8
16	3/1123	176.3	1543	1.9	24.4	41	6/2300	198.2	6422	8.8	504.4
17	3/1300	192.5	2354	3.2	30.7	42	7/0200	218.9	6987	10.6	557.6
18	3/1621	177.3	1787	2.2	41.7	43	7/0830	188.1	5861	7.6	595.7
19	3/2048	190.8	2122	2.8	50.2	44	7/1100	175.7	6483	7.8	611.3
20	3/2300	198.6	2407	3.4	56.9	45	7/1304	169.3	5914	6.9	642.2
21	4/0220	222.0	2692	4.2	82.3	46	7/1945	153.2	6131	6.4	677.6
22	4/0913	232.2	3431	5.6	118.4	47	7/2300	141.4	6490	6.3	696.5
23	4/1050	242.2	3409	5.5	135.0	48	8/0300	55.8	6050	2.6	708.7
24	4/1300	248.7	600 (1)	5.5 (2)	151.6 (2)	49	8/0833	28.8	5015	1.0	712.3
25	4/1600	231.3	3397	5.5	168.2	50	8/1200	19.8	4273	0.6	713.5

(1) Run is suspect.

(2) Although the sample run was suspect, the emissions rate (lbs/hr) and cumulative values were generated using the best estimate between runs 23 & 25.

Figure 2

WHITE WINE FERMENTATION EXHAUST ETHANOL EMISSIONS

Tank No. 576
 Capacity (gals): 350,110
 Actual (gals): 280,000
 Location: United Vintners
 (Madera Facility)

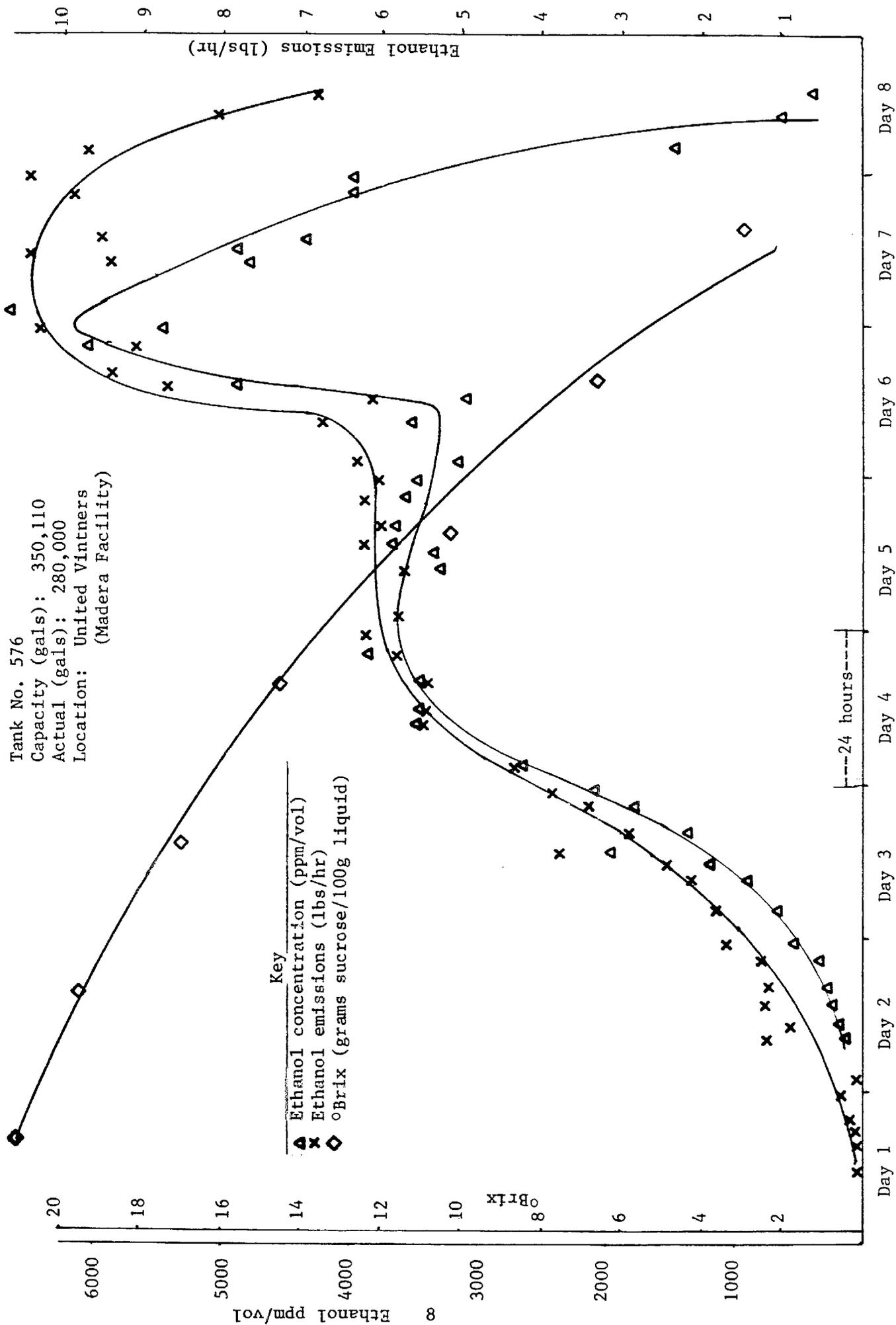
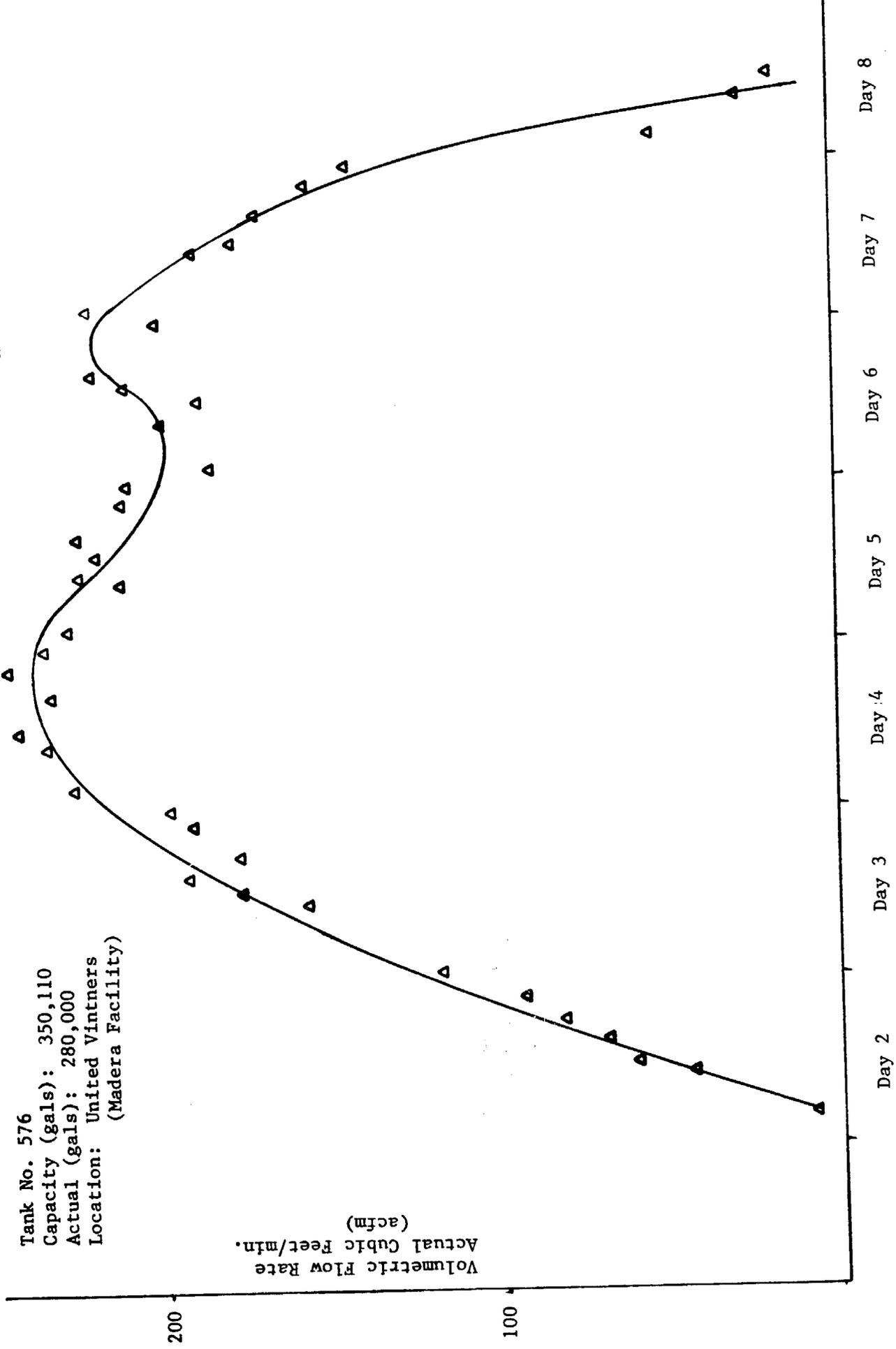


Figure 3

WHITE WINE FERMENTATION VOLUMETRIC EXHAUST FLOW

Tank No. 576
Capacity (gals): 350,110
Actual (gals): 280,000
Location: United Vintners
(Madera Facility)



SUMMARY AND CONCLUSIONS

Ethanol emission factors have been determined for the fermentation process. Additional measurements of ethanol fugitive emissions, generated from storage and handling during production, have been completed. Four fermentation tanks were monitored throughout their complete fermentation periods. The choice of tank location and type was made in an attempt to represent some of the variations in California wine production, given the time and budgetary limitations of the project. Final results listing ethanol fermentation emissions and emission factors are found in Table 13. Results for fugitive ethanol emissions and emission factors are detailed in Table 14.

The tabulated ethanol fermentation emissions (maximum lbs/hr and total lbs emitted) indicate a simple relationship between the volume of fermenting juice and wine type (i.e., red vs. white). Ethanol losses during red wine fermentation were higher than losses during white wine fermentation. The larger the volume of fermenting juice, the larger was the maximum quantity of ethanol emitted per unit time, or quantitatively, at the peak fermentation more CO₂ was produced and exhausted per unit time and thus more ethanol emitted through entrainment.

Ethanol emissions have been related to fermentation process conditions in order to generate emission factors, which in turn may be compared to historical data and theoretical attempts to characterize ethanol losses during fermentation.

Historical data representing ethanol emission factors as percent of total ethanol emitted versus fermentation temperature are graphed in Figure 13. Emission factors determined by EAL have been included in the graph and are in good agreement. In general, white wine fermentation emission factors are found at the lower end of the temperature range and red wine factors at the upper end. Comparison of EAL data to that of the California Air Resources Board (CARB) shows agreement for two separate white wine fermentations at approximately the same fermentation interval activity. Specifically, CARB reported an "ethanol concentration increase from 1,902 parts

TABLE 13

ETHANOL FERMENTATION EMISSIONS AND EMISSION FACTORS

Source	Location	FERMENTATION PARAMETERS				EMISSIONS				EMISSION FACTORS		
		Juice Volume (gal)	Average Temp. (°F)	Yeast Type	Duration (hours)	Maximum Ethanol Emission Rate (Lbs/Hr)	Total Ethanol Emitted (Lbs)	Ethanol Emitted (Lbs) / 10 ³ Gal Juice	Ethanol ⁽¹⁾ Emitted (Lbs) / Ton Grapes	% Ethanol Emitted Per Ethanol Produced		
White Wine Fermentation Exhaust	United Vintners (Madera)	280,000	56	Montrachet	172	10.6	714	2.6	0.56	0.35		
White Wine Fermentation Exhaust	Robert Mondavi (Oakville)	5,800	60	Montrachet	512	0.05	8.2	1.4	0.31	0.2		
Red Wine Fermentation Exhaust	United Vintners (Madera)	44,000	83	Sacromices Servicia	26	31.0	342	7.8	1.7	1.3		
Red Wine Fermentation Exhaust	United Vintners (Oakville)	8,100	72	Montrachet	77	4.7	85.3	10.5	2.3	0.82		

(1) 220 Gallons Juice/Ton Grapes

TABLE 14
 ETHANOL FUGITIVE EMISSIONS AND EMISSION FACTORS

Location: United Vintners, Oakville

<u>Area</u>	<u>(mg/m³)</u>	<u>(grams/hr)</u>	<u>(ppm by vol.)</u>
Storage (Locations 1, 2, 5, 6) Ref. Figure	0.04-0.08	0.003-0.007	0.02-0.04
Handling (Location 3)	2.2	0.4	1.4
Handling (Location 4, adjacent to drag screen)	6.5	1.0	3.4
Handling (Location 7, immediately above drag screen)	5429	923	2888
Handling (Location 8, immediately above pomace press)	1134	193	603

Location: Robert Mondavi, Oakville*

<u>Area</u>			
Handling (Location 1)	56	4.8	30
Storage (Location 2)	43	3.7	23
Storage (Location 3)	15	1.3	8

*The storage and handling areas at Robert Mondavi (Oakville) were undergoing final clean up operations of the crush season, possibly explaining the relatively higher ethanol values compared to those at United Vintners(Oakville).

TABLE 14 (continued)

Location: Inglenook (Rutherford), bottling process (i.e., handling)

<u>Area</u>	<u>(mg/m³)</u>	<u>(grams/hr)</u>	<u>(ppm by vol.)</u>
Room Air	32	-- *	17
Source, Corking Vent Outlet	654	1.8	348
Source, Filling Vent Outlet	3536	27.2	1881

ETHANOL FUGITIVE EMISSION FACTORS
HANDLING PROCESSES

<u>Process</u>	<u>Ethanol</u>
Drag Screen	0.5 lbs ethanol/10 ⁻³ gal juice
Pomace Press	0.02 lbs ethanol/ton of pomace
Wine Bottling	0.1 lbs ethanol/10 ⁻³ gal wine (white)

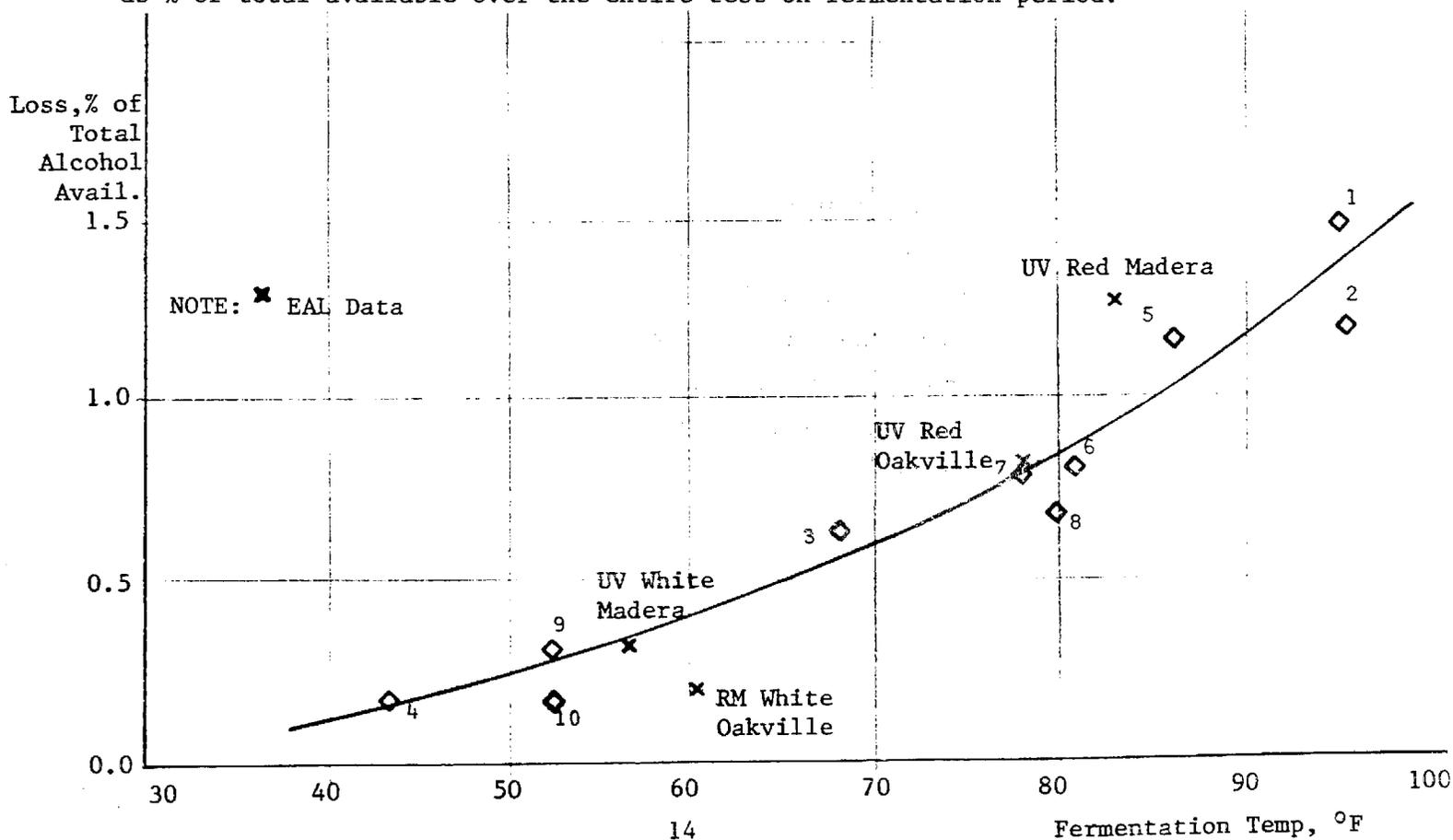
*No significant turbulence or air movement (i.e., ethanol dispersion).

Figure 13

Summary of Ethanol Loss Studies

Study	Alcohol Content	Initial Sugar	Fermentation Temperature	Alcohol Lost*
1. Mathieu and Mathieu		18.0%	95°F(35°C)	1.5 %
2. Flanze and Boudet		18.2	95 (35)	1.2
3. "		18.2	68 (20)	0.65
4. "		18.2	43 (5)	0.17
5. Warkentin and Nury	4.6-10.6%range		86 (30)	1.17
6. "	(7.6% avg.)		80.6 (27)	0.83
7. Zimmerman, Rossi, and Wick		21	79.7 (26.5)	0.84
8. "		16	79.7 (26.5)	0.70
9. Air Resources Board (using Warkentin and Nury formula)	3-4% range		52 (11)	0.3
10. Air Resources Board (based on measured alcohol loss)	(3.5% avg.)		52 (11)	0.2
EAL/UV Red Wine Madera	entire range	23	84 (29)	1.3
EAL/UV Red Wine Oakville	"	23.5	72 (22)	0.82
EAL/UV White Wine Madera	"	23	57 (14)	0.35
EAL/RM White Wine Oakville	"	22.4	63 (17)	0.2

as % of total available over the entire test on fermentation period.



per million at the beginning of the test (approximately 60 hrs. after yeast inoculation) to 4,565 ppm at the end of the test^(B). This compares well with EAL's data for a similar interval where ethanol concentrations ranged from 2,122 to 4,273 ppm (Ref. Table 3).

EAL's data may also be compared to the Environmental Protection Agency's (EPA) emission factor formula as described in Supplement 10 of AP.42, Feb. 1980, (ref. Table 15) where:

$$EF = (0.136T - 5.91) + [(B - 20.4)(T - 15 - 21)(0.00085) + C]$$

and: 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/10³ gal for red wine

Final results of the fugitive emissions study indicate greater ethanol losses during handling stages of wine production than during storage. Table 14 summarizes the comparison between the final storage phase of wine production and three main handling processes during production. Table 14 also includes fugitive emission factors for the wine bottling process and the drag screen and pomace press or solids extraction process.

Fermentation ethanol losses measured during this study are consistent with results from past tests (Ref. Figure 13). A general review of the existing data indicate that ethanol losses are dependent upon fermentation temperature, duration of the fermentation period, and the volume of fermenting juice. Ethanol losses from all the parameters appear to be characteristic of predicted stoichiometric behavior. The fermentation process is stoichiometrically characterized in the following equation:

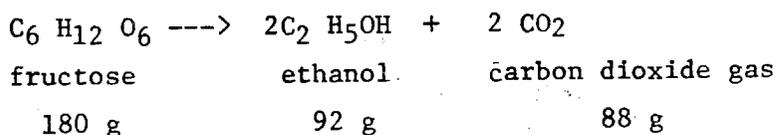


TABLE 15

COMPARISON OF EAL AND EPA EMISSION FACTORS

Wine Type/ Location	Fermentation Temperature(°F)	Initial Sugar (°Brix)	EMISSION FACTOR (lbs ethanol/10 ³ gals)	
			Measured	EPA Formula
White Wine/U.V. Madera	57	23	2.6	2.6
White Wine/R.M. Oakville	63	22.4	1.4	1.7
Red Wine/U.V. Madera	84	23	7.8	9.1
Red Wine/U.V. Oakville	72	23.5	10.5	7.5

The determined ethanol emission factors can be used, together with Gay-Lussac stoichiometry, in order to perform an internal check on the complete ethanol emissions source test.

Example

Location: United Vintners (Madera)

Source: White wine fermentation tank No. 576

Questions: To what extent does the measured total cumulative/pounds of ethanol (ETOH) emitted agree with the value predicted by stoichiometry?

- Given:
- o Volume of fermenting juice = 280,000 gallons
 - o Initial sugar = 20°Brix where °Brix = $\frac{\text{grams sugar}}{100 \text{ mls juice}}$
 - o Final sugar = 3°Brix

- o Actual yield of alcohol (ethanol) = 47% by weight, (not theoretical 51.1%) due to conversion into other microbiological products and assimilation by yeast.⁽⁶⁾

Step 1: 17 grams of sugar are consumed per 100 mls. of juice from 20 to 3 °Brix.

thus: $(17 \text{ g sugar}) \times 0.47 = 7.99 \text{ grams ETOH produced/100 mls. juice}$

Step 2: Grams ETOH produced per gallon of

$$\text{juice} = \frac{(7.99 \text{ g ETOH})}{100 \text{ mls. juice}} \times \frac{1000 \text{ mls.}}{1 \text{ liter}} \times \frac{3.79 \text{ liters}}{1 \text{ gallon}} = 302.8$$

Step 3: Total cumulative pounds of ETOH

$$\text{produced} = \frac{(302.8 \text{ g ETOH})}{1 \text{ gal. juice}} \times 280,000 \text{ gals.} \times \frac{1 \text{ lb.}}{454 \text{ g}} = 186761.9 \text{ lbs ETOH}$$

Step 4: Finally, $186761.9 \text{ lbs ETOH} \times 0.0035^* = 654 \text{ total cumulative lbs ETOH emitted}$

Recall: 642 total cumulative lbs ETOH emitted (measured)

Conclusion: The theoretical value of total cumulative ETOH emitted (lost) agrees with the measured value to within 1.8%

*EAL calculated emission factor.

RECOMMENDATIONS

Emission Inventories

Historical data and the results from this report contribute to the confidence with which ethanol emissions from wineries may be quantified. However, additional testing of the fermentation process would serve to further validate the data base. For example, independent monitoring of red and white wine fermentations at similar temperatures could narrow the variability of the temperature versus ethanol emission factor curve shown in Figure 13. Although present methods of monitoring sugar consumption/ethanol production are adequate, results describing carbon dioxide production and subsequent entrainment of ethanol would complete the mass balance picture.

Control Measures

Control of ethanol emissions may be economically justified through resource recovery. The reclamation of ethanol could produce distillation material. The remainder of this section is a discussion of possible control devices with comments on their applicability, efficiency, and costs.

Exhaust Vapor Refrigeration (condensation): The effluent is cooled to a temperature at which ethanol condenses. This method would require a certain energy cost outlay to maintain optimum refrigeration of the exhaust. Purchase, installation, maintenance and operation of the system may exceed the price of recovered ethanol, especially if the abatement unit were to be permanently mounted on a fermentation tank. Only limited information was obtained regarding refrigeration/condensation methods. The only document reviewed was a French paper, in which a conceptual schematic is presented⁽⁹⁾.

Activated Carbon Adsorption: This process consists of an airstream conditioning system including dehumidification and particulate filtration stages. The exhaust stream would then pass through one of two vessels containing activated carbon specifically chosen for ethanol recovery. When the vessel which is on line becomes saturated, the airflow would automatically

switch to the second vessel. The initial vessel will then be processed to strip the ethanol from the carbon (steam desorption). This ethanol will be returned to the plant in a water mixture which can then be purified to any required level by using existing distillation equipment. Purchase and installation would be approximately \$35,000 based on the following parameters⁽¹⁰⁾:

270 cfm of exhaust at 80 - 90°F, Relative Humidity of 70 - 80%
 18000 ppm of ethanol
 24 hour/day operation

Maintenance and operational costs would vary depending on whether the system would be permanently installed or semi-mobile allowing abatement to take place as needed (Ref. Figure 14).

Wet Scrubber Exhaust System (Ref. Figure 15): The exhaust stream passes through a mist eliminator and into the "contact face area" where exhaust fumes are sprayed by a series of nozzels. The scrubber liquid would be water and recirculation could be employed. Periodic testing of the scrubber wafer would indicate a point at which the ethanol/water mixture should be transferred to distillation and scrubber water replenished. The scrubber system is relatively light-weight (plastic materials) with minimal energy demand.

The wet scrubber system appears to be the most attractive ethanol emissions control technology for the following reasons:

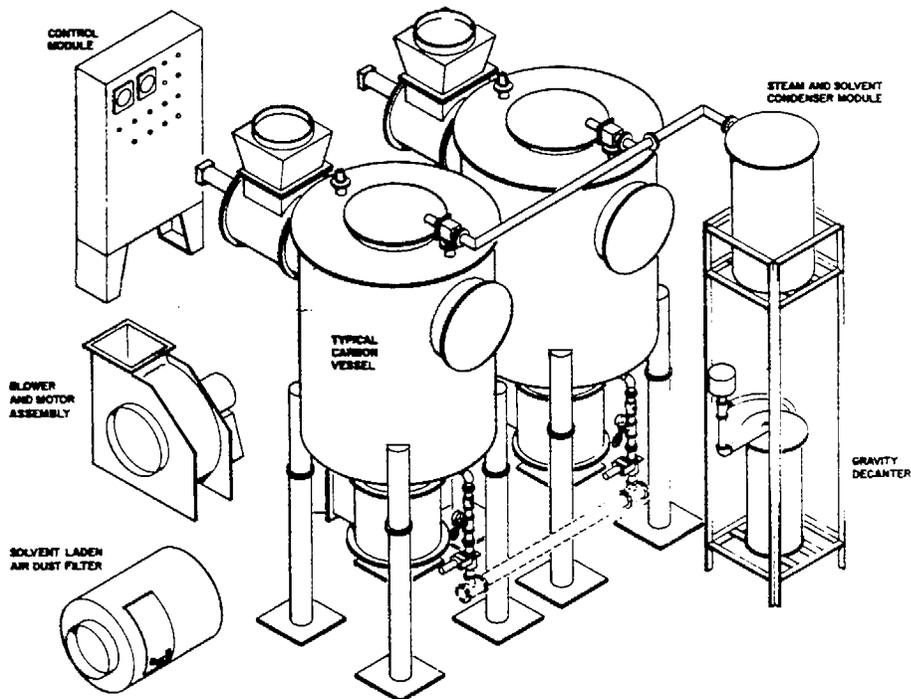
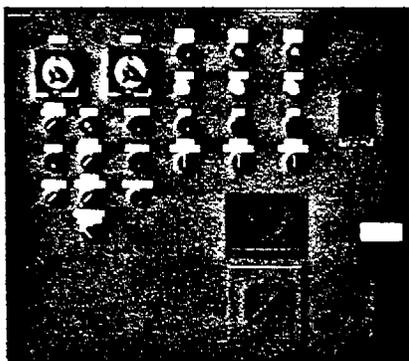
<u>Item</u>	<u>Comments</u>
Cost ⁽¹¹⁾	Approximately \$4,000./unit
Adaptability	Could be moved from one fermentation tank to another as needed
Energy Use	Minimal, only need to operate low hp fans (approx. 2 hp) and pumps

Wet scrubbing would be the most cost effective control measure in terms of capital and energy expenditures. However, if separation or reconcentration of the dilute product solution were required for economically efficient recovery of the ethanol, the associated costs would be higher. Wet scrubbers have been used in the study of ethanol emissions from fermentation tanks and thus, indirectly, as control devices⁽¹²⁾.

VIC 500 Series System

- Modular concept
- Completely automatic operation
- Safety controls
- Explosion-proof motors, blowers and starters (as required)
- Low initial investment
- Low pressure steam desorption

500 SERIES—TWO VESSEL SOLVENT VAPOR RECOVERY SYSTEM PICTURED, ONE OF MANY VERSATILE COMBINATIONS.

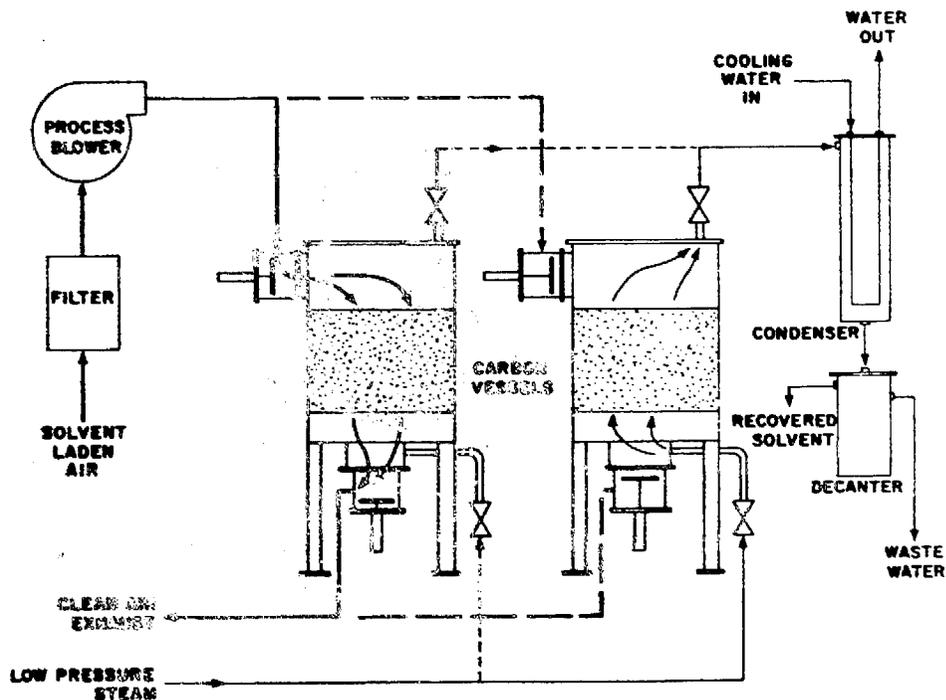


Automatic controls are available in various NEMA classifications for on-site or remote mounting, electromechanical or programmable. Optional exhaust gas analytical equipment and recorders.



* Protected by one or more of the following patents: Patent No. 2,480,320; 2,910,137; 2,982,375; 2,893,925; 3,029,612; 3,089,250; 3,095,284; 3,726,074; Licensed Under U.S. Patents No. 2,772,747; 2,760,584; 2,702,433; 2,755,563; Canadian Patents No. 470,085; 612,477; 618,334; 680,220; 687,299; and other Patents applied for in U.S. and Foreign Countries.

All specifications shown are subject to change without notice. All Vic equipment is sold under our standard warranty. Copy available on request. Purchaser agrees to these terms when accepting delivery of equipment.



VIC MANUFACTURING COMPANY

1620 Central Ave. N.E., Minneapolis, MN 55413 (612) 781-6601



APC6005-12/81

Figure 15
WET SCRUBBER

Wet scrubbers are used to remove particulate matter and gaseous pollutants from industrial exhaust streams. They are highly effective in removing particulate matter and are also used to remove sulfur dioxide and nitrogen oxides.

Wet scrubbers are classified into several types based on the mechanism of pollutant removal. The most common types are spray tower scrubbers, venturi scrubbers, and packed bed scrubbers.

Wet scrubbers are used in a variety of industries, including power generation, metal processing, and chemical manufacturing. They are also used in municipal waste incinerators and other large-scale industrial facilities.

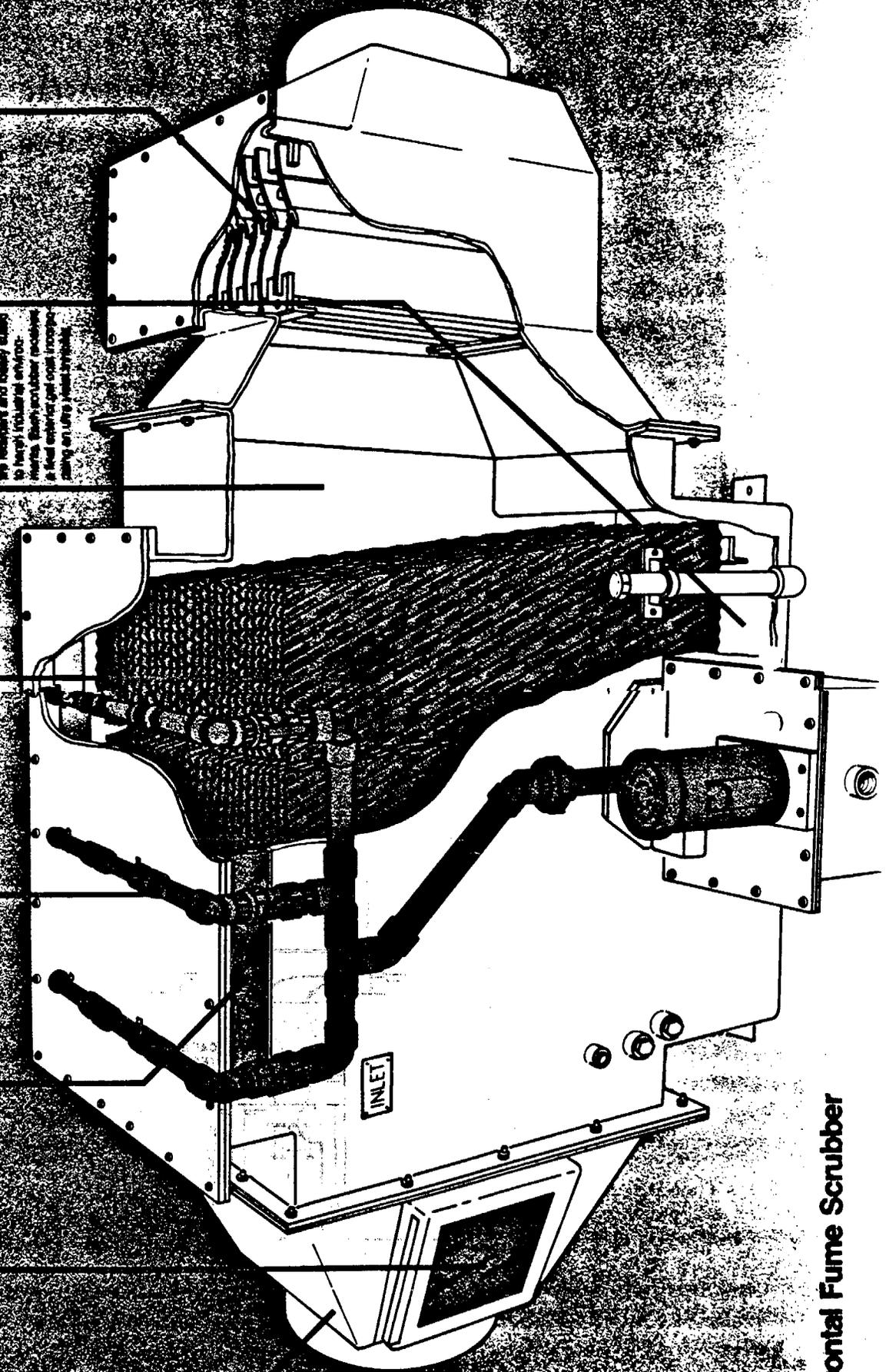
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Wet scrubbers are classified into several types based on the mechanism of pollutant removal. The most common types are spray tower scrubbers, venturi scrubbers, and packed bed scrubbers.

Wet scrubbers are used in a variety of industries, including power generation, metal processing, and chemical manufacturing. They are also used in municipal waste incinerators and other large-scale industrial facilities.

Wet scrubbers are highly effective in removing particulate matter and gaseous pollutants from industrial exhaust streams. They are also used to remove sulfur dioxide and nitrogen oxides.

Wet scrubbers are classified into several types based on the mechanism of pollutant removal. The most common types are spray tower scrubbers, venturi scrubbers, and packed bed scrubbers.



Horizontal Fume Scrubber

Control of fugitive emissions from handling, bottling, and storage operations would be most efficiently performed by prevention of emissions through use of enclosed transfer and handling systems and enclosure of process and storage areas so that emissions from those areas could be ducted to the fermentation tank scrubbers.

