Appendix K

Reasonably Available Control Technology Analysis (RACT) for Wine Fermentation, Wine Storage Tanks, and Brandy Aging

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Appendix K: Reasonably Available Control Technology (RACT) Analysis for Wine Fermentation, Wine Storage, and Brandy Aging

I. EXECUTIVE SUMMARY

A. Summary of results

This report constitutes the technical and economic analysis conducted by the San Joaquin Valley Unified Air Pollution Control District (District) to determine the appropriate level of Reasonably Available Control Technology (RACT) for wine fermentation, wine storage tanks, and brandy aging operation. Based on the results of the analysis, the District believes that there is no feasible RACT-level control for wine fermentation, wine storage tanks, and brandy aging because of the following reasons:

- Currently, there is no achieved in practice control technology to control VOC emissions from wine fermentation or brandy aging.
- Technologically feasible control options to reduce VOC emissions from wine fermentation and wine storage tanks are not economically feasible. The estimated cost effectiveness is $32,000 to $48,000 per ton for red wine fermentation, $18,000 to $52,000 per ton for white wine fermentation, and $38,000 to $84,000 per ton for wine storage tanks. These cost effectiveness values exceed the threshold generally established by EPA for sources subject to existing Control Technique Guidance documents (CTGs)[1], which is about $4,400 per ton of VOC ($2,000 per ton 1980 dollars adjusted to 2007 dollars)[2]. There is also concern that emissions control could contaminate the product or impact wine quality and consistency.
- For brandy aging emissions control, the estimated cost effectiveness is about $1,000 per ton of VOC for catalytic oxidizer to $5,300 per ton for water scrubber. Although these values appear to be economically reasonable in comparison with the $4,400 per ton threshold generally established by EPA for sources subject to existing CTGs, the District believes that there is no feasible RACT-level control because the control technology has not yet been installed, operated and evaluated. A brandy facility operator was recently issued an Authority to Construct permit by the District. As such, control of brandy aging emissions could not be considered as achieved in practice at this time until after a few years when it can be determined that there would be no adverse impacts on aging operation and most importantly on the quality or consistency of the product. (See discussion in Section B.1 and Section VI of this report.)

To determine RACT, the District researched control technologies that may have been achieved in practice, as well as controls that may be technologically feasible for wine fermentation, wine storage tanks, and brandy aging. Even though the cost effectiveness of controlling emissions from wine storage tanks has been determined to be economically infeasible, the District considered the use of pressure vacuum valves

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[1] May 18, 2006 Memorandum from William T. Harnett, Director of air Quality Policy Division, to Regional Air Division Directors. "RACT Qs & As – reasonably Available Control Technology (RACT): Questions and Answers". On page 2, answer to question #6 stated that: "EPA has never issued a general cost of control for VOC, but costs of control in CTGs generally ranged around $2000/ton in 1980s dollars."

[2] Cost effectiveness value in 2007 dollars based on an 3% average inflation rate = $2000/ton x $(1.03)^{27\text{ yrs}}$ = $4,443/ton

and temperature control as achieved in practice BACT because they are in-place on virtually all wine storage tanks located in the District. Since there are no achieved in practice emission control technologies for wine fermentation or brandy aging and the fact that these source categories have never been controlled by other states in the nation or worldwide, the District evaluated control options that may be technologically feasible. The control technologies that were evaluated include thermal oxidation, catalytic thermal oxidation, regenerative thermal oxidizer, wet scrubbing (absorption), adsorption vapor recovery, and condensation, refrigeration, and cryogenic systems). These technologies are exhaust-type controls, which require the installation of ducting system to capture the emissions from the tanks and then sent to the control device for destruction or adsorption/absorption of VOC. Biological oxidation and temperature control of fermentation have been determined to be not technologically feasible. A detailed discussion of each control option is presented in Section IV of this report.

B. Background

1. Reasonably Available Control Technology (RACT)

EPA defines RACT in the Strelow memorandum[3] as: “the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available, considering technological and economic feasibility.” Documents that are useful in establishing RACT include EPA’s Control Technique Guidance documents (CTGs), Alternative Control Technique guidelines (ACTs), Maximum Achievable Control Technology (MACT), National Emission Standards for Hazardous Air Pollutants (NESHAP), New Source Performance Standards (NSPS), EPA’s RACT/BACT/Lowest Achievable Emission Reduction (LAER) Clearinghouse, regulations adopted in other California air districts, other states in the nation or other countries. There are no CTG, ACT, MACT, NESHAP, NSPS, RACT, BACT, LAER or other federal documents that could be used to establish the appropriate RACT level for this source category. In fact District staff were unable to find any examples of any wine fermentation or branding aging emissions control currently being implemented either nationally or worldwide. District Rule 4694 (Wine fermentation and Storage Tanks) is the first regulation in the world requiring VOC control from wine fermentation and storage tanks. In the absence of achieved in practice control technology for wine fermentation or brandy aging, the District conducted a technical and economic analysis of all possible control options to determine RACT. The District believes that there is no feasible RACT-level control because none of the candidate controls are economically feasible. The unit cost for emissions reductions from wine fermentation and storage is very high compared to controls for other existing sources mandated-to-date by the District or other air quality agencies in California. It is important to mention that even though the unit cost of emissions reduction is very high for wine storage tanks, the District considers pressure vacuum (PV) valve as achieved-in-practice Best Available Control Technology since most storage tanks already have existing PV valves.

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[3] The Strelow RACT Memorandum, published in BNA Environmental Reporter, December 9, 1976, pages 1210-1212.

Recently, the District has issued an Authority to Construct permit for one brandy aging facility which has been proposed for purposes of generating Certified Emissions Reduction Credit (CERs) to offset the required wine fermentation emissions reduction required by Rule 4694 (Wine Fermentation and Storage Tanks). The proposed facility will modify an existing brandy aging warehouse to make it meet the EPA Test Method 204 requirements for a Permanent Total Enclosure so that the ethanol emissions could be captured and destroyed using regenerative thermal oxidizer technology. However, the provisions of the permit requiring the operation of the capture and control system are provisional, based upon successful demonstration that the operation of the controls does not result in unacceptable impacts on brandy quality or consistency. Therefore, the District believes that, at this time, there is no feasible RACT-level control for brandy aging emissions until such time when the facility operator could successfully determine that the control would have no adverse impact on product quality or the aging process.

2. Wine fermentation, wine storage, and brandy aging operation

Wine is an alcoholic beverage produced by fermentation of sugars in fruit juices, primarily grape juice. “Fermentation, the process which converts grape juice to wine, occurs via anaerobic breakdown of organic compounds, by action of microorganisms or their extracts, to products simpler than the starting substrate. With wine, breakdown of grape juice is caused by yeast. The yeast provides complicated enzymes that, in the presence of sugar, form alcohol, carbon dioxide, glycerin, and other products. The amount of time required to complete fermentation is a function of fermentation temperature, at 55 to 60^{0}F, wines are fermented in 7 to 10 days, while at 75 to 80^{0}F, wines take 3 to 6 days to ferment.”[4] In commercial wineries fermentation commonly occurs in fixed-roof steel tanks (fermenters) by inoculation of must with yeast. After fermentation, wine is transferred a number of times between storage tanks to perform various finishing operations such as “racking” (decantation for separation of sediment), filtration, malolactic fermentation (breakdown of malic acid to lactic acid and carbon dioxide).

Brandy is prepared by distilling fermented grape juice and then aging the distilled product in wooden casks (usually oak) which colors it, mellows the palate, and adds additional aromas and flavors. The changes that occur during the aging process are the result of interactions between the aging brandy and the oak barrel, driven by the conditions of the surrounding atmosphere which may have both diurnal and seasonal variation. Both ethanol and water evaporate from the surface of the barrel during the aging process with the rate of evaporation (and the style of the brandy) depending upon both the porosity of the barrel and the atmospheric conditions of the storage among other factors. The average brandy aging period is about 2 to 3 years. A detailed discussion of brandy making and aging process is presented in Section VII.

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[4] California Air Resources Board (ARB) 8/06/03 Draft Technical Assessment Document “Strategies and Costs for Winery Ethanol emission Control”.

C. Requirements for RACT Analysis

The District adopted Rule 4694 (Wine Fermentation and Storage Tanks) on December 15, 2005. The rule was submitted to the California Air Resources Board and was transmitted to the United States Environmental Protection Agency (EPA) on June 16, 2006 for inclusion in the state implementation (SIP). On October 16, 2006, EPA Region IX provided written comments expressing similar concerns as those previously discussed by EPA correspondence to the District in October and December 2005, and March and June 2006. Basically, EPA required the District to demonstrate that Rule 4694 meets RACT. EPA indicated that the analysis of RACT should systematically consider all possible controls for the sources and explain why rejected controls are technically or economically unreasonable to require.

D. Approach - Top down Analysis.

The District used a “top-down analysis” approach to determine the appropriate RACT-level control for reducing emissions from wine fermentation, wine storage, and brandy aging operations. A top-down analysis consists of (1) identifying technologically feasible control technologies for the emission source category; (2) eliminating infeasible control technologies; (3) calculating and analyzing cost effectiveness of available control technologies; and (4) selecting RACT based on most cost effective control technology option. A detailed top-down analysis for this source category is presented in Section IV of this report.

II. RACT BACKGROUND

A. Clean Air Act Requirements to Implement RACT

In the San Joaquin Valley Air Basin (SJVAB), monitored levels of ozone exceed National Ambient Air Quality Standards (NAAQS), which are set at levels that protect public health and welfare. Consequently, EPA has classified the SJVAB’s air quality as serious for its nonattainment designation for the federal eight-hour ozone NAAQS. Under the now revoked federal one-hour ozone standard, the SJVAB was classified as extreme nonattainment. As nonattainment area, Section 182(b)(2) and elsewhere in the Clean Air Act, the District is required to implement RACT for all NOx and VOC major sources within its jurisdiction. Wine fermentation and storage is a major VOC source, and as such RACT for this source category needs to be implemented. In addition, pursuant to the one-hour Ozone Attainment Demonstration Plan the District adopted Rule 4694 (Wine Fermentation and Storage Tanks) on December 15, 2006 to implement Best Available Retrofit Control Technology (BARCT). Upon submission of Rule 4694 to EPA for inclusion into the State Implementation Plan (SIP), EPA required the District to demonstrate that the rule implements RACT. To demonstrate RACT EPA stated that the analysis should systematically consider all possible control options and why rejected controls are technically and/or economically unreasonable to require. This report constitutes the District’s analysis of possible control options that may be technologically and economically feasible to determine the appropriate RACT requirements. Based on the analysis, the District believes that there is no feasible RACT-level control for this source category due to reasons discussed above in Section I.A as well as the detailed analysis presented in Section IV.

B. Cost Effectiveness Levels – What has EPA approved as RACT across the country?

Based on EPA's definition of RACT and the fact that there are no existing federal control requirements or technical guidance documents for controlling emissions from wine fermentation, wine storage, or brandy aging the District evaluated candidate control options that could be used to establish RACT requirements. In evaluating "economic feasibility" of requiring emission control, the District researched what EPA has historically considered as cost effective when adopting CTGs or other federal air emissions regulations. According to an EPA memorandum[5], the cost effectiveness for CTGs generally ranged around $2,000 per ton (1980 dollars), or $4,400/ton (adjusted to 2007 dollars). The District is not aware of any other EPA guidance that specifically states a cost effectiveness level that is acceptable for RACT. In the absence of a specific EPA threshold, the District believes that it is reasonable to judge economic feasibility or infeasibility based on what the District has historically mandated for other source categories. The District believes that high unit cost of emissions reduction shown in Section IV is "economically infeasible" to mandate so there is no feasible RACT-level control for this source category.

C. Control technologies for wine fermentation, wine storage tanks, and brandy aging that are achieved in practice or technologically feasible

Wine fermentation and wine storage tanks

After conducting research of technical documents relevant to wine fermentation emissions control, the District has determined that there are no technologies that have been achieved in practice or currently being used to control wine fermentation emissions. In the absence of achieved in practice control technologies, the District analyzed all possible options for VOC emissions control to determine their technological and economic feasibility. The control options that were analyzed are thermal oxidation, catalytic thermal oxidation, regenerative thermal oxidizer, wet scrubbing (absorption), adsorption vapor recovery, and condensation/refrigeration/ cryogenic systems. Biological oxidation and temperature control of fermentation are not technologically feasible as discussed in Section IV of this report.

The District conducted separate analysis for red wine and white wine because of fermentation processing differences, duration of fermentation, and emission factors. The analysis considered all possible control options for VOC and their respective costs

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[5] May 18, 2006 Memorandum from William T. Harnett, Director of air Quality Policy Division, to Regional Air Division Directors. "RACT Qs & As – reasonably Available Control Technology (RACT): Questions and Answers". On page 2, answer to question #6 stated that: "EPA has never issued a general cost of control for VOC, but costs of control in CTGs generally ranged around $2000/ton in 1980s dollars."

as listed in the tables below. The annual costs are based on the assumption that controls are maximized and multiple tanks are ducted to a single control device. The unit cost is expected to be higher for single tank control compared to manifolding multiple tanks, and therefore single tank controls were not analyzed. Furthermore, the District does not believe that controlling only large tanks (fermenters) is a viable option because operators would likely shift their fermentation process to smaller uncontrolled tanks, thereby resulting to no achievable emissions reduction.

The analysis demonstrated that all possible control options that may be technologically feasible to reduce VOC emissions from wine fermentation and wine storage tanks are not economically feasible. The cost effectiveness of controlling red wine fermentation is about $32,000 to $48,000 per ton of VOC reduced for a system that includes a Clean-in-place (CIP) process. Without a CIP, the red wine control cost is about $15,000 to $30,500 per ton VOC reduced. For white wine fermentation, the cost effectiveness is about $18,000 to $52,000 per ton of VOC reduced. Note that the $15,000 and $18,000 per ton values are for carbon adsorption control, which is conservatively low because it does not include the cost to regenerate the spent carbon either onsite or offsite. Carbon adsorption control cost will be higher if carbon regeneration cost is included (ARB Draft Technical Assessment Document[6] estimated carbon adsorption cost effectiveness of $44.09 per pound, or $88,180 per ton). It is important to mention that a control system which includes a CIP would be required as part of standard fermentation operation process and to prevent possible cross-contamination of wine products due to the spread of microbes via ductwork, especially for multiple tanks that are manifolded together using a single capture and control device. The cost effectiveness of controlling emissions from wine storage tanks is about $38,000 to $84,000 per ton of VOC reduced. The estimated cost effectiveness of about $204,000/ton of VOC for pressure vacuum (PV) valves to control emissions from wine storage tanks is not economically feasible. The District, however, considers the use of PV valves as achieved in practice BACT because they already in-place on virtually all existing winery storage tanks within the District.

The estimated cost effectiveness control options that may be technologically feasible for controlling VOC emissions from wine fermentation and wine storage emissions exceed the cost effectiveness threshold generally established by EPA for sources that are subject to CTGs as discussed below, and therefore can not be considered economically reasonable as RACT. As such, the District believes that there is no feasible RACT-level control for this source category. A detailed discussion of the cost analysis is presented in section IV of this report.

It is important to mention that the costs of controlling emissions from wine fermentation and storage are significantly much higher compared to the costs of control for other existing sources mandated-to-date by the District or other air quality agencies in California. Furthermore, it exceeds the threshold generally established by EPA for Control Technique Guidance documents (CTGs), which is around $2,000 per ton (1980

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[6] California Air Resources Board (ARB) 8/06/03 Draft Technical Assessment Document “Strategies and Costs for Winery Ethanol emission Control”, Table B-4, page 115.

dollars)[7]. Adjusted to 2007 dollars based on average annual inflation of 3%, the cost effectiveness of CTG[8] is about $4,400/ton.

The following tables summarize the results of the District's evaluation of technologically feasible control options. Section IV of this report presents detailed discussion of cost estimation methodology, sources of cost data, and assumptions/conditions used in estimating the capital investment cost, direct annual cost, and indirect annual cost, as well as annualized cost of feasible control options.

Total Annualized for VOC Control of Red Wine Fermentation
Includes Site Specific Costs, Clean–in-place (CIP), Maximum Vapor Rate Basis

	Thermal Oxidizer	Catalytic Oxidizer	Regenerative Thermal Oxidizer	Refrigerated Condenser	Water Scrubber	Carbon Adsorption
Total Annualized Cost ($)	6,290,000	5,517,800	4,732,500	4,555,400	5,791,300	4,420,800
Cost effectiveness ($/ton VOC)	48,300	41,300	36,400	35,300	44,900	32,300

Total Annualized for VOC Control of Red Wine Fermentation
Non-Site Specific Costs, No Clean–in-place (No CIP) Managed Vapor Rate Basis

	Thermal Oxidizer	Catalytic Oxidizer	Regenerative Thermal Oxidizer	Refrigerated Condenser	Water Scrubber	Carbon Adsorption
Total Annualized Cost ($)	3,968,100	3,113,500	2,286,100	2,174,100	2,965,000	2,090,800
Cost effectiveness ($/ton VOC)	30,500	23,300	16,700	16,900	23,000	15,300

Total Annualized for VOC Control of White Wine Fermentation
Non-Site Specific Costs, No Clean–in-place (No CIP), Managed Tank Flow

	Thermal Oxidizer	Catalytic Oxidizer	Regenerative Thermal Oxidizer	Refrigerated Condenser	Water Scrubber	Carbon Adsorption
Total Annualized Cost ($)	3,098,900	2,244,300	1,416,900	1,304,900	1,412,400	1,221,500
Cost effectiveness ($/ton VOC)	52,100	35,700	21,500	20,900	22,600	18,400

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[7] May 18, 2006 Memorandum from William T. Harnett, Director of air Quality Policy Division, to Regional Air Division Directors. "RACT Qs & As – reasonably Available Control Technology (RACT): Questions and Answers". On page 2, answer to question #6 stated that: "EPA has never issued a general cost of control for VOC, but costs of control in CTGs generally ranged around $2000/ton in 1980s dollars."

[8] Cost effectiveness value in 2007 dollars based on 3% average annual inflation rate = $2000/ton x $(1.03)^{27\text{ yrs}}$ = $4,443/ton

Storage Tank Emission Control Technology Analysis

Wine storage tanks perform two functions in the winery:

- Facilitation of post-fermentation processing operations such as racking, filtration, malolactic fermentation and bottling. In this role, the typical storage tank is filled and emptied several times per year and functions as a process vessel.
- Storage of wine between processing operations up to the final operation of bottling. In this role, the objective is to avoid oxidation of the wine by both minimizing the wine temperature and the exposure of the wine to air.

Emissions from storage tanks consist of both working losses and breathing losses. Working losses occur as a result of the displacement of the vapor space of the tank into the atmosphere due to tank filling operations. Working losses are primarily a function of tank throughput and the temperature and ethanol content of the wine. Breathing losses are the result of diurnal heating and cooling caused by the effect of atmospheric conditions on the contents of the tank. For a well-insulated tank, breathing losses will be negligible.

The table below summarizes the result of the District's evaluation of technologically feasible control options for storage tanks and their corresponding annualized costs as well as cost effectiveness. Section IV presents detailed discussion of cost estimation methodology, sources of cost data, and assumptions/conditions used in estimating the capital investment cost, direct annual cost, and indirect annual cost, as well as annualized cost of feasible control options. The analysis also indicated that PV valve and temperature control of storage tanks are not cost effective. However, since PV valves are currently being used on virtually all wine storage tanks within the District, they are considered as achieved in practice BACT and more stringent than RACT.

Total Annualized for VOC Control of Wine Storage Tanks
Non-Site Specific Costs, No Clean–in-place (No CIP)

	Thermal Oxidizer	Catalytic Oxidizer	Regenerative Thermal Oxidizer	Refrigerated Condenser	Water Scrubber	Carbon Adsorption
Total Annualized Cost ($)	272,400	184,200	210,600	285,800	129,500	251,900
Cost effectiveness ($/ton VOC)	75,700	51,200	58,500	83,800	38,000	70,000

Brandy Aging

The District is not aware of any brandy aging facility in the nation or worldwide that is currently controlling its ethanol emissions. In fact, the only known whiskey aging facility that was issued a Part 70 operating permit (Permit No. T 137-6928-00011 in December 2002) by the Indiana Department of Environmental Management (IDEM) is Joseph E.

Seagram & Sons, Inc. in Ripley County, Indiana. District staff reviewed the permit and found that there were no VOC control requirements specifically indicated for whiskey aging process. Therefore, the District believes that since IDEM (or EPA Region III which is the oversight agency for IDEM) did not require VOC control of the whiskey aging emissions, there is no feasible RACT-level control for similar distilled spirits like brandy. However on August 4, 2004, the Indiana Office of Environmental Adjudication [2004 OEA 58 (03-A-J-3003)][9] ordered the IDEM commissioner to rescind the permit for the Seagram facility. The District staff cannot find any facility in the nation that are mandated to control of brandy, whiskey or similar other distilled spirits. In the absence of achieved in practice control technologies, the District analyzed all possible control options for general VOC controls to determine their technological and economic feasibility. The control options that were analyzed are thermal oxidation, catalytic thermal oxidation, regenerative thermal oxidizer, wet scrubbing (absorption), adsorption vapor recovery, biological oxidation, and condensation/refrigeration/cryogenic systems. The estimated cost effectiveness analysis of controlling brandy aging emissions is about $1,000 to $5,300 per ton of VOC reduced as indicated below.

Total Annualized for VOC Control of Brandy Aging

	Thermal Oxidizer	Catalytic Oxidizer	Regenerative Thermal Oxidizer	Refrigerated Condenser	Water Scrubber	Carbon Adsorption	Biofilter
Total Annualized Cost ($)	569,700	351,400	410,320	410,700	1,723,400	454,500	781,100
Cost effectiveness ($/ton VOC)	1,700	1,000	1,200	1,300	5,300	1,300	2,300

III. Industry Background

A. Winemaking process

Wine production is predominantly a seasonal event, coinciding with the grape harvest season. Wine making involves three major steps: grapes are harvested, crushed, and then fermented. The wine fermentation step is typically a batch process. Within the San Joaquin Valley, about 97% of wine production occurs in the months of August through December. Fermentation is at its peak during September through October. About 74% of wine fermentation occurs within those months. During the peak of the grape harvest, wineries processing millions of gallons of wine annually will operate 24 hours per day, seven days of the week. For a given fermenter, it is possible to run one fermentation batch after another throughout the harvest season. Between each batch,

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[9] 2004 OEA 58 (03-A-J-3003) - Objection to the Issuance of Part 70 Operating Permit No. T-137-6928-0001 for Joseph Seagrams & Sons, Inc., Ripley County, Indiana.

the fermenter is sterilized in accordance with U.S. Food and Drug Administration requirements and readied for a new fermentation batch.

Seasonal throughput for a single fermenter varies from year to year and winery to winery. Assuming a fermentation season of 60 to 90 days, and a batch time of 5 days for red wine and 10 days for white wine, theoretical throughput for a single fermenter could be 12 to 18 batches for red wine and six to nine batches for white wine. According to the Wine Institute, this theoretical throughput is seldom achieved. The Wine Institute estimates that over 85% of wineries process 6 batches or less per tank, and 67% process 4 batches or less. According to a Wine Institute survey of nine large wineries operating in the District, the maximum number of batches for red and white wine was 18 and 8 batches respectively.

Quantitative characterizations of fermentation emissions will vary from winery to winery and within a winery. Emissions produced during fermentation depend upon process parameters, such as sugar content of the must, degree of temperature control, and type of wine being produced. During the fermentation process, glucose and fructose in must undergo reaction by yeast activity and produce ethanol and carbon dioxide (CO_2). The amount of ethanol emitted to the atmosphere depends on the fermentation temperature and duration, the sugar content of the must, and the volume of must. Because of their higher fermentation temperatures, shorter fermentation periods, and the presence of the cap, fermentation emissions per batch are higher for red wines than white wines. VOC concentrations and airflow rates for red wines reach higher peak values and vary more significantly than those encountered in white wine fermentation.

B. Winemaking Industry

Seventy percent of the State of California's wine production occurs within the District. The majority of wine production in the District occurs at large wineries, with annual wine production capacities of tens of millions of gallons. In 2002, 18 wineries in the District had annual permitted production volumes ranging from 5 million to greater than 50 million gallons. These 18 wineries accounted for 95% of the District's emissions from wine fermentation. Of the 109 wineries operating in the SJVAB in 2002, 70% of the wineries had annual production volumes of less than 200,000 gallons, and 58% of the wineries had annual production volumes of less than 2,000 gallons. Ethanol constitutes the predominant VOC emissions from wine fermentation and storage tanks.

Fermenters in use at large wineries in the District range in size from about 25,000 gallons to 600,000 gallons. Most fermenters have manhole located on the roof of the tank that is open during fementation. Emissions are vented through the manhole without the aid of mechanical equipment (e.g., fans). Of the 4,533 total permitted wine tanks in the District, about 32% or 1,457 tanks are used exclusively for wine storage; about 10% or 448 tanks are used exclusively for wine fermentation; and 58% or 2,628 tanks are used as both fermenters and storage tanks.

IV. Cost Effectiveness and RACT Determination for Wine Fermentation

A. Emission Control Technology For Control of Ethanol Emissions From Wine Fermentation Tanks

1. Background

Ethanol is the primary VOC produced during wine fermentation. Previous researchers[10] have demonstrated that ethanol is released to the atmosphere primarily as a result of equilibrium between the gas phase and the liquid phase of the fermenting wine. The liquid phase is mostly water with the minor components consisting of sugars, and ethyl alcohol. The gas phase is mostly carbon dioxide with trace amounts of water and ethyl alcohol. The gas stream leaving a fermentation tank varies in ethyl alcohol concentration and flow rate depending on the fermentation temperature, the volume of fermenting juice in the tank, and how complete the conversion of sugar to ethyl alcohol has progressed. Higher fermentation temperature and greater liquid volumes in the tank cause a greater emission rate. Fermentation is a batch process, with typical frequencies at two to four batches per month over a three-month crush period. Both the flow rate of the vent stream and the uncontrolled emission rate of ethanol are highly variable over the time of fermentation. In addition, red wine fermentations occasionally become unstable resulting in a “foam-over” of the tank contents (similar to the results of shaking an open carbonated beverage). Foam-overs can forcefully discharge thousands of gallons of liquids from the fermentation tank into the air. To be considered technologically feasible, an emission control system must be able to operate reasonably under this batch operation scenario and be able to accommodate occasional foam-overs without contaminating co-connected tanks.

Additionally, wine is a both a food grade product and a consumer product whose consumer acceptance is heavily influenced by style issues. Therefore, to be considered technologically feasible, an emission control system must 1) be designed to operate in accordance with the cleanliness and sanitation standards of the wine industry, the U.S. Food and Drug Administration, and with other requirements of state and local health authorities and 2) have no impact on the operation of the fermentation tank with respect to style, quality, or consistency of quality of the wine produced.

The US EPA’s RACT/BACT/LAER Clearinghouse (RBLC) database contains case-specific information on the "Best Available" air pollution technologies that have been required to reduce the emission of air pollutants from stationary sources (e.g., power plants, steel mills, chemical plants, etc.). This information has been provided by State and local permitting agencies. The RBLC contains no examples of controlling wine fermentation emissions. Additional literature searches produced no examples of fermentation emission control being implemented worldwide.

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[10] Modeling and Prediction of Evaporative Ethanol Loss During Wine Fermentations, Williams and Boulton, Am. J. Enol. Vitic., Vol 34, No. 4, 1983.

The District has prepared a BACT guideline for Ethanol Fermentation Process Tanks (Guideline 4.12.4) for ethanol production from corn fermentation. Guideline 4.12.4 establishes a 99.5% VOC emissions control efficiency using a fermentation-wet scrubber vented to a CO_2 recovery plant with a condenser and high-pressure scrubber; or equivalent.

Differences between wine fermentation and ethanol for fuel production necessitates consideration of alternative control technologies. Of specific concern is treatment of the wastewater from the wet scrubber. During corn fermentation, waste water from the wet scrubber is conveyed back to a slurry tank and reused in the manufacturing process. Wine is a food product and for food safety reasons, the return of the waste water to the wine is not possible. As a control technology for wine fermentation, wet scrubbers would require alternative wastewater treatment or disposal methods. Guideline 4.12.4 identifies thermal oxidation with 98% VOC control as an alternative technology. Thermal oxidizers have been successfully used in different industrial settings operating in the District and are readily available.

A review of established control technologies indicates that the following would be potentially applicable to the control of ethanol emissions from fermentation tanks:

1. Oxidation (conversion of the VOC to CO_2);

2. Absorption (“scrubbers”, which transfer the VOC in air emissions to a liquid waste stream);

3. Adsorption (often using activated carbon, which transfers the VOC in the air onto a solid substrate);

4. Condensation (conversion of the VOC gases into liquids); and

5. Biological control systems (e.g., bio-filters or bio-scrubbers)

6. Temperature control of fermentation (refrigeration) to reduce the evaporative ethanol emissions.

Review of the identified control technologies above indicates that options 1 through 5 are all classified as capture and control systems and therefore all share a common requirement for a capture system. Since the capture system is common to these options, issues regarding the installation of such a system on fermentation tanks are also common and will thus be considered independent of the control technology selected.

Each of the identified technologies, the common capture system and their potential application to wine fermentation is discussed in the following:

2. Emissions Capture System

The generic capture system consists primarily of a tank interface for connection of ductwork to the tank(s), ductwork running from the tank(s) to the control device including valving and instrumentation, and a separation device (knock out vessel) to prevent entrained liquids in the vent stream (such as might occur in a foam-over) from entering the control device and potentially damaging it. Most of the technological uncertainties and potential issues associated with the installation of capture and control systems on fermentation tanks are associated with the operability of the ductwork (capture) system and the potential impact of the ductwork system on the fermentation tank operation. Essential fermentation-specific features of the ductwork system are:

- The system must connect multiple tanks to a common control device. Reasons for this feature include:
  - The batch nature of the fermentation tank operation requires that multiple tanks be manifolded together to provide an averaging effect for reasonably continuous operation of a common control device. Due to the batch operation of each tank, the design capacity of a control device dedicated to a single tank would only be needed a few hours per week at the most and would operate a significant amount of time with zero or near-zero flow from the tanks. The result would be excessive operating cost for the control device and/or excessive turndown and cycling of the control device.
  - Installation of a dedicated control device for each tank would be prohibitively expensive since the compact layout of essentially all wineries generally dictates that the control device be installed at some distance from the tank, requiring a significant dedicated run of ducting from each tank to the remote location of the control device. In particular, red wine fermentation tanks are installed in close proximity with the grape receiving, crushing, pressing and other material handling equipment due to the requirements to handle solid materials in these tanks and it is expected that essentially all such installations would require remote location of the control device due to lack of plot space in the vicinity of the fermentation tanks. Since large wineries have hundreds of tanks including 40-60 red wine fermenters, installation of a dedicated control device for each tank would be extremely inefficient from both a capital investment standpoint (excessive investment in ductwork and control devices) and would require excessive utilization of plot space for siting numerous control devices in the winery.
- The system must be capable of handling entrained liquids from the fermentation tanks and of preventing cross-contamination between tanks. A reasonable design will include features to avoid entry of entrained liquid from each tank into the common header that interconnects the tanks and will then continuously slope the main header from a high point, where the tank connects to the header, down to the knock out vessel located at the control device to ensure that liquids entering the header are not distributed to any of the connected tanks. A design approach for minimizing the entry of liquids from the tank to the main header has been proposed in the Eichleay study for the Gallo-Livingston Winery[11] in which a motor operated isolation damper is installed in the branch duct from each tank to the main header. Closure of these valves would be actuated by a control system based on sensing a foam-over condition in the tank. In the event of a foam-over and a closure of the isolation damper, an individual tank vent system must also be provided to release the gases to

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[11] Eichleay Engineers, Fermenter VOC Emissions Control Cost Estimate, 2005.

the atmosphere to avoid over-pressure on the tank. The basic proposed design includes a frangible duct connection at the tank with an air gap which would allow large-scale venting of the tank with minimal entry of liquid into the ducting. A prototype of this duct connection design was demonstrated in 1990 in a program evaluating control of ethanol emissions from wine fermenters, conducted at the E. & J. Gallo Winery in Fresno, California [12]. The design of the VOC capture system allowed fermentation emissions to vent naturally through a manway located at the top of the tank. The VOC capture system consisted of an emissions collection hood, located above the manway, connected by ductwork to a VOC control device. The collection hood was larger than the manway and was suspended above the opening, creating an air gap between the tank and the hood. The design included a fan with a flow-rate sufficient to pull emissions into the collection hood and force the emissions through the ductwork to the emissions control device. Based on results reported in the Gallo study, District staff considers it reasonable to expect similar emissions collection systems to have a capture efficiency of at least 90%.

- Requirements for sloping of the main header (typically a minimum of ¼ inch per foot for efficient drainage) will set the elevation requirement of the main header at the most remote tank location. Minimum routing elevation of the headers within a plant is typically set at approximately 20 feet (and sometimes higher at major road locations) to avoid interference with operations and maintenance equipment access. These constraints can result in a high point elevation of 30 to 40 feet for the main header in a typical plant.
- The system must include provisions for cleaning and sterilization to meet the requirements for handling of food products. Fermentation systems must be cleaned and sterilized between each fermentation batch and this is typically accomplished by multiple washings with solutions of potassium hydroxide and chlorine dioxide. Since it would be impractical to disassemble the ductwork for cleaning between each batch, the ductwork design must incorporate a “clean-in-place” (CIP) system. Such a system has been proposed in the Eichleay study, consisting of a fixed spray header located inside the duct to apply the cleaning solutions to the inner wall of the duct plus ancillary systems to store and deliver the cleaning solutions to the spray system. In addition, cleanliness and corrosion-resistance considerations dictate that the ductwork be constructed of stainless steel.
- The ductwork system must be supported independently of the fermentation tanks since the tanks are generally not designed to support any significant structural load. The ductwork presents a substantial load since it must be constructed with sufficient wall thickness to be self-supporting over spans of 20+ feet and be durable enough for industrial plant operations as well as to support in-line components such as the motor operated valves, check valves

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[12] Akton Associates, A Demonstration Program, Ethanol Emissions Control from Wine Fermentation Tanks Utilizing Carbon Adsorption Technology, 1990

and other items. Internally it contains a spray header and wash nozzles and must be designed to run approximately 1/3 full of liquid due to the washing and sterilization operation. The potential load of the ductwork, combined with the elevation requirements for the ducting and the lack of structural support available from the tanks, dictates that substantial free standing steel structures be provided for support of the ductwork. Since the structures, along with their respective foundations, must be constructed in a highly congested area between storage tanks with little or non-existent crane access and must be constructed in a plant with on-going operations, it is reasonable to expect significantly higher costs per unit basis for steel and concrete structures erected under these conditions. Due to the congested nature of the plant environment and the limited window for construction due to plant operating requirements, construction approaches involving off-plot assembly of steel modules and setting of these modules with a helicopter were devised in the Eichleay study. Such installation would be conducted with craft labor on an overtime basis to accommodate a limited construction window and minimize costs for helicopter usage.

3. Adsorption Vapor Recovery

Adsorption vapor recovery is accomplished by passing the VOC-laden gas through beds containing adsorbents that have a high surface area to weight ratio. Typical adsorbents are activated carbon, zeolite, or organic polymers. As the gas stream passes through the bed, organic compounds adsorb weakly onto the adsorbent's surface. Adsorption of the hydrocarbon molecules proceeds until the available surface area is filled or saturated with VOC molecules. The VOC molecules are retained until the regeneration step, or disposal of the spent adsorbent.

Desorbing or removing captured VOCs regenerates the adsorbent. Decreasing the pressure, reducing the hydrocarbon concentration around the adsorbent or increasing the temperature of the bed can perform regeneration. A combination of these steps can also be used for regeneration. There are three basic types of adsorption systems available to recover or remove hydrocarbon vapors from an air stream. Two of these systems regenerate the adsorbent in-situ for reuse. The third system requires removal of the adsorbent to another site for regeneration.

The two systems that provide in-situ regeneration are: Pressure Swing Regenerated Systems and Thermally Regenerated Systems (or a combination of the two methods). Since the net result of the combined adsorption and regeneration process only results in transfer of the ethanol from the fermentation vent stream to another liquid or gaseous stream, further treatment of the effluent of the regeneration process is required to either destroy or recover the ethanol (typically thermal oxidation of the stripping gas stream or water treatment in the case of steam stripping).

The District considers adsorption vapor recovery (with appropriate handling of regeneration waste streams) as technologically feasible for application to wine fermentation. Based on California Air Resources Board (ARB) Suggested Control

Measure"[13], a control efficiency of 95% is considered reasonable for adsorption systems which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 86% for this technology.

4. Thermal Oxidation (Incineration)

A thermal oxidizer (TO) destroys VOCs by the process of combustion. A basic TO system consists of a combustion chamber, burner, stack, and combustion controls. All hydrocarbons are oxidized to carbon dioxide and water vapor by the proper mix of temperature, residence time and turbulence within the reactor chamber. Combustion of the contaminated gas stream occurs at high temperatures, normally 650^oC to 870^oC (1,200^oF to 1,600^oF) when treating low concentration streams. Recent guarantees provided by TO vendors for destruction of ethanol in air in other proposed projects under review by the District have been based on a minimum combustor temperature of 1,500^oF.

TO systems can be divided into recuperative or regenerative systems, based on methods used to increase operating efficiencies by capturing heat from the combustion process. Recuperative TO systems increase fuel efficiency by use of a gas pre-heating section and a heat recovery section. Heat recovery can be as high as 70%. A regenerative system provides extremely high thermal-energy recovery; up to 95% of heat energy can be recovered. Regenerative TO systems use a ceramic heat-exchange bed to preheat process air to within 5% of the oxidation temperature.

VOC conversion efficiencies range from 95% to 99.9% for TO systems. However, the combustion of supplemental fuel for the oxidation step (the amount depending upon the fuel value of the VOC and the level of heat recovery employed) produces NOx, an ozone precursor like VOC, thus offsetting some of the VOC emission reduction. The District considers thermal oxidation as technologically feasible for application to wine fermentation and that a control efficiency of 95% is reasonably achievable which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 86% for this technology.

5. Catalytic Thermal Oxidation

A catalytic thermal oxidizer (CTO) is essentially a thermal oxidation unit with a catalyst module. These units are similar in design to recuperative units, except that VOCs are oxidized using precious metal or metal-oxide-based catalysts instead of high temperature. Operating at about half the temperature of thermal oxidizers, catalytic units have smaller footprints and may offer lower operating costs in certain circumstances. Since catalyst are employed, they are subject to catalyst poisoning or deactivation due to operating upset and may require periodic catalyst replacement which represents a substantial operating cost.

Other industries have demonstrated typical VOC removal efficiencies of up to 98%. The District considers catalytic thermal oxidation as technologically feasible for

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[13] Nelson Chan, et. al, A suggested Control Measure for Control of Ethanol Emissions From Winery Fermentation Tanks. October 7, 1986

application to wine fermentation and that a control efficiency of 95% is reasonably achievable which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 86% for this technology.

6. Wet Scrubbing (Absorption)

The basic process involved in wet scrubbing is the contact of a polluted gas stream with a liquid solution. During operation, gas flows upward through a column containing packing or other mass transfer media. The scrubbing liquid is delivered to the top of the column and flows down (by gravity) through the porous mass transfer media, generating a substantial interfacial surface area between the gas and liquid phases in a counterflow arrangement which provides optimal mass transfer. Gaseous contaminants are absorbed into the liquid and the decontaminated gas stream flows out of the scrubber.

Many scrubbing applications achieve emission reduction efficiencies of 99.9%. In a pilot study conducted by ARB in 1987, wet scrubbing demonstrated greater than 90% reduction in ethanol emissions. The District considers wet scrubbing as technologically feasible for application to wine fermentation and that a control efficiency of 90% is reasonably achievable which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 81% for this technology.

7. Condensation, Refrigeration, and Cryogenic Systems

Condensation, refrigeration, and cryogenic systems remove organic vapor by condensing the target gases on cold surfaces. These cold conditions can be created by passing cold water through an indirect heat exchanger, by spraying cold liquid into an open chamber with the gas stream, by using a refrigerant to create very cold coils, or by injecting cryogenic gases such as liquid nitrogen into the gas stream. The concentration of VOCs is reduced to the level equivalent to the vapor pressures of the compounds at the operating temperature. Removal efficiencies attainable with this approach depend strongly on the outlet gas temperature. For cold-water-based condensation systems, the outlet gas temperature is usually in the 40 to 50°F range, and the VOC removal efficiencies can be in the 90% to 99% range depending on the vapor pressures of the specific compounds. For refrigerant and cryogenic systems, the removal efficiencies can be considerably above 99% due to the extremely low vapor pressures of essentially all VOC compounds at the very low operating temperatures of -70°F to less than -200°F. Water vapor content in the gas stream may place a lower limit on the outlet gas temperature due to potential ice formation.

The application of refrigerated condenser to the control of ethanol emissions from a fermentation tank was examined by the wine industry(x). The results of that study indicated that a 90 % ethanol recovery could be achieved at an outlet gas temperature of -12 ^{0}F. However, it was noted that ice formation could be a problem at this temperature and that special equipment designs would be required for reasonable operation. In addition, the ethanol is recovered in aqueous solution and must be further process for recovery of the ethanol. The District considers refrigerated condensation as technologically feasible for application to wine fermentation and that a control efficiency of 90% is reasonably achievable which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 81% for this technology.

8. Biological Oxidation

Biological oxidation systems are a relatively new means of air pollution control. VOCs can be removed by forcing them to absorb into an aqueous liquid or moist media inoculated with microorganisms that consume the dissolved and/or adsorbed organic compounds. The control systems usually consist of an irrigated packed bed that hosts the microorganisms (biofilters). A presaturator is often placed ahead of the biological system to increase the gas stream relative humidity to more than 95%. The gas stream temperatures are maintained at less than approximately 105°F to avoid harming the organisms and to prevent excessive moisture loss from the media.

Biological oxidation systems are used primarily for very low concentration VOC-laden gas streams. The VOC inlet concentrations are often less than 500 ppmv and sometimes less than 100 ppmv. The overall VOC destruction efficiencies are often above 95%. The District does not consider biological oxidation to be technologically feasible for application to wine fermentation based on the following:

- Emissions from the tanks only occur approximately 12 weeks per year. The short and potentially intermittent nature of the emissions would not be appropriate to maintaining a healthy bed of microorganisms in the filter.
- Wine is a food-grade product and requires stringent sterilization practices from the standpoint of eliminating contamination and preserving product quality. The introduction of a system containing microorganisms is not considered feasible within the sterilization practices normally employed. The microorganisms could potentially be a health risk due to potential contamination of the wine.

9. Temperature Control of Fermentation

Ethanol losses from fermentation increase with increasing temperature. Therefore, lowering fermentation temperatures could result in lower ethanol emissions. However, there is a lack of empirical data supporting accurate characterization of the resulting emission reduction or establishment of the appropriate fermentation temperature limits. Actual emission reductions would be determined by complex interactions including factors such as non-isothermal fermentation, presence of the pomace cap in red wine fermentation, and starting and ending Brix levels. The ARB Technical Assessment Document (TAD) presents a hypothetical 15 percent and 30 percent reduction in ethanol emissions from red wine and white wine fermentations respectively. The authors note, however, that emission reductions of that magnitude would probably be achieved in only a few isolated cases. Because of the lack of empirical data and the uncertainty of achievable emissions reductions, and due to potential issues concerning the impact of fermentation temperature control on the style of wine produced, the District does not consider temperature control to be a viable VOC control option at this time.

B. Cost Effectiveness for Red Wine Fermentation

1. Approach for Cost Effectiveness

Because of processing differences, red wine fermentation has an emission factor about 2.5 times greater than white wine fermentation. Red wine has an emissions factor of 6.2 lb VOC/1,000 gallons, and white wine has an emissions factor of 2.5 lb/1000 gallons of fermented must. In addition, red wine fermentation batches are completed in 3 to 5 days versus 10 to 14 days for white wine fermentation. Therefore, a red wine fermentation tank of a given size will potentially operate at significantly higher throughput and produce significantly higher emissions per unit of throughput relative to a white wine fermentation tank of the same size. As a result of these fundamental differences in emission rate, cost effectiveness for red wine will be considered separately from that for white wine.

The following emission control technologies have been determined to be technologically feasible for control of VOC emissions from wine fermentation tanks:

- Oxidation (86% control)
- Refrigerated Condenser (81% control)
- Wet Scrubber (81% control)
- Carbon Adsorption (86% control)

Since “oxidation” includes recuperative and regenerative thermal oxidizers plus catalytic oxidizers, the cost effectiveness of the following cases will be examined for the determination of RACT for red wine fermentation:

Case 1 Thermal oxidation with 0% heat recovery (low capital/high operating cost)
Case 2 Catalytic oxidation with 50% heat recovery (mid range capital/mid range operating cost)
Case 3 Regenerative thermal oxidation with 95% heat recovery (high capital/low operating cost)
Case 4 Refrigerated Condenser
Case 5 Water scrubber
Case 6 Carbon adsorption

The approach of the cost effectiveness analysis will be to first determine which, if any, of the above cases potentially qualifies as RACT based on having a potential cost effectiveness below the assumed EPA threshold of $4,400/ton of VOC. All cases which are shown to have a cost effectiveness higher than $4,400/ton will be discarded. Cases which fall below the threshold will then be further examined and compared with respect to relative cost effectiveness, technical risk, reasonableness, and socio-economic impact to determine which, if any, qualify as RACT for red wine fermentation.

To establish a comparative physical scope of each of the above cases, the District’s approach is based on applying the six different control technologies to the actual red wine fermentation tanks at the E & J Gallo Winery at Livingston, California, rather than a hypothetical red wine fermentation installation. The rationale for this is based on the following:

- The Gallo facility at Livingston is sufficiently representative of typical red wine fermentation facilities located at major source wineries to allow it to serve as a general model for the physical scope requirements of such facilities.
- The availability of plot space for installation of ductwork and control devices is a significant cost factor for all major red wine fermentation facilities. Basing the cost effectiveness analysis on an actual representative facility ensures that these factors are considered in the analysis.
- The Eichleay study details the potential application of VOC controls to this facility and addresses many of the technical issues and site specific factors. This study developed two separate estimates, one for the fermentation control system installation (main estimate) and a second "utilities" estimate to cover the clean-in-place system, the expansion of the plant electric utility and the instrument air system. District staff has reviewed the estimating methodology employed in the Eichleay estimates and found that the estimating approach is fundamentally sound and follows accepted practice in the engineering and construction industry, applying reasonable unit rates and costs for materials and labor for development of direct costs. This information is available to use as a basis for this cost effectiveness analysis.
- Parametric studies to examine the impact of tank throughput on cost effectiveness, based on the Livingston capital cost model, will be generally applicable to other sites since the capital cost for ductwork and a control device are more a function of total connected tank capacity rather than the number of tanks connected to the control device. Given a total connected tank capacity, changes in annual throughput are strictly an operational phenomena based on the average number of tank turns per season for the collection of tanks. For a given total connected tank capacity, a collection of smaller tanks (50,000 gallon capacity for a major source winery) is expected to be somewhat more expensive than a system consisting of fewer, larger tanks due to costs associated with increased complexity in the ductwork and supporting structure as well as the increased instrumentation count and associated electrical requirements. Since the Livingston facility primarily consists of red fermentation tanks of 100,000 gallon or larger capacity, a parametric study of throughput will be slightly optimistic when considering only 50,000 gallon tanks.

2. Estimating Approach and Basis

Estimates of Total Capital Investment (TCI), annual costs, potential emission reductions, and the resulting cost effectiveness were prepared for each of the control technology cases above. The general approach and basis of the estimates is as follows:

- EPA's cost model for VOC incineration systems, as presented in the EPA Control Cost Manual, Section 3.2, Tables 2.8 and 2.9, was used for all cases with the exception of the refrigerated condenser (case 4) estimate which used Section 3.1, Table 2.3 for Total Capital Investment (note that the EPA cost model was adjusted to a California location by taking sales tax at 8% rather than 3%).

- All estimates are based on the general facilities design prepared by Eichleay for the Gallo winery at Livingston, CA. Using this basis, the impact of substituting different control technologies will be examined. It is assumed that the basic scope of ductwork and supports, tank modifications, ancillary systems and site specific costs will be common to all technologies.
- The feasibility of application of VOC controls to multiple fermentation tanks has not been demonstrated and significant uncertainties exist with respect to the actual design requirements. The general facilities design as prepared by Eichleay contains significant scope with respect to site specific factors. In addition, the Eichleay study based the capacity of the control device and ductwork on a peak vapor generation rate occurring simultaneously from all tanks connected to a control device. The District's analysis of this design basis indicates that the probability of such a simultaneous occurrence is potentially small and that, by management of the timing of fermentation batches in the collection of tanks, the ductwork and control device could conceivable be sized at a capacity of less than 70% of the simultaneous peak rate without significantly affecting the potential production rate of the connected tanks. To examine the sensitivity of the results to these factors, the District will consider two potential capital investment scenarios with respect to each control technology case:
    1. Site specific with CIP, Simultaneous Peak Vapor Rate – includes complete facility design with CIP as prepared by Eichleay for Gallo Modesto with the ductwork and control device designed for a simultaneous peak vapor generation rate from all tanks connected to the control device.
    2. Non-site specific without CIP, Managed Fermentation Tanks – reflects a hypothetical and optimistic case wherein costs for all site specific factors and CIP are negligible and assumes that tank management procedures can be implemented to maintain the combined vapor generation rate from all tanks at less than 70% of the peak simultaneous generation rate.
- This facility consists of 60 red wine fermentation tanks with a combined nominal capacity of 6,850,000 gallons. In the general facilities design as prepared by Eichleay the tanks are grouped into four separate groups of tanks, each group separately manifolded together and ducted to a separate dedicated control device. The tank groupings are designated as:

VOC-1	Seventeen (17) 100,000 gallon tanks
VOC-2	Twelve (12) 200,000 gallon tanks
VOC-3	Ten (10) 100,000 gallon tanks and seven (7) 50,000 gallon tanks
VOC-4	Fourteen (14) 100,000 gallon tanks

- Base control device capacity (per the Eichleay study) is based on a peak vapor rate of 9.75 scfm/1000 gallons of wine fermenting (85 ^{0}F fermentation temperature) and assumes all fermenters connected to the control device are simultaneously operating at maximum vapor generation rate. Per the study, an additional 23.6 % flow capacity must be added to the control device to account for the combustion air which must be added. On this basis, the four control devices have been determined to require the following capacities:

VOC Device	Capacity of Device and Ductwork per Eichleay Study	Capacity of Control Device with Tank Management (70%)
VOC-1	16,000	12,480
VOC-2	22,000	17,160
VOC-3	13,000	10,140
VOC-4	13,000	10,140

- Purchased equipment costs for the knock out vessels and the ductwork have been extracted from the main Eichleay estimate. A purchased material cost of $148,000 for the knock out vessels was taken from page 15 of Eichleay's main estimate. Sizing criteria is presented in the Eichleay study and the pricing was developed based on Eichleay's in-house estimating data for this type of equipment derived from purchasing experience on previous projects. A material cost of $1,105,000 for the ductwork has been extracted from pages 16 through 23 of the main Eichleay estimate. Estimated ductwork quantities are based on Eichleay plan drawing SK-30913-001 and the process flow diagram presented in Eichleay drawing SK-30892-003. Unit costs for fabricated stainless steel ductwork are based on a budgetary quotation obtained by Eichleay from Viron International, a ductwork spool fabricator.
- Ductwork sizing for the Eichleay study was based on admission of the combustion air for the RTO at the connection to the tank. This basis added 23.6% to the flow capacity of the ductwork. For those control technologies not based on combustion, this duct capacity will not be needed. Ductwork capacity could hypothetically be reduced by 1.0/1.236 = 81%. Since capacity is a function of the square of the duct diameter, the net effect is a reduction in average duct diameter of $(81\%)^{1/2}$ = 90%. Using a capacity exponent from Table 1.9, Section 2, Chapter 1 of the EPA Control Cost Manual for plate 304 stainless steel duct, cost for ductwork materials, extracted from the Eichleay study is $1,105,000 x $(0.90)^{1.23}$ = $970,000.
- For consideration of the "managed fermentation tank" operation with total vapor flow at 70% of the Eichleay case, the following adjustments will be made to the costs for the knock out vessels and the ductwork:

  Knock out vessels: The cost extracted from the Eichleay study will be adjusted to a 70% capacity factor using a capacity exponent of 0.6. Therefore, at 70% capacity, cost for the knock out vessels is $148,000 x $(0.70)^{0.6}$ = $120,000.

  Ductwork: The most optimistic case for the ductwork is to assume that not only can a 70% capacity reduction in fermenter flow be achieved but also that the combustion air for incinerator operation can be admitted at the control device and not at the tank (per the basis of the Eichleay study). Ductwork capacity could hypothetically be reduced by 0.70/1.236 = 57%. Since capacity is a function of the square of the duct diameter, the net effect is a reduction in average duct diameter of $(57\%)^{1/2}$ = 75%. Using a capacity exponent from Table 1.9, Section 2, Chapter 1 of the EPA Control Cost Manual for plate 304 stainless steel duct, cost for ductwork materials, extracted from the Eichleay study is $1,105,000 x $(0.75)^{1.23}$ = $776,000.

- Direct costs taken from the Eichleay study will be used for estimation of site specific and other costs not covered by the equipment factors in the EPA VOC incineration cost model. These costs include site preparation, structural steel pipeway for ductwork support with helicopter setting of steel structures, clean-in-place (CIP) system, expansion of the plant electric utility, modification of fermentation tanks for duct connections, and the instrumentation system for control of tank foam-overs.
- Site preparation costs to develop a plot area for the VOC control equipment have been extracted from page 4 of the main Eichleay estimate. Costs include subcontract pricing for demolition of an existing road, installation and compaction of fill, and new area and road pavement. These costs total $1,254,000 and are based on budgetary subcontract pricing obtained by Eichleay.
- Total direct cost for structural steel (labor + materials + subcontracts) has been extracted from the total presented on page 8 of the Eichleay estimate ($2,532,000). Steel design and quantities in this estimate are based on Eichleay plan drawing SK-30913-001 and the steel structure sections presented in Eichleay drawing SK-S12. Pricing is based on quotation obtained by Eichleay from a structural steel fabricator in Bakersfield, CA.
- Pricing for use of a helicopter to set steel structures and ductwork was taken from page 24 of the main Eichleay estimate. Pricing was obtained by Eichleay from a helicopter firm based out of the Fresno Airport.
- The Eichleay utility estimate developed a total direct cost of $4,700,000 for both the CIP system and the expansion of the plant electric utility. A direct cost for the electric utility expansion of $314,000 (including prorated craft overtime) was extracted from page 8 of the utilities estimate. The balance of the total direct cost ($4,386,000) is taken as the cost for the CIP system (this figure includes a small amount for expansion of the plant instrument air system also). To determine the TCI for both items, the TCI of the utilities estimate ($8,880,000) was prorated to each item based on respective direct costs.
- The direct costs (materials, labor, and subcontracts) to modify the fermentation tanks for installation of new nozzles required for connection of ductwork includes costs for build and teardown of scaffolding in each tank, demolition of existing insulation, machine cutting of each tank, fabrication and installation of new nozzles, and post-weld passivation of the tank. These costs are taken from pages 15 and 16 of the main estimate and total $487,000.
- The direct cost for an instrumentation system for control of tank foam-overs was taken from page 13 of the main Eichleay estimate and totals $572,000 for capacitance probes, actuated butterfly valves and switches. Design basis for the system is presented in Eichleay drawing SK-30892-007. Unit material costs are

based on budgetary vendor's pricing obtained by Eichleay. Unit labor factors and costs are based on Eichleay's in-house estimating data.

- The EPA model cost factor for foundations and supports is normally taken at 8% of purchased equipment cost which in this case includes only the control device, the knock out vessel and the ductwork. It thus does not factor in the costs of foundations for the substantial steel structures required for this project. Therefore, the direct cost for installation of foundations was taken from the Eichleay study and substituted for the EPA factor in this account. Concrete foundation design consists of drilled concrete piers for supporting of pipeway structures and conventional mat foundations for support of the control devices. Drilled concrete piers require a minimal footprint relative to conventional footers and for this reason are the standard approach for support under new steel columns when they are being installed in congested areas in existing industrial facilities. Direct costs (material + labor + subcontract) for concrete foundations have been extracted from page 4 of the estimate (excavations allowances for control device foundations totaling $21,800 and the total from page 5 ($444,950)) which covers drilling, rebar fabrication and setting, forming, pouring and finishing of the drilled piers and mat foundations. Estimated quantities are based on Eichleay plan drawing SK-30913-001 and the steel structure sections presented in Eichleay drawing SK-S12. The unit costs are based on Eichleay's historical experience with subcontract pricing for these items.
- Annual natural gas usage of 67,412 therms was estimated for the Gallo Livingston design by Eichleay (Appendix G of the Eichleay study) based on a 12 week season and 95% thermally efficient RTO's operating 50% of the time with an ethanol concentration of 6,034 ppmv for 50% of the time and in hot standby the other 50% with allowance for startups. Energy cost was established at $0.61/therm based on current operations at Livingston. Annual natural gas cost so determined is $110,500 per year. This natural gas usage and cost basis will be used as the basis for the cost effectiveness calculations, factored as required for the thermal efficiency basis of the proposed control unit.
- Power consumption for the Gallo facility is estimated by Eichleay at 586 kWh with an annual cost of $141,800 (Appendix G of the Eichleay study). Since essentially all this power is consumed by the induced draft fans at the VOC control unit, this power basis will be assumed to be the same for the induced draft fans associated with all control technologies, factored down as required for control units not requiring combustion air.
- Total Capital Investment has been annualized based on a 10 year equipment life and a 10% opportunity cost for capital (CRF = 0.163).
- Calculation of potential emissions is based upon the red wine emission factor of 6.2 lb-ethanol per 1000 gallons of must and upon the proposed average number of turns for the total red fermentation tankage capacity at Livingston. The average number of tank turns is converted to a tankage throughput based on a typical fermentation working capacity of 75% of the nominal tank capacity.

- Calculated VOC emission reductions will be debited for collateral NOx production from firing of natural gas where applicable based on 1 lb NOX = 1 lb VOC. NOx production is based on 0.1 lb-NOx/MMBtu per AP-42.
- Historical information provided by the industry indicates that, on average, red wine fermenters operate with 3 to 5 turns per season. For reference, actual production figures for Livingston for 2004 indicate that the total red fermenter capacity was turned 3.6 times. To screen the potential control cases for cost effectiveness within the RACT threshold, an average annual throughput of 10 tank turns was assumed for the Livingston facility, almost three times the historical throughput and double the average turnover for 50,000 gallon tanks as reported by the industry.

3. Cost Effectiveness Estimates

Table 1 presents the development of Total Capital Investment (TCI) for all control cases based on the general facilities design prepared by Eichleay and Table 2 presents the associated annual costs, emission reductions, and cost effectiveness for each collection and control case. Table 3 presents TCI for the non-site specific “managed tank operation” without CIP as described previously and Table 4 presents the associated annual costs, emission reductions, and cost effectiveness for each control case under this scenario. Discussion of each results are as follows:

Case 1: Collection and Control with a Thermal Oxidizer

The thermal oxidizer pricing for this case was taken from the EPA Control Cost Manual, Section 3.2, Figure 2.4, based on the control device capacities from the Eichleay study and with a 0% energy recovery. As such, it represents a minimum capital investment/maximum operating cost scenario for use of a oxidizer. The price from Figure 2.4 (1999 dollars) was adjusted to 2006 dollars based on average annual inflation of 3%.

Annual fuel cost for this case was calculated based on the Eichleay estimate of annual fuel consumption for RTO’s with 95% energy recovery. Since this case includes no heat recovery, the Eichleay estimate was divided by 0.05 (factor of 20) to make it reflect this case.

With 10 tank turns and an expected collection and control efficiency of 86%, cost effectiveness of this control option ranges from $30,500 per ton for the most optimistic case (Table 4) up to $48,300 per ton for the general facilities design presented by Eichleay (Table 2).

Case 2: Collection and Control with a Catalytic Oxidizer

The thermal oxidizer pricing for this case was taken from the EPA Control Cost Manual, Section 3.2, Figure 2.6, based on the control device capacities from the Eichleay study and with a 50% energy recovery. As such, it represents a mid range capital investment/mid range operating cost scenario for use of a oxidizer. The price from Figure 2.6 (1999 dollars) was adjusted to 2006 dollars based on average annual inflation of 3%.

Annual fuel cost for this case was calculated based on the Eichleay estimate of annual fuel consumption for RTO's with 95% energy recovery. Since this case includes no heat recovery, the Eichleay estimate was multiplied by 0.5/0.05 = 10 to make it reflect this case.

With 10 tank turns and an expected collection and control efficiency of 86%, cost effectiveness of this control option ranges from $23,300 per ton for the most optimistic case (Table 4) up to $41,300 per ton for the general facilities design presented by Eichleay (Table 2).

Case 3: Collection and Control with a Regenerative Thermal Oxidizer

The thermal oxidizer pricing for this case was taken from the Eichleay study which was based on budget quotation obtained by Eichleay during the study. This pricing appears to be consistent with EPA Control Cost Manual, Section 3.2, Figure 2.5, based on the control device capacities from the Eichleay study. As such, it represents a high capital investment/low operating cost scenario for use of a oxidizer.

Annual fuel cost for this case was that calculated by the Eichleay study for of annual fuel consumption for RTO's with 95% energy recovery.

With 10 tank turns and an expected collection and control efficiency of 86%, cost effectiveness of this control option ranges from $16,700 per ton for the most optimistic case (Table 4) up to $34,600 per ton for the general facilities design presented by Eichleay (Table 2).

Case 4: Collection and Control with a Refrigerated Condenser

The refrigerated condenser pricing for this case was taken from the EPA Control Cost Manual, Section 3.1, Chapter 2, Figure 2.5, based on the control device capacities from the Eichleay study, adjusted downward by 23.6% since no combustion air would be required for this case. The price from Figure 2.5 (1990 dollars) was adjusted to 2006 dollars based on average annual inflation of 3%.

Electric power cost for I.D. fan operation was factored down from the thermal oxidizer case by dividing by 1.236 to account for no need for combustion air with this technology.

No electric power cost was allowed for operation of the refrigeration and for handling of the aqueous ethanol solution. Since these costs would be substantial, the calculated cost effectiveness is optimistically low.

With 10 tank turns and an expected collection and control efficiency of 81%, cost effectiveness of this control option ranges from $16,900 per ton for the most optimistic case (Table 4) up to $34,600 per ton for the general facilities design presented by Eichleay (Table 2).

Case 5: Collection and Control with a Water Scrubber

The water scrubber pricing for this case was extrapolated from two budgetary quotations obtained in a study by STI[14], based on the control device capacities from the Eichleay study, adjusted downward by 23.6% since no combustion air would be required for this case. The price from STI (2003 dollars) was adjusted to 2007 dollars based on average annual inflation of 3%.

Water disposal costs for this case were also taken from the STI study based on a 12-week operating season. Using the STI assumptions, water disposal requirements were taken to be 6 gallons per minute for each 5,000 cfm of flow with a disposal cost of $0.25/gallon.

Electric power cost for I.D. fan operation was factored down from the thermal oxidizer case by dividing by 1.236 to account for no need for combustion air with this technology.

With 10 tank turns and an expected collection and control efficiency of 81%, cost effectiveness of this control option ranges from $23,000 per ton for the most optimistic case (Table 4) up to $44,200 per ton for the general facilities design presented by Eichleay (Table 2).

Case 6: Collection and Control with Carbon Adsorption

Pricing for the carbon adsorption systems was interpolated from pricing obtained by the wine industry for carbon adsorption systems and presented in the TAD (page 77). Sizing was based on the control device capacities from the Eichleay study, adjusted downward by 23.6% since no combustion air would be required for this case. The price from page 77 (1991 dollars) was adjusted to 2007 dollars based on average annual inflation of 3%.

No utility costs were allowed for operation of the carbon regeneration system or for handling water or vapor streams containing the captured ethanol. Since these costs would be substantial, the calculated cost effectiveness is optimistically low.

With 10 tank turns an expected collection and control efficiency of 81%, cost effectiveness of this control option ranges from $15,300 per ton for the most optimistic case (Table 4) up to $31,700 per ton for the general facilities design presented by Eichleay (Table 2).

4. RACT Selection for Red Wine Fermentation

The six cases examined under the most optimistic capital investment scenario yielded a lowest evaluated cost effectiveness of $15,300 per ton for carbon adsorption control technology. For reasons already discussed, this evaluated cost effectiveness is artificially low. Other factors making this evaluated cost optimistically low include:

- Only direct costs for structural steel installation, tank modifications, the foam over control system and helicopter-based construction were included with no indirect costs. These costs could be 50-100% higher when indirect costs are applied.

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[14] Sonoma Technology, Inc., Control Technology Evaluation: Wineries – Fermentation Processes, 2003.

- The EPA cost model only applies factors for engineering, construction and field expense, contractor fees and contingency to the purchased equipment costs rather than the total direct cost. Since other direct costs such as foundations and supports, electrical and piping all have a substantial indirect cost, these costs are ignored in this evaluation. Standard practice in the engineering and construction industry for a factored estimate of this type is to apply indirect cost factors to the total direct cost.
- EPA cost model factors for engineering, construction and field expenses and contingency are low relative to typical experience and practice in the engineering and construction industry for industrial construction of this type. Engineering costs and construction and field expense are each more typically 10-20%, of total direct cost. Industry practice would consider an estimate of this type to have an accuracy of no better than ± 25%. Based on this, industry practice is to set contingency at 15-20% of total direct cost as a minimum.
- EPA cost model factors for operating and maintenance labor, at ½ hour per shift, are significantly lower than would be required for a system of this type. Both the District and industry expect that a minimum of a full time operating person would be required to manage the four VOC control systems during the crush season. There would also be additional operational impacts on the fermentation tank operation to perform CIP operations on ductwork and ensure proper operation with the control devices. Preventative maintenance outside of the crush season would include CIP of the main headers, opening and inspecting all equipment and performing normal maintenance, repairs and check out for all four VOC systems. Such maintenance alone could be expected to require 3-4 weeks for a crew of four maintenance personnel, far exceeding the maintenance cost included with this study.

The above analysis indicates that there are currently no technologically feasible VOC control technologies which offer a cost effectiveness that is less than EPA's assumed RACT threshold of $4,400/ton of VOC. Therefore, the District believes that there is no feasible RACT-level control for red wine fermentation.

EPA Cost Model **Table 1 Total Capital Investment for VOC Control of Red Wine Fermentation**
Site specific Costs, CIP, Maximum Vapor Rate Basis

Control Device	Case 1 Thermal Ox Site Specific, w/CIP	Case 2 Catalytic Oxidizer Site Specific, w/CIP	Case 3 RTO Site Specific, w/CIP	Case 4 Refrigerated Condenser Site Specific, w/CIP	Water Scrub Site Specific, w/CIP	Case 6 Carbon Adsorption Site Specific, w/CIP
Direct Costs						
Purchased Equipment Costs						
Control Device	$507,000	$1,349,000	$1,877,000	$1,800,000	$287,000	$1,573,000
Knock Out Vessels	$148,000	$148,000	$148,000	$148,000	$148,000	$148,000
Ductwork	$1,105,000	$1,105,000	$1,105,000	$970,000	$970,000	$970,000
Subtotal Equipment (A)	$1,760,000	$2,602,000	$3,130,000	$2,918,000	$1,405,000	$2,691,000
Instrumentation (0.10 x A)	$176,000	$260,000	$313,000	$292,000	$141,000	$269,000
Sales Tax (0.08 x A)	$141,000	$208,000	$250,000	$233,000	$112,000	$215,000
Freight (0.05 x A)	$88,000	$130,000	$157,000	$146,000	$70,000	$135,000
Purchased Equipment Cost (PEC)	$2,165,000	$3,200,000	$3,850,000	$3,589,000	$1,728,000	$3,310,000
Direct Installation Costs						
Foundations and Supports (Eichleay Study)	$467,000	$467,000	$467,000	$467,000	$467,000	$467,000
Handling & Erection	$303,000	$448,000	$539,000	$502,000	$242,000	$463,000
Electrical	$87,000	$128,000	$154,000	$144,000	$69,000	$132,000
Piping	$43,000	$64,000	$77,000	$72,000	$35,000	$66,000
Site Prep & Miscellaneous						
Structural Steel Pipeway	$2,532,000	$2,532,000	$2,532,000	$2,532,000	$2,532,000	$2,532,000
Site Prep	$1,254,000	$1,254,000	$1,254,000	$1,254,000	$1,254,000	$1,254,000
CIP System	$8,294,000	$8,294,000	$8,294,000	$8,294,000	$8,294,000	$8,294,000
Electrical Utility	$594,000	$594,000	$594,000	$594,000	$594,000	$594,000
Tank Modifications	$487,000	$487,000	$487,000	$487,000	$487,000	$487,000
Foam Over Control System	$572,000	$572,000	$572,000	$572,000	$572,000	$572,000
Helicopter Use	$977,000	$977,000	$977,000	$977,000	$977,000	$977,000
Total Direct Costs	$17,775,000	$19,017,000	$19,797,000	$19,484,000	$17,251,000	$19,148,000
Indirect Costs						
Engineering	$217,000	$320,000	$385,000	$359,000	$173,000	$331,000
Construction & Field Expenses	$108,000	$160,000	$193,000	$179,000	$86,000	$166,000
Contractor Fees	$217,000	$320,000	$385,000	$359,000	$173,000	$331,000
Start Up	$43,000	$64,000	$77,000	$72,000	$35,000	$66,000
Performance Test	$22,000	$32,000	$39,000	$36,000	$17,000	$33,000
Contingencies	$65,000	$96,000	$116,000	$108,000	$52,000	$99,000
Total Indirect Costs	$672,000	$992,000	$1,195,000	$1,113,000	$536,000	$1,026,000
Total Capital Investment	**$18,447,000**	**$20,009,000**	**$20,992,000**	**$20,597,000**	**$17,787,000**	**$20,174,000**

EPA Cost Model

Table 2 Annual Costs for VOC Control of Red Wine Fermentation
Includes Site Specific Cost, CIP, Maximum Vapor Rate

Control Device	Case 1 Thermal Ox	Case 2 Catalytic Ox	Case 3 RTO	Case 4 Refrigerated Cond.	Case 5 Water Scrubber	Case 6 Carbon Adsorption
Total Capital Investment	$18,447,000	$20,009,000	$20,992,000	$20,597,000	$17,787,000	$20,174,000
Direct Annual Costs						
Labor & Materials						
Operating Labor (0.5 hr/shift-unit @ $12.95/hour)	$1,632	$1,632	$1,632	$1,632	$1,632	$1,632
Supervisor (15% of operator cost)	$245	$245	$245	$245	$245	$245
Operating Materials (15% of total maintenance cost)	$490	$490	$490	$28,360	$490	$490
Maintenance Labor (0.5 hr/shift-unit@ $12.95/hour)	$1,632	$1,632	$1,632	$1,632	$1,632	$1,632
Maintenance Materials (100% of maintenance labor)	$1,632	$1,632	$1,632	$1,632	$1,632	$1,632
Utilities						
Natural Gas	$2,210,000	$1,105,000	$110,500	$0	$0	$0
Electricity	$141,800	$141,800	$141,800	$114,700	$114,700	$114,700
Water Disposal	$0	$0	$0	$0	$1,879,000	$0
Total Direct Annual Cost	**$2,357,400**	**$1,252,400**	**$257,900**	**$148,200**	**$1,999,300**	**$120,300**
Indirect Annual Costs						
Overhead (60% of labor & Mat'ls)	$3,400	$3,400	$3,400	$20,100	$3,400	$3,400
Administrative Charges (2% of TCI)	$368,900	$400,200	$419,800	$411,900	$355,700	$403,500
Property Taxes (2% TCI)	$368,900	$400,200	$419,800	$411,900	$355,700	$403,500
Insurance (1% TCI)	$184,500	$200,100	$209,900	$206,000	$177,900	$201,700
Capital Recovery (CRF = 0.163)	$3,006,900	$3,261,500	$3,421,700	$3,357,300	$2,899,300	$3,288,400
Total Indirect Annual Cost	**$3,932,600**	**$4,265,400**	**$4,474,600**	**$4,407,200**	**$3,792,000**	**$4,300,500**
Total Annualized Cost	**$6,290,000**	**$5,517,800**	**$4,732,500**	**$4,555,400**	**$5,791,300**	**$4,420,800**
Emission Reductions						
Annual Average Tank Tunover	10	10	10	10	10	10
Collection & Control Efficiency	86%	86%	86%	81%	81%	86%
Annual Emission Reduction (tons)	130.22	133.60	136.63	129.00	129.00	136.97
Cost Effectiveness $/ton	**$48,300**	**$41,300**	**$34,600**	**$35,300**	**$44,900**	**$32,300**

EPA Cost Model

Table 3 Total Capital Investment for VOC Control of Red Wine Fermentation
Non-Site specific Cost, No CIP, Managed Vapor Rate Basis

Control Device	**Case 1** **Thermal Ox** Non-Site Specific, No CIP	**Case 2** **Catalytic Oxidizer** Non-Site Specific, No CIP	**Case 3** **RTO** Non-Site Specific, No CIP	**Case 4** **Refrigerated Condenser** Non-Site Specific, No CIP	**Case 5** **Water Scrub** Non-Site Specific, No CIP	**Case 6** **Carbon Adsorption** Non-Site Specific, No CIP
Direct Costs						
Purchased Equipment Costs						
Control Device	$456,000	$1,089,000	$1,511,000	$1,464,000	$253,000	$1,366,000
Knock Out Vessels	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
Ductwork	$776,000	$776,000	$776,000	$776,000	$776,000	$776,000
Subtotal Equipment (A)	$1,352,000	$1,985,000	$2,407,000	$2,360,000	$1,149,000	$2,262,000
Instrumentation (0.10 x A)	$135,000	$199,000	$241,000	$236,000	$115,000	$226,000
Sales Tax (0.08 x A)	$108,000	$159,000	$193,000	$189,000	$92,000	$181,000
Freight (0.05 x A)	$68,000	$99,000	$120,000	$118,000	$57,000	$113,000
Purchased Equipment Cost (PEC)	$1,663,000	$2,442,000	$2,961,000	$2,903,000	$1,413,000	$2,782,000
Direct Installation Costs						
Foundations and Supports (Eichleay Study)	$467,000	$467,000	$467,000	$467,000	$467,000	$467,000
Handling & Erection	$233,000	$342,000	$415,000	$406,000	$198,000	$389,000
Electrical	$67,000	$98,000	$118,000	$116,000	$57,000	$111,000
Piping	$33,000	$49,000	$59,000	$58,000	$28,000	$56,000
Site Prep & Miscellaneous						
Structural Steel Pipeway	$2,532,000	$2,532,000	$2,532,000	$2,532,000	$2,532,000	$2,532,000
Site Prep	$0	$0	$0	$0	$0	$0
CIP System	$0	$0	$0	$0	$0	$0
Electrical Utility	$0	$0	$0	$0	$0	$0
Tank Modifications	$487,000	$487,000	$487,000	$487,000	$487,000	$487,000
Foam Over Control System	$572,000	$572,000	$572,000	$572,000	$572,000	$572,000
Helicopter Use	$977,000	$977,000	$977,000	$977,000	$977,000	$977,000
Total Direct Costs	$7,031,000	$7,966,000	$8,588,000	$8,518,000	$6,731,000	$8,373,000
Indirect Costs						
Engineering	$166,000	$244,000	$296,000	$290,000	$141,000	$278,000
Construction & Field Expenses	$83,000	$122,000	$148,000	$145,000	$71,000	$139,000
Contractor Fees	$166,000	$244,000	$296,000	$290,000	$141,000	$278,000
Start Up	$33,000	$49,000	$59,000	$58,000	$28,000	$56,000
Performance Test	$17,000	$24,000	$30,000	$29,000	$14,000	$28,000
Contingencies	$50,000	$73,000	$89,000	$87,000	$42,000	$83,000
Total Indirect Costs	$515,000	$756,000	$918,000	$899,000	$437,000	$862,000
Total Capital Investment	**$7,546,000**	**$8,722,000**	**$9,506,000**	**$9,417,000**	**$7,168,000**	**$9,235,000**

EPA Cost Model

Table 4 Annual Costs for VOC Control of Red Wine fermentation
Non-Site Specific Cost, No CIP, Managed Vapor Rate Basis

Control Device	**Case 1 Thermal Ox**	**Case 2 Catalytic Oxidizer**	**Case 3 RTO**	**Case 4 Refrigerated Condenser**	**Case 5 Water Scrubber**	**Case 6 Carbon Adsorption**
Total Capital Investment	$7,546,000	$8,722,000	$9,506,000	$9,417,000	$7,168,000	$9,235,000
Direct Annual Costs						
Labor & Materials						
Operating Labor (0.5 hr/shift-unit @ $12.95/hour)	$1,632	$1,632	$1,632	$1,632	$1,632	$1,632
Supervisor (15% of operator cost)	$245	$245	$245	$245	$245	$245
Operating Materials (15% of total maintenance cost)	$490	$490	$490	$28,360	$490	$490
Maintenance Labor (0.5 hr/shift-unit@ $12.95/hour)	$1,632	$1,632	$1,632	$1,632	$1,632	$1,632
Maintenance Materials (100% of maintenance labor)	$1,632	$1,632	$1,632	$1,632	$1,632	$1,632
Utilities						
Natural Gas	$2,210,000	$1,105,000	$110,500	$0	$0	$0
Electricity	$141,800	$141,800	$141,800	$114,700	$114,700	$114,700
Water Disposal	$0	$0	$0	$0	$1,315,000	$0
Total Direct Annual Cost	**$2,357,400**	**$1,252,400**	**$257,900**	**$148,200**	**$1,435,300**	**$120,300**
Indirect Annual Costs						
Overhead (60% of labor & Mat'ls)	$3,400	$3,400	$3,400	$20,100	$3,400	$3,400
Administrative Charges (2% of TCI)	$150,900	$174,400	$190,100	$188,300	$143,400	$184,700
Property Taxes (2% TCI)	$150,900	$174,400	$190,100	$188,300	$143,400	$184,700
Insurance (1% TCI)	$75,500	$87,200	$95,100	$94,200	$71,700	$92,400
Capital Recovery (CRF = 0.163)	$1,230,000	$1,421,700	$1,549,500	$1,535,000	$1,168,400	$1,505,300
Total Indirect Annual Cost	**$1,610,700**	**$1,861,100**	**$2,028,200**	**$2,025,900**	**$1,530,300**	**$1,970,500**
Total Annualized Cost	**$3,968,100**	**$3,113,500**	**$2,286,100**	**$2,174,100**	**$2,965,600**	**$2,090,800**
Emission Reductions						
Annual Average Tank Tunover	10	10	10	10	10	10
Collection & Control Efficiency	86%	86%	86%	81%	81%	86%
Annual Emission Reduction (tons)	130.22	133.60	136.63	129.00	129.00	136.97
Cost Effectiveness $/ton	**$30,500**	**$23,300**	**$16,700**	**$16,900**	**$23,000**	**$15,300**

C. Cost Effectiveness for White Wine Fermentation

1. Estimating Approach and Basis for White Wine

Differences between red and white fermentation with respect to sizing and installation of a VOC control device and to the potential emission reductions which can be achieved are as follows:

- White wine fermentation produces only 2.5 lb of ethanol emission per 1000 gallons fermented versus 6.2 lb per 1000 gallons for red wine.
- White wines are fermented at maximum temperatures of 60 ^oF versus 85 ^oF for red wine.
- Due to the lower temperature and reaction rate for white wine fermentation, vapor flow from a white wine fermenter is substantially reduced relative to a red wine fermenter.
- Due to the much slower fermentation rates for white wine, these tanks are only turned an average of two times per season versus an average of four turns for red wine fermentation.
- Due to lower reaction rates, foam over is not a significant problem for white wine fermenters.

However, as with red wine fermenters, white wine fermenters require a ductwork system for capture and collection of the ethanol emissions and a system for cleaning and sterilization (CIP system). As with red fermenters, they are typically installed in close proximity, lacking plot space for installation of control devices and are not designed to provide structural support for ductwork.

Based on the above a simplified approach, based on the estimates of capital investment and operating cost already developed for red wine, will be employed to examine the potential cost effectiveness of VOC control for white wine fermentation:

- A review of fermentation modeling results presented by Williams and Boulton, showing ethanol concentration and emission rate from fermentation operations at 60 and 85 ^oF, it is estimated that the peak vapor flow rate for fermentation at 60 ^oF is approximately 58% of that for fermentation at 85 ^oF. Based on this, it will be optimistically assumed that a white wine emission control system can be sized for 50% of the size of a red wine control system, given equivalent fermentation tank volume to be controlled. To model this scenario using the capital and operating costs which have been prepared for red wine, the control system scope and sizing for the red wine case will be utilized to reflect white wine fermentation but the connected hypothetical white wine fermentation tankage capacity will be assumed to be twice that of the tankage volume in the red wine case. Therefore the four VOC control systems previously identified for control of red wine emissions at Gallo-Modesto will be assumed to be connected to white wine fermentation tankage of 2 x 6,850,000 = 13,700,000 gallons (nominal capacity).
- It will be optimistically assumed that the collection system ductwork is sufficiently reduced in size such that the steel support structures are not required and that the ductwork can be supported from the tanks or routed on existing steel supports.

Therefore, costs for steel structures and the use of a helicopter for construction will not be included.

- Since white wine does not experience the foaming problems of red wine, it will be assumed that foam over control instrumentation is not required.
- As was assumed in the most optimistic case for red wine, it will be assumed that site specific costs and costs for the CIP system are negligible.
- It will be assumed that water disposal costs for the water scrubber case are proportional to the emission reductions. The value estimated for red wine will be factored down on this basis.
- All other costs, as estimated for the six technology cases for red wine, will be assumed to be the same for white wine.
- To provide the most optimistic evaluation of cost effectiveness, it will be assumed that the white wine tankage is operated at six turnovers per season, three times the industry average throughput for white wine fermentation tanks.

2. Cost Effectiveness Estimates for White Wine Fermentation

Tables 5 and 6 present a “most optimistic” case for control of white wine, based on using the six technologically feasible control device technologies previously identified. Note that these estimates of capital investment and operating costs are the same as presented in Tables 3 and 4 except that costs for structural steel, the foam control system, and helicopter based construction have been deleted. The emission reductions are based on a tankage capacity twice that used for red wine, six tank turns per season, and 2.5 lb-ethanol/1000 gallons.

As shown, “most-optimistic” cost effectiveness estimates range from $18,400 to $52,100 per ton.

3. RACT Selection for White Wine Fermentation

The six cases examined under the most optimistic capital investment scenario yielded a lowest evaluated cost effectiveness of $18,400 per ton for carbon adsorption control technology. Due to the simplifying assumptions and other factors as discussed for red wine, the District’s opinion is that these results significantly understate the true cost effectiveness for control of ethanol emissions from white wine fermentation. The above analysis indicates that there are currently no technologically feasible VOC control technologies which offer a cost effectiveness that is less than EPA’s assumed RACT threshold of $4,400/ton of VOC. Therefore, the District believes that there is no feasible RACT-level control for white wine fermentation.

EPA Cost Model

Table 5 Total Capital Investment (TCI) for VOC Control of White Wine Fermentation
Non-Site Specific, No CIP, Managed Tank Vapor Flow

Control Device	**Case 1** **Thermal Ox** Non-Site Specific, no CIP	**Case 2** **Catalytic Oxidizer** Non-Site Specific, no CIP	**Case 3** **RTO** Non-Site Specific, no CIP	**Case 4** **Refrigerated Condenser** Non-Site Specific, no CIP	**Case 5** **Water Scrub** Non-Site Specific, no CIP	**Case 6** **Carbon Adsorption** Non-Site Specific, no CIP
Direct Costs						
Purchased Equipment Costs						
Control Device	$456,000	$1,089,000	$1,511,000	$1,464,000	$253,000	$1,366,000
Knock Out Vessels	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
Ductwork	$776,000	$776,000	$776,000	$776,000	$776,000	$776,000
Subtotal Equipment (A)	$1,352,000	$1,985,000	$2,407,000	$2,360,000	$1,149,000	$2,262,000
Instrumentation (0.10 x A)	$135,000	$199,000	$241,000	$236,000	$115,000	$226,000
Sales Tax (0.08 x A)	$108,000	$159,000	$193,000	$189,000	$92,000	$181,000
Freight (0.05 x A)	$68,000	$99,000	$120,000	$118,000	$57,000	$113,000
Purchased Equipment Cost (PEC)	$1,663,000	$2,442,000	$2,961,000	$2,903,000	$1,413,000	$2,782,000
Direct Installation Costs						
Foundations and Supports (Eichleay Study)	$467,000	$467,000	$467,000	$467,000	$467,000	$467,000
Handling & Erection	$233,000	$342,000	$415,000	$406,000	$198,000	$389,000
Electrical	$67,000	$98,000	$118,000	$116,000	$57,000	$111,000
Piping	$33,000	$49,000	$59,000	$58,000	$28,000	$56,000
Site Prep & Miscellaneous						
Structural Steel Pipeway	$0	$0	$0	$0	$0	$0
Site Prep	$0	$0	$0	$0	$0	$0
CIP System	$0	$0	$0	$0	$0	$0
Electrical Utility	$0	$0	$0	$0	$0	$0
Tank Modifications	$487,000	$487,000	$487,000	$487,000	$487,000	$487,000
Foam Over Control System	$0	$0	$0	$0	$0	$0
Helicopter Use	$0	$0	$0	$0	$0	$0
Total Direct Costs	$2,950,000	$3,885,000	$4,507,000	$4,437,000	$2,650,000	$4,292,000
Indirect Costs						
Engineering	$166,000	$244,000	$296,000	$290,000	$141,000	$278,000
Construction & Field Expenses	$83,000	$122,000	$148,000	$145,000	$71,000	$139,000
Contractor Fees	$166,000	$244,000	$296,000	$290,000	$141,000	$278,000
Start Up	$33,000	$49,000	$59,000	$58,000	$28,000	$56,000
Performance Test	$17,000	$24,000	$30,000	$29,000	$14,000	$28,000
Contingencies	$50,000	$73,000	$89,000	$87,000	$42,000	$83,000
Total Indirect Costs	$515,000	$756,000	$918,000	$899,000	$437,000	$862,000
Total Capital Investment	**$3,465,000**	**$4,641,000**	**$5,425,000**	**$5,336,000**	**$3,087,000**	**$5,154,000**

EPA Cost Model

Table 6 Annual Costs for VOC Control of White Wine Fermentation
Non-Site Specific, No CIP, Managed Tank Vapor Flow

Control Device	**Case 1** **Thermal Ox** Non-Site Specific, no CIP	**Case 2** **Catalytic Oxidizer** Non-Site Specific, no CIP	**Case 3** **RTO** Non-Site Specific, no CIP	**Case 4** **Refrigerated Condenser** Non-Site Specific, no CIP	**Case 5** **Water Scrubber** Non-Site Specific, no CIP	**Case 6** **Carbon Adsorption** Non-Site Specific, no CIP
Total Capital Investment	$3,465,000	$4,641,000	$5,425,000	$5,336,000	$3,087,000	$5,154,000
Direct Annual Costs						
Labor & Materials						
Operating Labor (0.5 hr/shift-unit @ $12.95/hour)	$1,632	$1,632	$1,632	$1,632	$1,632	$1,632
Supervisor (15% of operator cost)	$245	$245	$245	$245	$245	$245
Operating Materials (15% of total maintenance cost)	$490	$490	$490	$28,360	$490	$490
Maintenance Labor (0.5 hr/shift-unit@ $12.95/hour)	$1,632	$1,632	$1,632	$1,632	$1,632	$1,632
Maintenance Materials (100% of maintenance labor)	$1,632	$1,632	$1,632	$1,632	$1,632	$1,632
Utilities						
Natural Gas	$2,210,000	$1,105,000	$110,500	$0	$0	$0
Electricity	$141,800	$141,800	$141,800	$114,700	$114,700	$114,700
Water Disposal	$0	$0	$0	$0	$631,200	$0
Total Direct Annual Cost	**$2,357,400**	**$1,252,400**	**$257,900**	**$148,200**	**$751,500**	**$120,300**
Indirect Annual Costs						
Overhead (60% of labor & Mat'ls)	$3,400	$3,400	$3,400	$20,100	$3,400	$3,400
Administrative Charges (2% of TCI)	$69,300	$92,800	$108,500	$106,700	$61,700	$103,100
Property Taxes (2% TCI)	$69,300	$92,800	$108,500	$106,700	$61,700	$103,100
Insurance (1% TCI)	$34,700	$46,400	$54,300	$53,400	$30,900	$51,500
Capital Recovery (CRF = 0.163)	$564,800	$756,500	$884,300	$869,800	$503,200	$840,100
Total Indirect Annual Cost	**$741,500**	**$991,900**	**$1,159,000**	**$1,156,700**	**$660,900**	**$1,101,200**
Total Annualized Cost	**$3,098,900**	**$2,244,300**	**$1,416,900**	**$1,304,900**	**$1,412,400**	**$1,221,500**
Emission Reductions						
Annual Average Tank Tunover	6	6	6	6	6	6
Collection & Control Efficiency	86%	86%	86%	81%	81%	86%
Annual Emission Reduction (tons)	59.53	62.90	65.94	62.42	62.42	66.27
Cost Effectiveness $/ton	**$52,100**	**$35,700**	**$21,500**	**$20,900**	**$22,600**	**$18,400**

V. Cost effectiveness and RACT Determination for Control of Ethanol Emissions from Wine Storage

A. Emission Control Technology for Control of Emissions from Wine Storage

1. Background

Wine storage tanks perform two functions in the winery:

- Facilitation of post-fermentation processing operations such as racking, filtration, malolactic fermentation and bottling. In this role, the typical storage tank is filled and emptied several times per year and functions as a process vessel.
- Storage of wine between processing operations up to the final operation of bottling. In this role, the objective is to avoid oxidation of the wine by both minimizing the wine temperature and the exposure of the wine to air.

Emissions from storage tanks consist of both working losses and breathing losses. The former losses occur as a result of the displacement of the vapor space of the tank into the atmosphere as a result of tank filling operations and is primarily a function of tank throughput and the temperature and ethanol content of the wine. Breathing losses are the result of diurnal heating and cooling caused by the effect of atmospheric conditions on the contents of the tank. For a well-insulated tank, breathing losses will be negligible.

After fermentation, wine is transferred a number of times between storage tanks to perform various finishing operations such as “racking” (decantation for separation of sediment), filtration, malolactic fermentation (breakdown of malic acid to lactic acid and carbon dioxide), and bottling operations. Since the bottling process is a year-round operation, each batch of wine will have a definite residence time in storage, before bottling, which includes the time spent in performing the various post-fermentation finishing processes. The post-fermentation operations result in “working losses” from the storage tanks since they require draining and filling the tanks several times. Storage before bottling generates “breathing losses” from the tanks.

The District has prepared a BACT guideline for wine storage tanks (Guideline 4.12.8). Guideline 4.12.8 establishes the installation of insulation and a pressure/vacuum valve set within 10% of the maximum allowable working pressure of the tank, “gas tight” tank operation and maintenance of a continuous storage temperature not exceeding 75 ^{o}F within 60 days of completion of fermentation as “achieved in practice”. The following capture and control options are also identified as technologically feasible:

- Refrigeration of wine or equivalent
- Capture of VOCs and thermal or catalytic oxidation or equivalent
- Capture of VOCs and carbon adsorption or equivalent
- Capture of VOCs and absorption or equivalent (water scrubber)
- Capture of VOCs and condensation or equivalent (refrigerated condenser)

The US EPA's RACT/BACT/LAER contains no examples of controlling wine storage tank emissions. Additional literature searches produced no examples of wine storage tank emission control being implemented worldwide.

2. Pressure/Vacuum Valves on Wine Storage Tanks w/ "Gas Tight" Operation

VOCs (ethanol) are emitted from the storage tanks as a result of both working losses (which occur when the liquid level in the tank changes) and breathing losses (expansion and contraction effects due to temperature variations). The proposed pressure/vacuum valve limits these emissions by requiring the maximum amount of variation in tank pressure before allowing the tank to vent to the atmosphere or allowing air admission to the tank. These valves are in common use in this application in the industry for purposes of minimizing contact of the wine with oxygen to preserve product quality.

3. Storage Tank Insulation

Application of insulation to a storage tank isolates the contents from the impact of diurnal heating and cooling cycles due to sunlight and atmospheric conditions and minimizes the resulting breathing losses from the tank. Insulation is commonly applied to wine storage tanks in conjunction with refrigeration of the tank to maintain the wine contents below 40 ^{o}F during storage to preserve wine quality. As mentioned previously, breathing losses are considered negligible for a well insulated tank.

4. Refrigerated Storage (Temperature Control)

As mentioned, refrigeration is commonly employed in conjunction with tank insulation for purposes of preserving product quality during long term storage. Maintaining the wine at a reduced temperature lowers the volatility of the ethanol and thus reduces the emissions from working losses and essentially eliminates breathing losses. Since the majority of the storage tank emissions result from working losses associated with wine transfer operations rather than with tank breathing losses, the most effective utilization of refrigeration requires that the fermented must be cooled immediately after fermentation, prior to transfer operations such as racking and clarification.

4. Capture and Control

The balance of the identified technologically feasible controls consist of capture and control technologies and have been previously discussed in this document under wine fermentation. The general discussion previously presented is applicable to wine storage as well. However, application of each of the technologies to wine storage is based on maintaining the tank in a "gas tight" condition, connected to the control device via ducting, and therefore the District considers that the capture efficiency associated with each technology is 100%. Therefore, based on the previous discussion, the capture and control systems are considered to have the following overall emission control efficiencies:

Capture of VOCs and thermal or catalytic oxidation: 95% control

Capture of VOCs and carbon adsorption: 95% control

Capture of VOCs and water scrubber: 90% control

Capture of VOCs and refrigerated condenser: 90% control

B. Cost Effectiveness Analysis

1. Approach for Cost Effectiveness

The following cases will be examined for cost effectiveness for control of wine storage tank emissions::

Case 1 Pressure/Vacuum Valve with "Gas Tight" Tank Operation

Case 2 Storage Tank Insulation

Case 3 Storage Tank Refrigeration (with Insulation)

Case 4 Thermal oxidation with 0% heat recovery (low capital/high operating cost)

Case 5 Catalytic oxidation with 50% heat recovery (mid range capital/mid range operating cost)

Case 6 Regenerative thermal oxidation with 95% heat recovery (high capital/low operating cost)

Case 7 Refrigerated Condenser

Case 8 Water scrubber

Case 9 Carbon adsorption

The approach of the cost effectiveness analysis will be to first determine which, if any, of the above cases potentially qualifies as RACT based on having a potential cost effectiveness below the EPA's assumed RACT threshold of $4,400/ton of VOC. All cases which are shown to have a cost effectiveness higher than $4,400/ton will be discarded. Cases which fall below the threshold will then be further examined and compared with respect to relative cost effectiveness, technical risk, reasonableness, and socio-economic impact to determine which, if any, qualify as RACT for wine storage tanks.

To establish a comparative physical scope of each of the above cases, the District's approach is based on applying the nine different control technologies to a hypothetical 650,000 gallon storage tank (43' diameter x 60 feet tall) located in Fresno, CA. For options controlling multiple tanks, a hypothetical assembly of eight (8) 650,000 gallon capacity tanks aligned in two groups of 4 on either side of a common pipeway. The rationale for this is based on the following:

- A 650,000 gallon tank is representative of the largest storage tanks currently in use in the San Joaquin Valley. Due to economy of scale, it can be assumed that applying controls to this size of tank will provide the most optimistic cost effectiveness and that all smaller tanks, equipped with the same controls, will be less cost effective.
- Fresno is centrally located in the valley and provides a reasonable basis for average atmospheric conditions.
- An assemblage of eight tanks grouped along a pipeway is a reasonably common yet generic arrangement for wine storage tanks and provides significant total storage capacity for economy of scale with respect to controls. Cost effectiveness based on this configuration should provide an optimistic assessment of cost effectiveness relative to the average storage tank installation in the San Joaquin Valley. Larger

assemblages of tanks of this size could result in significant increases in collection manifold sizes and elevations due to combining flows from large numbers of tanks and to the sloping requirements for installation of free-draining ductwork.

2. Estimating Approach and Basis

The approach for cost effectiveness determination will be based on the following elements:

- Cases 1-3 are process modifications rather than installation of emission controls. A simplified cost effectiveness for these cases was calculated based on only a direct cost of certain major components of the scope to demonstrate that the proposed process modification exceeds the cost effectiveness threshold for RACT.
- EPA's cost model for VOC incineration systems, as presented in the EPA Control Cost Manual, Section 3.2, Tables 2.8 and 2.9, was used for all capture and control cases with the exception of the refrigerated condenser (case 7) estimate which used Section 3.1, Table 2.3 for Total Capital Investment (note also that the EPA cost model was adjusted to a California location by taking sales tax at 8% rather than 3%).
- All estimates are based on the model 650,000 gallon capacity storage tank (43' dia. x 60' tall).
- All capture and control cases (cases 4-9) are assumed to be manifolded together to a common control device based on a tank battery of eight (8) 650,000 gallon tanks.
- Potential uncontrolled emissions from each model storage tank have been determined to be 947 lb-ethanol/year based on simulation of a 650,000 gallon uninsulated tank containing wine with 13.9 % ethanol and which experiences 6 turnovers per season[15]. Tank simulation was performed using the TANKS 4.0 program, setting the pressure/vacuum valve setting to zero to simulate tank operation without a valve.
- Control device capacity for cases 4-9 is 1450 scfm based air displacement from the tanks during filling operations and upon an assumed pumping capability to fill a storage tank in a single 8-hour shift. It is assumed that all eight tanks can possibly fill at the same time.
- Each capture and control case is assumed to have the same requirements for the collection system consisting of ducting which connects all eight tanks to a common manifold which, in turn, connects to a knock out vessel located just upstream of the control device. The minimum scope of the collection system was determined to be:
  - Tank modifications to add a new vent nozzle on each tank
  - Installation of 60 feet of 6' dia. stainless steel ducting from each tank to the central manifold (total of 480 linear feet)
  - Installation of a 10" dia. stainless steel central manifold ducting (250 linear feet)
  - Installation of a knock out pot upstream of the control device

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[15] Average storage tank turnovers of six per year is based on conversation with Bob Calvin of Constellation Wine and is corroborated by Authority to Construct applications received to date by the District for new wine storage tanks.

- It was optimistically assumed that the cost of structural supports and of the clean-in-place (CIP) system for cleaning and sterilization of the ductwork would be negligible.
- Purchased costs for ducting were taken from the EPA Control Cost Manual, Section 2, Chapter 1 and corrected to last quarter 2006 by assuming average 3% annual inflation. An allowance of $5,000 was used for the knock out vessel and an allowance of $2000 per tank was used for the tank modifications to add a vent nozzle.
- Potential site specific costs such as site preparation, electric utility expansion and natural gas utility expansion were optimistically ignored.
- Total Capital Investment was annualized based on a 10 year equipment life and a 10% opportunity cost for capital (CRF = 0.163).
- Electric power costs were considered only for the induced draft fan required to deliver the 1450 cfm combined vent from the tanks through the control device and to the vent stack (assumed to be the same for all cases). Power costs for refrigeration and for regeneration of activated carbon were optimistically ignored.
- Pricing for natural gas and electricity were applied at $0.61/therm and $0.12/kwh based on the Eichleay study for fermentation control for Gallo's Modesto winery.

3. Cost Effectiveness Analysis for Wine Storage Tanks

Case 1 - Pressure/Vacuum Valve

The 650,000 gallon storage tank model (TANKS 4.0) was revised to include a pressure/vacuum valve using default pressure and vacuum settings of 0.03 psig per TANKS 4.0. The resulting simulation indicated that breathing losses from a single tank were reduced from 387 lb/year to 373 lb/year for a net reduction in breathing loss of 14 lb/year with an ethanol content of 53.7 wt%. This yields a negligible emission reduction of only 8 lb/yr, or 0.004 tons/year. Working losses were not affected as would be expected.

Assuming a de minimus investment cost of $5000 to install a flanged nozzle on the stainless steel storage tank and to purchase and install a pressure/vacuum valve and associated stainless steel piping yields an annualized investment of 0.163 x $5000 = $815/year. Cost effectiveness of the pressure/vacuum valve will thus be on the order of $815/0.004 = $204,000/ton.

Case 2 - Storage Tank Insulation

To evaluate the potential effectiveness of insulation in controlling ethanol emissions from wine storage tanks, it was optimistically assumed that the tank insulation value is high enough to effectively eliminate the impact of changing ambient conditions, such that the tank contents stays at a uniform annual average temperature throughout the year. The net result of this assumption is that breathing losses from the tank are negligible. It is also assumed that the tank is equipped with a pressure/vacuum valve since this is a common practice in the industry for quality control reasons. With a pressure vacuum valve in place, the elimination of all breathing losses would potentially result in a reduction in tank losses of 373 lb/year, equivalent to 200 lb-ethanol/year (0.10 tons/year).

The cost to insulate a new 43' dia. x 60 ft tall, 650,000 gallon tank during initial construction is estimated at $131,900 based on an installed insulation cost[16] of $16.21per square foot. Note that insulation costs for insulating existing storage tanks would be considerably higher since an existing tank may require structural modifications to support the weight of the insulation and would require scaffolding of the tank to perform the installation (scaffolding is used for general construction of a new tank and the scaffolding cost would therefore is not be directly attributable to the installation of insulation in the case of new tank construction). Annualized direct cost of insulation on a new tank is thus 0.163 x $132,000 = $21,500/year. Cost effectiveness of insulation, based only on the initial investment for insulation is determined to be $21,500/(0.10 tons/year) = $215,000/ton.

Case 3 - Refrigerated Storage

Based on simulations with TANKS 4.0, maintaining a controlled 40 ^{o}F storage temperature on wine with 13.9% ethanol in a 650,000 gallon tank reduces ethanol emissions by 758 lb/year (0.38 tons per year) relative to an uninsulated and unrefrigerated tank, equipped with a pressure/vacuum valve at a Fresno, CA location.

To evaluate the potential cost effectiveness of 40 ^{o}F refrigerated storage in controlling ethanol emissions from wine storage tanks, capital investment requirements are based on applying insulation to a 650,000 gallon tank plus installation of purchased refrigeration capacity of 21 tons[17]. Using the estimate of insulation cost developed above and adding the bare purchase price of a 21 ton refrigeration unit (based on EPA Control Cost Manual, Section 3.1, Figure 2.5, the investment (2006) for a 650,000 gallon tank would be:

Insulation (not including tank mods or scaffolding) =	$132,000
Purchase price for 21 ton refrigeration (no installation cost included) =	$112,000
Total Cost =	$244,000

Optimistically ignoring both the installation costs for the refrigeration and the annual cost associated with operations and maintenance, annualized direct cost of refrigeration plus insulation on a new tank is thus 0.163 x $244,000 = $39,700/year and the cost effectiveness would be estimated at $39,700/0.38 = $105,000/ton.

Collection and Control Cases:

Table 7 presents the development of Total Capital Investment for all cases and Table 8 presents the annual costs, emission reductions, and cost effectiveness for each collection and control case. Discussion of each case follows:

Case 4 - Collection and Control with a Thermal Oxidizer

Capital investment for this case as well as all remaining capture and control cases is presented in 7. Annual costs, emission reductions and calculated cost effectiveness are presented in Table 8. The selected thermal oxidizer for this case was priced from the EPA

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[16] Information provided by T. Vitali of O'Neal Beverages (2006) for 3" thick spay-on urethane foam insulation on the tank walls and 9" thick urethane foam on the roof, based on actual insulation costs for new 190,000 gallon tanks at the O'Neal Winery in Parlier.

[17] 0.032 tons per 1000 gallons of insulated storage capacity based on estimated capacity requirements supplied by Tom Vitiali at O'Neal Beverages.

Control Cost Manual, Section 3.2, Figure 2.4, based on a 1,450 scfm unit with 0% energy recovery. As such, it represents a minimum capital investment scenario for use of a thermal oxidizer. The price from Figure 2.4 (1990 dollars) was adjusted to 2006 dollars based on average annual inflation of 3%.

The emission reduction for this case is:

8 tanks x 947 lb-ethanol/tank x 1 ton/2000 lb x 95% = 3.60 tons-ethanol/year.

Annual fuel cost for this case was calculated based on heating the 1,450 scfm to 1,500 ^{o}F with no heat recovery but allowing a 50% reduction from the theoretical fuel consumption based on using a variable frequency drive on the ID fan, allowing turn down of the unit. With an expected collection and control efficiency of 95%, cost effectiveness of this control option is optimistically estimated at $75,700 per ton.

Case 5 - Collection and Control with a Catalytic Oxidizer

The catalytic oxidizer for this case was priced from the EPA Control Cost Manual, Section 3.2, Figure 2.6, based on a 1,450 scfm unit with 50% energy recovery. As such, it represents a mid range capital investment scenario for use of oxidizer technology. The price from Figure 2.4 (1990 dollars) was adjusted to 2006 dollars based on average annual inflation of 3%.

The emission reduction for this case is:

8 tanks x 947 lb-ethanol/tank x 1 ton/2000 lb x 95% = 3.60 tons-ethanol/year.

Annual fuel cost for this case was calculated based on heating the 1,450 scfm to 600 ^{o}F with a 50% reduction for heat recovery and another 50% reduction for turndown capability based on using a variable frequency drive on the ID fan. With an expected collection and control efficiency of 95%, cost effectiveness of this control option is optimistically estimated at $51,200 per ton.

Case 6 - Collection and Control with a Regenerative Thermal Oxidizer (RTO)

The regenerative thermal oxidizer for this case was priced based on vendor quotations from the STI wine fermentation study for RTO's with capacities of 500 scfm and 5000 scfm. These prices were interpolated to determine the price of a 1,450 scfm unit. RTO's typically have an energy efficiency of approximately 95% and, as such, this case represents a maximum capital investment scenario for use of a thermal oxidizer. The price derived from the STI data (2003 dollars) was adjusted to 2006 dollars based on average annual inflation of 3%.

The emission reduction for this case is:

8 tanks x 947 lb-ethanol/tank x 1 ton/2000 lb x 95% = 3.60 tons-ethanol/year.

Annual fuel cost for this case was calculated based on heating the 1,450 scfm to 1,500 ^{0}F with 95% heat recovery. With an expected collection and control efficiency of 95%, cost effectiveness of this control option is optimistically estimated at $58,500 per ton.

Case 7 - Collection and Control with a Refrigerated Condenser

It was assumed that the refrigerated condenser would operate at a condensing temperature of –12 ^{o}F and achieve a 90% collection and control based on the TAD. The refrigerated condenser duty for this case was determined to be 9.6 tons of refrigeration and was priced based on the EPA Control Cost Manual, Section 3.1, Figure 2.5, based on a –20 ^{o}F refrigerant condensing temperature. The price from Figure 2.5 (1990 dollars) was adjusted to 2006 dollars based on average annual inflation of 3%.

The emission reduction for this case is:

8 tanks x 947 lb-ethanol/tank x 1 ton/2000 lb x 90% = 3.41 tons-ethanol/year.

Electric power costs for operation of the refrigeration were ignored in the analysis.

With an expected collection and control efficiency of 90% per the TAD, cost effectiveness of this control option is optimistically estimated at $83,800 per ton.

Case 8 - Collection and Control with a Water Scrubber

The selected water scrubber for this case was priced based on vendor quotations obtained from the STI study for scrubbers with capacities of 500 scfm and 5000 scfm. These prices were interpolated to determine the price of a 1,450 scfm unit. The price derived from the STI data (2003 dollars) was adjusted to 2006 dollars based on average annual inflation of 3%.

The emission reduction for this case is:

8 tanks x 947 lb-ethanol/tank x 1 ton/2000 lb x 90% = 3.41 tons-ethanol/year.

Costs for disposal of ethanol-laden water from operation of the scrubber were not included in the analysis.

With an assumed collection and control efficiency of 95%, cost effectiveness of this control option is optimistically estimated at $38,000 per ton.

Case 9 - Collection and Control with Carbon Adsorption

The selected water scrubber for this case was priced based on pricing presented in the TAD for activated carbon adsorption systems including carbon canisters, blower, and regeneration system. Prices from the TAD were interpolated to determine the price of a 1,450 scfm unit. The price derived from the TAD (1991 dollars) was adjusted to 2006 dollars based on average annual inflation of 3%.

The emission reduction for this case is:

8 tanks x 947 lb-ethanol/tank x 1 ton/2000 lb x 95% = 3.60 tons-ethanol/year

Utility costs for operation of the carbon regeneration system were not included in the analysis. With an expected collection and control efficiency of 95%, cost effectiveness of this control option is optimistically estimated at $70,000 per ton.

4. RACT Selection for Wine Storage Tanks

The nine cases examined under an optimistic capital investment scenario yielded evaluated cost effectiveness ranging from $38,000 per ton for water scrubber control technology to $75,700 per ton a thermal oxidizer without heat recovery. For reasons already discussed, these evaluated cost effectiveness are artificially low. Factors making these evaluated costs optimistically low include:

- It was assumed that the cost of engineered structures to support the ductwork would be negligible.
- It was assumed that the cost of the CIP system was negligible.
- Cases 1 through 3 based the capital investment on only the purchase cost of the equipment or the direct cost of a major element. Other significant direct cost and all the indirect costs were ignored.
- Site specific costs for site preparation, electricity or fuel gas supply were ignored.
- Utility costs for refrigeration, carbon regeneration, water disposal, and waste stream handling were ignored.
- The EPA cost model only applies factors for engineering, construction and field expense, contractor fees and contingency to the purchased equipment costs rather than the total direct cost. Since other direct costs such as foundations and supports, electrical and piping all have a substantial indirect cost, these costs are ignored in this evaluation. Standard practice in the engineering and construction industry for a factored estimate of this type is to apply indirect cost factors to the total direct cost.
- EPA cost model factors for engineering, construction and field expenses and contingency are low relative to typical experience and practice in the engineering and construction industry for industrial construction of this type. Engineering costs and construction and field expense are each more typically 10-20%, of total direct cost. Industry practice would consider an estimate of this type to have an accuracy of no better than ± 25%. Based on this, industry practice is to set contingency at 15-20% of total direct cost as a minimum.

The above analysis indicates that there are currently no feasible VOC control technologies which offer a cost effectiveness less than EPA’s assumed threshold of $4,400 per ton. Therefore, there is no feasible RACT-level control exist for wine storage tanks.

EPA Cost Model

Table 7 Total Capital Investment for VOC Control on Wine Storage Tanks
Non-Site Specific, No CIP (Cases 4 through 9)

Control Device	**Case 4** **Thermal Ox** Assume CIP Cost Negligible	**Case 5** **Catalytic Ox.** Assume CIP Cost Negligible	**Case 6** **RTO** Assume CIP Cost Negligible	**Case 7** **Refrigerated Condenser** Assume CIP Cost Negligible	**Case 8** **Water Scrubber** Assume CIP Cost Negligible	**Case 9** **Carbon Adsorption** Assume CIP Cost Negligible
Direct Costs						
Purchased Equipment Costs						
Control Device	$55,000	$77,300	$140,400	$260,500	$30,300	$210,800
Knock Out Vessels	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Ductwork	$88,400	$88,400	$88,400	$88,400	$88,400	$88,400
Subtotal Equipment	$148,400	$170,700	$233,800	$353,900	$123,700	$304,200
Instrumentation	$14,800	$17,100	$23,400	$35,400	$12,400	$30,400
Sales Tax	$11,900	$13,700	$18,700	$28,300	$9,900	$24,300
Freight	$7,400	$8,500	$11,700	$17,700	$6,200	$15,200
Purchased Equipment Cost (PEC)	$182,500	$210,000	$287,600	$435,300	$152,200	$374,100
Direct Installation Costs						
Foundations and Supports	$14,600	$16,800	$23,000	$34,800	$12,200	$29,900
Handling & Erection	$25,600	$29,400	$40,300	$60,900	$21,300	$52,400
Electrical	$7,300	$8,400	$11,500	$17,400	$6,100	$15,000
Piping	$3,700	$4,200	$5,800	$8,700	$3,000	$7,500
Site Prep & Miscellaneous						
Site Prep	$0	$0	$0	$0	$0	$0
CIP System	$0	$0	$0	$0	$0	$0
Electrical Utility	$0	$0	$0	$0	$0	$0
Tank Modifications	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000
Total Direct Costs	$249,700	$284,800	$384,200	$573,100	$210,800	$494,900
Indirect Costs						
Engineering	$18,300	$21,000	$28,800	$43,500	$15,200	$37,400
Construction & Field Expenses	$9,100	$10,500	$14,400	$21,800	$7,600	$18,700
Contractor Fees	$18,300	$21,000	$28,800	$43,500	$15,200	$37,400
Start Up	$3,700	$4,200	$5,800	$8,700	$3,000	$7,500
Performance Test	$1,800	$2,100	$2,900	$4,400	$1,500	$3,700
Contingencies	$5,500	$6,300	$8,600	$13,100	$4,600	$11,200
Total Indirect Costs	$56,700	$65,100	$89,300	$135,000	$47,100	$115,900
Total Capital Investment	**$488,900**	**$559,900**	**$761,100**	**$1,143,400**	**$410,100**	**$984,900**

EPA Cost Model

Table 8 Annual Costs for VOC Control on Wine Storage Tanks
Non-Site Specific, No CIP (Cases 4 through 9)

Control Device	**Case 4 Thermal Ox**	**Case 5 Catalytic Ox.**	**Case 6 RTO**	**Case 7 Refrigerated Condenser**	**Case 8 Water Scrubber**	**Case 9 Carbon Adsorption**
Total Capital Investment	$488,900	$559,900	$761,100	$1,143,400	$410,100	$984,900
Direct Annual Costs						
Labor & Materials						
Operating Labor (0.5 hr/shift-unit @ $12.95/hour)	$7,100	$7,100	$7,100	$7,100	$7,100	$7,100
Supervisor (15% of operator cost)	$1,100	$1,100	$1,100	$1,100	$1,100	$1,100
Operating Materials (15% of total maintenance cost)	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100
Maintenance Labor (0.5 hr/shift-unit@ $12.95/hour)	$7,100	$7,100	$7,100	$7,100	$7,100	$7,100
Maintenance Materials (100% of maintenance labor)	$7,100	$7,100	$7,100	$7,100	$7,100	$7,100
Total Labor & Materials	$24,500	$24,500	$24,500	$24,500	$24,500	$24,500
Utilities						
Natural Gas	$126,000	$22,700	$6,300	$0	$0	$0
Electricity	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000
Water Disposal	$0	$0	$0	$0	$0	$0
Total Direct Annual Cost	**$153,500**	**$50,200**	**$33,800**	**$27,500**	**$27,500**	**$27,500**
Indirect Annual Costs						
Overhead (60% of labor & Mat'ls)	$14,700	$14,700	$14,700	$14,700	$14,700	$14,700
Administrative Charges (2% of TCI)	$9,800	$11,200	$15,200	$22,900	$8,200	$19,700
Property Taxes (2% TCI)	$9,800	$11,200	$15,200	$22,900	$8,200	$19,700
Insurance (1% TCI)	$4,900	$5,600	$7,600	$11,400	$4,100	$9,800
Capital Recovery (CRF = 0.163)	$79,700	$91,300	$124,100	$186,400	$66,800	$160,500
Total Indirect Annual Cost	**$118,900**	**$134,000**	**$176,800**	**$258,300**	**$102,000**	**$224,400**
Total Annualized Cost	**$272,400**	**$184,200**	**$210,600**	**$285,800**	**$129,500**	**$251,900**
Emission Reductions	3.60	3.60	3.60	3.41	3.41	3.60
Cost Effectiveness $/ton	**$75,700**	**$51,200**	**$58,500**	**$83,800**	**$38,000**	**$70,000**

VI. Cost Effectiveness and RACT Determination for Brandy Aging

A. Emission Control Technology For Control of Ethanol Emissions From Brandy Aging

1. Background

Brandy is prepared by distilling fermented grape juice and then aging the distilled product in wooden casks (usually oak) which colors it, mellows the palate, and adds additional aromas and flavors. The changes which occur during the aging process are the result of interactions between the aging brandy and the oak barrel, driven by the conditions of the surrounding atmosphere which may have both diurnal and seasonal variation. Both ethanol and water evaporate from the surface of the barrel during the aging process with the rate of evaporation (and the style of the brandy) depending upon both the porosity of the barrel and the atmospheric conditions of the storage among other factors.

In the typical aging operation, the freshly distilled brandy is transferred to tankage where the proof is adjusted to approximately 100-120 proof by addition of water and then transferred to a gauging tank which is equipped with instrumentation to accurately determine the volume of the contents. The brandy is then transferred by batch into “lots” of oak barrels. The amount of brandy transferred into a “lot” of barrels is determined based on the difference between the starting and the ending volume of brandy in the gauging tank. The volume so determined is then corrected for temperature and proof content, using methods specified by the Alcohol and Tobacco Tax and Trade Bureau (TTB), U.S. Department of Treasury, to determine the number of proof-gallons transferred into the “lot” of barrels (a proof-gallon is one gallon of 100 proof brandy at 60 ^{o}F). The “lot” of barrels is then placed into a warehouse for an average aging period of 2-3 years.

After completion of the required aging period, the barrels are removed from the warehouse by “lot” and dumped into a gauging tank to determine the residual volume and proof in the “lot” of barrels. The result is corrected for temperature and proof to yield the number of residual proof-gallons in the “lot”. The difference between the proof-gallons filled and the residual proof-gallons is the loss to the atmosphere and is reported as proof-gallons lost per barrel-year. The filling and dumping of barrels to and from storage is rigidly controlled, metered, and reported for tax purposes, using the methods specified by the TTB. Depending upon aging practices, warehouse construction and site specific conditions, annual brandy losses may vary between 1.5 and 4.5 proof gallons per barrel, equivalent to a range of approximately 5 to 15 lb-ethanol/year-barrel.

The US EPA’s RACT/BACT/LAER Clearinghouse (RBLC) database contains case-specific information on the "Best Available" air pollution technologies that have been required to reduce the emission of air pollutants from stationary sources (e.g., power plants, steel mills, chemical plants, etc.). This information has been provided by State and local permitting agencies. The RBLC contains no examples of controlling brandy aging emissions. Additional literature searches produced no examples of brandy aging emission control being implemented worldwide.

The District has issued an Authority to Construct permit for one brandy aging facility which has been proposed for purposes of generating Certified Emission Reductions (CER’s) to offset required wine fermentation emission reductions required pursuant to the

District's Rule 4694, *Wine Fermentation and Storage Tanks*. The proposed facility will modify an existing brandy storage warehouse to capture ethanol emissions and destroy them using regenerative thermal oxidizer technology. However, the provisions of the permit requiring operation of the capture and control system are provisional, based upon successful demonstration that operation of the controls does not result in unacceptable impacts on brandy quality or consistency.

A review of the emission mechanism for brandy aging and of the established VOC control technologies indicates that the following would be potentially applicable to the control of ethanol emissions from brandy aging operations:

1. Oxidation (conversion of the VOC to CO_2);

2. Absorption ("scrubbers", which transfer the VOC in air emissions to a liquid waste stream);

3. Adsorption (often using activated carbon, which transfers the VOC in the air onto a solid substrate);

4. Condensation (conversion of the VOC gases into liquids); and

7. Biological control systems (e.g., bio-filters or bio-scrubbers)

8. Modification of the aging warehouse and/or the aging operation to reduce the evaporative ethanol emissions.

Review of the identified control technologies above indicates that options 1 through 5 are all classified as capture and control systems and therefore all share a common requirement for a capture system. Since the capture system is common to these options, issues regarding the installation of such a system on a brandy aging operation are also common and will thus be considered independent of the control technology selected.

Each of the identified technologies, the common capture system and their potential application to brandy aging is discussed in the following:

2. Emissions Capture System

The brandy storage warehouse functions as an enclosure from which the ethanol emissions can be captured. The capture efficiency is primarily a function of the configuration of this structure. Since such a structure can be sealed and ventilated to a control device such that it qualifies as a "Total Enclosure" pursuant to U.S. EPA Method 204, the theoretical capture efficiency would be considered to be 100%. However, since the brandy storage operation (and its emissions) is a continuous 24 hour/day operation throughout the year, it would be difficult and expensive to continuously maintain the warehouse in "Total Enclosure" status due to on-going requirements to transport product into and out of the warehouse and to requirements for maintenance during which the warehouse must be opened or the control device must be shut down. During such periods, uncontrolled emissions are delivered to the atmosphere in the absence of expensive air lock systems and/or redundant control devices.

Based upon information supplied by industry, the District has determined that warehouse enclosures can potentially achieve a capture efficiency of 90% based on a warehouse designed to EPA Method 204 criteria for a "Total Enclosure" and appropriate allowances for time periods during which the enclosure does not qualify under Method 204 due to operational and maintenance issues.

3. Thermal Oxidation (Incineration)

A thermal oxidizer (TO) destroys VOCs by the process of combustion. A basic TO system consists of a combustion chamber, burner, stack, and combustion controls. All hydrocarbons are oxidized to carbon dioxide and water vapor by the proper mix of temperature, residence time and turbulence within the reactor chamber. Combustion of the contaminated gas stream occurs at high temperatures, normally 650^{o}C to 870^{o}C (1,200^{o}F to 1,600^{o}F) when treating low concentration streams. Recent guarantees provided by TO vendors for destruction of ethanol in air in other proposed projects under review by the District have been based on a minimum combustor temperature of 1,500^{o}F.

TO systems can be divided into recuperative or regenerative systems, based on methods used to increase operating efficiencies by capturing heat from the combustion process. Recuperative TO systems increase fuel efficiency by use of a gas pre-heating section and a heat recovery section. Heat recovery can be as high as 70%. A regenerative system provides extremely high thermal-energy recovery; up to 95% of heat energy can be recovered. Regenerative TO systems use a ceramic heat-exchange bed to preheat process air to within 5% of the oxidation temperature.

VOC conversion efficiencies range from 95% to 99.9% for TO systems. However, the combustion of supplemental fuel for the oxidation step (the amount depending upon the fuel value of the VOC and the level of heat recovery employed) produces NOx, an ozone precursor like VOC, thus offsetting some of the VOC emission reduction. The District considers thermal oxidation as technologically feasible for application to brandy storage and that a control efficiency of 95% is reasonably achievable which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 86% for this technology.

4. Catalytic Thermal Oxidation

A catalytic thermal oxidizer (CTO) is essentially a thermal oxidation unit with a catalyst module. These units are similar in design to recuperative units, except that VOCs are oxidized using precious metal or metal-oxide-based catalysts instead of high temperature. Operating at about half the temperature of thermal oxidizers, catalytic units have smaller footprints and may offer lower operating costs in certain circumstances. Since catalyst are employed, they are subject to catalyst poisoning or deactivation due to operating upset and may require periodic catalyst replacement which represents a substantial operating cost.

Other industries have demonstrated typical VOC removal efficiencies of up to 98%. The District considers catalytic thermal oxidation as technologically feasible for application to brandy storage and that a control efficiency of 95% is reasonably achievable which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 86% for this technology.

5. Adsorption Vapor Recovery

Adsorption vapor recovery is accomplished by passing the VOC-laden gas through beds containing adsorbents that have a high surface area to weight ratio. Typical adsorbents are activated carbon, zeolite, or organic polymers. As the gas stream passes through the bed, organic compounds adsorb weakly onto the adsorbent's surface. Adsorption of the hydrocarbon molecules proceeds until the available surface area is filled or saturated with VOC molecules. The VOC molecules are retained until the regeneration step, or disposal of the spent adsorbent.

Desorbing or removing captured VOCs regenerates the adsorbent. Decreasing the pressure, reducing the hydrocarbon concentration around the adsorbent or increasing the temperature of the bed can perform regeneration. A combination of these steps can also be used for regeneration. There are three basic types of adsorption systems available to recover or remove hydrocarbon vapors from an air stream. Two of these systems regenerate the adsorbent in-situ for reuse. The third system requires removal of the adsorbent to another site for regeneration.

The two systems that provide in-situ regeneration are: Pressure Swing Regenerated Systems and Thermally Regenerated Systems (or a combination of the two methods). Since the net result of the combined adsorption and regeneration process only results in transfer of the ethanol from the fermentation vent stream to another liquid or gaseous stream, further treatment of the effluent of the regeneration process is required to either destroy or recover the ethanol (typically thermal oxidation of the stripping gas stream or water treatment in the case of steam stripping).

The District considers adsorption vapor recovery (with appropriate handling of regeneration waste streams) as technologically feasible for application to brandy aging. Based on a draft technical assessment document (TAD) prepared by ARB[18], a control efficiency of 95% is considered reasonable for adsorption systems when controlling ethanol emissions from wine fermentation, a more demanding application due to the presence of large amounts of CO2. This efficiency, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 86% for this technology.

6. Wet Scrubbing (Absorption)

The basic process involved in wet scrubbing is the contact of a polluted gas stream with a liquid solution. During operation, gas flows upward through a column containing packing or other mass transfer media. The scrubbing liquid is delivered to the top of the column and flows down (by gravity) through the porous mass transfer media, generating a substantial interfacial surface area between the gas and liquid phases in a counterflow arrangement which provides optimal mass transfer. Gaseous contaminants are absorbed into the liquid and the decontaminated gas stream flows out of the scrubber.

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[18] Strategies and Costs for Winery Ethanol Emission Control – Technical Assessment Document (Draft),August 6, 2003, p. 34.

Many scrubbing applications achieve emission reduction efficiencies of 99.9%. In a pilot study[19] conducted by ARB in 1987, wet scrubbing demonstrated greater than 90% reduction in ethanol emissions when operated for control of ethanol emissions from wine fermentation tanks.. The District considers wet scrubbing as technologically feasible for application to wine fermentation and that a control efficiency of 90% is reasonably achievable which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 81% for this technology.

7. Condensation, Refrigeration, and Cryogenic Systems

Condensation, refrigeration, and cryogenic systems remove organic vapor by condensing the target gases on cold surfaces. These cold conditions can be created by passing cold water through an indirect heat exchanger, by spraying cold liquid into an open chamber with the gas stream, by using a refrigerant to create very cold coils, or by injecting cryogenic gases such as liquid nitrogen into the gas stream. The concentration of VOCs is reduced to the level equivalent to the vapor pressures of the compounds at the operating temperature. Removal efficiencies attainable with this approach depend strongly on the outlet gas temperature. For cold-water-based condensation systems, the outlet gas temperature is usually in the 40 to 50°F range, and the VOC removal efficiencies can be in the 90% to 99% range depending on the vapor pressures of the specific compounds. For refrigerant and cryogenic systems, the removal efficiencies can be considerably above 99% due to the extremely low vapor pressures of essentially all VOC compounds at the very low operating temperatures of -70°F to less than -200°F. Water vapor content in the gas stream may place a lower limit on the outlet gas temperature due to potential ice formation.

The application of refrigerated condenser to the control of ethanol emissions from a fermentation tank was examined by ARB[20]. The results of that study indicated that a 90 % ethanol recovery could be achieved at an outlet gas temperature of -12 ^{0}F when controlling ethanol emissions from wine fermentation tanks. However, it was noted that ice formation could be a problem at this temperature and that special equipment designs would be required for reasonable operation. In addition, the ethanol is recovered in aqueous solution and must be further process for recovery of the ethanol. The District considers refrigerated condensation as technologically feasible for application to brandy aging and that a control efficiency of 90% is reasonably achievable which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 81% for this technology.

8. Biological Oxidation

VOCs can be removed by forcing them to absorb into an aqueous liquid or moist media inoculated with microorganisms that consume the dissolved and/or adsorbed organic compounds. The control systems usually consist of an irrigated packed bed that hosts the microorganisms (biofilters). A presaturator is often placed ahead of the biological system to increase the gas stream relative humidity to more than 95%. The gas stream

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[19] Nelson Chan, et. al, A suggested Control Measure for Control of Ethanol Emissions From Winery Fermentation Tanks. October 7, 1986

[20] Strategies and Costs for Winery Ethanol Emission Control – Technical Assessment Document (Draft),August 6, 2003, p. 31.

temperatures are maintained at less than approximately 105°F to avoid harming the organisms and to prevent excessive moisture loss from the media.

Biological oxidation systems are most often used for very low concentration VOC-laden gas streams for odor control. The VOC inlet concentrations are often less than 500 ppmv and sometimes less than 100 ppmv and achieve control efficiencies exceeding 95%. However, biofilters have been demonstrated[21] in industrial applications achieving 90% control efficiency when controlling higher ethanol inlet concentrations (up to 3 g/1000 m^3). The District considers biological oxidation to be technologically feasible for application to brandy aging and that a control efficiency of 90% is reasonably achievable which, when combined with an expected capture efficiency of 90%, yields an overall emission reduction of 81% for this technology.

9. Modification of the aging warehouse and/or the aging operation to reduce evaporative ethanol emissions

Emission reduction could theoretically be achieved by a combination of atmospheric control in the storage warehouse and by barrel management practices. This is evidenced by a potential 300% variation in emission factors between different brandy aging operations in the San Joaquin Valley. However, warehouse and barrel management are the primary variables which are manipulated by the aging operation to produce specific style characteristics in each product. Since brandy is a consumer product whose consumer acceptance is heavily influenced by style issues, manipulation of these variables for the purpose of emission control would result in fundamentally changing the final product of the process, potentially leading to loss of both market share and competitive edge. Therefore, the District does not consider this approach as a technologically feasible approach and it will not be considered further.

C. Cost Effectiveness for Brandy Aging

1. Approach for Cost Effectiveness

The following emission control technologies have been determined to be technologically feasible for control of VOC emissions from brandy aging operations:

- Oxidation (86% control)
- Refrigerated Condenser (81% control)
- Wet Scrubber (81% control)
- Carbon Adsorption (86% control)
- Biofiltration

Since “oxidation” includes recuperative and regenerative thermal oxidizers plus catalytic oxidizers, the cost effectiveness of the following cases will be examined for the determination of RACT for brandy aging:

Case 1 Thermal oxidation with 0% heat recovery (low capital/high operating cost)
Case 2 Catalytic oxidation with 50% heat recovery (mid range capital/mid range operating cost)

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[21] J.S.Devinny, et.al.,Biofiltration for Air Pollution Control,CRC Press, Boca Raton, 1999, p. 235.

Case 3 Regenerative thermal oxidation with 95% heat recovery (high capital/low operating cost)
Case 4 Refrigerated Condenser
Case 5 Water scrubber
Case 6 Carbon adsorption
Case 6 Biofiltration

The approach of the cost effectiveness analysis will be to first determine which, if any, of the above cases potentially qualifies as RACT based on having a potential cost effectiveness below EPA's assumed RACT threshold of $4,400/ton of VOC. Cases which are shown to have a cost effectiveness higher than $4,400/ton will be discarded. Cases which fall below the threshold will be considered potential candidates for RACT and will then be further examined and compared with respect to relative cost effectiveness, technical risk, reasonableness, and socio-economic impact to determine which, if any, actually qualify as RACT for brandy aging.

2. Estimating Approach and Basis

The approach for cost effectiveness determination will be based on the following elements:

- EPA's cost model for VOC incineration systems, as presented in the EPA Control Cost Manual, Section 3.2, Tables 2.8 and 2.9, was used for all capture and control cases with the exception of the refrigerated condenser (case 7) estimate which used Section 3.1, Table 2.3 for Total Capital Investment (note also that the EPA cost model was adjusted to a California location by taking sales tax at 8% rather than 3%).
- All estimates are based on a warehouse ventilation rate of 10,000 scfm based on industry estimates of the required ventilation rate for a large brandy storage warehouse in the San Joaquin Valley with a storage capacity of 161,500 barrels. The ethanol emission factor will be assumed to be the minimum within the typical range (1.5 proof gallons loss per barrel-year) to determine the maximum value of cost effectiveness (least cost effective) for this warehouse configuration (consideration of higher emission factors will result in lower values – more cost effective).
- Potential uncontrolled emissions are 401 tons-VOC/year for an annual brandy loss of 1.5 proof gallons per barrel based on a storage capacity of 161,000 barrels and a factor of 3.31 lb-ethanol/proof gallon.
- Each case is assumed to have the same requirements for collection ducting from the warehouse to the control device which is based on a warehouse of approximately 156,000 square feet, consistent with a ventilation rate of 10,000 scfm. The ducting is estimated to consist of 1,290 linear feet of collection ductwork within the warehouse with an average diameter of 12 inches plus 450 linear feet of main header ducting with a diameter of 25 inches.
- Purchased costs for ducting were taken from the EPA Control Cost Manual, Section 2, Chapter 1 and corrected to 1st quarter 2007 by assuming average 3% annual inflation.
- Each case is assumed to have the same requirements for warehouse modifications for compliance with EPA Method 204. Allowances of $30,000 and $10,000 were

placed in the estimate for installation of automated doors and miscellaneous building modifications respectively.

- Potential site specific costs such as site preparation, electric utility expansion and natural gas utility expansion were optimistically ignored.
- Power consumption by the induced draft fan is common to all cases and is based on an induced draft fan rated at 10,000 scfm, 10 inches water column static pressure differential, and a fan efficiency of 65%.
- Total Capital Investment was annualized based on a 10 year equipment life and a 10% opportunity cost for capital (CRF = 0.163).
- Pricing for natural gas and electricity were applied at $0.61/therm and $0.12/kwh based on current prices reported by Gallo for these items at their Livingston winery.

3. Cost Effectiveness Analysis for Brandy Aging Operations

Case 1 - Collection and Control with a Thermal Oxidizer

Capital investment for this case as well as all other capture and control cases is presented in Table 9. Annual costs, emission reductions and calculated cost effectiveness are presented in Table 10. The thermal oxidizer for this case was priced from the EPA Control Cost Manual, Section 3.2, Figure 2.4, based on a 10,000 scfm unit with 0% energy recovery. As such, it represents a minimum capital investment scenario for use of a thermal oxidizer. The price from Figure 2.4 (1990 dollars) was adjusted to 2007 dollars based on average annual inflation of 3%.

Annual fuel costs are based on an industry estimate of 3.2 billion Btu/year (32,000 therms/yr) for a facility of this size with 95% heat recovery (approximately 50% of theoretical fuel consumption when not allowing for heating value of ethanol). This was divided by 0.05 to convert it to an expected fuel consumption of 640,000 therms/year for this zero heat recovery case.

With an expected collection and control efficiency of 86%, cost effectiveness of this control option is estimated at $1,700 per ton.

Case 2 - Collection and Control with a Catalytic Oxidizer

The catalytic oxidizer for this case was priced from the EPA Control Cost Manual, Section 3.2, Figure 2.6, based on a 10,000 scfm unit with 50% energy recovery. As such, it represents a mid range capital investment scenario for use of oxidizer technology. The price from Figure 2.4 (1990 dollars) was adjusted to 2007 dollars based on average annual inflation of 3%.

Annual fuel cost for this case was calculated based on applying a 50% heat recovery factor to the zero heat recovery case of 640,000 therms.

No allowance was applied for potential catalyst replacements during the 10 year equipment life.

With an expected collection and control efficiency of 86%, cost effectiveness of this control option is estimated at $1,000 per ton.

Case 3 - Collection and Control with a Regenerative Thermal Oxidizer (RTO)

The RTO for this case was priced from the EPA Control Cost Manual, Section 3.2, Figure 2.5, based on a 10,000 scfm unit with 95% energy recovery. As such, it represents a high range capital investment scenario for use of oxidizer technology. The price from Figure 2.5 (1999 dollars) was adjusted to 2007 dollars based on average annual inflation of 3%.

The industry estimate of 3.2 billion Btu/year (32,000 therms/yr) for a facility of this size with 95% heat recovery (approximately 50% of theoretical fuel consumption when not allowing for heating value of ethanol) was used for annual fuel cost.

With an expected collection and control efficiency of 86%, cost effectiveness of this control option is estimated at $1,200 per ton.

Case 4 - Collection and Control with a Refrigerated Condenser

It was assumed that the refrigerated condenser would operate at a condensing temperature of $-12\ ^{o}$F and achieve a 90% collection and control based on the TAD. The refrigerated condenser duty for this case was determined to be 78.6 tons of refrigeration and was priced based on the EPA Control Cost Manual, Section 3.1, Figure 2.5, based on a $-20\ ^{o}$F refrigerant condensing temperature. The price from Figure 2.5 (1990 dollars) was adjusted to 2007 dollars based on average annual inflation of 3%.

Electric power costs for operation of the refrigeration were estimated at 1.54 kw/ton.

With an expected collection and control efficiency of 90%, cost effectiveness of this control option is estimated at $1,300 per ton.

Case 5 - Collection and Control with a Water Scrubber

The water scrubber for this case was priced based on vendor quotations obtained from a study of the application of the application of water scrubbers to the control of ethanol emissions from wine fermentation tanks by Sonoma Technology, Incorporated (STI)[22]. The STI study presented prices for scrubber with capacities of 500 scfm and 5000 scfm. These prices were extrapolated with a consistent exponent factor to determine the price of a 10,000 scfm unit. The price derived from the STI data (2003 dollars) was adjusted to 2007 dollars based on average annual inflation of 3%.

Water disposal costs for this case were also taken from the STI study. Using the STI assumptions, water disposal requirements were taken to be 6 gallons per minute for each 5,000 cfm of flow with a disposal cost of $0.25/gallon.

With an expected collection and control efficiency of 81%, cost effectiveness of this control option is estimated at $5,300 per ton.

Case 6 - Collection and Control with Carbon Adsorption

The carbon adsorption system for this case was priced based on pricing presented in the Technical Assessment Document (TAD)[23] for activated carbon adsorption systems including carbon canisters, blower, and regeneration system. Prices from the TAD were

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[22] Control Technology Evaluation: Wineries – Fermentation Processes, Sonoma Technologies, Inc., October 21, 2003.

[23] Strategies and Costs for Winery Ethanol Emission Control – Technical Assessment Document (Draft),August 6, 2003, p. 77.

interpolated to determine the price of a 10,000 scfm unit. The price derived from the TAD (1991 dollars) was adjusted to 2007 dollars based on average annual inflation of 3%.

Utility costs for operation of the carbon regeneration system were also included in the analysis based on the TAD. Per unit values derived from that document, combined costs for steam and cooling water used for regeneration were determined to be $99.63/ton-ethanol.

Water disposal cost resulting from carbon regeneration were calculated at $175 per ton of ethanol emission reduction based on unit values derived from the TAD and the water disposal cost of $0.25 per gallon from the TAD.

With an expected collection and control efficiency of 86%, cost effectiveness of this control option is optimistically estimated at $1,300 per ton.

Case 7 - Collection and Control with Biofiltration

The biofilter size for this case was determined to be 315 cubic meters based on the size of another 10,000 scfm unit presented by Devinney[24]. Per Devinney, biofilter reactor costs range from $1,000 to $3,500 per cubic meter[25]. An average cost of $2,250 per cubic meter (1997 cost) was used and was adjusted to 2007 dollars based on average annual inflation of 3%.

Potential water injection costs for humidification of the biofilter were ignored.

With an expected collection and control efficiency of 81%, cost effectiveness of this control option is estimated at $2,300 per ton.

4. Cost Effectiveness Summary for Brandy Storage

The seven cases examined yielded evaluated cost effectiveness values ranging from $1,000 per ton for catalytic oxidizer control technology to $5,300 per ton for a water scrubber. All cases evaluated lie below the EPA's assumed RACT threshold of $4,400/ton with the exception of the water scrubber technology which is only marginally above the threshold, primarily due to the costs associated with water disposal. Although these values appear to be economically reasonable in comparison with the $4,400 per ton threshold generally established by EPA for sources subject to existing CTGs, the District believes that there is no feasible RACT-level control because the control technology has not yet been installed, operated and evaluated. As stated above, the brandy facility operator was recently issued an Authority to Construct permit by the District. As such, control of brandy aging emissions could not be considered as achieved in practice at this time until after a few years when it can be determined that there would be no adverse impacts on aging operation and most importantly on the quality or consistency of the product.

Factors which might increase the evaluated cost effectiveness (less cost effective) are:

- Site specific costs for site preparation, electricity or fuel gas supply were ignored.

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[24] Devinney, et.al., p. 236.

[25] Devinney, et.al., p. 175.

- The EPA cost model only applies factors for engineering, construction and field expense, contractor fees and contingency to the purchased equipment costs rather than the total direct cost. Since other direct costs such as foundations and supports, electrical and piping all have a substantial indirect cost, these costs are ignored in this evaluation. Standard practice in the engineering and construction industry for a factored estimate of this type is to apply indirect cost factors to the total direct cost.
- EPA cost model factors for engineering, construction and field expenses and contingency are low relative to typical experience and practice in the engineering and construction industry for industrial construction of this type. Engineering costs and construction and field expense are each more typically 10-20%, of total direct cost. Industry practice would consider an estimate of this type to have an accuracy of no better than ± 25%. Based on this, industry practice is to set contingency at 15-20% of total direct cost as a minimum.

Factors which might decrease the evaluated cost effectiveness (more cost effective) are:

- The evaluation is based on the lower range of emission factors for ethanol loss. Use of an average emission factor would make all options more cost effective.
- The capital cost is based on the larger end of the expected range of warehouse storage capacities. Use of a more average size facility (smaller facility) with more average emission factors (higher emission factors) would make all cases more cost effective.

EPA Cost Model

Table 9 Total Capital Investment for VOC Control on Brandy Storage Operations

Control Device	**Case 1 Thermal Ox**	**Case 2 Catalytic Ox.**	**Case 3 RTO**	**Case 4 Refrigerated Condenser**	**Case 5 Water Scrubber**	**Case 6 Carbon Adsorption**	**Case 7 Biofilter**
Direct Costs							
Purchased Equipment Costs							
Control Device	$114,100	$261,400	$425,900	$267,800	$65,900	$380,100	$1,000,900
Knock Out Vessels	$0	$0	$0	$0	$0	$0	$0
Ductwork	$46,900	$46,900	$46,900	$46,900	$46,900	$46,900	$46,900
Subtotal Equipment	$161,000	$308,300	$472,800	$314,700	$112,800	$427,000	$1,047,800
Instrumentation	$16,100	$30,800	$47,300	$31,500	$11,300	$42,700	$104,800
Sales Tax	$12,900	$24,700	$37,800	$25,200	$9,000	$34,200	$83,800
Freight	$8,100	$15,400	$23,600	$15,700	$5,600	$21,400	$52,400
Purchased Equipment Cost (PEC)	$198,100	$379,200	$581,500	$387,100	$138,700	$525,300	$1,288,800
Direct Installation Costs							
Foundations and Supports	$15,800	$30,300	$46,500	$31,000	$11,100	$42,000	$103,100
Handling & Erection	$27,700	$53,100	$81,400	$54,200	$19,400	$73,500	$180,400
Electrical	$7,900	$15,200	$23,300	$15,500	$5,500	$21,000	$51,600
Piping	$4,000	$7,600	$11,600	$7,700	$2,800	$10,500	$25,800
Site Prep & Miscellaneous							
Automated Doors (2)	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000
Warehouse Modifications	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Total Direct Costs	$293,500	$525,400	$784,300	$535,500	$217,500	$712,300	$1,689,700
Indirect Costs							
Engineering	$19,800	$37,900	$58,200	$38,700	$13,900	$52,500	$128,900
Construction & Field Expenses	$9,900	$19,000	$29,100	$19,400	$6,900	$26,300	$64,400
Contractor Fees	$19,800	$37,900	$58,200	$38,700	$13,900	$52,500	$128,900
Start Up	$4,000	$7,600	$11,600	$7,700	$2,800	$10,500	$25,800
Performance Test	$2,000	$3,800	$5,800	$3,900	$1,400	$5,300	$12,900
Contingencies	$5,900	$11,400	$17,400	$11,600	$4,200	$15,800	$38,700
Total Indirect Costs	$61,400	$117,600	$180,300	$120,000	$43,100	$162,900	$399,600
Total Capital Investment	**$553,000**	**$1,022,200**	**$1,546,100**	**$1,042,600**	**$399,300**	**$1,400,500**	**$3,378,100**

EPA Cost Model

Table 10 Annual Costs for VOC Control on Brandy Storage Operations

Control Device	**Case 1 Thermal Ox**	**Case 2 Catalytic Ox.**	**Case 3 RTO**	**Case 4 Refrigerated Condenser**	**Case 5 Water Scrubber**	**Case 6 Carbon Adsorption**	**Case 7 Biofilter**
Total Capital Investment	$553,000	$1,022,200	$1,546,100	$1,042,600	$399,300	$1,400,500	$3,378,100
Direct Annual Costs							
Labor & Materials							
Operating Labor (0.5 hr/shift-unit @ $12.95/hour)	$7,100	$7,100	$7,100	$7,100	$7,100	$7,100	$7,100
Supervisor (15% of operator cost)	$1,100	$1,100	$1,100	$1,100	$1,100	$1,100	$1,100
Operating Materials (15% of total maintenance cost)	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100
Maintenance Labor (0.5 hr/shift-unit@ $12.95/hour)	$7,100	$7,100	$7,100	$7,100	$7,100	$7,100	$7,100
Maintenance Materials (100% of maintenance labor)	$7,100	$7,100	$7,100	$7,100	$7,100	$7,100	$7,100
Total Labor & Materials	$24,500	$24,500	$24,500	$24,500	$24,500	$24,500	$24,500
Utilities							
Natural Gas	$390,400	$72,300	$19,520	$0	$0	$0	$0
Electricity	$22,300	$22,300	$22,300	$149,400	$22,300	$22,300	$22,300
Carbon Regeneration	$0	$0	$0	$0	$0	$34,400	$0
Water Disposal	$0	$0	$0	$0	$1,576,800	$60,300	$0
Total Direct Annual Cost	**$437,200**	**$119,100**	**$66,320**	**$173,900**	**$1,623,600**	**$141,500**	**$46,800**
Indirect Annual Costs							
Overhead (60% of labor & Mat'ls)	$14,700	$14,700	$14,700	$14,700	$14,700	$14,700	$14,700
Administrative Charges (2% of TCI)	$11,100	$20,400	$30,900	$20,900	$8,000	$28,000	$67,600
Property Taxes (2% TCI)	$11,100	$20,400	$30,900	$20,900	$8,000	$28,000	$67,600
Insurance (1% TCI)	$5,500	$10,200	$15,500	$10,400	$4,000	$14,000	$33,800
Capital Recovery (CRF = 0.163)	$90,100	$166,600	$252,000	$169,900	$65,100	$228,300	$550,600
Total Indirect Annual Cost	**$132,500**	**$232,300**	**$344,000**	**$236,800**	**$99,800**	**$313,000**	**$734,300**
Total Annualized Cost	**$569,700**	**$351,400**	**$410,320**	**$410,700**	**$1,723,400**	**$454,500**	**$781,100**
Emission Reductions	344.79	344.79	344.79	324.75	324.75	344.79	344.79
Cost Effectiveness $/ton	**$1,700**	**$1,000**	**$1,200**	**$1,300**	**$5,300**	**$1,300**	**$2,300**