Control Measure CM 1: AUTO REFINISHING

Control Measure Description

This control measure would reduce ROG emissions from automobile refinishing facilities through lower VOC limits for some categories of coatings based on the comparable South Coast Rule 1151.

Background and Regulatory History

The District regulates ROG emissions from auto refinish operations by setting volatile organic compound (VOC) limits on various types of paints and surface preparation solvents used in auto refinishing. In addition, the amount of some high-VOC coating is limited by a volume relationship with other coatings. This prevents "gaming" by using high-VOC coatings for general, rather than specialized purposes. Also, the rule requires the use of spray technology that is transfer efficient, to minimize the amount of paint that misses or bounces off the intended surface.

Regulation 8, Rule 45: Motor Vehicle and Mobile Equipment Coating Operations, which includes auto refinishing and new and used mobile equipment coating, was adopted in 1989. Auto refinish facilities were previously subject to the less stringent standards in Regulation 8, Rule 4: General Solvent and Surface Coating Operations, which limits facility emissions but not the VOC content of paints. The rule was also amended several times, most significantly in 1994. The emissions from auto refinishing operations (both coating and solvent) have been reduced from over 11 tons per day prior to the implementation of Rule 45 to approximately 3.3 tons per day today.

Emissions Subject to Control

The emissions from auto refinishing are included in the emission inventory as point sources. Any coating operation that uses 30 gallons of coating and solvent per year is required to have a District operating permit, and must submit usage information annually from which emissions are calculated. Auto refinish coating emissions are *Category 274* in the emissions inventory. *Category 275* is solvent used for surface preparation and clean up in auto refinishing and mobile coating operations.

	Emissions Subject to Control (TPD, Summer)	
Year	*Cat. 274*	*Cat. 275*
2003	2.12	1.21
2006	2.21	1.26

Proposed Method of Control

This proposal draws from two sources, 1) South Coast Rule 1151: Motor Vehicle and Mobile Equipment Non-Assembly Line Coating Operations, and 2) a draft suggested rule developed by the CAPCOA Enforcement Managers that recommends lower VOC coating and elimination of two coating categories.

Adoption of the South Coast limits was proposed for the 2000 Clean Air Plan and evaluated in the 2001 Ozone Plan for the One Hour Federal Standard RACM Analysis. At that time, an analysis of the lower South Coast limit for clear coatings showed a cost effectiveness of $35,000 per ton. However, as costs have come down since that analysis, the potential to reduce emissions at a reasonable cost should be re-examined.

The coating categories proposed for elimination, multi-stage topcoats and specialty coatings, would be replaced by VOC limits for individual coatings that make up the categories. For multi stage topcoats, the individual coatings consist of base coat (or color coat), and clear coat. Although there are often a number of base coats of varying translucency, the base coat/clear coat application form a coating system. Currently, Bay Area Regulation 8, Rule 45: Motor Vehicle and Mobile Equipment Coating Operations, allows averaging of VOC contents of the coatings in the system based on specified formulae for the number of layers of coating used. The VOC limit would be replaced by VOC limits for each type of coating. The other category of coating proposed for elimination is specialty coating. Specialty coating is a catch-all category for any coating that does not fit within the iterated categories. It would be eliminated and replaced with two categories of coating, antiglare or safety coating, and uniform finish coating. Both of these categories would have VOC limits significantly lower than the existing limit for specialty coatings, 840 g/l, but the existing rule constrains use of these coatings whereas the draft suggested rule does not.

Currently, the Stationary Source Division of ARB is conducting a survey of available automotive coatings and plans to analyze the reactivity of coating constituent solvents. The Enforcement Managers' draft has not yet been discussed with the affected industry, nor have emission reductions or cost effectiveness been quantified. At the direction of CAPCOA, the development of a staff report and regulatory proposal will be initiated by the San Joaquin and South Coast districts, with other districts to consider emission reductions based on the results. Any control measure should also consider the results of the ARB survey. It is anticipated that this effort will take at least until mid-2004. Because the auto refinish industry varies little between districts, coordination of statewide efforts is desirable.

Emission Reductions Expected

The emission reduction estimates consider only the implementation of a requirement to use high solids, low VOC clear topcoat. Additional reductions are possible from the elimination of coating categories, however, they cannot be quantified at this time.

Furthermore, a reduction in the emissions from associated solvent surface preparation and clean up should be considered. The emissions from implementation of a low-VOC clear coat standard would result in emissions reductions of 33%, or 0.7 tons per day.

Costs of Control

The control costs are based on the cost to the finisher of a high solids low-VOC clear coat, resulting in a reduction in the basecoat/clearcoat coating system or a reduction in the VOC attainable in individual coating categories. Currently, the Bay Area rule allows most coating companies to sell clear coat that has about 420 grams/liter VOC content (3.5 lbs/gal). There is also clear coat available at 250 – 265 g/l VOC content, used sometimes with higher VOC base coats to comply with the average VOC standard for basecoat/clearcoat systems. Due to increased production of low VOC clear coats because of South Coast Rule 1151 that mandates their use, the cost has come down since the 2000 investigation. High solids low-VOC clear coats are now available at lower cost than the conventional material used to meet Bay Area regulations, and the reducer or thinner used is also less expensive. Based on the clear coat alone, on which the emissions reductions are based, adoption of lower VOC standards could now save money. Some other elements of the rule could negate that cost savings, but the rule would still likely be cost effective.

Other Impacts

No significant adverse environmental impacts are expected as a result of the adoption of this control measure. The affected industry is already regulated and proposed changes in paint formulations will not be implemented in a way that will add to waste streams or impact other media.

References

South Coast Rule 1151: Motor Vehicle and Mobile Equipment Non-Assembly Line Coating Operations, and staff report dated 12/11/98
2001 Ozone Plan for the One Hour Federal Standard RACM Analysis
Bay Area Regulation 8, Rule 45: Motor Vehicle and Mobile Equipment Coating Operations
CAPCOA Enforcement Managers' Automotive Coatings Model Rule, Final Draft, 7/19/02
e-mail communication with Barb Fry, ARB Stationary Source Division, 5/20/03

Suggested Measure Reference # 27, 28, 29

Control Measure SS 2: GRAPHIC ARTS OPERATIONS

Control Measure Description

This control measure would reduce ROG emissions from printing operations by reducing the allowable VOC limit for flexographic ink used on porous substrates and by limiting the VOC content of clean up solvent used on flexographic presses.

Background and Regulatory History

The District regulates ROG emissions from graphic arts operations by setting volatile organic compound (VOC) limits on various types of inks and coating used in printing press operations. Also, fountain solutions used to wet image plates and solvents used to clean presses are limited by vapor pressure and/or VOC content. Regulation 8, Rule 20: Graphic Arts Printing and Coating Operations was first adopted in 1980. The initial rule was based on an EPA Control Techniques Guideline for rotogravure and flexographic presses. Amendments in 1984 established standards for both letterpress and lithographic printing, and subsequent amendments made the limits applicable to smaller facilities, lowered allowable VOC limits and implemented the Bay Area Stratospheric Ozone Policy. Approximately 1600 graphic art establishments operate in the Bay Area, ranging from small local printing operations to large newspaper, magazine, and packaging operations.

Emissions Subject to Control

The emissions from printing operations are included in the emission inventory. Any printing operation that uses 30 gallons of coating or ink and solvent per year is required to have a District operating permit, unless the materials have less than 1% VOC by weight. This exemption has been a driving force in the development of soy based lithographic printing inks that have less than 1% VOC. The emissions inventory lists categories for gravure printing, flexographic printing, letterpress printing, lithograhic printing, silk screening and small in-house printing. The emissions that are the subject of this control measure are in category # 109 in the emissions inventory, which are all point sources.

	Emissions Subject to Control (TPD, Summer)	
Year	*Cat. 109 ink*	*Cat. 109 cleanup*
2003	0.36	0.06
2005	0.36	0.06

Proposed Method of Control

The CAPCOA All Feasible Measures review found the Sacramento Metropolitan Air Quality Management District (AQMD) and South Coast AQMD graphic arts rules to be

the most stringent rules considered feasible. In the South Coast, graphic arts (printing) operations are controlled by Rule 1130: Graphic Arts. In Sacramento, graphic arts operations are controlled by Rule 410: Graphic Arts Operations. Bay Area graphic arts operations are controlled by Regulation 8, Rule 20: Graphic Arts Printing and Coating Operations.

South Coast Rule 1130: Graphic Arts has one ink VOC limit that is more stringent than the Bay Area limit. Flexographic ink used on porous substrates are subject to a VOC limit of 225 grams/liter. All flexographic inks used in the Bay Area are subject to a VOC limit of 300 grams/liter.

Sacramento Rule 410: Graphic Arts, has no VOC limits for inks, coatings or adhesives that are more stringent than the VOC limits in Bay Area Rule 20. In fact, several ink VOC limits for screen printing are less stringent than Bay Area limits. However, the Sacramento rule does have a more stringent clean up limit for solvent used to clean flexographic presses. The clean up limits in both rules are expressed in terms of VOC content or vapor pressure or both, depending on the type of printing press or press component being cleaned. The Sacramento limit for flexographic press clean up solvent is 100 grams VOC/liter and 3 mm Hg vapor pressure. The Bay Area limit is 810 grams VOC/liter and 21 mm Hg vapor pressure. However, the South Coast has even more stringent VOC limits for graphic arts equipment clean up. The South Coast has adopted stringent VOC limits that become effective on 7/1/2005 and has no limits on the vapor pressure of solvents. The South Coast limits for clean up do not go into effect unless a technology review in 2004 finds them feasible. Among the South Coast VOC limits for clean up solvents, a 25 grams VOC/liter limit is in effect (SCAQMD Rule 1171) currently for clean up solvent used on flexographic presses, more stringent than the Sacramento limit.

The CAPCOA All Feasible Measures review process does not consider future effective VOC limits that require a technology review to be "feasible". The "feasibility", however, changes as the limits become effective and technology becomes available. Consequently, this control measure only analyzes the potential emissions reductions from the 25 gram per liter VOC limit for flexographic clean up solvent and 225 gram per liter VOC limit for flexographic ink, although additional emission reduction opportunities from the source category may be discovered during the rule development process.

Emission Reductions Expected

The Bay Area inventory for flexographic printing shows 0.36 tons per day organic emissions from printing and 0.06 tons per day organic emissions from solvent clean-up operations. A reduction in the allowable VOC content of flexographic ink could yield a 25% reduction [0.36 * (1 - 225/300) = 0.09 tons per day]. A reduction in the allowable VOC content of the flexographic clean up solvent would yield 0.058 tons per day [0.06 * (1-25/810)]. Combined emissions reductions are 0.15 tons per day. The emission reductions may be less, however, as the South Coast clean up solvent limit only affects

flexographic printing on porous substrates. Under Rule 1130, non-porous substrates, such as food packaging film, are allowed to use ink of 300 grams VOC/liter, which is the same as the Bay Area standard.

The potential emission reductions from this control measure appear to be greater than de minimis. In addition, the South Coast technical evaluation of lower VOC lithographic press clean up solvent, scheduled for 2004, may add to the potential emission reductions. The emissions from clean up solvent from litho presses in the Bay Area is currently 0.75 tons per day.

Costs of Control

Lower VOC flexographic ink is priced comparably with 300 g/l ink. Costs for lower VOC clean up solvent have yet to be determined.

Other Impacts

No significant adverse environmental impacts are expected as a result of the adoption of this control measure. The affected industry is already regulated and proposed changes in ink or cleaning solvent formulations will not be implemented in a way that will add to waste streams or impact other media.

References

Sacramento Metropolitan AQMD Rule 410: Graphic Arts
South Coast AQMD Rule 1130: Graphic Arts Operations, and staff report dated Sept., 1999
South Coast AQMD Rule 1171: Solvent Cleaning Operations
Telephone conversation, Gerald Boneto, California Printing Industries Council, 2/25/2004
Telephone conversation, Duke Nickoley, Flint Ink, 3/1/2004

Suggested Measure Reference # 33, 34

Control Measure SS 3: HIGH EMITTING SPRAY BOOTHS

Control Measure Description

This control measure would reduce ROG emissions from coating operations that emit in excess of 20 tons of emissions per year. It would require a reduction beyond the use of coatings that comply with existing District rules. Spray booths or enclosed coating operations could be abated to meet a standard based on a percent reduction requirement, or alternative lower emitting coating technology could be sought.

Background and Regulatory History

The District regulates industrial and commercial coating through industry or substrate specific rules. Due to the vast number of coating applications, fifteen of the fifty District organic compound rules affect these types of coating applications. Each rule sets specific volatile organic compound content (VOC) limits on various types of inks, coatings or adhesives, although the option exists in each rule to meet the VOC limits by the use of add on control technology. In addition, Regulation 2, Rule 2: New Source Review, requires the use of Best Available Control Technology (BACT) for new or modified sources that emit more than 10 pounds of organic compounds per day. For larger coating sources, BACT has required installation of abatement technology. Consequently, some of the sources that would be subject to this control measure would already meet the mandates for additional control. The South Coast has already implemented this control measure. Rule 1132: Further Control of VOC Emissions from High Emitting Spray Booth Facilities, is derived from the South Coast's 1999 AQMP, control measure CTS-09. Rule 1132 requires coating facilities that emit 20 tons of VOC per year from spray booths to reduce emissions by 65% from a 2001 baseline, primarily through the installation of abatement equipment, although alternative compliance options exist.

Emissions Subject to Control

There are 12 facilities in the Bay Area that do surface coating that emit 20 tons VOC per year. Of these, 47% of the total emissions are from 2 facilities, New United Motors Manufacturing in Fremont and Ball Metal Beverage Container in Richmond. Five of the facilities, including New United Motors and Ball Metal, are already abated, so emissions are controlled to at least the extent required by the South Coast rule. Of the remaining seven facilities, one is a mobile equipment manufacturer, one is a can manufacturer, one a foundry that has a significant coating source, two are metal parts manufacturers, and two are wood furniture companies.

Because this rule is source specific rather than source category or industry specific, the emissions are found in several source categories in the emission inventory. It is more appropriate to look at specific facilities that would be subject to the rule. The following table shows emissions on a facility by facility basis. *Emissions Subject to Control* consists of the emissions from specific sources at Bay Area facilities that emit 20 tons or

organic compounds per year in each of the source surface coating source categories from the emissions inventory.

Facility	*Emissions Subject to Control*	*Potential Reduction at 65%*
1	139 lb/day	90 lb/day
2	431 lb/day	280 lb/day
3	379 lb/day	246 lb/day
4	212 lb/day	138 lb/day
5	175 lb/day	114 lb/day
6	118 lb/day	77 lb/day
7	125 lb/day	81 lb/day

The emissions total 0.79 tons per day and the reduction, assuming 65% control could be achieved on all operations, is approximately 0.5 tons/day.

Proposed Method of Control

The Bay Area, like the South Coast, has numerous rules that affect commercial and industrial coating operations. Some, such as Wood Products Coating and Automotive Refinish Coating, have already been identified for emission reductions (see Wood Products Coating and Auto Refinishing Control Measure Descriptions, respectively). Others, such as aerospace coating, have very small inventories or, such as can and coil coating, already have emissions largely controlled by abatement technology. For coating categories for which there is sufficient inventory and technical evidence that emissions can be further reduced, staff will continue to pursue emission reduction opportunities. However, this control measure is directed at various source categories at the highest emitting facilities. If emissions are sufficient, it is considered to be cost effective to abate emissions instead of reduce solvent content in coating materials. A 65% reduction requirement would also allow alternative coating technology such as ultraviolet cured coatings or very low VOC water based technology.

Several air pollution control devices are available to reduce VOC emissions from spray booths. They include commonly used control technologies such as carbon or zeolite adsorption, and thermal or catalytic oxidation, and newer technologies such as biofiltration, cryogenic condensation, ultraviolet oxidation, and hybrid concentrator/oxidation systems. A 65% reduction, as specified by the South Coast rule, could be achieved by any of these technologies.

Emission Reductions Expected

The South Coast rule only applies to emissions from spray booth operations, and exempts booths with air flows that have a low VOC concentration because control of these booths is much less cost effective. The South Coast staff report estimates that, due to this

exemption, emission reductions are about 15% less than they would have been had all sources had to reduce emissions by 65%. Based on the seven currently unabated Bay Area facilities with coating emissions of 20 tons per year, and assuming a 15% of the emissions would be exempted from the requirement due to cost or technical problems, an emissions reduction of approximately 0.3 tons per day could be achieved.

Costs of Control

The South Coast estimates that the cost effectiveness for control of spray coating operations subject to the rule is about $5484 per ton of emission reduction. The 20 ton per year threshold may be adjusted to improve rule effectiveness and cost-effectiveness.

Other Impacts

No significant adverse environmental impacts are expected as a result of the adoption of this control measure. The affected coating operations are part of existing industrial operations, so that an addition of emissions control equipment will not cause additional impacts. The proposed control option, however, will add emissions of NOx to the atmosphere if incineration is the preferred technology to comply with the proposal.

References

CST-10: Miscellaneous Industrial Coatings and Solvent Operations, South Coast 2003 Air Quality Management Plan, SCAQMD
Rule 1132: Further Control of VOC Emissions from High Emitting Spray Booth Facilities, and staff report, SCAQMD, 1/2001

Suggested Measure Reference # 35, 37

Control Measure SS 4: POLYESTER RESIN OPERATIONS

Control Measure Description

This control measure would reduce ROG emissions from polyester resin operations (fiberglass product manufacturing) by lowering some limits in Regulation 8, Rule 50: Polyester Resin Operations.

Background and Regulatory History

The District regulates ROG emissions from polyester resin operations by setting volatile organic compound (VOC) limits and monomer content limits. Monomers are relatively low molecular weight compounds that combine chemically to become a cured resin. Approximately 5% of resin monomers do not react, and are emitted. A reduction in allowable monomer content reduces ROG emissions. Also, for polyester resin spray-up applications, the rule requires the use of certain spray technologies that are relatively transfer efficient to minimize the amount of resin that misses or bounces off the intended surface. Regulation 8, Rule 50: Polyester Resin Operations, was adopted in 1990. Only minor amendments to the rule have been adopted since 1990.

Emissions Subject to Control

The emissions from polyester resin operations are included in the emission inventory as point sources. The emissions from this source category include organic emissions from mixing, pouring, impregnating, injecting, forming, spraying and curing with polyester resins. Any polyester resin operation is required to have a District operating permit, and must submit usage information annually. Emissions are calculated from the submitted information. Polyester resin operations are found in *Category 45: Fiberglass Products Manufacturing* in the emissions inventory. Clean-up solvent used in polyester resin operations is almost all acetone, a negligibly photochemically reactive solvent.

	Emissions Subject to Control (TPD, Summer)
Year	*Category 45*
2003	0.66
2006	0.69

Proposed Method of Control

South Coast Rule 1162: Polyester Resin Operations, amended in November 2001, sets monomer content standards for polyester resins used in a variety of applications. Currently, the Bay Area rule allows a monomer content of 35%, or 50% for materials used for corrosion-resistant or fire-retardant service. The South Coast rule allows from 10% to 35% for specified types of general purpose resins, 48% for resins used for corrosion-resistant service, 38% for fire-retardant service, and 40% for high strength service. The South Coast rule also sets monomer content standards for gel coats and

requires the use of non-atomizing spray application equipment, which is stated to reduce emissions by 40%.

Emission Reductions Expected

The Bay Area emissions inventory shows that polyester resin (fiberglass) products manufacturing operations emit 0.66 tons organic compounds per year. The South Coast rule development staff report states that the amendments adopted in November 2001 reduce emissions by 68%. In the Bay Area, this would achieve a reduction of approximately 0.45 tons organic compounds per day, although the previous South Coast rule had some provisions slightly more permissive than the existing Bay Area rule. At this time, the South Coast has delayed the non-atomizing spray provisions for gel coats from July 2003 until July 2004.

Costs of Control

The staff report for the 2001 amendments to South Coast Rule 1162 estimates the cost effectiveness of this measure at approximately $800 per ton ROG emissions reduced. Typically, improvements in transfer efficiency can save operators money because less material is used.

Other Impacts

Styrene, a toxic air contaminant, is the predominant organic compound emitted from polyester resin operations. A reduction in ROG emissions would also reduce exposure to styrene.

References

South Coast AQMD Rule 1162: Polyester Resin Operations, and staff report, SCAQMD, November, 2001
ARB-CAPCOA Suggested Control Measure For Polyester Resin Operations, CAPCOA Technical Review Group and CARB, September, 1990.

Control Measure Reference # 38

Control Measure SS 5: WOOD PRODUCTS COATING

Control Measure Description

This control measure would reduce ROG emissions from wood coating facilities by lowering some VOC limits in Regulation 8, Rule 32: Wood Products Coating.

Background and Regulatory History

The District regulates ROG emissions from wood coating facilities by setting volatile organic compound (VOC) limits on various types of coatings used on wood, clear and pigmented topcoats, sanding sealers, penetrating sealers (wash coats), fillers and stains. Also, the rule requires the use of spray technology that is transfer efficient to minimize that the amount of paint that misses or bounces off the intended surface.

Rule 32 regulates coatings used in the manufacturing of furniture, kitchen cabinets, outdoor speakers, picture frames, bathroom vanities and other wood products. Rule 32 was adopted in 1983 and amended several times. The most significant amendments were in 1991 and 1995. The rule exempts certain types of products and operations for which low VOC technology is not appropriate, such as musical instruments, antique refinishing and foundry patterns. Emissions from wood product coating have been reduced by 50% through the implementation of VOC limits in the rule. A reduction in the number of facilities operating in the Bay Area has also reduced emissions from this source category.

Emissions Subject to Control

The emissions from wood coating operations are included in the emission inventory as point sources. Any coating operation that uses 30 gallons of coating and solvent per year is required to have a District operating permit, and must submit usage information annually from which emissions are calculated. Wood product coating emissions are found in *Category 256* in the emissions inventory. *Category 257* is surface preparation and clean up solvents used in wood finishing operations.

	Emissions Subject to Control (TPD, Summer)	
Year	*Cat. 256*	*Cat. 257*
2003	2.74	0.44
2006	2.78	0.46

Proposed Method of Control

Several other California districts have adopted VOC limits that are more stringent than the Bay Area's. Generally, the difference between rules is marginal currently, but the other rules become more stringent in July, 2005. The following table illustrates the major

differences in the rules in four districts, expressed in allowable VOC content in grams/liter.

Coating	Bay Area current	South Coast[2] effective 7/05	Sacramento[2] effective 7/05	San Joaquin[2] effective 7/05
Clear topcoat	275/550[1]	275	275/550[2]	275
Sanding sealer	550	275	275	275
Color topcoat	275/550[1]	275	275	275
High solid stain	700	350	350	240
Low solid stain	480	120	120	120
Filler	500	275	275	275
Wash coat	480	120	120	120

Notes:
(1) The lower limits are for general wood products, the higher are for furniture.
(2) Other coating limits apply.
(3) The higher limit is for conversion varnish, a type of clear or colored topcoat.

The current Bay Area limits in Rule 32 are higher than the future limits in the other rules, 550 g/l for clear and colored topcoats and sealers, except for the Sacramento limit for conversion varnish, 700 g/l for high solids stains, and 480 g/l for low solids stains and washcoats. Based on the other districts adopted future limits, the following VOC limits are suggested for consideration, at a minimum:

High solids stain	350 g/l
Sealers	275 g/l
Filler	275 g/l
Low solids stains	120 g/l
Wash coats	120 g/l

Emission Reductions Expected

A 1998 study conducted by UC Davis under ARB contract 93-343 that accompanies the control measure found that high solids stains were 15% of the volume of coatings used, sealers were 23%, fillers were 3% and low solids stains and washcoats were 6%. The following table illustrates potential emission reductions from the above suggested limits, assuming that the volume percentage coating used is equivalent to a percentage of emissions and that there was no reduction in volumes used due to a higher solids content of lower VOC materials.

Coating	Current VOC (g/l)	Suggested VOC (g/l)	Calculation	Reduction tons/day
High solid stain	700	350	2.74*0.15* (700–350)/700	0.21 t/dy
Sealers	550	275	2.74*0.23* (550–275)/550	0.31 t/dy
Fillers	500	275	2.74*0.03* (500-275/500	0.04 t/dy
Low solid stain	480	120	2.74*0.06* (480-120)/480	0.12 t/dy
Wash coat	480	120	Included with low solid stains	

Together, the potential emission reduction is 0.68 tons per day. This does not include potential reductions from clear topcoats, which represent 48% of the volume of coating used. Because of the potential based on volume, and the lower limits in other rules, lower VOC limits should be investigated.

Costs of Control

In the staff report for the proposed amendments to South Coast Rule 1136, the cost effectiveness was estimated to range from $1900 to $2900 per ton for waterborne systems, and for acetone reformulated coatings to be slightly less, about $1600 per ton. At an inflation rate of 3%, this equates to a range of $2406 per ton to $3674 for waterborne coatings and $2026 per ton for acetone coatings. This is within the range of cost effectiveness of other surface coating control measures.

Other Impacts

During the course of rule development in 1990 and 1995 for Bay Area Regulation 8, Rule 32: Wood Products Coating, it was found that the Bay Area is home to a unique set of custom furniture and millwork manufacturers and antique refinishers, for which coatings designed for large factory environment applications would not be able to be employed. Consequently, coating technology that meets the requirements of wood product manufacturers in other districts may not be applicable to the Bay Area.

When the South Coast rule requirements came into effect, they found an increase in the use of an ozone depleting compound, 1,1,1 trichloroethane, of about 1 ton per day. Since that time, however, the Montreal Protocol and 1990 Clean Air Act amendments have phased out the production of this compound. The Bay Area rule does not exempt ozone depleting or toxic compounds, so proposed rule limits must be reviewed in this light. In addition, most districts have VOC limits on strippers. Most commercial furniture refinishers use methylene chloride for wood stripping, which is exempt in the other rules. Methylene chloride, pursuant to the Bay Area policy of not exempting ozone depleting or toxic substances is considered a VOC. A reduction in the VOC content for strippers in the Bay Area may be technically infeasible, however controls may be required for strippers through either the Bay Area risk reduction program or through the development of a statewide Air Toxic Control Measure.

References

Industrial Surface Coatings-Wood Furniture & Fixtures Emission Inventory Development, Robert P. Anex, et al, U.C. Davis Civil Engineering Department, June 1998, Air Resources Board Contract 93-343
Staff report, Proposed Amendments to Rule 1136 - Wood Products Coating, South Coast AQMD, May 10, 1996

Suggested Measure Reference # 44, 45

Control Measure SS 6: FLARES

Control Measure Description

This control measure would reduce ROG emissions from flares in petroleum refineries and chemical plants.

Background and Regulatory History

Flares in refineries provide for the safe disposal of liquid and gaseous hydrocarbons that are either automatically vented from process units through pressure safety valves, control valves or manually drawn from units. Blowdown systems gather hydrocarbon flow, separate liquid from gases, recover condensable oil and water, and discharge the gases to be combusted at the flare.

The 2001 Ozone Attainment Plan contained two measures related to flaring operations at petroleum refineries. Control measure SS-15 included a commitment to adopt a regulation requiring monitoring of flows to flares and calculation of emissions from flares. On May 21, 2003, the Bay Area adopted new Regulation 12, Rule 11: Flare Monitoring at Petroleum Refineries. Further study measure FS-8 in the 2001 Ozone Plan committed the District to assess the viability of controlling flare emissions at petroleum refineries. In December, 2002 a draft technical assessment document was completed that recommended that routine flaring could be minimized by equipment control strategies or by pollution prevention strategies.

Emissions Subject to Control

Emissions from flares at petroleum refineries are reported in Category 15 in the emissions inventory, *Flares and Blowdown Systems*. The emissions inventory for this category is derived from the calculated emissions based on data analyzed during the development of the 2001 Ozone Plan and incorporated into the emissions inventory. The base year for these data is 1999.

	Emissions Subject to Control (TPD, Summer)
Year	*Cat. 15 Flares and Blowdown Systems*
2003	13.78
2006	14.36

Current 2003 data shows that the volume of flare gas sent to flares has been reduced by over 50% from 2001 and 2002. This reduction can be attributed to two things: 1) the installation at one refinery of new compressors with sufficient capacity to halt routine flaring at that refinery, and 2) greater attention to operating practices at refineries that have minimized the need for flaring. Also, improvements in flow monitors and better gas

composition information are helping to replace engineering assumptions made for the 2001 Ozone Plan with refined data and better emission estimates.

Proposed Method of Control

Flaring in refineries can be roughly categorized as being one of three types, routine flaring as part of petroleum product manufacturing, flaring during startups and shutdowns of process units, and flaring during process upsets and emergencies. The reductions already achieved in flaring are primarily the result of reduced routine flaring. Flares exist as emissions controls and safety devices that function during upsets, unanticipated breakdowns of pressurized equipment, or unforeseen events such as power outages. Either by carefully controlling processes, including startup and shutdown, or by equipment modifications, some flaring may be able to be eliminated.

The December 2002 draft technical assessment document concluded that routine flaring could be minimized by equipment control strategies or by pollution prevention strategies. Equipment control strategies require the installation of new equipment or devices and can include physical changes to the flare system. Potential equipment control strategies include: 1) installation of additional flare gas compressors, 2) improvement in the reliability of existing flare gas compressors, and 3) addition of gas storage capacity to hold flare gas. Pollution prevention strategies eliminate the likelihood of flaring by changes in operation or process design. Pollution prevention strategies can include the installation of redundant equipment and devising monitoring and maintenance programs to reduce the need for flaring.

Emission Reductions Expected

Emissions from flares fluctuate on a daily, monthly and yearly basis. The emission inventory estimates developed for the 2001 Ozone Plan are not expected to be consistent with present or future estimates. An estimate of emission reductions for this control measure will be based on an analysis of reductions already achieved and any further regulatory controls.

Costs of Control

Equipment control strategy costs can vary greatly depending on the specifics of each refinery. Flare gas compressors cost between one and eight million dollars depending on the size of the compressor. Also, additional gas storage capacity or equipment to process the gas may need to be installed. Costs for operational controls or process changes that could minimize flaring may have economic benefits. Costs of this proposed control measure will be determined as part of the rule development process.

Other Impacts

Flares act to burn gases released from process units to avoid fires or explosions. As long as safety considerations are not compromised, significant adverse environmental impacts are not expected as a result of adding equipment to process flare gas or making changes to minimize flaring. Large flaring events are of particular concern to communities

around refineries. Implementation of this measure may reduce public exposure to emissions from these events. The affected flare systems are part of existing refinery operations, so that additional equipment added to these systems will not cause additional impacts. However, to the extent that additional control equipment is required, there may be an increase in incineration technology used to abate emissions. Incineration and flares both generate NOx emissions.

References

Technical Assessment Document, Further Study Measure 8, Flares, BAAQMD, Dec. 2002

Suggested Measure Reference # 26, 31, 42

Control Measure SS 7: GASOLINE BULK TERMINALS AND PLANTS

Control Measure Description

This control measure would reduce ROG emissions from gasoline bulk terminals and bulk plants by requiring backpressure monitors and controls to shut down loading when backpressure exceeds a set standard, setting more stringent liquid and vapor leak standards, increasing enforceability, and setting a more stringent emission standard.

Background and Regulatory History

The District regulates ROG emissions from gasoline terminals and bulk plants under Regulation 8, Rule 33, and Rule 39, respectively. Both rules also set standards for gasoline delivery vehicles. Gasoline terminals receive gasoline products by pipeline or barge and load it into trucks for delivery to gasoline dispensing facilities. Gasoline bulk plants receive gasoline products by truck and also load it into trucks for shipment to gasoline dispensing facilities. The principal difference is that bulk plants have the ability to balance or return gasoline vapors to the point of origin via truck, whereas gasoline bulk terminals must process them on site.

Rule 33 for bulk terminals was adopted in 1983 and Rule 39 for bulk plants was adopted in 1987. Rule 33 sets an emission standard of 9.6 grams per cubic meter gasoline loaded (0.08 lb/1000 gal loaded). Rule 39 sets an emission standard of 60 grams per cubic meter gasoline loaded (0.5 lb/1000 gal loaded). Both rules also require equipment maintenance, set liquid leak standards and set standards for gasoline delivery vehicles consistent with the requirements of the California Health and Safety Code. Section 41962 requires the ARB to set standards for gasoline delivery vehicles and pre-empts districts' authority to set standards or to certify vehicles.

Emissions Subject to Control

Gasoline bulk terminals and plants are considered point sources and emissions are calculated for each facility. *Category 64* is for gasoline truck loading at gasoline bulk plants. *Category 898* is for gasoline loading at bulk terminals. The evaporative emissions from trucks during transport and from storage tanks at bulk plants and terminals are not part of this source category and are not part of this control measure.

	Emissions Subject to Control Category, tons/day	
Year	*Category 64*	*Category 898*
2003	0.28	0.97
2006	0.28	0.97

Proposed Method of Control

This control measure, which targets gasoline bulk plants and terminals subject to Bay Area Regulation 8, Rule 33: Gasoline Bulk Terminals and Gasoline Delivery Vehicles, and Regulation 8, Rule 39: Gasoline Bulk Plant and Gasoline Delivery Vehicles, has six specific elements:

1) A requirement to install backpressure monitors on loading racks during gasoline cargo tank loading at terminals and automatic shutoffs if backpressure exceeds 18" H_20, which prevents popping the cargo tank's pressure/vacuum (P/V) valve.
2) A requirement for new vapor recovery piping at loading racks to have a backpressure shutoff at 12" H_20.
3) More stringent leak standards for liquid leaks than the current 3 drops/minute and disconnect leaks than the current 10 ml per disconnect, averaged over 3 disconnects. More stringent standards for vapor leaks than the current 100% LEL measured one inch from the leak source.
4) Incorporation of California Air Resources Board standards for bulk plant certification to increase the enforceability of the standards.
5) A prohibition on loading unless the cargo tank and terminal are compatible.
6) A reduction in the allowable emission standard for bulk terminals.

A requirement for a 12" backpressure at the loading racks shutoff would affect only new equipment installation. California standards and an incompatibility loading prohibition incorporate existing law to make the rules clearer and enforcement easier. Leak standards and disconnect standards would require increased maintenance and operator monitoring but would involve no new equipment installation.

Emission Reductions Expected

Emission estimates are derived from a reduction in the allowable emission rate from 0.08 lbs organic emissions per 1000 gallons loaded to 0.04 lbs/1000 gallons loaded. This is a 50% reduction, or 0.14 tons/day, although existing control equipment at some bulk terminals may already comply with this standard. Further reductions from backpressure monitors on vapor piping and automatic shutoffs, and more stringent leak standards are expected, but cannot be quantified at this time.

Costs of Control

Installation of a pressure monitoring and automatic shutoff system at the bulk terminal loading racks would eliminate excess emissions during loading. Estimated costs for a pressure monitoring and automatic shutoff system are between $20,000 and $35,000 initial costs, with ongoing maintenance costs after installation. The cost will vary depending on the number of lanes at the terminal. There are 14 bulk terminals currently operating in the District. The cost effectiveness of this proposal will be determined, along with an estimate of the potential emissions reductions from prevention of backpressure popping the cargo tank's P/V valves. Vapor processing equipment that

meets current BACT standards is expected to comply with a more stringent emission limitation without additional equipment installation.

Other Impacts

Any new equipment would be installed within existing gasoline bulk terminals. No adverse environmental impacts are expected.

References

Ken Kunaniec, personal conversations, 3/24/03, 5/1/03, 6/16/03
Bay Area Regulation 8, Rule 33: Gasoline Bulk Terminals and Gasoline Delivery Vehicles
Draft Memo, Ken Kunaniec, BAAQMD, 10/06/03

Suggested Measure Reference # 32

Control Measure SS 8: MARINE LOADING OPERATIONS

Control Measure Description

This control measure would further reduce ROG emissions from marine loading operations by controlling currently unregulated cargoes, requiring more stringent emission limitations, and/or controlling housekeeping operations such as tank washing, tank venting or gas freeing aboard marine vessels that result in ROG emissions.

Background and Regulatory History

Regulation 8, Rule 44: Marine Vessel Loading Terminals and Regulation 8, Rule 46: Marine Tank Vessel to Marine Tank Vessel Loading were both adopted in 1989. Reg 8-44 limits precursor organic emissions (ROG) from loading specified organic liquids at marine terminals or from the loading of tank vessels that previously contained these organic liquids. Reg 8-44 affects mostly petroleum refineries, chemical plants, bulk terminal distribution facilities, and shipping companies. Reg 8-46 applies to marine vessel to marine vessel loading operations, termed lightering. Regulation 8, Rule 44 and Rule 46, currently require control of specified organic liquids: gasoline, gasoline blending stocks, aviation gas, JP-4 aviation fuel, and crude oil. The existing emission standard in these rules for loading operations is 2 pounds of precursor organic compound emissions per thousand barrels of organic liquid loaded, or a 95% reduction in emissions.

In the 2001 Ozone Attainment Plan for the San Francisco Bay Area, the District committed to study the viability of further controls on marine vessel loading and marine tank vessel activities in Further Study Measure 11. A draft technical assessment document was completed in December, 2002. The document recommends several changes to Bay Area Regulation 8, Rules 44 and 46 and concludes that there are viable strategies to further control emissions from these operations. In addition, the technical assessment document recommends changes to the emissions inventory to better account for emissions from unregulated cargo.

Emissions Subject to Control

Emissions from marine vessels are divided into several categories in the emissions inventory. Categories 86 and 87 are ship and barge lightering, respectively. Categories 88, 89, and 90 are the emissions from vessel ballasting, the loading of water into a tank that contains organic vapors from crude oil, gasoline and other organic liquids, respectively. Category 91 is for cleaning and gas freeing of vessels. Categories 795 through 798 are the emissions at marine terminals at the refineries from the loading and unloading of crude oil and gasoline (including other products) in tankers and barges. Categories 799 through 802 are the emissions from the loading and unloading of crude oil and gasoline in tankers and barges at locations other than the petroleum refineries.

	ROG Emissions Subject to Control (TPD, Summer) Categories				
Year	*86, 87*	*88, 89, 90*	*91*	*795, 796, 797, 798*	*799, 800, 801, 802*
2003	0.07	1.40	0.56	0.25	0.36
2006	0.07	1.52	0.60	0.25	0.39

The reactive organic (ROG) emissions from these activities total 2.64 tons per day in 2003 and 2.83 tons per day in 2006.

The technical assessment document prepared in December, 2002 includes the results of source tests conducted on unregulated cargo. The results of these tests are not yet incorporated into the inventory data shown above.

Proposed Method of Control

Further study measure FS-11 from the 2001 Ozone Attainment Plan looks at the potential to control currently unregulated cargo, or further limit emissions from marine loading activities. Marine loading and ballasting are already limited by the standards in Bay Area Regulation 8, Rule 44 and 46. In December, 2002, Bay Area staff released a draft technical assessment document (TAD). Source tests conducted in development of the TAD found a number of cargoes that are currently not subject to the rule that had significant emissions that resulted from loading.

The technical assessment document contains three recommendations: 1) a requirement that cargoes be controlled based on emissions rather than type of cargo as in the current rule, and the development of methodology to easily determine applicability of the standards to any given load; 2) a reduction in the fugitive emission standards (measured as a concentration of organic compounds in ppm) based on the current South Coast standard of 1000 ppm; and 3) a requirement to control emissions from ballasting into non-segregated tanks where a regulated cargo was previously stored.

Emission Reductions Expected

A preliminary assessment of the potential reductions estimates that ROG reductions from 0.2 to 0.5 tons per day could be achieved from control of additional cargo and/or control to a more stringent level. In addition, unregulated housekeeping emissions are estimated to be able to be reduced by from 0.5 tons per day or more.

Costs of Control

The technical assessment document estimates costs of control for these additional emissions reductions. The TAD assumes that at least one facility may need to modify its control system and notes that the original costs of control were between $1,000,000 and $30,000,000 per terminal, in addition to costs of $100,000 to $2,000,000 per ship to retrofit to accommodate vapor recovery equipment. Estimates of the cost to control unregulated cargo is from $9000 to $15,000 per load. At 50,000 barrels per load and

6,400,000 barrels loaded yearly of currently unregulated cargo, 90% of which would need control, costs range from $1,036,800 to $1,728,000 yearly. Given the emission reduction estimates of 0.22 to 0.5 tons per year, the cost effectiveness for the control of currently unregulated cargo ranges from $5680 to $21,600 per ton of ROG reduced.

Control of housekeeping emissions is expected to be cost effective, because tank cleaning done under vapor recovery may speed up the process, resulting in fewer demurrage fees for shipping operators. A demurrage fee is a charge for detaining a ship beyond that necessary for loading or unloading cargo. Based on the costs of technology necessary to control housekeeping emissions, a full analysis of the cost effectiveness of this control suggestion will be part of the rule development effort.

Other Impacts

The marine loading operations are part of existing industrial complexes, both part of and apart from refinery operations. The addition of control equipment and associated piping and hardware is not expected to result in adverse environmental impacts. However, to the extent that additional control equipment is required, there may be an increase in incineration technology used to abate emissions. Incineration generates NOx emissions.

References

Technical Assessment Document, Further Study Measure 11, Regulation 8, Rules 44 and 46, Marine Loading Operations, BAAQMD, Dec. 2002
Draft Staff Report, Proposed Revision and Consolidation of Regulation 8, Rule 44 and Rule 46: Marine Loading Operations, BAAQMD, Oct. 2003

Suggested Measure Reference # 26, 36

Control Measure SS 9: ORGANIC LIQUID STORAGE TANKS

Control Measure Description

This control measure would reduce ROG emissions from organic liquid storage tanks by supplementing existing requirements in Regulation 8, Rule 5: Storage of Organic Liquids.

Background and Regulatory History

Regulation 8, Rule 5: Storage of Organic Liquids, was adopted in 1978. The rule mandates equipment standards for large organic liquid storage tanks. The rule applies to tanks storing liquids with a vapor pressure of at least 0.5 psia. Larger tanks and tanks storing highly volatile liquids are required to meet more stringent standards. This control measure applies primarily to large, floating roof tanks that are typically found at petroleum refineries and chemical plants, and gasoline bulk plants and terminals.

The 2001 Ozone Attainment Plan included two commitments regarding organic liquid storage tanks. Control Measure SS-12 focused on inspection requirements and was implemented through an amendment to Regulation 8, Rule 5 in November 2002. Further Study Measure FS-10 focuses on enhanced control requirements for tanks. A draft technical assessment document (TAD) was released in January 2004. The TAD investigated the feasibility of requiring controls on lower vapor pressure liquids than Reg 8-5 currently requires, retrofitting external floating roof tanks with domes to reduce evaporation from air movement across the tank, imposing more stringent tank cleaning standards, requiring external floating roof tanks to be retrofitted with vapor recovery, a provision to allow minor maintenance and encourage more frequent self-inspections, and phasing out riveted tanks currently in service.

Emissions Subject to Control

Emissions from storage tanks are included in the emissions inventory in Petroleum Refinery Evaporation, Storage Tanks. *Categories 55, 56, 57,* and *58* address cone roof tanks, external floating roof tanks, internal floating roof tanks, and other tanks. *Category 940* addresses tank cleaning in petroleum refineries. Fuels Distribution contains the emission inventory categories for gasoline tanks in bulk terminals and bulk plants (*Categories 62* and *63*). Other organic liquid storage tanks are found in *Categories 84* and *85*, which address cone roof tanks and other types of tanks, respectively, in both point and area sources. This control measure focuses on point (permitted) sources.

Emissions are derived from AP-42 correlation equations. The technical assessment document recommends that several elements in the calculations change, because the equations currently in use do not account for evaporative losses through deck fittings and do not account for "zero-gap" seals that are required on many tanks. Potential changes to the calculations are the subject of ongoing discussions with refinery representatives.

Emissions Subject to Control (TPD, Summer)
Categories

	55	*56*	*57*	*58*	*940*	*62 - 63*	*84*	*85*
2003	2.10	1.31	.08	.05	.05	.56	.78	.15
2006	2.19	1.36	.08	.05	.05	.56	.82	.15

The ROG emissions subject to control total 5.08 tons per day in 2003 and 5.26 tons per day in 2006.

Proposed Method of Control

The draft technical assessment document (TAD) has several recommendations to reduce emissions from organic liquid storage tanks: 1) a requirement for domes to reduce wind speed over floating roof tanks that store liquids with at least 3.0 psia vapor pressure, 2) improved standards for degassing and cleaning tanks and for storing and transporting removed sludges, and 3) implement an inspection and maintenance program that provides an incentive for more frequent tank inspections.

The TAD did not recommend that three items be pursued as controls: 1) lowering the applicability of the rule to lower vapor pressure material, 2) requiring external floating roof tanks to be retrofitted to internal floating roofs or fixed roofs with vapor recovery, and 3) phasing out of riveted tanks.

Emission Reductions Expected

The staff report for South Coast Rule 1178, which requires that domes be retrofit onto floating roof tanks, estimates emission reductions of approximately 46%. The Bay Area may not achieve the same reductions because many Bay Area tanks are subject to more stringent seal requirements than in the South Coast. The emission inventory for tank cleaning is very small, although as tanks are cleaned infrequently, the emissions may be significant on days when tank cleaning occurs. Further work will quantify potential emission reductions from sludge handling. Also, emissions reductions for an inspection and maintenance program have not been determined.

Costs of Control

The cost effectiveness of requiring domes on external floating roof tanks is $10,917 per ton of ROG emissions reduced, according to the South Coast staff report for Rule 1178; however, as noted above, if the emission reductions are lower, the measure would be more costly in dollars per ton ROG emissions reduced. Cost effectiveness for the remaining recommendations will be determined.

Other Impacts

Refinery and non-refinery tanks exist in industrial areas. Additional requirements related to tank cleaning or maintenance programs are not expected to have any adverse environmental impacts. Organic liquid storage tanks can be large, up to 200 feet in diameter in some cases. Adding domes to these structures may impair some views or

visual scenes. Also, the addition of domes would mean that entry to verify compliance would be treated as confined space entry and subject to various additional safety standards. Some inspections now required may not be able to be accomplished.

References

Proposed Rule 1178: Further Reductions of VOC Emissions From Storage Tanks At Petroleum Facilities, Staff Report, South Coast AQMD, December 11, 2001
Technical Assessment Document, Further Study Measure 10, Organic Liquid Storage Tanks, BAAQMD, January, 2004
Conversation, Julian Elliot, February 26, 2004

Suggested Measure Reference # 25, 26, 30, 40

Control Measure SS 10: PRESSURE RELIEF DEVICES

Control Measure Description

This control measure would further reduce ROG emissions from pressure relief devices in petroleum refineries and chemical plants.

Background and Regulatory History

Pressure relief valves (PRVs) or pressure relief devices (PRDs) are safety devices installed in refinery and chemical plant process units on pressure vessels and tanks. They function to release overpressures that could threaten the integrity of the process vessel or tank. These devices are typically vented either directly to atmosphere through a PRV or PRD, or to atmosphere through a blowdown system. Some blowdown systems vent to atmosphere with limited controls, most are vented to a flare.

The District regulates ROG emissions from pressure relief devices via requirements in Regulation 8, Rule 28: Pressure Relief Devices at Petroleum Refineries and Chemical Plants. Reg 8-28 was first adopted in 1980 and significantly amended on December 17, 1997. The amendments require refineries to conduct PRD monitoring, reporting, and release prevention planning. Also, the rule requires controls for new PRDs and for PRDs that have repeat releases. In the 2001 Ozone Attainment Plan for the San Francisco Bay Area, the District committed to study the viability of further controls on PRDs in Further Study Measure 8. A draft technical assessment document was completed in December, 2002. The document recommends several changes to Bay Area Regulation 8, Rule 28 and identifies two strategies to further control emissions from these devices. No comments have been received in response to the technical assessment.

Emissions Subject to Control

Emissions from pressure relief devices are reported in Category 19 in the emissions inventory, *Pressure Relief Valves*. The emissions inventory for this category is derived from the annual updates submitted by the affected industries. The emission inventory since 1980 shows significant differences year to year, because of the episodic nature of the releases. For example, 2000 data shows ROG emissions of 0.6 tons per day. 2002 data, the most recent year for which plant submissions are available, shows ROG emissions of 0.18 tons per day. 2003 and future year emissions are calculated from 2002 data.

	Emissions Subject to Control (TPD, Summer)
Year	*Cat. 19 Pressure Relief Valves*
2003	0.19
2006	0.19

Regulation 8, Rule 28 also requires that emissions be calculated for releases and submitted to the District. The highest calculated emission release from a single event during the study period used for the technical assessment document was 32,000 pounds (16 tons) organic compounds. This occurred during one day. The lowest calculated emission from a release event in the study was 6 pounds and the median calculated emission was between 3600 and 3700 pounds.

Proposed Method of Control

The technical assessment document for Further Study Measure 8 from the 2001 Ozone Plan suggests further controls on pressure relief devices and recommends several changes to Bay Area Regulation 8, Rule 28: Episodic Releases from Pressure Relief Devices at Petroleum Refineries and Chemical Plants. The standards in Reg 8-28 for existing PRDs that require prevention measures, hazards analyses and controls do not become effective until the first scheduled turnaround for repair or maintenance of the process unit that contains the PRD. The recommendations are: 1) make PRDs subject to the existing Reg 8-28 requirements prior to a turnaround, 2) amend timelines that are the basis of the definition of repeat ventings, 3) require monitoring or indicators so ventings can be verified and emissions quantified, 4) include a leak or emission standard, and 5) implement recommendations from previous rule audits. These measures would make the rule more enforceable and provide more complete information about releases. Also, vapor recovery systems will need to be evaluated to see if potential emissions could be reduced by routing releases through the existing systems. Because one possible way to minimize ventings is to route gases through flares, this effort will be coordinated with current efforts regarding control of emissions from flares.

Emission Reductions Expected

Based on estimates by EPA and others, increased monitoring requirements can be expected to reduce emissions by about 20%. This would result in ROG emissions reductions of 0.037 tons per day. These potential emission reductions do not account for any emissions inventory adjustments based on data reported pursuant to the requirements of Reg 8-28. It should be noted that a 20% reduction in the highest day calculated emissions from the technical assessment would result in emissions of over 0.04 tons per day annualized (16 tons/day / 365 days/year).

The emissions on an annualized basis (tons per day annualized) are not sufficient to suggest a control measure. This control measure is recommended for inclusion in an ozone strategy because of the potential to reduce a large amount of organic emissions during release events. The technical assessment document notes that during the study period, an average of 12 releases per year occurred. ROG Emissions from the emissions inventory calculated for 12 days equal 5.6 tons per day. A reduction of 20% equals 1.1 tons per day.

The technical assessment document also contains reported emissions estimates for 30 releases during the study period, from 8/03/1998 through 10/19/2002. The emissions are

only from petroleum refineries. The ROG emissions based for these 30 days total 89.38 tons or 2.98 tons per day. A reduction of 20% would be about 0.6 tons per day.

Costs of Control

To be determined.

Other Impacts

Any rule development effort directed at pressure relief devices needs to recognize that the purpose of these devices is safety. PRVs and PRDs prevent overpressurization of vessels to avoid fires or explosions. As long as safety considerations are not compromised, significant adverse environmental impacts are not expected as a result of either adding to the existing rule or requiring more control of emissions from these devices. When these devices release, there is the potential for a large amount of toxic compounds to be released in fairly close proximity to communities. Consequently, there may be a large reduction in potential exposure to those compounds from implementation of this control measure. The affected systems are part of existing refinery operations, so that additional equipment added to these systems will not cause additional impacts. However, to the extent that additional control equipment is required, there may be an increase in incineration techology used to abate emissions. Incineration generates NOx emissions.

References

Technical Assessment Document, Further Study Measure 8, Pressure Relief Devices, BAAQMD, Dec. 2002

Suggested Measure Reference # 26, 39

Control Measure SS 11: WASTEWATER SYSTEMS

Control Measure Description

This control measure would reduce ROG emissions from refinery wastewater systems by requiring control, covers or water traps at various emission points such as open drains, sumps, junction boxes and manholes.

Background and Regulatory History

The District regulates ROG emissions from wastewater systems by setting equipment standards which require minimum gaps in seals around around oil-water separators, gauging and sampling wells, dissolved air flotation units, slop oil vessels, separator effluent channels and junction boxes. The rule has emission limits measured in parts per million concentration as an option in lieu of these standards for large oil-water separators and requires vapor recovery with efficiency standards (percent control efficiency) for sludge de-watering units. The rule also allows vapor recovery with efficiency standards as an option for oil-water separators, slop oil vessels and dissolved air flotation units. Regulation 8, Rule 8 was first adopted in 1979, significantly amended in 1989 and amended to address EPA policy issues in 1993 and 1994.

Emissions Subject to Control

In December, 2002, the staff of the California Air Resources Board and District produced a technical assessment document (TAD) that characterized the emissions from refinery wastewater systems. Emissions as shown in the District's emission inventory are reported as point sources. Categories exist for refinery oil-water separators (*Category 11*) which includes fugitive emissions from process drains, and refinery wastewater treatment (*Category 12*) which includes the biological and/or chemical treatment, settling and clarification to meet water discharge standards that occurs after the oil-water separator. The emissions inventory is shown below

	Emissions Subject to Control (TPD, Summer)	
Year	*Cat. 11 separators*	*Cat. 12 treatment*
2003	3.63	0.13
2006	3.80	0.14

Category 11 consists of oil-water separators and process drains, as well as some other sources such as dissolved air flotation units. Process drains consitute most of the emissions, 2.43 tons/day in 2003 and 2.55 tons in 2006. The TAD estimated emissions by a combination of wastewater sampling to determine organic content, and industry and EPA emissions models to calculate emissions from refinery wastewater drains, junction boxes and manholes. The emissions from these models are estimated to be 3.31 tons/day

from the combination of these emission points. This increase will be incorporated into the District emission inventory.

Proposed Method of Control

A variety of methods can provide controls for open process drains, junction boxes and manholes, such as installation of vapor recovery on emission points accompanied by a control device, seals or traps on drains and open points in junction boxes and manhole covers, and the installation of solid piping where openings to the atmosphere exist. The most cost effective option is to require the installation of water seals on these emission points and to promulgate an emission standard to verify their effectiveness along with a program to assure that the water seals are maintained. The national New Source Performance Standard for refinery wastewater systems requires that emissions from drains meet a 500 ppm hydrocarbon concentration standard. An option not to install water seals could be added as long as emissions from drains do not exceed the ppm standard.

Emission Reductions Expected

Based on established emission reduction factors for water seals, emissions from drains, junction boxes and manholes could be reduced by 65% Based on the emissions in the inventory, a reduction of 65% would reduce emissions by 1.6 tons per day. Based on the TAD estimates, the emission reduction that could be achieved is 1.8 tons per day, accounting for drains already controlled . The emission estimates do not account for the fraction of diesel oil in the wastewater. This could increase the estimates of emissions, and would also increase the estimates of emissions reductions.

Costs of Control

Staff estimated costs for controls on drains, junction boxes and manholes. The cost of controlling drains is from $1100 to $3000 per ton reduced, the cost for junction boxes is from $3300 to $4400 per ton reduced, and the cost for manhole covers is from $3100 - $8800 per ton reduced. The overall cost effectiveness for this proposed measure is from $1900 to $4200 per ton emissions reduced.

Other Impacts

No significant adverse environmental impacts are expected as a result of the adoption of this control measure. The affected wastewater systems are part of existing refinery operations, so that additional equipment added to these systems will not cause additional impacts. The proposed control option will not add to other atmospheric pollutants because additional incineration or adsorption of hydrocarbon vapors is not anticipated. In addition, the existing water treatment systems are designed to handle much greater influent than exists in normal flows. Consequently, additional hydrocarbons going into the treatment system will not result in exceedances of the refineries water discharge permits.

References

Draft Technical Assessment Document: Potential Control Strategies to Reduce Emisions from Refinery Wastewater Collection and Treatment Systems, CARB, and BAAQMD, Jan. 2003
SJVUAPCD Rule 4625: Wastewater Separators
South Coast AQMD Rule 1176: VOC Emissions from Wastewater Systems

Suggested Measure Reference # 24, 25, 26, 43

Control Measure SS 12: BOILERS RATED BETWEEN 5 AND 10 MMBTU/HR

Control Measure Description

This control measure would reduce emissions of nitrogen oxides (NOx) from boilers by extending controls to boilers smaller than those currently regulated by Bay Area Regulation 9, Rule 7.

Background and Regulatory History

The District regulates NOx emissions from boilers under three separate rules, all of which were adopted pursuant to California Air Resources Board (CARB) pollution transport regulations (California Code of Regulations beginning at section 70600). Each BAAQMD boiler rule regulates a different category of boilers. BAAQMD Regulation 9, Rule 7 imposes a 30 ppm NOx limit on industrial, institutional, and commercial boilers with a rated heat input of 10 million BTU/hr or more. Regulation 9, Rule 10 imposes a slightly more stringent NOx limit equivalent to 28 ppm on refinery boilers with a rated heat input of 10 million BTU/hr or more. Regulation 9, Rule 11 applies to extremely large boilers used to generate electricity and imposes a NOx limit equivalent to 15 ppm on boilers with a rated heat input of 250 million BTU/hr or more.

The small boilers to which this measure applies are generally sold as "package boilers" that are equipped and shipped complete with burners, automatic controls and accessories, and mechanical draft equipment. They are generally used in high-rise office buildings, large hotels, and some industrial facilities to supply heat, steam, or hot water. A small number of boiler manufacturers – Ajax, Bryan, Cleaver-Brooks, Kewanee, Teledyne Laars, Parker, Peerless, Rite, and Thermo Pak – manufactured most of the boilers of this size installed in San Francisco.

Emissions Subject to Control

Boiler emissions are included in the BAAQMD inventory in several different categories. Emissions from boilers at power plants are found in the category called *fuels combustion – power plants.* Emissions from boilers at refineries are found in the category called *fuels combustion – oil refineries external combustion.*

The emissions from other boilers, including smaller boilers not already subject to the existing BAAQMD rules, are included in the emission inventory source category called *fuels combustion – other external combustion*. This category includes external combustion sources such as boilers, furnaces, space heaters, and ovens. Boilers already subject to Regulation 9, Rule 7 have air quality permits, and emissions from these boilers are included in the point source portion of this category. Most emissions from the smaller boilers that are the target of this control measure are included in the area source portion of this inventory category (the exception would be small boilers located at facilities required to have a permit for other reasons). These area source emissions are estimated by subtracting fuel usage by the point sources from total fuel usage as obtained from fuel consumption data. Emissions in this category are estimated to be 15.78 tons of NOx per day for 2003.

To determine more precisely the emissions within the *other external combustion* inventory category that are attributable to Bay Area boilers in the size range subject to this measure, data from a boiler database developed by the San Francisco Department of Building Inspection (DBI) was used. Although San Francisco's population represents about one-tenth of the Bay Area total population, it represents about one-fourth of the population in heavily urbanized areas. This is important because boilers are not generally found in suburban areas except at laundries, some light industrial locations, and some schools. The San Francisco boiler population was therefore multiplied by 5 and rounded to arrive at boiler population estimates for the entire Bay Area.

Based on the DBI database, there are an estimated 420 boilers with a capacity greater than 5 million Btu/hr and less than or equal to 10 million Btu/hr in the Bay Area. Total estimated NOx emissions from these boilers are set forth below. Future-year emissions in this small boiler sub-category have been derived using the same growth factors used in the broader *fuels combustion – other external combustion* inventory category.

Year	*Emissions Subject to Control (TPD, Summer)*
2003	1.90
2006	1.99

Note that these emission estimates are likely to change during rule development as better population and emissions information becomes available. For example, Bay Area boiler service companies have indicated that estimates based on the DBI database may significantly understate the numbers of boilers for this particular size range.

Proposed Method of Control

This measure would extend the NOx limit of 30 ppm found in Regulation 9, Rule 7 to smaller boilers in the 5 to 10 million BTU/hr range. Control would generally be achieved by installation of low-NOx burners. A more stringent standard may be possible depending upon the performance of generally available low-NOx burners. Low-NOx burners are available on new boilers manufactured by most of the major boiler manufacturers. In addition, low-NOx burners are available as retrofits for some models, and virtually all of these retrofits are claimed to achieve NOx levels of 30 ppm or less. For many models, however, low-NOx retrofits are unavailable.

Emission Reductions Expected

The maximum total estimated NOx emission reduction that could be achieved, assuming retrofit of all boilers in this size range, would be 1.44 tons per day. However, emission reductions are likely to be significantly lower because many of the boilers in this size range are used for space heating. Annual usage of boilers used for space heating is relatively low, and installation of controls is not likely to be cost effective. For this reason, most boiler rules, including BAAQMD Regulation 9, Rule 7, exempt boilers with low annual usage (less than 90,000 therms). Up to 80% of boilers in this size range may be exempt, based on data developed by the Sacramento Metropolitan AQMD.

Available emission reductions are likely to be in the range from 0.5 to 1.0 tons per day. On the other hand, emission reductions could be higher if the number of boilers is found to be higher than currently estimated or if available low-NOx burners are generally capable of meeting a standard more stringent than 30 ppm. Any emission reductions could probably be achieved in a cost-effective manner only over a period of at least 5 years, given the likelihood that low-NOx burner retrofits will be unavailable for many existing boilers. Most air districts have allowed boiler operators at least 5 years to achieve similar emission limits.

Costs of Control

Installation of low-NOx burners is expected to have a cost effectiveness of $5000 per ton or better based on cost data developed by the South Coast AQMD during development of its Rule 1146.1 and by the Ventura County APCD during development of it Rule 74.15.1. For boilers with low annual usage, controls would be much less cost effective than $5000 per ton.

Other Impacts

Bay Area NOx reductions may reduce ambient levels of fine particulate pollution, because some fraction of the NOx emissions is ultimately converted to nitrate particles in the atmosphere. However, these reactions are not currently well understood and are difficult to quantify.

Minor adverse environmental impacts may occur as a result of this control measure. Photochemical modeling from the 1980's and 1990's and recent ambient measurements indicate that Bay Area NOx reductions are likely to cause an increase in localized Bay Area ozone levels. In addition, ambient measurements suggest an emerging "ozone weekend effect" in the Sacramento area that may mean Bay Area NOx reductions are counterproductive in reducing downwind ozone. Further information on the benefits and disbenefits of Bay Area NOx reductions may come from photochemical modeling associated with the Central California Ozone Study.

Some NOx technologies may adversely affect boiler turndown, capacity, CO levels, or efficiency. Rule provisions should be designed to avoid, for example, efficiency decreases and resulting increases in fuel use that might come from widespread use of boiler derating, water or steam injection, or burners modified to reduce flame temperatures.

BAAQMD air quality permits are not currently required for boilers with an input capacity smaller than 10 million BTU/hr unless they also fire liquid fuels. To implement this control measure, amendments to BAAQMD Regulation 2, Rule 1 to require permits for small boilers would probably be necessary. If boilers in the 5 to 10 million BTU/hr range are as numerous as boiler service companies suggest, the administrative burden for the District could be significant.

References

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Suggested Measure Reference # # 46, 47, 48, 49, 55

Control Measure SS 13: LARGE WATER HEATERS AND SMALL BOILERS

Control Measure Description

This control measure would reduce emissions of nitrogen oxides (NOx) from water heaters larger than those currently regulated by BAAQMD rules and boilers smaller than those currently regulated by BAAQMD rules. NOx limits would be imposed on units with a rated heat input capacity greater than 75,000 BTU/hr and less than or equal to 2 million BTU/hr.

Background and Regulatory History

The District regulates NOx emissions from water heaters under Regulation 9, Rule 6, which imposes a NOx limit of 40 nanograms NOx per joule of heat output on water heaters with a rated heat input capacity of 75,000 BTU/hr or less. The regulated water heaters are conventional tank water heaters typically found in single-family residences.

Boilers are regulated under three separate rules. Two rules apply to large industrial boilers at refineries and power plants (Regulation 9, Rules 10 and 11, respectively). The third rule, Regulation 9, Rule 7, imposes a 30 ppm NOx limit on industrial, institutional, and commercial boilers with a rated heat input of 10 million BTU/hr or more. Control measure SS-[fill in number] proposes to extend the Regulation 9, Rule 7 limits to smaller boilers with a capacity of from 5 to 10 million BTU/hr.

The water heaters to which this measure applies are tank type water heaters similar in appearance, design, and construction to the smaller water heaters subject to Regulation 9, Rule 6. These large water heaters range in size between 75,000 and 400,000 BTU/hr and are used in small hotels, apartment buildings, office buildings, and industrial and commercial facilities to supply hot water.

Units larger than 400,000 BTU/hr are typically small boilers and are different in appearance, design, and construction from water heaters. The small boilers to which this measure applies are generally sold as "package boilers" that are equipped and shipped complete with burners and controls. Boilers in this size range generally rely on natural draft rather than mechanical draft equipment. They are used in office buildings, hotels, schools, and industrial facilities to supply heat, steam, or hot water.

Emissions Subject to Control

Emissions from these units along with emissions from many other types of combustion equipment are included in the BAAQMD inventory in two different categories. Some emissions from water heaters are included in the emission inventory source category called *fuels combustion – domestic.* Combined missions from all types of equipment in this category are estimated to be 8.33 tons of NOx per day for 2003. Emissions from non-residential water heaters and boilers are included in the source category called *fuels combustion – other external combustion*, which includes external combustion sources such as boilers, furnaces, space heaters, and ovens. Emissions in this category are estimated to be 15.78 tons of NOx per day for 2003.

To determine more precisely the emissions attributable to Bay Area water heaters and boilers in the size range subject to this measure, data from a boiler database developed by the San Francisco Department of Building Inspection (DBI) was used. Although San Francisco's population represents about one-tenth of the Bay Area total population, it represents about one-fourth of the population in heavily urbanized areas. This is important because large water heaters and boilers are not generally found in suburban areas except at laundries, some light industrial locations, and some schools. The San Francisco boiler population was therefore multiplied by 5 and rounded to arrive at water heater and boiler population estimates for the entire Bay Area.

Based on the DBI database, there are an estimated 12,300 water heaters with a capacity from 75,000 to 400,000 Btu/hr in the Bay Area. The number of boilers with a capacity over 400,000 BTU/hr and up to 2 million BTU/hr is estimated at 10,500. Total estimated NOx emissions from these water heaters and boilers are set forth below. Future-year emissions for these units have been derived using the same growth factors used in the *fuels combustion – other external combustion* inventory category.

Year	*Emissions Subject to Control (TPD, Summer)*
2003	5.30
2006	5.54

Note that these emission estimates are likely to change during rule development as better population and emissions information becomes available.

Proposed Method of Control

This measure would impose a NOx limit of 40 nanograms per joule of heat output as found in Regulation 9, Rule 6 on large water heaters with a capacity greater than 75,000 BTU/hr and less than or equal to 400,000 BTU/hr. For boilers larger than 400,000 BTU/hr and less than or equal to 2 million BTU/hr, the measure would impose the NOx limit of 30 ppm found in Regulation 9, Rule 7. All limits would apply to new units only. These limits would be identical to limits for new units adopted by the Santa Barbara County APCD (SBCAPCD Rule 360). Water heaters and boilers with burners capable of meeting these NOx limits are widely available from numerous manufacturers.

Rather than impose the limits only on new units, the South Coast AQMD adopted retrofit requirements (in Rule 1146.2) for units with a capacity between 400,000 BTU/hr and 2 million BTU/hr. However, because operators of the units were given approximately 10 years to comply, the requirements are similar in effect to those adopted by the Santa Barbara APCD. In addition, South Coast AQMD staff have reported a non-compliance rate of 80% with rule limits for units subject to RECLAIM. In addition, it appears that retrofits are unavailable for most of these smaller units.

Emission Reductions Expected

The total estimated NOx emission reduction that could be achieved, assuming a 10 year life expectancy for these units and replacement of all units with complying units by the end of the 10-year period, would be 3.9 tons NOx per day. This emission reduction would be achieved year-by-year over the 10-year period as new units replace existing units.

Costs of Control

Based on cost data developed by the South Coast AQMD during development of its Rule 1146.1, cost effectiveness is expected to range from a net cost savings (due to higher efficiency of low-NOx units) to approximately $3,000 per ton of NOx reduced.

Other Impacts

Bay Area NOx reductions may reduce ambient levels of fine particulate pollution, because some fraction of NOx emissions is ultimately converted to nitrate particles in the atmosphere. However, these reactions are not currently well understood and are difficult to quantify.

Burners used to comply with the control measure may reduce energy usage. Low-NOx burners have higher thermal efficiencies than conventional units. Energy savings from use of low-NOx units may be as high as 20%.

Minor adverse environmental impacts may occur as a result of this control measure. Photochemical modeling from the 1980's and 1990's and recent ambient measurements indicate that Bay Area NOx reductions are likely to cause a localized increase in Bay Area ozone levels. In addition, ambient measurements suggest an emerging "ozone weekend effect" in the Sacramento area that may mean Bay Area NOx reductions are counterproductive in reducing downwind ozone. Further information on the benefits and disbenefits of Bay Area NOx reductions may come from photochemical modeling associated with the Central California Ozone Study.

Some NOx technologies may adversely affect boiler turndown, capacity, CO levels, or efficiency. Rule provisions should be designed to avoid, for example, efficiency decreases and resulting increases in fuel use that might come from widespread use of boiler derating, water or steam injection, or burners modified to reduce flame temperatures.

BAAQMD air quality permits are not currently required for these water heaters and boilers and would not be required for implementation of this measure. NOx limits for these units would be enforced through a sales and installation prohibition. The District would enforce the sales ban at the distributor level, and local building departments would prohibit installation of heaters that do not comply with rule requirements. Implementation of the measure is not expected to impose a significant administrative burden for the District.

References

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South Coast AQMD. Rule 1146.2.

Suggested Measure Reference # 46, 47, 48, 49, 51, 52, 53, 57

Control Measure SS 14: STATIONARY GAS TURBINES

Background

This control measure would reduce emissions of nitrogen oxides (NOx) from stationary gas turbines through the revision of existing limits to reflect current best available retrofit control technology (BARCT).

Regulatory History

The District regulates NOx emissions from stationary gas turbines under Regulation 9, Rule 9. The rule was adopted in 1993 pursuant to California Air Resources Board (CARB) pollution transport regulations (California Code of Regulations beginning at section 70600). The CARB regulations required the BAAQMD to adopt by 1994 best available retrofit control technology (BARCT) for source categories that collectively amounted to 75% of the 1987 nitrogen oxides emission inventory. The BAAQMD standards for existing turbines are 9 to 42 ppm depending upon turbine size, with small turbines subject to less stringent limits.

The CARB transport regulations were amended in 2003 and now require adoption of "all feasible measures" to reduce ozone precursor emissions.

In 2002, the San Joaquin Valley Unified APCD adopted amendments to its gas turbine rule (Rule 4703) that impose turbine NOx standards more stringent than the standards found in the rules of most other air districts. The most significant of the SJVUAPCD amendments require larger turbines (greater than 10 megawatts) to meet standards of either 3 or 5 ppm, depending upon the installation date of NOx controls.

Emissions Subject to Control

Turbine emissions are included in the BAAQMD inventory in the category called *fuels combustion – turbines*. Estimated emissions for the category are set forth below.

Year	*Emissions Subject to Control (TPD, Summer)*
2003	1.77
2006	1.83

Proposed Method of Control

Most emission reductions would come from the installation of selective catalytic reduction (SCR) on large turbines (>10 MW) that do not currently use SCR to control NOx emissions.

There are approximately 50 stationary turbines operating in the BAAQMD. Five of the turbines already meet 5 ppm limits, and the measure would not reduce emissions for those turbines. Another 10 large turbines currently meet 9 ppm limits using SCR. Emission reductions from requiring these turbines to meet a 5 ppm limit are likely to be

minor, and cost effectiveness for controls is likely to be poor unless the limit can be achieved through catalyst resizing. Eight large turbines are currently subject to a 15 ppm limit, and adoption of the SJVUAPCD limits would require that they meet a 5 ppm limit. These turbines are all larger than 10 MW and do not use SCR for NOx control. Installation of SCR may not be feasible for all 8 turbines because of site-specific constraints.

Some very minor emission reductions might come from the installation of dry low-NOx combustors (DLN) on small tubines (<10 MW) currently subject to 42 ppm limits. The San Joaquin limits are 35 ppm limit if DLN is not available and 25 ppm if DLN is available. DLN appears to be available for less than half of the 13 Bay Area turbines in this size range. Emission reductions would be minor.

Emission Reductions Expected

Requiring tubines larger than 10 MW to meet a 5 ppm standard would reduce emissions by approximately 1.2 tons per day, assuming SCR installation is feasible and cost effective for all turbines in this category. Additional minor emission reductions may be achievable for some smaller turbines through the installation of DLN. Greater precision in the emission reduction estimate cannot be achieved without detailed investigation for each turbine.

Costs of Control

The SJVUAPCD found that cost effectiveness for the installation of SCR on turbines larger than 10 MW ranged from approximately $5,000 per ton to approximately $10,000 per ton. Cost effectiveness for the installation of DLN on smaller turbines was in this same range.

Other Impacts

Bay Area NOx reductions may reduce ambient levels of particulate pollution, because some fraction of the NOx emissions is ultimately converted to nitrate particles in the atmosphere. However, these reactions are not currently well understood and are difficult to quantify.

Minor adverse environmental impacts may occur as a result of this control measure. Photochemical modeling from the 1980's and 1990's and recent ambient measurements indicate that Bay Area NOx reductions are likely to cause localized increases in Bay Area ozone levels. In addition, ambient measurements suggest an emerging "ozone weekend effect" in the Sacramento area that may mean Bay Area NOx reductions are counterproductive in reducing downwind ozone. Further information on the benefits and disbenefits of Bay Area NOx reductions may come from photochemical modeling associated with the Central California Ozone Study.

Additional use of SCR would increase ammonia emissions and the hazards associated with the transportation and use of ammonia, since the SCR system relies on ammonia injection to reduce NOx.

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U.S. Environmental Protection Agency. 2000. "Compilation of Emission Factors, AP-42 , 5th Ed., Chapter 3.1: Stationary Gas Turbines, Supplement F" and supporting materials including Background Document and turbine database.

Suggested Measure Reference # 50, 54, 56