BOARD MEETING DATE: March 4, 2016 AGENDA NO. 25

PROPOSAL: Rule 1147 Technology Assessment

SYNOPSIS: At its September 9, 2011 meeting, the SCAQMD Board amended Rule 1147 – NOx Reductions from Miscellaneous Sources. The rule requires staff to conduct a technology assessment and report to the Board on the availability of burner systems and heating units for processes with NOx emissions of one pound per day or less. The draft technology assessment considers potential changes to Rule 1147 for specific categories of equipment based on analysis of technical feasibility and cost effectiveness. Staff has proposed to hire a third party to review the draft Technology Assessment, report findings to Rule 1147 stakeholders and incorporate the reviewer's comments. This action is to receive and file the draft Rule 1147 Technology Assessment.

COMMITTEE: Stationary Source, November 20, 2015; February 19 and January 22, 2016, Reviewed

RECOMMENDED ACTION:
Receive and file.

Barry R. Wallerstein, D. Env.
Executive Officer

PF:JC:GQ:WB

---

**Background**

Rule 1147 – NOx Reductions from Miscellaneous Sources, was adopted by the SCAQMD Board on December 5, 2008 with a compliance schedule phased in over 10 years. Rule 1147 incorporates two control measures of the 2007 AQMP: CMB-01 – NOx Reductions from Non-RECLAIM Ovens, Dryers and Furnaces and MCS-01 – Facility Modernization. Control Measure MCS-01 proposed that existing in-use equipment meet best available control technology (BACT) emission limits in place at the time the AQMP was adopted. Control Measure CMB-01 proposed emission NOx limits in the range of 20 ppm to 60 ppm for ovens, dryers, kilns, furnaces and other combustion equipment. Emission reductions from the equipment addressed by Rule 1147 and Control Measure CMB-01 of the 2007 AQMP were also proposed in prior AQMPs.

Rule 1147 was amended September 9, 2011 to delay implementation dates up to two years, remove a requirement for fuel or time meters and provide compliance flexibility for small and large sources. In addition, the rule includes a requirement for a technology assessment on the availability of low NOx burner systems for processes with NOx emissions of one pound per day or less and that are not typically subject to a BACT requirement as new sources. The technology assessment also includes an evaluation of cost and cost effectiveness for small and low emission sources.

**Technology Assessment**

Initially the SCAQMD technology assessment targeted sources in which burner technology was either not available or the retrofit cost was comparable to the cost of replacing the unit. Several categories of equipment were identified and removed from Rule 1147 and the requirement for a permit through the May 2013 amendments to SCAQMD Rules 219 and 222. Staff continued its technical evaluation and developed Rule 1153.1 – Emissions of Oxides of Nitrogen from Commercial Food Ovens to move existing in-use food ovens, roasters and smokehouses from Rule 1147 into their own rule. Rule 1153.1 was adopted on November 7, 2014 and provided more appropriate temperature ranges for defining emission limits, food oven specific emission limits, later compliance dates and an exemption for small units.

The last phase of the technology assessment focuses on the remaining categories of small and low emission equipment that were not addressed through the Rule 219, 222 and 1153.1 rulemaking efforts. While the focus of this report is on equipment with NOx emissions of 1 pound per day or less, the report also includes information and analysis applicable to larger units. This information is provided in order to address stakeholders' concerns regarding the availability of technology for larger equipment.

This assessment utilizes information on affected equipment from the SCAQMD permit system, New Source Review and Rule 1147 emissions testing programs, and from discussions with equipment and burner manufacturers, affected businesses, consulting engineers and industry representatives. The technology assessment provides information on the types and number of equipment affected by Rule 1147, emissions characteristics of this equipment and estimates of the cost and cost effectiveness of replacing existing older combustion systems. This information provides insight into compliance and affordability challenges faced by businesses affected by Rule 1147.

With the exception of a few categories of equipment, the technology review demonstrates that low NOx burner systems are available for every category of equipment subject to Rule 1147 and have been since the late 1990's. However, staff has identified the following three types of equipment for which burners are not readily available or cannot be retrofitted: 1) low temperature ovens and dryers with heat inputs of less than 325,000 Btu per hour (0.325 mmBtu/hour); 2) existing heated process tanks, evaporators and parts washers; and 3) low temperature burn-off ovens and incinerators.

**Cost and Cost Effectiveness**

The staff report for the adoption of Rule 1147 in 2008 reviewed costs for a wide range of equipment with heat inputs from less than 1 million Btu per hour to over 20 million Btu per hour. That analysis of cost and cost effectiveness was averaged over a wide range of burner sizes. However, most of the equipment subject to Rule 1147 requirements have heat inputs less than 4 million Btu per hour, and burners used in Rule 1147 equipment are typically smaller than 2 million Btu per hour. The most common burner size in Rule 1147 equipment is about 1 million Btu per hour. Most of the burner sizes analyzed in the 2008 staff report are larger and rarely used in equipment subject to Rule 1147. The burner sizes evaluated in 2008 are more likely to be found in units at RECLAIM facilities.

In the 2008 Rule 1147 staff report, the average cost effectiveness for replacing the smallest burners with the lowest potential NOx emission reductions was estimated to be about $22,400 per ton (adjusted to 2015 dollars). In the current analysis, the cost effectiveness of replacing burners and other components in small and low emission units varies widely. It is highly dependent upon how often a unit is used, which determines potential emission reductions. Staff estimates that a cost effectiveness range of $15,000 to $46,000 per ton is typical for retrofits of small and low emission equipment. However, retrofits of specific types of low emission equipment could result in cost effectiveness as high as $88,000 per ton of NOx reduced.

Staff has used the current SCAQMD BACT Guidelines criteria of $27,000 per ton for equipment that does not have a defined BACT as a guide to evaluate the cost effectiveness of low NOx retrofits for Rule 1147 equipment. Based on this analysis, staff is suggesting a delay of the requirements for equipment with NOx emissions of 1 pound per day or less until the equipment is modified, relocated or replaced with a new unit. This delay would include all spray booths and most small ovens and furnaces. Staff estimates that 4,900 to 5,650 out of 6,400 Rule 1147 units would be affected by this proposal.

**Recommendations**
As a result of this technology assessment, the following changes are proposed for consideration:

- Exempt sources with total rated heat input less than 325,000 Btu per hour from the Rule 1147 NOx emission limit.
- Change the NOx emission limit from 30 ppm to 60 ppm NOx for the primary chamber for all burn-off ovens, burnout furnaces and incinerators.
- Delay compliance for existing in-use heated process tanks, evaporators and parts washers from the NOx emission limit until the combustion system or tank is modified, replaced or relocated.
- Delay compliance with the NOx emission limit for existing in-use spray booths until the heating system is modified or replaced or the unit is relocated.
- Delay compliance with the NOx emission limit for existing in-use units with actual NOx emissions of one pound per day or less until the combustion system is modified or replaced or the unit is relocated.

**Comments Received**
Staff held a meeting of the Rule 1147 Task Force on February 17, 2016 to receive comments on a draft copy of the Technology Assessment that was released for public review. Staff also received comments in a letter from Furnace, Dynamics, Incorporated sent to SCAQMD staff on February 18, 2016. Stakeholders also provided comments at the Stationary Source Committee meeting on February 19, 2016. The attached Draft Technology Assessment does not yet include a discussion of these comments, but staff will incorporate these comments, other stakeholder's comments, contractor suggestions and staff responses into the next draft of the technology assessment, after the contractor meets with stakeholders.

The comments received at the Rule 1147 Task Force Meeting, in the comment letter and at the Stationary Source Committee focused on staff's initial recommendations and potential future rule amendments including: additional criteria for identifying low emission units, providing long term mitigation options, delaying compliance dates, and individual cost effectiveness calculations for every permit application. Another major category of comments dealt with rule implementation by SCAQMD Engineering and Compliance, including permit application review time, changing how potential emissions are estimated under new source review, and postponing Rule 1147 enforcement actions. There were a few comments received by letter and one comment at the committee meeting on the analysis of cost effectiveness in the technology assessment. These comments will be incorporated into the final document and discussed with stakeholders and the contractor prior to presenting the draft final technology assessment to the Stationary Source Committee.

Key stakeholder requests and staff responses are summarized in the table below:

## Stakeholder Requests and Staff Response

| | |
|---|---|
| • Delay compliance or exempt small and low emission units | • Agree: Exempt small units and delay for low emission units |
| • Change emission limit for burn-off ovens | • Agree: Raise emission limit for primary chamber |
| • Exempt existing in-use heated process tanks | • Agree: Delay compliance until modified, replaced or moved |
| • Delay compliance for existing in-use spray booths | • Agree: Delay compliance for low emission booths until modified, replaced or moved |
| • Provide more options for demonstrating low emissions other than default PTE | • Rule currently allows options requested, but staff will clarify in rule and provide additional guidance |
| • Provide different exemption criteria for some equipment, including a 400,000 Btu/hr threshold and a pound per day measurement based on fuel usage | • Staff will work with stakeholders to evaluate alternatives |

**Future Activity**

Staff will continue working with members of the Rule 1147 Task Force and other stakeholders to collect additional information regarding the feasibility and cost of replacing combustion systems in equipment subject to Rule 1147. Staff will release a Request for Proposals to hire a third-party consultant to review the technology assessment and report back to the Rule 1147 Task Force. Staff has invited stakeholders to participate in the contractor selection process, and the contractor will present draft findings at a future Rule 1147 Task Force meeting, receive feedback and answer questions. The results of the contractor analysis and staff response will be reported back to the Stationary Source Committee with a draft final assessment and a list of actions to consider for future rule amendment.

**Attachment**

Draft Technology Assessment for Rule 1147 Small and Low Emission Sources

**ATTACHMENT**

# SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

## Draft Technology Assessment for Rule 1147 Small and Low Emission Sources

## February 2016


**Deputy Executive Officer**
Planning, Rule Development, and Area Sources
Philip M. Fine, Ph.D.

**Assistant Deputy Executive Officer**
Planning, Rule Development, and Area Sources
Jill Whynot

**Planning and Rules Director**
Planning, Rule Development, and Area Sources
Joe Cassmassi

Author: Wayne Barcikowski – Air Quality Specialist

Reviewed by: Gary Quinn, P.E. – Program Supervisor
William Wong – Principal Deputy District Counsel

**SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT**
**GOVERNING BOARD**

# LIST OF CONTRIBUTORS

**Companies, Organizations and Individuals**

| | |
|---|---|
| Baker Furnace | Tim Bacon / Gary Gorman |
| California Auto Body Association | |
| California Small Business Alliance | |
| Eclipse / Elster Thermal Solutions | |
| FDI | Anthony Endres |
| George T. Hall Company | Manny Perez |
| IPE | Jim Waggoner |
| J.R. Sandoval Enterprises | Linda Holcomb |
| Logan Mechanical | |
| Maximum Equipment & Technical | Jason Luevanos |
| Maxon Corporation / Honeywell | Sal Militello / Miro A. Cavka |
| MidCo International | Charles Aiello |
| PowerFlame | |
| RelyOn Technologies | Al Ortiz |
| Sempra Energy Utilities | Daniel McGivney / Noel Muyco |
| Spray Tech / Junair | Dennis McIntire |
| Spray Zone | |
| Western Combustion | |
| Wirth Gas Equipment | Allan Roughton |

**SCAQMD Staff**

Cher Snyder
Amir Dejbakhsh
Mohan Balagopalan
Andrew Lee
Al Baez
Stacey Ebiner
Fred Del Rosario
Ed Muehlbacher
Charles Tupac
Jason Aspell
Doug Gordon
Rodney Millican
Van Phan
Mark Von Der Au
Heidee de la Cruz
Monica Fernandez-Neild
Derek Hollinshead
Glenn Kasai
Ricky Lai
Tom Lee
Tracy Nguyen
Marilyn Potter
Thai Tran
Carey Willoughby

# TABLE OF CONTENTS

# EXECUTIVE SUMMARY

# EXECUTIVE SUMMARY

## Background

SCAQMD Rule 1147 – NOx Reductions from Miscellaneous Sources was adopted in December 2008 and is an important component of the attainment strategy to meet the federal annual PM2.5 ambient air quality standard as well as meet the ozone standard. The rule regulates NOx emissions from combustions sources that were not addressed by SCAQMD rules other than Rule 474 – Fuel Burning Equipment - Oxides of Nitrogen. Rule 474 was last amended in 1981 and limits NOx emissions rates from equipment burning gaseous fuels to 125 ppm and equipment burning liquid and solid fuels to 225 ppm (at 3% oxygen). Many categories of equipment used in a wide variety of processes are now regulated by Rule 1147. However, similar equipment can have a wide range of operating characteristics, process temperatures and emissions rates. Because of the number and variety of equipment affected, the rule compliance schedule was phased in over 10 years starting in 2010.

Rule 1147 was amended September 2011 to address compliance challenges, remove a requirement for fuel or time meters, delay compliance dates and provide regulatory relief to affected businesses. Throughout the rule amendment process, discussions with affected businesses, equipment manufacturers, and installers focused on concerns that there were many unique pieces of equipment and on the availability of cost effective and affordable low NOx technology. A major concern was the impact of the rule on small and low use equipment with NOx emissions of one pound per day or less. To address this challenge, the amended rule provided two solutions: first, sources with daily emissions rates less than or equal to one pound per day were given a delay of up to two years (until 2017 at the earliest) before they were required to comply with emission limits. These small and low emission units originally had compliance dates five years later than larger units. Second, Rule 1147 included a requirement that staff perform a technology assessment for these small and low emission sources that are not typically subject to the best available control technology (BACT) requirement as new sources.

## Technology Assessment

Initially the technology assessment targeted sources where burner technology was either not available or the retrofit cost is comparable to the cost of replacing the unit. Several categories of equipment were identified and removed from Rule 1147 and the requirement for a permit through the May 2013 amendments to SCAQMD Rules 219 and 222. Staff continued its technical evaluation and developed Rule 1153.1 – Emissions of Oxides of Nitrogen from Commercial Food Ovens to move existing in-use food ovens, roasters and smokehouses from regulation by Rule 1147 into their own rule. Rule 1153.1 was adopted in November 2014 and provided more appropriate temperature ranges for defining emission limits, food oven specific emission limits and later compliance dates. In addition, Rule 1153.1 provided a small source exemption for existing in-use units with emissions of up to one pound per day.

The last phase of the technology assessment focuses on the remaining categories of Rule 1147 equipment that were not addressed through the Rule 219, 222 and 1153.1 actions. This assessment utilizes information on affected equipment from the SCAQMD permit system, SCAQMD emissions testing programs and discussions with equipment and burner manufactures, affected businesses, consulting engineers and industry and business representatives. This report provides information on the types and number of equipment affected by Rule 1147, emission characteristics of these equipment and estimates of the cost and cost effectiveness of replacing old burners. Taken together, this information provides insight into compliance and affordability challenges faced by businesses affected by Rule 1147. While the focus of this report is on equipment with NOx emissions of 1 pound per day or less, the report also includes information and analysis applicable to larger units. This information is provided in order to address stakeholder's concerns regarding the availability of technology for larger equipment.

Staff conducted extensive outreach to equipment manufacturers and product installers. Staff went into the field to identify equipment that will comply with Rule 1147 emission limits with available burners and those that may not. Rule development staff has worked closely with industry representatives and other staff to develop solutions to unique compliance challenges. These discussions resulted in a number of proposals to staff that are included in this report.

Ten major categories of equipment were evaluated through the technology assessment including: afterburner technologies, spray booths, crematories, fryers, heated process tanks, metal melting furnaces, heat treating, multi-chamber burn-off ovens and incinerators, ovens and dryers. As a result of this assessment, the following five recommendations are proposed for consideration in future rule development:

- Exempt sources with total rated heat input less than 325,000 Btu per hour from the Rule 1147 NOx emission limit
- Change the NOx emission limit from 30 ppm to 60 ppm NOx for the primary chamber of all multi-chamber burn-off ovens, burn-out furnaces and incinerators for all process temperature
- Delay compliance for existing in-use heated process tanks, evaporators and parts washers from the NOx emission limit until such time the combustion system or tank is modified, replaced or relocated
- Delay compliance with the NOx emission limit for existing in-use spray booths until the heating system is modified or replaced or the unit is relocated
- Delay compliance with the NOx emission limit for existing in-use units with actual NOx emissions of one pound per day or less until the combustion system is modified or replaced or the unit is relocated

Staff estimates that 4,900 to 5,650 out of 6,400 units would be affected by these proposed changes. Staff will continue working with members of the Rule 1147 Task Force and other stakeholders to collect additional information regarding the feasibility and cost of replacing combustion systems in equipment subject to Rule 1147. Staff will release a Request for Proposals (RFP) to hire a third-party consultant to review the technology assessment and report back to the Rule 1147 Working Group. Staff has invited stakeholders to participate in the contractor selection process. The results of the contractor analysis and staff response will be reported back to the Stationary Source Committee with a list of actions to consider for future rule amendment.

# BACKGROUND

# INTRODUCTION

The California Health and Safety Code requires the AQMD to adopt an Air Quality Management Plan to meet state and federal ambient air quality standards and adopt rules and regulations that carry out the objectives of the AQMP. The California Health and Safety Code also requires the AQMD to implement all feasible measures to reduce air pollution.

SCAQMD Rule 1147 was adopted December 2008 and because of the number and variety of equipment affected, the rule compliance schedule was phased in over 10 years. The NOx reductions from Rule 1147 are a vital component of our attainment strategy and essential for achieving compliance with federal and state ambient air quality standards for PM2.5, PM10 and ozone. Rule 1147 was also amended in September 2011 to address compliance challenges and provide regulatory relief for affected businesses.

# REGULATORY HISTORY

Rule 1147 – NOx Reductions from Miscellaneous Sources, was adopted by the AQMD Governing Board on December 5, 2008. Rule 1147 incorporates two control measures of the 2007 Air Quality Management Plan (AQMP): NOx Reductions from Non-RECLAIM Ovens, Dryers and Furnaces (CMB-01) and Facility Modernization (MCS-01).

Control measure MCS-01 proposed that equipment operators meet best available control technology (BACT) emission limits at the end of a combustion system's useful life. Control measure CMB-01 proposed emission NOx limits in the range of 20 ppm to 60 ppm (referenced to 3% oxygen) for ovens, dryers, kilns, furnaces and other miscellaneous combustion equipment. Emission reductions from the equipment addressed by Rule 1147 and control measure CMB-01 of the 2007 AQMP were proposed in prior AQMPs (e.g., control measure 97CMB-092 from the 1997 AQMP).

Rule 1147 was amended September 9, 2011 to delay implementation dates one to two years, remove a requirement for fuel or time meters and provide compliance flexibility for small and large sources. In addition, the rule includes a requirement for a technology assessment for small and low emission sources that are not typically subject to the best available control technology (BACT) requirement as new sources.

# RULE REQUIREMENTS

Rule 1147 established nitrogen oxide (NOx) emission limits for a wide variety of combustion equipment and affects both new and existing (in-use) combustion equipment. Rule 1147 requires equipment with AQMD permits that are not regulated by other NOx rules to meet an emission limit of 30 to 60 parts per million (ppm) of NOx depending upon equipment type and process temperature. The compliance schedule for existing equipment is phased in over 10 years starting in 2010. Compliance dates for emission limits are based on the date of equipment manufacture and emission limits are applicable to older equipment first. Owners of existing equipment are provided at least 15 years of use before they must meet rule emission limits. The first group of equipment affected had to comply with rule emission limits when they were 20 to 30 years old. Owners of small units and units with emissions of one pound per day or less will comply with emission limits later starting in 2017.

Rule 1147 also establishes test methods and provides alternate compliance options including a process for certification of equipment NOx emissions through an AQMD approved testing program. Certification eliminates the requirement for end-users to test their equipment. Other rule requirements include equipment maintenance and recordkeeping.

In developing rule, staff worked extensively with many stakeholders. Staff held Task Force meetings with representatives from affected businesses, manufacturers, trade organizations and other interested parties. Staff also had separate meetings with manufacturers and distributors of equipment and burner systems. In addition, staff met individually with and visited local businesses to observe operations and equipment affected by Rule 1147. Staff committed to continued discussion with industry through the Rule 1147 Task Force and meetings with individual businesses on issues affecting small business including availability of low NOx burners for unique applications and specific processes.

The majority of the comments made at the Public Workshop and Task Force meetings for the 2011 amendment supported the proposed delay of compliance dates and limits on the use of meters. However, some consultants commented that the compliance delay was not needed and the AQMD should have made a greater effort to educate businesses affected by Rule 1147. An enhanced outreach program to the regulated community was a high priority for the AQMD.

The comments on the proposed amendments received at the workshop and meetings for the 2011 amendment typically fit into two categories. One set of comments dealt with implementation of the rule and asked for clarification or simplification of rule requirements. In response, staff proposed a number of changes relating to equipment identification, maintenance, recordkeeping, and source testing requirements, which ultimately will result in cost savings compared to the original rule. In addition, the amendment added a mitigation fee option that allows business with equipment emissions greater than one pound per day to delay compliance by three years but will provide emission reductions from other sources during that three year period. Together with AQMD efforts to streamline the permit modification process, the amendment helped businesses comply with rule requirements.

The second category of comments received addressed issues beyond the scope of the 2011 amendment which was crafted to respond to the compliance challenges existing at the time. These comments included proposals for new alternative industry-specific rules, questioning availability of low NOx replacement burners, requests for exemption from the rule for small sources, requests to reevaluate rule cost and cost effectiveness and a request to require a cost effectiveness analysis for every piece of equipment subject to the rule. To address many of these issues and as previously stated, the rule amendment committed the SCAQMD to conduct a technology assessment for smaller sources with emissions of one pound per day or less no later than 18 months prior to the first effective compliance date for these smaller sources (July 1, 2017).

## AFFECTED INDUSTRIES AND EQUIPMENT

A wide variety of processes use equipment that is regulated by Rule 1147. These processes include, but are not limited to, food products preparation, printing, textile processing, product coating; and material processing. A large fraction of the equipment subject to Rule 1147 heats air that is then directed to a process chamber and transfers heat to process materials. Other processes heat materials directly such kilns, process tanks and metallurgical furnaces.

Rule 1147 affects manufacturers (NAICS 31-33), distributors and wholesalers (NAICS 42) of combustion equipment, as well as owners and operators of ovens, dryers, furnaces, and other equipment in the District (NAICS 21, 23, 31-33, 42, 44, 45, 48, 49, 51-56, 61, 62, 71, 72, 81, and 92). The units affected by the rule are used in industrial, commercial and institutional settings for a wide variety of processes. Some examples of the processes regulated by the rule include metal casting and forging, coating and curing operations, asphalt manufacturing, baking and printing.

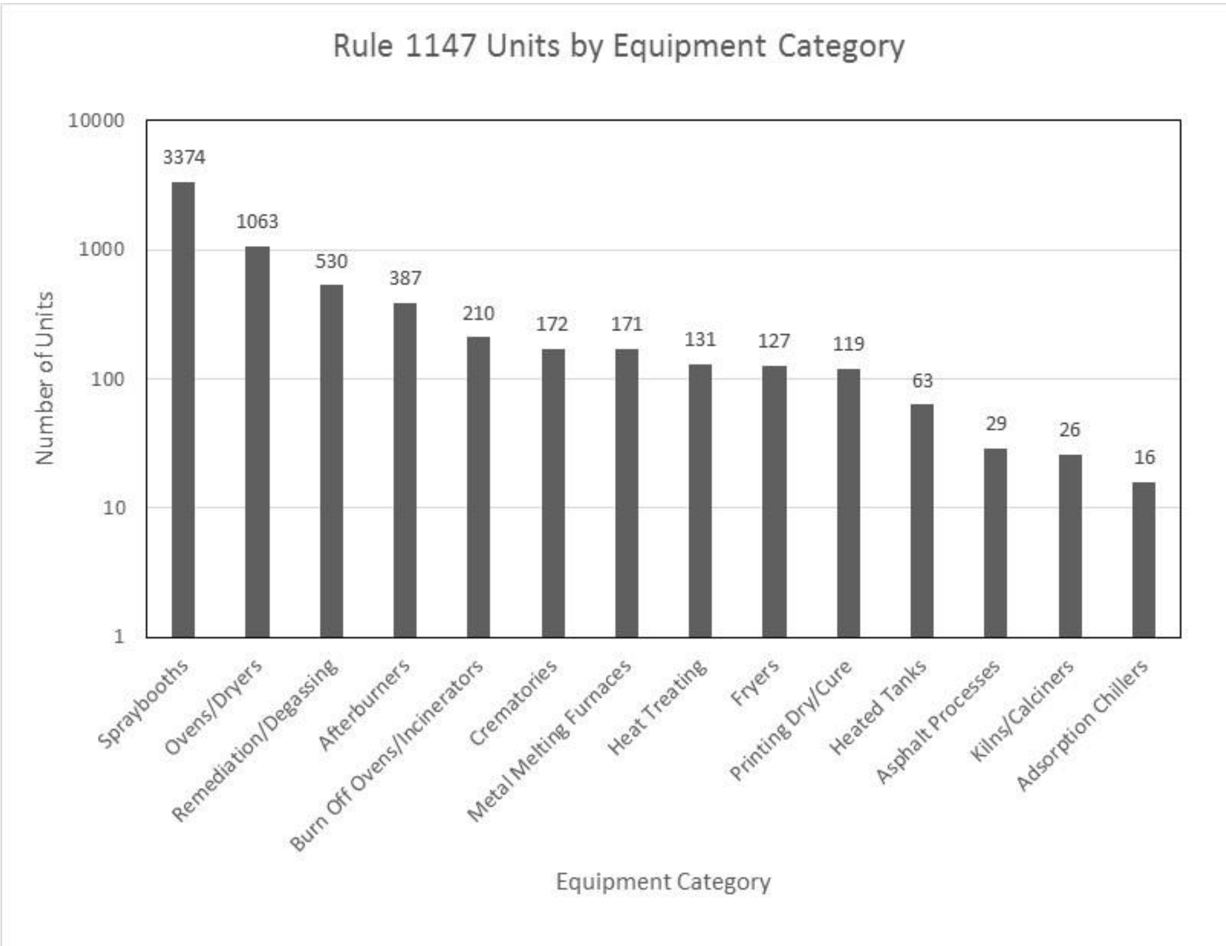
Staff originally estimated approximately 6,600 units subject to the emission limits of Rule 1147 are located at approximately 3,000 facilities. Staff estimated that about 1,600 units at about 800 facilities affected meet the NOx emission limits of Rule1147. This leaves about 2,200 facilities that are expected to require retrofit of burners in their equipment. Staff estimated as many as 2,500 permitted units with NOx emission limits greater than one pound per day and an additional 2,500 permitted units with NOx emission limits of less than one pound per day will require modification to comply with the emission limits.

Based on an update of the active permitted equipment in the SCAQMD, an estimate of the number of equipment potentially subject to Rule 1147 and the fraction of units in different categories is presented in Figure 1-1. Staff estimates that as many as 6,400 pieces of equipment are potentially subject to Rule 1147 requirements. More than half of the units (≈ 3,400) are spray booths and prep-stations. Excluding spray booths and prep-stations, staff estimates that at least one quarter of the units in each category will meet Rule 1147 emission limits without retrofitting burners.

The second largest category of equipment is ovens and dryers with approximately 1,100 units subject to the rule. Staff estimates that at least one-third of the permitted ovens will meet Rule 1147 emission limits based on a sample of the burners used in the ovens. There are also approximately 500 additional ovens and dryers with SCAQMD permits that are not subject to Rule 1147 because they are heated electrically, with infrared lamps, or using a boiler or thermal fluid heater. Electric, infrared lamp, and boiler and thermal fluid heated ovens and dryers are not included in the Figure 1-1.

The third largest group of equipment is air pollution control units that capture and incinerate VOCs, CO, PM and toxics. There are approximately 900 afterburners, degassing units and remediation units. The remaining categories of equipment have significantly fewer units with high temperature processes (metal melting, heat treating, burn off ovens, kilns and crematories) being the next largest group with approximately 700 units in these five categories. Although these categories have fewer equipment, many units have significantly higher emissions than spray booths and small ovens. Appendix A provides a more detailed summary of the industries and equipment categories affected by Rule 1147.

Figure 1-1




Based on permitted emissions and information provided by manufacturers, vendors and businesses, staff has calculated an emissions inventory of 3.0 to 5.2 tons of NOx per day from the equipment regulated by Rule 1147. Spray booths (≈ 3,400 units) contribute about 0.5 to 0.6 tons per day. Other types of equipment with permit limits of one pound per day or less (≈ 1,500 units) have NOx emissions totaling about 0.4 tons per day. Equipment with a potential to emit of more than one pound per day (≈ 1,500 units) contribute NOx emissions of 2.1 to 4.2 tons per day. These emission estimates are consistent with the 6.2 tons per day emission estimate developed from the 2007 AQMP for adoption of Rule 1147 in 2008.

Note that the AQMP inventory was based on fuel use and default emission factors. The 2007 AQMP inventory did not take into account lower emissions from units that met

BACT emission limits. Using the midpoint of the estimated range from the above calculation for larger sources gives a total inventory estimate for all equipment of about 4.1 tons of NOx per day. This estimate is consistent with the AQMP inventory and permit information that at least one quarter of the units have burners that can comply with BACT and Rule 1147 emission limits.

In addition, staff estimates that as many as half of the units (750 out of 1,500) with a potential to emit greater than one pound per day may have actual daily NOx emissions less than a pound per day. If this estimate is correct, then more than half of units with emissions greater than one pound per day of NOx (about 375) have already submitted test protocols and test results. Moreover, because of the Rule 1147 compliance schedule, most of the remaining half of the 750 units with actual emission greater than one pound per day have been permitted since the late 1990s and installed burners that comply with BACT and Rule 1147 NOx emission limits.

# TECHNOLOGY ASSESSMENT

## SOURCES OF INFORMATION

This report includes information from the technology assessments for Rule 1147 adoption in 2008, the rule amendment in 2011 and new information from the Rule 1147 emission testing program. This information is summarized by equipment category and by rule emission limit. The basis for the technology based emission limits in the rule are in Part D of the SCAQMD BACT Guidelines. In addition, testing performed to demonstrate compliance with SCAQMD permit limits indicated when an emission limit was achieved in practice and was used in the technology assessments for rule adoption and amendment. While the focus of this report is on equipment with NOx emissions of 1 pound per day or less, the report also includes information and analysis applicable to larger units. This information is provided in order to address stakeholder's concerns regarding the availability of technology for larger equipment.

The appendices to this report provide detailed information on affected industries, emission testing, cost effectiveness calculations, available technology and emission test results for these equipment categories. Appendix A provides a detailed summary of the equipment categories and businesses affected by Rule 1147. Appendix B of this report includes a summary of the sources of information used for rule adoption and the subsequent 2011 amendment. Appendix C provides a discussion of the SCAQMD emission test program, testing guidelines and a summary of the Rule 1147 emissions test completed. Appendices E through N provide details on the equipment, burners and emission test results for the different categories of equipment subject to Rule 1147.

In addition to information available from SCAQMD programs, this report includes recommendations from equipment and burner manufactures, affected businesses, consulting engineers and industry and business representatives. Staff conducted outreach to equipment manufacturers and product installers. Staff went into the field to identify equipment that will comply with Rule 1147 emission limits with available burners and those that may not. Rule development staff has worked with industry representatives and other staff to develop solutions to compliance challenges. These discussions resulted in a number of proposals to staff that are included in this report.

## RESULTS OF THE RULE 1147 EMISSION TESTING PROGRAM

Emission testing is performed to demonstrate compliance with an emission limit. Testing companies do enough calibration, testing and calculation to prove that pollutant concentration or mass emissions are below the applicable limit. Most Rule 1147 emission test results are adjusted by the testing company or SCAQMD staff to address issues with a test's acceptable range or with other testing and calculation issues. While emission tests can demonstrate compliance with an emission limit, many test results cannot be used to accurately estimate concentrations or mass emissions from individual units and categories of equipment. However, the Rule 1147 testing program does demonstrate that burners and their control system comply with the rule emission limits.

Table 2-1 provides a summary of submitted Rule 1147 NOx emission test results that have completed SCAQMD staff review and demonstrated compliance with Rule 1147 emission limits. These test results indicate that equipment subject to Rule 1147 comply with the NOx emission limits. Table 2-1 shows the number of test results and average NOx emission concentrations for units tested at the highest and at a low firing rate if applicable. In most cases the highest firing rated tested is the normal operating condition. However, in a small number of cases the low firing rate is the normal condition. The table also indicates the applicable NOx emission limit for each category of equipment. Table 2-1 does not include results from tests that were subsequently repeated because the original test did not comply with the test method, test protocol or SCAQMD guidelines.

Table 2-1

Rule 1147 Emission Test Results

| Equipment Category | Rule 1147 NOx Limit (ppm [1]) | Number of Units Tested at Normal/High Fire | Average NOx Concentration at Normal/High Fire (ppm) | Number of Units Tested at Low Fire | Average NOx Concentration at Low Fire (ppm) |
|---|---|---|---|---|---|
| **Afterburner/ Regenerative Thermal Oxidizer** | 30 or 60 [2] | 13 | 26 | 4 | 13 |
| **Afterburner/ Thermal or Catalytic Oxidizer** | 30 or 60 [2] | 9 | 40 | 1 | 41 |
| **Afterburner/ Remediation Unit** | 60 | 2 | 23 | 1 | 24 |
| **Spray Booth (Automobile)** | 30 | 10 | 24 | | |
| **Spray Booth (Other)** | 30 | 13 | 18 | 2 | 22 |
| **Crematory** | 60 | 20 | 50 | | |
| **Dryer/Asphalt** | 40 | 1 | 35 | | |
| **Fryer** | 60 | 7 | 29 | | |
| **Fuel Cell Heater** | 30 or 60 [2] | 1 | 11 | 1 | 9 |
| **Heated Tank** | 60 | 7 | 37 | 1 | 34 |
| **Metallizing Spray** | 30 or 60 [2] | 1 | 22 | | |
| **Metal Heat Treat** | 60 | 23 | 48 | | |
| **Metal Melting (Large)** | 60 | 8 | 42 | 1 | 58 |
| **Metal Melting Pot/Crucible** | 60 | 5 | 54 | | |
| **Multi-chamber Burn Off Oven or Furnace** | 30/60 or 60/60 [3] | 11 | 42 [4] | | |
| **Multi-chamber Incinerator** | 30/60 or 60/60 [3] | 1 | 54 [4] | | |
| **Oven/Dryer** | 30 or 60 [2] | 112 | 20 | 35 | 21 |
| **Print Dryer/Oven** | 30 | 19 | 20 | 4 | 23 |
| **Textile Shrink Dryer** | 30 | 2 | 24 | | |
| **Textile Tenter Dryer** | 30 | 4 | 23 | 4 | 26 |
| **Unit Heater** | 30 or 60 [2] | 3 | 20 | 1 | 13 |
| | | | | | |
| **Number of Units** | | 272 | | 55 | |

[1] The Rule 1147 NOx limit is based on a reference level of 3% oxygen ($O_2$) in the exhaust. All emission test results are converted to a concentration in parts per million at the reference level of 3% $O_2$.

[2] The emission limit depends upon the process temperature.

[3] The emission limit for the primary chamber varies depending upon process temperature.

[4] Average NOx emissions measured after the secondary chamber (afterburner).

## BURNER AVAILABILITY AND FEASIBILITY TO RETROFIT UNITS

While the Rule 1147 emissions testing program indicates that the rule limits are achievable for all categories of equipment with current available technology, there is one situation where low NOx burners are not available. There is also one type of process for which staff recommends changing an emission limit based on the type of burners used in that process. In addition, there are several related categories of equipment where it is not feasible to retrofit an existing unit.

### Burners for Small Ovens and Dryers

Low NOx burners are not available for very small low temperature ovens or dryers. The smallest burners produced are between 0.4 and 0.5 mmBtu per hour. If an oven requires a burner to consistently operate below about 0.3 mmBtu per hour, low NOx burners are not available to meet the 30 ppm NOx emission limit. There are smaller low NOx burners for high temperature applications that must meet an emission limit of 60 ppm. However, these applications typically require multiple burners and the total heat input exceeds 0.4 mmBtu per hour. Based on these findings, staff is considering exempting units with heat inputs less than 325,000 Btu per hour from the rule emission limit.

### Emission Limit for Burn off Ovens and Furnaces

The second category of equipment that may have difficulty meeting an emission limit of 30 ppm in low temperature applications is burn off ovens, furnaces and incinerators. Burn off ovens and furnaces melt and incinerate coatings and other materials on a product that is being recycled. This occurs in a chamber where the process temperature may be above or below 800 °F. For processes below 800 °F the NOx emission limit is 30 ppm. The incinerated materials go to a second chamber or incinerator that operates above 800 °F and has a NOx emission limit of 60 ppm.

However, the preferred type of burner for the primary incineration chamber is the same type of burner used in high temperature applications such as afterburners. These are also the same types of burners used in kilns, direct fired furnaces and crematories. These burners have been designed to comply with emission limits in the 50 to 60 ppm range. After discussions of this issue with equipment and burner manufacturers, staff is considering changing the emission limit for the primary chamber of burn off ovens, furnaces and incinerators to 60 ppm.

### Heated Process Tanks, Evaporators and Parts Washers

The Rule 1147 testing program has identified three types of heating systems used in process tanks, evaporators and some parts washers that comply with the NOx emission limit. There is no information yet available for the fourth type of heating system. For all four of these systems, the burners and heat exchangers or tubes are designed as one integrated system. If an individual heated tank or evaporator system using any of systems does not comply with the emission limit, then the whole tank will have to be replaced. Exempting existing in-use units from complying the rule emission limit unless the combustion system is modified would address the issue that it is not feasible to retrofit an existing heated tank with different burners. If a tank is retrofitted with new burners, the owner will likely replace the heating tubes or heat exchanger. If the owner rebuilds a process tank, then a rule compliant system can be installed at that time.

# COST AND COST EFFECTIVENESS

## REVIEW OF SCAQMD COST EFFECTIVENESS ANALYSIS

There is no single cost or cost effectiveness limit established by the SCAQMD Board for use in rule development, permitting or other programs. Cost effectiveness for CARB and SCAQMD rules and programs differ and depend upon the program, the pollutant, the nature of the process and equipment affected and the types of feasible emission control options. For example, in 1993 a $15,000 per ton criteria for RECLAIM Trading Credits was adopted by the Board for the SCAQMD emission trading program to trigger additional evaluation and potential rule amendment. Adjusted to 2015 dollars using the Marshall & Swift Equipment Cost Index, that criteria would now be approximately $25,000 per ton. However, for amendment of the SOx RECLAIM program in 2010, the SCAQMD Board approved an amendment with cost effectiveness up to $60,000 per ton (adjusted to 2015 dollars).

For Rule 1147 adoption, staff estimated average cost effectiveness for replacement of different sizes of burners. Most of the burners evaluated for adoption of Rule 1147 were too large and not used by equipment subject to the rule. Those burners are only used by large equipment subject to the RECLAIM program. Most of the equipment subject to Rule 1147 requirements have heat inputs less than 4 million Btu per hour and burners used in Rule 1147 equipment are less than 2 million Btu per hour. The most common burner size in Rule 1147 equipment is 1 million Btu per hour. In the 2008 staff report, the average cost effectiveness for replacing the smallest burners with the lowest potential NOx emission reductions was about $22,400 per ton (adjusted to 2015 dollars).

For new source review under SCAQMD Regulation XIII, cost effectiveness can be included in the determination of what is best available control technology (BACT) for emission control for non-major sources. For BACT decisions affecting new sources at major facilities, cost or cost effectiveness is not included in the evaluation. However, BACT determinations for non-major (minor) sources are established by two approaches. One path evaluates technology and cost effectiveness as part of a public process to establish minor source BACT. The public process includes workshops and stakeholder input. The cost effectiveness for those decisions varies depending upon the pollutant, process and equipment involved. Note that there is one important difference in the calculation of cost effectiveness between traditional BACT analysis and rule development. For rule development, a best estimate of equipment's useful life is used in the calculation of cost effectiveness instead of a fixed 10 year assumption that is associated with financing of new equipment.

Historically, the second path used to establish minor source BACT was demonstration by a permitted unit at a non-major facility that an emission limit was "achieved in practice." If an emission limit was achieved in practice at a non-major facility, that emission limit became minor source BACT and was required by SCAQMD for applications for subsequent SCAQMD permits for similar new units regardless of the cost and cost effectiveness.

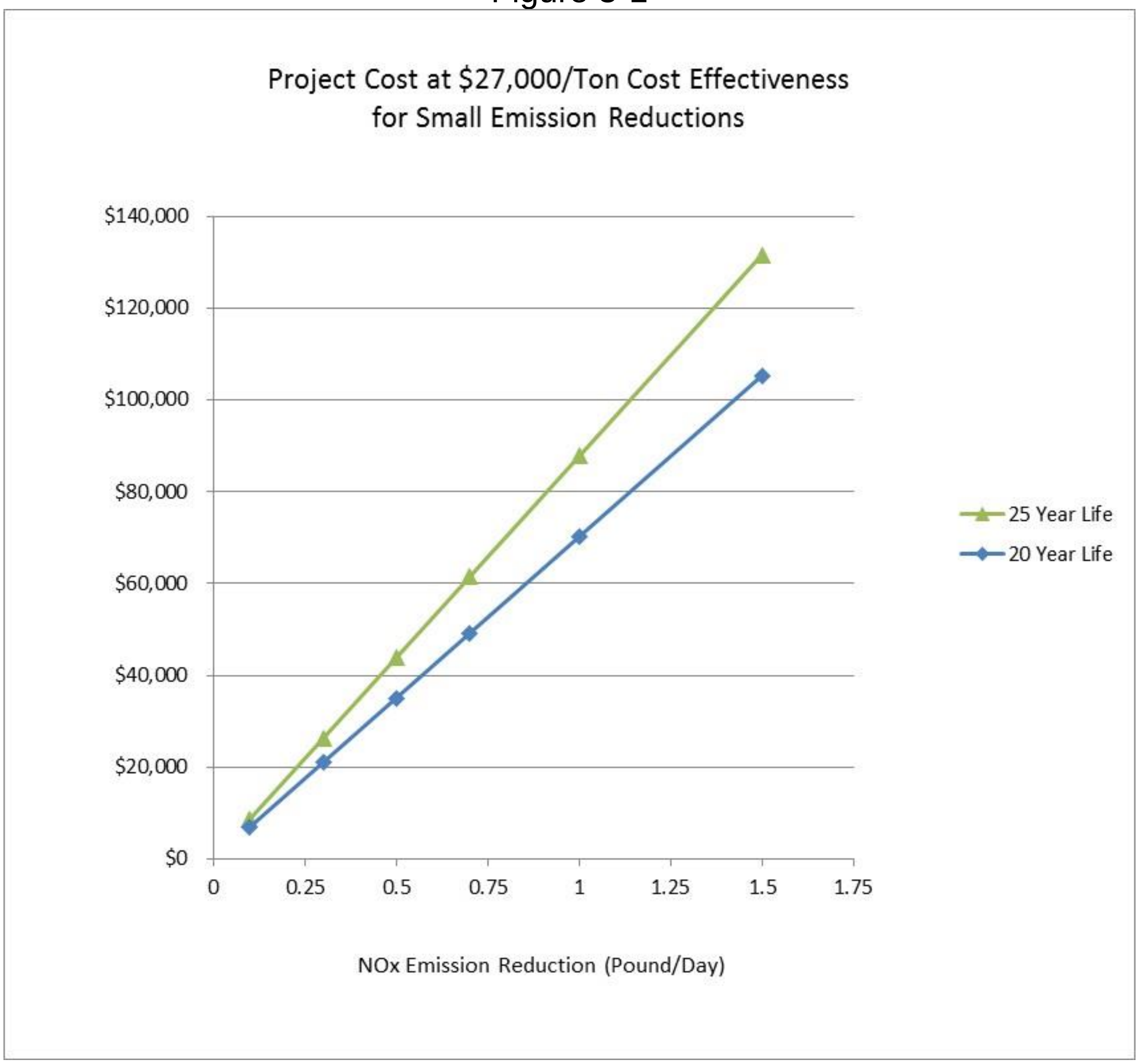
The SCAQMD has also established maximum cost effectiveness criteria in the SCAQMD BACT guidelines for sources for which there is no defined minor source BACT (Appendix

D). These cost effectiveness criteria is adjusted every calendar quarter by the Marshall & Swift Equipment Cost Index to account for changes in equipment cost. The cost effectiveness criteria for processes that do not have an established BACT is currently about $27,000 per ton of NOx for average cost effectiveness and about $81,000 per ton of NOx for the incremental cost effectiveness between two or more control options. The incremental cost effectiveness for Rule 1147 equipment is the difference in cost and emissions between an old natural gas burner (BACT prior to 1998) and a low NOx gas burner meeting rule emission limits. These minor source BACT criteria are appropriate for the analysis of cost effectiveness for small equipment with emissions of one pound per day or less.

## SCAQMD BACT COST EFFECTIVENESS CRITERIA

The cost to retrofit equipment and the NOx emission reductions for the project can be illustrated for different cost effectiveness criteria with a graph. Figure 3-1 shows an example using small emission reductions of approximately a pound per day and project cost that results in a cost effectiveness of $27,000/ton of NOx reduced. The cost is shown for projects with equipment lifetimes of 20 and 25 years.

Figure 3-1



For emission reductions of 0.25, 0.5 and 1 pound per day, project costs of $20,000, $40,000 and $80,000 have cost effectiveness of $27,000 per ton. Emission reductions of 0.25 to 1 pound per day bound the range of emission reductions achievable from small and low emission equipment that are the subject of this technology assessment. This equipment has NOx emissions of one pound per day or less, are exempt from the BACT requirement under new source review and have more time to comply with Rule 1147 emission limits.

## DISCOUNTED CASH FLOW ANALYSIS

For calculating cost and cost effectiveness, SCAQMD BACT guidelines (Appendix D) and rule development use a discounted cash flow (DCF) analysis to estimate the cost and cost effectiveness of emission control options. The DCF method is used to calculate a net present value (NPV) of current and future expenses and savings (cash flows) from installing emission control equipment. When determining the cost and cost effectiveness of a control option, the current costs associated with the purchase and installation of equipment are added to the net current value of future costs and savings associated with operating the new equipment. In a situation where one emission control system is replacing another, the future cost and savings incorporated into the analysis are those above and beyond the cost of maintaining and operating the current equipment.

To calculate the cost effectiveness of an emission control system, the purchase, installation and operating cost of new equipment (the NPV) is divided by the emission reduction benefit of the new equipment over the operating life of the equipment. The operating life of equipment can vary from about 10 years for a residential tank type water heater to 25 or more years for residential heating furnaces, boilers, ovens, furnaces, kilns and afterburners. There is a significant number of permitted equipment including ovens, kilns, furnaces and afterburners systems operating in the SCAQMD that are 20 to 50 years old.

## LEVELIZED CASH FLOW ANALYSIS

In response to recommendations from a SCAQMD sponsored review of its socioeconomic analysis conducted by Abt Associates and stakeholder comments, all current and future rule analyses will include both the DCF and levelized cast flow (LCF) estimates of costs and cost effectiveness. The cost-effectiveness values based on DCF and LCF methods are not directly comparable to each other: DCF discounts all future operation and maintenance costs to their present values whereas LCF amortizes the initial capital and installation costs over the equipment lifetime. This is why DCF values are always lower than LCF values for the exact same amount of estimated compliance cost.

## EXCLUDED COSTS

Because the useful life of boilers, ovens and furnaces can be several decades, the cost of routine maintenance and equipment replacement unrelated to control equipment is not included in the cost effectiveness analysis of regulatory requirements to meet emission standards. For example, a boiler’s heat exchange tubes may be replaced several times over the boiler’s life. Burners and combustion control systems in boilers and other equipment must be maintained and are routinely repaired or replaced. In addition, heat treating furnaces have refractory and door seals replaced several times over the furnace’s lifetime. Indirect fired heat treating furnaces also require replacement of heating tubes and may require replacement of heat shields and recirculation fans as the furnace ages. Furnace refractory, seals, tubes and heat shields may be replaced two to three times over a twenty year period. These routine maintenance and repair expenses are independent of the cost of upgrading equipment to meet emission standards.

Costs for demonstrating compliance with SCAQMD rules and regulations are excluded from cost effectiveness analyses for emission control equipment. SCAQMD BACT Guidelines, permit processing policy, and rule development process do not include the cost of demonstrating rule compliance such as source testing in the calculation of emission control equipment cost effectiveness. However, compliance demonstration costs including emissions testing, recordkeeping and other costs beyond what is recommended by equipment manufacturers are included in the socioeconomic assessment for rule adoptions.

Compliance demonstration costs are not included in a cost effectiveness analysis of new pollution control systems because all units regulated by a rule are subject to the same compliance costs. All units required to meet the Rule 1147 NOx emission limit must be tested and the owner/operator must keep maintenance and test records. A rule compliant unit that does not replace its heating system has the same compliance costs as a unit that does replace burners and other components. Moreover, costs due to compliance with other SCAQMD rules such as Regulation XIII (new source review), including BACT and emission offsets, should not be included in the calculation of cost effectiveness for emission control equipment installed to comply with Rule 1147 emission limits.

## CALCULATION OF COST EFFECTIVNESS PER BURNER

The calculation of cost and cost effectiveness for Rule 1147 adoption and the 2011 amendment were done on a per burner basis. There are four reasons for this approach. First, combustion systems retrofit to comply with Rule 1147 emission limits use the same system components whether the unit has one or multiple burners. Burners, valves, and control systems will be the same for each burner. The system component that will differ is the combustion air blower (fan). Some units will use packaged burners with an integrated combustion air blower (fan) and others will use an external blower for one or multiple burners. Second, the cost per burner for a burner with its own integrated combustion air blower is higher than for a system with multiple burners and one blower. Third, most small or low emission units have only one burner and tend to use package burners with integrated combustion air blowers. Fourth, the emissions for the whole unit and per burner will be comparable whether one or multiple combustion air blowers are used. For these reasons, the cost effectiveness analysis in this document focuses on the cost and emission reduction per burner replaced utilizing the cost for a burner with an integrated blower.

## COST AND COST EFFECTIVNESS OF REPLACING BURNER SYSTEMS

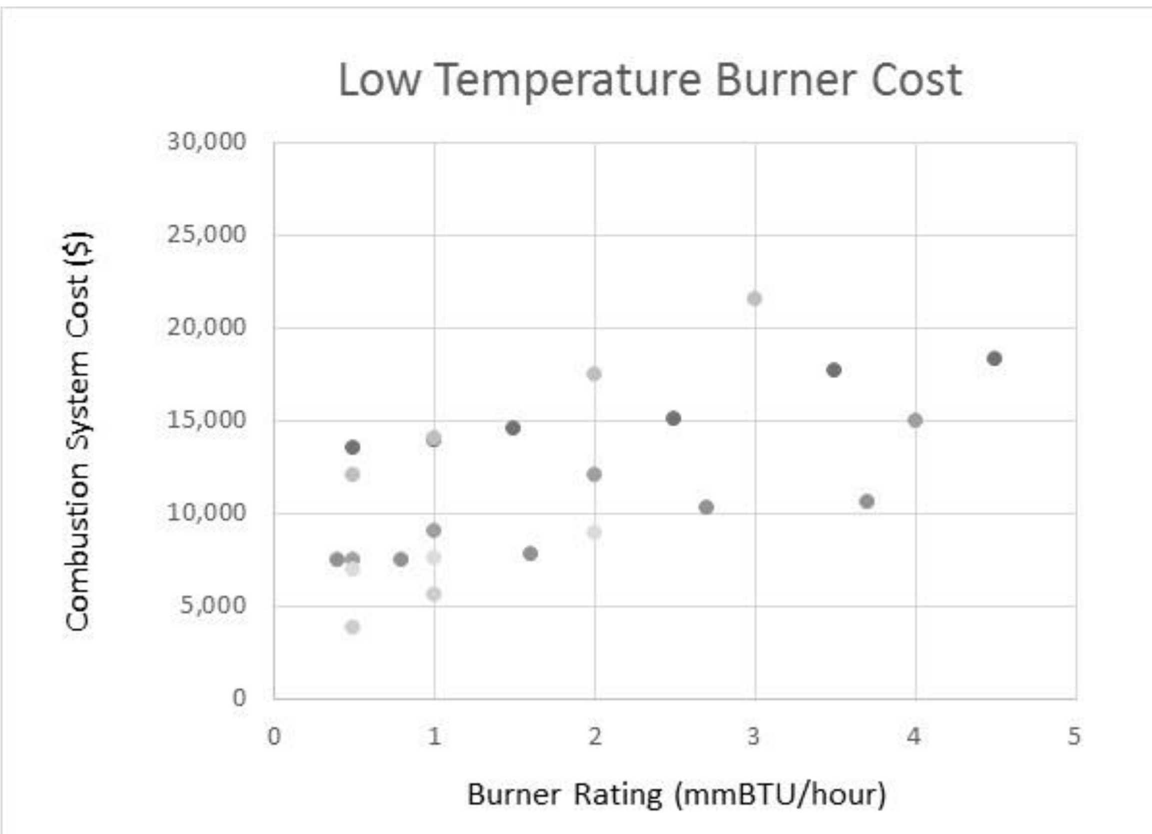
The cost of replacing burners and other combustion system components with the most commonly used low NOx burners is shown in Figures 3-2 and 3-3. Burner and combustion system replacement cost for low temperature applications that are required to comply with a 30 ppm NOx limit are displayed in Figure 3-2. Figure 3-3 shows replacement cost for high temperature applications that are required to meet a 60 ppm NOx limit. These figures include information for the most common burners from the three manufacturers that provide the majority of low NOx burners used in Rule 1147 equipment in the SCAQMD.

**Burner Cost and Cost Effectiveness for Low Temperature Ovens and Dryers**

Figure 3-2 summarizes information on low NOx burners and system components for low temperature operations including ovens and dryers. These costs represent a typical equipment cost to the customer and do not include tax, shipping and installation costs. The information provided is for nozzle mix burners with packaged combustion air blowers including the Eclipse Winnox and HaloFire, the Maxon Cyclomax and Ovenpak-LE and the MidCo low NOx burner.

Other types of systems can also be installed in ovens and dryers, but the cost of those alternatives are comparable to the cost of burner systems with packaged combustion air blowers. The cost for a burner with a separate combustion air blower is comparable to the cost of a packaged burner. Separate combustion air blowers are used for larger burners or where multiple burners with one blower providing combustion air to all reduces the cost of the system. Low NOx line burners are also available from Eclipse and Maxon but are more commonly used for larger systems than those that are the focus of this report. However, the cost for small line burners are comparable to the cost of the low NOx packaged burner systems shown in Figure 3-2.

Figure 3-2




Eclipse and Maxon each have two nozzle mix low NOx burner product lines for low temperature applications. Each has one system that was developed about 15 years ago (Cyclomax and Winnox) and a recently developed burner system (HaloFire and Ovenpak-LE). Maxon also has a third low NOx burner (the M-Pakt) that uses a different technology to lower NOx that is not included in this Figure but has been installed in a small number of units in the SCAQMD. The M-Pakt burner costs more than the burners included in Figure 3-2 but can achieve significantly lower NOx emissions (less than 10 ppm).

Because some replacements do not require the replacement of the fuel supply components and the control system while other retrofits require the replacement of all components, the Maxon Cyclomax and Eclipse Winnox cost in Figure 3-2 only include the cost of the burner with combustion air blower. The Eclipse HaloFire and the Maxon OvenPak-LE cost include the replacement of fuel and control systems. If a retrofit with a Winnox and Cyclomax burner requires replacement of other components including fuel and control systems, the total equipment replacement cost is comparable to the cost of purchasing a HaloFire or OvenPak-LE with all combustion system components. The MidCo low NOx burners are only sold with MidCo fuel and control system components and have two costs depending upon options requested. Replacement of a units fuel line and control system components depend upon the age of the original equipment and the replacement burner. If fuel line and control system components do not meet current building and safety codes, then they must be replaced with new components that comply with current code requirements.

The majority of the low emission equipment (1 pound/day NOx) subject to Rule 1147 have combustion systems rated less than 2 mmBtu/hour. Most use single burners rated less than 2 mmBtu/hour. The cost for installing a burner in the size range of 0.5 to 2 mmBtu/hour is a good estimate of the cost to replace combustion systems in typical low emission units. The cost of packaged burners and combustion systems of this size varies from about $5,000 to $15,000 with typical equipment costs ranging from $7,500 to $15,000.

However, to calculate total cost of replacing equipment, shipping, tax and installation costs must be added. One approach to estimate installed cost is an established EPA method that uses a multiplying factor to include sales tax and estimate shipping and installation cost. Based on the EPA method and the sales tax rate in southern California, the SCAQMD has used a factor or 1.87 times the cost of equipment to estimate installed cost. In this method, installation costs are assumed to be 50% of the equipment cost and are included in the factor. A contingency can also be included to address uncertainties in the cost estimation. For this analysis an additional 13% is added which results in an installed cost estimating factor of 2.0. Using this factor, an estimated cost for installing a low NOx burner in small ovens and dryers is approximately $30,000 [$15,000 X 2.0] but can be lower or higher depending upon the components replaced and other factors.

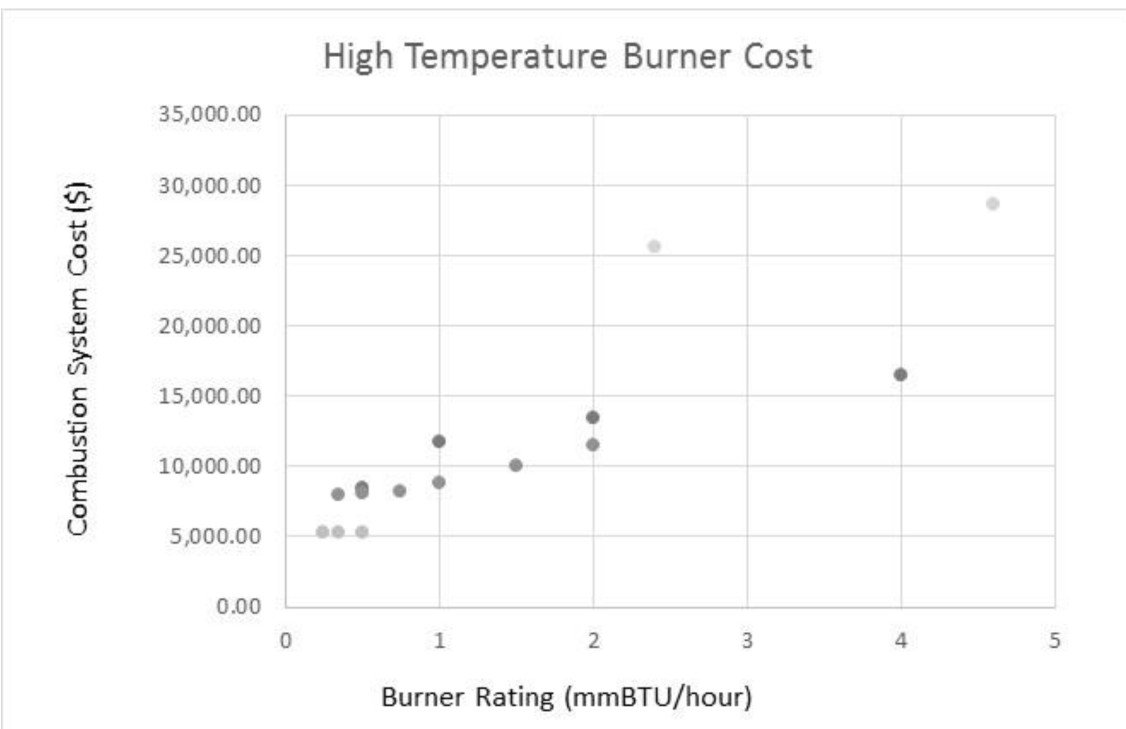
The cost effectiveness of replacing oven and dryer burners in this size range can be estimated using the NOx reductions possible from low emission units. Emission reductions of 0.25, 0.5 and 0.75 pounds per day over 260 days per year and 20 years result in a cost effectiveness of $46,154, $23,077, and $15,385 per ton for a project cost of $30,000. Since most reductions are likely in the range of 0.25 to 0.5 pounds per day, the range is best represented as $23,000 to $46,000 per ton of NOx reduced with the midpoint of this range at $34,500 per ton. This cost effectiveness to replace combustion systems for low emission ovens and dryers is greater than the SCAQMD BACT $27,000 per ton average criteria but less than the $81,000 per ton incremental criteria for minor source BACT.

In summary, the cost of replacement burners and combustion system components can vary depending upon which components must be replaced. Depending upon the age of the original installation, the burner or the entire combustion system may be replaced. In addition, installation cost can vary depending upon the particular piece of equipment and whether the equipment owner has requested additional work that is not required for compliance with Rule 1147 emission limits. Additional cost will be incurred when upgrading capacity and performing other equipment maintenance. Disregarding other costs the equipment owner may choose to include in a retrofit project, the cost effectiveness for low emission units to comply with the Rule 1147 emission limit may exceed the SCAQMD minor source BACT average criteria for NOx.

**Burner Cost and Cost Effectiveness for High Temperature Applications**

Figure 3-3 displays burner and combustion system costs for high temperature applications. These costs represent a typical equipment cost to the customer and do not include tax, shipping and installation costs. The three most common burners used in high temperature applications to comply with the Rule 1147 NOx emission limit of 60 ppm are the Maxon Kinedizer, the Eclipse Thermjet and Eclipse Tube Firing Burner (TFB). The Kinedizer and Thermjet are used in direct fired heating applications including metal melting, heat treating and in afterburners. The TFB is used for indirect heating applications such as heat treating. Burners from other major manufacturers including Bloom, Facultatieve, and North American/Fives have also been available for more than 15 years and were tested for Rule 1147 compliance. However, these systems were original installed burners and were not retrofits. Staff is not aware of any units that were retrofit with burners from these manufacturers in order to comply with Rule 1147.

Figure 3-3



Pot and crucible furnaces use small nozzle mix burners from a number of manufacturers. Figure 3-3 includes cost for different sizes of the Eclipse Ratio Air burner which has been installed in a small crucible furnace to comply with the Rule 1147 NOx emission limit. A Kinedizer burner has also been used to retrofit a small crucible furnace to increase capacity, reduce fuel cost and lower NOx emissions.

The cost per burner for high temperature applications is similar to the cost for low temperature applications. However, in larger metal melting and heat treating furnaces, multiple small burners are typically used to provide a more even distribution of heat in the furnace. In situations with multiple burners, the furnace is designed with one combustion air blower for all burners. However, the Eclipse Thermjet, the Ratio Air and the Maxon Kinedizer are also used in many applications requiring one burner. Consequently, the cost shown for the Thermjet, Ratio Air and Kinedizer in Figure 3-3 includes the cost of an individual combustion air blower, new fuel supply components and a new control system. In situations where multiple burners are installed with one combustion air blower and a common control panel, the cost per burner will be less. The cost for each TFB burner is based upon the cost for a system with six burners, new combustion air blower, fuel supply components and control system. The cost of the TFB burner also includes a flue gas recirculation (FGR) system for each burner that lowers NOx emissions. The FGR system is currently available for burners rated up to 0.5 mmBtu per hour.

For small high temperature applications up to 2 mmBtu per hour, the cost per burner is similar to the cost for low temperature applications and is in the range of $5,000 to $15,000. Using the EPA based multiplier factor of 2.0 to estimate installation cost for individual NOx burners in small high temperature equipment is approximately $10,000 to $30,000 but can be lower or higher depending upon the components replaced, number of burners and other factors.

Similar to the case of replacing burners in low temperature applications, the cost effectiveness of retrofitting smaller high temperature units with low NOx burners for emission reductions of 0.5 pounds per day or less may exceed the SCAQMD minor source BACT NOx average cost effectiveness criteria. For example, replacing burners at a cost of $10,000 to $30,000 per burner for an emission reduction of 0.5 pound per day per burner over 25 years gives a cost effectiveness range of $6,150 to $18,500. However, emissions are highly dependent on the size of unit and operating schedule. A reduction of 0.25 pounds per day per burner for the same cost gives a cost effectiveness range of $12,300 to $37,000 per ton. With this smaller emission reduction, the cost effectiveness may exceed the minor source BACT average cost effectiveness criteria of $27,000 per ton depending upon the cost of the burners and other components selected. For emission reductions less than 0.2 pound per day the cost effectiveness is likely to exceed the BACT average cost effectiveness criteria.

As with low temperature applications, the cost of replacing burners and combustion system components varies depending upon components replaced. Contingent upon the age of the original equipment, the burner or the entire combustion system may require replacement. Installation cost varies between equipment and locations. In addition, the equipment owner may request additional work that is not required for compliance with Rule 1147 emission limits which will increase the cost of the project.

**Heating System Cost and Cost Effectiveness for Spray Booths**

The cost difference to a customer between a new certified rule compliant heated spray booth and a new non-compliant unit is less than $10,000 based on information from manufacturers, vendors and the cost of booths prior to rule adoption. The cost for new units includes markups from the booth manufacturer applied to the cost of the burner, gas train and control system. Most of the specialty booths used for applications other than auto body repair were tested with standard burners, so there was no additional equipment cost to comply with Rule 1147 limits. However, the cost for adding a new natural gas fired certified heating system to an existing spray booth varies from $30,000 to $50,000 with a typical cost of about $40,000. The heating system cost varies depending upon the manufacturer, type of booth and the individual installation.

The cost of a complete new booth is highly variable depending upon the type of booth and options. According to vendor supplied information, the cost to purchase and install a new spray booth is about 20% higher than in 2008 when Rule 1147 was adopted. This increase is consistent with industry data on the cost to purchase and install new equipment (i.e., Marshall & Swift Equipment Cost Index which includes inflation, the cost of materials and manufacturing costs). The typical new installation is a semi down draft (side draft) booth for about $80,000. A new basic cross draft booth without recirculation is less and the cost of a new full down draft booth is about $115,000 and up depending upon options. Although the cost for semi down draft and down draft booths are higher than for a basic cross draft, the heating system costs are about the same for basic and premium booths from the same manufacturer or vendor.

The cost effectiveness of a new low NOx SCAQMD certified auto repair booth is at most $22,000 per ton [($10,000 at most) / (70% reduction in NOx) X (0.25 lb/day / 2000 lb/ton) X 260 days/year X 20 years)]. For higher volume shops, the cost effectiveness is lower than $22,000/ton.

The cost to retrofit a used booth to install in the SCAQMD as a new permitted unit is significantly less than purchasing a new booth. However, the cost effectiveness for retrofitting an existing permitted auto repair booth with an SCAQMD certified heating system is $88,000 per ton of NOx reduced based on a cost of $40,000 and a 20 year life. For a high volume booth used two shifts a day, the cost effectiveness could be less than half this value ($44,000/ton). For a booth retrofit costing $30,000 the cost effectiveness is $33,000 to $66,000 per ton depending upon the number of cars processed. This cost effectiveness of retrofitting an existing permitted booth is higher than the minor source average cost-effectiveness criteria of $27,000 per ton and may exceed the incremental cost effectiveness of $81,000 per ton used for equipment without a defined BACT.

Depending upon the age of a used booth, the owner may have to upgrade the booth to meet current building and safety codes. The local building and safety agency may require mechanical, electrical, fire safety and other components be upgraded or replaced. These costs are not attributable to Rule 1147 and are also not included in the cost effectiveness analysis for new, modified or relocated units that require a new SCAQMD permit.

The preceding analysis indicates the cost effectiveness for upgrading existing spray booths to comply with the Rule 1147 emission limit exceeds the minor source average cost-effectiveness criteria of $27,000 per ton used by SCAQMD for equipment categories without a defined BACT and in some cases may exceed the incremental criteria of $81,000 per ton. However, the cost effectiveness for new units is at most $22,000 per ton and is less than the BACT Guidelines criteria. Because the cost effectiveness to retrofit an existing permitted booth is significantly higher than the minor source BACT criteria, staff is considering amending Rule 1147 to delay compliance for existing in-use permitted booths and heating units until they are modified, relocated or replaced. Staff is proposing that new, modified, or relocated units requiring an SCAQMD permit continue to be required to comply with the Rule 1147 NOx limit at the time of modification or installation. Currently a change of ownership in a business with an existing in-use permitted booth is exempt from the retrofit requirement unless the booth or heating unit is modified, relocated, replaced or becomes 20 years old.

## EXAMPLES OF CALCULATIONS FOR SMALL SOURCES

A number of equipment replacement scenarios have been submitted to SCAQMD staff as examples of high cost effectiveness for replacing burners in some small Rule 1147 equipment. This section reevaluates some of those scenarios presented to staff. In order to accurately reflect equipment operation and regulatory requirements, the following analyses use permit application information provided by the applicant, SCAQMD permit conditions and SCAQMD BACT guidelines.

### Afterburner Controlling Smoke and Odors from Smokehouse

An after burner for a smokehouse has been in operation since the 1960s. The afterburner is rated at 250,000 Btu/hour, is 50 years old and uses pipe burners. NOx emissions are more than 101 ppm (0.136 pound/million Btu). According to the equipment permit and application, the smokehouse operates 12 hours per day for three days a week and 4 hours per day two days per week. This operating schedule was confirmed by the company owner when recently questioned by an SCAQMD inspector. A permit condition requires the afterburner to operate whenever the smokehouse is in use (40 to 44 hours per week). If the current afterburner operates an average of 40 hours per week every week, NOx emissions over 25 years are 0.88 tons (0.25 mmBtu/hour X [0.136 lb/mmBtu] X [40 hour] X [52 weeks/year] X [25 years] / [2000 lb/ton]). While this operating schedule includes some holidays, it ignores second shifts and weeks when the company operates on a Saturday.

Because of the age and design of this particular afterburner, the entire unit likely needs to be replaced in order to comply with the Rule 1147 NOx emission limit. The burners in the unit are pipe burners which are pipes with holes in them. A consultant working with the company estimated that a replacement rule compliant afterburner would cost about $30,000 (equipment and installation). Staff also contacted vendors to estimate the cost of a replacement afterburner for this application. Based on vendor information, a total project cost of $30,000 is typical for a new afterburner of this size. A new rule compliant afterburner with emissions of less than 60 ppm (0.72 lb/mmBtu) would reduce emissions by at least 0.42 tons over 25 years. The estimated cost effectiveness for this emission reduction is $30,000 divided by 0.42 tons or about $71,000/ton. For this afterburner and other types of equipment with very small burners, the cost of retrofitting or replacing the unit may be higher than the minor source BACT average cost effectiveness criteria for sources without a defined BACT.

The analysis of this case presented to staff showed a much higher cost effectiveness than $71,000/ton because it assumed the afterburner operates only one hour per day. However, this afterburner must be operated at all times the oven is operating and contains smoke. This requirement is common to all emission control equipment permitted in the SCAQMD. In fact, the operator of this particular unit was cited in the past by the SCAQMD for not operating the afterburner consistent with this permit requirement.

**Small Heated Process Tank or Evaporator**

Many small heated process tanks and evaporators have burners, heat exchangers, and tank dimensions that are specific to each manufacturer and product line. Replacement with different burners may require replacement of the entire tank if the heat exchange system cannot be replaced. The cost for replacing the smallest process tank and heat exchange system is at minimum $30,000 to $40,000. Burners purchased separately for a new tank rated less than one mmBtu/hour may cost as much as $5,000 to $10,000. The minimum cost for a new tank with burners is about $40,000.

Most small heated tanks and evaporators operate with burners that cycle between high fire and off. A typical small system has burners in the size range of 350,000 Btu per hour (0.35 mmBtu/hour) to one million Btu per hour. NOx emissions based on a burner rating of 0.7 mmBtu/hour, a 20 year life and a default emission factor of 0.136 lb/mmBtu for natural gas are about 0.43 pounds per day or 1.1 tons over 20 years [(0.7 mmBtu/hour) X (50%) X (0.136 lb/mmBtu) X (9 hours/day) X (5 days/week) X (52 weeks/year) X (20 years)/(2000 lb/ton)]. This operating schedule does not take into account holidays but it also does not include any weeks with second shifts or operation on Saturdays. A rule compliant system (60 ppm NOx or 0.72 lb/mmBtu) would reduce NOx emission by about 0.52 tons over a 20 year period. The cost effectiveness for replacing the whole system would be about $79,000 per ton ($40,000/ 0.52 tons). The cost to retrofit or replace this type of small low emission unit may be higher than the minor source BACT average cost effectiveness criteria for sources without a defined BACT.

**Burners for Generating Smoke and Heating Smokehouse Oven**

A smokehouse has been in operations since the 1960s. The burner in the smokehouse is rated 35,000 Btu/hour with NOx emissions of more than 101 ppm (0.136 pound/million Btu of natural gas). Since 1990, BACT for smokehouse smoke generators is an electric heating element instead of a gas fired burner. An electric heating element costs less than $100 including tax and shipping. Electric heating elements come in a variety of shapes and sizes. If the smokehouse burner is similar to round burners used in water heaters or ranges prior to 1983, the owner could also replace the old burner with a low NOx burner (15 ppm) used in modern water heaters for about $100. The cost to install a circuit for the electric heating element or retrofit the gas burner would be about $500 for a total cost of about $600.

The burner/heating element in the smokehouse is used to heat wood chips to slowly generate smoke. It is also used to heat the smokehouse and is assumed to operate an average of two hours per day for 5 days each week. The amount of time the burner fires is determined the amount of wood chips and by the required oven temperature. The oven temperature depends upon the type of sausage produced and whether the smoked products contain sodium nitrite. Products without nitrites must be smoked at a higher temperature to kill bacteria.

For this example, the NOx emissions over 20 years are 50 pounds (0.0250 tons). The cost effectiveness for replacing the burner with a heating element or low NOx burner is at most $24,000/ton of NOx reduced ($600/0.0250 ton). If the burner or heating element operates for more than two hours per day, the cost effectiveness is lower. This example highlights that some small equipment can be retrofit to comply with Rule 1147 emission limits for low cost and reasonable cost effectiveness. Note that on adoption of Rule 1153.1 at the November 2014 Board meeting, existing smokehouses were removed from Rule 1147, included in Rule 1153.1 and are not required to comply with the rule's emission limits.

## RECOMENDATIONS

## RULE CHANGES UNDER CONSIDERATION

The emission testing program for Rule 1147 indicates that most equipment regulated by the rule can comply with the NOx emission limit (i.e., Table 2-1). The appendices of this report discuss the emissions test results for each category of equipment which demonstrate compliance with rule emission limits. However, low NOx combustion systems are not available for some types of small units. In addition, some categories of equipment are difficult to retrofit. Based on technical feasibility, staff is considering the following changes to Rule 1147:

- Exempt new and existing in-use units with total rated heat input of less than 325,000 Btu/hour from the Rule 1147 NOx emission limit. There are no burners in this size range for ovens and dryers that are designed to meet BACT and Rule 1147 emission limits. The smallest low NOx air heating burners designed to comply with the 30 ppm NOx limit are 400,000 to 500,000 Btu/hour (0.4 to 0.5 mmBtu/hour). If this size burner is set up to operate at less than 325,000 Btu/hour and used in an oven that requires the burner to frequently operate at heat inputs of less than 30% of its capacity, then the burner is not likely to comply with the 30 ppm emission limit. While there are burners in this size range for high temperature equipment including heat treating furnaces and kilns, these units typically use multiple small burners (four or more), have total heat ratings much greater than 325,000 Btu/hour and must comply with a 60 ppm emission limit. This change would affect an unknown number of small units regulated by Rule 1147.
- Delay compliance with the NOx emission limit for in-use heated process tanks, evaporators and parts washers with an integrated heated tank until such time the combustion system or tank is modified. New units would be required to meet the emission limit unless the total unit heat rating is less than or equal to 325,000 Btu/hour. Source test information on three of the four available types of heating systems for these heated process tanks can comply with the emission limits. However, if a unit does not comply with the emission limit, the entire process tank must be replaced. Staff estimates this change would affect less than 50 units subject to the Rule 1147 NOx emission limit.
- Change the NOx emission limit from 30 ppm to 60 ppm NOx for the primary chamber of multi-chamber incinerators, burn-off ovens, burn-out furnaces and incinerators that operate below 800 °F. This new limit will be the same compliance limit required for higher temperatures. The burner needed for the primary chamber of these devices is not designed to achieve 30 ppm. This change would affect a small unknown number of units.

Based on cost effectiveness considerations, staff is considering the following changes to Rule 1147:

- Delay compliance with the NOx emission limit for most existing in-use spray booths until the booth or heating system is modified, relocated or replaced. Modified, relocated and new spray booths and prep stations would be required to meet the emission limit at the time of modification or installation unless the total unit heat rating is less than or equal to 325,000 Btu/hour. However, staff is considering to evaluate existing in-use operations with multiple booths and locations separately from smaller operations with one location and single booths and prep stations. The cost effectiveness for a new unit that meets the Rule 1147 NOx emission limit is at most $22,000 per ton. The cost effectiveness for retrofitting an existing unit can be as high as $88,000 per ton. This change will affect more than half of the units now subject to Rule 1147 emission limits. This will result in delays in emission reductions of 0.3 to 0.4 tons/day starting July 1, 2017. These emission reductions forgone will be reduced as new units replace old units.

- Delay compliance with the NOx emission limit for other existing in-use units with actual NOx emissions of one pound per day or less until the unit or combustion system is modified, relocated or replaced. In addition, if the unit's emissions exceed one pound per day of NOx at a later date, then the unit must comply with the NOx emission limit. Staff is considering to further evaluate operations with multiple small units whose emissions are significant. Unit emissions can be documented using gas or time meters and daily recordkeeping. The cost effectiveness for retrofitting low emission units varies considerably and can be significantly higher than the SCAQMD BACT Guidelines average cost effectiveness criteria for equipment for which BACT has not been defined. This change will affect at least one quarter of the in-use units subject to the Rule 1147 emission limit. This will result in delays of emission reductions of about 0.3 to 0.5 tons/day starting in July 1, 2017. These forgone reductions will decrease as new units replace old units.

These five changes to the rule would address infeasibility of retrofitting specific types of units and reduce cost by delaying compliance with the NOx concentration limit for units with low emissions. These changes would affect at least 4,900 permitted units of which two thirds are spray booths. In addition, up to half of the remaining 1,500 units subject to Rule 1147 may also have NOx emissions less than one pound per day which would result in compliance delays for 5,650 out of 6,400 units. These changes will result in a delay in emission reductions of 0.6 to 0.9 tons per day. However, these forgone emission reductions will be made up over 15 to 25 years as old units are replaced with new compliant units.

# REFERENCES

# REFERENCES

EPA, 2002. *EPA Air Pollution Control Cost Manual, Sixth Edition* [EPA-452-02-001], United Stated Environmental Protection Agency, February 2002

SCAQMD, 2011. *Rule 1147 – NOx Reductions from Miscellaneous Sources*, South Coast Air Quality Management District, September 2011.

SCAQMD, 2008. *Rule 1147 – NOx Reductions from Miscellaneous Sources*, South Coast Air Quality Management District, December 2008.

SCAQMD, 2000. *Best Available Control Technology Guidelines Part D: BACT Guidelines for Non-Major Polluting Facilities*, South Coast Air Quality Management District (October 2000, Revised October 3, 2008)

# APPENDICES

# Appendix A – Summary of Rule 1147 Equipment Categories

# SUMMARY OF RULE 1147 EQUIPMENT CATEGORIES

Units regulated by Rule 1147 are used in commercial, industrial, government and institutional settings and by a variety of businesses. Rule 1147 affects manufacturers (NAICS 31-33), distributors and wholesalers (NAICS 42) of combustion equipment, as well as owners and operators of ovens, dryers, furnaces, and other equipment in the SCAQMD (NAICS 21, 23, 44, 45, 48, 49, 51-56, 61, 62, 71, 72, 81, and 92).

A wide variety of processes use equipment that is regulated by Rule 1147. These processes include, but are not limited to, coating; printing, textile processing, material processing, and manufacturing using wood, plastics, ceramic and metal materials. A large fraction of the equipment subject to Rule 1147 heat air that is then directed to an oven or dryer in order to dry or cure materials or coatings (convective heating). In addition, most paint booths and semi-enclosed prep-stations that are used to control overspray of coatings during application also have a heat source to accelerate curing and drying of coatings. Other types of equipment heat products directly using a combination of radiant and convective heating (e.g., radiant ovens, kilns, process tanks and furnaces). Some ovens, dryers, furnaces and kilns do not use burners to provide heat and consequently are not regulated by Rule 1147. They use electric heaters, electric infrared lamps, or heat provided by a boiler or thermal fluid heater. Boilers and thermal fluid heaters are regulated by SCAQMD Rules 1146, 1146.1 and 1146.2.

In 2008 SCAQMD staff originally estimated about 6,600 pieces of equipment located at approximately 3,000 facilities would be subject to the emission limits of Rule 1147. Staff also estimated that at least 1,600 units at about 800 facilities already met the NOx emission limits of Rule1147. The remaining 2,200 facilities were expected to require retrofit of at least one unit. Staff estimated up to 2,500 permitted units with NOx emission limits greater than one pound per day and an additional 2,500 permitted units with NOx emission limits of less than one pound per day might require modifications in order to comply with the emission limits.

Based on an update of the active permitted equipment in the SCAQMD, an estimate of the number of equipment potentially subject to Rule 1147 and the fraction of units in different categories is presented in Figures A-1, A-2 and A-3 below. Staff estimates that as many as 6,400 pieces of equipment are potentially subject to Rule 1147 requirements. More than half of the units (≈ 3,400) are spray booths and prep-stations. Excluding spray booths and prep-stations, staff estimates that at least one quarter of the units in each category will meet Rule 1147 emission limits without retrofitting burners.

The second largest category is ovens and dryers with approximately 1,100 units subject to the rule. Staff estimates that at least one-third of the permitted ovens will meet Rule 1147 emission limits based on a sample of the burners used in the ovens. There are also approximately 500 additional ovens and dryers with SCAQMD permits that are not subject to Rule 1147 because they are heated electrically, with infrared lamps, or using a boiler or thermal fluid heater. Electric, infrared lamp, and boiler and thermal fluid heated ovens and dryers are not included in the Figures A-1, A-2 and A-3.

The third largest group of equipment is air pollution control units that capture and incinerate VOCs, CO, PM and toxics. There are approximately 900 afterburners, degassing units and remediation units. The remaining categories of equipment have significantly fewer units with metallurgical processes (metal melting and heat treating) being the next largest group with approximately 300 units between the two categories. Although these categories have fewer equipment, many include equipment with significantly higher emissions.

Figure A-1

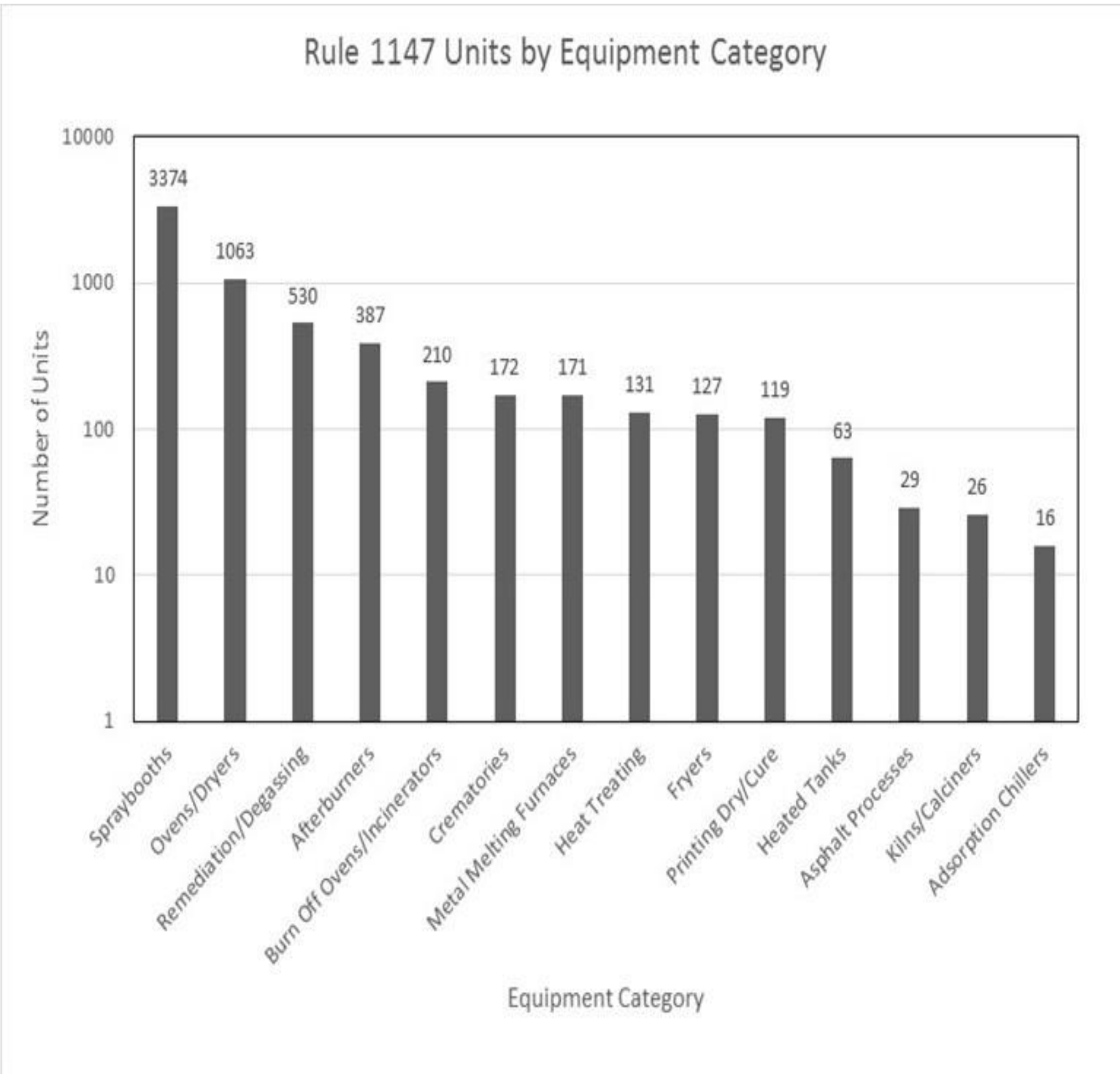


Figure A-2

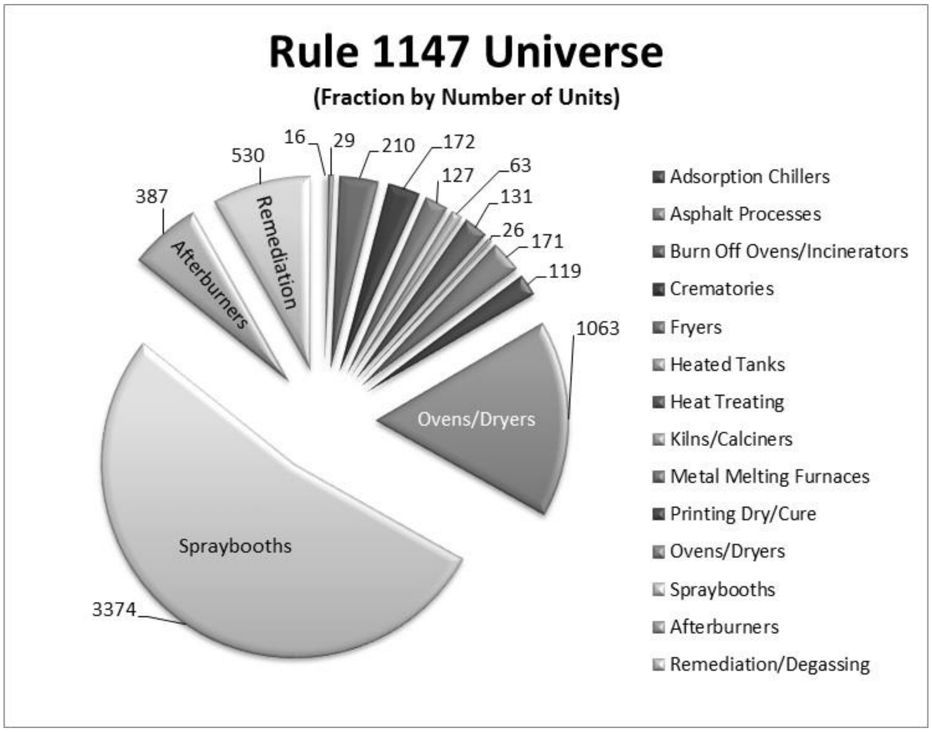
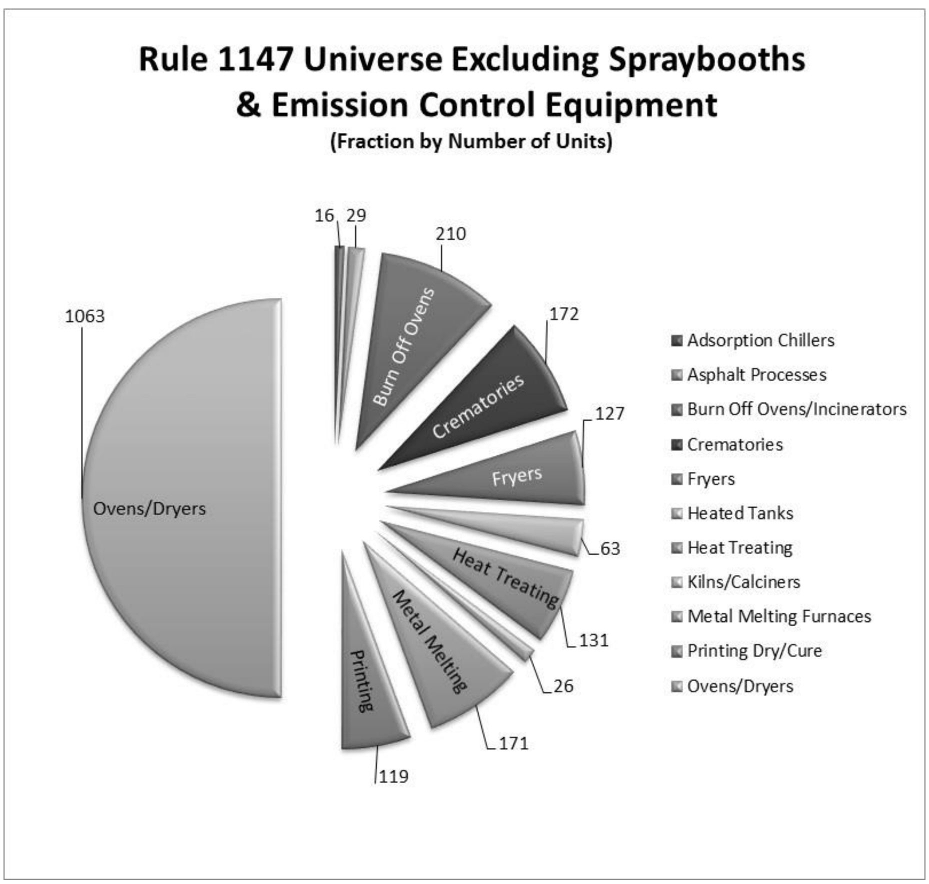



Figure A-3



The focus of this technology assessment is on smaller low emission equipment with emissions of one pound per day or less. An emission level of one pound per day is used to determine a unit's Rule 1147 compliance schedule. Units with emissions of one pound per day or less are provided up to 20 years from date of manufacture before they are required to demonstrate compliance with the NOx emission limit. Units with emissions greater than one pound per day must demonstrate compliance by the time a unit is 15 years old. New or relocated units must demonstrate compliance when they are installed. A potential to emit (PTE) of greater than one pound per day for new or relocated units also triggers the requirement to install best available control technology (BACT) under new source review (NSR) pursuant to SCAQMD Regulation XIII.

Staff has estimated the number of Rule 1147 units with NOx emissions greater than one pound per day based on a unit's PTE in the SCAQMD permit database. For spray booths and prep stations (semi-enclosed spray booths), approximately 5% (about 170) have NOx emissions greater than one pound per day. These higher emitting booths are either larger than the booths used for refinishing automobiles and light trucks or they are used in a production line at a manufacturing facility. For the remaining categories of equipment, approximately 50% have a PTE greater than one pound per day. This means approximately 1,700 units subject to Rule 1147 potentially have NOx emissions greater than one pound per day. The remaining 4,700 units have a PTE of one pound per day or less.

In previous analyses presented in rule staff reports and to the Rule 1147 Task Force, staff estimated that with the exception of spray booths at least 25% of the units in each category will comply with Rule 1147 limits without retrofitting burners. However, recent results from emissions testing of Rule 1147 units suggest that the compliance rate for units with their original burners and NOx emissions greater than one pound per day could be 50% or greater for some categories of equipment. In addition, some units with a PTE less than one pound per day have low emissions because the owner originally installed BACT compliant burners and reduced their PTE below one pound per day. New or modified sources are not required to purchase emission offsets if the average emission increase is a pound per day or less.

As an alternative to estimating emissions based on the inventory developed for the SCAQMD AQMP, total NOx emissions from equipment subject to Rule 1147 can be estimated using these units' PTE and other information. Business owners and equipment vendors indicate typical automotive booths and many other booth operations have annual average emissions of less than one third pound per day. However, up to 200 booths used in manufacturing and other applications may have emissions of a pound per day or more. Based on this information, the 3,400 permitted booths and spray stations have emissions of 0.5 to 0.6 tons NOx per day. The 1,500 other types of combustion equipment with PTE of less than or equal to a pound per day have average emissions of 0.5 pound per day per unit for a total of about 0.4 tons NOx per day. Based on this approach, the 4,700 Rule 1147 units with a PTE equal to or less than one pound per day emit about one ton of NOx per day.

The average PTE for the remaining 1,500 units is 5.6 pounds NOx per day using each units 30 day average PTE. The 30 day average PTE is calculated for a month using the weekly operating schedule but the monthly emissions are divided by 30 days instead of the number of days the equipment operates each month. Assuming these 1500 units emit at least half of their 30 day average PTE, the range for the emission estimate from the 1,500 greater than one pound per day units is from 2.1 to 4.2 tons of NOx per day. Using the range for the emission estimates calculated above provides an estimated total Rule inventory of 3.0 to 5.2 tons of NOx per day from the equipment regulated by Rule 1147. This emissions estimate is consistent with the 6.2 tons per day emission estimate developed from the 2007 AQMP for adoption of Rule 1147 in 2008.

It should be noted that the AQMP inventory was based on fuel use and default emission factors. The 2007 AQMP inventory did not take into account lower emissions from units with burners that can achieve BACT emission limits. Using the midpoint of the estimated range for larger sources gives a total inventory estimate of 4.1 tons of NOx per day for Rule 1147 equipment. This emission estimate is consistent with the AQMP inventory and permit information that at least one quarter of the units have burners that can comply with BACT and Rule 1147 emission limits.

In addition, staff estimates that as many as half of the units (750 out of 1,500) with a potential to emit greater than one pound per day may have actual daily NOx emissions less than a pound per day. If this estimate is correct, then half of the units with actual NOx emissions greater than one pound per day of NOx have already been tested (about 375) and comply with Rule 1147 emission limits. Moreover, because of the Rule 1147 compliance schedule, most of the remaining half of the 750 units are likely to have been permitted since 2000 and would have installed burners that will comply with BACT and Rule 1147 emission limits.

# Appendix B – SCAQMD BACT and Test Results for Emission Limits Achieved in Practice and Used for Rule Development

## SCAQMD BACT AND TEST RESULTS FOR EMISSION LIMITS ACHIEVED IN PRACTICE AND USED FOR RULE DEVELOPMENT

Rule 1147 was adopted on December 5, 2008 and amended September 9, 2011. Rule 1147 is based on two control measures from the 2007 Air Quality Management Plan (AQMP): NOx reductions from Non-RECLAIM Ovens, Dryers and Furnaces (CMB-01) and Facility Modernization (MSC-01). NOx emission from ovens, furnaces, kilns and afterburners had been proposed as control measure CMB-02 in the 1994 and 1997 AQMPs. Facility Modernization was a new AQMP measure that proposed equipment be upgraded to the best available control technology (BACT) available at the time the 2007 AQMP was adopted. The Facility Modernization measure is also proposed to be continued in the upcoming revision to the AQMP.

This appendix provides a summary of the NOx BACT determinations and SCAQMD permit limits achieved in practice by different types of units prior to rule adoption in 2008 and the 2011 rule amendment. The following figures were presented in rule development Task Force meetings and Rule 1147 Staff Reports for the 2008 adoption and the 2011 amendment. Figures B-1 to B-4 identify BACT determinations that were published by the SCAQMD and other air agencies prior to rule adoption. Figures B-5 and B-6 identify NOx emission limits that were achieved in practice through test results for equipment permitted prior to rule adoption. Figures B-7 and B-8 identify additional emission test results indicating NOx emission limits that were achieved in practice by permitted equipment tested in the SCAQMD prior to the 2011 rule amendment.

Figure B-1

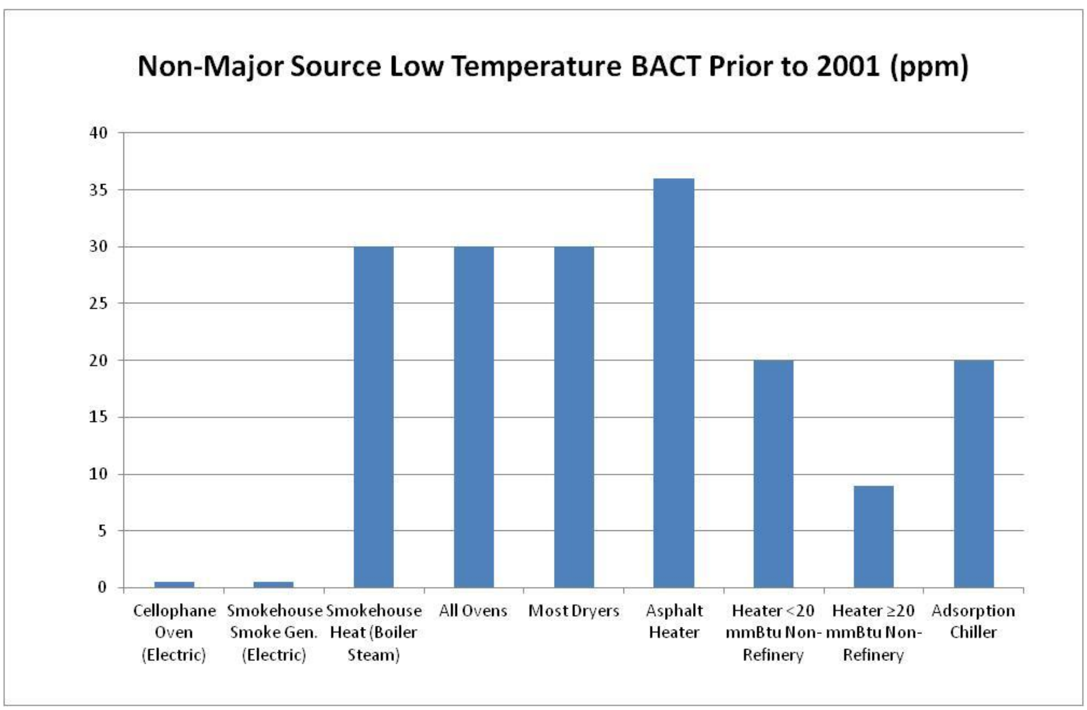


Figure B-2

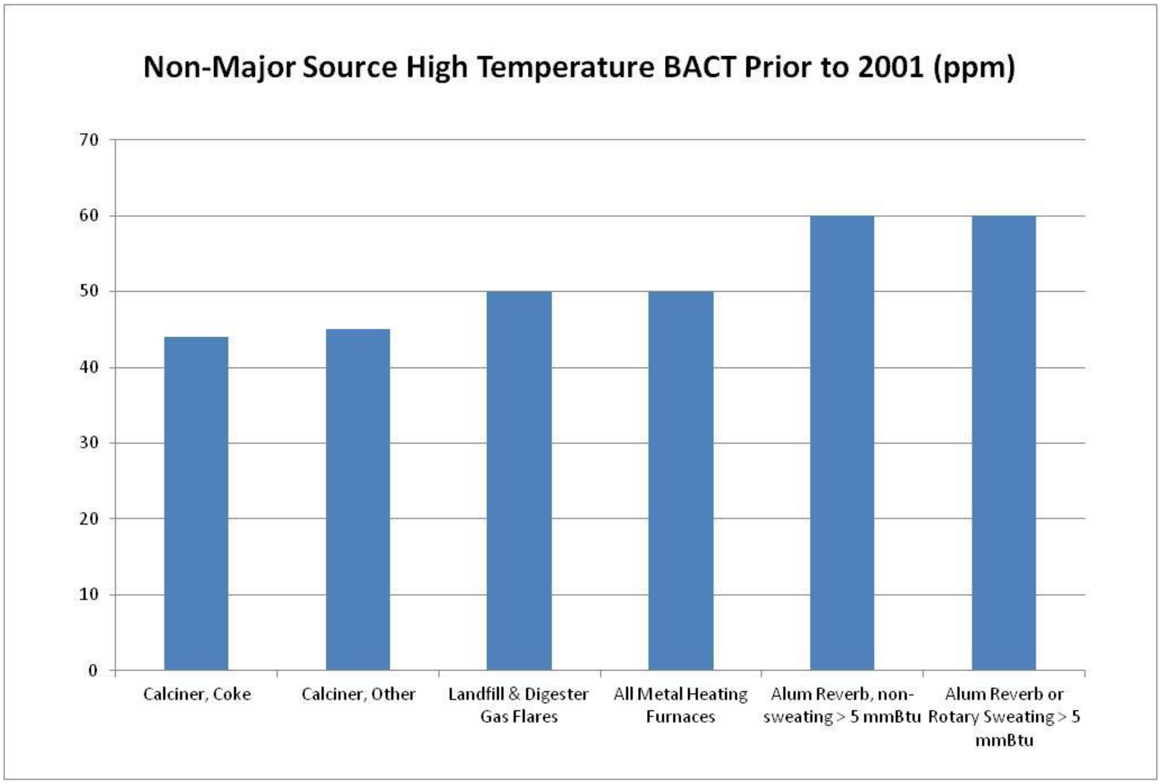



Figure B-3

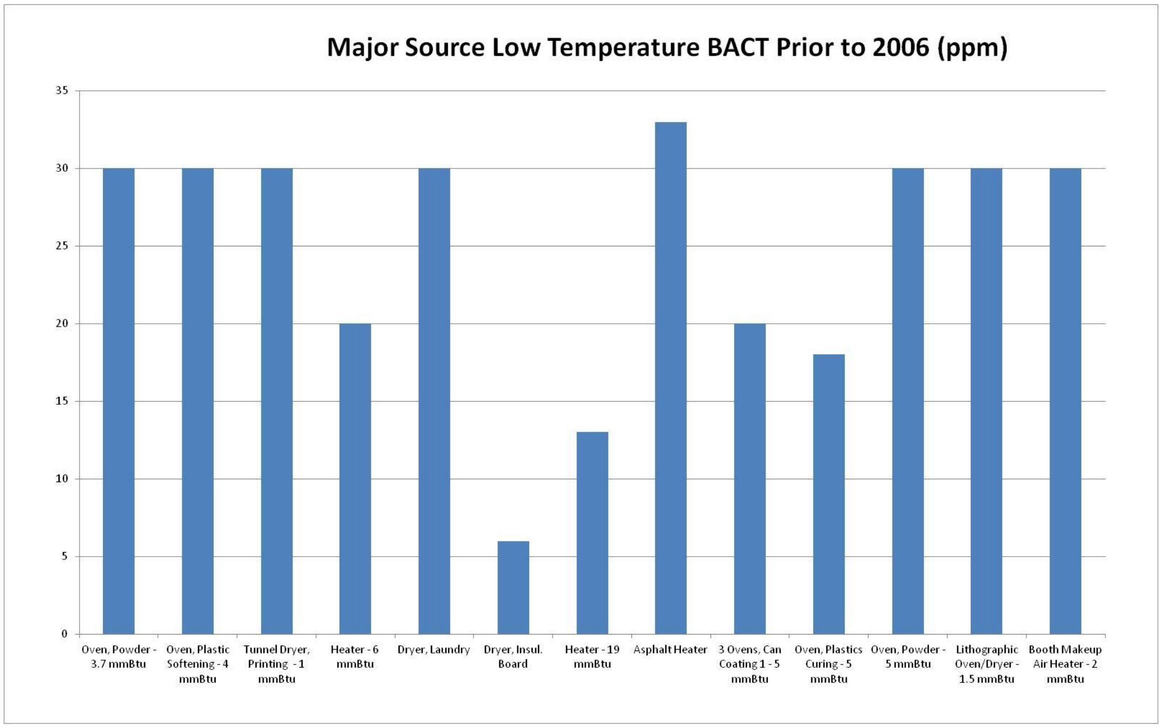


Figure B-4

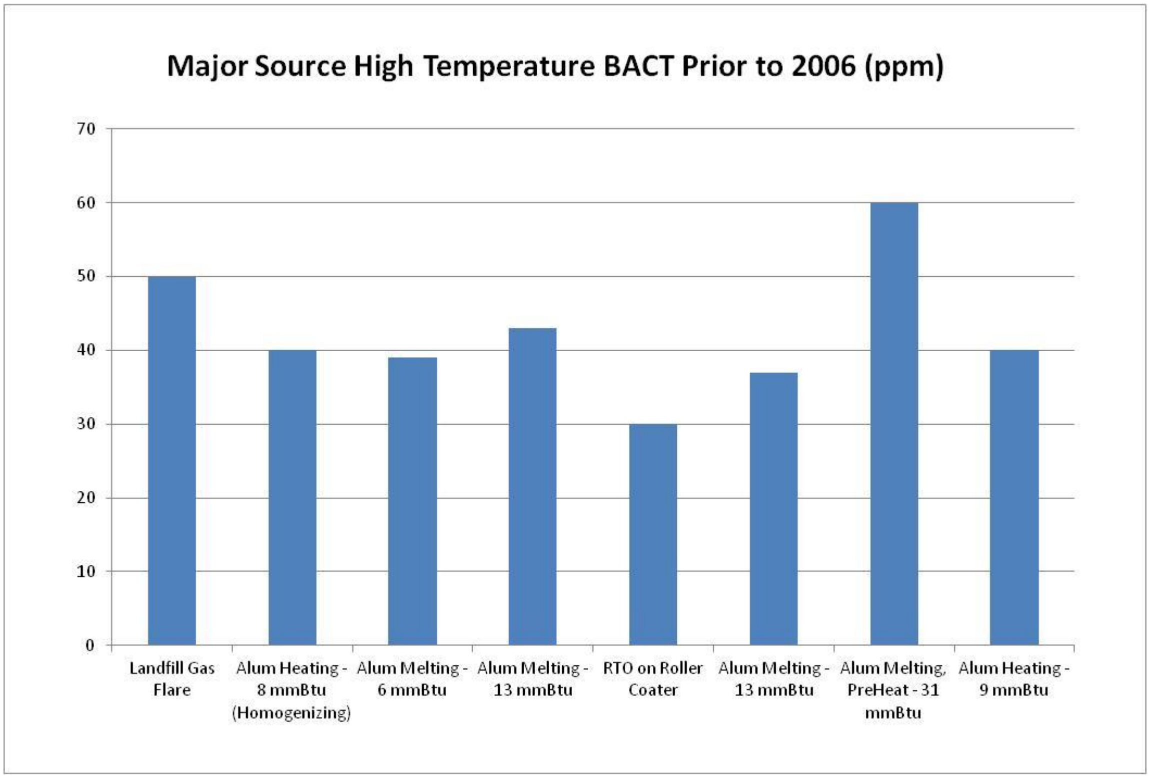



Figure B-5

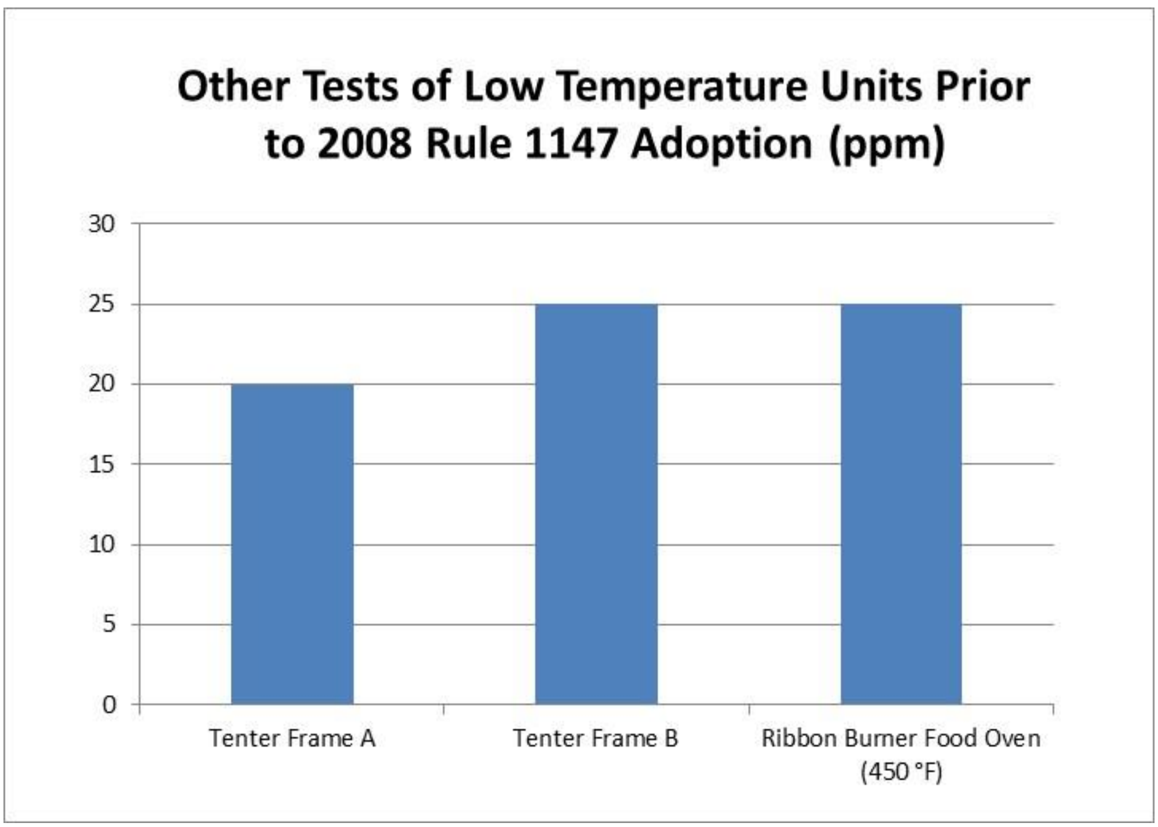


Figure B-6

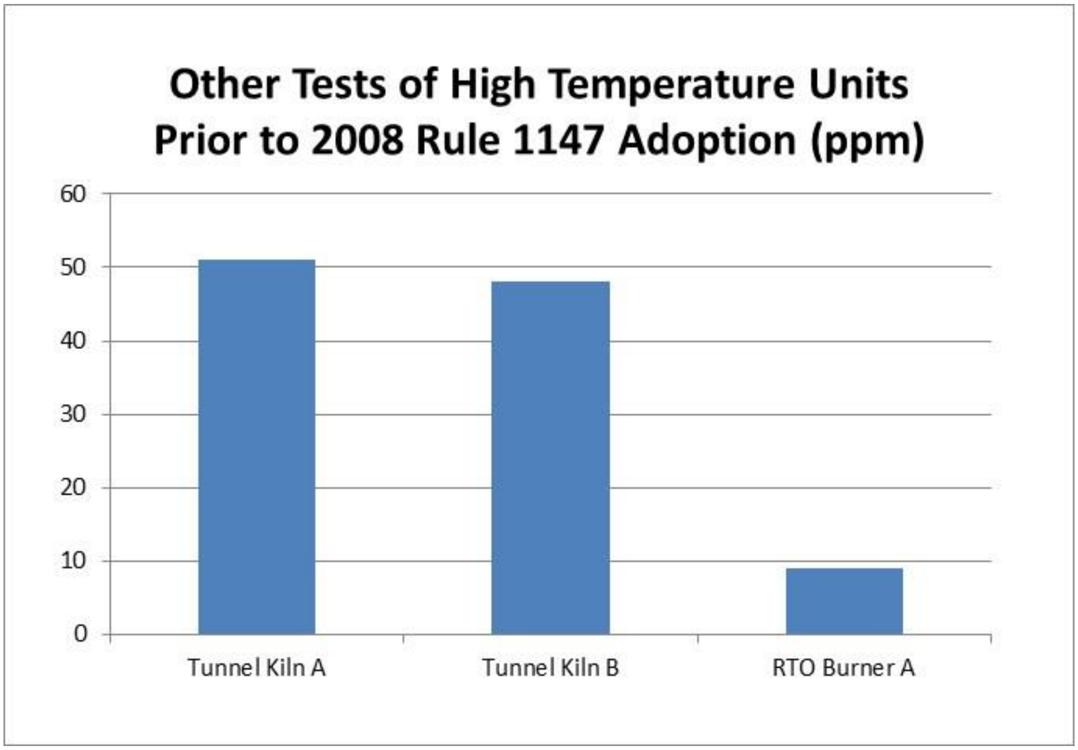



Figure B-7

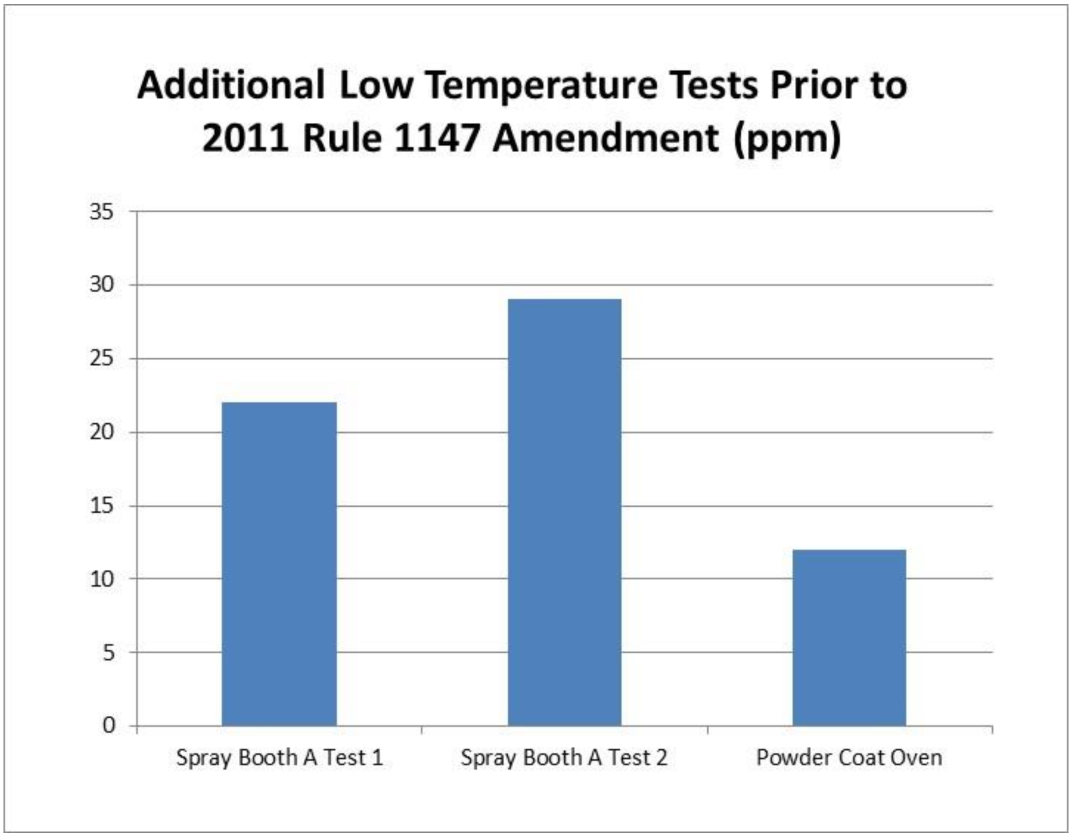
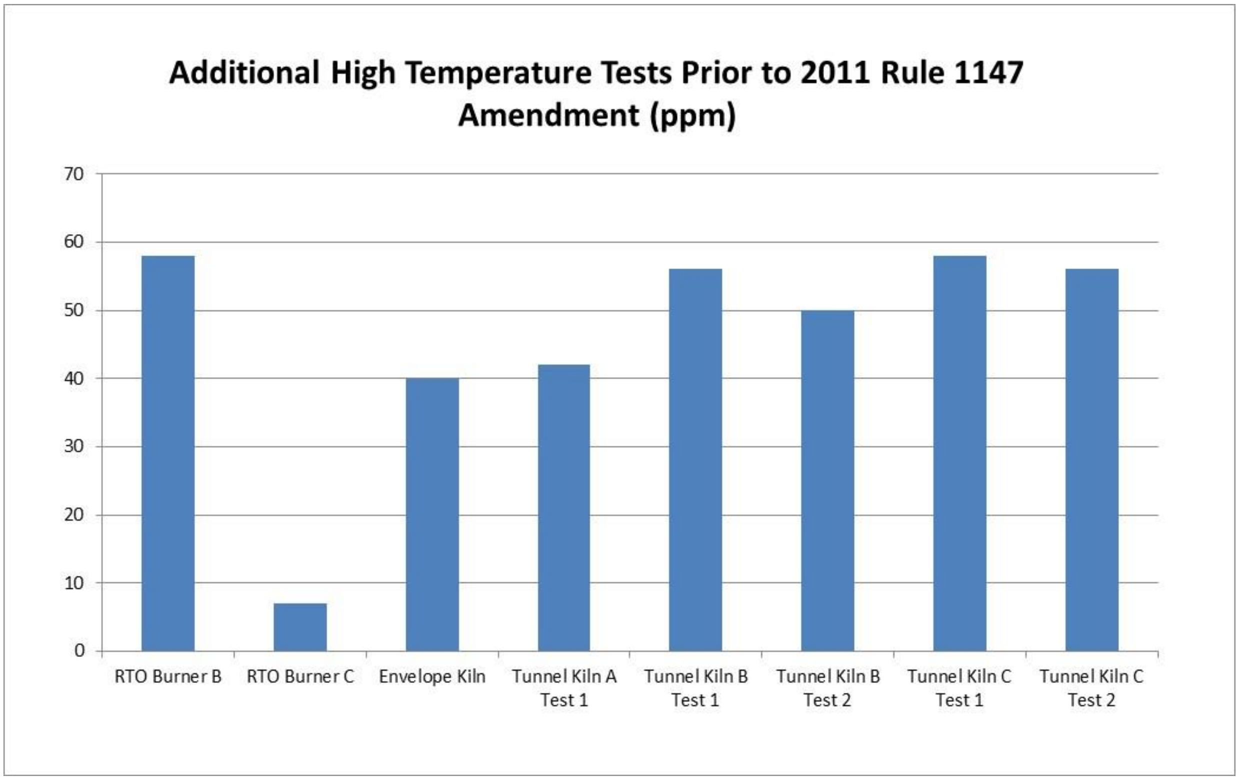


Figure B-8


Additional High Temperature Tests Prior to 2011 Rule 1147 Amendment (ppm)
70
60
50
40
30
20
10
0
RTO Burner B
RTO Burner C
Envelope Kiln
Tunnel Kiln A Test 1
Tunnel Kiln B Test 1
Tunnel Kiln B Test 2
Tunnel Kiln C Test 1
Tunnel Kiln C Test 2

# Appendix C –Rule 1147 Emission Testing and Test Limitations

# RULE 1147 EMISSION TESTING AND TEST LIMITATIONS

Demonstrating compliance with emission or other limits is required for Rule 1147 and all federal, state and SCAQMD air pollution regulations. In order for a new or amended SCAQMD rule to be approved for inclusion in the State Implementation Plan (SIP), test methods must be identified in the rule and approved by CARB and EPA. Rule 1147 identifies test methods that may be used to determine NOx, CO, $O_2$ and $CO_2$ concentrations and mass emissions.

In addition to EPA approved test methods, the SCAQMD also provides guidelines and generic test protocols to assist equipment owners and testing companies to prepare for and perform approvable emission tests. Because of the large variety of equipment regulated by Rule 1147, the equipment owner and the testing company must submit a test protocol and receive SCAQMD approval before testing a unit.

Emission testing can be more difficult for open direct fired units and dryers that heat large quantities of air because pollutant concentrations are diluted. Examples of these types of equipment include conveyor type ovens, textile dryers and drying ovens. Testing these units may require using a calibrated fuel meter in order to demonstrate compliance with the rule's fuel-based mass emission limit (pounds per million BTU of fuel) and additional sampling and analysis to determine carbon dioxide ($CO_2$) concentrations in the exhaust. $CO_2$ concentrations are used as an alternative to $O_2$ concentrations in order to adjust NOx concentrations to the Rule 1147 reference level of 3% $O_2$ when exhaust oxygen ($O_2$) concentrations are high (close to ambient levels),

The test results used for this report have been reviewed by SCAQMD Engineering, Compliance and Source Testing staff. When Rule 1147 emission testing protocols and test reports are reviewed by SCAQMD staff, they are rated as acceptable, conditionally acceptable, or unacceptable. Test reports are classified unacceptable when the report does not include all required documentation, the test was not performed consistent with the test method and approved protocol, or the test results cannot be used to demonstrate compliance with the applicable emission limit.

Tests reports are classified conditionally acceptable when the test results indicate compliance with the applicable emission limit but results are adjusted by SCAQMD staff, emissions cannot be estimated accurately but mass emissions or concentrations are equal to or less than the applicable emission limit or carbon monoxide (CO) emissions cannot be accurately determined. Rule 1147 does not include a CO emission limit because the SCAQMD is in compliance with federal and California ambient air quality standards. However, CO concentrations are routinely measured to ensure compliance with permit or facility requirements if applicable.

The most common reason for an emission test report to be rated conditionally acceptable is the reported emissions of NOx or CO have been adjusted by staff so results are consistent with SCAQMD testing and reporting guidelines. Mass emissions or concentrations may be adjusted higher or lower but the adjusted results demonstrate compliance with the rule limit.

For many test results, emissions are expressed as less than a specific concentration or mass emission rate that demonstrates compliance with the applicable emission limit. In order to be considered accurate, SCAQMD guidelines require that test results fall between 20% and 95% of the concentration of the highest concentration (high span) calibration gas used for that pollutant for that test. When results are not within the test's acceptable range, they are adjusted up to 20% of the acceptable range if they are lower, additional calibration gasses are tested to expand the range or define a lower sub-range, or the test is repeated using a different set of calibration gasses.

Adjustment up to the low end of the acceptable range (20% of the high span calibration gas) is a common result for equipment with dilute pollutant concentrations and high $O_2$ concentration in the unit's exhaust. Although these test results can be used to demonstrate that pollutant levels are less than a specific concentration (i.e., the low end of the acceptable range), they cannot be used to accurately estimate concentration or mass emissions. When the estimated concentrations are lower than the acceptable range of the individual test but an adjustment up to 20% of the acceptable range is still less than or equal to the applicable emission limit, the test result is satisfactory for the needs of the client and no further calibration or testing is performed by the testing company.

Test results for CO are often adjusted up to 20% of the acceptable range and because most permits do not limit CO emissions, no further analysis for CO is performed. However, when CO concentrations are adjusted up to 20% of the acceptable range, the adjusted estimated CO concentration can be up to three orders of magnitude higher than the actual concentration.

In summary, testing is performed to demonstrate compliance with an emission limit and businesses and testing companies do enough calibration, testing and calculation to prove that pollutant concentration or mass emissions are below the applicable limit. Most Rule 1147 emission test results are adjusted by the testing company or SCAQMD staff to address issues with a test's acceptable range or with other testing and calculation issues. As a result, most test results can demonstrate compliance but cannot be used to accurately estimate concentrations or mass emissions from individual units and categories of equipment.

Table C-1 provides a summary of submitted Rule 1147 NOx emission test results that have completed SCAQMD staff review and demonstrated compliance with Rule 1147 emission limits as of March 2015. Table C-1 shows the number of test results and average NOx emission concentrations for units tested at the highest and at a low firing rate if applicable. In most cases the highest firing rated tested is the normal operating condition. However, in a small number of cases the low firing rate is the normal condition. The table also indicates the applicable NOx emission limit for each category of equipment. Table C-1 does not include results from tests that were subsequently repeated because the original test did not comply with test method or SCAQMD guidelines. In addition, the table does not include test results for units that were shut down or that were withdrawn by the unit operator.

Table C-1

Rule 1147 Emission Test Results

| Equipment Category | Rule 1147 NOx Limit (ppm [1]) | Number of Units Tested at Normal/High Fire | Average NOx Concentration at Normal/High Fire (ppm) | Number of Units Tested at Low Fire | Average NOx Concentration at Low Fire (ppm) |
|---|---|---|---|---|---|
| **Afterburner/ Regenerative Thermal Oxidizer** | 30 or 60 [2] | 13 | 26 | 4 | 13 |
| **Afterburner/ Thermal or Catalytic Oxidizer** | 30 or 60 [2] | 9 | 40 | 1 | 41 |
| **Afterburner/ Remediation Unit** | 60 | 2 | 23 | 1 | 24 |
| **Spray Booth (Automobile)** | 30 | 10 | 24 | | |
| **Spray Booth (Other)** | 30 | 13 | 18 | 2 | 22 |
| **Crematory** | 60 | 20 | 50 | | |
| **Dryer/Asphalt** | 40 | 1 | 35 | | |
| **Fryer** | 60 | 7 | 29 | | |
| **Fuel Cell Heater** | 30 or 60 [2] | 1 | 11 | 1 | 9 |
| **Heated Tank** | 60 | 7 | 37 | 1 | 34 |
| **Metallizing Spray** | 30 or 60 [2] | 1 | 22 | | |
| **Metal Heat Treat** | 60 | 23 | 48 | | |
| **Metal Melting (Large)** | 60 | 8 | 42 | 1 | 58 |
| **Metal Melting Pot/Crucible** | 60 | 5 | 54 | | |
| **Multi-chamber Burn Off Oven or Furnace** | 30/60 or 60/60 [3] | 11 | 42 [4] | | |
| **Multi-chamber Incinerator** | 30/60 or 60/60 [3] | 1 | 54 [4] | | |
| **Oven/Dryer** | 30 or 60 [2] | 112 | 20 | 35 | 21 |
| **Print Dryer/Oven** | 30 | 19 | 20 | 4 | 23 |
| **Textile Shrink Dryer** | 30 | 2 | 24 | | |
| **Textile Tenter Dryer** | 30 | 4 | 23 | 4 | 26 |
| **Unit Heater** | 30 or 60 [2] | 3 | 20 | 1 | 13 |
| | | | | | |
| **Number of Units** | | 272 | | 55 | |

[1] The Rule 1147 NOx limit is based on a reference level of 3% oxygen ($O_2$) in the exhaust. All emission test results are converted to a concentration in parts per million at the reference level of 3% $O_2$.
[2] The emission limit depends upon the process temperature.
[3] The emission limit for the primary chamber varies depending upon process temperature.
[4] Average NOx emissions measured after the secondary chamber (afterburner).

# Appendix D – Calculation of Cost Effectiveness

## CALCULATION OF COST EFFECTIVENESS

Cost effectiveness calculations for this document are performed using the methodology in SCAQMD's BACT guidelines and cost effectiveness analyses for rule development. Note that there is one key difference in the calculation of cost effectiveness between the BACT Guidelines and rule development. For rule development, a best estimate of equipment's useful life is used in the calculation of cost effectiveness instead of a fixed 10 year assumption that is associated with financing of new equipment. In addition, in rule development various emission control options are evaluated to determine the option that provides the most reductions and reasonable cost effectiveness.

For new source review (NSR) under SCAQMD Regulation XIII, equipment for which BACT is defined must meet the emission limits defined by BACT regardless of the cost. This applies to equipment at both major and non-major sources (facilities). However, for permit applications for new equipment without established BACT at non-major sources, SCAQMD staff is required to evaluate the cost effectiveness of emission reduction options. New, modified or relocated equipment with a potential to emit of one pound per day or less are not required to comply with BACT by the SCAQMD.

The cost effectiveness analysis determines which emission reduction options are below the SCAQMD Board approved maximum cost effectiveness limits established by the SCAQMD BACT committee for equipment without minor source BACT. In addition, the SCAQMD BACT guidelines and rule development are required to calculate incremental cost effectiveness for the difference in cost and emission reductions between two or more emission control options. The cost effectiveness criteria for processes that do not have an established BACT is currently about $27,000 per ton of NOx for average cost effectiveness and about $81,000 per ton of NOx for the incremental cost effectiveness between two or more control options. A copy of the section of the SCAQMD BACT Guidelines that discusses calculation of cost effectiveness is included in Attachment 1 of this appendix.

# Attachment 1 of Appendix D – Cost Effectiveness Methodology from Part C: Policy and Procedures for Non-Major Polluting Facilities of July 2006 SCAQMD Best Available Control Technology Guidelines

## Attachment 1

### Cost Effectiveness Methodology

Cost effectiveness is measured in terms of control costs (dollars) per air emissions reduced (tons). If the cost per ton of emissions reduced is less than the maximum required cost effectiveness, then the control method is considered to be cost effective. This section also discusses the updated maximum cost effectiveness values, and those costs, which can be included in the cost effectiveness evaluation.

There are two types of cost effectiveness: average and incremental. Average cost effectiveness considers the difference in cost and emissions between a proposed MSBACT and an uncontrolled case. On the other hand, incremental cost effectiveness looks at the difference in cost and emissions between the proposed MSBACT and alternative control options.

Applicants may also conduct a cost effectiveness evaluation to support their case for the special permit considerations discussed in Chapter 2.

### Discounted Cash Flow Method

The discounted cash flow method (DCF) is used in the MSBACT Guidelines. This is also the method used in the 1999 Air Quality Management Plan. The DCF method calculates the present value of the control costs over the life of the equipment by adding the capital cost to the present value of all annual costs and other periodic costs over the life of the equipment. A real interest rate* of four percent, and a 10-year equipment life is used. The cost effectiveness is determined by dividing the total present value of the control costs by the total emission reductions in tons over the same 10-year equipment life.

### Maximum Cost Effectiveness Values

The MSBACT maximum cost effectiveness values, shown in Table 4, are based on a DCF analysis with a 4% real interest rate.

**Table 4: Maximum Cost Effectiveness Criteria (Second Quarter 2003)**

| Pollutant | Average (Maximum $ per Ton) | Incremental (Maximum $ per Ton) |
|---|---|---|
| ROG | 20,200 | 60,600 |
| NOx | 19,100 | 57,200 |
| SOx | 10,100 | 30,300 |
| $PM_{10}$ | 4,500 | 13,400 |
| CO | 400 | 1,150 |

The cost criteria [in Table 4] are based on those adopted by the AQMD Governing Board in the 1995 BACT Guidelines, adjusted to second quarter 2003 dollars using the Marshall and Swift Equipment Cost Index. Cost effectiveness analyses should use these figures adjusted to the latest Marshall and Swift Equipment Cost Index, which is published monthly in Chemical Engineering.

* The real interest rate is the difference between market interest rates and inflation, which typically remains constant at four percent.

## Top Down Cost Methodology

The AQMD uses the top down approach for evaluating cost effectiveness. This means that the best control method, with the highest emission reduction, is first analyzed. If it is not cost effective, then the second-best control method is evaluated for cost effectiveness. The process continues until a control method is found to be cost-effective.

AQMD staff will calculate both incremental and average cost effectiveness. The new MSBACT must be cost effective based on both analyses.

## Costs to Include in a Cost Effectiveness Analysis

Cost effectiveness evaluations consider both capital and operating costs. Capital cost includes not only the price of the equipment, but the cost for shipping, engineering and installation. Operating or annual costs include expenditures associated with utilities, labor and replacement costs. Finally, costs are reduced if any of the materials or energy created by the process result in cost savings. These cost items are shown in Table 5. Methodologies for determining these values are given in documents prepared by USEPA through their Office of Air Quality Planning and Standards (OAQPS Control Cost Manual, 4th Edition, USEPA 450/3-90-006 and Supplements).

The cost of land will not be considered because 1) add-on control equipment usually takes up very little space, 2) add-on control equipment does not usually require the purchase of additional land, and 3) land is non-depreciable and has value at the end of the project. In addition, the cost of controlling secondary emissions and cross-media pollutants caused by the primary MSBACT requirement should be included in any required cost effectiveness evaluation of the primary MSBACT requirement.

**Table 5: Cost Factors**

Total Capital Investment

Purchased Equipment Cost
- Control Device
- Ancillary (including duct work)
- Instrumentation
- Taxes
- Freight

Direct Installation Cost
- Foundations and Supports
- Handling and Erection
- Electrical
- Piping
- Insulation
- Painting

Indirect Installation Costs
- Engineering
- Construction and Field Expenses
- Start-Up
- Performance Tests
- Contingencies

## Total Annual Cost

- Direct Costs
  - Raw Materials
  - Utilities
    - Electricity
    - Fuel
    - Steam
    - Water
    - Compressed Air
  - Waste Treatment/Disposal
  - Labor
    - Operating
    - Supervisory
    - Maintenance
  - Maintenance Materials
  - Replacement Parts

- Indirect Costs
  - Overhead
  - Property Taxes
  - Insurance
  - Administrative Charges
- Recovery Credits
  - Materials
  - Energy

# Appendix E – Afterburner Technologies

## AFTERBURNER TECHNOLOGIES

The afterburner category is comprised of a variety of technologies that are used to capture and incinerate VOCs, PM and toxic air contaminants. These include direct flame afterburners (often called an oxidizer or incinerator), regenerative thermal oxidizers (RTO) that heat a ceramic bed which oxidizes pollutants, and catalytic oxidizers which incinerate pollutants with the help of a catalytic matrix. Remediation systems for removing contaminants from soil or groundwater also use the same types of technologies to incinerate VOCs or toxic air contaminants.

Alternative non-combustion technologies for control of VOC, PM and toxic air pollutants are also available and include electrostatic precipitation, wet or dry scrubbers, carbon adsorption, and other filter media. Remediation systems and some other types of units may combine carbon adsorption or other technologies with a direct flame, catalytic or regenerative thermal oxidizer. An afterburner or oxidizer can also be as simple as a stack with a burner and pilot flame (i.e., a flare).

At the time of rule development, two sources of information were available to identify BACT for this category of equipment. BACT determinations had been made for flare based oxidizers. These determinations established a BACT/LAER limit for non-major and major sources of 50 ppm NOx. However, there were a significant number of flare based oxidizers that had been permitted with a 60 ppm NOx limit prior to that BACT determination. In addition, emission test results that varied across a range from below 30 ppm up to about 50 ppm NOx for new catalytic and regenerative thermal oxidizer systems were being used by the SCAQMD permitting group as the basis to require new applicants to meet equivalent emission limits. Given the variety of processes used as afterburners, their different emission characteristics and older equipment permitted at emission levels close to but above some current BACT levels, a rule NOx limit of 60 ppm was proposed for this category of equipment and adopted in Rule 1147.

Depending upon the type of afterburner system, different burners are used. Most of the RTOs tested use a high temperature Maxon Kinedizer burner but one uses an air heating burner from Eclipse – the Winnox burner. A Kinedizer burner is also used in a remediation unit that incorporates an RTO. Thermal and catalytic oxidizers use a variety of burners from Maxon, MidCo, Eclipse, and others. Some of these units use air heating burners and others use higher temperature burners such as the Eclipse Thermjet. A variety of burners are also used in remediation units that incorporate a thermal or catalytic oxidizer.

Newer flare based systems incorporate low NOx burners that can meet the 60 ppm NOx limit (e.g., John Zink and Flare Industries/Bekaert). However, RTO based systems offer a significant advantage over direct flame systems because they can significantly reduce fuel consumption and the cost of operating the system. Staff is aware of one facility that replaced an old flare based oxidizer with a new RTO in order to meet the Rule 1147 emission limit and to reduce fuel cost.

The afterburners that have been tested are used to control emissions from a wide variety of processes. Afterburners are widely used to control emissions of VOCs and PM from printing, coating and chemical manufacturing operations. Afterburners are also used for the control of VOCs from food bakery ovens and fryers. Larger coffee roasters are required to use afterburners to control emissions of PM, toxics and for odor control. One tested unit controls emission of PM from an animal feed dryer. Several of the tested units are portable and are used to control emissions of VOCs from degassing of storage tanks, pipelines and other equipment.

The 24 units tested easily passed the 60 ppm NOx limit. Most of the units were tested with their original burners. The RTO and remediation units have average NOx emissions of about 25 ppm at high fire with a range of 16 to 55 ppm. One unit with emissions of 55 ppm NOx has a Maxon Kinemax burner instead of a Kinedizer. Thermal and catalytic oxidizers averaged about 40 ppm NOx with a range of 21 to 54 ppm at high fire. Units with air heating burners including the Eclipse Winnox have lower emissions than units with high temperature burners such as the Eclipse Thermjet.

A large number of afterburner units using different combustion technologies have been tested and comply with the Rule 1147 NOx emission limit of 60 ppm. Most of the units complied with the emission limit using their original burners. The emission vary depending upon the combustion technology. However, all of the units for which tests were submitted and reviewed comply with the rule emission limit.

# Appendix F – Spray Booths

# SPRAY BOOTHS

A variety of coating operations use heated spray booths and prep stations. Prep stations are paint booths that are not fully enclosed. The majority of heated spray booths in the SCAQMD are auto body refinishing booths used for refinishing passenger cars and light trucks. Larger booths are used for industrial coating operations, large trucks and trailers and a variety of maintenance applications. In addition, auto body type spray booths are also used by manufacturing operations for drying and curing components and assembled products. An achieved in practice LAER/BACT limit of 30 ppm NOx for makeup air heaters in spray booth applications and the fact that many SCAQMD permitted booths are used as curing or drying ovens in manufacturing operations justified a Rule 1147 NOx limit of 30 ppm. It should be noted that BACT for ovens and most dryers has been 30 ppm NOx since 1998.

To date, only new or relocated spray booths have been subject to the Rule 1147 emission limit. Because more than 90% of in-use heated booths are estimated to have annual average emissions less than one pound per day of NOx, existing units are not subject to the emission limit until on or July 1, 2017. Most of the new booths have been installed in the SCAQMD are for auto body repair and have been permitted based on certification of the burner and related components of the makeup air unit for the booth.

Auto body repair businesses use paint booths for reducing the amount of spray leaving the facility and keeping dust off newly painted surfaces. In addition, booths speed up the drying process by moving air through the booth. Spray booths can also be fitted with heating units that further accelerate the drying and curing of coatings.

Auto body repair businesses use heated booths in order to increase the number of painted cars that can be dried in a day. Businesses that coat four or more cars a day use heated booths. About three painted cars can be dried each day with an unheated booth. According to spray booth vendors, the average number of cars dried per day in a spray booth is about five. The maximum number of cars that can be processed by a heated booth during one shift is eight. Some auto body repair businesses operate more than one shift per day thus increasing the number of cars processed.

## Technology

Ten booths used in auto body repair from a variety of manufacturers have been tested as part of the process to certify a company's spray booth heating systems. These certified units comply with the Rule 1147 emission limit of 30 ppm NOx and with workplace exposure standards for CO. To date, all of the certified spray booths have used a burner system from MidCo. This new low NOx burner replaced line burners in a number of booth manufacturers heating units. Many of the previous units were built around a MidCo line burner. Since 2010, more than 125 low NOx heating systems based on the MidCo low NOx burner have been installed in the SCAQMD. The majority of these have been installed in heating units for new auto body spray booths.

Several spray booth manufacturers have taken advantage of the option to certify their booths and heating system. Certified models do not require individual emission tests. Currently there are 32 models of booths and heating systems from eight manufacturers certified compliant with the Rule 1147 emission limit. Non-certified models must perform individual tests in order to receive an SCAQMD permit. The SCAQMD certified systems vary from basic cross flow booths to down flow booths constructed with below ground air exhaust systems. The manufacturers represent a significant portion of the industry and include companies that manufacture their booths and heating systems in California.

The SCAQMD permitting group certifies the whole spray booth mechanical system including the combustion components. This approach significantly increases the cost of retrofitting existing spray booths with certified low NOx burners. To use an SCAQMD certified burner on a used spray booth, the owner/operator must also install a new heater box, blower, other mechanical components with a new thermostat and control system for moving air in addition to installing the burner, mounting hardware and combustion control system.

Other manufacturers have decided not to certify their heating units, but instead have decided to have their distributors and local installers test each new installation. For example, three auto body booths at one location have been tested and complied with the Rule 1147 NOx limit using a newer design line burner from Maxon.

Other types of booths and some auto body booths used for different applications have also been tested and comply with the Rule 1147 emissions limit. These units submitted individual emission test results. Thirteen test results have been submitted for booths that are not used for auto body repair. These booths use heating units or burners from Hastings, MidCo, PowerFlame, and Riello. In these cases, the air movement system and other components were not required to be replaced by the SCAQMD.

The burners in these other booths use a variety of technologies to achieve the emission limit of 30 ppm. The heater manufactured by Hastings is a roof mounted unit that can also be used to heat other processes or large building spaces such as a warehouse. All of the burners in these systems use premixing of air and fuel with a controlled amount of excess air to reduce emissions. The MidCo burner uses a knit steel fabric material to stabilize and spread the flame over a larger surface area to reduce peak flame temperature and NOx emissions. The Hastings, PowerFlame and Riello burners use premixing, swirl for mixing with air in the combustion zone and other technologies to keep emissions low. The new control systems for these low NOx burners can be the most important component of the system because they provide more precise tuning and control of the combustion process across the firing range of the burner.

**Cost Effectiveness of Rule Compliant Spray Booth Heating Systems**

NOx Emissions for most auto body spray booths average less than on half pound per day on an annual basis. NOx emissions contribute to the formation of secondary particulates in addition to ozone. A typical booths' annual average NOx emissions are less than one third pound per day. However, during late fall and winter when PM 2.5 concentrations can be high, daily NOx emissions can be two to three times annual average emissions.

The cost difference between a new certified rule compliant heated spray booth and a new non-compliant unit is less than $10,000 on typical new booth based on information from manufacturers, vendors and the cost of booths prior to rule adoption. The cost for new units includes markups from the booth manufacturer applied to the cost of the burner, gas train and control system. Most of the specialty booths used for applications other than auto body repair were tested with standard burners, so there was no additional equipment cost to comply with Rule 1147 limits. However, the cost for adding a new natural gas fired certified heating system to an existing spray booth varies from $30,000 to $50,000 with a typical cost of about $40,000. The cost varies depending upon the manufacturer, type of booth and the individual installation.

The cost of new booths are highly variable depending upon the type of booth and options. According to vendor supplied information, the cost to purchase and install a new spray booth is about 20% higher than in 2008 when Rule 1147 was adopted. This increase is consistent with industry data on the cost to purchase and install new equipment (i.e., Marshall & Swift Equipment Cost Index which includes inflation, the cost of materials and manufacturing costs). The typical new installation is a semi down draft (side draft) booth with for about $80,000. A new basic cross draft booth without recirculation is less and costs $65,000 to $80,000. However, some vendors do not sell heated cross flow booths. The heating system and installation cost of the booth and heating constitute most of the cost for a new basic cross draft booth. A new full down draft booth is about $115,000 and up depending upon options. Although the cost for semi down draft and down draft booths are higher than for a basic cross draft, the heating system costs are about the same for basic and premium booths from the same manufacturer or vendor.

The cost effectiveness for a new SCAQMD certified low NOx auto repair booth is at most $22,000 per ton [($10,000 at most) / (70% reduction in NOx) X (0.25 lb/day / 2000 lb/ton) X 260 days/year X 20 years)]. In higher volume shops, the cost effectiveness is better (lower than $22,000/ton).

The cost to retrofit a used booth to install in the SCAQMD as a new permitted unit is significantly less than purchasing a new booth. However, the cost effectiveness for retrofitting an existing in-use auto repair booth with a SCAQMD certified heating system is $88,000 per ton of NOx reduced based on a cost of $40,000 and a 20 year life. The cost of the heating system ranges from $30,000 to $50,000. For a high volume booth used two shifts a day, the cost effectiveness could be less than half this value ($44,000/ton). For a booth retrofit costing $30,000 the cost effectiveness is $66,000 per ton. This cost effectiveness of retrofitting an existing permitted booth is higher than the minor source average cost-effectiveness criteria of $27,000 per ton used by SCAQMD for equipment without defined BACT. Depending upon the number of cars processed per day, the retrofit cost effectiveness may also be higher than the BACT incremental cost effectiveness criteria of $81,000 per ton.

It must be noted that depending upon the age of the used booth, the owner may have to upgrade the booth to meet current building and safety codes. The local building and safety agency may require mechanical, electrical, fire safety and other components be upgraded or replaced. These costs are not attributable to Rule 1147 and are also not included in the cost effectiveness analysis for new, modified or relocated units that require a new SCAQMD permit. The SCAQMD BACT Guidelines does not include the cost of compliance with non SCAQMD regulations in the calculation of cost effectiveness. The calculation of cost effectiveness is an analysis of the cost of new equipment and the cost of operating the new equipment. In the cost effectiveness analysis for new rule requirements, the recurring costs for new or modified equipment are those above and beyond the costs associated with original existing equipment.

The cost effectiveness for upgrading existing spray booths to comply with the Rule 1147 emission limit exceeds the minor source cost-effectiveness criteria of $27,000 per ton used by SCAQMD for equipment categories without a defined BACT. However, the cost effectiveness for new units is at most $22,000 per ton and is less than the BACT Guidelines criteria. Because the cost effectiveness to retrofit an existing permitted booth is significantly higher than the minor source BACT criteria, staff is considering amending Rule 1147 to delay compliance for existing in-use permitted booths and heating units until they are modified (modification of the combustion or air circulation system), relocated (including moved to a different location within the facility) or replaced. Staff is proposing that new, modified, or relocated units requiring an SCAQMD permit continue to be required to comply with the Rule 1147 NOx limit at the time of modification or installation. A change of ownership in a business with an existing in-use permitted booth would be exempt from the retrofit requirement unless the booth or heating unit is modified, relocated or replaced.

# Appendix G – Crematories

# CREMATORIES

Twenty crematories have been tested and comply with the Rule 1147 NOx emission limit. This list includes units tested with their original burners and units tested after replacing their burners. The burners tested in these units are manufactured by Eclipse, Facultatieve and others. The most common burner installed for new units in the SCAQMD and for replacing old burners is the Eclipse Thermjet, a medium to high velocity burner used in many high temperature applications including kilns, metal melting, heat treating and burn off furnaces.

Crematories are constructed as two integrated chambers each with their own burners. The first chamber is used for incineration and the second is an afterburner for reducing emissions of PM, VOCs and odors. Typically both chambers use the same type of high temperature burner but the size and number of burners in each chamber may differ. The primary chamber typically has one or two smaller burners than the one burner used in the secondary chamber afterburner section.

The Rule 1147 NOx emission limit for crematories is 60 ppm. The NOx emission concentrations for the tested crematories average 50 ppm with a range from 30 to 59 ppm. The 20 crematory tests that have been reviewed and comply with the emission limit include those with original burners and many units with new burners and control systems. Many crematories more than 20 years old had burners that are no longer produced and would not comply with the Rule 1147 emission limit. However, those crematories replaced their burners and comply with the 60 ppm NOx emission limit. Most crematories less than 20 years old have been installed with burners that comply with the Rule 1147 NOx emission limit and will not require replacement a retrofit. These units will only be required to demonstrate compliance through an emissions test.

The Rule 1147 test program has demonstrated that the NOx emission limit of 60 ppm is achieved by the burners and combustion control system available since the late 1990s. Crematories that have had their burners replaced use the same burners that are installed in new units. The average emission concentration from the tested units is 50 ppm and some units are significantly lower.

# Appendix H – Fryers

# FRYERS

There are two major types of fryers – conveyor and batch type. In addition, there are different types of heating systems including immersion tube heating in conveyor units and external oil heating systems for many batch type fryers. The external oil heaters use a heat exchanger with a gas fired burner or another heat source such as a thermal fluid heater regulated by SCAQMD Rules 1146.1 or 1146.2. Both types of fryers and heating systems have been tested and comply with the rule 1147 emission limit.

Seven existing in-use fryers have completed emission testing and comply with the Rule 1147 NOx emission limit of 60 ppm. The tested units are from three different manufacturers. All units were tested with their original burner systems. One unit is a conveyor fryer with many small immersion tube burners and a total heat rating of 1.5 mmBtu/hour. The other units use single burners with a heat exchanger and have heat ratings from 1.5 to 2.5 mmBtu/hour. The average NOx emissions are about 30 ppm with a range from 14 ppm to 56 ppm.

A variety of systems from three different manufacturers have been tested and comply with the Rule 1147 NOx emission limit. The units complied with the 60 ppm using different types of heating systems. Based on the units completing testing, the Rule 1147 emission limit is achievable with the original heating systems installed for these fryers.

# Appendix I – Heated Process Tanks

# HEATED PROCESS TANKS

Heated process tanks, parts washers and evaporators are a category of 1147 equipment for which it is difficult to accurately estimate the number of units that are subject to Rule 1147. While evaporators and parts washers with an integrated heated tank are typically separate units with their own permit, most process tanks are permitted as part of a process line with other processes and tanks. Because Rule 1147 only applies to units that require a permit; an individual tank is only subject to Rule 1147 if it is heated by burners and either has emissions of VOC, PM or toxic air contaminants or the rating of the burner system is greater than two million BTU per hour (2 mmBtu/hour).

For example, tanks with mixing from an air sparging system are more likely to have VOC, PM or toxic emissions and require emission controls and a permit than those that do not. Otherwise a tank is exempt from the requirement for a permit as defined by SCAQMD Rule 219. However, if a process tank does not require a permit, it is still included in the description of a process line in order to provide a complete description of the process for SCAQMD permitting and compliance staff. Process lines are permitted as one unit in order to reduce the cost and administrative burden of permits.

There are approximately 1,400 process tanks identified in the SCAQMD permit system. About 1,200 of them are unheated, heated electrically or heated by a boiler. Of the remaining 200, at least 160 have burners rated less than the size requiring a permit. The number of heated process tanks subject to Rule 1147 is estimated to be between 20 and 40 with a best estimate of 25 units. The heat ratings of process tanks subject to Rule 1147 varies from 2.2 to 9 mmBtu/hour. Staff has also identified 23 evaporators with SCAQMD permits that are potentially subject to Rule 1147. There are also an unknown number of parts washers that are potentially subject to Rule 1147 depending upon their size, configuration and emissions. Tanks, evaporators and washers with electric, boiler steam or thermal fluid heating are exempt from Rule 1147. Equipment heated using a separate enclosed heated tank are potentially subject to SCAQMD Rules 1146, 1146.1 or 1146.2 which regulate boilers and enclosed process heaters.

Many heated process tanks, evaporators and parts washers use immersion heating tubes to heat a solution in a tank. Immersion tube burners fire into and heat a tube and that heat is transferred to the solution from the tube by conduction and convection. The efficiency of heat transfer depends upon the diameter and length of the tube. The efficiency of heat transfer in a tank system can vary from about 60% to over 90%.

To date only a few heated process tanks and evaporators have performed testing because some were installed within the last 15 years, others have emissions less than or equal to one pound per day and most are exempt because they do not require a permit. Seven units have been tested and reviewed by SCAQMD staff. None of these units replaced their burners. All tested units comply with the Rule 1147 NOx limit of 60 ppm for heated process tanks, evaporators and washers with their original burners.

Process tanks, evaporators and washers with their own burners use a variety of heat exchange systems to heat a solution or assist in evaporation. Most process tanks use a constant diameter tube to heat a solution. Evaporators either use custom designed air to solution heat exchangers or constant diameter tubes to provide heat to a solution. Most parts washers use a custom designed heat exchange system or a separate water heater.

Custom designed heat exchange systems have various configurations but start out with a combustion zone with a larger cross section than the remainder of the heat exchanger. These systems typically start with a combustion chamber that is about 8 to 16 inches across that extends the full length of the burner's flame. The combustion section of the heat exchanger is large because manufacturers use burners that are designed for a wide variety of applications including boilers, furnaces and ovens.

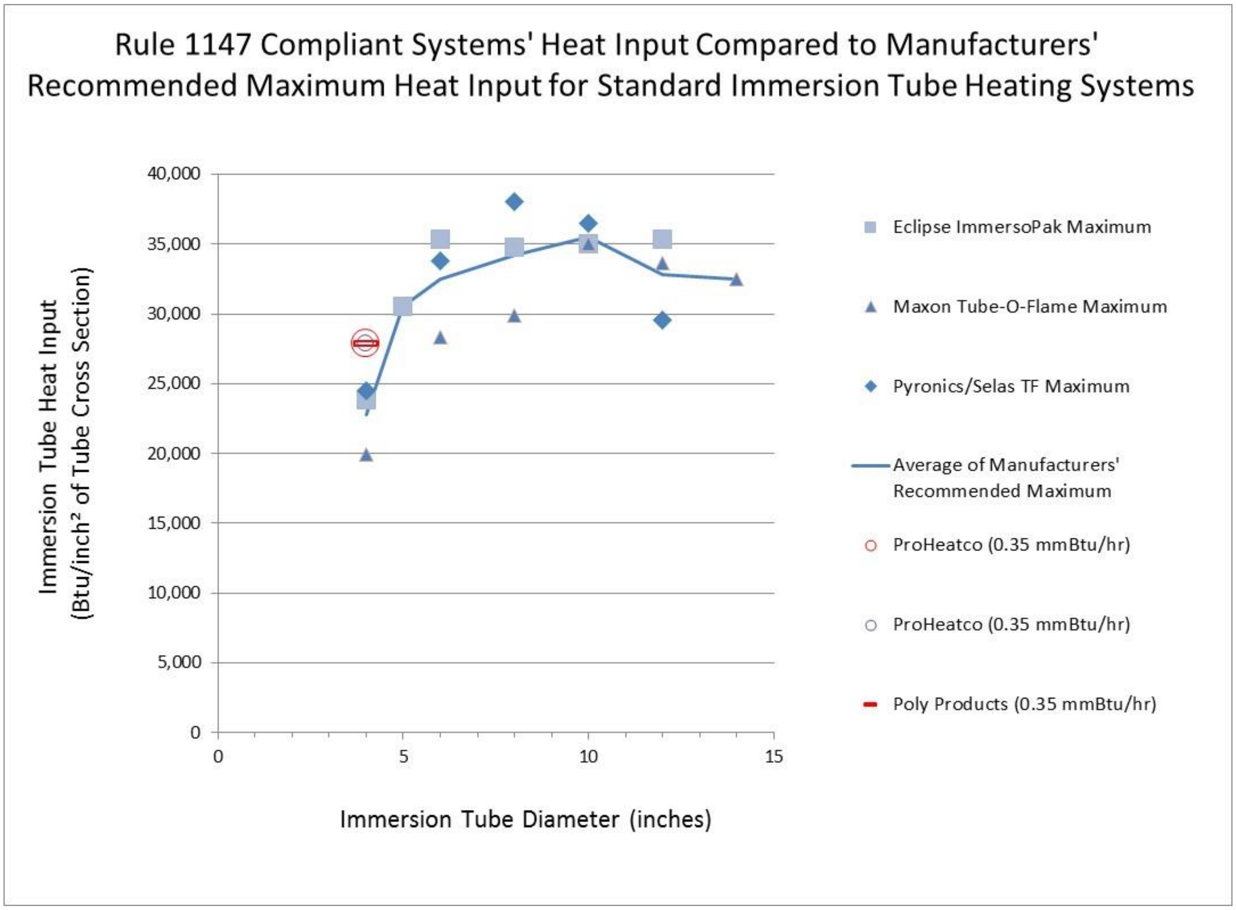
Emission testing has been performed on three evaporators using custom designed heat exchangers – two units from Encon using MidCo burners and one unit from Lakeview Engineering unit using a burner from Industrial Combustion. The heat input for these systems are 220,000 and 650,000 Btu/hour for the Encon evaporators and 1.5 mmBtu/hour for the unit built by Lakeview Engineering. NOx emission for these units ranged from 25 to 52 ppm.

Most process tanks and some evaporators use a constant diameter tube system and immersion tube burners to heat the solution tank. However, there are three types of heat exchange systems using constant diameter tubes. Each system has its own range of tube diameter depending upon the amount of pressure the burner produces and the allowable heat input to an individual tube. In addition, burners for these systems can be set up in a variety of ways depending upon the type of process tank. Burners can be set to fire at a maximum firing rate and off, fire at a high and low rate or modulate and fire across the whole range of the burner. Burners can also be set to fire at a fixed amount of combustion air or variable amount of combustion air in order to maintain a constant ratio of fuel and air over the firing range of the burner.

The most common heating tube system typically has tubes that vary from about four inches up to 14 inches in diameter. Burners for this system are available from many manufacturers including Eclipse, Maxon, Selas/Pyronics and Titan Engineering. The heat input in this type of system varies from about 20,000 to 30,000 Btu per square inch of tube cross section in four and five inch tubes and 25,000 to 40,000 Btu per square inch in six to 14 inch diameter tubes. Three of these systems have been tested – two heated evaporator tanks from Proheatco and one heated evaporator tank from Poly Products. All of these systems use a burner with a maximum rating of 350,000 Btu/hour and 4 inch diameter heating tubes. NOx emissions from these three units vary from 30 to 55 ppm. In addition, preliminary testing of a unit at another facility with a higher output burner of about 3 mmBtu/hour indicates that unit has NOx emissions of 40 to 50 ppm.

Figure I-1 provides a summary of burner and tube characteristics of the three tested units from Proheatco and Poly Products. The figure illustrates that the units have firing rates (heat input per square inch) near the maximum recommended by three major manufacturers for the most common type of tube immersion tube heating burners. This metric is important because it impacts the formation of NOx in the heating tubes. The information presented in Figure I-1 and the emission test data indicate that it is technically feasible to comply with the Rule 1147 NOx limit with the most common type of immersion heating burners.

Figure I-1




A second type of tube heating system uses burners that produce higher pressures and can fire into smaller diameter tubes. This type of system uses tubes two to eight inches in diameter with heat inputs per tube cross sectional area double the heat inputs of the standard system discussed above. Eclipse, Maxon and PowerFlame manufacture burners for this type of application. There are currently no emission test results available for these types of burners so it is not possible to determine if they comply with the Rule 1147 NOx emission limit of 60 ppm.

A third type of tube heating system for process tanks has been installed in new heated tanks. This system has a new type of burner from Maxon (an XPO burner) that requires larger diameter tubes (14 inches and above). An SCAQMD approved emissions test on one of these systems (required for Regulation XIII and new source review) with a 3.3 mmBtu/hour burner showed emissions of 4 ppm NOx at high fire and 34 ppm at low fire.

The Rule 1147 testing program has identified three types of heating systems used in process tanks and evaporators that comply with the NOx emission limit. There is no information yet available for a fourth type of heating system that uses high pressure burners firing into smaller diameter tubes of 2 to 8 inches. A fifth type of tank heating system with tube firing burners used in heat treating also been demonstrated to meet the 60 ppm NOx limit but have not yet been tested in heated tank applications.

For all five types of tank heating systems, the burners and heat exchangers or tubes are designed as one integrated system. If an individual heated tank or evaporator system using any of the four systems does not comply with the emission limit, then the whole tank will likely have to be replaced. Delaying compliance for existing in-use units from the rule emission limit until the combustion system is modified or replaced will address the issue that it is not feasible to retrofit an existing heated tank with different burners. If a tank is retrofitted with new burners, the owner will replace the heating tubes or heat exchanger. If the owner rebuilds a process tank, then a rule compliant system can be installed at that time.

SCAQMD staff is considering to amend Rule 1147 to delay compliance with the NOx emission limit for existing in-use process tanks, evaporators and parts washers with an integrated heated tank until the combustion system is modified or replaced. New units would still be required to meet the emission limit unless the total unit heat rating is less than or equal to 325,000 Btu/hour. Staff estimates this change would affect less than 50 heated tanks and evaporators currently subject to the Rule 1147 emission limit. There are more than 1,200 process tanks which are not subject to Rule 1147 requirements because they are exempt from the requirement for a permit by SCAQMD Rule 219, are unheated or are heated electrically or with a boiler.

# Appendix J – Heat Treating

## HEAT TREATING

Heat treating typically involves heating metals or alloys in a furnace or oven in order to develop specific properties in the metal or alloy before and after a part is made. However, heating can also be used to treat metals and nonmetallic refractory materials in a manufactured vessel, furnace or other product using temporary burners systems. The burners used in these systems are the same kinds of burners used in direct fired heat treating furnaces and kilns. Kilns are used for heat treating products made from ceramics, clay and other non-metallic materials.

Metal heat treating temperatures vary from a few hundred degrees Fahrenheit, used in tempering, to over 2,100 degrees for forging steel and titanium. With the exception of tempering, steel and titanium alloy heat treatments are typically at higher temperatures than for non-ferrous alloys based on aluminum. Kilns processing non-metallic materials also vary temperature depending upon the material and final product.

The type of burners used for heat treating depend upon the temperature required and whether they fire directly into the furnace or into tubes and heat is then transferred from the tubes to the furnace by fans. Lower temperature heat treating ovens have burners that are typically found in other types of ovens including air heating burners such as Eclipse Winnox and Maxon Cyclomax burners. Higher temperature direct fired furnaces typically use a different type of burner with a higher flame velocity, longer flame length and more radiant heat output for heating refractory material in the furnace or the tubes they fire into. High velocity burners are also used because they increase mixing and eliminate temperature stratification in direct fired furnaces. The new control systems for these low NOx burners are an important component of the system because they provide more precise tuning and control of the combustion process across the firing range of the burner.

Indirect fired furnaces typically have specialized tube firing burners. However, high velocity burners, similar to those found in direct fired applications, have also been used in indirect fired furnaces permitted in the SCAQMD. Temperature stratification in indirect fired furnaces is avoided because large fans move the air in the furnace past the tubes and into the section where the material being treated is held. High velocity and tube firing burners are available from many manufacturers including North American/Fives, Bloom, Eclipse, Maxon, Hot Work, Hauck, Industrial Combustion, and Selas. Tube firing burners from a number of manufacturers including Bloom, Hauck, North American/Fives, and Eclipse also have an option to add flue gas recirculation (FGR) to reduce NOx emissions.

Heat treating furnace designs have evolved over time. Newer furnace designs have more and smaller burners than many earlier designs. For both direct and indirect fired furnaces, more burners provide better control of the temperature profile in the furnace. Finer control of the furnace temperature allows the operator to meet newer more stringent temperature uniformity requirements than those that were in existence when older furnace designs were first built. Some of the older furnace designs predate modern temperature uniformity standards developed since the 1970s. The number and type of burners used in a furnace depend upon the size of the furnace, type of heat treating, process temperature and temperature uniformity requirements of the heat treating processes performed by the furnace.

Figures J-1 to J-4 summarizes the size and number of burners in the heat treating furnaces that have successfully completed emission testing. This information indicates that most of the burners used have heat ratings of 0.5 mmBtu/hour (500,000 Btu/hour) or less and the largest burners are about 2 mmBtu/hour. The largest furnaces have a heat rating of about 8 mmBtu/hour. There are furnaces permitted in the SCAQMD with larger heat ratings, but they are found at facilities in the RECLAIM program and are exempt from Rule 1147.

Figure J-1

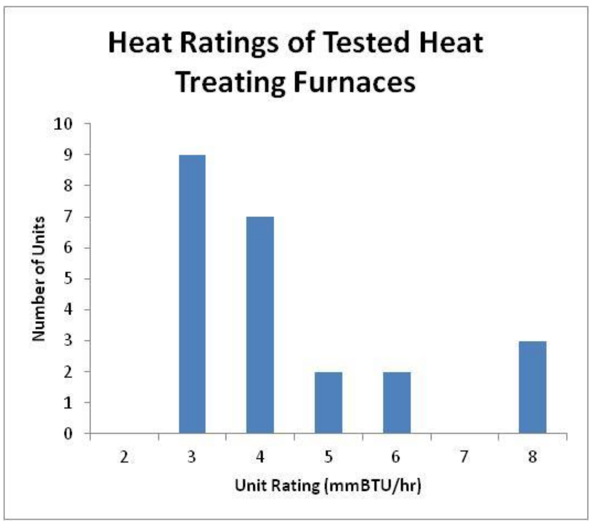



Figure J-2

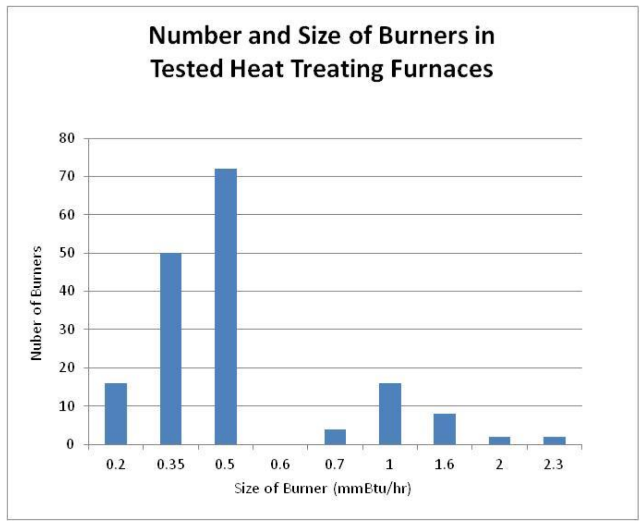



Figure J-3

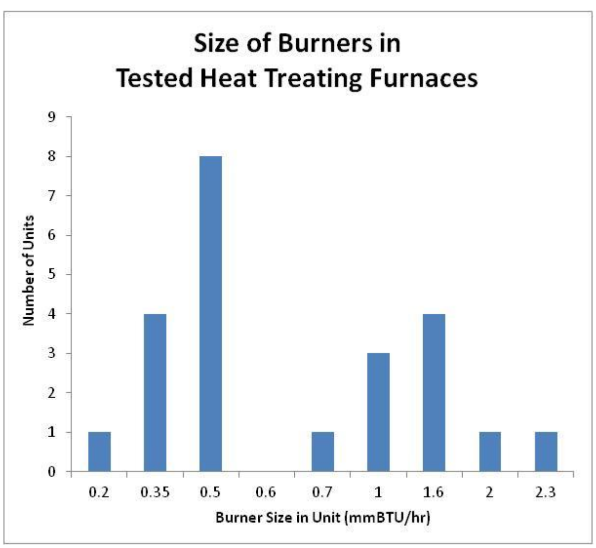
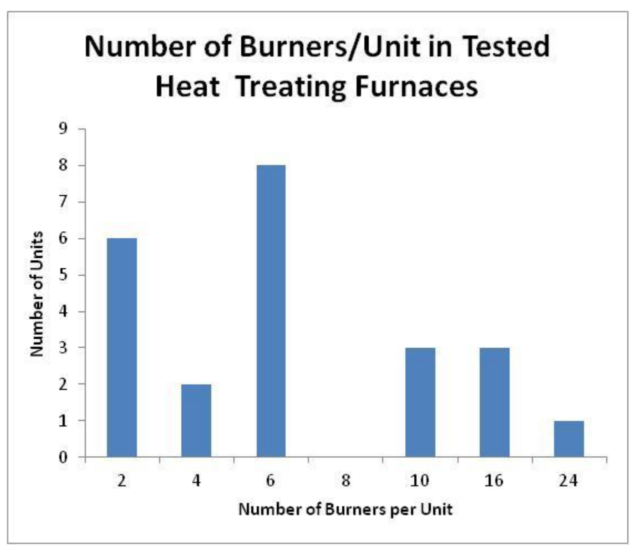



Figure J-4



The emission test results for heat treating furnaces indicate most furnace NOx emission concentrations are in the range from 45 ppm to 55 ppm with an average of about 50 ppm. These results cover a variety of furnaces processing aluminum and steel alloys across a broad temperature range. Some of the furnaces were new and were required to meet the new source BACT requirement of 50 ppm NOx, but most have been in use long before Rule 1147 was adopted in 2008 and before the BACT limit of 50 ppm was put in place in 2000. To date, only a few furnaces have had their burners replaced, added an FGR system or replaced their furnace in order to comply with Rule 1147. Most heat treating furnaces tested have met the Rule 1147 emission limit with their existing burners.

Kilns use the same burners that are found in direct fired heat treating furnaces and crematories. Kilns are used to heat treat clay, ceramic and other nonmetallic materials. Kilns are also used to heat treat glazes and other coatings applied to products made from these materials. Rule development staff have not yet received new emission test results for kilns from the Rule 1147 testing program. However, there were a number of emission tests completed on small and large kilns prior to rule adoption in 2008 and the rule amendment in 2011. These test results are summarized in Appendix B of this document. The emission test results demonstrate that a variety of kilns comply with the Rule 1147 emission limit of 60 ppm NOx with the burners installed prior to rule adoption. In addition, many small kilns are not subject to Rule 1147 because they are exempt from the requirement for a permit under SCAQMD Rule 219 (some of these use electric heat).

# Appendix K – Metal Melting

## METAL MELTING

A variety of metal melting furnaces are subject to Rule 1147. They include small pot and crucible furnaces for melting lead, lead alloys, aluminum, zinc and zinc alloys and larger units including kettle furnaces for galvanizing and reverberatory furnaces for melting aluminum. There are about 170 metal melting furnaces potentially subject to Rule 1147 NOx emission limits. Most of the furnaces subject to Rule 1147 melt non-ferrous metals and alloys. Furnaces for melting iron or making steel are often electric and therefore not subject to Rule 1147. There are also many furnaces at large facilities which are exempt from Rule 1147 because the facility is in the RECLAIM program.

To date, most of the metal melting furnaces tested complied with the Rule 1147 NOx limit with the burners in place when the rule was adopted. All of the larger kettle and reverberatory furnaces passed the emission limit with their original burners. However, one kettle furnace and one reverberatory furnace were recently built to replace older units and were subject to BACT under new source review. The four larger furnaces whose permits identified the burner manufacturer had Eclipse burners.

Of the five small pot and crucible melting furnaces tested, three furnaces met the emission limit with their original burners. The other two units had their burners replaced before testing. This type of furnaces can be built with burners from many manufacturers including Eclipse, Maxon, MidCo and others. One pot furnace had its original burner replaced with an Eclipse Ratio Air burner in order to comply with the NOx emission limit of 60 ppm. The new burner also had low CO emissions. A second company chose to replace two burners on a large pot furnace (2 mmBtu/hour originally) with one larger 2.4 mmBtu/hour Maxon Kinedizer LE burner, but it is not known whether the original burners would have met the Rule 1147 NOx limit. The burners were replaced in order to increase production of the furnace and to reduce fuel consumption and emissions. The new configurations was subject to BACT under new source review and complies with the Rule 1147 NOx emission limit and has low CO emissions.

The heat ratings of the pot/crucible furnaces tested ranged from 0.5 - 2.4 mmBtu/hour. The NOx emissions for these pot/crucible furnaces were in the range of 49 to 60 ppm. The eight kettle and reverberatory furnaces have unit heat ratings from 1.2 – 6 mmBtu/hour with emission ranging from 40 ppm to 53 ppm. However, the units greater than 4 mmBtu/hour have multiple burners rated 1.2 – 1.5 mmBtu/hour. The highest heat rating for a unit with one burner is 2 mmBtu/hour. There are furnaces with larger heat ratings permitted in the SCAQMD, but they are at facilities in the RECLAIM program and are exempt from Rule 1147.

The eight metal melting furnaces tested complied with the Rule 1147 NOx emission limit. Two of the units were new and built to replace old units. It is not known whether the old units would comply with the emission limit. One pot/crucible furnace was rebuilt with a larger burner to increase capacity. Another small pot furnace had its burner replaced to comply with the Rule 1147 NOx emission limit.  All of the unmodified units, the new units and the units with replaced burners complied with the rule emission limit.

# Appendix L – Multi-chamber Burn-off Ovens and Incinerators

## MULTI-CHAMBER BURN-OFF OVENS AND INCINERATORS

This category includes various equipment that are used for similar purpose but named differently. These units may be called burn-off or burn-out ovens, kilns or furnaces and incinerators. However, all of the units perform a similar function and operate in a similar fashion. They are built with a primary chamber for melting, vaporizing or pyrolizing some material on a part or piece of equipment in order to recycle the material or component. Some units are used for incinerating material that cannot be reclaimed or must be incinerated prior to disposal. The primary chamber leads to an integrated secondary afterburner chamber that destroys particulate matter, carbon monoxide, VOCs and any other organic material that enter this afterburner section. The incinerated material is reduced to carbon dioxide and water vapor.

The Rule 1147 NOx emission limit for the primary chamber of a furnace depends upon the process temperature in this burn-off chamber. If the process temperature exceeds 800 °F, then the NOx emission limit in the primary chamber is 60 ppm. If the process temperature is lower, then the NOx limit is 30 ppm which is consistent with a typical oven or low temperature furnace operating at those temperatures. The NOx limit for the secondary afterburner chamber is 60 ppm NOx and the same as for other afterburners.

Twelve burn-off ovens, furnaces and incinerators have completed review of their test results. Most units were tested with original burners. The number of burners in these units varies from two to six burners and the most common configuration has two or three burners. The heat ratings of the units range from 0.5 to 2.2 mmBtu/hour. The average NOx concentration in the stack after the afterburner section is less than 45 ppm and the range is from 26 to 54 ppm.

Discussion with a local manufacturer of burn-off furnaces indicates that it is not possible to use the preferred type of burner and meet a 30 ppm emission limit in the primary chamber for a process temperature less than 800 °F. The typical burner that is used to remove materials from a part is the same type of high temperature medium to high velocity burner used in crematories, kilns, heat treating and some types of afterburners. These burners are designed to have NOx emissions in the 40 to 60 ppm range.

The manufacturer has tested a design with an air heating burner in the afterburner section to achieve emissions of less than 30 ppm in the secondary chamber and meet an average emission limit for the two chambers of less than 45 ppm NOx. However, this redesign will not achieve the required PM, VOC and carbon monoxide reductions in all applications. In addition, using the averaging provision of the rule may not always achieve compliance with the NOx limit. Company representatives have suggested that since it is not always possible to comply with the emission limit of 30 ppm in the primary chamber of these types of devices, the NOx limit in the primary chamber should be 60 ppm NOx regardless of the process temperature. SCAQMD staff agree with this assessment and are considering a rule change that the NOx emission limit in both chambers of this type of equipment should be

60 ppm at any process temperature. This change in the rule limit would affect a small number of equipment regulated by Rule 1147.

# Appendix M – Ovens and Dryers

## OVENS AND DRYERS

Excluding spray booth systems, the number of ovens and dryers under permit in the SCAQMD is slightly less than 1,200 units. This is the second largest category of equipment regulated by Rule 1147. These units are used in a variety of processes including curing of coatings and other materials, drying coated and printed products, and drying materials. The oven or dryer can be a small enclosed batch oven with a heating system, a large walk in oven, a conveyor system with a coating tank or coating spray station followed by a heated oven, or a drying room with a unit heater. Some printing and all textile drying operations use large conveyor units with multiple burners for high speed production of large quantities.

There are a variety of burners used in ovens and dryers. Each type of burner has its own characteristic emission profile. For example, radiant infrared burners have low emissions and NOx concentrations are typically less than 20 ppm. The most common type of burners used are nozzle mixing air heating burners. Some of the same types of ovens use premix burners with a metal fiber fabric cylinder or panel as a flame holding surface. Other units are designed to use line type air heating burners. Some small ovens and large conveyor systems use many flat panel radiant infrared burners. Powder coating operations are one of the processes that use radiant burners. Radiant infrared burners are required to directly heat a part in order to melt and then cure the coating. Ovens in which combustion gases cannot come in contact with the produce use indirect fired heater units with an air to air heat exchanger to provide clean heated air to the oven. However, both direct and indirect-fired unit heaters can be used to provide heat and move air through large drying ovens or rooms.

Ovens subject to the Rule 1147 NOx emission limit use burners from a number of manufacturers. The most common burners used in the SCAQMD are line and nozzle mix burners manufactured by Eclipse and Maxon. Two thirds of the tested ovens and dryers use Maxon burners and one fourth of the units use Eclipse burners. Eclipse burners used in compliant ovens and dryers include the Eclipse Winnox and Linnox product lines. Maxon burners used in compliant ovens include several versions of the OvenPak series, the Cyclomax, the LN-4 line burner and the Kinedizer. However, low NOx burners from other manufacturers including MidCo, PowerFlame, Riello, and Yukon also comply with the Rule 1147 NOx emission limit. The newer control systems for these low NOx burners are the most important component of the combustion system because they offer more precise tuning and control of the combustion process across the firing range of the burner.

Most ovens and dryers tested use only one burner. However, coating, printing and curing lines often have multiple burners. Many coating and printing lines use two identical burners, but the oven section of a coating line can also have up to 40 infrared radiant panels.

The tested ovens’ heat ratings varies across a wide range from 0.4 mmBtu/hour for a small batch oven up to 20.5 mmBtu/hour for a large rotary dryer. However, most ovens have ratings less than 2.5 mmBtu/hour. Most burners in ovens with multiple burners are also less than 2.5 mmBtu/hour. The most common size of burner installed in all types of oven is 1.0 mmBtu/hour.

Figures M-1 through M-4 identify burner heat rating, number of burners and the range of the heat ratings for the tested units. Printing oven and textile dryer data is not included in Figures M-1 and M-2. Printing oven data is summarized in Figures M-3 and M-4.

Figure M-1

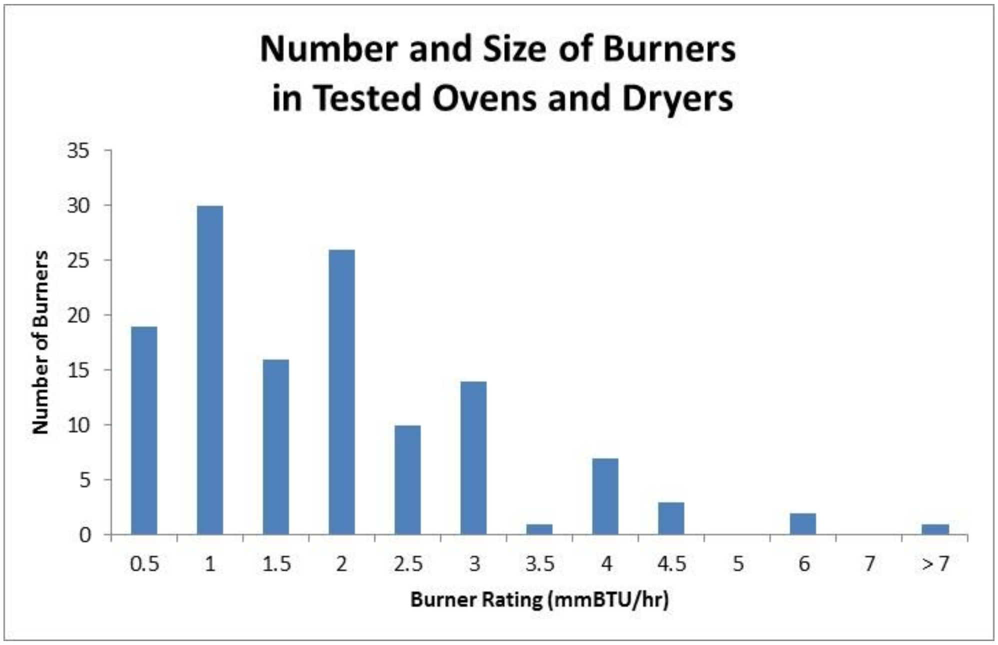



Figure M-2

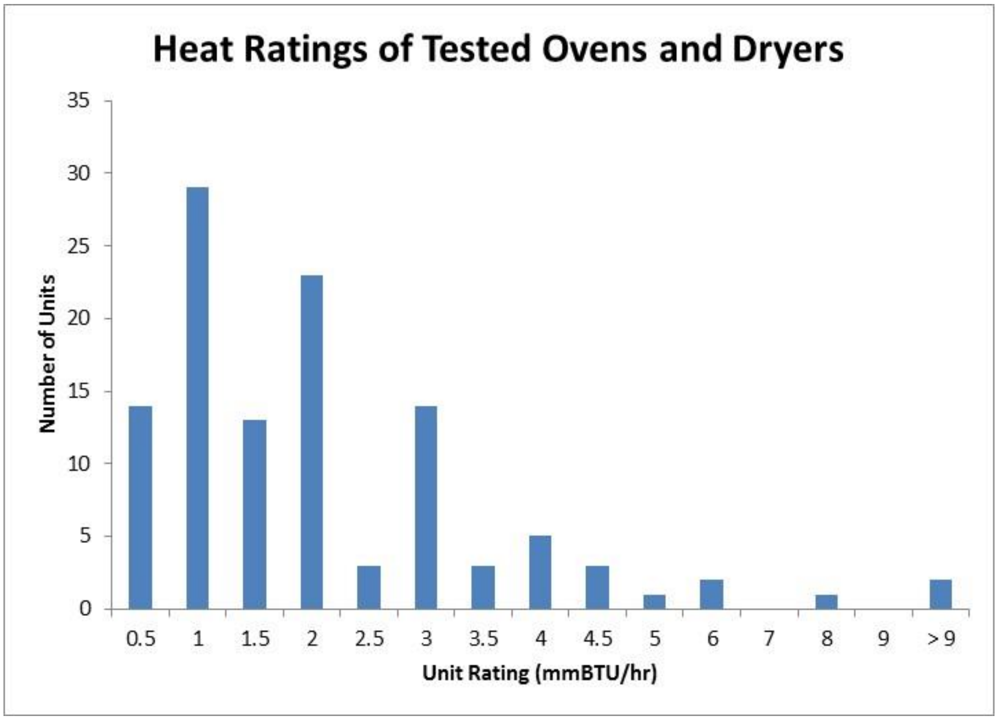


Figure M-3

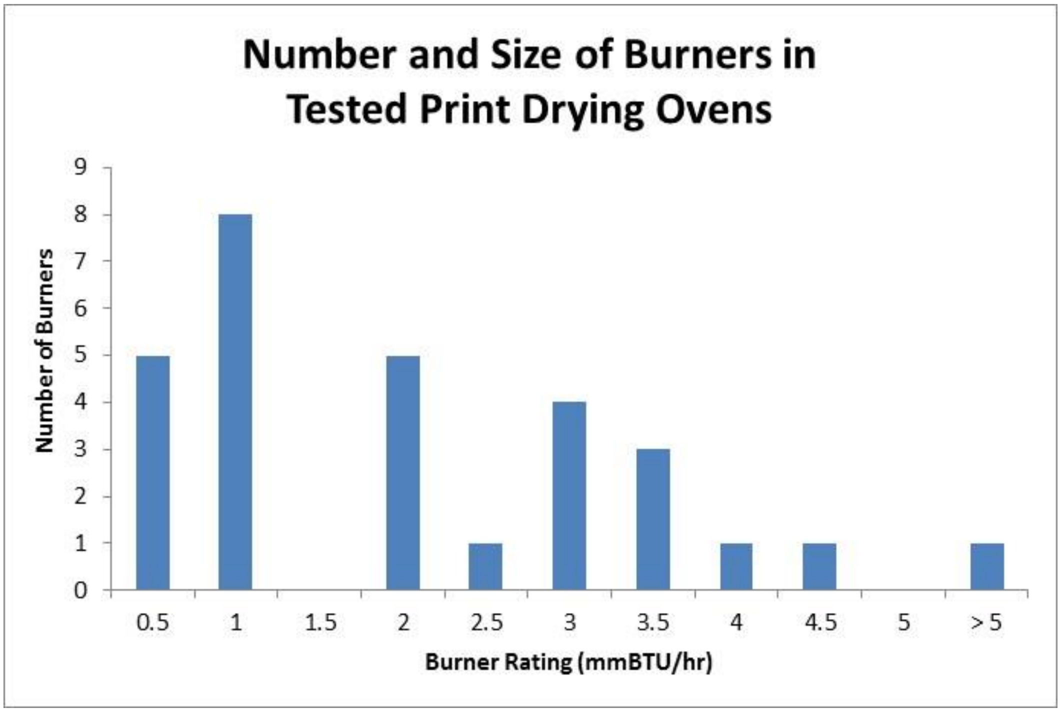
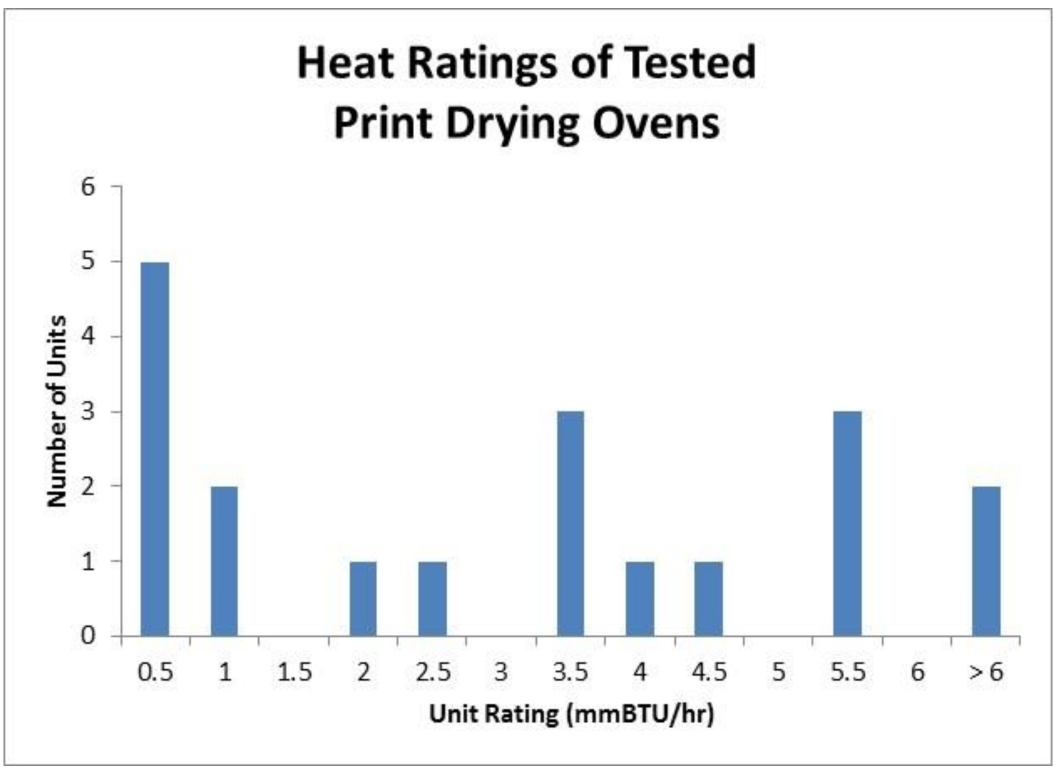



Figure M-4




Printing oven and dryer heat ratings vary from about 0.4 mmBtu/hour to 7.4 mmBtu/hour. The most common burner size in these ovens is also 1.0 mmBtu/hour. Textile tenter dryers typically have eight or nine burners that are rated less than 1.0 mmBtu/hour. The other type of textile dryer typically has four burners each rated about 1.0 mmBtu/hour.

The emission test results for ovens and dryers indicate that all types of units tested comply with the Rule 1147 NOx emission limit. Table M-1 provides a summary of the completed Rule 1147 emission tests for ovens and dryers. At this time, 140 units used for a variety of processes have approved test results and comply with the 30 ppm NOx limit. The average emission concentration for most ovens and dryers is about 20 ppm NOx. The average emission concentration for textile dryers is about 25 ppm NOx. The range of emission concentrations for all ovens and dryers is from 4 ppm to 30 ppm. The range emission concentrations for printing lines and ovens is 4 ppm to 29 ppm and for textile dryers is 14 ppm to 27 ppm. In addition, two ovens complied with the rule limit by averaging emissions from the oven and an afterburner that must comply with a NOx emission limit of 60 ppm.

Table M-1

Rule 1147 Emissions Test Results for Ovens and Dryers

| Equipment Category | Rule 1147 NOx Limit (ppm [1]) | Number of Units Tested at Normal/High Fire | Average NOx Concentration at Normal/High Fire (ppm) | Number of Units Tested at Low Fire | Average NOx Concentration at Low Fire (ppm) |
|---|---|---|---|---|---|
| **Oven/Dryer** | 30 or 60 [2] | 112 | 20 | 35 | 21 |
| **Print Dryer/Oven** | 30 | 19 | 20 | 4 | 23 |
| **Textile Shrink Dryer** | 30 | 2 | 24 | | |
| **Textile Tenter Dryer** | 30 | 4 | 23 | 4 | 26 |
| **Unit Heater** | 30 or 60 [2] | 3 | 20 | 1 | 13 |
| | | | | | |
| **Number of Units** | | 140 | | 44 | |

[1] The Rule 1147 NOx limit is based on a reference level of 3% oxygen ($O_2$) in the exhaust. All emission test results are converted to a concentration in parts per million at the reference level of 3% $O_2$.

[2] The emission limit depends upon the process temperature.

The results from the Rule 1147 emission testing program indicate that rule compliant technology is available for ovens and dryers from many sources. In addition, all of the types of ovens and dryers under permit in the SCAQMD can comply with the Rule 1147 NOx limit. However, there is a lower limit on the availability of low NOx burners for ovens and dryers. The smallest low NOx burners available are rated 0.4 and 0.5 mmBtu/hour (400,000 and 500,000 Btu/hour). Burners in this size are available from a number of manufacturers including Eclipse, Maxon, MidCo and PowerFlame. For lower firing rates, oven manufacturers will use this size of burner but limit the firing rate to less than the burner's maximum capacity. If these burners must regularly operate at less than 30% of the maximum firing rate, it may be difficult to comply with the NOx emission limit. Because there is a lower limit on the size of compliant burners for ovens and dryers, staff is considering an exemption from the Rule 1147 NOx emission limit for units with heat input capacities less than 325,000 Btu/hour.

# Appendix N – Food Ovens

## FOOD OVENS

Food ovens in use at the time SCAQMD Rule 1153.1 was adopted are no longer subject to Rule 1147. However, new food ovens are currently subject to Rule 1147 requirements. Staff are currently evaluating alternative rule development options for exempting new food ovens from Rule 1147. Although new food ovens may be exempt from Rule 1147 in the future, some operators of food ovens have reported results under the rule's emission testing program. At the time of this report, 13 food ovens used for a variety of baking and cooking operations have completed testing under the Rule 1147 program.

These ovens use burners from many manufacturers including Eclipse, Ensign/Selas, Flynn, Maxon and Weishaupt. Eclipse, Maxon and Weishaupt burners air heating burners are used in both batch and conveyor type convective ovens. Ensign and Flynn provide ribbon burners for heating specific types of conveyor ovens and some small batch ovens. For example, conveyor ovens with moving bands that must be heated in order to cook products on the band such as chips and crackers require ribbon or a similar type of burner. Batch type convective ovens can use a variety of burners and do not require ribbon burners. In addition, there are many conveyor type convective ovens that do not require or use ribbon burners. These convective batch and conveyor ovens use air heating nozzle mix or line burners.

Radiant infrared burners are used in both batch and conveyor ovens. This type of burner is available from many manufacturers including those identified earlier in this discussion. Three bakery ovens using only radiant infrared burners were tested and complied with Rule 1147 and Rule 1153.1 emission limits. This type of burner is used in both batch type and conveyor type ovens. The average NOx emission concentration for these burners is 13 ppm with a range of 6 to 19 ppm. Ovens with radiant infrared burners are exempt from the Rule 1153.1 requirement to perform an emissions test because these burners have NOx emissions significantly less than the emission limits in the rule (40 and 60 ppm NOx).

Four ovens with ribbon burners have been tested through the Rule 1147 emission testing program. Two baking ovens with operating temperatures less than 500 °F both had NOx emission concentrations of 21 ppm at their high or normal fire rate. One had NOx emission concentrations of 26 ppm at low fire. One of the units is used for baking tortillas and the other unit is used for baking breads and snacks. In addition, two griddle ovens used for making English muffins and other products cooked in griddles had emission concentrations of 41 ppm and 45 ppm. Griddle ovens with ribbon burners typically operate at temperatures above 500 °F. Both of these ovens comply with the Rule 1153.1 NOx emission limit of 60 ppm for this process temperature.

Five convection type ovens using nozzle mix air heating burners have been tested and comply with Rule 1147 and 1153.1 NOx emission limits. Two of the ovens are used to cook meat products and three cook breads and snacks. These ovens have average emission concentrations of 25 ppm NOx with a range of 22 ppm to 30 ppm. One of these units has a permit limit of 25 ppm NOx that was established prior to adoption of Rule 1147. This oven has been operating for more than seven years with this permit condition and demonstrates that a 25 ppm NOx emission limit is achieved in practice for convection ovens.

The remaining oven that was tested is used for cooking meat and has two cooking sections. The first section is a charbroiler and the second is a convective heating section using steam and heated air. The heated air in the second section is produced using an Eclipse Air Heat line burner. The NOx emission concentration from all burners for this unit was 33 ppm. This result demonstrates compliance with Rule 1153.1 NOx emission limits of 40 ppm and 60 ppm. However, given the design and purpose of this unit, the first section of this device is exempt from the emission limits of Rules 1147 and Rule 1153.1 because it is a charbroiler. The exemption for charbroiling in both Rules 1147 and 1153.1 was not taken into account when the emission test protocol was prepared for this unit.

The results for the 13 food ovens tested through the Rule 1147 program indicate that every type of food oven and burner comply with Rule 1153.1 NOx emission limits. In addition, convection ovens using air heating burners, ovens with radiant infrared burners and conveyor type food ovens with ribbon burners operating at less than 500 °F also comply with the Rule 1147 NOx emission limit of 30 ppm. Moreover, another conveyor oven with ribbon burners and a process temperature less than 500 °F was tested prior to Rule 1147 adoption and had NOx emissions of less than 30 ppm (Figure B-5, Appendix B).

Currently, there are projects funded by SEMPRA Energy and the California Energy Commission to reduce NOx emissions from ribbon burners used in commercial and residential cooking ovens. The data from the Rule 1147 and Rule 1153.1 emissions testing programs and these technology projects will provide staff with data to determine how Rule 1147 and Rule 1153.1 should be amended in the future to limit NOx emissions from new food ovens.

[This Page Intentionally Left Blank]