Source Category: Glass Manufacturing

INTRODUCTION

The purpose of this document is to provide a forum for public review and comment on the evaluation of candidate control measures that may be considered by the States in the Midwest Regional Planning Organization (MRPO) to develop strategies for ozone, PM2.5, and regional haze State Implementation Plans (SIPs). Additional emission reductions beyond those due to mandatory controls required by the Clean Air Act may be necessary to meet SIP requirements and to demonstrate attainment. This document provides background information on the mandatory control programs and on possible additional control measures.

The candidate control measures identified in this document represent an initial set of possible measures. The MRPO States have not yet determined which measures will be necessary to meet the requirements of the Clean Air Act. As such, the inclusion of a particular measure here should not be interpreted as a commitment or decision by any State to adopt that measure. Other measures will be examined in the near future. Subsequent versions of this document will likely be prepared for evaluation of additional potential control measures.

The evaluation of candidate control measures is presented in a series of "Interim White Papers." Each paper includes a title, summary table, description of the source category, brief regulatory history, discussion of candidate control measures, expected emission reductions, cost effectiveness and basis, timing for implementation, rule development issues, other issues, and a list of supporting references. Table 1 summarizes this information for the cement kiln source category.

SOURCE CATEGORY DESCRIPTION

The glass manufacturing process consists of melting prepared formulations of raw materials and allowing them to cool without crystallizing. Glass products are classified by both chemical composition and by the type of product produced. The main compositions are soda-lime glass, lead crystal and crystal glass, borosilicate glass, and other special glasses. The main product types are flat glass, container glass, pressed and blown glass, and fiberglass.

The manufacturing process requires raw materials, such as sand, limestone, soda ash, and cullet (scrap and recycled glass), be fed into a furnace where a temperature is maintained in the 2,700°F to 3,100°F range. The raw materials then chemically react creating a molten material, glass. The molten glass is drawn off, continuously or by batch, and then formed into the final product by pressing, blowing, drawing, rolling and/or floating. Finishing steps include annealing, grinding, polishing, coating and/or decorating. Undesirable products are separated and reused as cullet.

Greater than 50 percent of the glass melting furnaces are a regenerative design, with two chambers containing refractory "checker bricks" for capturing heat. The flow of combustion air (influent) and flue gas (effluent) alternate passing through the checkers to recover heat and provide heat, respectively. Recuperative glass melting furnaces are also used which rely on heat exchanges to continuously preheat combustion air. Natural gas is the preferred source of heat used by the industry, although oil, electricity and combinations of fuel and electricity are used.

TABLE 1 – CONTROL MEASURE SUMMARY FOR GLASS MANUFACTURING

Control Measure Summary	**NOx Emissions (tons/year) in 5-state MRPO Region**	
2002 Existing measures : NSPS; PSD/NSR; State RACT Rules	2002 Base:	15,354
2009 On-the-Books measures: Wisconsin Rule 428.05	Reduction: 2009 Remaining:	<u>-338</u> 15,016
Candidate measure: Apply "Highly Cost-Effective" Reasonably Available Controls to all Glass Manufacturing Plants in Region *Measure ID:* GLASS1 *Emission Reductions:* average of 30% control from 2002 in MRPO region *Control Cost:* less than $2,000/ton *Timing of Implementation*: Assumes full reductions achieved in 2009 *Implementation Area*: 5-State MRPO region	2009 Reduction: 2009 Remaining:	<u>-4,269</u> 10,748
Candidate measure: Apply "Cost-Effective" Reasonably Available Controls to all Glass Manufacturing Plants *Measure ID:* GLASS2 *Emission Reductions:* average of 75% control from 2002 in MRPO region *Control Cost:* $2,000/ton to $4,000/ton *Timing of Implementation*: Assumes full reductions achieved in 2009 *Implementation Area*: 5-State MRPO region	2009 Reduction: 2009 Remaining:	<u>-11,262</u> 3,754

Note: the 2009 emission estimates presented here are not growth-adjusted.

The furnace operation is the main source of pollution at a glass manufacturing plant. The reaction of nitrogen and oxygen in the furnace creates nitrogen oxide (NOx) emissions. This occurs in the combustion zone and in the checkers in the production of flat glass furnace where temperatures can reach 2,300°F. Particulate emissions result from the volatilization of materials that later form condensates and from material handling. Sulfur dioxide (SO2) emissions are the product of oxidation of sulfur containing compounds in fuels and in the raw material formulations. Volatile organic compound (VOC) emissions may be associated with the use of lubricants, mold release agents and coatings used in the decoration of finished products.

Table 2 shows the 2002 emission inventory for glass and fiberglass manufacturing facilities in the 5-state MRPO region.

REGULATORY HISTORY

Emission control regulations for glass manufacturing historically focused on particulate and arsenic emissions. Since the mid-90's, regulations for the control of NOx emissions have also been adopted in a few states. Both on-the-books and potential future regulatory programs are briefly discussed in the following paragraphs.

On-the-Books Regulation

Under Title I of the Clean Air Act, EPA has developed New Source Performance Standards (NSPS) for certain specified categories of new and modified large stationary sources. The NSPS for Glass Manufacturing Plants is contained in 40 CFR Part 60 Subpart CC and applies to any glass melting furnace facility constructed or modified after June 15, 1979. Subpart CC specifies emission standards only for particulate matter.

Title I also subjects new and modified large stationary sources that increase their emissions to permitting requirements that impose control technologies of varying levels of stringency (known as New Source Review, or NSR). NSR prescribes control technologies for new plants and for plant modifications that result in a significant increase in emissions, subjecting them to Best Available Control Technology (BACT) in attainment areas and to the Lowest Achievable Emission Rate (LAER) in nonattainment areas. The control strategies that constitute BACT and LAER evolve over time and are reviewed on a case-by-case basis in state permitting proceedings.

In June 1994, EPA published an Alternative Control Techniques (ACT) Document addressing NOx emissions from glass manufacturing. Several control technologies and their cost effectiveness were described. Control efficiencies ranged from 40 to 85%. The cost effectiveness estimates ranged from $790 to $9,900 per ton of NOx reduced. The ACT did not provide recommendations on regulatory limits.

EPA finalized the NOx SIP call in 1998 to begin to address interstate transport of air pollution. The final version of the rule called for NOx emission reductions in twenty-two states (including Ohio, Indiana, Illinois, and the southern half of Michigan, but not Wisconsin) that contributed to 1-hour ozone nonattainment in other states. The rule required affected states to amend their SIPs and limit NOx emissions from a core group of sources including electric generating units, industrial boilers and turbines, large internal combustion engines, and cement kilns. The rule did not recommend States include glass manufacturing plants because analyses had indicated the control of glass plants was not cost-effective relative to sources chosen for the core group. Estimated control costs for glass manufacturing facilities exceeded the "highly cost effective" threshold of $2,000 per ton for inclusion as non-EGU point sources.

TABLE 2 – 2002 EMISSIONS FROM GLASS AND FIBERGLASS MANUFACTURING FACILITIES

Plant Name	SIC Code	2002 Annual Emissions (tons/year)			
		SO2	**NOx**	**VOC**	**PM10**
ILLINOIS					
KIMBLE GLASS Chicago Heights, IL	3221 – Pressed or Blown Glass/Glassware Containers	1	11	0	1
SAINT-GOBAIN CONTAINERS Dolton, IL	3221 – Pressed or Blown Glass/Glassware Containers	358	973	2	166
OWENS-BROCKWAY Streator, IL	3221 – Pressed or Blown Glass/Glassware Containers	328	477	24	80
PILKERTON NORTH AMERICA Ottawa, IL	3211 – Flat Glass	206	552	7	132
SAINT-GOBAIN CONTAINERS Lincoln, IL	3221 – Pressed or Blown Glass/Glassware Containers	157	374	0	31
PPG INDUSTRIES Mt. Zion, IL	3211 – Flat Glass	170	1,759	124	115
TOTAL ILLINOIS		**1,220**	**4,146**	**157**	**525**
INDIANA					
ANCHOR GLASS CONTAINER Lawrenceburg, IN	3221 – Pressed or Blown Glass/Glassware Containers	174	521	11	51
INDIANA GLASS COMPANY Dunkirk, IN	3229 – Pressed or Blown Not Elsewhere Classified	36	87	6	22
SAINT-GOBAIN CONTAINERS Dunkirk, IN	3221 – Pressed or Blown Glass/Glassware Containers	261	160	33	126
OWENS BROCKWAY Lapel, IN	3221 – Pressed or Blown Glass/Glassware Containers	187	282	18	62
ANCHOR GLASS CONTAINER Winchester, IN	3221 – Pressed or Blown Glass/Glassware Containers	270	666	23	141
US MINERAL PRODUCTS Huntington, IN	3296 – Mineral Wool & Fiberglass	2	43	17	32
KNAUF FIBERGLASS Shelbyville, IN	3296 – Mineral Wool & Fiberglass	1	129	107	296
BPB AMERICA Lagro, IN	3296 – Mineral Wool & Fiberglass	35	12	6	21
THERMAFIBER Wabash, IN	3296 – Mineral Wool & Fiberglass	28	61	134	269
JOHNS MANSVILLE Richmond, IN	3296 – Mineral Wool & Fiberglass	19	52	34	49
TOTAL INDIANA		**1,013**	**2,012**	**389**	**1,069**
MICHIGAN					
OWENS-BROCKWAY Charlotte, MI	3221 – Pressed or Blown Glass/Glassware Containers	81	34	13	59
GUARDIAN INDUSTRIES Carlton, MI	3211 – Flat Glass	208	651	15	132
GUARDIAN FIBERGLASS Albion, MI	3296 – Mineral Wool & Fiberglass	0	41	120	82
TOTAL MICHIGAN		**289**	**726**	**148**	**273**

Plant Name	**SIC Code**	**2002 Annual Emissions (tons/year)**			
		SO2	**NOx**	**VOC**	**PM10**
OHIO					
ANCHOR HOCKING GLASS Lancaster, OH	3229 – Pressed or Blown Not Elsewhere Classified	51	700	5	58
TECHNEGLAS, INC. Columbus, OH	3229 – Pressed or Blown Not Elsewhere Classified	5	163	17	1
GE LOGAN LIGHTING PLANT Logan, OH	3229 – Pressed or Blown Not Elsewhere Classified	36	881	4	55
GE QUARTZ Willoughby, OH	3229 – Pressed or Blown Not Elsewhere Classified	0	179	0	9
LIBBEY GLASS Toledo, OH	3229 – Pressed or Blown Not Elsewhere Classified	204	376	0	48
OWENS BROCKWAY Zanesville, OH	3221 – Pressed or Blown Glass/Glassware Containers	176	361	21	79
HOLLINEE, L.L.C. Shawnee, OH	3229 – Pressed or Blown Not Elsewhere Classified	0	5	127	17
THOMSON Circleville, OH	3229 – Pressed or Blown Not Elsewhere Classified	14	1,410	38	15
JOHNS MANSVILLE – DEFIANCE PLANT Defiance, OH	3296 – Mineral Wool & Fiberglass	5	80	119	237
JOHNS MANSVILLE Defiance, OH	3296 – Mineral Wool & Fiberglass	27	36	66	157
JOHNS MANSVILLE – PLANT 3 Defiance, OH	3296 – Mineral Wool & Fiberglass	6	50	390	189
OWENS CORNING Newark, OH	3296 – Mineral Wool & Fiberglass	58	642	182	648
JOHNS MANSVILLE – PLANT #01-W Waterville, OH	3296 – Mineral Wool & Fiberglass	113	125	86	112
JOHNS MANSVILLE – WATERVILLE 07 Waterville, OH	3296 – Mineral Wool & Fiberglass	0	38	62	70
TOTAL OHIO		**695**	**5,046**	**1,118**	**1,693**
WISCONSIN					
CARDINAL FG Portage, WI	3211 – Flat Glass	56	1,420	35	50
CARDINAL FG Menomonie, WI	3211 – Flat Glass	49	1,577	26	0
SAINT-GOBAIN CONTAINERS Burlington, WI	3221 – Pressed or Blown Glass/Glassware Containers	239	426	23	80
Walworth, WI	Fiberglass				
TOTAL WISCONSIN		**344**	**3,423**	**84**	**130**
TOTALS FOR MRPO REGION		**3,561**	**15,354**	**1,895**	**3,692**

Two National Emissions Standards for Hazardous Air Pollutants (NESHAPs) promulgated under Title III of the CAA apply to glass manufacturing facilities. On August 4, 1986, EPA issued a NESHAP applicable to glass manufacturing plants that use commercial arsenic as a raw material. Facilities subject to this NESHAP are required to use particulate control devices to comply with the limits on arsenic emissions. On June 14, 1999, EPA published a NESHAP with Maximum Achievable Control Technology (MACT) requirements that apply to the manufacture of wool fiberglass. This MACT standard includes limits requiring control of both particulate and formaldehyde emissions. The particulate limit serves as a surrogate for three metals: arsenic, chromium, and lead. The formaldehyde limit is intended to control phenol and methanol emissions as well.

Midwest RPO Regulations

In the Midwest RPO States, glass manufacturing plant emissions are subject to PM and SO2 limits, and in one State, NOx limits.

PM Limits – Glass manufacturing plants are subject to a process weight-based (curve) limit for PM emissions. Existing sources (as of 1972) in Illinois and all sources in Indiana, Michigan, and Ohio are subject to the same limit. New sources in Illinois and all sources in Wisconsin are subject to more stringent process weight-based limits. In Illinois, glass plants in portions of Chicago and East St. Louis are exempt from the process weight curve and subject to a more stringent lb/ton limit. Sources in Wisconsin must also comply with a 0.65 lb/lb of gas-released limit.

SO2 Limits – Fuel burning limits on SO2 emissions apply to glass plants in Illinois, Indiana, and Michigan. In Illinois, except furnaces in Chicago and glass treating in East St. Louis, glass plants must also comply with a 2,000-ppm process emission limit. Indiana has also established source specific limits for two plants. Plants in Ohio must comply with one of two process-weight-based curves for SO2 emissions, depending on location, with the exception of two units in Muskingum County, which are subject to source specific limits. All glass plants in Wisconsin are subject to a 1,035 lb/hour limit for SO2 emissions.

NOx Limits – Wisconsin's regulations limits NOx emissions to 4 lbs/ton from new glass manufacturing plants with 50 MMBtu/hour or greater heat input. Existing glass manufacturing furnaces with a maximum design heat input of 75 mmBtu/hour were required to complete a combustion optimization study to minimize NOx by December 31, 2002. No other MRPO States have NOx limiting regulations that apply to glass plants. It appears that only two furnaces in Wisconsin had NOx reductions after 2002; no other furnaces in the region appear to have any NOx controls in 2002.

On-the-Way Regulations

On April 15, 2004, EPA proposed amendments to its July 1999 regional haze rule. These amendments would apply to the provisions of the regional haze rule that require emissions controls known as best available retrofit technology or BART for industrial facilities emitting air pollutants that reduce visibility. The BART requirements of the regional haze rule apply to facilities built between 1962 and 1977 that have the potential to emit more than 250 tons a year of visibility-impairing pollutants. Those facilities fall into 26 categories, including glass fiber processing plants. Under the proposed BART guidelines, states are required to conduct source-by-source BART determinations to identify which facilities must install controls and the type of controls to be used. Three MRPO glass fiber processing plants were identified, two in Illinois and one in Ohio. These three plants, however, did meet the criteria requiring individual facility BART analyses.

CANDIDATE CONTROL MEASURES

Most glass manufacturing plants utilize particulate control systems to meet PM limits, and, where applicable, the NESHAP and NSPS requirements. Particulate control systems include wet scrubbers, baghouses and electrostatic precipitators. Particulate controls will also capture any process sulfate emissions. The use of baghouses and electrostatic precipitators provide a similar, high level of particulate control in the 99% range.

SO2 emissions can be reduced by changes in fuels consumed, limits on raw materials charged, or by add-on control systems. Currently, natural gas is the fuel of choice by most glass manufacturers, minimizing the SO2 emissions from fuel combustion. Individual plants have accepted permit limits on material usage rates in order to control SO2 emissions. The add-on control systems include both wet scrubbers and dry scrubbers followed by a baghouse. Scrubber systems remove both SO2 and PM. Particulate and SO2 removal efficiencies will vary significantly with scrubber design and site-specific factors.

VOC emissions from glass manufacturing are relatively minor and not subject to control requirements. In addition, emissions of PM and SO2 are relatively minor on a regional-scale. Insight into the effectiveness of additional controls for these pollutants would require the conduct of facility specific analyses. Therefore, no additional control measures are considered for this White Paper for PM, SO2 or VOC.

NOx Control Options

Several alternative different control technologies are available to glass manufacturing facilities to limit NOx emissions. These options include combustion modifications (low NOx burners, oxy-fuel firing, oxygen-enriched air staging), process modifications (fuel switching, batch preheat, electric boost), and post combustion modifications (fuel reburn, SNCR, SCR). These control approaches and their effectiveness are summarized in Attachment I. The potential control efficiencies achievable by the different approaches and their cost effectiveness ($/ton) vary significantly. Since the combustion and process modification options affect energy efficiency, larger facilities have likely considered one or more of these control options.

EPA presented analyses in support of the Clear Skies legislation in June 2002 that estimated the costs to control NOx emissions from larger glass manufacturing operations to be $2,600/ton. In support of the Interstate Air Quality Rule, EPA estimated a 30% reduction in NOx emissions might be achievable across 30 states if glass manufacturing was included as a non-EGU.

State and Local Regulations

Several States have adopted requirements to limit NOx emissions from glass manufacturing. For comparison, the uncontrolled emission rates reported in AP-42 are 6.2 lbs/ton for container manufacturing, 8.0 lbs/ton for flat glass manufacturing, and 8.5 lbs/ton for pressed and blown glass product manufacturing. Estimates of uncontrolled emissions in EPA's ACT were somewhat higher than reported in AP-42. The ACT reported uncontrolled emission rates for container manufacturing facilities were reported from 5 to 21 lbs/ton; for flat glass manufacturing, from 8 to 26 lbs/ton; and for pressed and blown glass manufacturing, from 16 to 28 lbs/ton.

New Jersey – Limits NOx emissions from commercial container manufacturing to 5.5 lbs/ton for facilities producing 14 tons or greater of glass per day. Limits NOx emissions from specialty container manufacturing to 11 lbs/ton for facilities producing 7 tons glass per day or more. Performance levels for new sources are 4 lbs/ton for commercial container manufacturing, 7 lbs/ton for flat glass, and 4 lbs/ton for pressed and blown glass.

Massachusetts – Limits NOx emissions from container glass melting furnaces to 5.3 lbs/ton for facilities producing 14 tons or more glass per day.

Bay Area Air Quality Management District – Limits NOx emissions from glass melting furnaces to 5.5 lbs/ton for facilities producing 5 tons or more of glass per day.

South Coast Air Quality Management District - Limits NOx emissions from glass melting furnaces to 4.0 lbs/ton with exemptions for flat glass and fiberglass melting furnaces and furnaces feed entirely with remelt feed streams.

San Joaquin Valley Unified Air Pollution Control District – Limits NOx emissions from glass melting furnaces to 4.0 lbs/ton for container glass and fiberglass furnaces, and 9.2 lbs/ton for flat glass furnaces with compliance required by the next furnace rebuild or no later 3/31/2008. Prior to rebuild/compliance deadline furnaces must meet 5.5 lbs/ton for container glass and fiberglass furnaces, and 12 lbs/ton (or higher with sliding scale based on capacity utilization) for flat glass furnaces.

<u>New Source Determinations</u>

Several BACT determinations for NOx emissions were identified by reviewing EPA's RACT/BACT/LAER Clearinghouse and permit-related information found via internet searches. The majority of the permit cases were for flat glass manufacturing furnaces, with BACT identified as either furnace design incorporating low-NOx burners or use of fuel-reburn technology. The BACT limits were typically expressed in terms of lbs/hour (rather than lbs/ton) and varied significantly.

Measure GLASS1 – Apply "highly cost effective" NOx controls to all furnaces Use EPA "highly cost effective" threshold of $2000/ton; assume an average across the MRPO region a *30 percent reduction* in NOx emissions (for example, low NOx burners or SNCR).

Measure GLASS2 – Apply "cost effective" NOx controls to all furnaces Use "cost effective" threshold of $4000/ton; assume average across the MRPO region a 75 *percent reduction* in NOx emissions (for example, oxy-firing or SCR)

EMISSION REDUCTIONS

We estimated the emission reductions expected from adoption of control measures to limit NOx emission from glass manufacturing in the following manner:

1. Obtained 2002 actual NOx emissions from the MRPO's 2002 inventory (and updated the emissions for Illinois based on updated data supplied by the state). Information regarding glass manufacturing facilities in the MRPO region operating in 2002 was previously shown in Table 2.
2. There are two furnaces in Wisconsin where controls have been applied after 2002 that will provide emission reductions in the future. Reductions from these on-the-books controls were calculated using control information provided by the state of Wisconsin.
3. We assumed the adoption of NOx limits requiring highly cost-effective controls for all glass manufacturing would achieve on average across the MRPO region a 30 percent reduction in NOx emissions and requiring cost-effective controls would average a 75 percent reduction. Based on information provided by the states, most of the plants were essentially uncontrolled in 2002. We assumed the requirements would be adopted and the reductions achieved by 2009.

Table 3 summarizes the actual annual emissions for 2002 and the project emissions for 2009.

TABLE 3
COMPARISON OF ACTUAL, ON-THE-BOOKS, AND CANDIDATE CONTROL MEASURES

		On-the Books Controls (WI Rule 428.05)		*GLASS 1* "Highly Cost Effective" Controls @30% Reduction from Uncontrolled		*GLASS 2* "Cost Effective" Controls @75% Reduction from Uncontrolled	
State	**2002 Actual**	**Reduction from 2002**	**2009 Remaining**	**Reduction from 2002**	**2009 Remaining**	**Reduction from 2002**	**2009 Remaining**
IL	4,146	0	4,146	1,244	2,902	3,110	1,037
IN	2,013	0	2,013	604	1,409	1,510	503
MI	726	0	726	218	508	545	182
OH	5,046	0	5,046	1,514	3,532	3,785	1,262
WI	3,423	338	3,085	689	2,396	2,314	771
MRPO	**15,354**	**338**	**15,016**	**4,269**	**10,748**	**11,262**	**3,754**

Note: the 2009 emission estimates presented here are not growth-adjusted.

COST EFECTIVENESS AND BASIS

Attachments 1 summarize the cost-effectiveness for various control options available to glass manufacturing facilities. We used the data from the references listed to estimate the range of costs for the candidate control measures. The actual control costs and the specific control options that available for an individual glass manufacturing plant will vary depending on a number of source-specific factors. The available cost data indicates several potential control options with costs in the "highly cost effective" range of $500 to $2,000/ton with the potential to provide a 30 percent reduction from uncontrolled. There are also several potential control options that can reduce NOx by about 75 percent at a cost-effectiveness level of less than $4,000/ton

TIMING OF IMPLEMENTATION

Generally, sources are given a 2-4 year phase-in period to comply with new rules. Under the NOx SIP Call for Phase I sources, EPA provided a compliance date of about 3½ years from the SIP submittal date. Most MACT standards allow a 3-year compliance period. Under Phase II of the NOx SIP Call, EPA provided a 2-year period after the SIP submittal date for compliance. States generally provided a 2-year period for compliance with RACT rules. For the purposes of this White Paper, we have assumed that SIP rules would be adopted in early 2007 and that a 2-year period after SIP submittal is adequate for the installation of controls. Thus, emission reductions available from the control of glass manufacturing plants would occur in 2009.
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RULE DEVELOPMENT ISSUES

Developing emission control regulation for glass manufacturing plants will likely require a source-by-source assessment, since the feasibility of controls at a particular site are highly dependent on site-specific conditions (furnace design, feed materials, products, fuels used, existing equipment configurations, etc.). MRPO States could require sources to develop source specific RACT analyses implemented through the permitting process, similar to the BART control scenario, which requires source-by-source control determinations implemented through the permitting process.

GEOGRAPHIC APPLICABILITY

The suggested control measures would apply to all glass manufacturing plants throughout the MRPO region, not just in nonattainment areas.

SEASONAL APPLICABILITY

In addition to emission reductions during the ozone season to attain the ozone NAAQS, reductions are needed throughout the year to address the PM2.5 NAAQS and regional haze. Thus, the candidate control measures are intended to be applied on an annual basis. An alternative scenario could be developed to create separate ozone season and non-ozone season emission control requirements if more stringent control is needed during the ozone season.

AFFECTED SCCs

The primary SCCs affected by this candidate control measure are:

3-05-012-01	Fiberglass Manufacturing, Regenerative Furnace (Wool-type Fiber)
3-05-012-02	Fiberglass Manufacturing, Recuperative Furnace (Wool-type Fiber)
3-05-012-07	Fiberglass Manufacturing, Unit Melter Furnace (Wool-type Fiber)
3-05-012-11	Fiberglass Manufacturing, Regenerative Furnace (Textile-type Fiber)
3-05-012-12	Fiberglass Manufacturing, Recuperative Furnace (Textile-type Fiber)
3-05-012-13	Fiberglass Manufacturing, Unit Melter Furnace (Textile-type Fiber)
3-05-014-01	Glass Manufacture, Furnace/General
3-05-014-02	Glass Manufacture, Container Glass: Melting Furnace
3-05-014-03	Glass Manufacture, Flat Glass: Melting Furnace
3-05-014-04	Glass Manufacture, Pressed and Blown Glass: Melting Furnace

REFERENCES

1. STAPPA/ALAPCO. *Controlling Nitrogen Oxides under the Clean Air Act: A Menu of Options. Glass Furnaces.* July 1994.
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3. Air & Waste Management Association. *Air Pollution Engineering Manual - Chapter 15 Mineral Products Industries, Glass Manufacturing*. 1992.
4. New Jersey Department of Environmental Protection, *State of Art Manual for the Glass Industry*, July 1997.
5. California Air Resources Board, *Sources and Control of Oxides of Nitrogen Emissions*, August 1997.
6. Reaction Engineering International, and Energy & Environmental Strategies. *Stationary Source NOX and PM Emissions In the WRAP Region: An Initial Assessment of Emissions, Controls, and Air Quality Impacts*. Prepared for the Western Governor's Association. October 1, 2003.

7. European Commission, Integrated Pollution Prevention and Control (IPPC) Bureau. *Reference Document on Best Available Techniques in the Glass Manufacturing Industry*. December 2001.
8. U.S. DOE, *Technology Success Story: Glass, Oxygen-Enriched Air Staging*, Office of Industrial Technologies, www.oit.doe.gov/glass, April 2002.
9. U.S.EPA, *Clear Skies Details: Mechanisms and Impact*, Clear Skies Act of 2002 Workshop Presentation, June 19, 2002.
10. U.S. EPA, *Technical Support Document: Identification and Discussion of Sources of Regional Point Sources NOx and SO2 Emissions other than EGUs*, January 2004.
11. Glass Manufacturing Industry Council, *Glass Melting Technology: A Technical and Economic Assessment*, Prepared for the U.S. DOE Industrial Technologies Program, October 2004.

Attachment 1 – NOx Control Technologies for Glass Manufacturing Plants

Technology	Description	Applicability	Performance	Cost[1] ($/ton)
Low NOx Burners	Use of burner's designed to reduce peak flame temperature with slower mixing of fuel and air, minimum injection velocities, and higher emissivity flames	Not all furnace designs can accommodate longer flame length created by low-NOx burners	30 to 40% reduction in NOx 5.5 lbs NOx/ton for end-port furnaces 9 lbs NOx/ton for side-port furnaces	790 – 1,920 (EPA, 1994) 323 – 1,045 (IPCC, 2001)
Oxy-Firing	Replacing the combustion air with pure (>90%) oxygen thus reducing the nitrogen levels (thermal NOx) during combustion. Reduced air volumes result in higher energy efficiency.	Oil and gas fired furnaces. Currently used in greater than 25% of glass furnaces	75 to 85% reduction in NOx 1.25 to 4.1 lbs NOx/ton	2,150 - 4,400 (EPA, 1994) 1,254 – 2,542 (IPCC, 2001) 2,352 (DOE, 2002)
Oxygen-Enriched Air Staging (OEAS)	Staged combustion process where in first stage, reduces amount of primary combustion air entering firing port to reduce NOx formation followed by an oxygen-enriched second stage to complete combustion with no additional NOx formed	Successfully retrofit on endport and sideport regenerative furnaces	30 to 75% reduction in NOx	585 (DOE, 2002)
Batch Preheat	Raw materials and cullet preheated before adding to furnace. Heat from waste heat in furnace exhaust via direct heat transfer (contact with flue gas) or indirect heat transfer (plate heat exchanger). Alternatively, low-NOx conventional burner used for preheat. Preheat reduces heat-load for furnace thereby reducing NOx emissions.	When 50% or more cullet is used in feed for fossil fuel-fired furnaces	10 to 20% energy savings from reduced fuel usage and lower furnace temperatures resulting in corresponding reductions in NOx	890 -1,040 (EPA, 1994) 5,000 (DOE, 2002)
Electric Boost	Electric current passed through the glass mixture in furnace to provide heat, thus reducing fuel requirement and associated NOx generation.	Currently used in most container glass plants and in more than one half of all regenerative tank glass furnaces. Not viable for some colored glasses. Used to extend life of furnaces or increase capacity.	10 to 30% reduction in NOx 2.4 to 3.6 lbs NOx/ton	2,600 – 9,900 (EPA, 1994) 7,100 (DOE, 2002)
Fuel Switching – Gas to Oil	Oil combustion, while increasing fuel nitrogen, provides a flame higher in luminosity resulting in more efficient heat transfer than when gas is burned	Many furnaces can burn both fuels	30 to 50% reduction in NOx	

Fuel Reburn	Injection of fuel post combustion zone to creating reducing atmosphere for converting NO to N2; Includes" Reaction and Reduction in Regenerators" (3R) process which is based on injecting gas or oil into flue gas at regenerator entrance	Regenerative furnaces; successfully tested in wide range of glass plants	50 to 65% reduction in NOx	571 – 1,349 (for 3R, IPCC, 2001)
Selective Non Catalytic Reduction (SNCR)	Ammonia injection in furnace exhaust to creating reducing atmosphere for converting NOx to N2		20 to 60% reduction in NOx	830 – 2,000 (EPA, 1994) 840 – 1,617 (IPCC, 2001) 1,382 (DOE, 2002)
Selective Catalytic Reduction (SCR)	Same as SNCR but with use of catalyst at lower temperature		75 to 90% reduction in NOx	810 – 2,950 (EPA, 1994) 727 – 1,941 (IPCC, 2001) 3,000 (DOE, 2002)

[1]Cost data from EPA, *Alternative Control Techniques Document* (EPA, 1994); DOE, *Technology Success Story: Glass, Oxygen-Enriched Air Staging* (DOE, 2002); and IPCC, *Best Available Techniques in the Glass Manufacturing Industry* (IPCC 2001).
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U.S. EPA *Alternative Control Techniques Document – NOx Emissions from Glass Manufacturing*, EPA-453/R-94-037, June 1994.

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