Air Quality Permit Issuance and Varying Interpretations of BACT in the Flat Glass Industry

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ABSTRACT

During the past several years, six flat glass manufacturing facilities have received air quality construction permits under the Prevention of Significant Deterioration air quality regulations in the states of Wisconsin, Iowa, New York, Kentucky and North Carolina. While production methods and emissions were similar, interpretation of the Best Available Control Technology (BACT) requirement varied significantly depending on the state and the supervising office of the USEPA. Beginning in 1991 with facilities in Wisconsin, BACT had required the installation of a spray drier - electrostatic precipitator emission control system for the control of PM_{10} and SO_2 emissions, with no provision to control NO_x emissions. Subsequent BACT determinations by other states no longer required the spray drier - electrostatic precipitator system, based on the premise that this equipment was not cost effective. These same determinations did require use of the *"3R Process"*, an innovative control method, to reduce NO_x emissions by approximately 50%. Litigation over the most recent BACT determination continues due to a petition filed under 40 CFR Part 70.8 of the Title V operation permit regulations. Evaluation of this petition by USEPA suggests the agency does not agree with the cost effectiveness criteria used in recent state determinations to establish BACT for flat glass plants. Consideration of the BACT determination history for flat glass plants will assist with future plant design and air pollution control determinations.

INTRODUCTION

During the past several years, six flat glass manufacturing facilities have received air quality construction permits under the Prevention of Significant Deterioration (PSD) air quality regulations in the states of Wisconsin, Iowa, New York, Kentucky and North Carolina. While production methods and emissions from the glass melting furnace were similar for each of these plants, interpretation of the Best Available Control Technology (BACT) requirement of the PSD regulations varied significantly depending on the state and the supervising office of the USEPA.

The federal PSD regulations were originally promulgated in 1977 under 40 CFR Part 52.21. Most states have adopted these rules into their own code and assumed responsibility from USEPA for their implementation. For a new facility to receive an air quality construction permit under the PSD rules, each air pollutant must be controlled using BACT. As defined under the federal PSD regulations, BACT is an "emission limitation based on the maximum degree of reduction determined on a case-by-case basis taking into account energy, environmental, and economic impacts and other costs."

BACT determination procedures are currently outlined in USEPA's 1990 draft document, *New Source Review Workshop Manual,* and then interpreted on a case-by-case basis by USEPA and each state.[1] As noted in the *Manual*, a 1987 top-down policy interpretation enforced by USEPA specifies that BACT must be the most stringent control technology. If the applicant demonstrates there are sufficient technical considerations, or energy, environmental, or economic impacts, the most stringent technology may not be achievable, and the next most effective alternative is evaluated.

Recent BACT determinations are documented by USEPA on its RACT/BACT/LAER Clearinghouse Internet site (www.epa.gov/ttn).[2] Contact with the regulatory agencies of individual states is often necessary to identify BACT determinations not included in the Clearinghouse and to determine site specific information.

A review of recent BACT determinations for the flat glass industry shows several developments to be considered for future projects:

- The interpretation of BACT has varied depending on the USEPA region and state.
- New NO_x control technologies for glass furnaces will substantially reduce future emissions.

FLAT GLASS MANUFACTURING PROCESS

Air pollution emissions from the flat glass manufacturing are generated by the following operations:

Glass Furnace - A furnace is typically sized in the 500 to 700 ton per day of glass range. It melts the raw materials which include silica sand, soda ash (Na_2CO_3), high calcium limestone ($CaCO_3$), dolomitic limestone ($CaCO_3 \cdot MgCO_3$), salt cake (Na_2SO_4), cullet (broken glass), rouge, and carbon. Natural gas is the fuel in recently constructed plants. The furnace generates the majority of the plant emissions. Control methods include no add-on control equipment, use of electrostatic precipitators, and use of electrostatic precipitators in combination with reagent spray driers. Air pollutants discharged by the furnace include particulate matter (PM_{10}), sulfur dioxide (SO_2), nitrogen oxides

(NO_x), carbon monoxide (CO), sulfuric acid (H_2SO_4), and trace amounts of inorganic contaminants such as trace metals and fluorine.

Raw Materials Handling - The delivery, handling and mixing of raw materials such as sand, limestone and broken glass generates dust or PM_{10} which is typically controlled using baghouses.

Annealing Lehr - After the molten glass flows from the furnace to form a flat sheet, it is cooled in a lehr. SO_2 is injected to react with the glass surface and lubricate the glass transport rollers. This prevents staining and scratching of the glass surface. A portion of the gas is emitted. To date, the use of packed bed scrubbing to control the SO_2 emissions has been used for two flat glass plants. Others plants either release the gas as fugitive emissions into the plant or duct these into the furnace.

Emergency Generators - Backup electrical generation capacity is provided by diesel fuel-fired generators. These have been approved with limitations on operating hours to limit annual emissions and avoid consideration of emission controls. In some instances, the use of extremely low sulfur diesel fuel oil (i.e. 0.05% sulfur) has been required.

RECENTLY APPROVED PERMITS FOR FLAT GLASS PLANTS

Table 1 summarizes recently constructed flat glass manufacturing plants which have required air quality permits under the PSD air quality regulations. This table identifies flat glass plants which have received BACT determinations which have been documented at the USEPA New Source Review RACT/BACT/LAER Clearinghouse Database at the Clean Air Technology Center Web Site, and more recent projects. All of these flat glass plants are currently in operation.

Table 1. Summary of Recently Constructed Flat Glass Manufacturing Facilities

Flat Glass Plant	Approved Capacity (tons per day)	Permit Issuance Date	PSD Air Pollutants
Cardinal FG Mooresville, NC	600	1998	PM_{10} SO_2 NO_x
AFG Industries Richmond, KY	600	1997	PM_{10} SO_2 NO_x
Guardian Industries Geneva, NY	700	1997	PM_{10} SO_2 NO_x
Guardian Industries DeWitt, IA	700	1995	PM_{10} SO_2 NO_x
Cardinal FG Portage, WI	550	1994	PM_{10} SO_2 NO_x CO
Cardinal FG Menomonie, WI	550	1991	PM_{10} SO_2 NO_x CO

References: 2,3,4,5,6,7,8,9,10,11,12

GLASS FURNACE BACT DETERMINATIONS FOR PM_{10} AND SO_2

BACT Determinations for PM_{10}

Table 2 summarizes glass furnace BACT determinations for PM_{10}. The most recent determinations were made for new flat glass plants in Iowa, New York, Kentucky and North Carolina during the period from 1995 to 1998. For these plants, BACT for PM_{10} emissions was determined to be equivalent to the New Source Performance Standard for glass manufacturing plants under 40 CFR Part 60 Subpart CC. The NSPS, originally adopted in 1980, includes a particulate matter limitation of 0.5 grams per kilogram (1 lbs per ton) of glass produced. Compliance is based on measurement of front-half particulate collected on the heated filter of the USEPA Method 5 test sampling train. This NSPS is applicable to furnaces referred to as "modified-process" under the NSPS , or those designed to minimize emissions without the use of add-on pollution controls.

Table 2. Recent Flat Glass Manufacturing BACT Determinations for PM_{10} and SO_2

Flat Glass Facility	Pollutant: PM_{10}		Pollutant: SO_2	
	Control Method	Emission Limit	Control Method	Emission Limit
Cardinal FG Mooresville, NC	Furnace Design	1 lbs/ton (FH) 1.5 lbs/ton (Total)	Low salt cake use: 10 lbs/1000 lbs sand	2 lbs/ton
AFG Industries Richmond, KY	Furnace Design	25 lbs/hr (FH) 1 lbs/ton (FH)	Low salt cake use: 10 lbs/1000 lbs sand	50 lbs/hr 2 lbs/ton
Guardian Industries Geneva, NY	Furnace Design	29.2 lbs/hr (FH) 1 lbs/ton (FH)	Low salt cake use: 10 lbs/1000 lbs sand	60 lbs/hr 2.07 lbs/ton
Guardian Industries DeWitt, IA	Furnace Design	1 lbs/ton (FH) 150 lbs/hr (Total) [6 lbs/ton (Total)]	Low salt cake use: 10 lbs/1000 lbs sand	2 lbs/ton
Cardinal FG Portage, WI	Electrostatic Precipitator Furnace Design	5.5 lbs/hr (FH) [0.24 lbs/ton (FH)] 25.5 lbs/hr (Total) [1.1 lbs/ton (Total)]	Spray Drier Low salt cake use: 13 lbs/1000 lbs sand	15 lbs/hr [0.65 lbs/ton]
Cardinal FG Menomonie, WI	Electrostatic Precipitator Furnace Design	5.5 lbs/hr (FH) [0.24 lbs/ton (FH)] 25.5 lbs/hr (Total) [1.1 lbs/ton (Total)]	Spray Drier Low salt cake use: 13 lbs/1000 lbs sand	15 lbs/hr [0.65 lbs/ton]

References: 2,3,4,5,6,7,8,9,10,11,12

FH = Front-half particulate matter emissions.
Total = Front-half and back-half particulate matter emissions.

Electrostatic precipitators (EP) are currently being used to control furnace PM_{10} emissions in Wisconsin and California. The use of EP control equipment was evaluated as a BACT emission control option for the four most recently approved flat glass plants. However, it was concluded by the state regulatory agencies in Iowa, New York, Kentucky and North Carolina that the cost effectiveness in units of $ per ton of pollutant removed was beyond the level considered reasonable and was therefore not indicative of BACT.

Other control methods considered for PM_{10} included the use of fabric filter baghouses or wet scrubbing systems. Baghouses have been rejected as technically infeasible due to the lack of use at existing flat glass plants, and potential glass quality problems due to varying pressure drops during baghouse operation and cleaning.[4] Wet scrubbing was rejected due to its lower performance compared to the EP option.

Back-half, condensible particulate emissions from a glass furnace have been measured to be 50 to 100% of the front-half particulate, potentially doubling the total particulate emissions. Back-half particulate emissions are not regulated under the NSPS. Attention to potential back-half particulate emissions varies under state regulatory programs. If quantified, the back-half emissions are included in the determination of compliance with requirements for total particulate emissions. The back-half emissions may be considered in the evaluation of air quality impacts and compliance with the National Ambient Air Quality Standard for PM_{10}. Air quality permits issued to plants located in states which regulate back-half particulate matter emissions will often include separate limitations for back-half or total particulate emissions, in addition to the front-half particulate limitation.

BACT Determinations for SO_2

Table 2 summarizes glass furnace BACT determinations for SO_2. Recent BACT determinations for SO_2 have required reduced use of salt cake (i.e. sodium sulfate) as a raw material to the furnace in order to minimize the amount of sulfur added to the furnace. Salt cake acts as a flux to improve the refining of the liquified raw materials, and thus cannot be eliminated from the process. Based on a salt cake usage of 10 lbs per 1000 lbs of sand, the SO_2 limitation for the four most recently approved plants was established at 2 lbs per ton of glass produced.

Spray driers are currently being used to control furnace SO_2 emissions in Wisconsin and California. This control method injects an alkaline reagent such as soda ash (Na_2CO_3) into the flue gas to neutralize the SO_2. The reaction products are captured in the EP which follows the spray drier. The use of a spray drier will typically increase the amount of dust or PM collected by the EP by a factor of 10. While this would be expected to increase the amount of dust requiring disposal, it results in dust composed of unreacted soda ash and sodium sulfate or salt cake. The dust collected in the EP is used as a raw material for the furnace at the two Wisconsin flat glass plants. The use of the spray drier was evaluated as an emission control option for the four newest flat glass plants. It was concluded by each state regulatory agency that the cost effectiveness in units of $ per ton of pollutant removed was beyond the level considered reasonable and not indicative of BACT.

Cost Effectiveness Estimates for PM_{10} and SO_2

Table 3 presents the spray drier-EP cost effectiveness estimates used for recent flat glass plant BACT determinations. [9,13,14] The combined cost effectiveness (i.e. $ per ton of PM_{10} and SO_2 removed) is presented for comparison. The values considered economically infeasible by state regulatory agencies ranged from $3,626 in Iowa to $4,529 in North Carolina. All costs have been adjusted to equivalent 2000 dollars using Vatavuk Air Pollution Control Cost Indexes.[15]

Table 3. Comparison of Spray Drier - EP Cost Estimates for PM_{10} and SO_2

Flat Glass Facility	Permit Issuance Date	Cost Effectiveness [a] ($ per ton of PM_{10} and SO_2 removed)		Spray Drier-EP Required?
		Unadjusted	Adjusted to 2000$	
Cardinal FG Mooresville, NC	1998	$4,810	$4,529	No
AFG Industries Richmond, KY	1997	$4,682	$4,363	No
Guardian Industries Geneva, NY	1997	$4,217	$3,930	No
Guardian Industries DeWitt, IA	1995	$3,877	$3,626	No
Cardinal FG Portage, WI	1994	$3,849	$3,903	Yes
Cardinal FG Menomonie, WI	1991	$5,066	$5,407	Yes

[a] Unadjusted cost effectiveness estimates are taken from project technical support documents. Adjusted estimates are corrected to 2000 dollars ($) using the Vatavuk Air Pollution Control Indexes.

In some instances, state agencies considered only the cost effectiveness of removal of PM_{10} alone. In other instances, agencies considered a combined cost effectiveness of removal of PM_{10} and SO_2 together. The combined cost effectiveness is presented in Table 3. This reflects the cost of a spray drier-EP control system which controls both PM_{10} and SO_2. The spray drier cannot be used unless followed by a PM_{10} control device such as an EP or baghouse to collect the reaction products and unused neutralizing reagent.

The cost effectiveness estimates reflect uncontrolled PM_{10} and SO_2 emissions based on the use of pollution prevention methods such improved furnace design and operation, and low sulfur input from raw materials. As uncontrolled emissions exiting the furnace are reduced, the estimated cost effectiveness will increase, and the need for additional add-on control equipment is reduced.

Prior to the four plants approved in Iowa, New York, Kentucky and North Carolina, two plants were approved in Wisconsin in 1991 and 1994 which required the use of the spray drier-EP control system for PM_{10} and SO_2.[10,12] The Wisconsin Department of Natural Resources had initially approved the Menomonie, Wisconsin plant in 1991 without the use of add-on control equipment on the basis that the cost effectiveness of this equipment was not representative of BACT.[16] This air quality permit was challenged by USEPA Region 5 and an appeal was filed with the Administrator for USEPA under 40 CFR 124.19. USEPA Region 5 argued that the spray-drier-EP system was already demonstrated on an existing flat glass plant in Victorville, California and cost effectiveness could not be used to eliminate this system as BACT.[17] Rather than delay construction of the plant during litigation over the permit and the use of cost effectiveness for BACT determinations, Cardinal FG chose to install the spray drier-EP system. For their next project in Portage, Wisconsin in 1994, the spray drier-EP system was installed as BACT to assure permit issuance would not be delayed by a challenge by USEPA Region 5 due to conflict over the BACT determination.

A subsequent flat glass project in Iowa was not required to install the spray drier-EP system as BACT.[7] The Iowa plant was larger than either of the Wisconsin plants and had similar emissions. As shown in Table 3, the cost effectiveness for this plant was lower than that estimated for the two Wisconsin plants, yet the cost effectiveness was used by the Iowa Department of Natural Resources (IDNR) to eliminate the consideration of add-on control equipment as BACT. Comments were submitted to IDNR and USEPA on the draft air quality permit requesting a consistent interpretation of the BACT requirement similar to that used for the two Wisconsin plants.[18] However, IDNR did not require add-on emission control equipment for PM_{10} and SO_2[19] This decision was not challenged by the regional USEPA office (i.e. Region 7) or the Administrator of USEPA.

Subsequent glass plant projects in New York, Kentucky and North Carolina in 1997 and 1998 were approved using cost effectiveness as a basis for rejecting the spray drier-EP control system as BACT for PM_{10} and SO_2 emissions.[3,5,6]

Though not shown in Table 3, another flat glass plant project in Virginia in 1998 received a draft air quality permit from the Department of Environmental Quality which did not require the use of add-on emission controls as BACT.[20] These controls were also rejected on the basis of cost effectiveness. This project was abandoned before a final permit was issued.

Recent Glass Furnace PM_{10} and SO_2 Emission Measurements

Table 4 summarizes recent flat glass furnace emission compliance test results for PM_{10} and SO_2 at flat glass plants. These indicate that all recently approved glass plants have complied with the emission limitations established as BACT for these air pollutants.

Table 4. Recent Flat Glass Furnace Compliance Test Results for PM_{10} and SO_2

Flat Glass Facility	Test Date	PM_{10} (lbs per ton of glass)		SO_2 (lbs per ton of glass)	
		Limitation	Test Result	Limitation	Test Result
Cardinal FG Mooresville, NC	March 2000	1.0 (FH) 1.5 (Total)	0.2 (FH) 0.3 (Total)	2.0	1.8
AFG Industries Richmond, KY	Dec 1999	1.0 (FH)	0.6 (FH)	2.0	1.5
Guardian Industries Geneva, NY	June 1999	1.0 (FH) n/a (Total)	0.4 (FH) 1.2 (Total)	2.1	1.1
Guardian Industries DeWitt, IA	Feb 1999 June 1997	1.0 (FH) 150 (Total)	0.6 (FH)	2.0	1.8
Cardinal FG Portage, WI	April 1999	0.24 (FH) 1.11 (Total)	0.06 (FH) 0.56 (Total)	0.65	0.54
Cardinal FG Menomonie, WI	August 2000	0.24 (FH) 1.11 (Total)	0.06 (FH) 0.62 (Total)	0.65	0.56

References: 4,21,22,23,24

Considerations for Future PM_{10} and SO_2 BACT Determinations

The most recently approved flat glass plant was in North Carolina in 1998. This combination construction-operation permit, was challenged by a local environmental group under the Title V petition procedures of 40 CFR Part 70.8.[25] As of March 2001, this Title V petition has been under review by the USEPA Administrator and headquarters staff for at least two years. In order to resolve the petition, key issues were identified by USEPA. One of the issues receiving USEPA scruitiny is the use of cost effectiveness as a basis for rejecting the use of a spray drier-EP system for the control of PM_{10} and SO_2.[13] USEPA staff have indicated during petition negotiations that while each state has the ability to establish its own procedures for the determination of BACT, USEPA itself rejects the use of cost effectiveness to eliminate add-on control equipment from consideration as BACT.[26] This suggests that USEPA could at some point challenge a flat glass plant BACT determination as it did for the Wisconsin flat glass plant in 1991. However, this action would not be supported by recent BACT determinations for flat glass plants located in four different states and four different USEPA regions which have used cost effectiveness as a basis for rejecting the use of add-on emission control equipment for the glass furnace.

GLASS FURNACE BACT DETERMINATIONS FOR NO_X AND CO

BACT Determinations for NO_x

Historical BACT determinations for NO_x emissions are summarized in Table 5. NO_x emissions are generated in the glass furnace by the combustion process reaction between nitrogen and oxygen present in the combustion air. Control methods must address the combustion process or reduce emissions after they have been generated. Early BACT determinations for the two Wisconsin plants had concluded that no control methods for NO_x were currently technically feasible. Approved emissions were approximately 17.5 lbs per ton of glass.

Table 5. Recent Flat Glass Manufacturing BACT Determinations for NO_x and CO

Flat Glass Facility	Pollutant: NO_x		Pollutant: CO	
	Control Method	Emission Limit	Control Method	Emission Limit
Cardinal FG Mooresville, NC	3R Process	11 lbs/ton (1st yr) 9 lbs/ton (2nd yr) 7 lbs/ton (3rd yr)	Furnace Design	100 tons/yr [0.9 lbs/ton]
AFG Industries Richmond, KY	3R Process	11 lbs/ton (1st yr) 9 lbs/ton (2nd yr) 7 lbs/ton (3rd yr)	Furnace Design	None
Guardian Industries Geneva, NY	3R Process	190 lbs/hr [6.5 lbs/ton]	Furnace Design	21.9 lbs/hr [0.75 lbs/ton]
Guardian Industries DeWitt, IA	Furnace Design	325 lbs/hr [11.1 lbs/ton]	Furnace Design	None
Cardinal FG Portage, WI	Furnace Design	400 lbs/hr [17.5 lbs/ton]	Furnace Design	51.3 lbs/hr [2.2 lbs/ton]
Cardinal FG Menomonie, WI	Furnace Design	400 lbs/hr [17.5 lbs/ton]	Furnace Design	51.3 lbs/hr [2.2 lbs/ton]

References: 2,3,4,5,6,7,8,9,10,11,12

The most recently approved BACT determinations in New York, Kentucky and North Carolina have required the use of the *3R Process*. The "3R" stands for "reaction and reduction in the regenerators". It is a proprietary control method for glass plants licensed from Pilkington PLC. Like the reburn process on utility boilers, this emission control method introduces additional natural gas into the glass furnace exhaust gas to generate a reducing atmosphere.

The *3R Process* is a relatively new technology for flat glass plants. When it was first required as BACT in New York it had only limited use at the Pilkington's Libbey Owens Ford flat glass plant in Lathrop, California and pilot testing at Cardinal FG in Portage, Wisconsin. These facilities indicated that short-term emissions of 7 pounds NO_x per ton of glass were feasible. For the New York plant, the use of the *3R Process* was initially concluded to be technically infeasible and rejected as BACT for the final air quality permit. The permit was challenged through USEPA environmental appeals board. An out of court settlement required the use of the *3R Process* with an emission limitation of 190 lbs per hour, equivalent to an emission factor of 6.5 lbs per ton of glass at capacity.

Subsequent BACT determinations in Kentucky and North Carolina used the New York decision requiring the *3R Process* as an indication this method was now technically feasible. Since the New York plant was still under construction, these two determinations considered the *3R Process* to be innovative control technology and established phased emissions limitations beginning at 11 lbs per ton of glass and finishing at 7 lbs per ton of glass three years after plant start-up.

For the most recent Cardinal project, costs for operation of the *3R Process* were estimated to be $1,044 lbs per ton per NO_x removed (1998 $), which is typically considered economically feasible for BACT determinations.[4] The major costs for this alternative was the licensing fee from Pilkington and the increased natural gas usage.

For recent BACT determinations, other NO_x control alternatives evaluated included the following:

- selective catalytic reduction (SCR)
- oxygen-enriched air staging (OEAS)
- selective non-catalytic reduction ammonia injection (SNCR)

SCR injects ammonia or other reagents, then passes the flue gas through a catalyst at 300 to 400 °C to reduce NO_x to N_2. OEAS uses an oxygen-deficient combustion flame to inhibit initial NO_x formation. Oxygen is then added within the furnace to complete combustion of the fuel. SNCR requires the injection of ammonia into the flue gas at 900 to 1000 °C to reduce NO_x to N_2.

At the time recent glass plant projects were approved, SCR and OEAS were considered to be technically infeasible since they had not been demonstrated on flat glass plants.

SNCR has been used on existing flat glass plants. This option was rejected in favor of the 3R Process which was expected to achieve lower NO_x emissions and avoid potential environmental impacts associated with ammonia injection. The AFG Industries plant in Victorville, California has demonstrated SNCR efficiencies of 12 to 38% and emissions of 8.4 to 10.7 lbs/ton, as opposed to the 7.0 lbs per ton expected from the *3R Process*.[4] Additional environmental impacts were also associated with the SNCR system including the emission of unreacted ammonia . The Victorville system had also caused excessive plume opacity during periods when the ambient temperature dropped below 40 °F, limiting its use during these periods of high opacity.

BACT Determinations for CO

Historical BACT determinations for CO emissions are summarized in Table 5. Early BACT determinations for CO either approved the uncontrolled emissions or did not analyze this pollutant. The two Cardinal plants in Wisconsin were approved with CO limitations of 2.2 lbs per ton of glass. Their limitations were based on 1990 tests at the AFG Industries plant in Springhill, Kansas.

Neither the Guardian Industries plant in Iowa or AFG Industries plant in Kentucky received CO limitations. In the case of Kentucky, the permit application estimated emissions using an older USEPA emission factor of <0.1 lbs per ton, resulting in emissions too low to regulate or verify.

Recent limitations for the Guardian plant in New York and Cardinal FG plant in North Carolina were established below the 100 ton per year threshold at which a BACT determination and other PSD approval requirements would apply.

Recent NO_x and CO Emission Measurements

Table 6 summarizes recent emission compliance test results for NO_x and CO at flat glass plants. These indicate that all recently approved glass plants have complied with the emission limitations established as BACT for these air pollutants.

Table 6. Recent Flat Glass Plant Compliance Test Results for NO_x and CO (lbs per ton)

Flat Glass Facility	Test Date	NO_x (lbs per ton of glass)		CO (lbs per ton of glass)	
		Limitation	Test Result	Limitation	Test Result
Cardinal FG Mooresville, NC	March 2000	11.0	10.0	0.9	0.6
AFG Industries Richmond, KY	Dec 1998	11.0	8.6	n/a	n/a
Guardian Industries Geneva, NY	August 2000	6.5	6.3	0.75	0.2
Guardian Industries DeWitt, IA	June 1997	11.1	10.3	n/a	n/a
Cardinal FG Portage, WI	April 1999	17.5	13.3	2.2	0.2
Cardinal FG Menomonie, WI	August 2000	17.5	16.3	2.2	0.7

References: 4,21,22,23,24

Both the Cardinal FG plant in North Carolina and AFG Industries plants have been able to use the *3R Process* to comply with their current NO_x limitations of 11.0 lbs per ton of glass. The AFG compliance test results suggest that the next limitation of 9.0 lbs per ton will be achievable as well. The Guardian Industries plant in New York needed to achieve lower emissions immediately with the *3R Process*. Recent measurements suggest that the plant's 6.5 lbs per ton limitation is achievable. The Guardian Industries plant in Iowa uses low-NO_x burners, and Cardinal FG plants in Wisconsin do not require any emission control methods to assure compliance with their current NO_x limitations.

Considerations for Future NO_x and CO BACT Determinations

Both of the newer plants, Cardinal FG in North Carolina and Guardian Industries in New York, have achieved simultaneous compliance with their SO_2, NO_x and CO emission limitations. However, the *3R Process* creates reducing zones during fuel combustion to minimize NO_x emissions. These reducing zones also encourage incomplete combustion and the formation of CO, and decreased sulfur retention by the glass. Reduced sulfur retention may increase SO_2 emissions and unwanted formation of seeds or bubbles in the glass. Guardian Industries initially had difficultly simultaneously complying with the NO_x and CO limitations, but through careful furnace combustion control have resolved the conflict between the discharge of these two pollutants. Future NO_x reductions below 7 lbs per ton of glass will require attention to its effect on glass quality and emissions of CO and SO_2.

Success of recent flat glass furnaces retrofitted with oxy-firing systems may provide another NO_x control. At the Libbey-Owens-Ford flat glass plant in Rossford, Ohio, the 6F1 furnace rebuild incorporated the use of oxy-firing. Compliance tests on this furnace were conducted in November 1998. Measured NO_x emissions were 58.3 lbs per hour at 514 tons per day of throughput for an emission factor of 2.8 lbs per ton of glass.[27] This is well below the emissions achieved at newly constructed flat glass plants using the *3R Process*. The Ohio furnace continues to operate successfully with the oxy-firing system. However, another furnace was more recently rebuilt at the same glass plant, but used a conventional regenerative rather than the oxy-firing furnace, since the long-term technical and economic costs of oxy-firing are not fully understood.[28] Completed in 2000, the reconstruction of a furnace at the PPG flat glass plant in Fresno, California incorporated the use of oxy-firing to assure compliance with the state air quality permit limitations of 7.0 lbs per ton (30-day rolling average) and 9.0 lbs per ton (24-hour average).[29,30] Future success of both the Ohio and California oxy-firing systems will determine if oxy-firing will be a viable NO_x control method.

CONCLUSIONS

The air quality permit history and supporting documents for recent flat glass manufacturing plants were reviewed. This allows the following conclusions:

- BACT for PM_{10} requires furnace design and operation to limit emissions to the NSPS level of 1 lbs per ton of glass.

- BACT for SO_2 requires limitations on sulfur bearing raw materials to maintain emissions of 2 lbs per ton of glass.

- For the most recent flat glass plants, the use of add-on control equipment such as a spray drier-EP system has been shown to be economically infeasible due to high cost effectiveness. Unless there is intervention by USEPA or reduction in cost effectiveness threshold used by individual states, this will hold true for future glass plants.

- BACT for NO_x currently requires the use of the *3R Process* to attain emissions of 7 lbs per ton of glass. More experience with the control system may allow lower emissions to be achieved.

- Initial experience with oxy-firing shows promise of further NO_x reductions.

- BACT for CO while concurrently using this method has not yet been established, though emissions of 0.2 lbs per tons of glass have been achieved while simultaneously achieving low NO_x emissions.

REFERENCES

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KEY WORDS

flat glass, glass manufacturing, Prevention of Significant Deterioration, PSD, Best Available Control Technology, BACT, glass furnace