19177

GLASS MANUFACTURING
AP-42 Section 8.13
Reference Number
4

Good Section on Glass

A REVIEW OF AIR POLLUTION PROBLEMS AND CONTROL IN THE CERAMIC INDUSTRIES

by

Arch B. Tripler, Jr., and
G. Ray Smithson, Jr.,
Battelle Memorial Institute
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Presented at
72nd Annual Meeting
American Ceramic Society
Philadelphia, Pennsylvania

May 5, 1970

A REVIEW OF AIR POLLUTION PROBLEMS AND CONTROL IN THE CERAMIC INDUSTRIES

by

A. B. Tripler, Jr., and
G. R. Smithson, Jr.,
BATTELLE MEMORIAL INSTITUTE
Columbus Laboratories
Columbus, Ohio

Introduction

There is no segment of the ceramic industry that, in the absence of control measures, does not contribute to air pollution, either by dust, gaseous emission, or both. However, with the proper selection and use of control equipment, many plants operate well within the current air pollution limits set by government agencies. Although much remains to be done, for the immediate future there is no other choice but to follow directives and make use of available control apparatus. Where available equipment is inadequate, or special needs must be met, research and development will be necessary. Despite the additional costs, it will result in improved public relations, improved health of workers, and therefore greater efficiency and improved labor relations, reduced health and liability insurance costs, recovery and reuse of some materials that were formerly wasted, and a reversal of the present trend toward rapidly deteriorating air quality.

For the most part, the problems of air pollution in the ceramic industry stem from the large amounts of dust and fumes which form at various processing stages. Gaseous pollutants do form, but in some cases they react with process materials to become innocuous, e.g., SO_2 which reacts with alkaline materials in the cement kiln. The dust and fumes--or airborne particulate matter as they are more properly called--come in a variety of compositions and can vary from submicron sizes to pieces that can easily be seen by the unaided eye. The upper portion of Figure 1 illustrates the wide variations in particle sizes that exist for some typical dusts and fumes. There is no single piece of equipment that will collect over the complete size spectrum. The first logical step in deciding which type of collector to use is to collect and analyze the emissions at each processing step. This, in itself, is a job requiring knowledge, experience, and skill. We do not discuss methods for sampling and analysis of emissions in this paper but we do emphasize the necessity of having it done correctly.

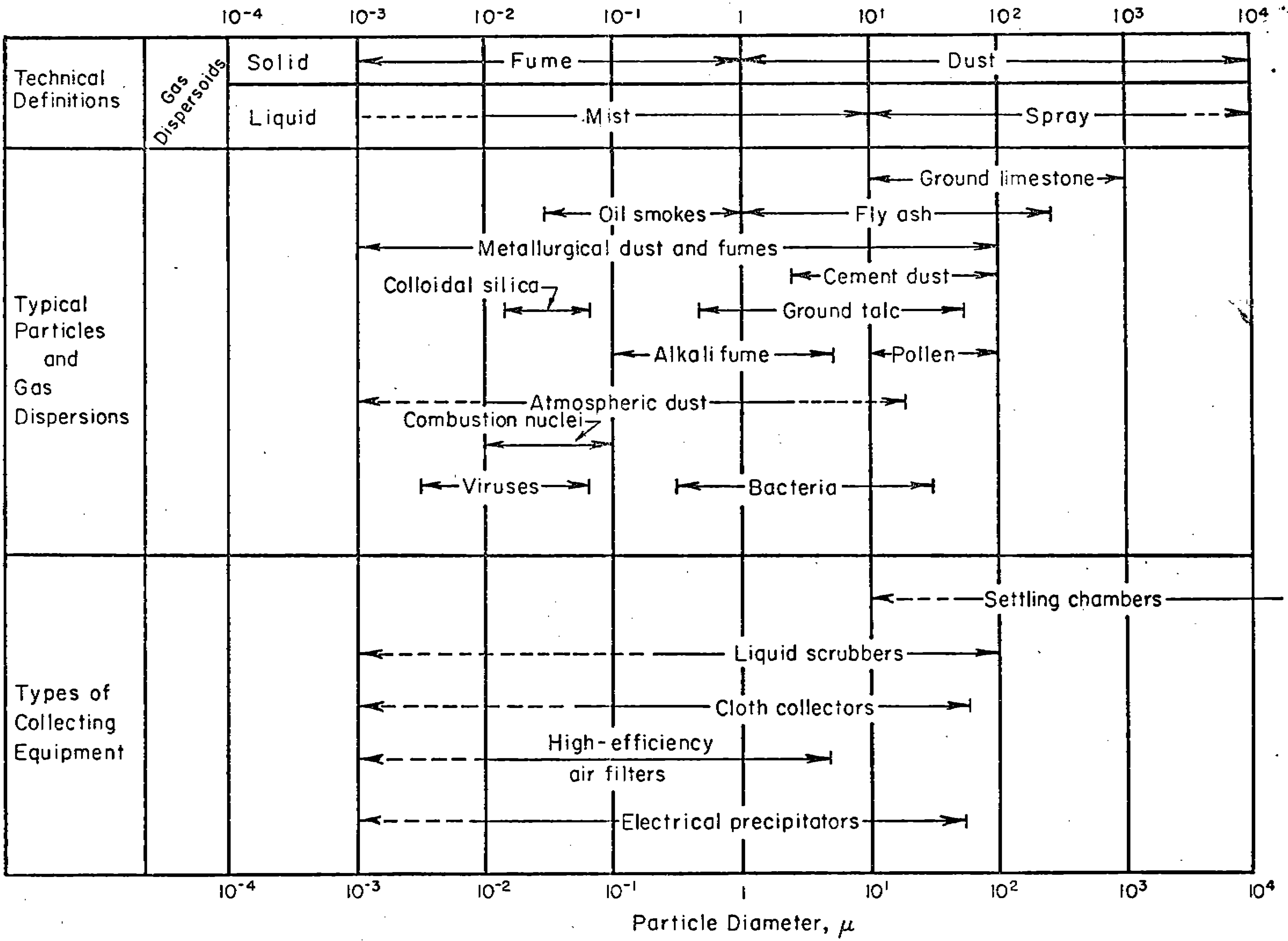

FIGURE 1. CHARACTERISTICS OF PARTICLES, PARTICLE DISPERSOIDS, AND COLLECTING EQUIPMENT[1]

The lower portion of Figure 1 shows the approximate span of particle sizes that can be collected by several types of equipment.

One of the simplest and least costly ways of collecting particulate matter is by use of mechanical collectors of which the cyclone is the most common form. Gas and entrained particles are carried into a constrained vortex. The mass and the rotation of the particles force them outwards toward the wall of the cylinder by centrifugal force. In striking the wall they lose velocity and are carried down by gravity or secondary eddies toward the outlet at the bottom. Efficiency falls off rapidly for particles less than 10 microns. The collector, however, improves in performance at concentrations of 3 grams per cubic foot or greater, due to particle-particle collision. Mechanical collectors can be used up to and somewhat above 2000 F. Multi-tube collectors for flows in the vicinity of 100,000 cfm cost from $.08 to $.10 per actual cubic feet per minute (acfm) of design capacity. This can run as high as $.25 per acfm for construction with heat-resistant materials. Installation adds 25 percent. Operating costs are about $.05 per year per acfm with maintenance amounting to perhaps $.04 per year per acfm.(1)*

The wet, inertial collection devices are called scrubbers and they collect droplets and particulates. Here the principle involves the impaction of particles on wetted surfaces or on droplets of scrubbing liquid. Scrubbers utilize high-gas-inlet velocity and therefore require relatively little space per acfm of capacity. Scrubbers are used to treat combustion gases and choice of a suitable scrubbing liquid makes possible the removal of gaseous pollutants as well as particulate matter.

The initial outlay for a 100,000 acfm wet scrubber ranges from $.25 to $.35 per acfm in mild steel, and to $.65 in stainless steel with about 25 percent added for installation costs. Operating costs are comparatively high running from $.25 to $.75 per acfm per year, depending on particle size distribution. Maintenance, on the other hand, is low, about $.01 to $.02 per acfm per year.(1)

Fabric filters are used widely to remove particulates from gaseous emissions. One highly developed type consists of tubular, fabric bags which are inflated by the gas to be cleaned as it passes from inside the bag to the outside. Velocity is low so that many bags are needed and for this reason the space requirements for bag houses are substantial. Bags have a high collection efficiency regardless of particle size. Heavy buildup of cake on bags causes the pressure

*Numbers in parentheses are reference numbers and the listings are found at the end of each section.

drop to rise and bags will rupture if this condition isn't remedied. Modern bag houses incorporate means for cleaning bags by a variety of methods: mechanical shaking, collapsing, pneumatic agitation, shock waves, pressure pulse, etc. Temperature must be maintained above the dew point to avoid fouling. Fabrics can withstand temperatures from 150 F to 600 F depending on material, a choice that also is dictated by the corrosive nature of the emissions.

Bag filter units cost \$.50 to \$1.20 per acfm of capacity initially. Installation adds 30 percent and operating costs are about \$.07 per acfm per year. Maintenance, largely bag replacement, runs 10 to 25 percent of original cost annually, depending on material.(1)

The electrostatic precipitator has the advantages of low power input, high gas volumes, and high efficiency down to sub-micron particle size. They sometimes are used in series with mechanical collectors or scrubbers. In this case the electrostatic collector is deliberately made undersized (and therefore costs less). It captures particles but cannot prevent re-entrainment of many of them. The particles agglomerate as they are collected and therefore when re-entrained can be collected by the mechanical collector or scrubber at relatively low pressure drop.

Initial cost is about \$.80 per acfm for the 100,000 acfm range. However, in the more usual sizes of 10^6 acfm and larger, costs drop to \$.40 per acfm. Add 70 percent for installation and about \$.03 per year per acfm for operation. Maintenance is about \$.02 to \$.03 per acfm per year.(1)

Other methods for cleaning gases include adsorption on surface active materials such as activated carbon and ion exchange resins. Combustible gases frequently are burned. Tall chimneys also are used to get above an inversion layer or to take advantage of greater wind velocity aloft. This method does not prevent pollution--it just spreads it over a greater area.

In the following sections the glass, cement, mineral wool, asbestos, and brick industries will be examined to see how some of these devices have been applied to control air pollution.

Reference

(1) Walker, Alan B. and Frisch, Norman W., "Scrubbing Air", Science and Technology, Nov.-Dec., 1969, p. 18.

The Glass Industry

Glass manufacturing is one of the oldest of the ceramic industries. In the manufacture of glass products, there are three chief sources giving rise to air contaminants: (1) batching of dry, finely divided raw materials prior to melting, (2) gas or oil fired melting furnaces, and (3) the glass forming or similar process. The nature of the pollutants depends on the source.

In (1) the pollutants are classed as dust. One report[1] gives the average particle size as 300μ with a small percentage of particles below 50μ. (We believe that perhaps the percentage of particles below 50μ is larger than reported.) It is the particles from 10μ down to sub-micron size that are the most difficult to contain.

Conveyor systems can be completely closed and all access parts sealed with gaskets of polyurethane foam. With the completely closed system, exhaust equipment is unnecessary and small filtered vents or dust boxes can be attached to the conveying equipment or storage bins. On the other hand, hoppers and mixers should have exhaust systems. Even railroad hopper cars and hopper-bottom trucks should be sealed to receiving hoppers by fabric sleeves. Where rotating parts are involved, such as the rotating body of a mixer, suitable seals such as those made from PVC should be installed.

Details for local exhaust systems (as for bin and hopper ventilation) are given in "Industrial Ventilation"[2], in Sections 5 and 8. For example, if the belt speed is less than 200 fpm, then the ventilation should be 350 cfm per foot of belt width but not less than 150 cfm per foot of opening. If belt travel exceeds 200 ft/min, then the ventilation should be 500 cfm per foot of belt width but not less than 200 cfm per foot of opening. Further details are given in the reference.

Because of the small size of the particles, baghouses and filters are the most effective ordinary means for collecting batching dusts. In a baghouse the dust is separated from the air by means of a fabric filter woven with relatively large open spaces of perhaps 100μ size. Small particles are initially captured by means of interception, impingement, diffusion, gravitational settling, and electrostatic attraction. When a mat or cake has formed on the filter, further collection is accomplished mainly by sieving, with the fabric serving as a support structure for the mat. Periodically, accumulated dust is removed by automatic shaking but sufficient residual dust remains on the fabric to aid in further filtering.

The material emitted during the operation of glass furnaces is quite different from the dusts due to batching. Both particulate matter and gases are emitted. In stack analyses of emissions from a flint glass furnace and an amber glass furnace, the particle sizes ranged from about 1 micron to 37 microns and 1 micron to 17 microns, respectively. Table 1 lists the particulate matter analysis as determined by microquantitative analysis and spectrographic analysis. Table 2 lists compositions of gaseous effluents from gas-fired regenerative furnaces. There are several approaches to the problem of reducing the amounts of these effluents which reach the atmosphere. The first of these is with the furnace itself and if the furnace is operated properly, dust carryover can be kept at a minimum. This not only aids in air pollution control but is useful in prolonging checker life. Application of the design for a mathematical model originated by Brandon[3] has shown that the amount of particulate emission is a function of the following[1]:

(1) Process weight, lb/hr-ft^2
(2) Cullet, wt percent of charge
(3) Checker volume ratio, ft^3 checker/ft^2 melter
(4) Type of furnace (side port or end port)
(5) Type of fuel (U.S. grade 5, PS 300 oil or natural gas)
(6) Melter area, ft^2.

Figures 2, 3, 4, and 5 show the variation of particulate matter with the independent variables given above. Figure 2 is first used to obtain particulate emissions and then using Figures 3, 4, and 5, corrections are applied to the value from Figure 2 for process weight, cullet content of batch, and melter area, respectively. Objections may be justifiably raised that this is neither a realistically precise nor accurate model. However, the point we are making is that optimum process control is a function of identifiable process variables which if properly controlled can result in reduction of emissions. We know from our own experience that a haphazard approach to process control does result in excessive particulate emission in certain parts of the metallurgical industry. If proper process control reduces particulate emission, then it follows that the cost of containing the remainder of the emission will be reduced.

TABLE 1.
CHEMICAL COMPOSITION OF PARTICULATE EMISSIONS (QUANTITATIVE ANALYSES), METALLIC IONS REPORTED AS OXIDES[a]

SAMPLE SOURCE	BAGHOUSE CATCH	BAGHOUSE CATCH	BAGHOUSE CATCH	BAGHOUSE CATCH	MILLIPORE FILTER
TEST TYPE OF GLASS COMPONENTS	NO. 1 AMBER, WT %	NO. 2 FLINT, WT %	NO. 3 AMBER, WT %	NO. 4 FLINT, WT %	NO. 5 FLINT, WT %
SILICA (SiO_2)	0.03	0.3	0.1	4.1	3.3
CALCIUM OXIDE (CaO)	1.70	2.3	0.8	19.2	
SULFURIC ANHYDRIDE (SO_3)	46.92	25.1	46.7	30.5	39.4
BORIC ANHYDRIDE (B_2O_3)	3.67	1.3			
ARSENIC OXIDE (As_2O_3)	7.71				
CHLORIDE (Cl)	0.01				
LEAD OXIDE (PbO)	0.39				
$K_2O + Na_2O$	29.47	28.1	26.1	36.5	39.2
Al_2O_3		3.5		0.2	
FLUORIDE		8.6			
Fe_2O_3			0.1	0.6	
MgO				1.4	
ZnO			0.5		
UNKNOWN METALLIC OXIDE (R_2O_3)					6.5
LOSS ON IGNITION	10.10	30.8	25.7	7.5	11.6

(a) FROM REFERENCE (1).

TABLE 2.
CHEMICAL COMPOSITION OF GASEOUS EMISSIONS FROM GAS-FIRED, REGENERATIVE FURNACES[a]

GASEOUS COMPONENTS	FLINT GLASS	AMBER GLASS	GEORGIA GREEN
NITROGEN, VOL %	71.9	81.8	72.5
OXYGEN, VOL %	9.3	10.2	8.0
WATER VAPOR, VOL %	12.4	7.7	12.1
CARBON DIOXIDE, VOL %	6.4	8.0	7.4
CARBON MONOXIDE, VOL %	0	0.007	0
SULFUR DIOXIDE (SO_2), PPM	0	61	14
SULFUR TRIOXIDE (SO_3), PPM	0	12	15
NITROGEN OXIDES (NO, NO_2), PPM	724	137	NA
ORGANIC ACIDS, PPM	NA[b]	50	NA
ALDEHYDES, PPM	NA	7	NA

(a) FROM REFERENCE (1).
(b) NA = NOT AVAILABLE.

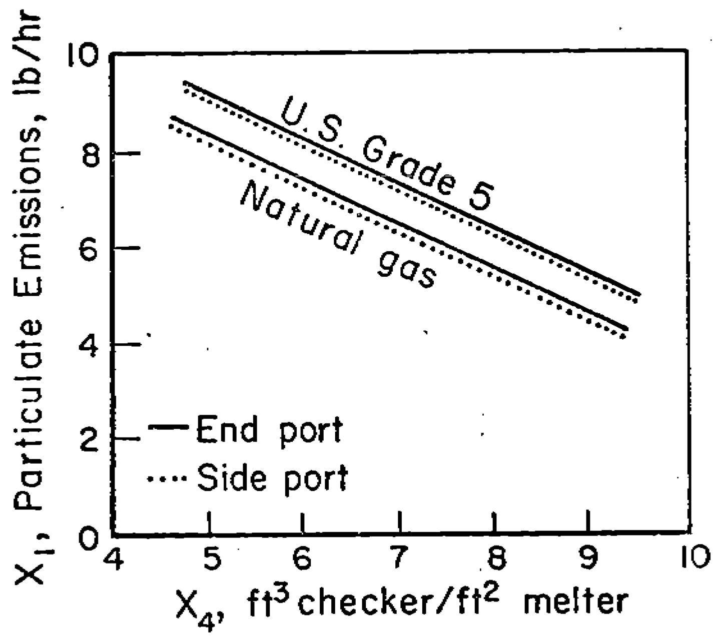

FIGURE 2. PARTICULATE EMISSIONS VERSUS CHECKER VOLUME PER FT^2 OF MELTER(1)

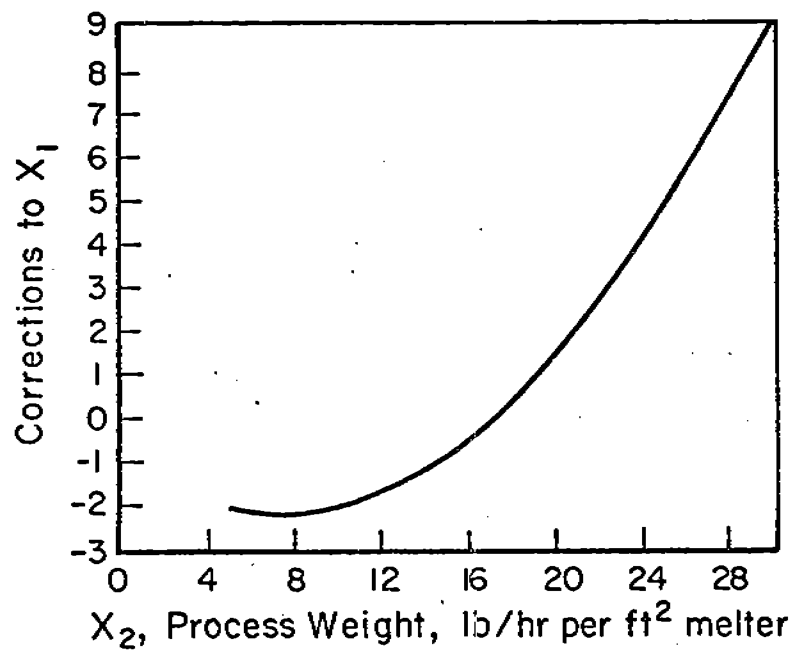

FIGURE 3. CORRECTION TO PARTICULATE EMISSIONS FOR PROCESS WEIGHT PER FT^2 MELTER[(1)]

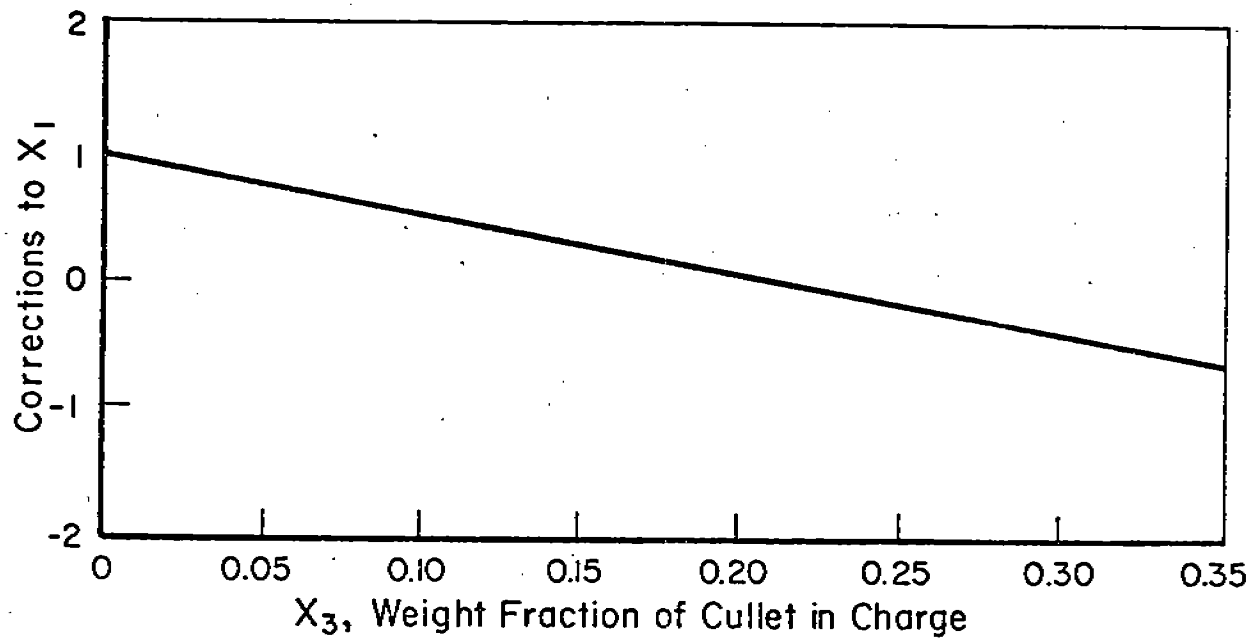

FIGURE 4. CORRECTION TO PARTICULATE EMISSIONS FOR CULLET CONTENT OF THE BATCH CHARGE[1]

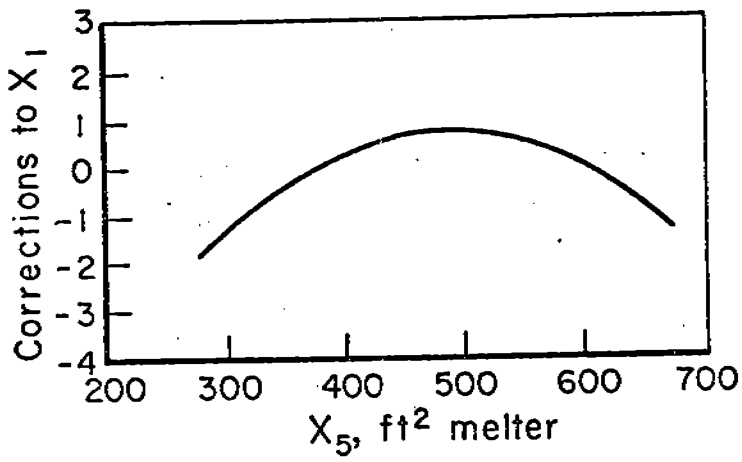

FIGURE 5. CORRECTION TO PARTICULATE EMISSIONS FOR MELTER AREA[1]

A new approach to batch preparation also may reduce particulate emissions. A number of ways have been suggested[4]; among them presintering, briquetting, pelletizing, and use of liquid alkali. While none of these may be easily applied, they at least indicate a line of thought that if coupled with sufficient ingenuity may achieve reduced emissions.

Furnace design, especially the checkers, may result in lower emissions. For example, progress has been made in designing furnaces that require less natural gas per ton of glass. Increase in checker volume has been largely responsible for this. Preheaters may result in further fuel reduction. Improved firing practice must also be considered. Application of electric melting is still another technique.

Changes in furnace design, modification of batching techniques, and use of optimum operating procedures may not reduce emissions to the level required by local regulations. In such a case additional measures must be adopted. The use of baghouses and centrifugal scrubbers has been recommended for regenerative furnaces.

The third most likely source in a glass plant for environmental contamination is the glass-forming machines. Heavy smoke results from vaporization of hydrocarbon lubricants on gob shears and gob delivery systems. In recent years, however, silicone emulsions and water-soluble oils have come into use with the virtual elimination of smoke. If smoke is not controlled by changes in process techniques, control can be established by an electrostatic precipitator or possibly by an after burner.

References

(1) Danielson, John A., editor, "Air Pollution Engineering Manual", U.S. Dept. Health, Education, and Welfare, Public Health Service, PHS Publication No. 999-AP-40 U.S. Government Printing Office, 1967.

(2) Anon., "Industrial Ventilation", American Conference of Governmental Industrial Hygienists, Committee on Industrial Ventilation, P.O. Box 453, Lansing, Michigan 48902, 10th Ed., 1968.

(3) Brandon, David B., "Developing Mathematical Models for Computer Control", ISA Journal, 6, 70, (1959) (July).

(4) Anon., "Can Presintering Solve Glass Batch Problem", Ceramic Industry, April, 1962, p. 82.