EQUIPMENT FOR CUPOLA-EMISSION CONTROL

By
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Foundry cupola emissions present a serious problem to the foundry industry. It is difficult to define emission quantities, composition, or particle size distribution except in the broadest of terms. Even with field test data, quantities can vary throughout the day and from day to day. It becomes apparent, however, that solids discharged from cupolas can be classified in three fractions—(1) cinders, (2) dust, (3) metallic fumes and smokes. Classifications are similar to those used in coal-burning boiler stacks so a comparison takes on considerable significance because the boiler stack has been the subject of long study. Air pollution control standards for boiler stacks have been established in many communities.

Cinders: Cinders from the cupola can be defined as extremely coarse particles generally larger than 200 mesh with a lower limit in the 325-mesh screen or 44 micron range. They are aspirated into the cupola gas stream generally in spurts, which occur as a charge is dropped and again later in the cycle as channeling of the blast air releases more material during low bed. As expected, the greater the height of charge fall, the greater the variation in charge height, the higher the quantities of cinders discharged.

Composition and quantity are a function of the charge and charging methods. While cinders are basically coke fines, quantities of scale, burnt sand, and disintegrated briquets will also be found to various degrees.

Consequently, cinder concentrations can be reduced by:

(a) frequent charging to reduce height of fall,
(b) screening of coke to remove fines, covered storage to prevent weathering, minimum handling from receipt to use,
(c) melting practice that uses lowest possible coke to iron ratio,
(d) smallest possible charging opening to reduce indraft volume and resultant stack draft velocities,
(e) close control of briquets if used to assure consistent compaction and bonding,
(f) after burning in cupola stack or hot blast heat exchanger,
(g) moderate and controlled air blast volume to tuyeres,
(h) proper scrap selection and sizing to prevent voids in bed, and
(i) even distribution of charge by use of most effective charging equipment.

Dust: A considerable fraction of any cupola stack emission will be finer solid particles in the 1 to 44 micron range. This fraction can be compared to the fly ash in the boiler stack analogy. Its composition, however, is not homogeneous, and varies from cupola to cupola. Abrading of coke produces coke dust, silica fines result from charging dirty sprues and risers, heat releases adhering fines on the crushed limestone, briquets disintegrate from attrition, scale and settled foreign material adheres to scrap during its transportation to and storage at the foundry.

Smokes and Fumes: Like the boiler stack, much of the visible appearance in the cupola stack discharge can be attributed to partial combustion of carbonaceous materials (oily scrap is a major source). With the reducing atmosphere in the melting zone, complete combustion is more difficult than in a boiler with its excess air to assure maximum burning efficiency.

Incineration in the cupola stack with CO igniters or in the hot-blast heat exchanger will appreciably reduce the brown smoke fraction of the visible emissions. Such incineration also reduces many coke cinders to ash, increasing the dust fraction to a certain extent.

Since this is a metallurgical process, metallic fumes will be formed and contribute to the visible fraction. Metallic fume concentrations vary with composition of scrap and will increase with briquet percentage of the charge, with increased molten metal temperatures, and during melt down.

Particle sizes of smokes and metallic fumes are sub micron in size with usual range in the 0.2 to 0.5 micron range.

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It appears unlikely that public education will successfully explain to neighbors that visible stacks are not necessarily the source of nuisance depositions. Until such recognition is achieved, the public will continue to trace any nuisance dust problem to the visible stacks in their immediate area.

Actually, the fume concentrations range from some 1 to 3 lb/hr/ton of melt for most cupolas.

Control Equipment

Proper selection of control equipment must evaluate the results needed in each of the above ranges, if performance of control equipment is to meet expected performance. Each fraction contributes to a different phase of the emission problem, as:

(a) Cinders are so large in particle size that settlement occurs within a very short distance from the cupola stack. With favorable cupola location, they do not contribute to either public nuisance problems in the neighborhood nor are they visible in the cupola stack gases. Where cupolas are located close to plant boundaries, nuisance quantities can be blown from roof or deflected from stack with high winds. Their elimination is helpful and often economically justified by reduced maintenance to foundry roofs, and immediate plant area gutters. With a 10 ton per hour melting rate, it will be usual for cinder quantities of 500 pounds per 8-hour day to settle in the stack area. Removal costs to one foundry with three cupolas in operation melting 60 tons per hour averages $25,000 per year.

(b) Dust settles at greater distance from the cupola stack with deposition occurring throughout the foundry plant area and in most cases in adjacent areas to the foundry property. This fraction usually accounting for 2 to 6 pounds per ton melt can be a nuisance to plant or neighborhood. Oxidizing metallic particles and some fluxes can attack auto finishes and other metallic surfaces with resultant property damage.

(c) Smokes and fumes are of such small particle size that prolonged suspension and natural dispersion removes them without difficulty except in areas of stable atmospheres. Because they contribute so greatly to the visibility of the stack effluent, control is desirable when cost can be reconciled and justified.

Control equipment can be quite readily fitted into the categories described.

A. Wet Cap

Original concept in such designs was one of a cinder catcher to reduce foundry roof maintenance. For such purpose, wet cap collectors on the cupola stack have been consistently successful and represent the major present day step toward cupola control by the foundry industry. Performance comparable to the boiler-low-pressure-drop cinder catcher could be expected. Collection appears excellent on plus 200-mesh particles, with good removal down to 325-mesh sizes. Removal of particles less than 44 microns appear doubtful.

Advantages

Typical design is shown in Fig. 1. Characteristics of this group of collectors include:

(1) *Simplicity:* It operates on stack draft and does not require induced draft fans, protective cooling, added horsepower for operation, cupola top lids with their actuating mechanism and control equipment to open lids in case of power or equipment failure.

(2) *Collection:* Collection is effective in the cinder range, removing that fraction which would otherwise require manual removal from roof and gutters. Collection of material as a slurry often fits refuse disposal into existing handling systems in the foundry. (Drain water can often be incorporated with slag quenching and sluicing system.)

(3) *Cost:* Equipment and installation costs are lowest of methods currently used for cupola emission control. This is true even though a collector is required for each cupola and any one unit is generally in service only on alternate days.

Disadvantages

(1) *Corrosion:* Water requirements per cupola are in the 100 to 300 gpm range, which makes recirculation of waste water including pumps and dewatering tanks usual. Sufficient acid is picked up from the cupola gases to require chemical treatment of the recirculated water. Corrosion will also be a factor reducing life of outer shell in zone of damp surfaces on cleaned gas areas. Entrained mist can be troublesome if collector is not properly designed for gas volume.

(2) *Protection:* Heat damage can occur with stoppage of water supply to the collector.

(3) *Collection:* Particulate removal is limited to coarse particles, generally above 44 microns. Discharge appearance is not improved and substantial quantities in the 1 to 44 micron sizes escape to atmosphere.

B. Dry Type Centrifugals

Efforts to provide more effective dust removal from the cupola stack gases have resulted in application of dry type centrifugals to cupola gas cleaning—equipment that has been effective for coal burning boiler fly

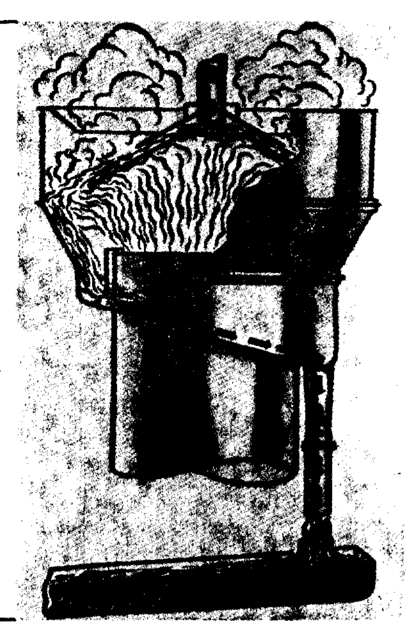
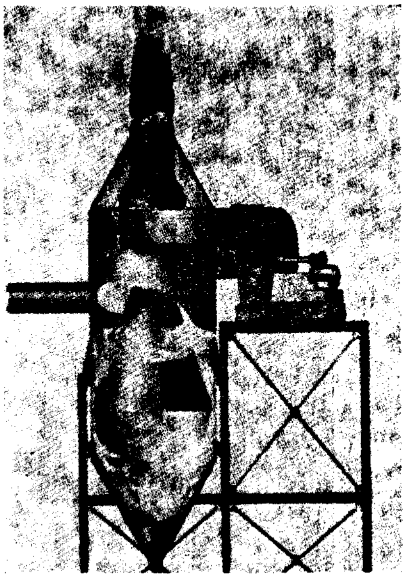
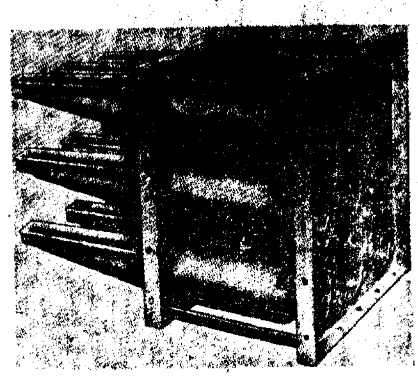


Fig. 1 — Cupola wet cap collector.





(Left)
Fig. 2 — Low pressure drop centrifugal collector.

(Right)
Fig. 4 — High efficiency centrifugal collector.

ash control. Similar removal effectiveness has been demonstrated on cupola gases where effective removal of particles down to 20 microns could be expected with low pressure drop centrifugals, down to the 5 to 10 micron range with high efficiency, high pressure drop designs.

Figure 2 illustrates low pressure drop design; Fig. 3 shows a typical installation, and Fig. 4 is typical of the higher pressure drop designs, with Fig. 5 indicating system incorporating such equipment. Characteristics of this group include:

Advantages

(1) *Collection:* Collection is effective in the "public nuisance" dust range. Equipment should eliminate damage or nuisance caused by solids deposition in plant and neighborhood area.

(2) *Dry Collection:* Dry gases eliminate corrosion problems and discharge a hot and dry gas stream, more conductive to dispersion of remaining smokes, fumes, and finer dust particles. Collected dust in dry form may aid in its disposal or can complicate its handling depending on disposal methods and refuse handling equipment used by the foundry.

(3) *Induced Draft:* Use of induced draft eliminates back pressure in the cupola and maintains calculated indraft control at the charge door opening.

(4) *Protection:* Protection devices bypass gas in case of failure.

(5) *Cost:* While more expensive than the wet cap, systems in this group are comparatively low in equipment cost and in replacement part and servicing required. Life expectancy of system elements should be long.

(6) *Future Improvement:* Elements of dry centrifugal systems are identical to those required should complete control of all solid emission be attempted. Design permits addition of aftercleaners should future regulations require without scrapping or altering equipment installed.

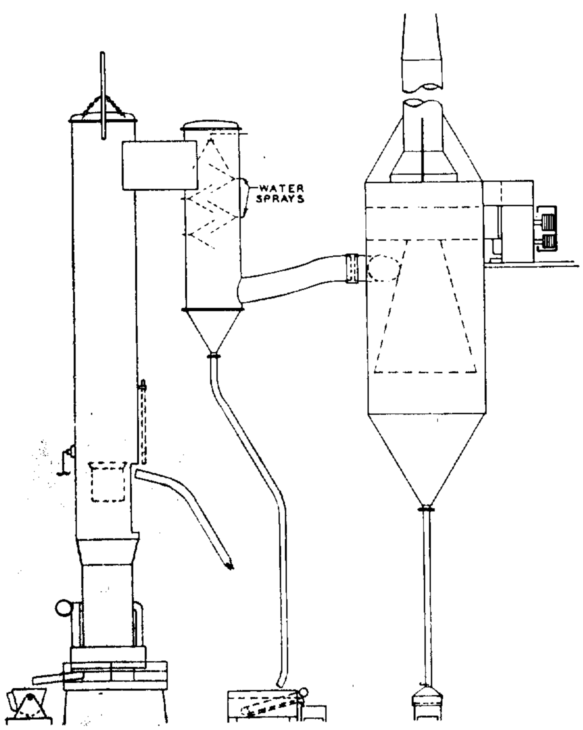


Fig. 3 — Low pressure drop centrifugal installation.

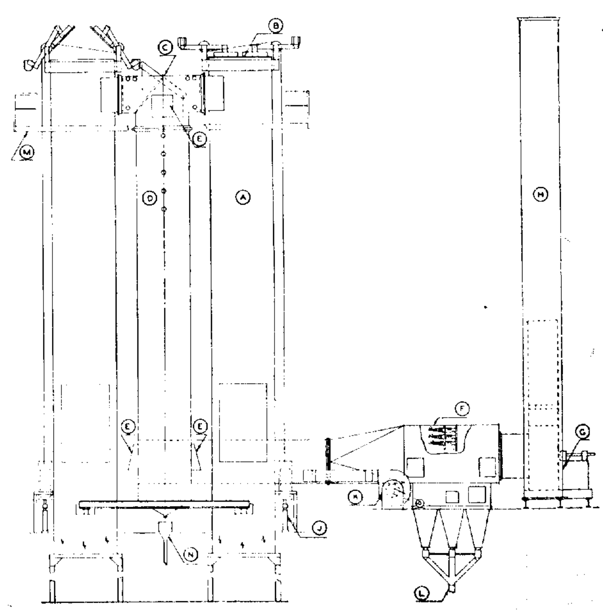


Fig. 5 — High efficiency dry centrifugal installation.

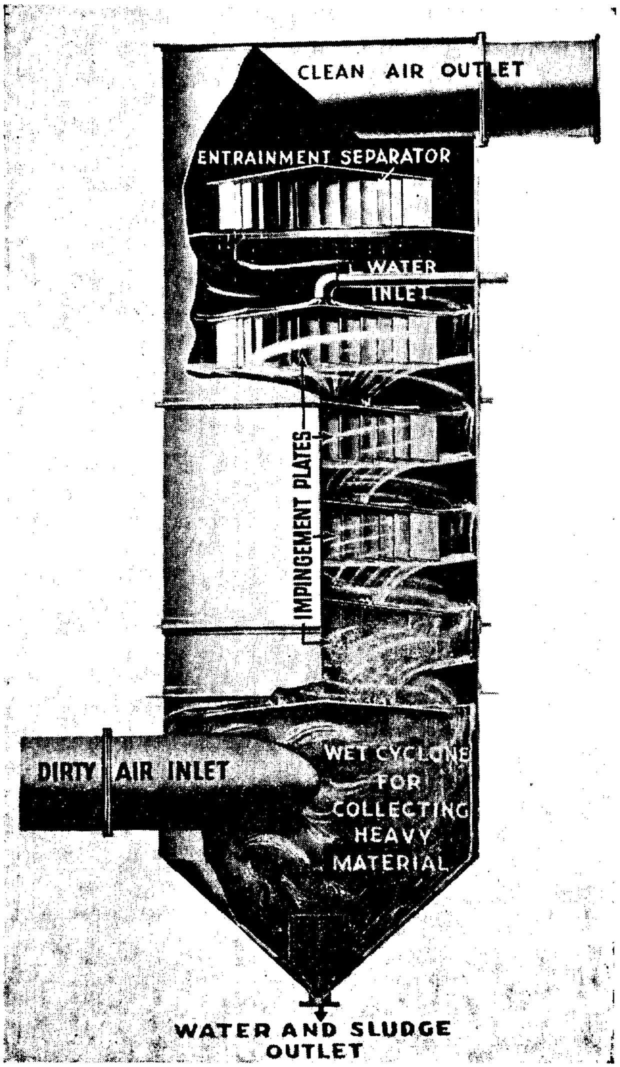


Fig. 6 — High efficiency wet centrifugal collector.

Disadvantages

(1) ***Induced Draft:*** Need for induced draft fan to overcome added resistance to gas flow of control equipment introduces substantial horsepower requirements. The need for cupola lids with their actuating mechanism, control equipment to open lids in case of power or equipment failure.

(2) ***Controlled Gas Cooling:*** Cooling towers or heat exchangers are required to reduce gas temperatures to the permissible range for handling through ducts, collectors, and induced draft fans. Controlled cooling is needed to reduce or eliminate excess water runoff and operational problems due to condensation.

C. Wet Dust Collectors

With extensive use of high efficiency wet dust collector designs by the foundry industry, it is logical to evaluate such equipment for the cupola emission problem. Excellent removal of particles down to 1 or 2 microns has been consistently demonstrated with substantial collection of sub-micron particles.

Figures 6 and 7 illustrate typical wet collector designs that have been applied to cupola gas cleaning. Performance can best be evaluated by a comparison with the dry centrifugal systems outlined above.

Advantages

(1) ***Collection:*** Collection is pratically complete on all dust particles, substantial on metallic fume, and negligible on smokes. (Discharge appearance, however, will not be substantially reduced although color will change with combination with steam plume.)

(2) ***High Temperature Handling:*** Use of water provides "flash cooling" at collector inlet permitting handling of gases throughout the cupola gas temperature range. (Precooling may be required to protect duct connections from excessive cupola gas temperatures unless refractory lined flues are used.)

(3) ***Induced Draft:*** Same indraft control at charging door opening is obtained.

(4) ***Protection:*** Gases can be bypassed in case of failure without damage to equipment.

(5) ***Wet Collection:*** Collection of material as sludge or slurry often fits refuse disposal into existing handling systems in the foundry. (Drain water can often be incorporated with slag quenching and sluicing system.)

Disadvantages

(1) ***Corrosion:*** The greater impingement, aeration, and centrifugal forces utilized in effective wet collector designs proportionately increase corrosion rates. It is debatable whether chemical treatment of water will be sufficient protection for damp surfaces

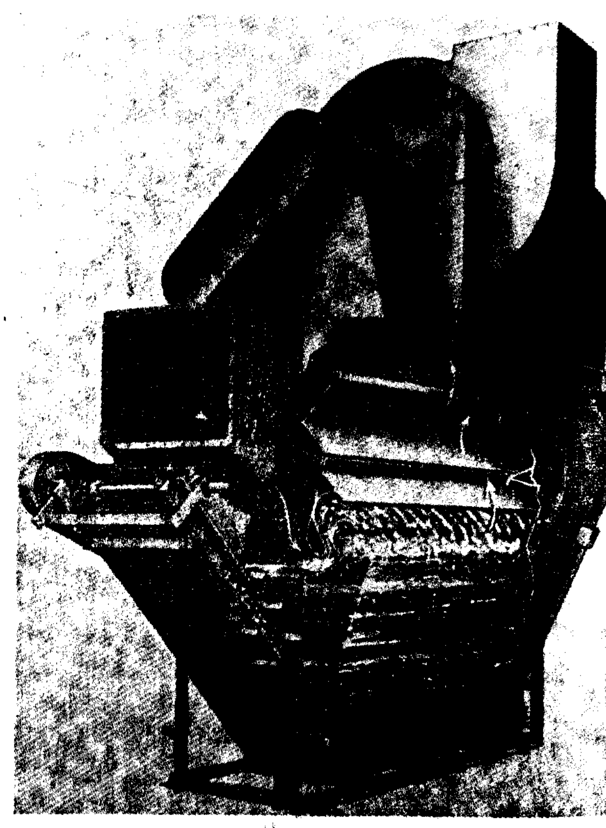


Fig. 7 — High efficiency hydrostatic collector.

in the cleaned gas, exhaust fan, and discharge stack surfaces.

(2) *Dispersion:* Exit gas conditions cooled from the extremely high temperatures of cupola gases will contain substantial quantities of water vapor. Exit temperatures will be in the 125 F-190 F range and will be close to saturation. Dispersion during stable atmospheres can be retarded. Possibility exists due to large volumes involved of condensation taking place under such conditions with precipitation of droplets in the nearby plant or neighborhood area.

(3) *Future Improvements:* Cooling in wet collectors is too effective to make addition of aftercleaners practical should complete control of all solid emissions be required at a future date. (With water vapor quantities introduced in cleaned gas discharge, reheating by bypassing a fraction of the hot gas around the collector requires bypassing of a major portion of the total hot gases handled.)

(4) *Cost:* System cost will be substantially increased over dry centrifugal if corrosion resistant materials of construction for collector, exhaust fan, and discharge stack are required. (Placing of exhauster on dry hot gas side requires controlled precooling or heat exchangers to keep gas within permissible temperature range.)

D. Electric Precipitators

The need in certain localities due to meterological or air pollution regulations for practically complete elimination of all visible cupola emissions has necessitated installation of either electrostatic precipitators or bag houses. Both collector types do provide excellent removal of the finest of solid smoke and metallic oxides. Systems involve the same general arrangements of induced draft fan, cupola lids, and controlled cooling outlined for the dry centrifugal system.

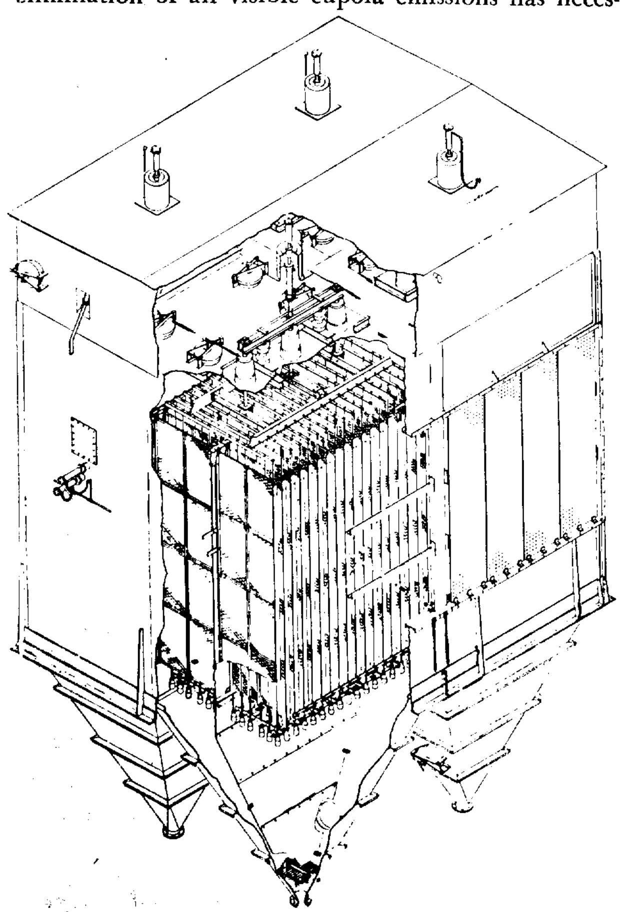


Fig. 8 — Electrostatic Precipitator.

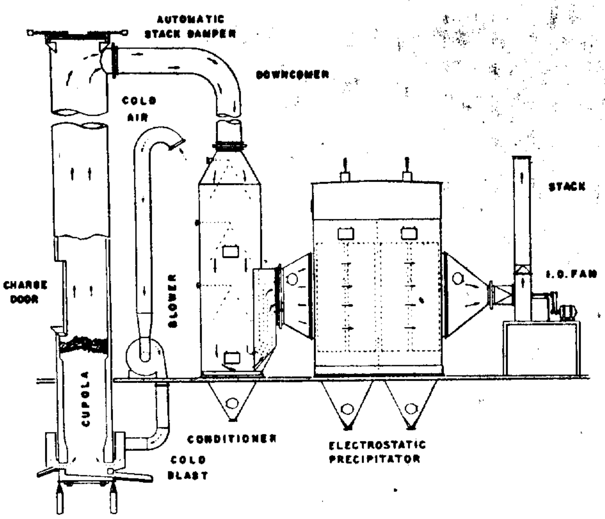


Fig. 9 — Electrostatic precipitator installation.

It is interesting to note that in boiler fly ash installations, it is rare that precipitators are employed except where gas volumes and fly ash loadings are many times those encountered in the foundry cupola. No fabric arresters have been installed for such boiler stack gas cleaning. In the electric precipitator, Fig. 8 and 9, collection is obtained by use of high voltages (50,000 to 70,000 volts) to charge the particles and attract them to grounded collector plates.

Advantages

(1) *Collection:* Excellent removal of solid particles in all size ranges when collector is designed of sufficient size to provide such order of performance.

(2) *Horsepower:* Pressure drop is low, making horsepower required substantially less than for any other induced draft collection system.

Disadvantages

(1) *Cost:* Initial equipment and erection cost is high—the cost could exceed dust control equipment costs for all other dust producing operations including shakeout, sand conditioning, and cleaning room operations.

Typical of many high performance refined designs, maintenance and servicing costs will be substantially greater than for equipment having lower order of collection.

(2) *Conditioning:* For certain fractions of cupola solids including the metallic oxides, gas temperatures and water vapor content must be closely controlled due to high resistivity of such fractions. Too efficient heat exchangers may reduce gas temperatures beyond point where needed water vapor can be cheaply introduced; fluctuations of cupola stack temperatures can complicate maintenance of optimum temperature range to collector. Desirable gas conditions for cupola

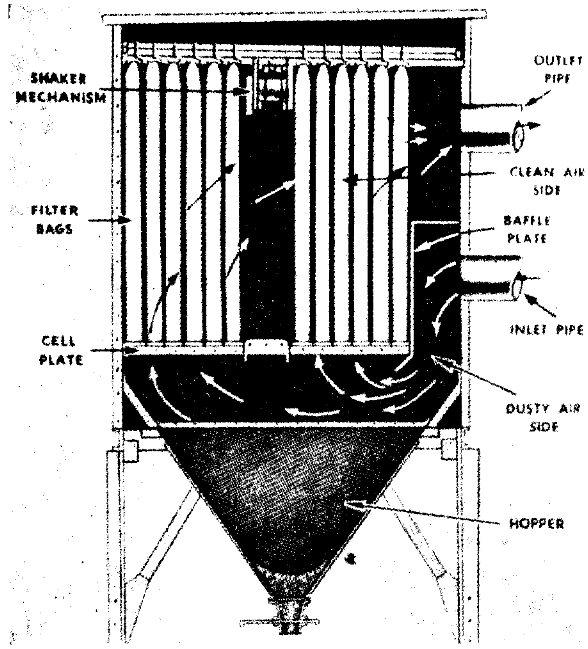


Fig. 10 — Fabric dust arrester.

type of contaminants has been reported as 200 F and 14 per cent minimum water vapor by volume.

(3) ***Disposal:*** Dry material disposal becomes most troublesome as particle sizes of collected material decrease. The ability to remove the submicron fraction introduced problems of refuse handling and secondary dust dispersion during disposal.

E. Fabric Collectors

Good fabric collectors, Fig. 10, can provide the highest order of collection efficiency on all particle sizes. Like the electric precipitator, its use has been confined to date to those areas where complete collection must be provided regardless of equipment cost and maintenance expense. A typical installation. Fig. 11, illustrates an installation designed for production foundries where length of melting period requires automatic, either continuous or periodic, removal of collected material from fabric surfaces without bypassing dirty gases during collector reconditioning cycle. Features include:

Advantages

(1) ***Collection:*** Excellent removal of all solid fractions with efficiency of removal unaffected by temperature or operational phases of cupola. Collection normally of higher order than comparable cost electric precipitator.

Disadvantages

(1) ***Cost:*** Initial equipment and erection cost is high although generally somewhat lower than electric precipitators designed for comparable performance. Replacement part costs include periodic replacement of synthetic filter fabric.

(2) ***Operation Temperature:*** Usual synthetic fabrics in use for cupola and other high temperature applications has an upper limit of 275 F. Keeping cupola gas temperatures below this figure takes accurate gas cooling equipment.

Glass fabrics can operate at temperatures up to 500 F although they appear unsuited to most fabric arrester designs due to abrading action during reconditioning.

(3) ***Disposal:*** Dry material disposal introduced same factors outlined under electric precipitator discussion.

F. Incineration

Consideration of cupola gas igniters of gas burning in heat exchangers cannot be divorced from evaluation of cupola control. With any control equipment except fabric arresters, after burning of the carbonaceous fraction is recommended to reduce discharge appearance. The advantage from a public relations standpoint will usually outweigh the formation of some additional dust particle through the reduction of coke cinders to ash.

To be effective, ignition time must be provided in the cupola stack. A distance from top of charging door to top of stack of not less than 25 feet appears indicated for combustion under usual cupola operations.

Summary

With the increasing publicity and legislation directed at air pollution throughout the United States, some degree of solids removal from cupola gases will be indicated in the foreseeable future for many lo-

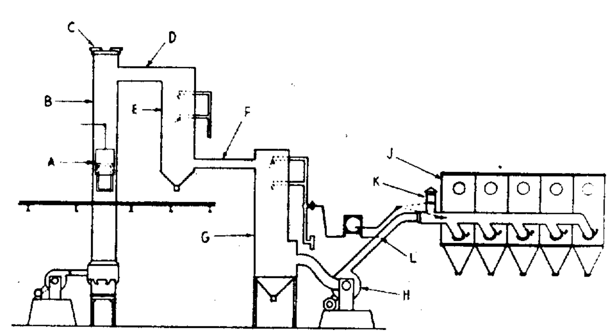


Fig. 11 — Fabric arrester installation.

TABLE 1 — RANGE OF CUPOLA EMISSIONS PER TON OF IRON MELTED IN COLD BLAST CUPOLA

Total Solids	10 to 20#/hr/ton melt
Cinders (plus 44 microns)	50 to 75% of total
Dust (44 to 1 microns)	2 to 6#/hr/ton melt
Fumes & Smokes (less than 1 micron)	1 to 3#/hr/ton melt

Cinder: Quantity is a function of blast volume per ton melted, charging methods, height of bed, quantity of coke fines. Incineration will reduce coke quantities emitted in this particle size range.

Dusts: Quantity is a function of scrap cleanliness, amount of coke and limestone fines, quality of briquets, charging methods, height of bed.

Fumes & Smokes: Fume quantity is a function of chemical composition of scrap, use of briquets, metal melting temperatures. Smokes are produced from oily scrap and incomplete combustion of coke.

TABLE 2 – COLLECTOR CHARACTERISTICS FOR 15 TONS/HR COLD BLAST CUPOLA OPERATED ON ALTERNATE DAYS

Assume Blast Volume	= 8,000 cfm @ 70°	**Assume Emissions**	15#/hr/ton/melt
Charging Door 40 sq. ft. @ 300 fpm	= 12,000 cfm @ 70°	**Consisting of Cinders**	8#/hr/ton/melt
Total Gas Volume	= 20,000 cfm @ 70°	**Dust**	4#/hr/ton/melt
	62,500 cfm @ 1200°	**Fumes**	3#/hr/ton/melt

Collector Type	Discharge Gas Temperature	H_2O Vapor @ Exit Temp. Added for Cooling	Total Vol. @ Exit Temp.	Lower Effective Collection Range (Micron)	Collector Pressure Drop W. G.	Probable H. P. (Note 1) Exit. Temp.	Probable H. P. 70°	Water Req'd. GPM	Probable Emission (Note 2) GR SCF	Probable Emission GR CFM @ 500°	Approx. Instal. Cost on Existing Cupolas
Wet Cap........	400-700°F	9,850 cfm	47,850 cfm @ 550°F	44	0.25"	—	—	200	0.45	0.25	$35,000
Low Pressure Drop Centrifugal With Cooling Tower..	350-500°F	10,200 cfm	43,600 cfm @ 425°F	30	1.5"	24	40	34.3	0.36	.20	50,000
With Heat Exchanger.....	600-700°F	None	41,800 cfm @ 650°F	30	1.5"	34	71	0	0.45	0.25	150,000
High Eff. Dry Centrifugal.	350-500°F	10,200 cfm	43,600 cfm @ 425°F	7	3.0"	34.3	57	34.3	0.27	0.15	55,000
Wet Collectors....	125-190°F	9,750 cfm	33,750 cfm @ 175°F	1	5.0"	52.5	63	48-100	0.11	0.062	75,000
Electric Precipitator	250-300°F	10,200 cfm	38,000 cfm @ 275°F	0.1	0.5"	18	25	41.2	0.039	0.021	100,000
Fabric Arresters (Synthetic Fabric).	250-275°F	9,600 cfm	36,800 cfm @ 260°F	0.1	4.0"	42.5	57.5	41.8	0.0096	0.0053	75,000
(Glass Fabric)....	400-500°F	10,200 cfm	44,200 cfm @ 450°F	0.1	4.0"	40.5	69.5	33.2	0.0206	0.0114	75,000

Note 1: Horsepower calculations assume pressure loss through dusts and cooling tower of 2" added to stated collecter loss except for Wet Cap. (5" with heat exchanger).

Note 2: Lower than the usual boiler stack acceptable emission regulations of 0.257 grains per cubic foot at 500°F (0.465 grains per standard cubic foot).

calities. Increased awareness to the public relations aspect of this problem is indicated by the widespread interest by the industry and the increasing numbers of control equipment installations currently in service.

The nature of the problem and some of the general ranges of control equipment characteristics have been reported in Tables 1 and 2. Installed cost figures reported are relative only and should be used with extreme caution. Where induced fans are employed, the influence of size of charging door on size and cost of equipment is substantial. Indraft velocities vary between 200 and 300 fpm with different designers. Comparison of equipment cost should recognize this possibility and costs should be accumulated on the same indraft basis.

Analysis of the substantial data existing from cupola emission studies (both published and in industrial files) would tend to describe the more usual cupolas as:

(1) Emission with cold blast usually from 10 to 20 lb per hr per ton melted; with incineration type of heat exchanger, emissions are somewhat reduced because part of the coarse fraction settles out in the heat exchanger.

(2) Cinder fraction (plus 44 micron or 325 mesh screen) often from 50 to 75 per cent.

(3) Dust fraction (1 to 44 microns) usually from 2 to 6 pounds per ton melted.

(4) Metallic fume and smoke fraction while some 99 per cent by number of particles account for 1 to 3 pounds per ton melted.

(5) Collection efficiency of fabric arresters 98 to 99 per cent; electric precipitators 92-99 per cent depending on size selection; high efficiency wet collectors 85 to 90 per cent; high efficiency dry centrifugals 70-85 per cent; low pressure drop dry centrifugals 60 to 70 per cent; wet caps 45 to 60 per cent.

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