Pollution Abatement of Ferro-alloy Furnaces in the United States

by R.A. PERSON* (presented by Dr Person)

SYNOPSIS

Ambient-air standards affecting existing ferro-alloy furnaces throughout the United States were issued in 1971. The standards, requiring final compliance by 1975, are based on the attainment of ambient-air quality rather than on considerations of technical or economic feasibility. The compressed compliance schedule has hindered optimum systems development, and the technical effort of the Ferroalloys Division of Union Carbide Corporation has concentrated on fume capture and collection, rather than on the furnace process. Developments with open furnaces have included the application of closer hooding to reduce gas volumes, the reduction of the high filter drag of high-temperature fibreglass bag filters by substitution of other fabrics and bag-cleaning methods, and the introduction of more-reliable designs to high-energy wet scrubbers. Abatement equipment on existing covered furnaces has been upgraded, operating techniques improved, and emission monitoring equipment perfected to bring some units into compliance. Limited production growth for those alloys that can be manufactured in sealed furnaces has delayed the application of this technique. Additional efforts have centred on the development of uses for collected fume, including possible recycling to the furnace.

In July 1973, it is estimated, approximately 50 per cent of the operable U.S. ferro-alloy capacity of about 1500 MW has pollution-control equipment. About 80 per cent of these installations should be capable of meeting 1975 standards. The direct economic consequences of pollution abatement, as documented in the Ferroalloys Association—Environmental Protection Agency joint study of atmospheric emissions, amount to $10 to $60 per net tonne of alloy, the higher number applying to high-silicon alloys. Indirect economic penalties also result from higher prices for electrical energy and carbonaceous reducing agents, which also must bear the cost of more stringent emission regulations applied to their production.

DEVELOPMENT OF REGULATIONS

Until 1971, the emission regulations pertaining to ferro-alloy furnaces were confined to individual states, regions, or municipalities, and many areas did not require pollution-abatement measures. A country-wide approach was set in motion by the passage of the 1970 Amendments to the Clean Air Act. Pursuant to these Amendments, national ambient-air standards for suspended particulates (see Table 1) were issued on April 30, 1971, by the federal control organization, the Environmental Protection Agency (EPA). This issuance set in motion a timetable requiring each state to develop an implementation plan for attainment of the primary standards by May 30, 1975. A necessary part of each plan was the promulgation of actual particulate-emission regulations theoretically capable of reducing emissions enough to attain or go below the air-quality standards in any region of a state.

Table 1

National air-quality standards for particulates[1] ($\mu g/m^3$)

	Primary*	Secondary*
Annual geometric mean	75	60
One-hour average, not more than once per year	260	
24-hour average, not more than once per year		150

*Primary standards are deemed to be necessary for the preservation of human health; secondary standards, for human welfare.

These regulations all contain two complementary criteria particularly restrictive to ferro-alloy production.

(1) Visual appearance. Particulate emissions are required to be less than 20 per cent equivalent opacity (No. 1 Ringelmann), not including water-vapour plumes.

(2) Process weight formula. The allowable weight rate of particulate emissions is an exponential function of the feed rate to a process. Although each state has slightly different constants in the formula, as shown in Table 2, the allowable emissions do not differ within the normal accuracy of sampling.

Table 2

Applicable emission formula constants for various U.S. ferro-alloy plant locations

$$E = aP^b,$$

where E = allowable particulate emission, lb/h,
P = process weight, NT/h, $P \leq 30$ NT/h.

State	*a*	*b*
Ohio	4,10	0,67
Alabama	3,59	0,62
West Virginia	3,04	0,72
Oregon	4,10	0,67
New York	3,76	0,665
Federal recommendation[2]	3,59	0,62

It is important to note that the preceding regulatory criteria bear no necessary relationship to ambient-air quality at a specific location, since no cognizance is taken of background, adjoining facilities, or meteorological conditions. Even more significant is the fact that no consideration is given to technical or economic feasibility.

The ferro-alloy industry is very stringently affected because the small particle size of the emissions leads to high opacity, the high gas enthalpies of open furnaces require expensive heat exchangers or collector volume increases, and the characteristically high weight ratio of fume to feed dictates a high-efficiency collection device to meet the process weight formula. This latter point is illustrated in Table 3 for representative furnaces.

New ferro-alloy furnaces will be subject to direct Federal emission standards, which, by law, must take cost

*Union Carbide Corporation, U.S.A.

Table 3

Emission limitations based on process weight formulae

Product	Furnace size MW	Process weight rate NT/h	Potential emissions with no control lb/h	Allowable emissions process weight formula lb/h
High-carbon FeMn	12	16,4	1000	26,7
Si Metal	15	7,7	1500	12,7
75% FeSi	20	9,3	1300	14,3
SiMn	30	21,4	1300	31,9
High-carbon FeCr	30	25,9	1800	36,3
50% FeSi	50	21,7	4100	32,2

and the best available techniques into account. As of July 1973, a particulate-emission standard has been proposed for new high-carbon ferromanganese, silicomanganese, and calcium carbide furnaces, based on the use of sealed or completely closed furnaces. This approach is regarded by the domestic ferro-alloy industry as being unduly restrictive and not representing adequately demonstrated technology.

ABATEMENT OF COVERED-FURNACE OPERATIONS

Since the 1930s, the Ferroalloys Division of Union Carbide Corporation has operated covered furnaces with mix seals round the electrodes[3]; in this design, a major part of the furnace gas is withdrawn and scrubbed before combustion. With the advent of strict regulations, the emission-control performance was often no longer sufficient for those products subject to 'blows' or slag 'boils' and those with a steel-scrap charge requiring intermittent feed. These furnace phenomena make maintenance of the electrode mix seal more difficult and can lead to gas and fume escape as fugitive emissions.

Reduction of the fugitive emissions has been satisfactorily accomplished on smaller furnaces producing high-carbon ferromanganese (up to 13 MW), 50 per cent ferrosilicon (up to 18 MW), and high-carbon ferrochromium (up to 10 MW) by a combination of programmes including:

(1) increasing gas-collection capacity up to three times the stoichiometric requirement, thus sacrificing the fuel value of the gas,
(2) decreasing the annular gap of the mix seal to improve its sealing action,
(3) improving the regularity and distribution of mix feed to the mix seals,
(4) continuous monitoring of fugitive emission stacks by bolometers to allow furnace operators to take corrective measures,
(5) developing improved operating and metallurgical techniques promoting deep electrode penetration and smooth operation, and
(6) instituting cover and scrubber maintenance practices to maximize system performance.

An example of the successful use of these techniques is illustrated in Table 4 for a 12 MW high-carbon ferromanganese furnace.

The application of the preceding programme has not been successful on covered furnaces producing silicomanganese and 65 and 75 per cent ferrosilicon and

Table 4

Emission reduction accomplished on covered 13 MW high-carbon ferromanganese furnace

Potential emissions with no control device, lb/h	600 to 1300
Emissions with original control system (1970), lb/h	
(a) Scrubber outlet	0,5
(b) Fugitive fumes	70,7
(c) Tapping fumes	0,8
Total	72,0
Bolometer reading, monthly average, Ringelmann units	2,10
Emissions after completion of emission reduction programme (1973), lb/h	
(a) Scrubber outlet	0,9
(b) Fugitive fumes	22,9
(c) Tapping fumes	0,8
Total	24,6
Bolometer reading, monthly average, Ringelmann units	0,55

on large furnaces for 50 per cent ferrosilicon. Silicomanganese production has been shifted to open furnaces, the programme is continuing on the furnaces for 65 and 75 per cent ferrosilicon, and a bag collector is being added to collect the fugitive fumes from a 50 MW furnace producing 50 per cent ferrosilicon[4].

The total effect of this type of emission-reduction programme on existing covered furnaces is illustrated by experience at the Marietta, Ohio, plant of the Ferroalloys Division, as shown in Table 5.

Table 5

Historical record of particulate emission reduction from ferro-alloy furnaces at Marietta, Ohio

	NT/a
Potential emission with no control	26 680
1967	8 570
1968	7 230
1969	2 570
1970	2 700
1971	1 500
1972	830
1973 (estimate)	780

Only one covered furnace, with unburnt gas withdrawn from the cover and mechanical seals round the electrodes to prevent fugitive emissions, is in operation in the United States. Within the last ten years, no new domestic furnaces have been built for those products most suited for manufacture in this type of furnace (high carbon ferromanganese and calcium carbide).

ABATEMENT IN OPEN-FURNACE OPERATIONS

A significant aspect of fume collection from open furnaces is the capture of the fume-containing gases. To a first approximation, the capital and energy requirements of the control system are proportional to the volumetric flow of gas, so that minimization of gas volume, consistent with satisfactory limitation of emissions, has been emphasized.

The evolution of hood designs for enclosure of open furnaces is illustrated in Figure 1. For those furnaces requiring enclosure of the electrode suspension, such as the packet type[5] at Alloy, West Virginia, it is necessary to leave gaps in the hood structure or provide movement capability to portions of the hood. With such hoods, it has been possible to reduce the volumetric flow to be handled by a collector from about 1 000 000 ft^3/min (roof monitor capture) to about 550 000 ft^3/min (hood capture).

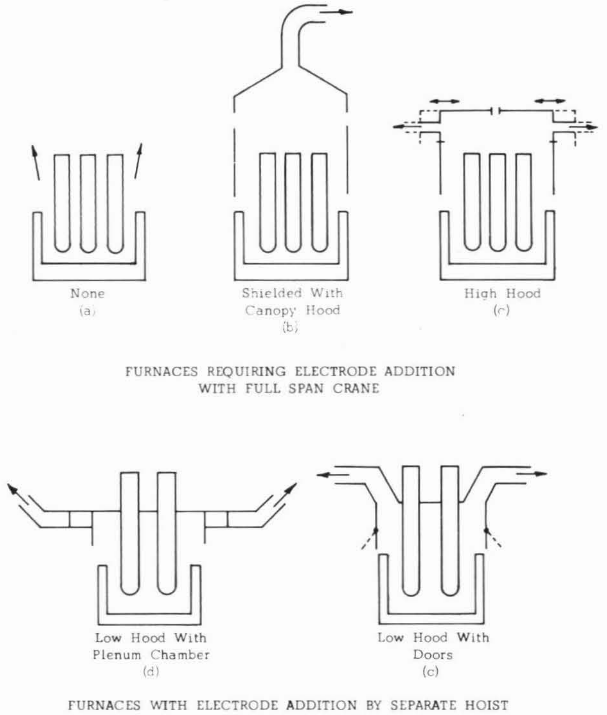


Figure 1
Hood design for open furnaces

Newer open furnaces, with provision for adding electrode sections under load, are capable of much closer hooding. By the addition of doors or movable panels, the air infiltration necessary to contain emissions has been further limited. As the average temperature within the hood increases, the buoyancy effects increase, and more careful sealing, as well as increased pressurization of mix spouts and the areas above the hood, becomes necessary.

For new open-furnace installations, a practical solution has been close hooding, coupled with a gas-to-air heat exchanger to cool the gas to the temperature limitations of the collector. Satisfactory experience has been obtained with U-tube convective coolers, where measurements under steady-state conditions yield an overall heat-transfer coefficient of 2,3 to 2,8 Btu/(h ft^2 °F) at mass velocities of 8000 lb/(h ft^2). The U-tube convective cooler also contains a sufficient mass of steel to serve as a heat sink to level out any temperature fluctuations from the furnace. Metal temperatures remain high enough to avoid possible dewpoint problems that might occur when a forced-air or water-cooled exchanger is used.

Wet-scrubber installations on open furnaces represent the lowest capital-investment collection system (exclusive of slurry treatment and disposal), but the highest operating cost. Three such installations on Ferroalloys Division furnaces have required substantial modifications since their initial installation to assure collection performance and to prevent furnace downtime[8]. Basic changes have included

(1) simplification and redesign of internal members and portions subject to erosion or deposition,
(2) pH control of recirculating scrubber liquor,
(3) monitoring equipment for vibration, and
(4) fan sprays to reduce impeller build-up.

For collection of fume from silicon and ferrochromium silicon operations, pressure drops of 60 inches water gauge have resulted in the attainment of only 96 per cent collection efficiency. This performance, coupled with slurry-treatment complexities, has tended to promote dry collection – bag filters in particular.

High-temperature bag filters on silica fume present major problems of high pressure drop, occasioned by the specific properties of silica fume, such as the small particle size, high electrical resistivity, and low bulk density. Initial installations on silicon furnaces of shaker-type fibreglass collectors (500°F limitation) were technically adequate but suffered from high pressure drop and an average bag life of only two years. Efforts to reduce this pressure drop by techniques of charge bleed-off and cleaning-cycle modifications did not result in significant improvements.

Major reductions in the pressure drop, expressed as filter drag, the ratio of pressure drop to volumetric flow per unit filtration area, were obtained only by changing the method of bag cleaning or by altering the filter fabric. Experimentation showed better performance with fibreglass ringed bags cleaned by reverse air. Additional tests with Nomex bags (E.I. Dupont trademark for high-temperature nylon with aromatic linkages, 400°F temperature limitation) showed further improvement. The overall performance resulting from these changes is summarized in Table 6.

Table 6
Filter drag of bag collectors on fume from silicon metal furnaces

	Filter drag, inches water gauge per ft^3/min/ft^2	Volumetric flow per unit area, ft/min, at pressure drop of 18 inches water gauge
Fibreglass, shaking	10	1,8
Fibreglass, ringed bag, reverse flow	9	2,0
Nomex, original shaking cycle	6	3,0
Nomex, ringed bag, reverse-flow cleaning	6	3,0
Nomex, improved shaking cycle	5	3,6

Measurements were based on multicompartment pressure-type collectors, with each compartment containing 144 bags, each 11,5 inches in diameter by 30,5 ft long. Inlet-gas temperatures varied from 300 to 400°F; inlet loading, from 0,5 to 1,0 grains per standard cubic foot.

Table 6 represents average values obtained from a full eight-compartment collector or a single compartment specially instrumented to determine the flow through that compartment alone. A definitive determination of filter drag is possible only when the actual flow rate to the individual bags under study is measured.

Dynamic performance of the bags in a multicompartment bag-house requires instantaneous measurement of the flow rate to an individual compartment. Figure 2 presents comparative curves of filter drag versus time for equilibrium conditions on one compartment of an 8-compartment bag-house. The data plotted in Figure 2 show the marked superiority of Nomex bags over fibreglass for silica-fume collection. It can be inferred from the lower values of residual drag that the improvement is largely due to a better cleaning action with Nomex bags. It is also indicated that Nomex bags are cleaned better by shaking than by reverse flow. There is no apparent sacrifice in the actual filtration efficiency, since EPA tests on one of the full-scale Nomex bag-houses showed a filtration efficiency of 99 per cent.

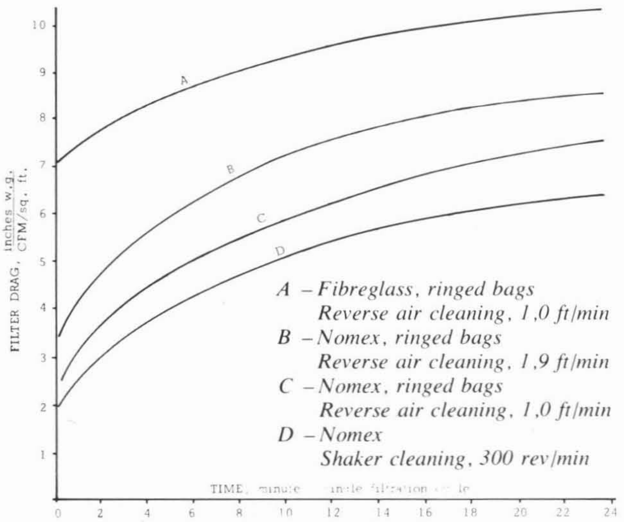


Figure 2

Dynamic performance of filter media on silicon-metal furnace fume

The improvement of the volumetric capacity has allowed an abatement of silicon-metal operations with less bag-house investment than originally projected. The original fibreglass bag-houses have been converted to Nomex to increase their capacity. An interconnected system now serves four types of furnace hoods, and collector capacity is optimized while conforming to the 400°F bag-house limitation. The current installation serving the Alloy, West Virginia, silicon-metal facility of 100 MW capacity is illustrated in Figure 3. The total installed fan power for this collection system is 13 000 hp.

Implementation of this type of bag-collector programme is still in progress at the Alloy plant and will be completed on other units by 1974. Total plant emissions will have decreased from an estimated 45 000 t/a with no control to a value of less than 500 t/a.

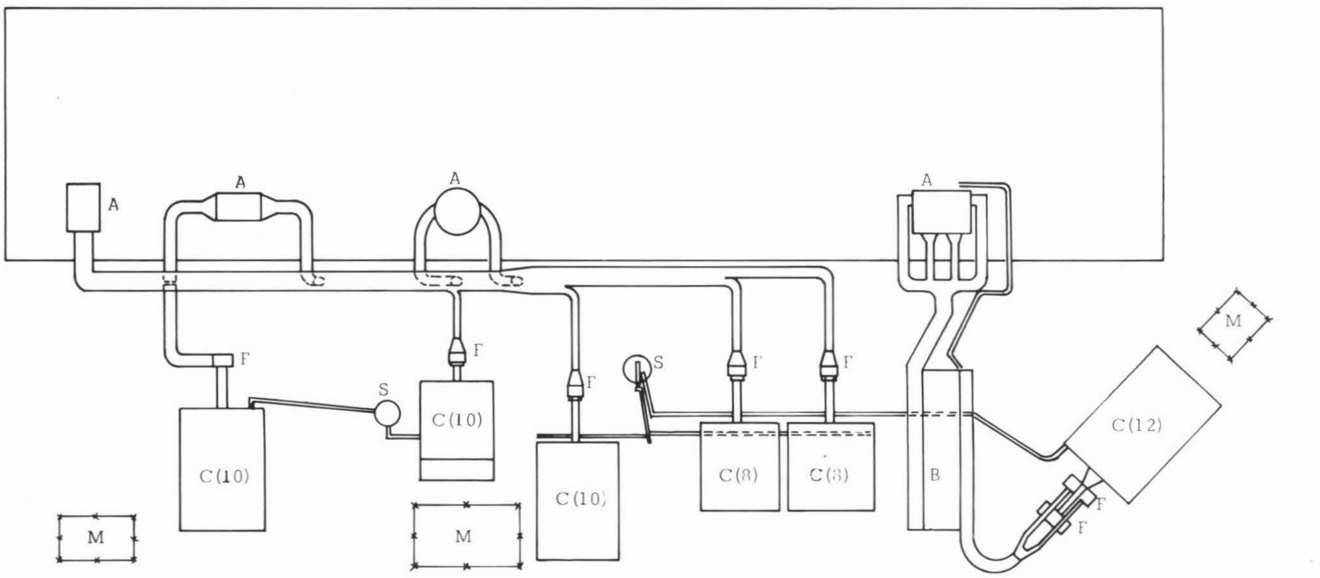
COLLECTION OF MISCELLANEOUS FUMES

Other fume-generation steps in ferro-alloy manufacture to which collection has been applied include tapping operations and ladle reactions. The collection of tapping fume has been incorporated in new furnaces, and a typical installation, where crane access to the tap hole is required, is shown in Figure 4. The tapping fume may be fed to the main furnace collector, or may be collected in a separate bag collector. In the latter case, for ferrosilicon and silicomanganese, pulse-jet collectors with a high ratio of volume to area (6:1) have been used satisfactorily. In these circumstances, the duty of the collector is intermittent enough to allow sufficient cleandown during non-tapping intervals. The high-ratio collector has also been successfully used for intermittent ladle reactions, such as the production of magnesium-ferrosilicon nodularizing alloys.

FUME UTILIZATION

Significant sales of fume appear to be confined to that from silicon metal and high-percentage ferrosilicon operations, where the fume can be used for insulation, refractory ingredient, or filler for rubber products. Silica fume is also amenable to recycle in those cases where the cost of pelletizing does not exceed the cost of silica raw material plus alternative disposition of the fume.

The range of analyses for tonnage quantities of fumes from various operations is given in Table 7. The silicomanganese and ferromanganese-silicon fumes contain sufficient manganese values to warrant recycle, and a pelletizing system is being installed for this purpose.



A – Furnace Hood
B – U-tube Cooler
C(x) – x-Compartment Bag Collector
F – Fan
M – Motor Power Station
S – Dust Storage Silo

Figure 3

Fume collection system, Alloy silicon facility

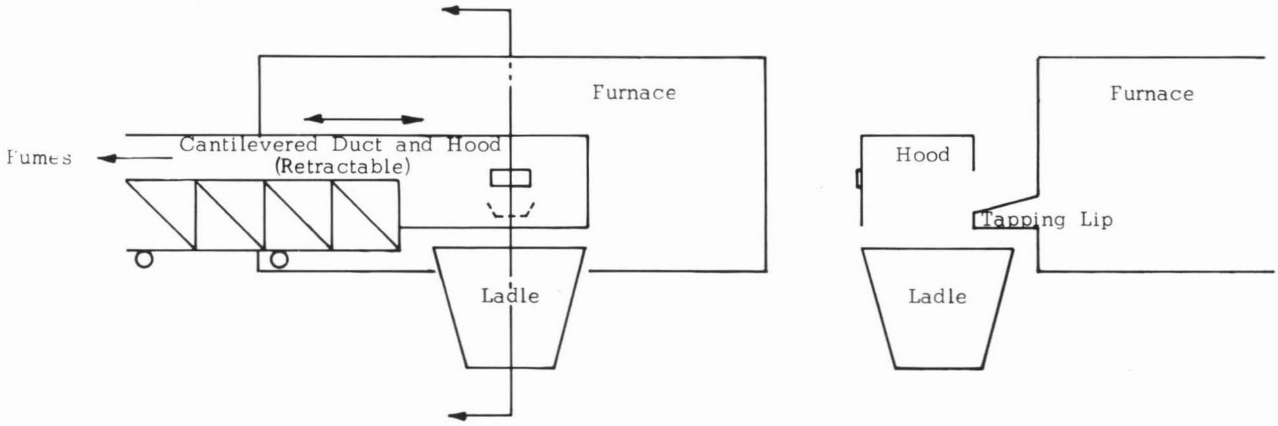


Figure 4
Capture system for tapping fumes

Table 7
Analysis range of ferro-alloy fumes

	SiO_2	MnO	Cr_2O_3	CaO	MgO
Silicon metal, 75% ferrosilicon	93 to 98				
Calcium—silicon	30 to 40			40 to 50	
Silicomanganese	15 to 30	30 to 40		<5	<5
Ferromanganese—silicon	30 to 40	35 to 45		<5	<5
Manganese ore—lime melt	3 to 10	10 to 25		30 to 45	
Ferrochromium—silicon	75 to 90		<5		5 to 10
Chromium ore—lime melt	10 to 15		10 to 20	15 to 25	5 to 10

WATER POLLUTION

Water-pollution aspects of ferro-alloy operations are largely confined to the treatment of scrubber effluent, but thermal pollution of once-through water-cooling systems is a potential problem in some locations. Detailed regulations are not yet developed, but the goal of the Water Pollution Control Act Amendments of 1972 is the elimination of water discharges by 1985. Thus, current efforts are directed towards the increased recycling of process-water streams, the increased use of water-to-air heat exchangers, and the minimization of blowdown from closed circulation systems.

ECONOMIC CONSEQUENCES OF POLLUTION CONTROL

At present (July 1973), it is estimated that approximately 50 per cent of the operable U.S. ferro-alloy capacity of about 1500 MW has pollution-control equipment. About 80 per cent of these controlled facilities should be capable of meeting 1975 standards. It is also estimated that control equipment is under construction on about 400 MW of furnace capacity. The present plans call for additional control equipment on only a portion of the remaining capacity, with the discontinuation of production in marginal facilities.

The total investment by the U.S. ferro-alloy industry in air-pollution-control equipment is expected to be about $200 million. In many cases involving existing furnaces, the investment in pollution-control equipment is greater than the original furnace investment. These courses of action have been justified only because the incremental investment is still less than a new facility.

In addition to the original investment, there is the continuing burden of operating costs, consisting chiefly of energy, equipment maintenance, and fume disposal. For the Ferroalloys Division of Union Carbide Corporation, these costs in 1972 amounted to 11,8 per cent of its capital investment in control equipment.

On an industry-wide basis[7], the costs for operation and amortization of recently installed control systems range from approximately $10 per tonne for manganese alloys to $60 per tonne for high-silicon alloys. The overall emission-control costs range from 4 to 15 per cent of sales prices for various ferro-alloys.

The preceding costs do not include the effect of increased environmental costs for the thermal generation of electrical energy or for the production of carbonaceous reducing agents, both of which are now subject to more stringent regulations. Also excluded from the previous financial considerations are the future costs for additional water-pollution control.

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In presenting his paper, **Dr Person** said:

I stated in my paper that U.S. particulate emission standards for new furnaces have not yet been promulgated, but it now appears that these will be 0,5 lb per megawatt-hour for chromium and manganese furnaces, and 1,0 lb per megawatt-hour for silicon and ferrosilicon furnaces. These values can be compared with the allowable emissions from process weight formulae (Table 3 in the paper), which range from 0,6 to 2 lb per megawatt-hour. The proposed standards for new furnaces are seen to be slightly more restrictive.

I mentioned that in the U.S.A. there have been four types of bag collectors, all pressure type with fans on the dirty-gas side, applied to the collection of fume from silicon-metal and ferrosilicon operations. These types are:
(1) fibreglass bags cleaned by shaking,
(2) fibreglass ringed bags cleaned by reverse flow,
(3) Nomex bags cleaned by shaking, and
(4) Dacron or Orlon bags cleaned by shaking.

The last category is not listed in Table 6 of my paper, as the Ferroalloys Division does not have experience with this type.

In the presentation of data on filter drag experienced on fume from silicon-metal operations, I mentioned that other U.S. ferro-alloy manufacturers had reported results better than those indicated by the Alloy tests, using fibreglass ring bags with reverse air cleaning. For ferrosilicon operations, filter drags as low as 6, and generally in the range of 6 to 8, had been reported by other ferro-alloy producers.

I also pointed out that the data presented on filter drag were intended as being representative of Ferroalloys Division operating experience only, and that these conditions would not necessarily be optimum for others.

The anomaly between curves B and C of Figure 2 of the paper, which indicates poorer performance at higher reverse flows, was explained on the basis that, at high reverse flow, the bags themselves collapsed enough to impede discharge of the filter cake.

I might add one other factor that has influenced our particular decision, and that is the basic physical ability of Nomex to withstand a higher pressure drop than fibreglass without damage. Under these circumstances, we are able to get more flow through a given baghouse even if the filter area is the same. The other potential advantage, which is not completely answered yet, is that of longer bag life. In our experience, bag life with fibreglass on fume from silicon-metal furnaces was approximately two years. Nomex bags in this type of service have been installed for approximately two years now. The original projection for Nomex was a five-year bag life, and indications are that this will be met; but, until the five years have elapsed, definitive comment cannot be made.

Water-pollution standards were promulgated in March 1974 for the U.S. ferro-alloy industry. Water effluents are chiefly the discharges from wet scrubbing systems, but cooling-tower blowdown, slag processing, and natural run-off are included. These standards, expressed as kilograms per megawatt-hour, are summarized in Table 8. The standards for 1977 represent application, in the opinion of the United States Environmental Protection Administration, of the best practicable control technology commercially available. The standards for 1983 are roughly 10 per cent of the 1977 standards and are intended to represent the best available technology economically achievable. The economic impact of water-pollution regulations on the U.S. ferro-alloy industry has not yet been fully evaluated.

With regard to air pollution, it is now projected that the U.S. ferro-alloy industry will have invested about 200 million dollars in abatement equipment. Some existing capacity is being phased out, but new capacity is under construction, and by the end of 1975 it appears there will be approximately 1500 MW capacity with installed air-pollution control equipment. Direct operating costs, i.e., labour, maintenance, and energy, excluding depreciation and interest, amount to somewhat greater than 10 per cent of the investment; for 1973, this figure was 12 per cent for the Ferroalloys Division of Union Carbide Corporation.

DISCUSSION

*Mr K.J. Bubenzer**:

It has been demonstrated that, if fibreglass is correctly applied, it can achieve pressure-drop figures superior to those for Nomex quoted by Dr Person.

Using the Japanese technique developed by Koyo Iron Works and Construction Company, filter-drag figures as low as 2,9 inches w.g. per $ft^3/min/ft^2$ (clean) and 3,6 inches w.g. per $ft^3/min/ft^2$ (dirty) have been achieved. These are a decided improvement on the results for Nomex published by Dr Person, namely approximately 5 inches w.g. per $ft^3/min/ft^2$, apparently in dirty conditions. It is difficult to comment on the filter-drag figures for fibreglass quoted by Dr Person, as no mention is made of the fabric weave, weight, yarn count, finishing, etc. All these factors must naturally affect the filter performance and pressure drop considerably.

Table 8

EPA water-effluent limitations (April 1974) – 30-day average

	Open furnace kg/MWh		Covered furnace kg/MWh		Slag processing kg/kg processed	
Constituent	1977	1983	1977	1983	1977	1983
Total suspended solids	0,160	0,012	0,209	0,016	1,33	0,136
Chromium	0,0032	0,0004	0,004	0,0005	0,026	0,0027
Hexavalent chromium	0,0003	0,00004	0,0004	0,00005		
Total cyanide			0,002	0,0003		
Manganese	0,032	0,0039	0,042	0,005	0,266	0,037
Phenols			0,004	0,0002		
pH	6,0–9,0		6,0–9,0		6,0–9,0	

24-hour maximum is twice 30-day average

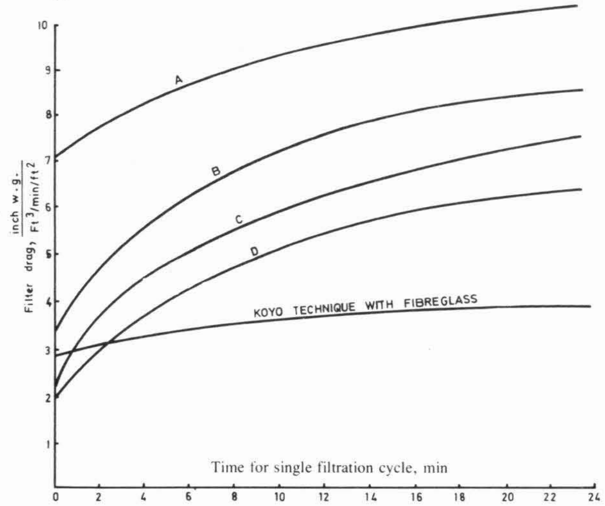
*Brandt Engineering, South Africa.

The Koyo technique incorporates certain design features that cumulatively result in a markedly lower pressure drop; this will reduce the power consumption of the gas-cleaning plant by about 17 per cent.

These are as follows:

(1) top entry of dirty gas into filter sleeves,
(2) grade WB 501 fibreglass fabric with crowfoot satin-weave and silicon—graphite finish,
(3) reverse air cleaning, and
(4) flow-back rings, which support the bags to prevent complete collapse under reverse air cleaning, and also serve the very important function of leading the very high electrostatic charges typical of ferro-alloy dusts to earth. This reduces to a minimum adhesion of dust to the filter fabric..

The practical results measured at ferro-alloy installations in Japan fitted with fibreglass filter bags are shown in Figure 1.



Figures given in Dr Person's paper:

A Fibreglass, ringed bag, reversed air cleaning, 10 ft/min
B Nomex, ringed bag, reversed air cleaning, 1,9 ft/min
C Nomex, ringed bag, reversed air cleaning, 1,0 ft/min
D Nomex, shaker cleaning, 300 rev/min.

Figure 1

Dynamic performance of filter media on silicon-metal furnace fume

Typical collection efficiencies are 99 per cent with an inlet loading of 3 to 5 g/Nm^3 and an emission of 30 to 40 mg/Nm^3. A bag life of 2 to 3 years is not at all uncommon.

It should also be noted that, though the upper temperature limit of fibreglass for continuous running is 260°C, it can for short periods withstand much higher temperatures – even as high as 450°C – without damage. This is an extremely useful property in the filtration of ferro-alloy gas. On the other hand, if Nomex is exposed to temperatures above 210°C, serious damage will occur.

Dr Person:

I think I would tend to rely on Mr Lømo's comments here in that it is extremely difficult to extrapolate the results from one plant to another, because of differences in reducing agents and raw materials, particularly the sulphur and volatile content of the reducing agents. I can supply the details on the fibreglass construction, but I am not sure they would be of interest to everyone here. One further comment I might make is that the temperature limitation for fibreglass is normally determined by the finish coating and, if the graphite—silicone coating disappears, then the bag tends to disappear and it would be for only extremely short periods that temperatures above 500°F could be tolerated.

In general terms, the graph presented appears to be a little too optimistic. It is extremely flat, and, under those conditions, it is almost indicative that the bags seem to be cleaning themselves and it is not really necessary to go through a cleaning cycle. But, in practical terms on the basis of our experience, I would hesitate to design a collector below a filter drag of 6.

Dr A. Sebastiani:*

In connection with the values presented in Table 7 of Dr Person's paper, I should like to know if he has any analysis of the recycled powders coming from silicon-metal furnaces. In my experience, the recycled silica has many impurities, mainly carbon and various oxides, which would not suggest utilization of rubber products.

By the way, if the silica content should be close to 99 per cent, it could easily pay the cost of the recycling. What is the filter drag for fibreglass, and what is the work temperature?

Dr Person:

With regard to the analysis of fume from the silicon-metal operations, in our experience the silica analysis has generally been above 98 per cent. The impurities that are detrimental to possible re-use are generally larger particles of mix blown from the furnace, of some type that can be separated out either in a precollector or by other means. With regard to recycling, I think we in the U.S. are generally in the position that the cost of pelletizing or producing a pellet of sufficient strength is greater than the cost of gravel delivered to the plant.

With regard to fibreglass filter drag, I believe the number is given in the paper, and our value for the maximum temperature for fibreglass is normally 500°F.

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*Orinoco Chemical Products, Italy.