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Experiences in Developing an Effective Pollution Control System for a Submerged Arc Ferroalloy Furnace Operation

Ref. 7-18 (1972 ed.)

by Renzo Ferrari

This report is not intended to be a collection of technical data. Instead I prefer to present a general view of our experience in air and water pollution problems which had to be solved in our plant at S. Vittore in Switzerland. I shall point out the problems encountered, the design changes made, and lastly, the results attained.

Our company has borne enormous expenses for the installation of pollution control. The amortization and operating costs of these plants, and the limitations imposed on production by the authorities placed us at grave disadvantage in comparison with other ferroalloy producers. We trust, therefore, that in the near future many of our competitors will be forced to assume similar smoke abatement expenses. In common decency, however, it cannot be wished that our colleagues be involved in such an ordeal as we have gone through, such as federal and state investigations, court cases, press and television criticism, inspections and checks of all kinds. We shall be glad if our experience is useful to our colleagues who have to tackle problems of fume control.

GENERAL DATA

The Company Valmoesa is part of a group which has been producing steel and ferro-alloys for many years in Switzerland and Italy. In 1956 our group was granted interesting hydroelectric concessions for two power stations on the left declivity of the Mesolcina Valley (Southern Switzerland) by the Government of Kanton Graubünden. There we constructed a 60 mva power station with a production of about 200 million kwh per year, concentrated during the months of April to November.

The Government intended to favor the industrialization of a still very poor valley. Different companies were interested in the concessions, but we were given preference because we committed ourselves to the Government to build an industrial plant in the Mesolcina Valley which would consume as much as possible the produced electrical energy—in any case, not less than one third of the total.

The hydro-electric concessions were obtained in July, 1956 and Valmoesa founded in June, 1957. We decided on a ferro-alloys production with a high unity consumption of energy and particularly silicon metal and silicon alloys because there is good availability of quartz in the Valley.

The first construction project included the following:

- Three 3-phase 9000 kva furnaces for silicon metal, FeSi 75, and CaSi
- Two single-phase 2500 kva furnaces for FeSiAl, FeSi 45, and FeSi 25
- One 3-phase 4000 kva furnace for steel ingots and castings.

The 9000 kva furnaces were meant to be operated for about eight months of the year during the period of high production of energy from spring through autumn. The single-phase furnaces and the steel furnaces were meant to be operated during the winter with the chief aim of maintaining the labor force.

The construction of the factory and furnaces was to be carried out gradually within about three years, following the erection of the power stations and energy production, through the following program:

- 1958—first 9000 kva Furnace and two single-phase furnaces
- 1960—second 9000 kva Furnace
- 1961—third 9000 kva Furnace and steel furnace

FACTORY SITE

While designing the factory layout, Fig. 2, the following usual technical and economic concepts were kept in mind: railway facilities; highway connection; proximity to power stations; flat land with water availability; living conditions for the labor.

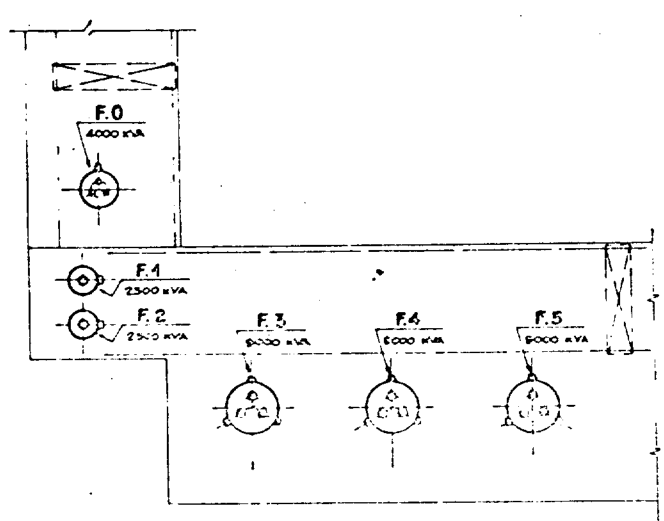

Fig. 1—Construction project 1957.

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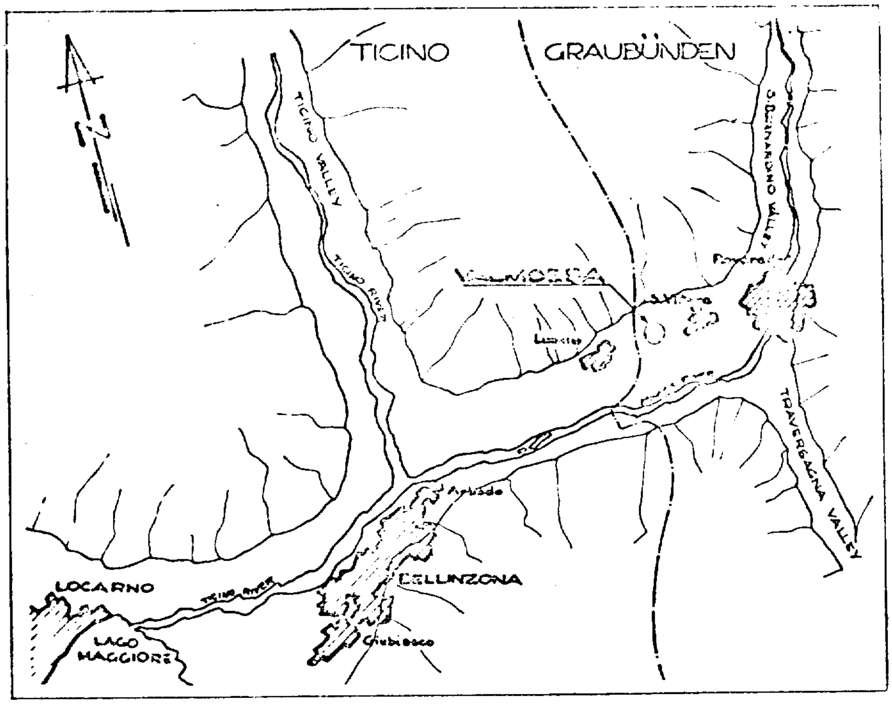


Fig. 2—Site of the factory.

It was considered that a 37-acre plot near S. Vottore was ideal, the Ticino border being 300 yds south and Bellinzona (capital of Kanton Ticino) lying at a distance of 4.3 miles in the same direction.

The chosen area is nicknamed "Siberia" by the local inhibitants, and on inquiring into the reason for this we learned that it is because the area is very cold in winter and hot in summer. This was our only meteorological test and the dismissal of the meteorological and geographical problems was an error to be dearly paid for in due course. As a matter of fact, the wind measurements carried on during the following years showed that, had the factory been positioned just a few kilometers further up the Valley, the smoke problems could have been substantially reduced; I will explain this later.

EXPERIENCE WITH THE SMOKE ABATEMENT PROBLEM

Normally, the fume collection problem in factories starts after years of undisturbed work with free emission of smoke. If the collection facilities have to be adapted to old furnaces in existent buildings, there are many justifications to temper the arbitrary imposition of controls. On the contrary, pollution problems began at Valmoesa immediately upon study of the plant project. As a matter of fact, in the factory building permit dated Feb., 1957, the Home Ministry of Kanton Graubünden documented the following:

> ". . . The utmost attention shall be paid to purifying the fumes. The Company is now cautioned that smoke efflux greater than that of a normal chimney will not be tolerated. The Company is requested to forward a detailed report concerning precautions they consider appropriate to take. . . ".

Previous experience of our group were as follows:

1) 1955-1956: a closed-top 12,000 kva furnace in an Italian factory producing pig iron and Standard FeMn. Desiring to recover the gas in order to use it in an open-hearth furnace, a *Theisen* centrifugal collector was applied. After some difficulties at the start the operation and efficiency were perfect. Gas entered the collector at rate of 2000 Nm^3/h at 800°C and content of solids was 200 gr/Nm^3. Exit gases were 30°C and content of solids 0.015 gr/Nm^3. No complaints were made concerning the dirty waste water of 70 m^3/h which was discharged into a canal.
2) 1953-1954: two open three-phase 6000 kva furnaces in an Italian factory producing standard SiMn. Collection was by a cyclone battery with efficiency about 15% and retention of the dust only bigger than 0.25 mm. These very bad results did not justify the suction costs. The factory was situated in an open valley with a traditionally industrial population. The complaints were modest and therefore the authorities never did insist on any controls. In 1961 the furnaces were shut down for economic reasons.
3) 1952-1954: one three-phase 6000 kva furnace in a factory in Switzerland in Kanton Wallis, producing CaSi 30/60 and FeSi 75. The valley ventilated [illegible] zone with other factories producing aluminum, magnesium, and calcium carbide. Air pollution control was attempted using a water-spray method proposed by two specialized manufacturers with no positive results. The problem was resolved by paying indemnities to the farmers near the factory.

Our previous pollution control experiences proved to be not useful to us in solving our problem at Valmoesa. We believe they had a negative influence, making us insensitive to a tremendous problem which heretofore we thought was readily solvable. The limit stated by the authorities concerning the smoke efflux of the S. Vittore factory to be not greater than that of a normal chimney, cannot be considered as well defined. What are the characteristics of a "normal chimney" and what quantity of fume does it emit? Because at this time we did not properly recognize fume problems, we neglected to define properly this important issue. Our approach was to assure the Government that we would supply gas cleaning equipment for the first 9000 kva furnace and we began immediately to study the problem. It was not at all possible to find literature or reports of experiments on this subject. On the other hand, it was easy to find publicity and promises from equipment manufacturers. Today some technical reports of great interest and useful orientation are available. Ten years ago the situation was very different with only a few furnaces for the production of ferro-alloys making attempts at gas cleaning and purification.

We contacted different manufacturers, keeping in mind installation and operating costs and guaranteed efficiency. We avoid naming the

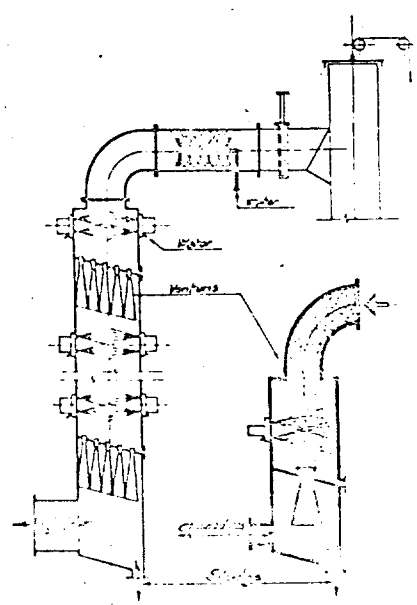


Fig. 3—Venturi cleaner type

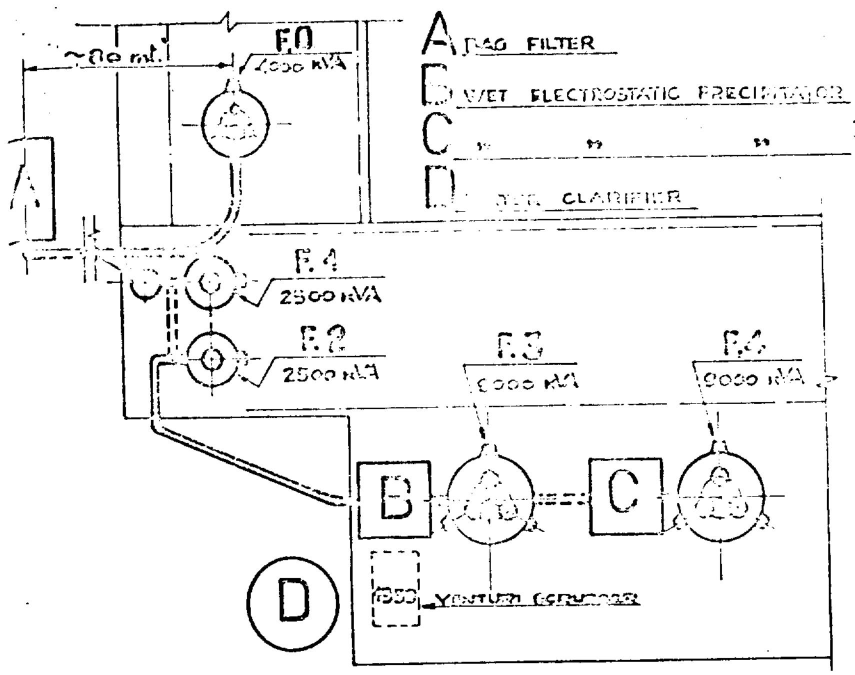


Fig. 4—Furnaces and cleaning equipment 1967.

manufacturers since we do not in-end to publicize those with whom re were successful, nor do we wish criticize those who delivered un-atisfactory plants. However, I asten to add that we received from ll their best cooperation and indeed he difficult technical problem [illegible] financial loss to our suppliers s well as ourselves.

In Feb. 1958, we ordered a cleaner f the Venturi type. The working rinciple of this method and layout f the plant are indicated in Fig. 3. Ve had been able to ascertain the ffectiveness of this filter when deal-ng with fumes from calcium car-ide and steel furnaces; the appli-ation of the same equipment on ilicon alloy furnaces was unknown. n the Conditions of Sale for this leaner for fumes from silicon metal nd FeSi 75, a guarantee was in-luded of a maximum content of a .10 gr/m³ dust in the purified gas.

HISTORY OF PURIFICATION

The Venturi-Scrubber was ready n Sept. 1959. Prior to this, for a ew months in 1958 and from April, 959, the first 3-phase furnace (Fur-ace No. 3) was producing silicon netal: the great accumulation of moke in the Valley was a disagree-ble surprise. During the night a big nushroom of smoke was formed bove the factory; the contrast gainst the greenery of surrounding nountains and the view from Bel-nzona--the smoke being between he town and the rising sun--mag-ified the phenomenon. Faced with he first protest from citizens and uthorities, it was easy to defend ur position by showing the guaran-ees given with the cleaner which as about to be constructed. Our hopes with respect to the efficiency of this cleaner broke down during the 1960 campaign. Only a maxi-mum of 30% dust was intercepted, yet there was an enormous develop-ment of water vapor which worsened the visual situation.

In Aug., 1960, tests were carried out on a wet and a dry gas cleaning plant, both working on the electro-static principle; each plant was capable of handling 10,000 Nm³/hr of gas. The situation was by now very precarious, because it was necessary to consume the energy produced (the power stations were not yet connected with the general distri-bution network), but the authorities refused permission to build addi-tional furnaces until they could as-certain the effectiveness of a new filter. The results obtained by the wet electrostatic filter test were very good; hence the government inspec-tors, present during tests, granted permission to construct the second 9000 kva furnace (Furnace No. 4) using this type of filter.

During campaigns in 1961 and 1962, the Venturi-Scrubber was greatly modified but efficiency im-proved little; in Sept., 1962, we re-ceived a decree from the authorities ordering the cessation of operations of Furnace No. 3 until the Venturi-Scrubber could be replaced by a new and more effective filter; the authorities also demanded the col-lection of fume from the two single-phase furnaces.

Meanwhile, in April, 1962, the new Furnace No. 4 [illegible] working equipped with a wet electrostatic cleaner with very acceptable collec-tion performance. We, therefore, ordered immediately a second larger electrostatic cleaner to service both Furnace No. [illegible] and the two single-phase furnaces. Closed during the 1963 campaign, Furnace No. 3 was connected with the second filter and restored to production in 1964. Despite its larger size, the new filter did not work satisfactorily when the two single-phase furnaces were added to the circuit. There were ab-normalities in respect to collection efficiency, mainly due to aerody-namic problems of suction. Only one single-phase furnace (Furnace No. 2) could be connected to the cleaner and give successful results. The other single-phase furnace—with the authorities' permission—could be kept working without collection, but only if producing alloys giving little gas development such as high carbon ferrochromium.

During 1963 and 1964 new fume collection problems were encoun-tered:

1) The 4000 kva steel furnace had been working since 1961 with an output of 75 tpd in three shifts. In response to a recom-mendation of the authorities, in 1964 we were forced to buy a cleaner for the steel furnace also. We chose a type which has already proved to give good results on other steel furnaces: bags made of glass fibre. The assembling was easy and results were good. Dimensions were built into the filter in order to be able to connect it also with the stack of the single-phase Furnace No. 1.
2) Dust intercepted by the two electrostatic filters was evacu-ated by water. When purchas-ing these wet cleaners, thought was given only to fume collec-tion efficiency; the problem of water pollution was under-esti-mated. On the other hand, several experts assured us that the dust slurry could easily be deposited in decanting basins. I shall later discuss the obstacles to be overcome and the diffi-culties with which we had to cope in relation to natural de-cantation. In 1965 we began operating a water cleaner which gave good results from the be-ginning. Fig. 4 shows the actual situation of furnaces and filter plants.

PRIMARY TECHNICAL DATA ON FURNACES

- *Single-phase furnaces No. 1 and No. 2* (Fig. 5): Carbon or Soderberg-paste electrodes. The electrode di-ameter may vary from 500-700 mm depending on production. Electrode automatic controlled with constant current. Transformer characteris-ties: single-phase rating 2500 kva; primary voltage [illegible] kv; secondary voltage range [illegible] to [illegible] v (in [illegible]-volt steps); secondary amperage range range [illegible] to [illegible] ka.

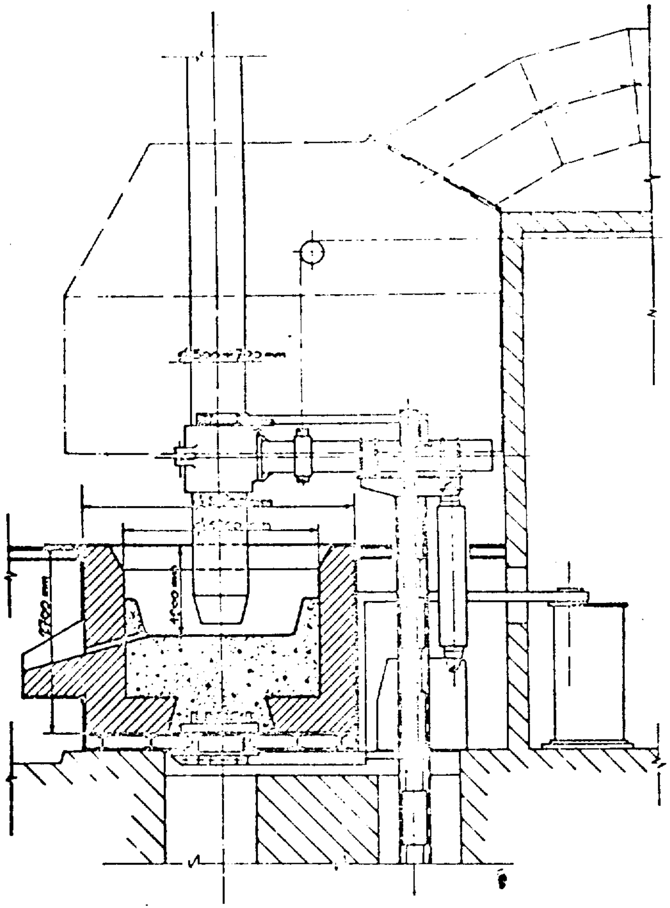


Fig. 5—Single-phase furnace, 2500 kva.

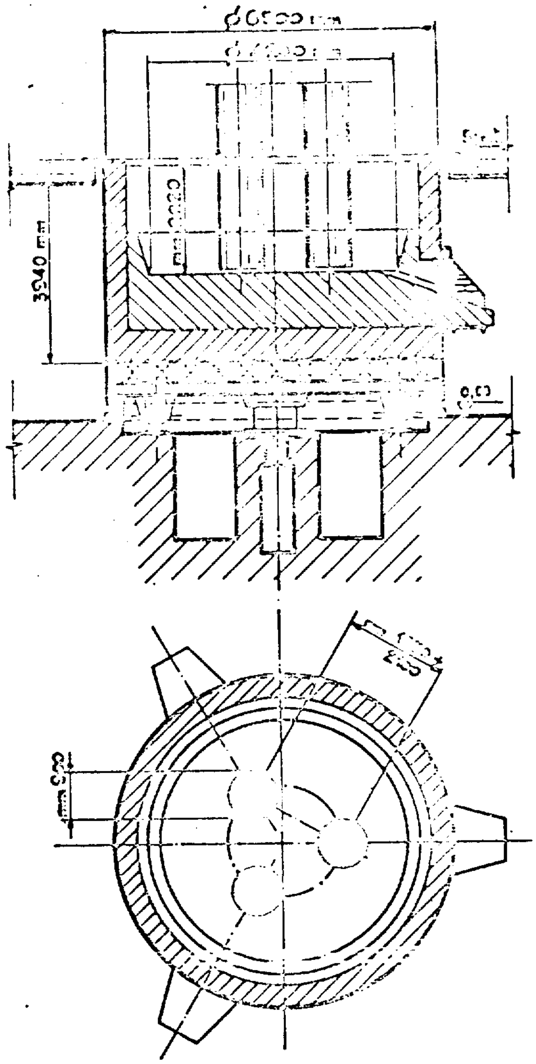


Fig. 6—9000 kva furnace.

Furnace No. 1 produces high carbon ferrochromium and silicon alloys with low percentage of Si; Furnace No. 2 produces FeSi 45, FeSiAl, and SiAl. The quantity of gas at the stack is approximately 20,000 Nm³/h per furnace. The dust content varies greatly depending on production. We consider an average of 0.80 gr/Nm³ for silicon alloys which corresponds to about 16 kg/h = 380 kg/day of dust coming from the furnace stack.

3-phase Furnaces No. 3 and No. 4 (Fig. 6): Shell rotating at variable speed. For the silicon alloys the speed we use is normally 360° during 90 hours; amorphous carbon or Soderberg paste electrodes with on-load electrode slipping; Transformer characteristics: 3-phase 50 cycle; kva rating 9000 kva; primary voltage 50 kv; secondary voltage range 92 to 140 (in 3 volt steps); secondary amperage range 45 to 37 ka.

The furnace always works with power loads higher than the rated one: normally the secondary voltage for various productions is higher than 115 v and the average load is between 8300 and [illegible] kw. The energy consumption is about 210,000 kwh/day. The silicon metal production is about 17,000 kg/day (18.7 N.T.) The production of FeSi 75 is about 23,000 kg/day (25.3 N.T.) Gas at the stack = 85,000-95,000 Nm³/h per furnace. The dust content in the fumes varies, depending on type of production and raw materials used. Even on the same product, content varies considerably according to the conditions of the furnace; producing silicon alloys the average dust content is 1.70 gr/Nm³. This represents about 150 kg/h or 3,600 kg/day per furnace of dust exhausted. Subse-

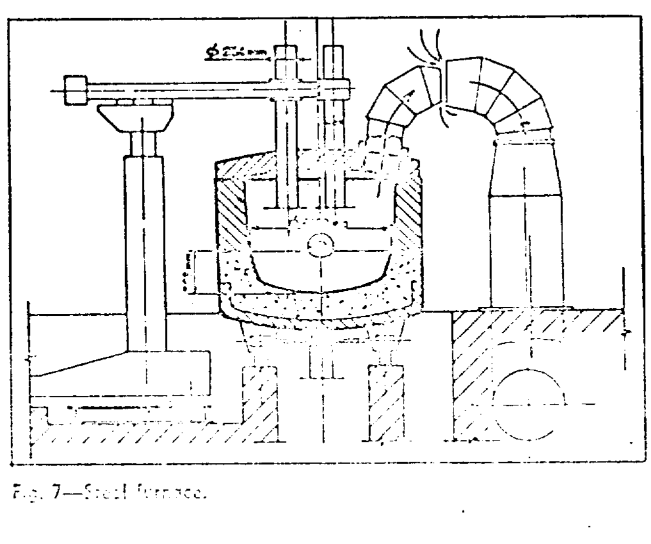


Fig. 7—Steel furnace.

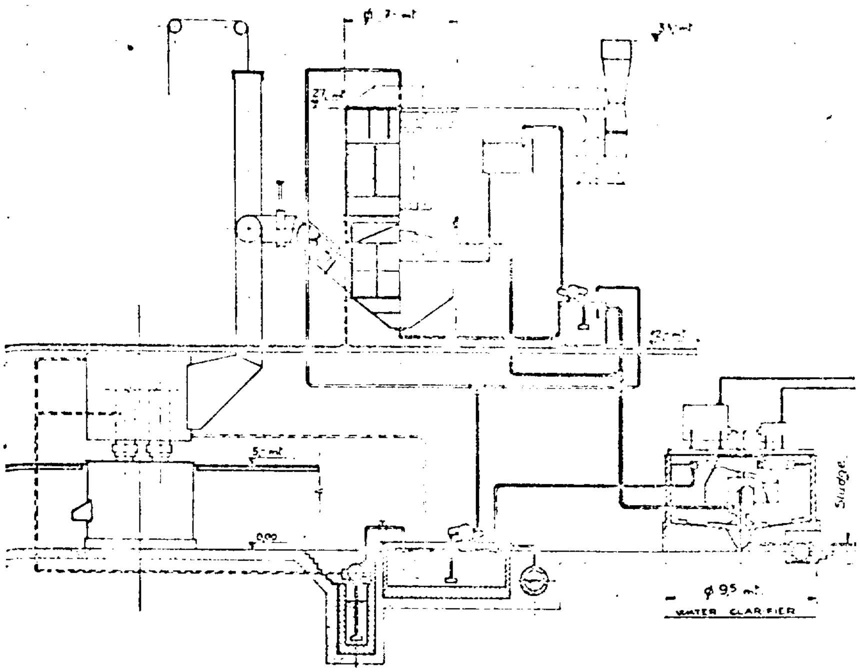


Fig. 8—Electrostatic precipitator and water clarifier.

quently, confirmation of these data will be clearly verified by the quantities of dust collected in the sludge in the decantation basins.

Furnace No. 0 for steel production (Fig 7): Electrical characteristics: 4000 kva transformer 50 cycles; primary voltage 8 kv; secondary voltage range 90 to 240 v (in 17-v steps); secondary amperage range 9 to 10 ka.

The steel production consists of normal grades for castings and special grades for ingots. *Productivity:* 3 tph, smoke at stack uptakes about 8000 Nm^3/hr.

The dust content varies depending on quality of scrap used. We typically produce quantities ranging from 6 to 10 kg/ton of produced steel. We did not measure the content of solid particles in the fumes. Weighing the collected dust, an average of 21 kg/hr (7 kg per ton of produced steel) can be found; therefore, the average content of dust in fumes is about 2.6 gr/Nm^3.

The furnace gases come in the [illegible] the lower part [illegible] [illegible] sprays [illegible] collecting [illegible]. The gases [illegible] up through a layer of glass balls 150 mm in depth. This layer is continuously subjected to a water spray coming from below and with the little balls maintained in constant motion by the force of the gases and high pressure water sprays, a foam is produced which intercepts the biggest dust particles; simultaneously the gas is cooled down to about 35°C and saturated with water vapor. The SiO_2 particles are thoroughly wetted in order to be intercepted more easily by the electro-filter.

The dust deposits on the electrostatic plates and once every half hour a violent shower of water lasting 3 min. removes the deposited dust. During this short period the cleaner efficiency diminishes and the outgoing gas has a dust content three times greater than the normal and rises to the average of 0.1[illegible] gr/Nm^3.

The amount of water required for each filter unit is distributed as follows:

a) Ball washer—This is a closed circuit requiring 30 m^3/h of make-up.
b) Washing of electrostatic plates —18 m^3/h
c) Fume cooling—About 14 m^3/h
d) Evaporation and losses in purified gas—about 6 m^3/h

Each filter requires, therefore, a total of 68 m^3/h of clean water and discharges about 60 m^3/h of dirty water containing suspended intercepted dust. The dirty water can be clarified and returned to the circuit. Also make-up water of about 6 m^3/h is necessary in order to compensate for the losses of water in the sludge from the water clarifier which is wasted in ponds.

The temperature of the water sent back into circuit has a tendency to increase and this can give a negative influence on the efficiency of electrostatic collector which requires rather low and constant gas temperatures (not higher than 60°C). It is therefore necessary to put a cooler at the exit of the water clarifier; it would not be wise to put it at the entrance because the clarifying process of water with flocculation is generally favored by high temperatures.

Water Clarifier. (See Fig. 8). In this [illegible] 130 m^3/h [illegible] from the two electrostatic filters B and C [illegible] No. 2, 3, 4) are treated. The process is based on the suspension of particles in the [illegible] by [illegible].

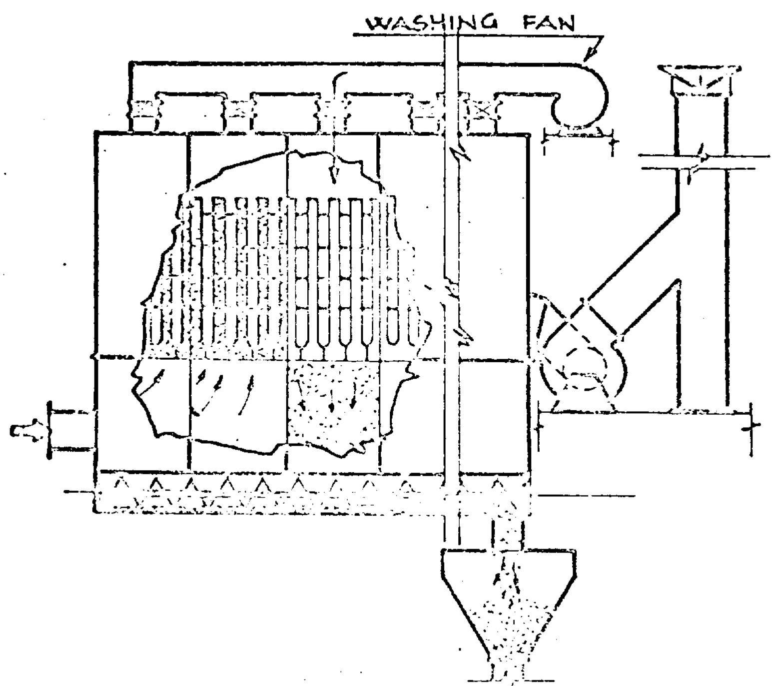


Fig. 9—Bag filter. Capacity at rating: 30,000 Nm^3/h. Active power: suction fan, 70 kw; counterflow fan, 3.0 kw; auxiliary equipment, 3.0 kw; Total, 76.0 kw. Energy consumption, 1200 kwh/day. Efficiency, Guaranteed maximum dust content at exit not greater than 0.050 gr/Nm^3

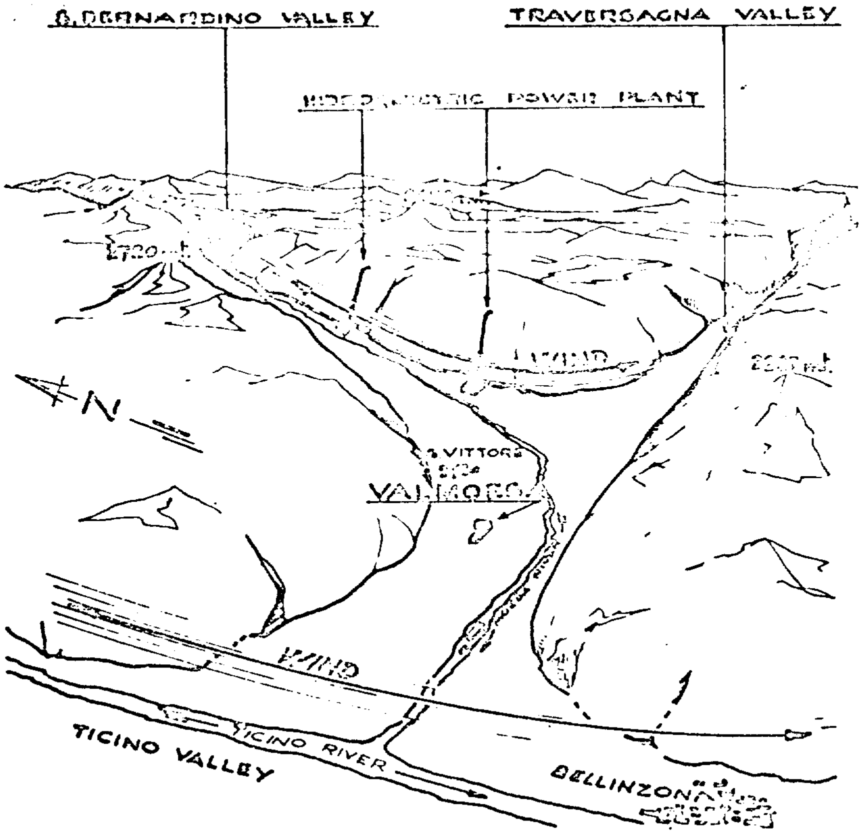


Fig. 10—Direction of wind.

Capacity	150 m^3/h
Energy consumption	600 kwh/day
Reagent	400 to 500 kg/day of hydrated lime $Ca(OH)_2$
Water loss	approximately 12 m^3/h in the sludge

Average characteristics of dirty water at the entrance are, with reference to the production of silicon metal and silicon alloys:

pH value	3 to 5
Dust	2.20 gr/lt (300 kg/h, 7200 kg/day)
Appearance	milky white

The purified water at the cleaner exit has the following characteristics:

pH value	8 to 10
Dust	nearly eliminated
Appearance	clear, slightly yellow-green

The sludge which is accumulated on the bottom of the cleaner is pumped to the natural decantation basins. We have two decantation basins which are used alternately. The sludge solidifies after some months and can be removed and accumulated by means of a power shovel.

The chemical composition of dried sludge depends on the production and is influenced by the addition of $Ca(OH)_2$. During the production of silicon metal, the content of SiO_2 in the dried sludge does not exceed 93%. Unfortunately, we have not found a commercial use for this material and now we have a stock of approximately 6000 tons; the annual production is approximately 2000 tons. The deposit of sludge, however, has proved useful to us. It shows in a persuasive way to skeptics, among both the townspeople and the authorities, the results we have achieved in clarification.

Bag Filter (Fig. 9). The furnace No. 0 for steel production and the single-phase Furnace No. 1 are connected to this filter. This purifier has been installed about 80 meters away from the furnaces in order that the gases cool down naturally along the overhead steel pipe from furnace to filter. Fumes arrive at the filter with a temperature of approximately 120°C.

The filter consists of 360 glass fiber bags (guaranteed up to 280°C) having a total surface of 600 m^2 divided in 6 cells. The cells in turn are excluded from the cleaning process and are cleaned for a period of 30 sec by a pneumatic counterflow which removes the dust deposited on fibres to the collecting storage bin.

Following are some problems connected with the gas cleaning which presented unforseen difficulties:

Location of Plant

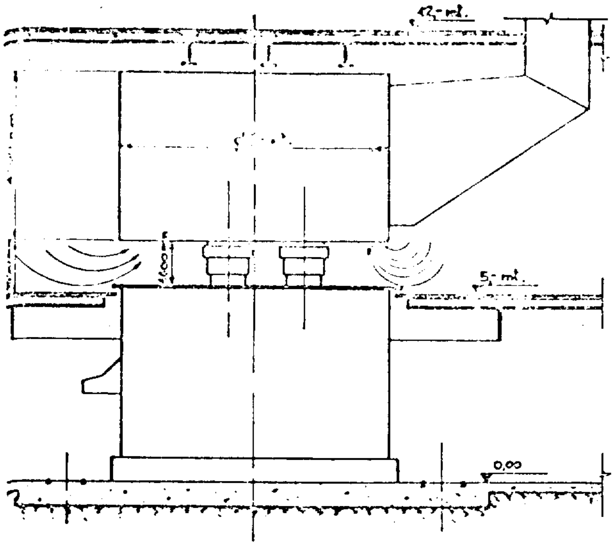
It has already been said that we neglected the study of atmospheric conditions of the site. This was not only a grave fault, but also a grave misfortune. In 1965 we collected data with relation to the wind situation as shown in Fig. 10.

The level ground of S. Vittore, and specifically the area nicknamed "Siberia", is excluded from predominant currents of wind. During summer, when the most difficult problems in pollution occur, the following phenomena can be observed: Complete standstill with no turbulence from 8 p.m. to 8 a.m.; light wind from East (to Bellinzona) from 9 a.m. to 12 a.m.; wind from West from 1 p.m. to 7 p.m.

Depolyment of fume developed during the night is stagnant above the factory like a cloud and in the early morning moves to Ticino; if it reaches the current of wind blow-

Table I. Electrostatic Precipitator.

	B (for Furnace No 2 & 3)	C (for Furnace No. 4)
Capacity	130,000 Nm^3/h	100,000 Nm^3/h
Entering gas temp.	135 to 270°C	135 to 320°C
Temp. of purified gas	30 – 60°C	
Dust content of incoming gas	variable between 0.7 and 4 $gr./Nm^3$	variable between 0.8 and 4.5 $gr./Nm^3$
Guaranteed efficiency	Max. content of 0.100 gr/Nm^3 in the purified gas	
Suction fan power requirements	120 kw	100 kw
Water Pump	90 kw	80 kw
Electrostatic section	40 kw	38 kw
Total power required	250 kw	218 kw
Energy consumption	4000 kwh/day	3700 kwh/day
Water consumption	70 Nm^3/h	65 Nm^3/h
Total pressure drop	150 mm H_2O	
Voltage in electrostatic section	varies between 30-50 KV	
Specific load amperes	0.50 – 0.60 mA/m^2 of plate	



·g. 11—Hood of the 9000 kva furnace.

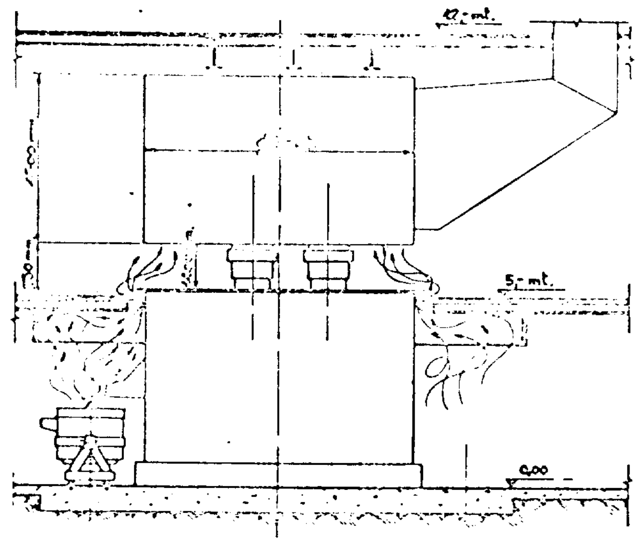


Fig. 12—Collection of fumes.

ng from north to south, the fume ırrives very dispersed, but still ;isible at the city of Bellinzona.

If the factory had been con- ;tructed a few kilometers further ıp the valley, we could have made ıse of the strong air currents in the ian Bernardino and Traversagna 'alleys. Rapid dispersion of fume ertainly would have substantially ɛssened the problems we en- ountered. Perhaps even a modest ficiency of filters would have been ıcceptable under these circum- ances.

onnection of Furnace with Filter

The connection of a completely pen furnace without a hood for the ıme collection, as some are in the 'nited States, would present great roblems. Even with a modern fur- ace equipped with hood and chim- ey, if smoke has to be conducted ɔ a cleaning station, technical and erodynamic problems can be en- ountered.

Constructors of furnaces, and pro- ucers of ferro alloys have treated ıe hood of an open arch furnace ı a stepchild, although they deem necessary to remove smoke from ıe operation and to protect workers ıd equipment from the heat. With ıe addition of adequate gas clean- g to the unit, constructors of fur- aces will have to be directly con- erned with solving the problems of ıs purification as these problems late to furnace design.

Tackling the problems of gas eaning of a furnace, considering ıe volume of air to be exhausted ıd relative power expenses, one els, for example, forced to dimin- h the amount of secondary air ıcked into the hood; but the ıaller the amount of secondary air, e higher the smoke temperature, d therefore the exposed parts of e furnace are going to suffer stress. Unfortunately, at Valmoesa we neglected the study of the problems of the hood and then encountered remarkable difficulties. Only one chimney and a height limitation, (Fig. 11) proved to be insufficient for giving a good and well distributed suction. In order to draw adequate secondary air in the zone opposite the chimney and to prevent the leakage of smoke, a strong suction of air is caused in the zone directly under the chimney entrance; the violent current can generate recirculation under the hood and local increases of heat, which are dangerous for the hood itself, the copper cables and other exposed parts.

Free height of entrance can possibly be varied, but is limited by the operating necessities of the charging machines. We had to modify the hood which now is water cooled. The copper band flexibles have been reduced to a minimum of length commensurate with minimum movement of the electrodes and are enclosed in an air-cooled casing.

Perhaps this problem of connection of furnaces to fume collectors will have as a consequence a new examination of technical and economical possibilities for the complete closure of furnaces, even for the production of silicon alloys. As a matter of fact, there exists some news about tests and attempts tending in this direction.

Once we had eliminated this principal problem, the authorities in 1965 also began to pay attention to the secondary sources of smoke such as outlets from the hood and the development of fume during casting operation. It is not easy to seal the hood perfectly, but it was finally accomplished. We took care that the smoke produced during the casting operation was collected according to the diagram of Fig. 12.

Opening the space between the shell and charging floor to allow the escape of smoke to the main hood has proven to be a simple and effective procedure.

Measurements

During recent years the measurements regarding smoke and water in the factory have been numerous and frequent, especially on the part of the authorities charged with the control. At the beginning we neglected this basic study, resulting in insufficient suction in the first Venturi plant, surprises in the granulation of dust, controversies in regard to efficiency, and so forth.

Amount and analysis of fumes, as well as amounts and physical and chemical analysis of dust, have to be determined with great care. It is advisable to engage specialized and independent Institutes for the acquisition of basic data, more so since the determination of collection efficiency will always have to be committed to an arbitration board.

The producers of ferro alloys know that the operation of a ferro-alloy furnace is very changeable; with the same kind of production and the same power, a blowing furnace develops at least 10 times more dust than a quiet one. But also under normal proceedings the variation of dust quantity is remarkable; for example, with Furnace No. 3 producing silicon metal (load = 8500 kw) we were able to establish by means of continuous sampling during 9 hr extreme values ranging from 0.8 to 4.5 gr/Nm³.

It is understood, therefore, that the average dust amount must be determined by means of statistical sampling. The following table indicates the results of partial analysis of dust, from smoke and purified gas, of samples taken during the production of silicon metal.

Overflow Water

While at present the problem of

Table II. Results of Particle Analysis.

Dust Size		Fumes	Cle[illegible]d [illegible]
		Weight Percentage	
> 100	μφ	1	0
100-50	μφ	7	3
50-25	μφ	10	4
25-10	μφ	12	5
10-5	μφ	4	6
5-2.5	μφ	4	5
2.5-1.0	μφ	4	14
1.0-0.5	μφ	10	24
0.5-0.25	μφ	21	39
0.25-0.15	μφ	13	
< 0.15	μφ	14	
		100	100

water clarification has been solved successfully, I must say that we had many problems and expenses in this area. The River Moesa, running through the valley, has very clear water of a greenish-blue color; it is rich in fish. Three kilometers down the valley the Moesa River flows in the Ticino River which, after 10 kilometers, enters into Lake Maggiore, known for its scenic beauty.

Almost immediately after ordering the wet smoke purifiers, we considered building decantation basins of ample area, confident that the decantation was going to be easy. To our dismay, only the dust of carbon and quartz deposited itself in basins. The fume particles continued right on out the overflow! The dirty water collected in a bottle clarified itself by means of natural sedimentation only after 56 hr!

The River Moesa has a changeable flow. The measurements carried out during 1963 at the side of Valmoesa show, for instance, a minimum of 3.61 m^3/sec. during February and a maximum of 68.3 m^3/sec during June, with a yearly average of 28.3 m^3/sec.

Surveys and measurements were carried out by the authorities during April, 1963 (average flow: 15.8 m^3/sec). Three kilometers down the valley the river water color was still noticeably whitish and dull, although the dirty water inflow represented a very limited percentage: 130 $m^3/h = 0.036\ m^3/sec.$, that is to say 0.23% of the river flow.

When choosing a wet purifying plant the overflow water problem has to be tackled at once, more so because it does not present particular difficulties if carefully studied.

Corrosion

The phenomenon of corrosion of metals was already noted at the Venturi-Scrubber. This purifier was operated only during a limited period and presented us with many collection problems. Owing to these reasons we neglected and also forgot the less pressing question of corrosion.

Constructing the first electrostatic precipitator, it was intended to eliminate the phenomenon of corrosion, covering metals [illegible] paints and correcting the pH value of the water by introduction of soda ash. But paints were insufficient to protect the metal; afterwards it could be noticed that corrosion worked in many parts under the paint layer.

Corrosiveness of the water mainly depends on the presence of sulfurous acid and partly sulfuric, coming from combustion of the sulfur contained in the carbon. It seems that ozone, too, is in the water and is partly responsible for corrosion. The formation of ozone can happen in the electrostatic part with the "black" discharges and even more during small but frequent discharges that can be observed during the washing operation of the electrostatic plates.

Nearly all parts of the two electrostatic precipitators exposed to the dirty water and to the wet gas were reconstructed in stainless steel between 1964 and 1966. In order to limit expenses for material we made remarkable modifications at the construction. After using stainless steel for the principal parts of the cleaning equipment, problems of corrosion were resolved and we have had no further troubles.

Now I should like to suggest other aspects of our experience which, I hope, may be of interest:

Dangers of Fume and of Dirty Waters

The Medical Service of the Labor Head Office officially declared that fumes coming from the stacks of furnace producing ferrosilicon and silicon metal are not dangerous for the health of people, animals and plants, even in zones nearby the factory. Also, dirty waters coming from precipitators and examined by various laboratories did not report to be toxic and had no bacterial effects.

During the writing of this report, the Board of Public Health is about to take samples of the collected sludge and clarified water coming from production of Chromium Silicide. We are watching carefully for the presence of hexavalent Chromium oxide (CrO_3) of which even small quantities can be toxic.

Defense to Avoid Pollution

There exist in Switzerland strict laws imposed by the Confederacy (1955) and by the Kanton (1959 Kanton Graubünden) to protect waters from pollution. On the other hand, we do not yet have laws imposed by the Confederacy or by the Kanton for the protection of the air.

The measures of the Authorities of Kanton Graubünden to force Valmoesa to the collection of fumes was based on the conditions published in the decree for the construction of the factory, to wit: ". . . emanations of fume greater than those of a normal chimney, will not be tolerated. . ".

The Authorities of Graubünden were compelled to proceed very [illegible] pressions of public opinion: petitions, articles in newspapers, television shows and so forth. Moreover, in July, 1964, 13 [illegible] Kanton Ticino [illegible] against Valmoesa, [illegible] of justice for ". . . the closure of the factory if a complete elimination of the smoke should not be achieved . . .". In the meantime, during the long phases of legal proceedings, which is not yet concluded, we made successful progress in purification and are confident of a decision in our favor.

Choice of the Cleaner Type

Our initial choice of the wet electrostatic filter was made for the following reasons:

1. During the trials in Aug., 1960 with the two electrostatic precipitators (a dry and a wet one), greater collection efficiency could be consistently achieved using the wet system.
2. We undervalued the problem of water pollution which would be associated with it.
3. We did not foresee the technical and economical problems in relation to corrosion.
4. There was only limited information about cleaners of the bag type to be used for silicon alloys, and too many unknowns existed to evaluate them properly. The durability of the tissue and the feasibility of detaching the powders deposited on the bags were not well defined. With the pressures upon us, we had no time to conduct trials with a semi-industrial plant of this type.
5. In view of the poor experiences we had with the Venturi type of collector, we disregarded any kind of cleaning based on wet scrubbing techniques.
6. In our program of production were included various qualities of ferroalloys. We were given the advice to use the wet electrostatic cleaner as being more flexible and suitable to various fume particle types.

After many doubts and much soul-searching, we are now of the opinion that our choice was not wrong considering the level of pollution control requested by the authorities and the results we have actually achieved.

Today it is surely easier to study and to find the best cleaner for either a specific fume or for general application. Aside from important theoretical studies published in recent years, there exists now an experience with data and results which should be available. According to an inquiry I made, today there are about 450 electric [illegible] furnaces for ferroalloys in the world. About 25 of them have [illegible] cleaners or will be connected within

Fig. 13—Situation in 1962.

Fig. 14—Situation in 1967.

1967 to various types of filters. Interests of furnace constructors and cautiousness of ferroalloys producers have not yet permitted a useful comparison of the real data in reference to gas cleaning in the industry. It would certainly be proper for an international association, with social aims, to collect and correlate these various data for the most effective approach to this serious pollution problem.

However, many constructors of cleaning equipment have acquired a remarkable amount of experience, and owing to the sacrifices of their first customers, they are now able to propose cleaning systems having high efficiency and assured operating results.

Encouraged by the experience which was developed with various cleaners, and wanting to avoid the associated problem of further water pollution, we thought it suitable to use the dry cleaner with fibre bags for collection of fumes from the steel furnace. Also in other factories of our group we are now assembling three electrostatic filters (bag type) for steel furnaces; one of these furnaces has a heat size of 70 tons.

Achieved Results (Figs. 13-14)

1. Clarification of waters is completely satisfactory. We continue the studies, however, in order to reduce the important expenses and to save costs of chemical reagents.
2. Excellent efficiency of the bag filters in cleaning gas on the steel furnace and the single-phase Furnace No. 1. Stack effluent gases are not visible. We have not yet exact data about durability of the bags. We had to replace the first set of bags after approximately 7000 operating hours; nearly all bags presented at the same time a creasing of tissue. This phenomenon was not due to the use, but to the mechanical assembly. Upon inspection in August of this year, after 3000 operating hr with the second set, the state of the tissue is still perfect.
3. The efficiency of the electrostatic precipitators after approximately 11 months is constant. We measure normal contents of gas; during washing operation (3 min. each half hour) the content increases to approximately 0.150 gr/Nm³. With this exception, the guarantee of 0.100 gr/Nm³ maximum has been achieved. The authorities are satisfied and accepted these results; however, they have invited us to try to improve the cleaning during the washing operation.

At the end of this 1967 furnace campaign we shall make some minor modifications, hoping to be able to decrease the washing operation cycle to one minute.

Cleaned gas effluent from the production of silicon metal and of ferrosilicon 75 can be described as follows: Slightly blue and nearly invisible at a dust content of 0.050 gr/Nm³; 0.100 gr/Nm³ already shows the existence of a furnace; 0.150 gr/Nm³ yields a gas of whitish-gray color and the fumes disperse at a distance of some hundred meters from the stack.

Efficiency of cleaning can be calculated as $\frac{A - B}{A}$, wherein A = content of dust in the furnace, B = content of dust in the cleaned gas.

Average contents measured in our filters are as follows:

$$A = 1.70 \text{ gr/Nm}^3, \quad B = 0.080 \text{ gr/Nm}^3$$

The average efficiency is therefore

$$\frac{1.70 - 0.08}{1.70} = 95.5\%$$

It seems to us very dificult to surpass this efficiency. I point out that the percentage efficiency has a limited importance as far as the visibility of effluent gas is concerned. Despite a high efficiency of purification, unsatisfactory results with regard to visibility of the discharged fume are possible; for example, if the dust of the fume is 4 gr/Nm³ and in the cleaned gas 0.200 gr/Nm³, efficiency is high (4.00—0.200/4.00 = 95%), but the result considered in point of view of visibility cannot be accepted. Effective filter performance can be best evaluated by the measure of its maintaining the maximum content of 0.100 gr/Nm³ in the cleaned gas, notwithstanding frequent variations in the dust content of the fume. We get this result, even if the dust content varies from 0.85 to 4.5 gr/Nm³.

During the first years interruptions of electrostatic precipitators were frequent; we had breakage of electrostatic wires, electric discharges, water stoppages, and high use of single parts owing to corrosion. These accidents hurt us badly because the authorities would not allow operation of furnaces without collection, even for a short period. We therefore have had to apply the rule: "If the filter is stopped, the furnaces have to be stopped." I should like to point out that in our factory are installed some indicators, sealed by authorities; these meters register the operation of filters and furnaces!

We studied and worked hard in order to eliminate the reasons for these failures and at last we have reached good results. During the last seven months the electrostatic filters have worked continuously without trouble. Once a week during the night from Friday to Saturday, we stop each filter for approximately two hours for control, cleaning and maintenance; by approval of the authorities, this work can be executed without stopping the furnace; we only have to reduce the load.

Among the results we reached I also have to acknowledge that our technicians now pay more attention to a good operating process. In order to reduce the fume, during our long years of difficulties, we tried to influence the operation of the furnace, paying [illegible] attention to the quality of mix preparation and blending, depth of the electrodes, electrical conditions, and the size and quality of raw material. All these factors can have great influence on the dust content of the fume.

Costs of Cleaning Equipment

The great difficulties we encountered brought enormous costs for the installations. From the beginning of the problem until March, 1967, we spent a total amount of $1.2 million. Costs of construction, modifications, studies and trials are included in this amount. General expenses, such as administrative costs, lawyers and experts' opinions for the process, costs for measurements and so forth, and indirect costs for loss of production are not considered. Amortization of this impressive amount is a great financial and technical problem; moreover, we do not know the real period we need to amortize different parts of the various installations.

Expenses we incurred cannot be directly applied to other factories which are considering the installation of cleaning equipment. We do estimate that to install equipment comparable to what we now have would not exceed $600,000. In this sum are included all expenses for the two electrostatic precipitators, the bag filters, the water clarifier and the decantation basins for sludge.

Working Costs

Unfortunately we are not yet prepared to give exact information about this important subject. We have had the equipment in service for only about a year and we think we need another year to define operating and maintenance expenses. The effective consumption of water and material for the collection of fume was indicated above and it is easy to derive consequent costs therefrom. One technician and three workmen per day are actually involved in operating and maintaining all filters; however, we are centralizing the switchboards in order to reduce this part of labor to only two men per day.

A very important part of wet electrostatic air clarification costs is the "flocculant" used to treat the waste water. Among the various types on the market, we have found a material that costs about $1.50/lb to be the most suitable.

Actually, operating expenses for our entire pollution control system amount to $140/day and we hope to reduce it to $90/day.

CONCLUSION

I wish to conclude this report by advising my colleagues not to undervalue and not to try to escape from the smoke abatement problem when claims and requests from authorities begin. The technical study should begin promptly and be well thought out. Injunctions and avalanches of claims can cause bungled studies and decisions. I highly recommend the approach of entrusting the exact determination of the principal data of the problem to independent institutes specialized in this field. In this way defense against claims and requests of authorities can better be accomplished and a comprehensive study will be, in any case, the best base to resolve the real problem. We made our initial study without qualified assistance with the result that our errors and failures, made during the long period in which we acquired our experience, were interpreted by public opinion for many years as a direct and wilful act made with malice aforethought. While we can admit a certain passiveness at the beginning, since 1960 we honestly and with enthusiasm have done everything possible to achieve the best level of pollution control at Valmoesa.

Finally, last year, the authorities acknowledge that "Valmoesa did everything for pollution control which is possible to do within the actual limits of the most advanced technology."

Many former enemies, among them vociferous and violent journalists, now treat us with comprehension and friendship. We can define ourselves "the most purified and inspected ferro-alloy factory in the world"; however, we would be pleased to cede as soon as possible this honorary diploma to other competitors of ours!

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Experiences in Developing an Effective Pollution Control System for a Submerged Arc Ferroalloy Furnace Operation

REF. 5 7.4-2

by Renzo Ferrari

This report is not intended to be a collection of technical data. Instead I prefer to present a general view of our experience in air and water pollution problems which had to be solved in our plant at S. Vittore in Switzerland. I shall point out the problems encountered, the design changes made, and lastly, the results attained.

Our company has borne enormous expenses for the installation of pollution control. The amortization and operating costs of these plants, and the limitations imposed on production by the authorities placed us at a grave disadvantage in comparison with other ferroalloy producers. We trust, therefore, that in the near future many of our competitors will be forced to assume similar smoke abatement expenses. In common decency, however, it cannot be wished that our colleagues be involved in such an ordeal as we have gone through, such as federal and state investigations, court cases, press and television criticism, inspections and checks of all kinds. We shall be glad if our experience is useful to our colleagues who have to tackle problems of fume control.

GENERAL DATA

The Company Valmoesa is part of a group which has been producing steel and ferro-alloys for many years in Switzerland and Italy. In 1956 our group was granted interesting hydroelectric concessions for two power stations on the left declivity of the Mesolcina Valley (Southern Switzerland) by the Government of Kanton Graubünden. There we constructed a 60 mva power station with a production of about 200 million kwh per year, concentrated during the months of April to November.

The Government intended to favor the industrialization of a still very poor valley. Different companies were interested in the concessions, but we were given preference because we committed ourselves to the Government to build an industrial plant in the Mesolcina Valley which would consume as much as possible the produced electrical energy—in any case, not less than one third of the total.

The hydro-electric concessions were obtained in July, 1956 and Valmoesa founded in June, 1957. We decided on a ferro-alloys production with a high unity consumption of energy and particularly silicon metal and silicon alloys because there is good availability of quartz in the Valley.

The first construction project included the following:

- Three 3-phase 9000 kva furnaces for silicon metal, FeSi 75, and CaSi
- Two single-phase 2500 kva furnaces for FeSiAl, FeSi 45, and FeSi 25
- One 3-phase 4000 kva furnace for steel ingots and castings.

The 9000 kva furnaces were meant to be operated for about eight months of the year during the period of high production of energy from spring through autumn. The single-phase furnaces and the steel furnaces were meant to be operated during the winter with the chief aim of maintaining the labor force.

The construction of the factory and furnaces was to be carried out gradually within about three years, following the erection of the power stations and energy production, through the following program:

- 1958—first 9000 kva Furnace and two single-phase furnaces
- 1960—second 9000 kva Furnace
- 1961—third 9000 kva Furnace and steel furnace

FACTORY SITE

While designing the factory layout, Fig. 2, the following usual technical and economic concepts were kept in mind: railway facilities; highway connection; proximity to power stations; flat land with water availability; living conditions for the labor.

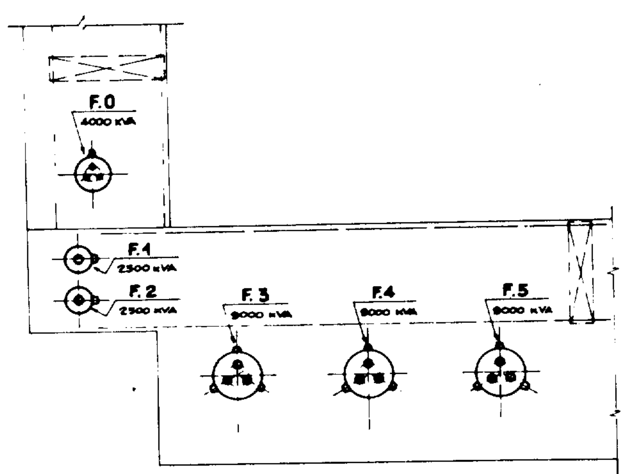

Fig. 1—Construction project 1957.

RENZO FERRARI is general manager of Valmoesa, S. Vittore/Grigioni, Switzerland.

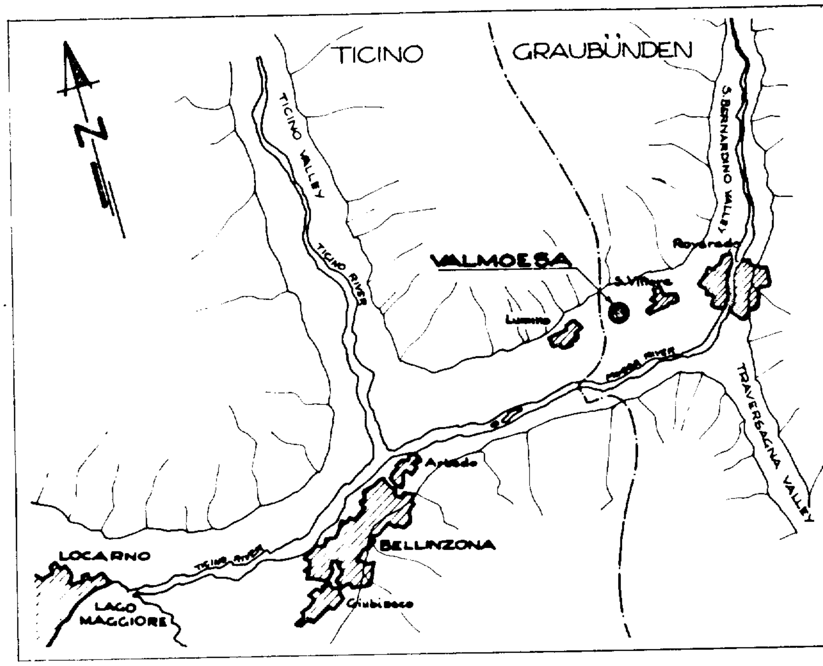

Fig. 2—Site of the factory.

It was considered that a 37-acre plot near S. Vottore was ideal, the Ticino border being 300 yds south and Bellinzona (capital of Kanton Ticino) lying at a distance of 4.3 miles in the same direction.

The chosen area is nicknamed "Siberia" by the local inhibitants, and on inquiring into the reason for this we learned that it is because the area is very cold in winter and hot in summer. This was our only meteorological test and the dismissal of the meteorological and geographical problems was an error to be dearly paid for in due course. As a matter of fact, the wind measurements carried on during the following years showed that, had the factory been positioned just a few kilometers further up the Valley, the smoke problems could have been substantially reduced; I will explain this later.

EXPERIENCE WITH THE SMOKE ABATEMENT PROBLEM

Normally, the fume collection problem in factories starts after years of undisturbed work with free emission of smoke. If the collection facilities have to be adapted to old furnaces in existent buildings, there are many justifications to temper the arbitrary imposition of controls. On the contrary, pollution problems began at Valmoesa immediately upon study of the plant project. As a matter of fact, in the factory building permit dated Feb., 1957, the Home Ministry of Kanton Graubünden documented the following:

"... The utmost attention shall be paid to purifying the fumes. The Company is now cautioned that smoke efflux greater than that of a normal chimney will not be tolerated. The Company is requested to forward a detailed report concerning precautions they consider appropriate to take. . . ".

Previous experience of our group were as follows:

1) 1955-1956: a closed-top 12,000 kva furnace in an Italian factory producing pig iron and Standard FeMn. Desiring to recover the gas in order to use it in an open-hearth furnace, a *Theisen* centrifugal collector was applied. After some difficulties at the start the operation and efficiency were perfect. Gas entered the collector at rate of 2000 Nm³/h at 800°C and content of solids was 200 gr/Nm³. Exit gases were 30°C and content of solids 0.015 gr/Nm³. No complaints were made concerning the dirty waste water of 70 m³/h which was discharged into a canal.
2) 1953-1954: two open three-phase 6000 kva furnaces in an Italian factory producing standard SiMn. Collection was by a cyclone battery with efficiency about 15% and retention of the dust only bigger than 0.25 mm. These very bad results did not justify the suction costs. The factory was situated in an open valley with a traditionally industrial population. The complaints were modest and therefore the authorities never did insist on any controls. In 1961 the furnaces were shut down for economic reasons.
3) 1952-1954: one three-phase 6000 kva furnace in a factory in Switzerland in Kanton Wallis, producing CaSi 30/60 and FeSi 75. The valley ventilated well and this was an industrial zone with other factories producing aluminum, magnesium and calcium carbide. Air pollution control was attempted using a water-spray method proposed by two specialized manufacturers with no positive results. The problem was resolved by paying indemnity to the farmers near the factory.

Our previous pollution control experiences proved to be not useful to us in solving our problem at Valmoesa. We believe they had a negative influence, making us insensitive to a tremendous problem which heretofore we thought was readily solvable. The limit stated by the authorities concerning the smoke efflux of the S. Vittore factory to be not greater than that of a normal chimney, cannot be considered as well defined. What are the characteristics of a "normal chimney" and what quantity of fume does it emit? Because at this time we did not properly recognize fume problems we neglected to define properly this important issue. Our approach was to assure the Government that we would supply gas cleaning equipment for the first 9000 kva furnace and we began immediately to study the problem. It was not at all possible to find literature or reports of experiments on this subject. On the other hand, it was easy to find publicity and promises from equipment manufacturers. Today some technical reports of great interest and useful orientation are available. Ten years ago the situation was very different with only a few furnaces for the production of ferro-alloys making attempts at gas cleaning and purification.

We contacted different manufacturers, keeping in mind installation and operating costs and guaranteed efficiency. We avoid naming the

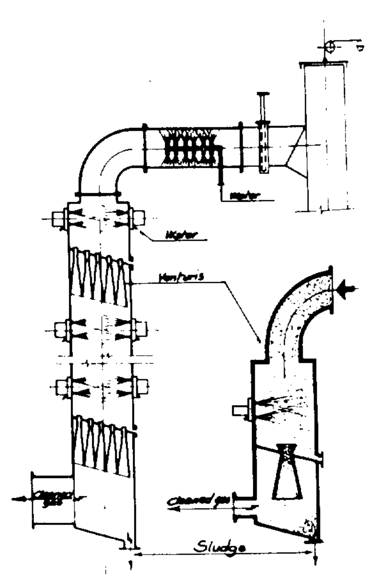

Fig. 3—Venturi cleaner type.

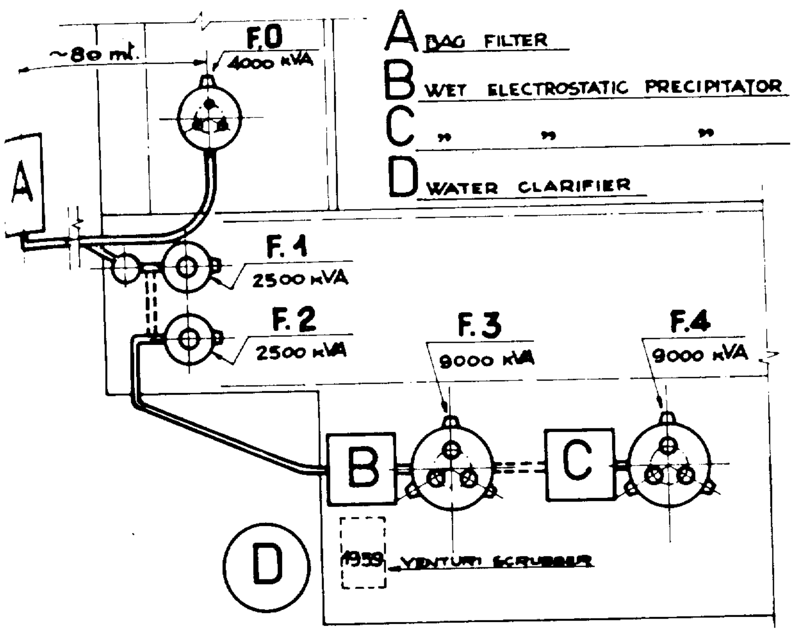

Fig. 4—Furnaces and cleaning equipment 1967.

manufacturers since we do not intend to publicize those with whom we were successful, nor do we wish to criticize those who delivered unsatisfactory plants. However, I hasten to add that we received from all their best cooperation and indeed the difficult technical problem caused financial loss to our suppliers as well as ourselves.

In Feb. 1958, we ordered a cleaner of the Venturi type. The working principle of this method and layout of the plant are indicated in Fig. 3. We had been able to ascertain the effectiveness of this filter when dealing with fumes from calcium carbide and steel furnaces; the application of the same equipment on silicon alloy furnaces was unknown. In the Conditions of Sale for this cleaner for fumes from silicon metal and FeSi 75, a guarantee was included of a maximum content of a 10 gr/m³ dust in the purified gas.

HISTORY OF PURIFICATION

The Venturi-Scrubber was ready in Sept. 1959. Prior to this, for a few months in 1958 and from April, 1959, the first 3-phase furnace (Furnace No. 3) was producing silicon metal, the great accumulation of smoke in the Valley was a disagreeable surprise. During the night a big mushroom of smoke was formed above the factory; the contrast against the greenery of surrounding mountains and the view from Bellinzona—the smoke being between the town and the rising sun—magnified the phenomenon. Faced with the first protest from citizens and authorities, it was easy to defend our position by showing the guarantees given with the cleaner which was about to be constructed. Our hopes with respect to the efficiency of this cleaner broke down during the 1960 campaign. Only a maximum of 30% dust was intercepted, yet there was an enormous development of water vapor which worsened the visual situation.

In Aug., 1960, tests were carried out on a wet and a dry gas cleaning plant, both working on the electrostatic principle; each plant was capable of handling 10,000 Nm³/hr of gas. The situation was by now very precarious, because it was necessary to consume the energy produced (the power stations were not yet connected with the general distribution network), but the authorities refused permission to build additional furnaces until they could ascertain the effectiveness of a new filter. The results obtained by the wet electrostatic filter test were very good; hence the government inspectors, present during tests, granted permission to construct the second 9000 kva furnace (Furnace No. 4) using this type of filter.

During campaigns in 1961 and 1962, the Venturi-Scrubber was greatly modified but efficiency improved little; in Sept., 1962, we received a decree from the authorities ordering the cessation of operations of Furnace No. 3 until the Venturi-Scrubber could be replaced by a new and more effective filter; the authorities also demanded the collection of fume from the two single-phase furnaces.

Meanwhile, in April, 1962, the new Furnace No. 4 started working equipped with a wet electrostatic cleaner with very acceptable collection performance. We, therefore, ordered immediately a second larger electrostatic cleaner to service both Furnace No. 3 and the two single-phase furnaces. Closed during the 1963 campaign, Furnace No. 3 was connected with the second filter and restored to production in 1964. Despite its larger size, this new filter did not work satisfactorily when the two single-phase furnaces were added to the circuit. There were abnormalities in respect to collection efficiency, mainly due to aerodynamic problems of suction. Only one single-phase furnace (Furnace No. 2) could be connected to the cleaner and give successful results. The other single-phase furnace—with the authorities' permission—could be kept working without collection, but only if producing alloys giving little gas development such as high carbon ferrochromium.

During 1963 and 1964 new fume collection problems were encountered:

1) The 4000 kva steel furnace had been working since 1961 with an output of 75 tpd in three shifts. In response to a recommendation of the authorities, in 1964 we were forced to buy a cleaner for the steel furnace also. We chose a type which has already proved to give good results on other steel furnaces: bags made of glass fibre. The assembling was easy and results were good. Dimensions were built into the filter in order to be able to connect it also with the stack of the single-phase Furnace No. 1.
2) Dust intercepted by the two electrostatic filters was evacuated by water. When purchasing these wet cleaners, thought was given only to fume collection efficiency; the problem of water pollution was under-estimated. On the other hand, several experts assured us that the dust slurry could easily be deposited in decanting basins. I shall later discuss the obstacles to be overcome and the difficulties with which we had to cope in relation to natural decantation. In 1965 we began operating a water cleaner which gave good results from the beginning. Fig. 4 shows the actual situation of furnaces and filter plants.

PRIMARY TECHNICAL DATA ON FURNACES

Single-phase furnaces No. 1 and No. 2 (Fig. 5): Carbon or Soderberg-paste electrodes. The electrode diameter may vary from 500-700 mm depending on production. Electrode automatic controlled with constant current. Transformer characteristics: single-phase rating 2500 kva; primary voltage 50 kv; secondary voltage range 50 to 110 v (in 5-volt steps); secondary amperage range range 30 to 25 ka.

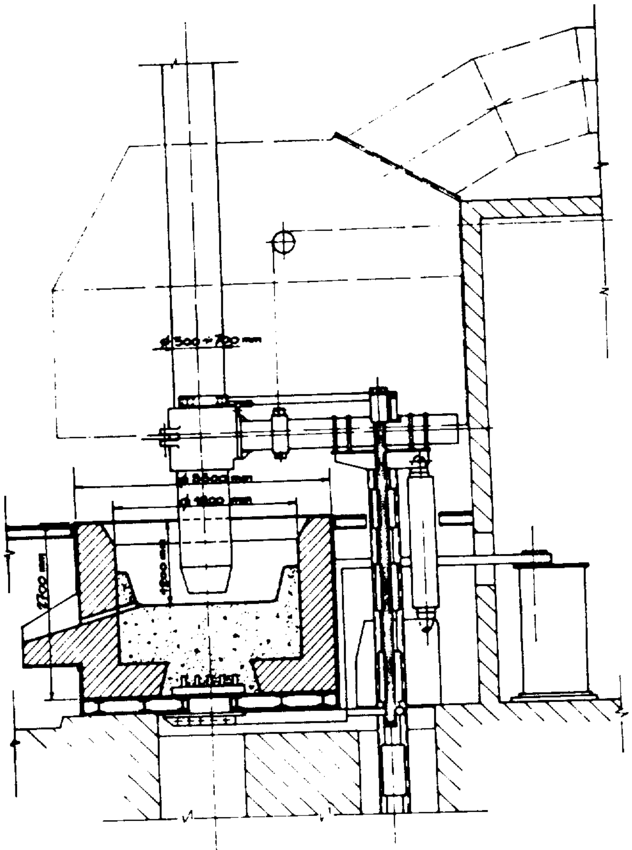

Fig. 5—Single-phase furnace, 2500 kva.

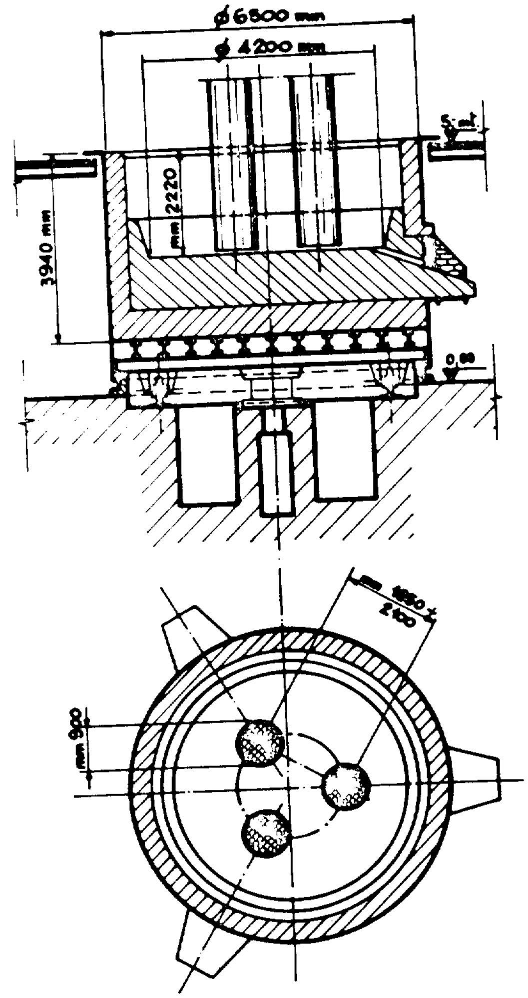

Fig. 6—9000 kva furnace.

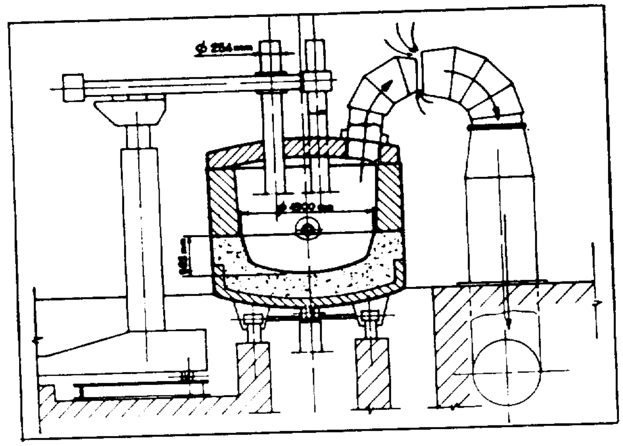

Fig. 7—Steel furnace.

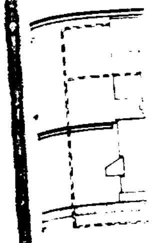

Fig. 8—Ele

Furnace No. 1 produces high carbon ferrochromium and silicon alloys with low percentage of Si; Furnace No. 2 produces FeSi 45, FeSiAl, and SiAl. The quantity of gas at the stack is approximately 20,000 Nm^3/h per furnace. The dust content varies greatly depending on production. We consider an average of 0.80 gr/Nm^3 for silicon alloys which corresponds to about 16 kg/h = 380 kg/day of dust coming from the furnace stack.

3-phase Furnaces No. 3 and No. 4 (Fig. 6): Shell rotating at variable speed. For the silicon alloys the speed we use is normally 360° during 90 hours; amorphous carbon or Soderberg paste electrodes with on-load electrode slipping; Transformer characteristics: 3-phase 50 cycle; kva rating 9000 kva; primary voltage 50 kv; secondary voltage range 92 to 140 (in 3 volt steps); secondary amperage range 45 to 37 ka.

The furnace always works with power loads higher than the rated one: normally the secondary voltage for various productions is higher than 115 v and the average load is between 8300 and 9000 kw. The energy consumption is about 210,000 kwh/day. The silicon metal production is about 17,000 kg/day (18.7 N.T.) The production of FeSi 75 is about 23,000 kg/day (25.3 N.T.) Gas at the stack = 85,000-95,000 Nm^3/h per furnace. The dust content in the fumes varies, depending on type of production and raw materials used. Even on the same product, content varies considerably according to the conditions of the furnace; producing silicon alloys the average dust content is 1.70 gr/Nm^3. This represents about 150 kg/h or 3,600 kg/day per furnace of dust exhausted. Subse-

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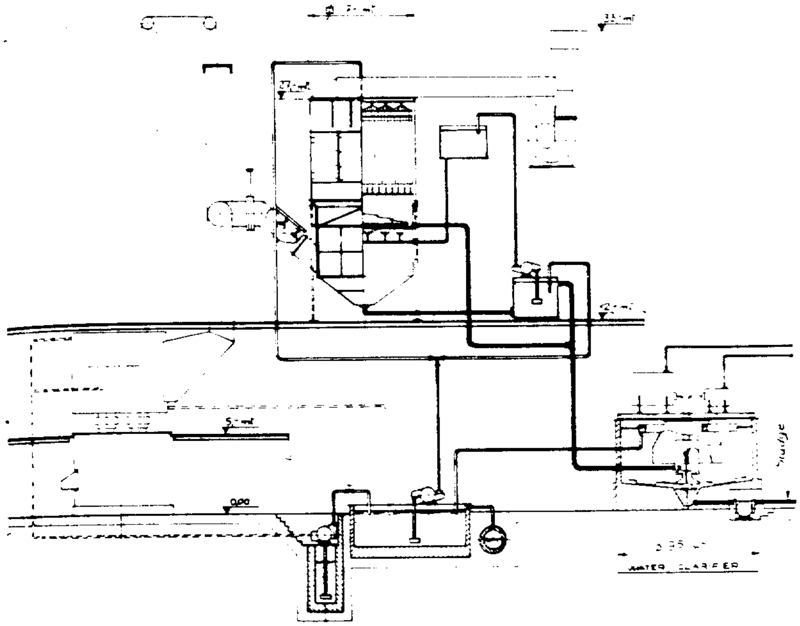

Fig. 8—Electrostatic precipitator and water clarifie..

quently, confirmation of these data will be clearly verified by the quantities of dust collected in the sludge in the decantation basins.

Furnace No. 0 for steel production (Fig 7): Electrical characteristics: 4000 kva transformer 50 cycles: primary voltage 8 kv: secondary voltage range 90 to 240 v in 17-v steps); secondary amperage range 9 to 10 ka.

The steel production consists of normal grades for castings and special grades for ingots. *Productivity*: 3 tph. smoke at stack uptakes about 8000 Nm³/hr.

The dust content varies depending on quality of scrap used. We typically produce quantities ranging from 6 to 10 kg/ton of produced steel. We did not measure the content of solid particles in the fumes. Weighing the collected dust, an average of 21 kg/hr (7 kg per ton of produced steel) can be found: therefore, the average content of dust in fumes is about 2.6 gr/Nm³.

The furnace gases come in through the lower part of the filter after having been cooled down by water sprays in the inclined section of the collecting main pipe. The gases pass up through a layer of glass balls 150 mm in depth. This layer is continuously subjected to a water spray coming from below and with the little balls maintained in constant motion by the force of the gases and high pressure water sprays, a foam is produced which intercepts the biggest dust particles: simultaneously the gas is cooled down to about 35°C and saturated with water vapor. The SiO_2 particles are thoroughly wetted in order to be intercepted more easily by the electro-filter.

The dust deposits on the electrostatic plates and once every half hour a violent shower of water lasting 3 min. removes the deposited dust. During this short period the cleaner efficiency diminishes and the outgoing gas has a dust content three times greater than the normal and rises to the average of 0.150 gr/Nm³.

The amount of water required for each filter unit is distributed as follows:

a) Ball washer—This is a closed circuit requiring 30 m³/h of make-up.
b) Washing of electrostatic plates —18 m³/h
c) Fume cooling—About 14 m³/h
d) Evaporation and losses in purified gas—about 6 m³/h

Each filter requires, therefore, a total of 68 m³/h of clean water and discharges about 60 m³/h of dirty water containing suspended intercepted dust. The dirty water can be clarified and returned to the circuit. Also make-up water of about 6 m³/h is necessary in order to compensate for the losses of water in the sludge from the water clarifier which is wasted in ponds.

The temperature of the water sent back into circuit has a tendency to increase and this can give a negative influence on the efficiency of electrostatic collector which requires rather low and constant gas temperatures (not higher than 60°C). It is therefore necessary to put a cooler at the exit of the water clarifier: it would not be wise to put it at the entrance because the clarifying process of water with flocculation is generally favored by high temperatures.

Water Clarifier. (See Fig. 8). In this installation dirty waters (abt. 130 m³/h) coming from the two electrostatic filters B and C (Furnaces No. 2, 3, 4) are treated. The process is based on the suspension of particles in the sludge by flocculation.

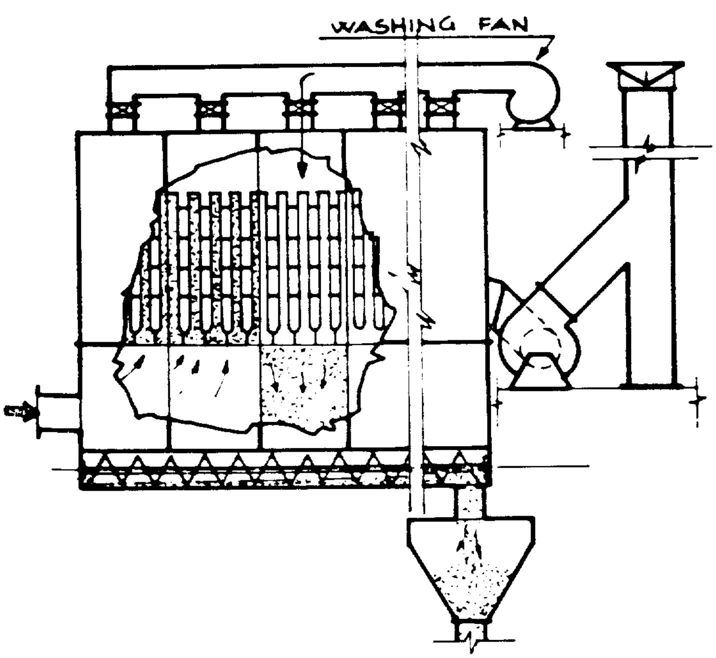

Fig. 9—Bag filter. Capacity at rating: 30,000 Nm³/h. Active power: suction fan, 70 kw; counterflow fan, 3.0 kw; auxiliary equipment, 3.0 kw; Total, 76.0 kw. Energy consumption, 1200 kwh/day. Efficiency, Guaranteed maximum dust content at exit not greater than 0.050 gr/Nm³.

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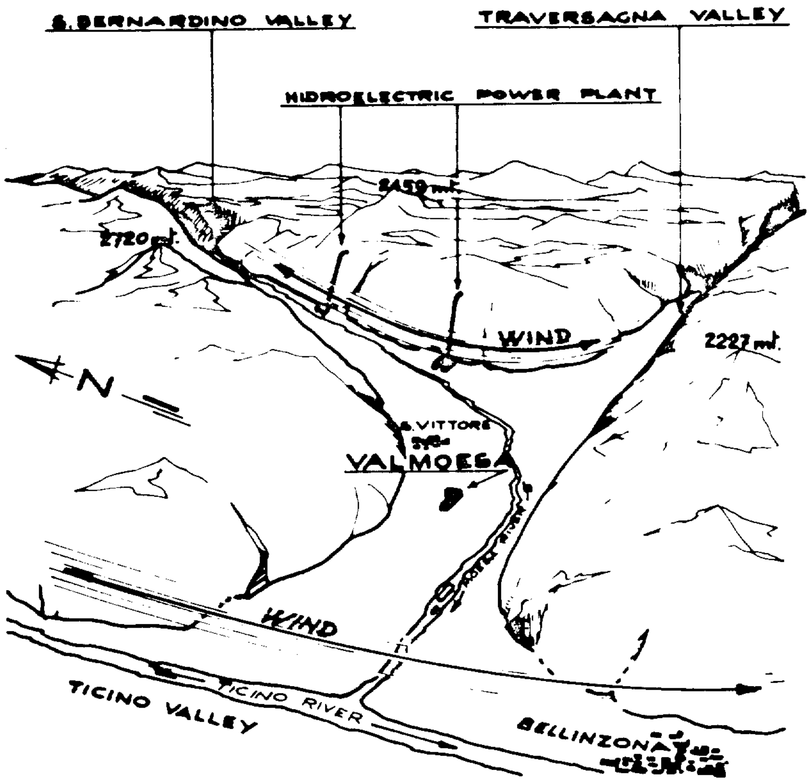

Fig. 10—Direction of wind.

Capacity	150 m^3/h
Energy consumption	600 kwh/day
Reagent	400 to 500 kg/day of hydrated lime $Ca(OH)_2$
Water loss	approximately 12 m^3/h in the sludge

Average characteristics of dirty water at the entrance are, with reference to the production of silicon metal and silicon alloys:

pH value	3 to 5
Dust	2.20 gr/lt (300 kg/h, 7200 kg/day)
Appearance	milky white

The purified water at the cleaner exit has the following characteristics:

pH value	8 to 10
Dust	nearly eliminated
Appearance	clear, slightly yellow-green

The sludge which is accumulated on the bottom of the cleaner is pumped to the natural decantation basins. We have two decantation basins which are used alternately. The sludge solidifies after some months and can be removed and accumulated by means of a power shovel.

The chemical composition of dried sludge depends on the production and is influenced by the addition of $Ca(OH)_2$. During the production of silicon metal, the content of SiO_2 in the dried sludge does not exceed 93%. Unfortunately, we have not found a commercial use for this material and now we have a stock of approximately 6000 tons; the annual production is approximately 2000 tons. The deposit of sludge, however, has proved useful to us. It shows in a persuasive way to skeptics, among both the townspeople and the authorities, the results we have achieved in clarification.

Bag Filter (Fig. 9). The furnace No. 0 for steel production and the single-phase Furnace No. 1 are connected to this filter. This purifier has been installed about 80 meters away from the furnaces in order that the gases cool down naturally along the overhead steel pipe from furnace to filter. Fumes arrive at the filter with a temperature of approximately 120°C.

The filter consists of 360 glass fiber bags (guaranteed up to 280°C) having a total surface of 600 m² divided in 6 cells. The cells in turn are excluded from the cleaning process and are cleaned for a period of 30 sec by a pneumatic counterflow which removes the dust deposited on fibres to the collecting storage bin.

Following are some problems connected with the gas cleaning which presented unforseen difficulties:

Location of Plant

It has already been said that we neglected the study of atmospheric conditions of the site. This was not only a grave fault, but also a grave misfortune. In 1965 we collected data with relation to the wind situation as shown in Fig. 10.

The level ground of S. Vittore and specifically the area nicknamed "Siberia", is excluded from predominant currents of wind. During summer, when the most difficult problems in pollution occur, the following phenomena can be observed: Complete standstill with no turbulence from 8 p.m. to 8 a.m.; light wind from East (to Bellinzona) from 9 a.m. to 12 a.m.; wind from West from 1 p.m. to 7 p.m.

Depolyment of fume developed during the night is stagnant above the factory like a cloud and in the early morning moves to Ticino; if it reaches the current of wind blow-

Table I. Electrostatic Precipitator.

	B (for Furnace No 2 & 3)	C (for Furnace No. 4)
Capacity	130,000 Nm^3/h	100,000 Nm^3/h
Entering gas temp.	135 to 270°C	135 to 320°C
Temp. of purified gas	30 — 60°C	
Dust content of incoming gas	variable between 0.7 and 4 gr./Nm^3	variable between 0.8 and 4.5 gr./Nm^3
Guaranteed efficiency	Max. content of 0.100 gr/Nm^3 in the purified gas	
Suction fan power requirements	120 kw	100 kw
Water Pump	90 kw	80 kw
Electrostatic section	40 kw	38 kw
Total power required	250 kw	218 kw
Energy consumption	4000 kwh/day	3700 kwh/day
Water consumption	70 Nm^3/h	65 Nm^3/h
Total pressure drop	150 mm H_2O	
Voltage in electrostatic section	varies between 30-50 KV	
Specific load amperes	0.50 + 0.60 mA/m^2 of plate	

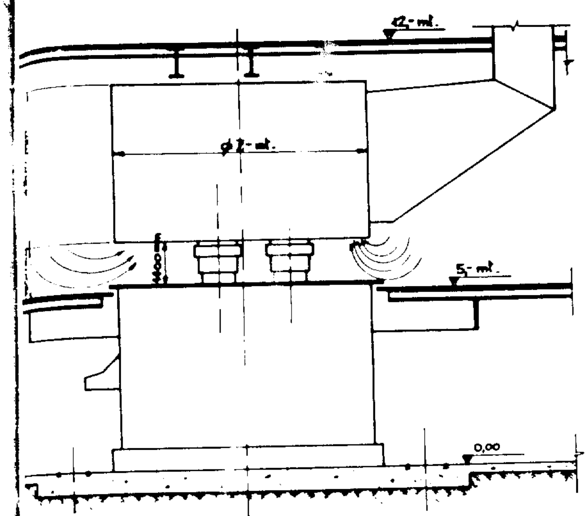

Fig. 11—Hood of the 9000 kva furnace.

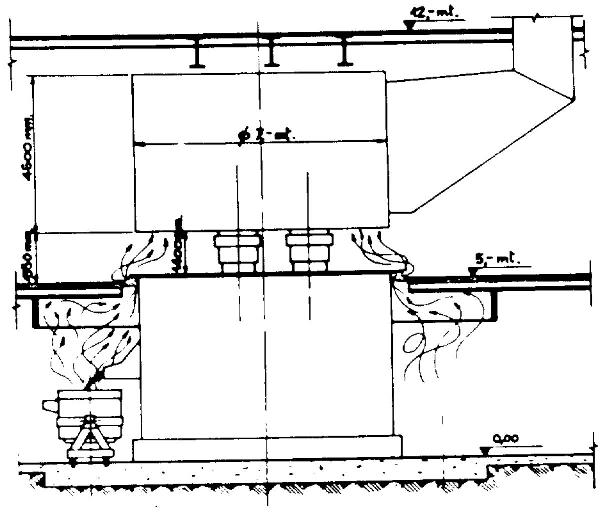

Fig. 12—Collection of fumes.

ng from north to south, the fume arrives very dispersed, but still visible at the city of Bellinzona.

If the factory had been constructed a few kilometers further up the valley we could have made use of the strong air currents in the San Bernardino and Traversagna Valleys. Rapid dispersion of fume certainly would have substantially lessened the problems we encountered. Perhaps even a modest efficiency of filters would have been acceptable under these circumstances.

Connection of Furnace with Filter

The connection of a completely open furnace without a hood for the fume collection, as some are in the United States, would present great problems. Even with a modern furnace equipped with hood and chimney, if smoke has to be conducted to a cleaning station, technical and aerodynamic problems can be encountered.

Constructors of furnaces, and producers of ferro alloys have treated the hood of an open arch furnace as a stepchild, although they deem it necessary to remove smoke from the operation and to protect workers and equipment from the heat. With the addition of adequate gas cleaning to the unit, constructors of furnaces will have to be directly concerned with solving the problems of gas purification as these problems relate to furnace design.

Tackling the problems of gas cleaning of a furnace, considering the volume of air to be exhausted and relative power expenses, one is, for example, forced to diminish the amount of secondary air sucked into the hood; but the smaller the amount of secondary air, the higher the smoke temperature, and therefore the exposed parts of the furnace are going to suffer stress.

Unfortunately, at Valmoesa we neglected the study of the problems of the hood and then encountered remarkable difficulties. Only one chimney and a height limitation, (Fig. 11) proved to be insufficient for giving a good and well distributed suction. In order to draw adequate secondary air in the zone opposite the chimney and to prevent the leakage of smoke, a strong suction of air is caused in the zone directly under the chimney entrance; the violent current can generate recirculation under the hood and local increases of heat, which are dangerous for the hood itself, the copper cables and other exposed parts.

Free height of entrance can possibly be varied, but is limited by the operating necessities of the charging machines. We had to modify the hood which now is water cooled. The copper band flexibles have been reduced to a minimum of length commensurate with minimum movement of the electrodes and are enclosed in an air-cooled casing.

Perhaps this problem of connection of furnaces to fume collectors will have as a consequence a new examination of technical and economical possibilities for the complete closure of furnaces, even for the production of silicon alloys. As a matter of fact, there exists some news about tests and attempts tending in this direction.

Once we had eliminated this principal problem, the authorities in 1965 also began to pay attention to the secondary sources of smoke such as outlets from the hood and the development of fume during casting operation. It is not easy to seal the hood perfectly, but it was finally accomplished. We took care that the smoke produced during the casting operation was collected according to the diagram of Fig. 12.

Opening the space between the shell and charging floor to allow the escape of smoke to the main hood has proven to be a simple and effective procedure.

Measurements

During recent years the measurements regarding smoke and water in the factory have been numerous and frequent, especially on the part of the authorities charged with the control. At the beginning we neglected this basic study, resulting in insufficient suction in the first Venturi plant, surprises in the granulation of dust, controversies in regard to efficiency, and so forth.

Amount and analysis of fumes, as well as amounts and physical and chemical analysis of dust, have to be determined with great care. It is advisable to engage specialized and independent Institutes for the acquisition of basic data, more so since the determination of collection efficiency will always have to be committed to an arbitration board.

The producers of ferro alloys know that the operation of a ferroalloy furnace is very changeable; with the same kind of production and the same power, a blowing furnace develops at least 10 times more dust than a quiet one. But also under normal proceedings the variation of dust quantity is remarkable; for example, with Furnace No. 3 producing silicon metal (load = 8500 kw) we were able to establish by means of continuous sampling during 9 hr extreme values ranging from 0.8 to 4.5 gr/Nm^3.

It is understood, therefore, that the average dust amount must be determined by means of statistical sampling. The following table indicates the results of particle analysis of dust, from smoke and purified gas, of samples taken during the production of silicon metal.

Overflow Water

While at present the problem of

Table II. Results of Particle Analysis.

Dust Size		Fumes	Cleaned Gas
		Weight Percentage	
> 100	μφ	1	0
100-50	μφ	7	3
50-25	μφ	10	4
25-10	μφ	12	5
10-5	μφ	4	6
5-2.5	μφ	4	5
2.5-1.0	μφ	4	14
1.0-0.5	μφ	10	24
0.5-0.25	μφ	21	39
0.25-0.15	μφ	13	
< 0.15	μφ	14	
		100	100

water clarification has been solved successfully, I must say that we had many problems and expenses in this area. The River Moesa, running through the valley, has very clear water of a greenish-blue color; it is rich in fish. Three kilometers down the valley the Moesa River flows in the Ticino River which, after 10 kilometers, enters into Lake Maggiore, known for its scenic beauty.

Almost immediately after ordering the wet smoke purifiers, we considered building decantation basins of ample area, confident that the decantation was going to be easy. To our dismay, only the dust of carbon and quartz deposited itself in basins. The fume particles continued right on out the overflow! The dirty water collected in a bottle clarified itself by means of natural sedimentation only after 56 hr!

The River Moesa has a changeable flow. The measurements carried out during 1963 at the side of Valmoesa show, for instance, a minimum of 3.61 m^3/sec. during February and a maximum of 68.3 m^3/sec during June, with a yearly average of 28.3 m^3/sec.

Surveys and measurements were carried out by the authorities during April, 1963 (average flow: 15.8 m^3/sec). Three kilometers down the valley the river water color was still noticeably whitish and dull, although the dirty water inflow represented a very limited percentage: 130 m^3/h = 0.036 m^3/sec., that is to say 0.23% of the river flow.

When choosing a wet purifying plant the overflow water problem has to be tackled at once, more so because it does not present particular difficulties if carefully studied.

Corrosion

The phenomenon of corrosion of metals was already noted at the Venturi-Scrubber. This purifier was operated only during a limited period and presented us with many collection problems. Owing to these reasons we neglected and also forgot the less pressing question of corrosion.

Constructing the first electrostatic precipitator, it was intended to eliminate the phenomenon of corrosion, covering metals with adapted paints and correcting the pH value of the water by introduction of soda ash. But paints were insufficient to protect the metal; afterwards it could be noticed that corrosion worked in many parts under the paint layer.

Corrosiveness of the water mainly depends on the presence of sulfurous acid and partly sulfuric, coming from combustion of the sulfur contained in the carbon. It seems that ozone, too, is in the water and is partly responsible for corrosion. The formation of ozone can happen in the electrostatic part with the "black" discharges and even more during small but frequent discharges that can be observed during the washing operation of the electrostatic plates.

Nearly all parts of the two electrostatic precipitators exposed to the dirty water and to the wet gas were reconstructed in stainless steel between 1964 and 1966. In order to limit expenses for material we made remarkable modifications at the construction. After using stainless steel for the principal parts of the cleaning equipment, problems of corrosion were resolved and we have had no further troubles.

Now I should like to suggest other aspects of our experience which, I hope, may be of interest:

Dangers of Fume and of Dirty Waters

The Medical Service of the Labor Head Office officially declared that fumes coming from the stacks of furnace producing ferrosilicon and silicon metal are not dangerous for the health of people, animals and plants, even in zones nearby the factory. Also, dirty waters coming from precipitators and examined by various laboratories did not report to be toxic and had no bacterial effects.

During the writing of this report, the Board of Public Health is about to take samples of the collected sludge and clarified water coming from production of Chromium Silicide. We are watching carefully for the presence of hexavalent Chromium oxide (CrO_3) of which even small quantities can be toxic.

Defense to Avoid Pollution

There exist in Switzerland strict laws imposed by the Confederacy (1955) and by the Kanton (1959 Kanton Graubünden) to protect waters from pollution. On the other hand, we do not yet have laws imposed by the Confederacy or by the Kanton for the protection of the air.

The measures of the Authorities of Kanton Graubünden to force Valmoesa to the collection of fumes was based on the conditions published in the decree for the construction of the factory, to wit: " . . . emanations of fume greater than those of a normal chimney, will not be tolerated. . .".

The Authorities of Graubünden were compelled to proceed ve[ry] strictly because of the strong ex[pressions] of public opinion: pe[titions], articles in newspapers, tele[vision] shows and so forth. Moreover, in July, 1964, 13 communities of Kanton Ticino began a laws[uit] against Valmoesa, asking the co[urt] of justice for ". . . the closure of the factory if a complete elimination of the smoke should not be achieved . . .". In the meantime, during the long phases of legal proceedings which is not yet concluded, we made successful progress in purification and are confident of a decision in our favor.

Choice of the Cleaner Type

Our initial choice of the wet electrostatic filter was made for the following reasons:

1. During the trials in Aug., 19[..] with the two electrostatic precipitators (a dry and a wet one) greater collection efficiency could be consistently achieved using the wet system.
2. We undervalued the problem of water pollution which would be associated with it.
3. We did not foresee the technical and economical problems in relation to corrosion.
4. There was only limited information about cleaners of the ba[g] type to be used for silicon alloys and too many unknowns existed to evaluate them properly. The durability of the tissue and the feasibility of detaching the powders deposited on the bags were not well defined. With the pressures upon us, we had no time to conduct trials with a semi-industrial plant of this type.
5. In view of the poor experiences we had with the Venturi type of collector, we disregarded any kind of cleaning based on wet scrubbing techniques.
6. In our program of production were included various qualities of ferroalloys. We were given the advice to use the wet electrostatic cleaner as being more flexible and suitable to various fume particle types.

After many doubts and much soul-searching, we are now of the opinion that our choice was not wrong considering the level of pollution control requested by the authorities and the results we have actually achieved.

Today it is surely easier to study and to find the best cleaner for either a specific fume or for general application. Aside from important theoretical studies published in recent years, there exists now an experience with data and results which should be available. According to an inquiry I made, today there are about 450 electric open furnaces for ferroalloys in the world. About 25 of them have gas cleaners or will be connected with

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Fig. 13—Situation in 1962.

Fig. 14—Situation in 1967.

1967 to various types of filters. Interests of furnace constructors and cautiousness of ferroalloys producers have not yet permitted a useful comparison of the real data in reference to gas cleaning in the industry. It would certainly be proper for an international association, with social aims, to collect and correlate these various data for the most effective approach to this serious pollution problem.

However, many constructors of cleaning equipment have acquired a remarkable amount of experience, and owing to the sacrifices of their first customers, they are now able to propose cleaning systems having high efficiency and assured operating results.

Encouraged by the experience which was developed with various cleaners, and wanting to avoid the associated problem of further water pollution, we thought it suitable to use the dry cleaner with fibre bags for collection of fumes from the steel furnace. Also in other factories of our group we are now assembling three electrostatic filters (bag type) for steel furnaces; one of these furnaces has a heat size of 70 tons.

Achieved Results (Figs. 13-14)

1. Clarification of waters is completely satisfactory. We continue the studies, however, in order to reduce the important expenses and to save costs of chemical reagents.
2. Excellent efficiency of the bag filters in cleaning gas on the steel furnace and the single-phase Furnace No. 1. Stack effluent gases are not visible. We have not yet exact data about durability of the bags. We had to replace the first set of bags after approximately 7000 operating hours; nearly all bags presented at the same time a creasing of tissue. This phenomenon was not due to the use, but to the mechanical assembly. Upon inspection in August of this year, after 3000 operating hr with the second set, the state of the tissue is still perfect.
3. The efficiency of the electrostatic precipitators after approximately 11 months is constant. We measure normal contents of gas; during washing operation (3 min. each half hour) the content increases to approximately 0.150 gr/Nm^3. With this exception, the guarantee of 0.100 gr/Nm^3 maximum has been achieved. The authorities are satisfied and accepted these results; however, they have invited us to try to improve the cleaning during the washing operation.

At the end of this 1967 furnace campaign we shall make some minor modifications, hoping to be able to decrease the washing operation cycle to one minute.

Cleaned gas effluent from the production of silicon metal and of ferrosilicon 75 can be described as follows: Slightly blue and nearly invisible at a dust content of 0.050 gr/Nm^3; 0.100 gr/Nm^3 already shows the existence of a furnace; 0.150 gr/Nm^3 yields a gas of whitish-gray color and the fumes disperse at a distance of some hundred meters from the stack.

Efficiency of cleaning can be calculated as $\frac{A - B}{A}$, wherein A = content of dust in the furnace, B = content of dust in the cleaned gas.

Average contents measured in our filters are as follows:

$$A = 1.70 \text{ gr/Nm}^3, \quad B = 0.080 \text{ gr/Nm}^3$$

The average efficiency is therefore

$$\frac{1.70 - 0.08}{1.70} = 95.5\%$$

It seems to us very difficult to surpass this efficiency. I point out that the percentage efficiency has a limited importance as far as the visibility of effluent gas is concerned. Despite a high efficiency of purification, unsatisfactory results with regard to visibility of the discharged fume are possible; for example,/if the dust of the fume is 4 gr/Nm^3 and in the cleaned gas 0.200 gr/Nm^3, efficiency is high (4.00—0.200/4.00 = 95%), but the result considered in point of view of visibility cannot be accepted. Effective filter performance can be best evaluated by the measure of its maintaining the maximum content of 0.100 gr/Nm^3 in the cleaned gas, notwithstanding frequent variations in the dust content of the fume. We get this result, even if the dust content varies from 0.85 to 4.5 gr/Nm^3.

During the first years interruptions of electrostatic precipitators were frequent; we had breakage of electrostatic wires, electric discharges, water stoppages, and high use of single parts owing to corrosion. These accidents hurt us badly because the authorities would not allow operation of furnaces without collection, even for a short period. We therefore have had to apply the rule: "If the filter is stopped, the furnaces have to be stopped." I should like to point out that in our factory are installed some indicators, sealed by authorities; these meters register the operation of filters and furnaces!

We studied and worked hard in order to eliminate the reasons for these failures and at last we have reached good results. During the last seven months the electrostatic filters have worked continuously without trouble. Once a week during the night from Friday to Saturday, we stop each filter for approximately two hours for control, cleaning and maintenance; by approval of the authorities, this work can be executed without stopping the furnace; we only have to reduce the load.

Among the results we reached I also have to acknowledge that our technicians now pay more attention to a good operating process. In order to reduce the fume, during our long years of difficulties, we tried to influence the operation of the furnace, paying particular attention to the quality of mix preparation and blending, depth of the electrodes, electrical conditions, and the size and quality of raw material. All these factors can have great influence on the dust content of the fume.

Costs of Cleaning Equipment

The great difficulties we encountered brought enormous costs for the installations. From the beginning of the problem until March, 1967, we spent a total amount of $1.2 million. Costs of construction, modifications, studies and trials are included in this amount. General expenses, such as administrative costs, lawyers and experts' opinions for the process, costs for measurements and so forth, and indirect costs for loss of production are not considered. Amortization of this impressive amount is a great financial and technical problem; moreover, we do not know the real period we need to amortize different parts of the various installations.

Expenses we incurred cannot be directly applied to other factories which are considering the installation of cleaning equipment. We do estimate that to install equipment comparable to what we now have would not exceed $600,000. In this sum are included all expenses for the two electrostatic precipitators, the bag filters, the water clarifier and the decantation basins for sludge.

Working Costs

Unfortunately we are not yet prepared to give exact information about this important subject. We have had the equipment in service for only about a year and we think we need another year to define operating and maintenance expenses. The effective consumption of water and material for the collection of fume was indicated above and it is easy to derive consequent costs therefrom. One technician and three workmen per day are actually involved in operating and maintaining all filters; however, we are centralizing the switchboards in order to reduce this part of labor to only two men per day.

A very important part of wet electrostatic air clarification costs is the "flocculant" used to treat the waste water. Among the various types on the market, we have found a material that costs about $1.50/lb to be the most suitable.

Actually, operating expenses for our entire pollution control system amount to $140/day and we hope to reduce it to $90/day.

CONCLUSION

I wish to conclude this report by advising my colleagues not to undervalue and not to try to escape, from the smoke abatement problem when claims and requests from authorities begin. The technical study should begin promptly and be well thought out. Injunctions and avalanches of claims can cause bungled studies and decisions. I highly recommend the approach of entrusting the exact determination of the principal data of the problem to independent institutes specializing in this field. In this way defense against claims and requests of authorities can better be accomplished and a comprehensive study will be, in any case, the best base to resolve the real problem. We made our initial study without qualified assistance with the result that our errors and failures, made during the long period in which we acquired our experience, were interpreted by public opinion for many years as a direct and willful act made with malice aforethought. While we can admit a certain passiveness at the beginning, since 1960 we honestly and with enthusiasm have done everything possible to achieve the best level of pollution control at Valmoesa.

Finally, last year, the authorities acknowledge that "Valmoesa did everything for pollution control which is possible to do within the actual limits of the most advanced technology."

Many former enemies, among them vociferous and violent journalists, now treat us with comprehension and friendship. We can define ourselves "the most purified and inspected ferro-alloy factory in the world"; however, we would be pleased to cede as soon as possible this honorary diploma to other competitors of ours!