INFLUENCE OF RAW MATERIALS ON THE PRODUCTION OF 75% FERROSILICON

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ABSTRACT

With this presentation, we would like to point out that, in producing 75% ferrosilicon, special attention should be paid to the strength of the sintered-structure of the dome formed at the upper reaction zone in the submerged-arc furnace. We would also like to demonstrate that the strength mentioned above plays an important role in operating a furnace stably and efficiently.

By selecting carbonaceous agents and adjusting mixing ratio for the furnace operation, we could give the sintered-structure the most desirable strength, leading to a successful operation in a commercial-size furnace. Using the spectrum analyzer for harmonic waves of the electrode current, we confirmed that there is a coincidence between the form of even number waves and the smelting condition around the electrode tip.

1. Preface

Electro Alloys Corporation, an affiliate of Nippon Denko Co., Ltd., is a Philippine ferroalloy producer jointly owned and operated by the Philippine and the Japanese partners. EAC has a 20-MVA open-type rotating-hearth furnace in Mindanao Island and produces 13,000 tons of ferrosilicon (75% Si) annually.

Partly because of restriction in supplying raw materials and partly because of economic reasons, it was necessary for EAC to use easy-melting silica from Panay Island and local brown coal (brown coal produced in the Philippines) in larger quantities than ever before. On the other hand, the previous data told us that these raw materials, Panay silica and local brown coal, might lead the furnace operation into serious trouble when used in large quantities.

In order to solve this problem, we observed the furnace and tried to find out an influence the aforementioned raw materials had on its operation. We noticed that, when the furnace operation is in trouble, descending of raw materials is usually much faster than that in normal operation. With this in mind, we investigated the physical and chemical properties to detect a cause of unsatisfactory furnace operation. We came to the conclusion that it is reasonable to assume that the insufficient strength of the sintered-structure of the dome formed at the upper reaction zone is the direct cause of the trouble.

Based on this assumption, it was considered necessary to add coking coal to the raw material mix in order to reinforce the strength of the sintered-structure when local raw materials are used.

This idea was applied to a series of test operations of a 100 KVA single-phase furnace. The results proved our idea and outlined the basic conditions when applying the idea to the commercial furnace operation. From the test data and experience thus obtained, we performed the practical operation using Panay silica and local brown coal on the 20 MVA furnace of EAC, realizing stable and satisfactory operation.

2. Chemical and Physical properties of Raw Materials

2.1 Quartzite

Table 1 shows typical chemical analysis and the refractoriness as the number of Seger cone of the Panay quartzite in question in comparison with the Japanese Imajo quartzite preferably used by most of the Japanese ferrosilicon producers.

The Panay quartzite is chert produced in the stratum of Tertiary period, and comparatively young mineral. The upper parts of the ore deposit are widely weathered. Accordingly, this Panay quartzite is generally soft. On the other hand, the Imajo quartzite is mind from a large scale deposit which is characterized by its homogeneous and hard ore body. Geologically, it is chert of paleozoic era and older mineral compared with the Panay quartzite.

Table 1. Chemical Analysis and Refractoriness

Quartzite	Chemical Analysis					Refractoriness
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K	SK
Panay Philippines	97.7	2.0	1.0	0.1	0.2	34^{-} -33
Imajo (Japan)	98.3	0.5	0.8	0.02	0.05	34^{+} -34

From Table 1. it is obvious that the Panay quartzite is easier to melt than the Imajo quartzite.
From a certain stock of the Panay quartzite, six lumps different in appearance were sampled and analyzed separately. The results are shown in Table 2 in order of SiO2 content.

Table 2. Chemical Analysis of the Panay Quartzite Lumps

	SiO2	Al2O3	Fe2O3	TiO2	K
A	99.0	0.5	0.25	0.07	0.08
B	98.4	1.1	0.75	0.05	0.07
C	97.2	1.9	1.20	0.11	0.20
D	96.0	2.7	1.30	0.13	0.25
E	94.0	3.9	1.20	0.18	0.26
F	89.8	8.1	2.60	0.46	0.94

It is clear from this data that the ore lot supplied to the plant may contain such lumps as substantially inferior in quality, the number of which may change from time to time.
We studied the relation between chemical analysis and the refractoriness (SK) of the quartzite on 25 samples of various quartzite. By interpreting the results shown in Fig. 1, we believe that the refractoriness of quartzite or silica quartz available in the market with more than 95% SiO2 may be influenced largely by the content of alumina, and be abruptly deteriorated if Al2O3 content exceeds 1.5%. Based on this, it is assumed that the inferior grade lumps, C - F listed in Table 2, have very low melting points.
In connection with this melting point property, we carried out the suspended-specimen melting test for the normal and inferior grade Panay quartzite and the Imajo quartzite as a reference in order to further study the high temperature softening properties. The results are shown in Table 3.
The outline of this test is as follows. The quartzite sample is pulverized and shaped into a rod of specific size, which is then sintered. The specimen thus sintered is suspended vertically in an electric oven, and a certain part at the mid-point of the specimen is heated.
Raising the temperature continuously, the rod specimen is stretched due to high-temperature softening and is torn off at a certain temperature. It is the basis of this test to observe the relation between the elongation and the temperature.

Fig. 1 Relation between chemical analysis and refractoriness

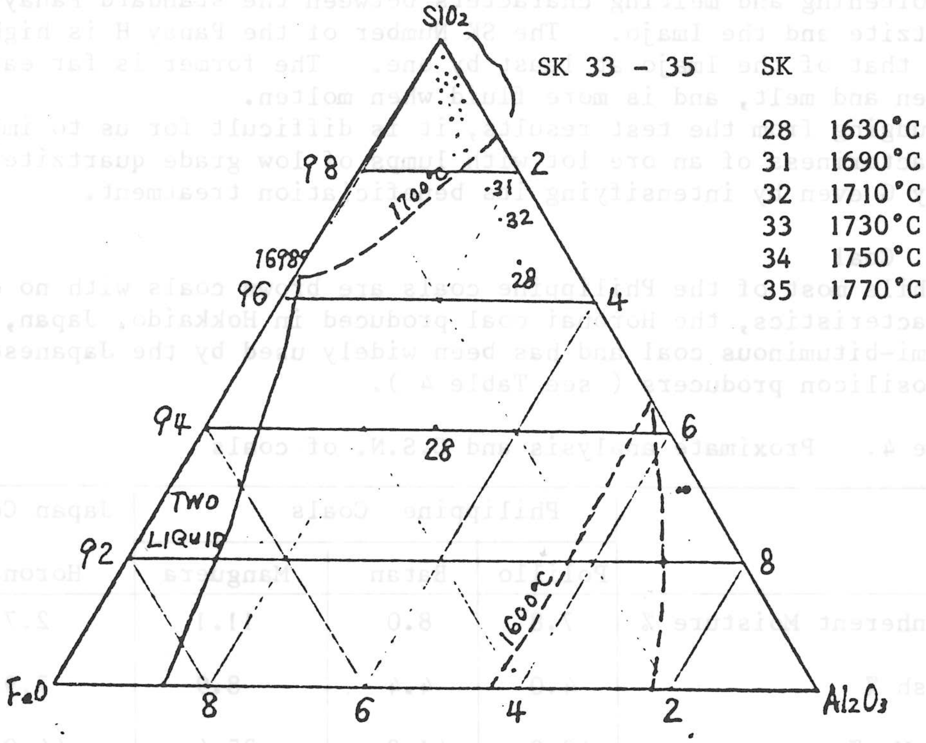


Table 3. The suspended-specimen melting test

	SK No.	Starting temperature of melting	Torn-off Temperature	Total length after elongation
Imajo	SK 34^{--}	1,660°C	1,740°C	720 mm
Panay G (low grade)	SK 30^{++}	1,580°C	1,650°C	650 mm
Panay H (standard grade)	SK 33	1,600°C	1,660°C	720 mm

The Panay H is composed of 98% of SiO2 and 1.3% of Al2O3. From the standpoint of chemical analysis, it can not be said that the Panay H is inferior to the Imajo. Comparing with the result of the suspended-specimen melting test for the Imajo, however, the torn-off temperature of the Panay H is lower by 80°C and the temperature difference between softening and torn-off is reduced by 20°C.

Taking the fact that the total length after elongation is almost the same, it may be said that the elongation on viscosity character of the Panay H during its softening and melting processes is sligthly different from that of the Imajo.

As far as the starting temperature of melting and the torn-off temperature are concerned, however, there is a considerable difference in softening and melting characters between the standard Panay quartzite and the Imajo. The SK Number of the Panay H is higher than that of the Imajo at least by one. The former is far easier to soften and melt, and is more fluid when molten.

Judging from the test results, it is difficult for us to improve the refractoriness of an ore lot with lumps of low grade quartzite like the Panay G even by intensifying its beneficiation treatment.

2.2 Coal

While most of the Philippine coals are brown coals with no coking-characteristics, the Horonai coal produced in Hokkaido, Japan, is a semi-bituminous coal and has been widely used by the Japanese ferrosilicon producers (see Table 4).

Table 4. Proximate analysis and C.S.N. of coals

	Philippine Coals			Japan Coal
	Polillo	Batan	Manguera	Horonai
Inherent Moisture %	7.8	8.0	11.1	2.7
Ash %	4.0	4.4	8.9	7.9
V.M. %	40.0	41.2	35.4	44.0
F.C. %	48.2	46.4	44.6	45.4
Button index(C.S.N.)	0	0	0	$2^1/2$

3. Preliminary Discussions on Smelting Process

3.1 " Sintered Dome-structure "

There are many reports on ferrosilicon smelting, especially on the formation mechanism of silicon in the furnace. Much has been discussed on this problem for the past 20 years, but the followings are generally accepted as formation reactions :
(1) one is the formation of silicon carbide from carbonaceous materials and silicon monoxide at the upper part of the furnace, and
(2) the other is the formation of silicon and silicon monoxide (which will ascend to react with carbon) at the lower part of the furnace.
These reactions are shown as follows :

$$2C + SiO \longrightarrow SiC + CO \qquad (1)$$
$$3SiO_2 + 2SiC \longrightarrow Si + 4SiO + 2CO \qquad (2)$$

This reaction mechanism is in good agreement with the furnace excavation observation (naked eye and microscopic observations, and X-ray diffraction analysis).

In order to proceed the smelting reaction continuously and stably, it is primarily necessary for the newly charged raw materials to stay at the upper reaction zone until the reaction represented by equation (1) is almost completed. When the ferrosilicon furnace is normally operated, the surface of the charge is descending slowly, and big (noticeable) gas blows are not observed for 30 to 50 minutes after mix is charged. Then the surface layer of the charge is poked to thrust down. Immediately after poking, new mix is charged and levelled off. This pattern of operation leads to the fact that the upper reaction zone is formed into a sintered body of dome-structure, under which exists an expanding cavity. The sufficient retention time for the reaction (1) may be given by the formation of this dome-structure. We call the strength supporting the dome-structure above the cavity as " bridging strength ". The following four factors constitute the bridging strength.

(a) Melting and adhesion of coal and its coking.
(b) Softening and adhesion of silica quartz.
(c) Decomposition of SiO, followed by deposition and melting. or sintering of the decomposed products.
(d) Upward pressure of the gas generated at the lower reaction zone.

In the next place, we would like to discuss how the coal and coke play an important role in forming the dome-structure.

3.2 The Role of Coal

When charged into the furnace as a constituent of the mix, coal is directly carbonized and then converted to silicon carbide, SiC, by successive reaction with silicon monoxide, SiO. It attracted our attention that while coal continues its carbonization and is evolving gases, it does not absorb any silicon monoxide gas.

When coking coal is used, it agglomerates, through carbonization, bulk materials of the raw material mix to some extent. On the other hand, non-coking coal can not agglomerate them.

The reaction velocity of ordinary coal with SiO in the furnace is much higher than that of ordinary coke when the coal has already been carbonized.

Accordingly, it should be noted that in case non-coking coal is used, the coal may play very little role in the formation of the sintered structure due to the fact that it can not agglomerate raw materials.

3.3 Silica Quartz

Silica quartz softens and melts at the upper reaction zone of the furnace. Softening and melting of silica quartz play an important role in the formation of the " sintered dome-structure ".

So it is desirable that the silica quartz has such properties as its melting point and the viscosity and stickiness suitable for the purpose.

One of the other points of the silica quartz to be discussed is size distribution. In case of the smaller sized silica quartz, the reaction shown below is much accelerated, resulting in the big loss of silica and carbonaceous materials.

$SiO_2 + C \longrightarrow SiO + CO$

This reaction also gives an adverse effect on the formation of the " sintered dome-structure " mentioned above. Accordingly, the size of the silica quartz to be charged should be larger than a specified diameter.

In case the bridging strength of the dome is very weak :

The following phenomena and reactions are expected to occur in the furnace when some of the unreacted raw materials caved into the lower reaction zone with a temperature higher than that of the upper zone :

1) $SiO_2 + C = SiO + CO$

$\Delta H_{289} = +166.0$ Kcal/mol

When unreacted silica with unreacted carbon is plunged into the lower reaction zone with a higher temperature, this reaction proceeds briskly and violently. This reaction is an endothermic reaction. It may decrease the temperature of the lower reaction zone abruptly, which will be a serious hindrance to the main reaction (2) and get the reaction crucible narrow.

2) $Si + C = SiC$

$\Delta H_{289} = -14.0$ Kcal/mol

When unreacted carbon contacts with molten silicon directly, the above reaction proceeds preferentially. SiC thus formed may be accumulated in the molten FeSi bath at the bottom of the furnace. If and when this accumulation continues for some time, SiC-suspended metal bath may become a hard spongy-refractory materials layer which is one of the most serious causes of the upheaval of the reaction crucible of the furnace.

3) Extinction of arc

When silica quartz is easy-melting and the reactivity of carbonaceous materials is notably low, there may be lava-like molten silica flow around the electrode surface, in which the unreacted carbonaceous materials are wrapped up (we call this type of operation " a gruel-like operation ").

If this flow will coat all the surface of an electrode tip, its arc will be extinguished. Just after arc extinction, the temperature of the lower reaction zone drops abruptly to such a temperature as the main reaction (2) no longer to proceed.

In case the bridging strength of the dome is very strong :

The dome would stay on at the charge level. The cave beneath the dome keeps expanding until the dome is mechanically broken down and fragments of the dome are caved in. In the extreme, the supply of raw materials into the lower reaction zone shows deficiency, and the temperature at the zone rises excessively in vain, deteriorating the electric power consumption per ton of product. Judging from the above discussion, there probably exsists the optimum condition of the bridging strength for stable furnace operation. The bridging strength is primarily influenced by the properties of silica quartz and carbonaceous materials.

4. Smelting Tests

Based on " Chemical and Physical Properties of Raw Materials " and " Preliminary Discussions on Smelting Process " discussed above, we concluded that the combined use of the Panay silica quartzite and the Philippine brown coal inevitably brings a deteriorated furnace operation due to the insufficient bridging strength for the sintered dome-structure. We, therefore, considered it a reasonable measure to replace a certain part of the brown coal by coking coal in order to improve the furnace operation. By replacing, it will strengthen the sintered-structure dome. A series of smelting tests using a 100 KVA single-phase electric furnace proved our idea and provided some of the technical requisites necessary for applying it to the operation of a commercial furnace.

1) Furnace

Transformer	100 KVA Single-phase with reactor		
Electrode	100 mm ø Graphite electrode		
Furnace crucible	carbon lined	inner diameter	450 - 500 mm ø
		inner depth	400 mm
Operating voltage (Tap voltage)	42 - 46 V		
Operating load	70 - 80 KW		

2) Raw Materials

Quartzite

	SiO2	Al2O3	Fe	Size
Imajo	98.3	0.5	0.17	15-30 mm
Panay	97.6	1.0	0.25	15-30 mm

Coke

	F.C.	Ash	V.M.	Size		*Index	Note
Mitsui	85.0	13.5	1.5	5-8mm	66%	1.24	For Ferroalloy
Kawasaki	85.8	12.5	1.7	5-8mm	57%	1.01	For Blast Furnace
Nagoya	86.9	11.5	1.6	5-8mm	70%	1.00	For Blast Furnace
Char	74.6	5.3	20.1	5-8mm	40%	1.40	Carbonized Philippine Coal

* X-ray Half-width Index

Coal

	F.C.	Ash	V.M.	Size	C.S.N.	Note
Polillo	53.9	3.8	42.3	5-20mm	0	Philippines
Batan	52.5	3.1	44.9	5-20mm	0	Philippines
Horonai	48.7	7.8	43.5	1-20mm	2 1/2	Japan
Yubari-shin	57.8	6.6	35.6	0-15mm	7	Japan
Blurr	67.7	0.7	31.6	0-8mm	8 1/2	New Zealand

Wood Chip

For paper mills less than 50mm

Hammer Scale

Fe 65% less than 20mm

3) Observation and measurements

Sensuous observation
In order to observe how the sintered-structure dome is being maintained, the following sensuous observations were made,
(a) Poking to poking time interval
(b) Touch of poking
(c) Descending of raw materials
(d) How sticky are the raw material charges inside the furnace crucible ?

Measurements
(a) Up-and-down movement of the electrodes
(b) Secondary current, secondary voltage, power load and power consumed
(c) Furnace hearth temperature
(d) Weight and chemical analysis of the tapped product
(e) Oscillograph wave form of electric current.
Voltage frequency analysis for electric current and voltage by a spectrum analyzer

4) Furnace excavation

After shut-down, the furnace was excavated to observe. Many samples were taken, analyzed and observed microscopically.

5) Test method

Each smelting test was started with the standard raw material mix and continued until the furnace thermally established its equilibrium (this equilibrium state was proven by the heat flow meter). After that, the raw material mix was changed according to the test schedule. Furnace condition and the stability of the dome were compared to those of the standard mix. Stoichiometric F.C. ratio of carbonaceous materials to silica quartz was designed to fix at 98 - 101%.
Standard raw material mixing ratio designated here is the one used at the Minamata plant of Nippon Keiso Kogyo Co., Ltd. for many years.

5. Technical Discussion on the Smelting Tests

5.1 Raw Materials

Summary of the smelting tests are shown in Table 5. The authors examined such factors as temperature of the tapped metal, unit power consumption, and descending of raw materials etc, to see whether the furnace operation was totally good or not.

In these tests, coke and coal were used mostly in the form of mixed brands. In Table 5, property of coke was standardized to express as weighted average of the half-width indexes, and that of coal as weighted average of C.S.N. values. We attached importance to reactivity in case of coke, and to coking character in case of coal.

1) Quartzite (Test No. : 0 vs. 16)
The characteristic difference between the Imajo quartzite and

the Panay quartzite is reflected clearly in the furnace condition. When the Imajo is replaced by the Panay, the descending speed of the raw materials is markedly accelerated.

2) Wood chip (Test No. : 1 vs. 4 & 5 : 2 vs. 6 & 7)
When we eliminate wood chip from the raw material mix, it makes the reaction crucible narrow. Mixing of wood chip plays a role in expanding the reaction crucible, but may likely decrease the bridging strength for the sintered dome-structure at the upper reaction zone.

3) Coal
In case of coal with C.S.N. index of more than 4, the dome was excessively sintered preventing the furnace from smooth and stable operation. In case of coal with C.S.N. index of less than 2.5, descending speed of the raw materials was accelerated. The above generalization can apply only to the test furnace of 100 KVA single-phase furnace. The authors had a test operation on a 23,000 KVA commercial ferrosilicon furnace charged with the above-mentioned standard raw material mix using the Imajo and the Horonai coal. The normal furnace operation was shifted to a test operation by replacing a part of Horonai coal with coking coal. The results were as follows :
In case of C.S.N. index of 3.5, some violent gas blows were observed and most of the surface charges were tightly sintered. In case of C.S.N. index of less than 3.0 (still some coking coal was mixed), the furnace could be operated smoothly and efficiently. When increasing the ratio of coal excessively in the raw material mix, we obtained a state similar to " a gruel-like operation " observed in our commercial operations even if the bridging strength of the dome is not changed noticeably. In this sense, the authors believe that there is a favorable range of coal ratio : 30 - 35% ratio of coal to total carbonaceous materials (F.C. base).

4) Coke (Test No. 18 vs. 19 : 21 vs. 22 - 26)
Judging from the practical experience as well as these 100 KVA furnace test results, the authors believe that the reactivity of coke contributes to the bridging strength of the dome. In this case, it seems favorable to use the coke with high reactivity of more than 1.1 of half-width index. But as the above results were obtained with coke of even size, there was hardly any influence of size distribution on the results. When we discuss the reactivity of coke, however, it is necessary for us to consider an influence of its size distribution. By applying our experience in operating a commercial furnace to the test results, we can say that even the coke with reactivity of 1.1 or smaller can be used. In test No. 24, all the coke was replaced by char which was incompletely carbonized and still had 20% of volatile matter. This high V.M. char had no adverse effect on the furnace operation.

5.2 Furnace Excavation Results

Fig.2 shows a model crucible structure of the furnace which

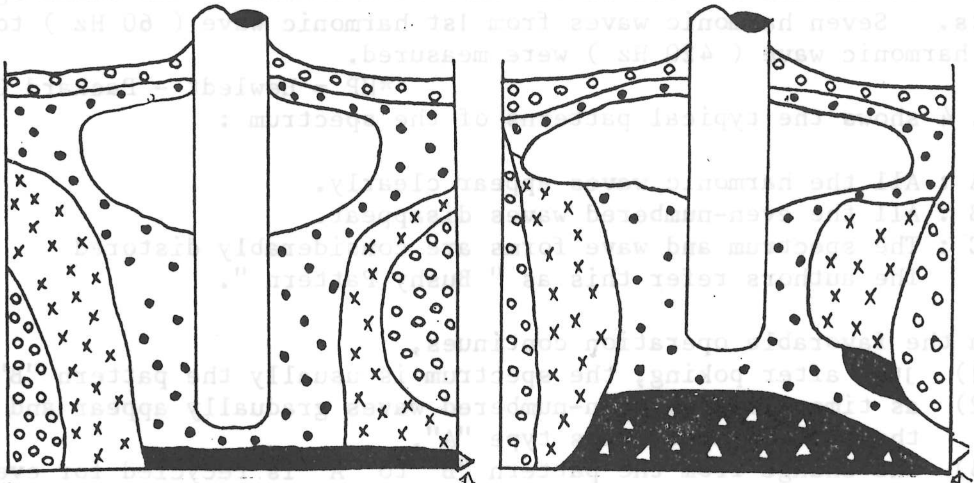
Table 5. Summary of the smelting tests

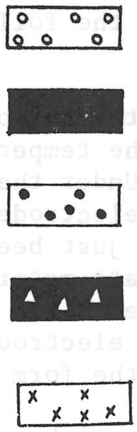
Test No.	Quartzite	Coke		Coal		Wood Chip KG/100kg of silica	Furnace Condition
		F.C.% Charged	Half-width Index	F.C.% Charged	C.S.N.		
0	Imajo	75	1.24	25	2.5	24	Standard furnace condition
1	"	75	1.24	25	7.0	0	The dome sintered too tightly to break and push down by poking.
2	"	75	1.24	25	1.5	0	Cavity beneath the dome became narrow.
3	"	75	1.24	25	4.5	24	No spontaneous raw materials descending. The dome sintered comparatively tightly.
4	"	75	1.24	25	3.1	24	Bridging strength was somewhat strong.
5	"	75	1.24	25	2.8	24	Ditto
6	"	75	1.24	25	1.8	24	Bridging strength was somewhat strong.
7	"	75	1.24	25	0.8	24	Descending of raw materials was fast.
8	"	75	1.24	25	0	24	Descending of raw materials was very fast.
9	"	71	1.24	29	3.1	24	Good operation
10	"	71	1.24	29	2.8	24	Good operation
11	"	65	1.40	35	3.1	24	Good operation
12	"	75	1.00	25	2.5	24	Descending of raw materials was rather fast. Gruel-like operation was found by furnace excavation observation.
13	"	75	1.10	25	1.8	24	Rather good operation
14	Panay	75	1.24	25	4.7	24	No spontaneous raw materials descending. Tight crusts around the electrode.
15	"	75	1.24	25	2.8	24	Good operation
16	"	75	1.24	25	2.5	24	Descending raw materials was fast.
17	"	67	1.24	33	2.9	24	Good operation
18	"	60	1.24	40	2.9	24	Rather good operation
19	"	75	1.0	25	2.8	24	Gruel-like operation
20	"	50-55	1.0	50-45	2.8-1.8	24	Descending of raw materials was very fast. Electrode went up.
21	"	75	1.24	25	3.5	24	Bridging strength was somewhat strong.
22	"	75	1.24	25	2.1	24	Bridging strength was weak. Gruel-like operation.
23	"	75	1.32	25	3.5	24	Good operation
24	"	75	1.40	25	3.5	24	Good operation
25	"	70	1.40	30	2.6	24	Rather good operation

stopped its operation after a normal and successful operation.

Fig. 3 is also a model picture showing the crucible structure of the furnace which stopped its operation after an abnormal furnace operation with faster descending of raw materials and with the crucible bed gone up.

Fig. 2 Fig.3





One of the most important differences between the two models, is the composition and distribution of the intermediate of raw materials surrounding the electrode and its tip. In case of Fig.2, the intermediate is characterized by the well blended mixture of SiC and SiO2. In case of Fig. 3, many falling streams of molten silica are found around the electrode in addition to the above-stated SiC - SiO2 mixtures. So-called " a gruel-like operation " is characterized by the existence of these falling streams of molten silica. This molten silica stream just beneath the cavity includes many particles of coke and carbonized carbonaceous material and has lower electric resistance. But when molten silica falls down in large quantity, we assumed that the electrode tip might be wrapped up in the layer of molten silica and the arc at the electrode tip might extinguish. Through observing furnace excavation, our assumptions presented above were proved by the fact that the silica stream contains no carbon near the bottom of the furnace crucible and around the electrode tip.

5.3 Frequency Analysis for Electrode Current

HP* spectrum analyzer was used to make frequency analysis for electrode current for the latter half of a series of the smelting tests. Seven harmonic waves from 1st harmonic wave (60 Hz) to the 7th harmonic wave (420 Hz) were measured.

*HP = Hewledt - Packard Co.

Fig. 4 shows the typical patterns of the spectrum :

A : All the harmonic waves appear clearly.
B : All the even-numbered waves disappear.
C : The spectrum and wave forms are considerably distored The authors refer this as " Bushy Pattern ".

When the favorable operation continues,

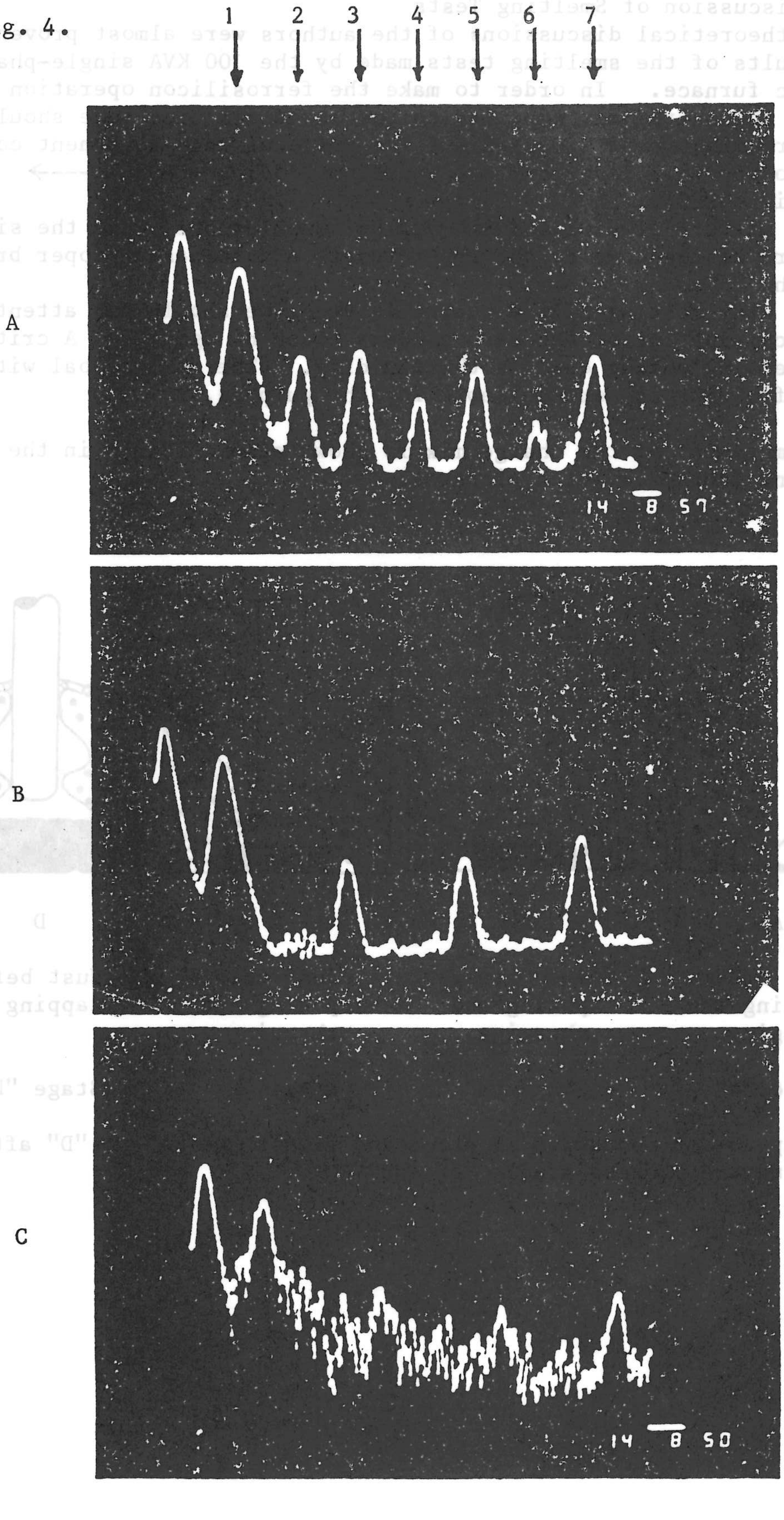
1) just after poking, the spectrum is usually the pattern "B",
2) as time elapses, even-numbered waves gradually appear and the pattern approaches type "A",
3) the change from the pattern "B" to "A" is recycled for every additional poking, and
4) the spectrum becomes the pattern "C" just before tapping.

Judging from the relation between the patterns and the corresponding operating stages, each pattern may probably mean the following furnace conditions.

A : The gap separating the electrode tip and the surrounding intermediate materials are expanding. The temperature around there is rising to the highest. Under these circumstances, arc is strong and stable at the electrode tip.
B : The cavity beneath the surface charge has just been filled with materials caved in and the intermediate materials are directly contacted with electrode. The electric current flows mostly from the side surface of the electrode, not from the electrode tip, and generates heat in the form of resistance heating.
C : The normal arc from the electrode tip can not be maintained due to the metal splash from the bath.

When descending of raw materials is fast, the pattern "A" can not be found, and as the electrode goes up, the pattern shifts to "C". When raw materials stop descending, only pattern "A" is found. The furnace condition, especially the one surrounding the electrode, shows good coincidence with the frequency analysis. Furnace condition is highly correnlated with the 2nd harmonic wave of the electrode current or voltage. Even in the commercial furnace, there seems to exist a good coincidence between the 2nd harmonic wave of the electrode voltage and the furnace condition. This will be a useful measure for judging the furnace condition continuously.

Fig. 4.



5.4 Discussion of Smelting Tests

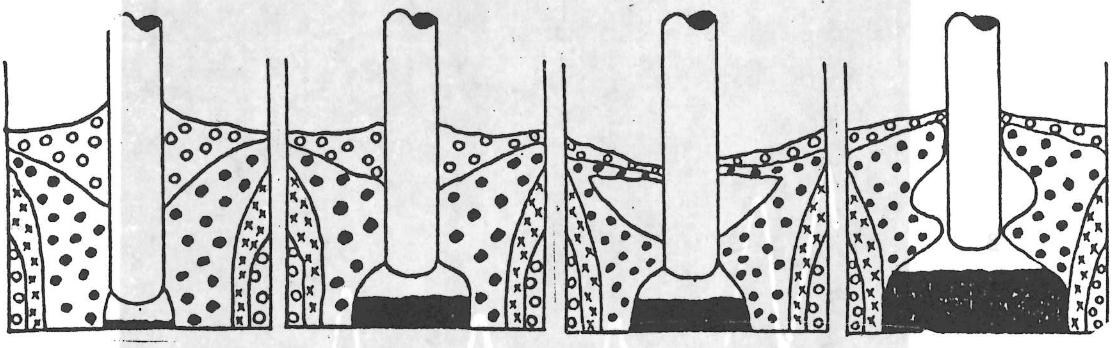
The theoretical discussions of the authors were almost proven by the results of the smelting tests made by the 100 KVA single-phase electric furnace. In order to make the ferrosilicon operation stable, the charge mix supplied to the lower reaction zone should be a uniform mixture of $SiO2 + SiC$ (The ratio of each component corresponds to the following chemical equation : $3SiO2 + 2SiC \longrightarrow Si + 4SiO + 2CO$).

Such mixture of SiO2 and SiC may be supplied only when the sintered-structure of the dome at the upper reaction zone has a proper bridging strength.

When easy-melting silica quartz is used, we should pay attention to the combination of the carbonaceous reducing agents. A criterion for selecting coking coal is the fluidity. The coking coal with higher fluidity is more suitable for the purpose.

The movement of the charge mix is shown schematically in the following four excavation pictures.

Fig. 5

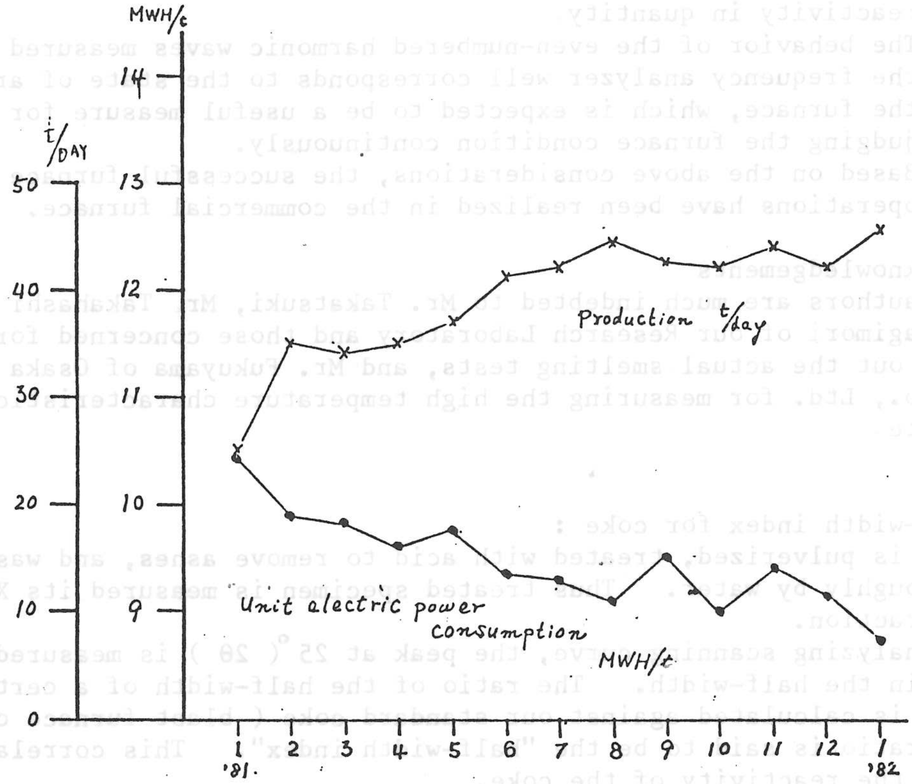


A	B	C	D
Just after tapping and charging	Just after poking and charging	Just before poking and charging	Just before tapping
Stage "A"	Stage "B"	Stage "C"	Stage "D"

A tap-to-tap operation is proceeded from stage "A" to "D" after repeating the process stages "B" and "C".

6. Operation Performance by a 20 MVA FeSi Furnace

Fig. 6 Operation performance of a 20 MVA furnace



The operation performance of a 20 MVA FeSi Furnace at Electro Alloys Corporation for 1981 is shown in Fig.6. The furnace had been charged with the following raw materials : Quartzite ; mainly the Panay quartzite : Coke ; Mitsui coke imported from Japan : Imported Coal ; Horonai coal (Semi-bituminuous coal) and/or Yubari coal (coking coal) imported from Japan : Local Coal ; Polillo coal : Charcoal ; local : Wood chips ; local : Iron source ; Mill scale.

For the first half of the year, the local coal was not used, but the use of charcoal has been increased to improve the furnace conditions. The mixture of local coal and coking coal was used for the second half of the year. And we confirmed the FeSi furnace being operated stably.

7. Summary

1) In the furnace operation of ferrosilicon, the bridging strength for the sintered-structure of the dome at the upper reaction zone plays an important role. There is a proper bridging strength for a certain furnace operation.
2) When coal is used as one of the carbonaceous reducing agents. Its C.S.N. should be adjusted precisely at a specified C.S.N. range according to the melting characteristics of the silica

quarts. Controlling of the C.S.N. can be made by selecting and mixing coals. The total coal quantity seems to be limited to less than 30 - 35% of the total fixed carbon necessary.

3) One of the methods to increase the bridging strength for the sintered-structure of the dome is to use coke with high reactivity in quantity.
4) The behavior of the even-numbered harmonic waves measured by the frequency analyzer well corresponds to the state of arc in the furnace, which is expected to be a useful measure for judging the furnace condition continuously.
5) Based on the above considerations, the successful furnace operations have been realized in the commercial furnace.

8. Acknowledgements

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NOTE :

Half-width index for coke :

Coke is pulverized, treated with acid to remove ashes, and washed thoroughly by water. Thus treated specimen is measured its X-ray diffraction.

By analyzing scanning curve, the peak at 25° (2θ) is measured to obtain the half-width. The ratio of the half-width of a certain coke is calculated against our standard coke (blast furnace coke). The ratio is said to be the "half-width index". This correlates with the reactivity of the coke.

Reference

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