CONSTRUCTION AND OPERATION
OF
THE SHAFT TYPE Fe-Mn SMELTING FURNACE

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ABSTRACT

At the Mizushima Ferro Alloy Manufacturing Company Ltd., the Fe-Mn smelting process was converted from the Electric furnace to the Shaft type smelting furnace (hereinafter called SF) in order to reduce the operating cost of the Fe-Mn process. The operating cost of the electric furnace process has increased due to the increased cost of electric power and the reduction in Fe-Mn consumption during the steelmaking process.
The SF process is more profitable than the electric furnace process not only in terms of electricity consumed but also in the utilization of process gas which generated during smelting. The SF has a 398 m^3 inner volume and equipment with the following features:

(1). Effective furnace shell cooling system even when there is a high heating load exerted on the shell.
(2). Highly resistant slag erosion refractries.
(3). Highly efficient gas cleaning equipment.
(4). Radiation type recuperator for the hot air generation.
(5). Highly controllable charging equipment for the burden distribution.

On June 24, 1985, the SF began blow-in and it's operation has continued satisfactorily to the present date.

1. INTRODUCTION

As a result of the first and second oil crises, a sudden rise in power costs occurred in Japan, which depended on the thermal power generated by petroleum. Since almost all of the ferro-alloy production in Japan depended on the electric furnace, this brought about a sudden rise in production costs. In addition to the above, there has bee a growing tendency towards the production of high grade steel and a diversification in steel quality which have served as the background to allowing new technologies such as the pretreatment of molten iron and the direct charging of manganese ore into convertors to come to the fore and to develop, and which have caused depressing the demand for manganese ferro-alloys (HcFeMn hereunder).
Under such economic conditions, ferro-alloy making companies face severe problems such as reduction of production scale, rationalization of management, etc.
Taking the above situations into consideration, we decided to undertake a fundamental rationalization of management by converting the expensive electric energy system into a less expensive coal energy system after taking energy balance, utility balance, etc. into account and by making use of the fact that Mizushima Ferro-Alloy Company Ltd. was located adjacent to Mizushima Works of Kawasaki Steel Corporation (KSC hereunder).
That is to say, we decided to change from a 4-electric furnace system to a system of 1-electric furnace and 1-smelting furnace (SF hereunder). (Refer to Table 1, Fig. 1.)
A study into the feasibility of this new system was begun in October of 1982 and it was finally realized when SF was blown-in on June 24, 1985. Since then, production has proceeded smoothly at our company.
In this presentation we wish to describe the outline of the construction plan of SF, its construction work, and the startup operation after the blow-in.

2. BASIC PLAN AND CONSTRUCTION WORK

2-1 Basic Plan

Our basic design for the construction of SF was as follows. It was also our intention to introduce as many plant technologies and operation technologies for iron-making as possible into the new system.

(1) Prolongation of the Life of the Furnace

The specifications of the equipment, which greatly influenced the overall operation of the system and the lives of the other equipment and for which repair and modifications were difficult under operational condition were of as high a standard or even higher than those of blast furnaces as a result of our experience gained in the operation of blast furnaces.
The SF furnace proper especially, was to be strong enough for a targeted service life of 10 years.

(2) Reduction of Construction Cost

In order to minimize the construction costs, the following were decided upon:
a) A recuperator was adopted as the equipment for generating the hot blast. Special attention was given to the safety, maintainability and economy of the system to make it comparable with the hot stove in a blast furnace.

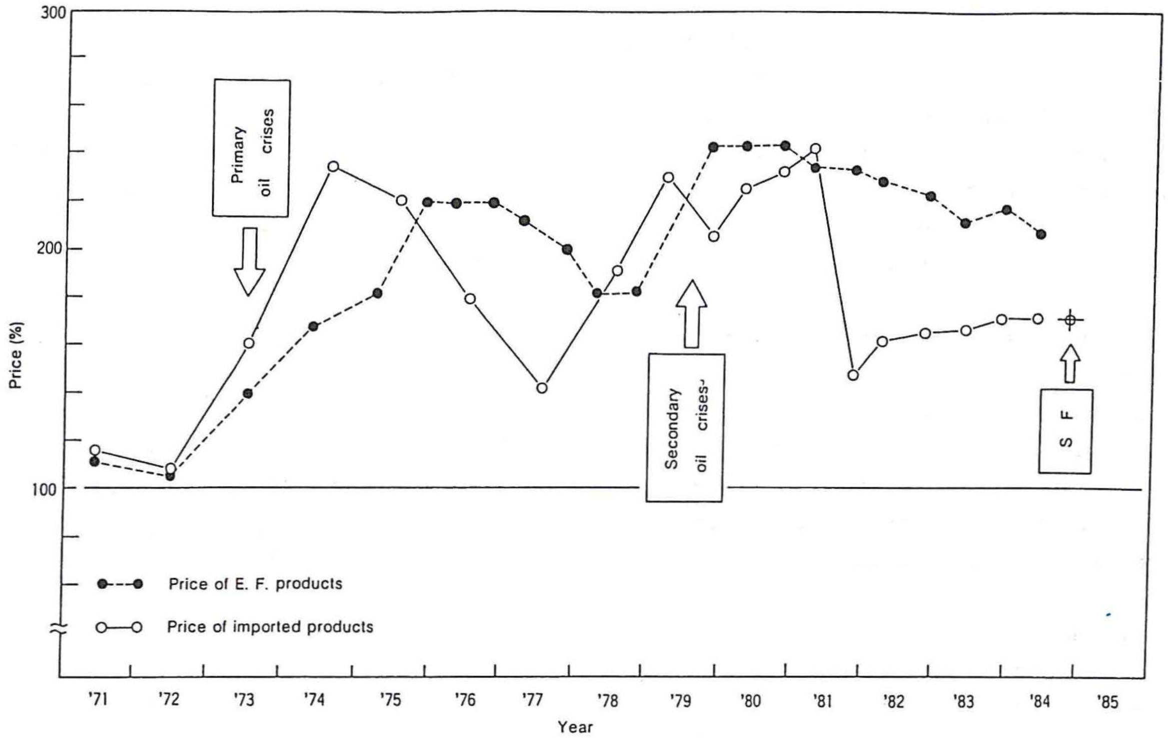

Fig. 1. Transition of price of ferro—manganese

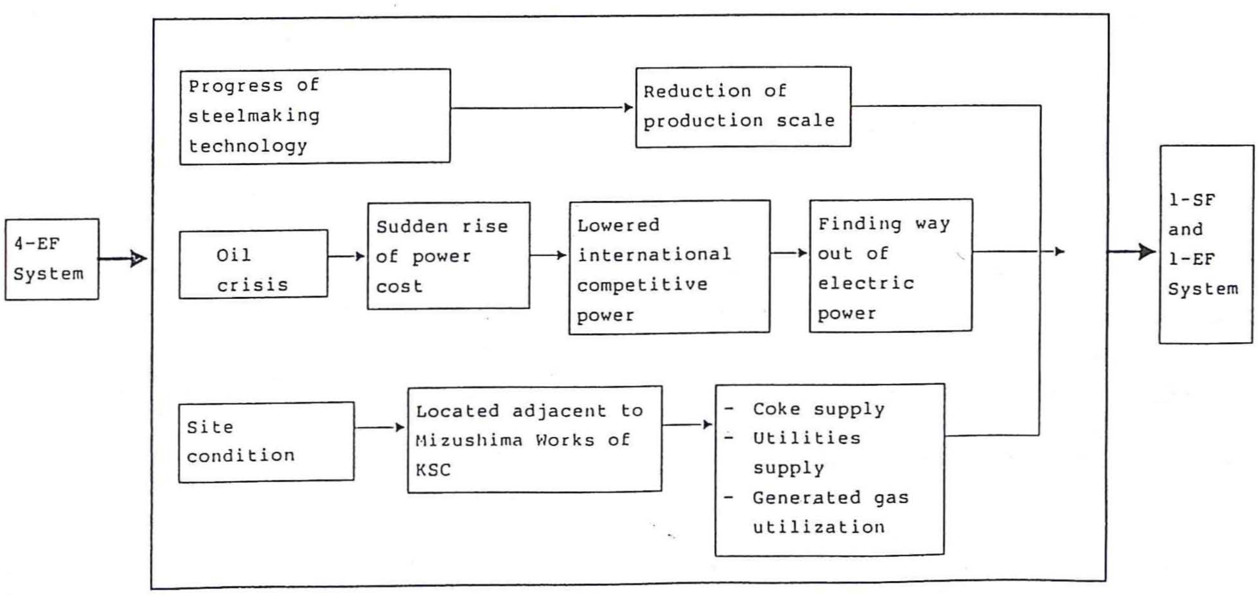

Table 1 Background and Conception on the adoption of SF

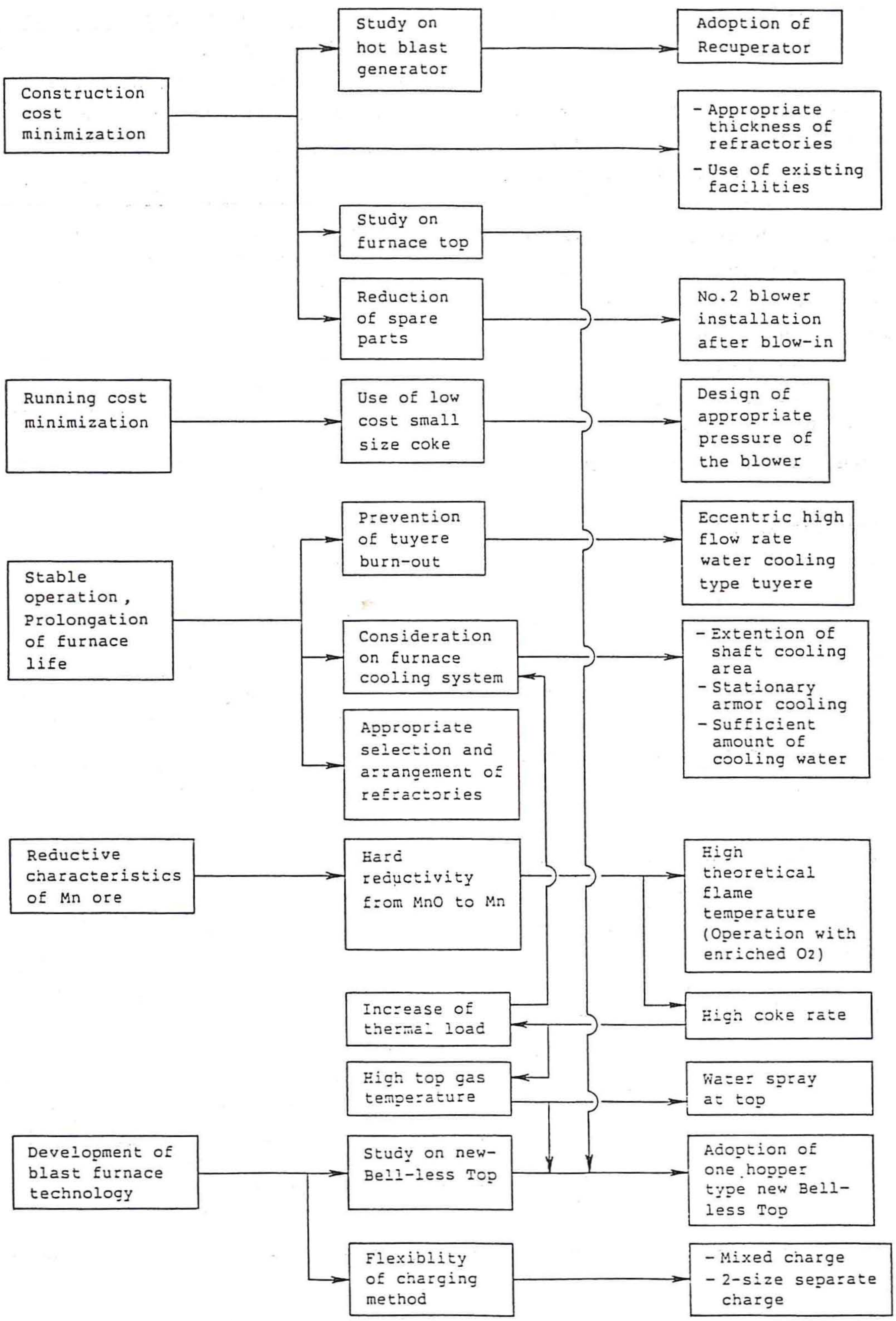

Table 2 Considerations as regards the basic plan

b) As much existing equipment, and as many buildings and foundations would be used as possible.

c) Although the principal object was to simplify the equipment in the system, there would be room for future expansion and improvement of each of them.

(3) As many new technologies as possible were applied in the hope that they would act as pioneers in the development of blast furnace technologies.

a) Adoption of Recuperator

b) Adoption of New Bell-less Top

c) Adoption of DDC (Direct Digital Control) System to the Instrumentation System

(4) Equipment installed should reduce the operational costs.

(5) Equipment installed should be that in which countermeasures against safety operation and improvement of working environmental were taken into consideration.

Considerations as regards the basic plan are shown in Table 2.

2-2 Basic Design Operating Conditions

In Table 3 are shown the basic design operating conditions of SF based on the results of feasibility studies.

Items	Specification
Inner volume	398 m³
Production	230 t/d
Blast volume	450 Nm³/min
Oxygen enrichment	7 ~ 8 %
Blast temperature	860 ℃
[Mn]	74.5 %
Coke rate	1,500 kg/t
Productivity	0.58 t/m³·d
Slag rate	580 kg/t
Top gas generation	4,890 Nm³/t

Table. 3
Operational condition for designing of S.F.

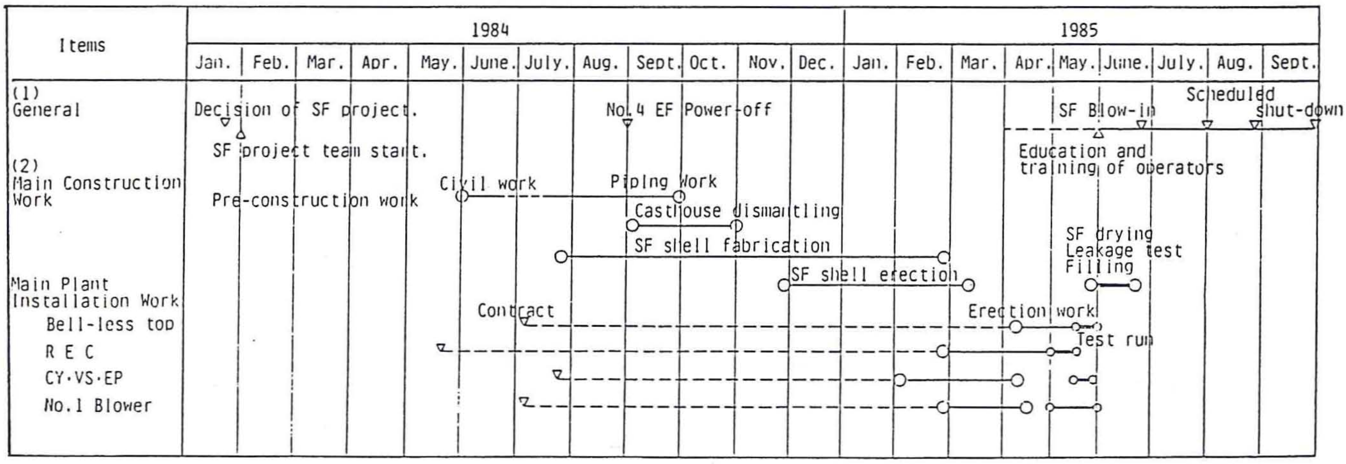

Table 4. Construction time Schedule of SF.

2-3 Construction Work

In Table 4 are shown the construction plan and the schedule for the construction work. The construction of this SF was completed in only 2 years and 11 months from the start of the feasibility study in October of 1982 to the blow-in of the furnace in June of 1985.

Although it was initially estimated that it would take 10 months for the overhaul and installation work at the furnace on the site, this was reduced by one week by utilizing large capacity cranes, and by following a detailed construction time schedule control system, etc.

The cost for this construction and the man-hours expected were as follows:

Construction cost	:	12 million US dollars at (240 Yen/Dollar)
Total man-hours	:	370,000 hr, with no accident

3. SF SYSTEM

In Table 5 are shown the basic specifications of SF system.

The furnace capacity and the maximum production capacity of the furnace were set at 398 m^3 and 270 t/d respectively taking the furnace supply and demand balance of HcFeMn into consideration. All of the facilities have been operating satisfactorily since the blow-in of the furnace according to the initially planned performance.

Described hereunder are the characteristics of the SF system.

(1) Layout

The layout of the system was decided on the premise that as many of the existing facilities would be used as possible to reduce the construction cost. (Refer to Fig. 2.)

Major existing facilities which were to be utilized were as follows:

a) Foundation of No.4 Electric Furnace → Foundation for SF
b) Foundation of the gas cleaning system of No.4 Electric Furnace → Foundation for Recuperator
c) Structure for No.4 Electric Furnace → Tower structure for SF
d) Material Reservoir for No.3 Electric Furnace → Coke Reservoir for SF
e) Product crusher and screen stations for No.3 Electric Furnace → Product crusher and screen stations for SF

(2) Furnace Proper

Carbon brick was used after taking deterioration resistance against Mn-Slag and resistance to alkali into consideration.

A cooling plate system was adopted for the cooling of the furnace. Becasue of the temperature rise at the furnace top, a water cooling system was adopted to cool the stationary armor. A eccentric high flow rate water cooling type tuyere was adopted to cope with the high theoretical flame temperature.

(3) Recuperator

A recuperator was adopted instead of hot stove for blast furnace to reduce the installation costs.

The recuperator system preheated both cold blast and combustion air in the flue pipe of recuperator to improve thermal efficiency.

The recuperator generates a normal hot blast of 860°C and a maximum of 900°C and its thermal efficiency is more than

80%. Satisfactory results exceeding 84% of thermal efficiency have been obtained from measurements taken during the actual operation of the furnace after the blow-in of it. (Refer to Fig.3)

(4) Furnace Top Equipment

Center feed type Cardan bell-less charging equipment was adopted in this SF system and pioneered the blast furnace technologies.

As shown in fig. 4 and Fig. 5, the distribution chute of this system is supported by a so-called Cardan joint, which is a universal joint capable of rotating independently around two shafts which cross each other at right angles. This has a device to cause a rocking motion in the distribution chute through a link mechanism. This is capable of not only changing the tilting angle of the distribution chute but also of moving the distribution chute in a circular motion at that tilting angle.

The basic specifications of the system are as follows:

Top gas pressure	: 0.15 kg/cm^2
Charging system	: Belt conveyor
Charging frequency	: 220 times/d
Length of chute	: 2,800 mm
Rotating motor	: 11/3.7 kw, 4P/12P
Tilting motor	: 11 kw,4P
Rotation rate	: 8 rpm
Lower seal valve	: 600 mm dia. Driving by hydraulic pressure
Countermeasure against heat	: Water cooling

This system is highly reliable and controllable as compared with the conventional system.

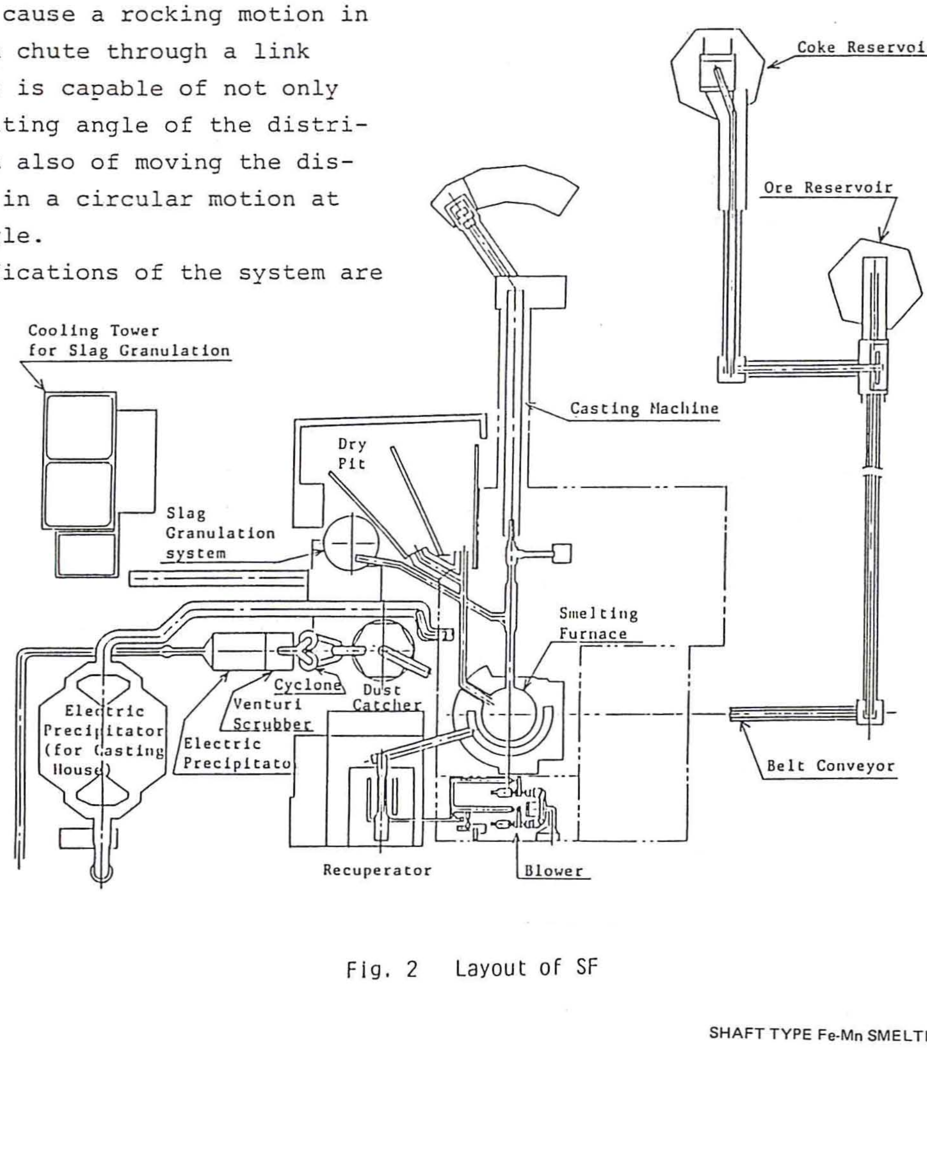

Fig. 2 Layout of SF

Table 5. Main specifications of SF equipment

Item	Specifications
1. Furnace proper	
1) Inner volume	398 m^3
2) Furnace support	Free standing type
3) Cooling system	- Shaft - Bosh : Cooling plates
	- Tuyere - Hearth: Water spray
4) Refractories	- Upper and middle shaft: High alumina brick
	- Lower shaft - Tuyere: SiC brick
	- Hearth: Carbon brick
5) Tuyere	- 13
	- Eccentric high flow rate water cooling type tuyere
6) Tap hole	1
7) Cinder notch	1
2. Cast house	
1) Tap hole opener	- 1 set, air driven
	- Effective length of opening: 3000 mm
2) Mud gun	- 1 set
	- Mud capacity: 0.1 m^3
	- Filling : Driven by hydraulic pressure
	- Rotation: Driven by electric power
3) Trough	- Non hot metal storage type
	- Mono-stage skimmer
4) Molten iron treatment	- 1-casting machine Max. 4.3 t/min
5) Slag treatment	- 2-dry pit
	- 1-slag granulation system
3. Furnace top equipment	
1) Charging pattern	- Standard charging pattern: C↓ O↓ and C↓ C↓ O↓ O↓
	- C-O mixed charging, coke two-size separate charging, etc.
2) Furnace top equipment	- One hopper type new bell-less top
	- Distribution chute: electric drive
	- Seal valve, flow control valve: hydraulic drive
4. Hot blast generator	- (Radiation + Convection) type recuperator
	- 1 set
	- Blast temperature: 860°C Max. 900°C
5. Gas cleaning system	
1) Dust catcher (DC)	- Gravity settling type
2) Cyclone (CY)	- Centrifugal type
3) Venturi scrabber (VS)	- 1-stage venturi throat variable type
4) Electric precipitator (EP)	- Wet type, 2-room
6. Stock house	
1) Coke reservoir	55 m^3 x 14 reservoirs
2) Ore reservoir	60 m^3 x 12 reservoirs
7. Blower	- Electric drive
	- Blower revolution: 13,400 rpm
	- Motor: 1400 kw x 3580 rpm
	- Blast volume and pressure: 535 Nm^3/min x 1.3 kg/cm^2

(5) Gas Cleaning System

As a gas cleaning system for coping with the high dust content of the gas, a Dust Catcher and Cyclone were adopted as the dry dust collectors, and a Venturi Scrubber and an Electric Precipitator were adopted as the wet dust collectors.
Measurement results of dust content in the gas after the blow-in of the furnace indicated that the dust content of the gas after passing through the gas cleaning system was less than 5 mg/Nm^3. Such results sufficiently satisfied our initial plan, and the system has shown a high dust collecting efficiency of 99.9%.

(6) Instrumentation Equipment

To improve its functioning and to make it compact, the most modern instrumentation technologies using DDC (Direct Digital Control) and CRT (Cathode-Ray Tube) were applied to SF system, in addition to a panel operation system.
The control panel and CRT have separate functions.
Important instrument for controlling valves, blast volume, blast pressure, etc., which are the basic areas in the operation and which require rapid responses during the operation, were controlled from an operation desk and control panel which also covered emergencies, and ensured safety.
CRT with keyboard has functions of setting various operation factors and monitoring indications and alarms throughout the complete control loop.
Shown respectively in Fig. 6 and Fig. 7 are the outlines of the instrumentation system and an example of sensor arrangement.

Date		Jul. 1985
Blast volume	Nm³/min	461
Blast temperature	℃	853^{7}
Atmospheric temperature	℃	24^{1}
Thermal efficiency	%	84^{3}

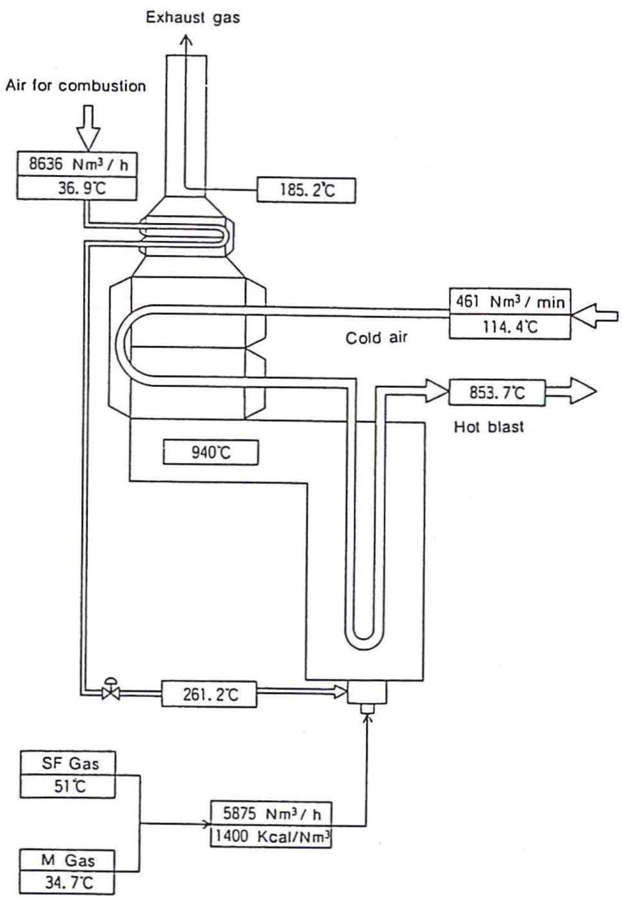

Fig. 3. Thermal efficiency of recuperater

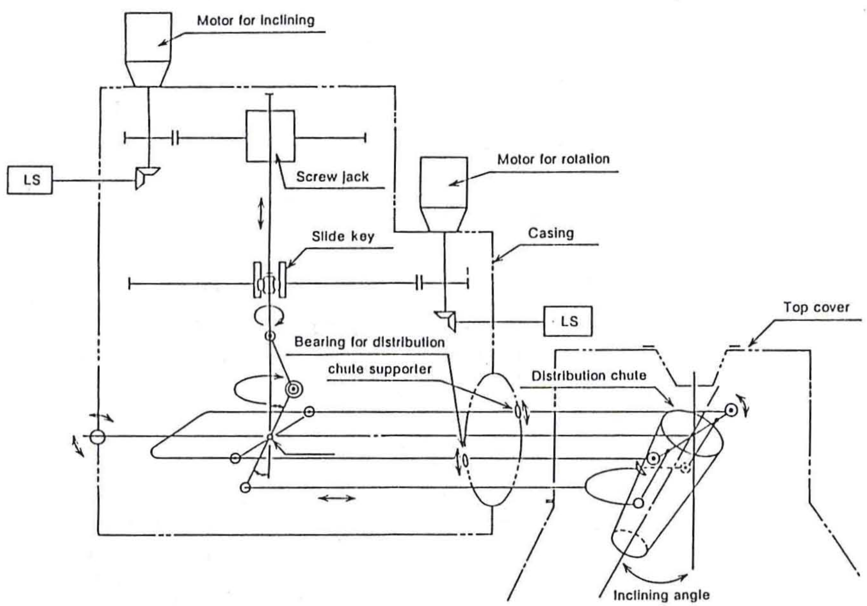

Fig. 4. Drive mechanism

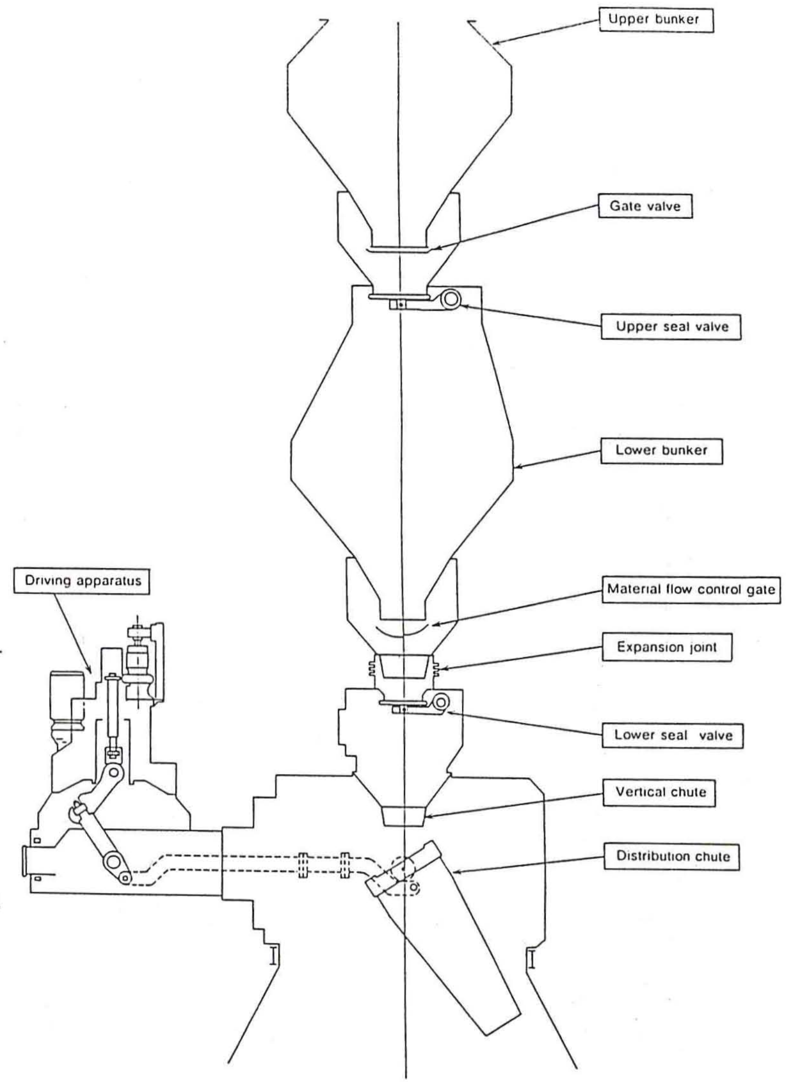

Fig. 5. General view of cardan type bell-less top

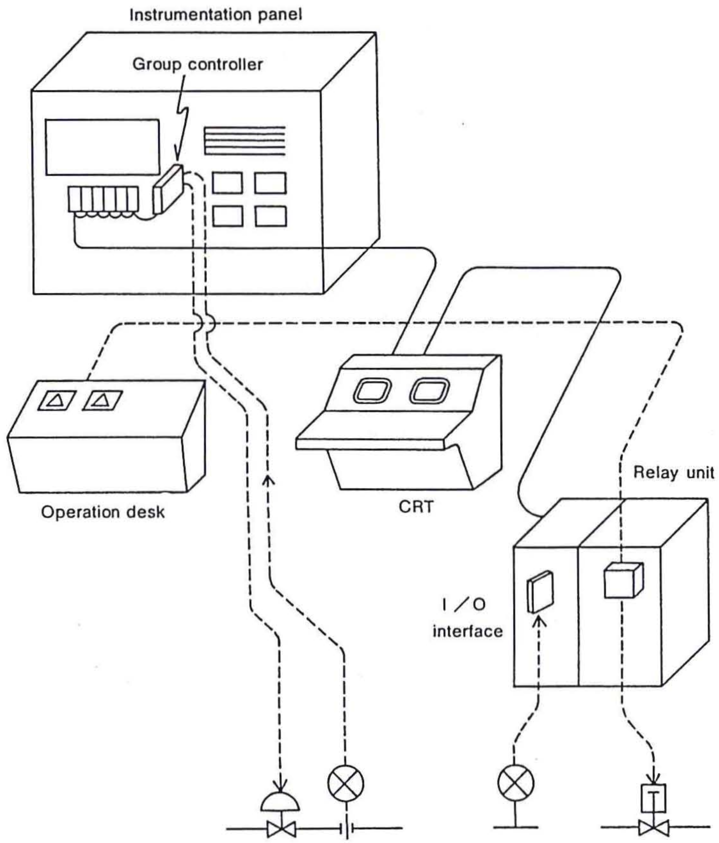

Fig. 6. Outline of Instrumentation system

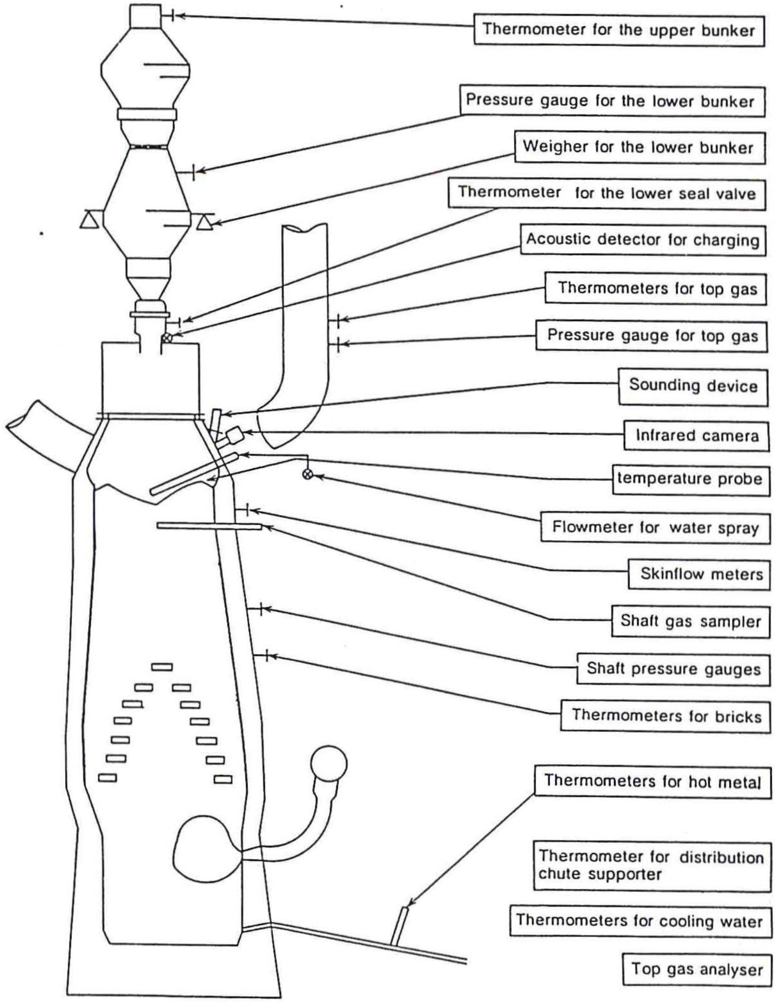

Fig. 7. Instrumentation of smelting furnace

4. OPERATION

The construction of SF progressed satisfactorily. It was completed about 1 week earlier than planned. The operation of new SF was begun at 1:55 p.m. on June 24, 1985.

Its blow-in operation and startup operation went very smoothly, and since then it has displayed continuous rating-ups as per the production plan.

Described briefly hereunder are the blow-in and startup operations of SF.

(1) Filling and Blow-in

In Table 6 are shown the results of the material filling operation of SF. In order to attain rapid temperature raise of the furnace, the coke rate was set at slightly higher level.

Top Charge : ore/coke 1.70
Mean Coke Rate : 3,873 kg/t
Setting of [Si]: 3.5%

The first tapping was carried out, as planned, quite satisfactorily between 10:00 ∿ 12:25 on the following day, June 25.

First Tapping : 69.9 ton
Temperature of Molten Iron: 1,364°C
[Si] : 3.55%

Steps	Inner volume of each step	Charged Material (kg/ch)						O/C	Charging number	Metal production* (kg/ch)	Slag production* (kg/ch)	Chemical content of slag*			
		Coke	Ore		Flux-material							CaO/SiO_2	Al_2O_3	MgO	SiO_2
			Sintered ore	Lump ore	Dolomite	Lime	Silica					(-)	(%)	(%)	(%)
9	30.2	3,500	4,170	1,780	30	250	390	1.7	3	3,785	1,499	1.0	13.5	7.0	36.6
8	27.5	〃	3,190	1,360	90	290	330	1.3	3	2,901	1,347	1.0	13.5	〃	36.9
7	27.8	〃	2,450	1,050	130	310	270	1.0	3	2,239	1,234	1.0	13.5	〃	37.1
6	30.2	〃	1,720	730	180	320	230	0.7	4	1,576	1,120	0.95	13.5	〃	38.4
5	35.7	〃	980	420	220	340	180	0.4	5	913	1,007	0.95	13.5	〃	38.8
4	38.9	〃	250	100	250	340	120	0.1	6	250	862	0.9	14.0	〃	40.0
3	62.4	〃	0	0	260	330	90	0	9	31	796	0.9	14.5	〃	40.0
2	67.3	〃	0	0	260	310	100	0	11	31	796	0.85	14.5	〃	41.0
1	Pile of sleeper														
Total (Average)	320	(3,500)	42,710 (971)	18,220 (414)	9,270 (211)	13,950 (317)	7,420 (169)	(0.395)	44	39,764 (903.7)	42,847 (973.8)	(0.93)	(13.9)	(7.0)	(38.6)

* These are calculated values.

Table 6 Results of the filling of material

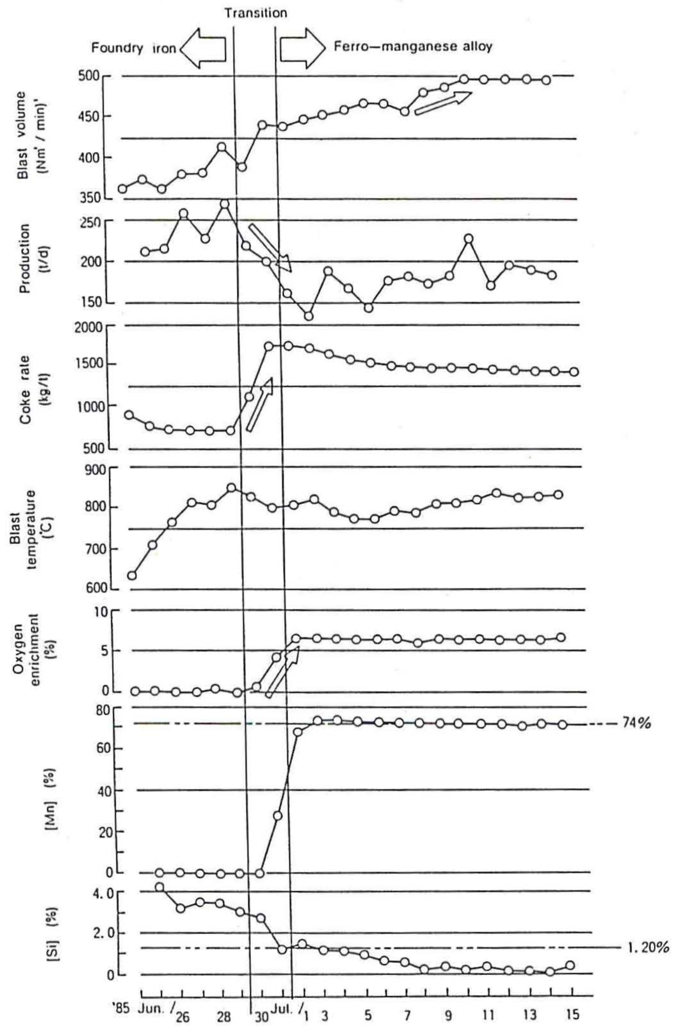

Fig. 8. Operational results of S. F. for one month after blow—in

items	data
Inner volume	398 m³
Production	240 t/d
Blast volume	550 Nm³/min
Oxygen enrichment	5 %
Blast temperature	800 ℃
[Mn]	74.5%
Coke rate	1485 kg/t
Productivity	0.60 t/m³·d
Slag rate	600 kg/t
Top gas generation	4800 Nm³/t
Manganese yield	91 %

Table. 7

Principal operational data of S. F.

(2) Startup Operation

Shown in Fig. 8 are the results of the startup operation after the blow-in. The foundry pig-iron making operation was conducted for a week after the start of the operation to increase the furnace temperature. The production of HcFeMn was begun on July 3, as planned, after a 2 day transition period. The production from the furnace continued to increase according to the production plan, and it reached 230 t/d in September, and 270 t/d in November which was the limit of the system's productive capacity. Adjustment of the furnace production has been made since then according to such things as sales amount, and stock. As for the coke rate, it was gradually reduced taking into consideration the increased production of gas along with the increased production of HcFeMn and the gas balance at Mizushima Works of KSC, and it is now maintained at the 1,500 kg/t level as was initially planned.

Comparisons of the properties of SF products obtained during this period and those of electric furnace products are shown in Table 8.

As can be seen from the table, there are few differences between SF products and electric furnace products except for the slightly higher [Si] content of the former.

From the above SF operation results, we feel that the conversion from electric furnace into SF was carried out successfully, and that these results were as initially planned both in respect to productivity and product quality.

	Mn		Si		C	
	x	σ	x	σ	x	σ
E F	74.1	0.57	0.02	0.01	6.89	0.08
S F	74.7	0.37	0.26	0.09	6.98	0.08

	P		S			
	x	σ	x	σ		
E F	0.121	0.006	0.001	0.0005		
S F	0.134	0.007	0.003	0.0009		

Table. 8 Comparison of quality of ferro—manganese by E. F. with one by S. F.

5. CONCLUSION

Owing to the energy situation, a shaft type Semlting Furnace for the production of HcFeMn was constructed to replace the existing electric furnace at Mizushima Ferro-Alloy Company Ltd. to convert the energy source from petroleum to coal.
The construction of this system was completed through the application of the ironmaking technologies of Kawasaki Steel Corporation and by adoption of the most modern technologies while at the same time aiming at the minimization of construction cost.
The new system is performing as planned, and has maintained a high reliability and operational efficiency, which has resulted in the remarkable savings in production cost through the reduction of energy costs.
This system is operating smoothly with satisfactory productivity and product quality and has attained our initial object.
We believe therefore that the transition was carried out successfully.