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Distribution
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ID/WG.14/40
1 July 1968

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Second Interregional Symposium
on the Iron and Steel Industry

Moscow, USSR, 19 September - 9 October 1968

E-7-1

EXPERIENCE AND ECONOMIC PROFIT OF CONTINUOUS CASTING IN STEEL PLANT 1/

by

Yoshimasa Kawamoto
Sumitomo Metal Industries, Ltd.,
Japan

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted by the author, without re-editing.

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SUMMARY

More than ten years have passed since continuous casting became a part of the steel industry.

Developments in continuous casting have been remarkable, for in recent years the number of continuous casting machines, including machines under construction, have reached 200 throughout the world.

In Japan, our Sumitomo Metal installed pilot machine firstly in 1955 and since 1965 continuous casting machines increased rapidly and in this year have reached 25, including machines under construction.

Our Sumitomo Metal made a technical contract with Mr. Irving Rossi (Concast AG) in 1953 and started on developments of continuous casting of steel, because we have expected economic profits and future prospects of this process.

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* This is a summary of a paper issued under the same title as ID/WG.14/40.

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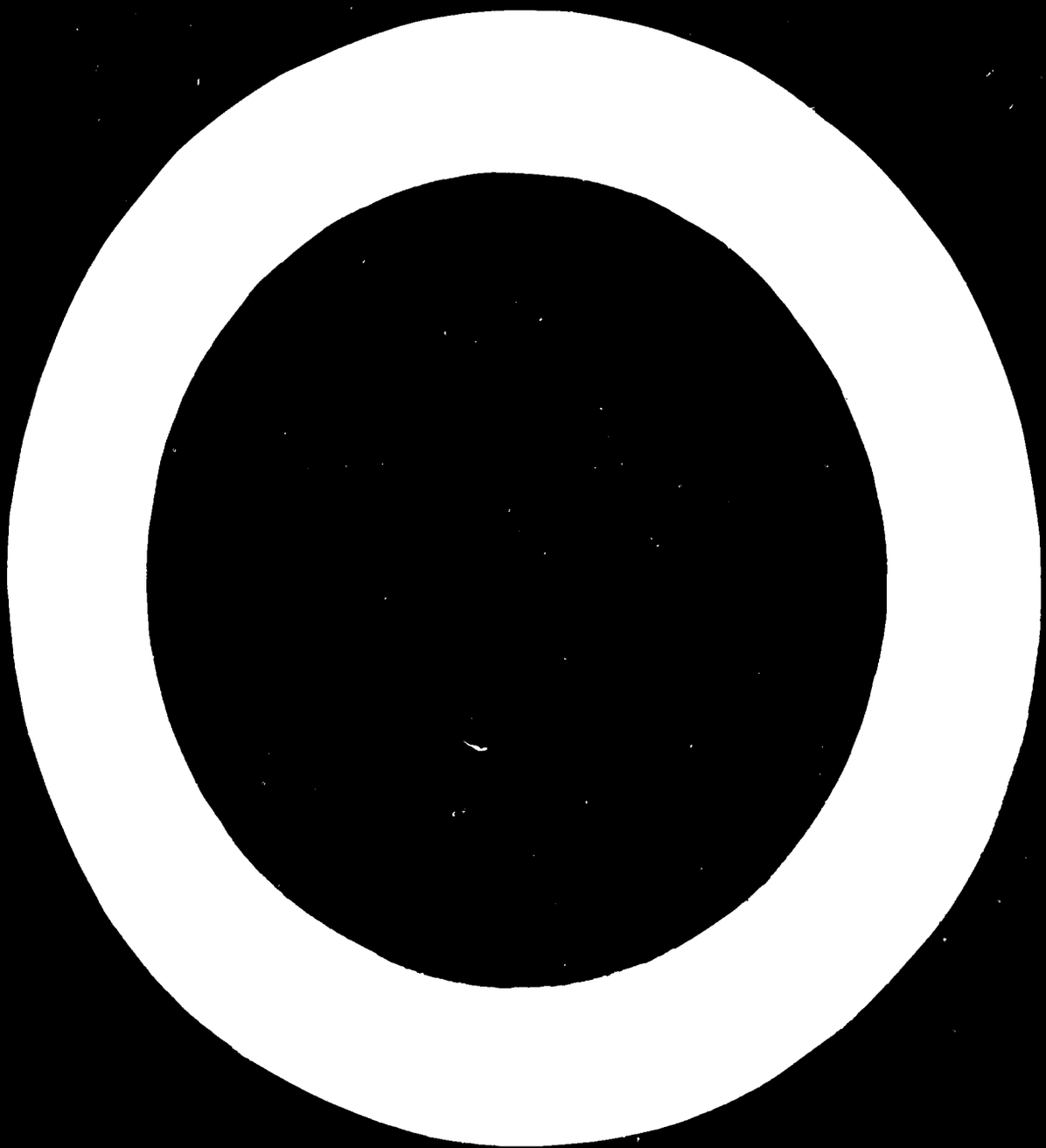


We installed above pilot machine in 1955 and have endeavoured developments of continuous casting technique of steel.

Now we installed and are under construction ten machines in Japanese steel plant, including our own machines.

Especially we present to this symposium about developments of continuous casting machine of steel billets.

1. Developments of S type (curved mould type) continuous casting machine

Hitherto continuous casting machines of steel were vertical type and total machine heights were greatly tall. This is large defect of continuous casting of steel.

Concast and Mannesmann groups have developed S type or curved mould type continuous casting machine for the purpose of solution of such defect. That is, the steel cast is made to follow a curved path on emerging from the mould by the simple thought of using a slightly curved mould instead of a straight one. In this result total machine height becomes less than half as compared with vertical type machine and total election cost becomes fifteen per cent cheaper, as a result of total height of machine becoming low. Moreover this machine is able to install easily in the existing casting shop, for it need not to build new shop.

Our Sumitomo Metal installed the first two strand curved mould type continuous casting machine at Kokko Steel Works Ltd in 1966 according to assistance of Concast AG. (Table 1)

This machine began to start from May 1966 and is casting about 10,000 t every month now.

Table 1

Outline of specification of continuous casting machine at Kokko Steel Works Ltd

Furnace	Basic electric arc furnace
Ladle Capacity	30 T
Type	Concast, Curved Mould
No. of Strands	2
Sections of Billet	130, 190 mm ϕ

Table 1 (continued)

Height	R ℓ $^{+\ 1.2\ m}_{-\ 8.0\ m}$
Bending Radius	8.5 m
Annual Capacity	120,000 T

2. Development of multistrand continuous casting machine

We began to design six strand curved mould type continuous casting machine from Spring of 1966 and operated from September 1967, at our Kokura Works. (Table 2) We have taken our experience of continuous casting in this machine and adopted some automatic control system.

These new trials succeeded and monthly production went over 10,000 T in only three months after operation.

We intend to produce 20,000 T every month from July 1968.

Table 2

Outline of specification of continuous casting machine at Sumitomo Metal, Kokura Works

Furnace	LD Converter
Ladle Capacity	70 T
Type	Concast, Curved mould
No. of Strands	6
Sections of Billet	92, 110 mm ϕ
Height	R ℓ $^{+\ 5.4\ m}_{-\ 1.2\ m}$
Bending Radius	5.5 m
Annual Capacity	200,000 T

3. Qualities of billets and productions

Continuous casting billets have the advantage that billet surfaces are excellent and chemical segregations are less as compared with conventional ingots. We have produced various kinds of steel by continuous casting machine and confirmed to get good quality production.

4. Economic profits of continuous casting

Economic profits of continuous casting of steel are as follows:

(1) Simplification of manufacturing process

(2) Improvement of production yield

(3) Improvement of atmosphere in steel casting plant

(4) Decrease of labour cost

For these above profits, we can decrease production cost consequently.

Our Sumito Metal could improve about ten per cent in production yield and decrease four per cent in production cost. (Table 3, Table 4)

Table 3

Comparison of yields between continuous casting and conventional casting (Deforming bar)

	Continuous Casting (%)	Conventional Casting (%)	Difference (%)
Steel Making			
Charge to tap	93.9	93.9	
Tap to Cast	97.2	96.5	
Cast to good billet	99.8	99.9	
Total	91.7	90.5	
Blooming	-	89.0	
Rolling	95.5	95.5	
Total	87.1	77.0	10.1

Table 4

Comparison of billet cast between continuous casting and conventional casting (In percentage of conventional blooming billet costs)

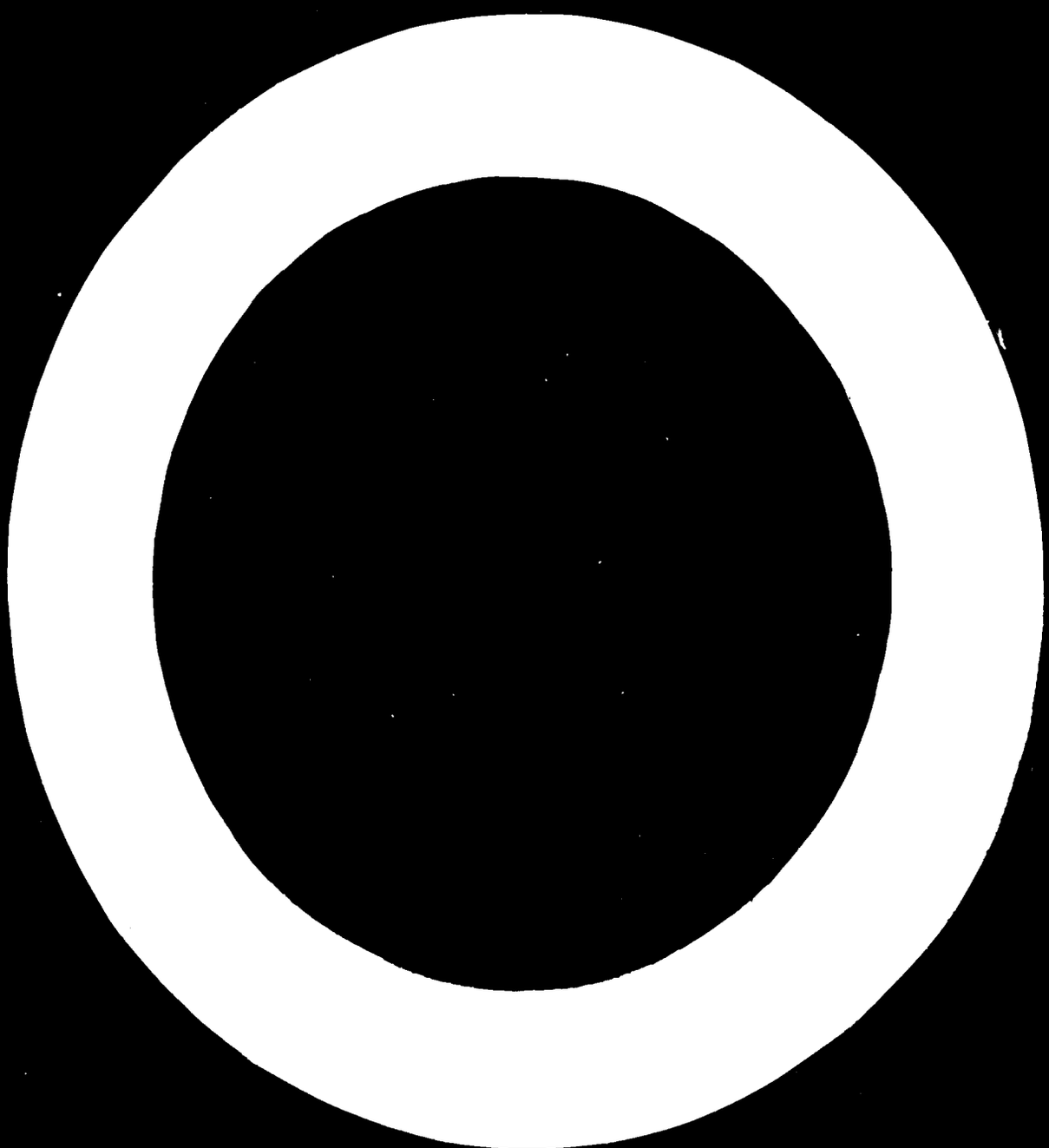
	Continuous Casting (%)	Conventional Casting (%)	Difference (%)
Materials	83.9	83.6	+ 0.3
Operation	11.9	9.1	+ 2.8
(Furnace)	(5.0)	(4.9)	
(Casting)	(6.9)	(4.2)	
Ingot Cost	95.8	92.7	+ 3.1
Blooming Cost	-	7.8	- 7.8
Billet Cost	95.8	100.0	- 4.2

5. Conclusion

Continuous casting of steel is popularizing throughout the world as epoch-making casting process, because it was confirmed that continuous casting can get as good quality productions as conventional casting and decrease production costs.

These facts were confirmed by experience of our Sumitomo Metal also.

We believe that the future prospects of continuous casting are brilliant and promising.



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Introduction

As well known, more than 10 years have passed since continuous casting became a part of the steel industry. But its recent developments have been remarkable, for the number of continuous casting machines in the world come to over 200, including machines under construction. Reasons for such remarkable development of continuous casting of steel exist not only in its economic profit such as simplification of manufacturing process, lower cost of equipment, increase of yield etc., but also in general understanding of qualitative superiorities of continuously cast billets over conventional ingots, i. e., their improved surface, reduction of segregation which is inevitable to large ingots.

In Japan a pilot plant for continuous casting of steel was first installed at Osaka Steel Works of Sumitomo Metal Industries, Ltd., in 1955. Since 1965 the continuous casting machine has increased in number and it counts 25 plants, 17 of them in operation and 8 either under construction or in determination to install, as seen in Table 1. Thus, the spread of the continuous casting machine in Japan is remarkable. Besides, there are many companies who have a program for such a machine. Therefore, the total number of the operating machines are expected to be over 40 after several years.

Table 1

Present State of Continuous Casting Machines of Steel in Japan

No.	Steel works	Starting up	Type	No. of Strands	Molds Capacities	Section	Steel Grades
1	Sumitomo Metal Industries, Ltd., Oosaka	(1965) 1960	Vertical	8	80	135~260φ	Carbon Steel Alloy Steel
2	Yawata Iron & Steel Co., Ltd., Hikari	1960	Vertical	1	40	max 180×1300	Stainless Steel
3	Kita-Nippon Steel Co., Ltd.,	1964	Vertical	8	10~15	115 175φ 150×750	Carbon Steel Alloy Steel
4	Nippon Yakin Kogyo Co., Ltd.,	1965	Vertical	1	50	143×970~1870	Stainless Steel
5	Fuji Iron & Steel Co., Ltd., Maroran	1965	Vertical	8	80	250φ 300×1000	Carbon Steel
6	Kokko Steel Works Ltd.,	1965	Curved Mold	8	80	180 190φ	Carbon Steel
7	Kobe Steel Works Ltd.,	1966	Vertical	8	85	110φ	Carbon Steel
8	Kobe Steel Works Ltd.,	1966	Vertical	4 or 8	85	300φ 150×945	Carbon Steel
9	Tohoku Metal Industries, Ltd.,	1967	Oleson	1	15	135φ	Carbon Steel
10	Toshiba Steel Co. Ltd.,	1967	Oleson	4	70	110 115 140φ 150×150	Carbon Steel
11	Yawata Iron & Steel Co., Ltd., Yawata	1967	Oleson	6	70	100~145φ	Carbon Steel
12	Yamato Steel works Ltd.,	1967	Curved Mold	1	50	150~250 ×300~1550	Carbon Steel
13	Wakoyama Steel works Ltd.,	1967	Oleson	1×8	85	90φ	Carbon Steel
14	Nishin Steel Co., Ltd., Kure	1967	Vertical	1	85	190×1350	Carbon Steel
15	Nippon Kokan Kabushiki Kaisha, Tsurumi	1967	Curved Mold	1	90	300×1600	Carbon Steel
16	Sumitomo Metal Industries Ltd., Kokura	1967	Curved Mold	6	70	95 110φ	Carbon Steel
17	Sumitomo Electric Industries, Ltd.,	1968	Oleson	2	30	115φ	Carbon Steel Alloy Stee.
18	Kawasaki Steel Corporation Mizushima	1968 under Construction	Curved Mold	4	180	300×250~300 250×250~400	Carbon Steel
19	Yawata Iron & Steel Co., Ltd., Yawata	1968 under Construction	Oleson	6	70	170φ	Carbon Steel
20	Yawata Iron & Steel Co., Ltd., Hikari	1968 under Construction	Vertical with bender	1	10~60	150~250φ 180~250φ	Stainless Steel bearing Steel
21	Nishin Seiko Co., Ltd., Himeji	1968 under Construction	Vertical	2	40	165φ 160×250 215×245	Carbon Steel
22	Sumitomo Metal Industries Ltd., Wakayama	1969	Vertical	1	50~100	max 180×1600	Stainless Steel Carbon Steel
23	Kobe Steel works Ltd.,	1969	Vertical	4 or 8	70		Carbon Steel
24	Fuji Iron & Steel Co., Ltd., Kamaishi	1969	Vertical	8			Carbon Steel
25	Nippon Kinzoku Co., Ltd.,	1969		1			Stainless Steel

1. Aim of Continuous Casting of Steel

Continuous casting of steel has the following 2 aims

1. Simplification of the manufacturing process; 2 Increase of yield

Generally speaking, the manufacturing process of rolled products is as follows: Melting — Ingot-making — Equalizing — Blooming Reheating — Rolling
It is possible to simplify the above process largely when ingot-making, equalizing and blooming are replaced by continuous casting. Furthermore, the cost of equipment for continuous casting is only some parts of the cost of a bloomer. Moreover the ready change of billet section is possible, for the operation gets flexible. Nextly, the total yield of a product to raw material of melting is about 75% in case of the conventional manufacturing process through ingot-making, equalizing and blooming, while that is about 85% in case of continuous casting. This means about 10% improvement in yield. Naturally, such simplification of the process and improvement in the yield lower the manufacturing cost in a large scale.

2. Developments of Continuous Casting of Steel by Sumitomo Metal Industries, Ltd.

As stated above, in Japan there are 25 machines which are either in operation or under construction. Our company, Sumitomo Metal Industries, Ltd., got the start of continuous casting of steel in Japan. Taking notice of economy and a promising future of continuous casting of steel, our company concluded a technical assistance agreement with Mr. Irving Rossi (Concast AG), pioneer in the field of continuous casting of steel, in 1953 and set about the development of continuous casting of steel. In 1955 our company constructed a one strand vertical continuous casting machine at our Osaka Steel Works, that is a test plant having the output rate of 10t/hr, as seen in Fig. 1. In fact, this was the first continuous casting machine of steel in Japan. This test plant could cast square billets in the range of 75mm to 170mm. Using this plant we endeavoured to develop techniques of continuous casting. At that time there were few continuous casting machines in the world and the technical level was very low. For about 3 years we had continued to study not only in metallurgy of continuous casting, but also machine designs. It was found out that continuous casting of steel has no metallurgical difficulties and, moreover it has many economic advantages, so that it is sufficiently available for the commercial production of steel. In 1960 this test plant was remodelled in a vertical 2 strand continuous casting machine with production rate of 30t/hr. by our design for the commercial production. This machine is shown in Fig. 2 and Photo. 1. The machine is supplied with molten steel from a 30t basic arc furnace and has cast various billets of carbon steel, alloy steel and stainless steel. Table 2 is an outline of the specification of this machine.

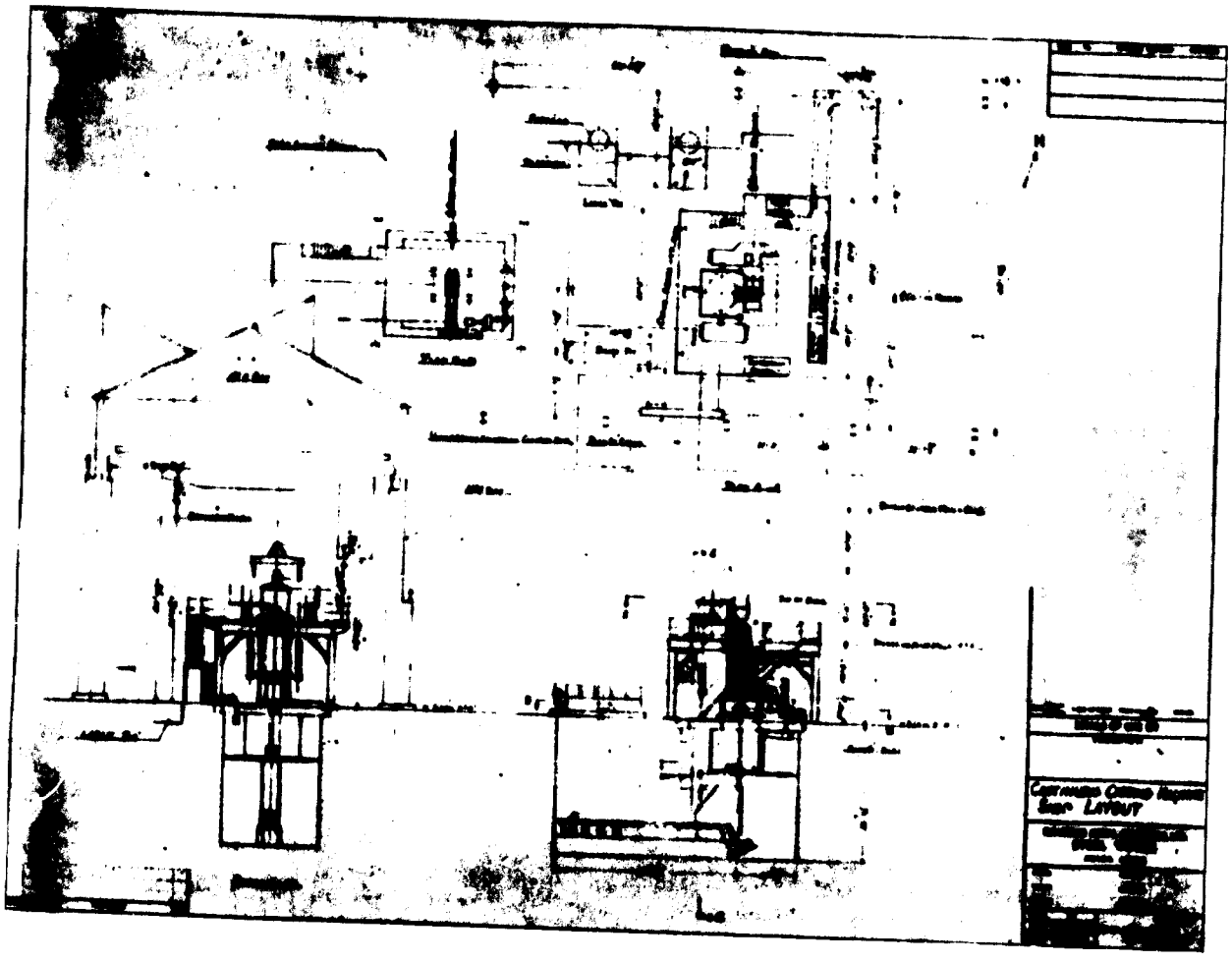


Fig. 1 General Assembly of One Strand Vertical Continuous Casting Machine, Sumitomo Metal, Osaka Works

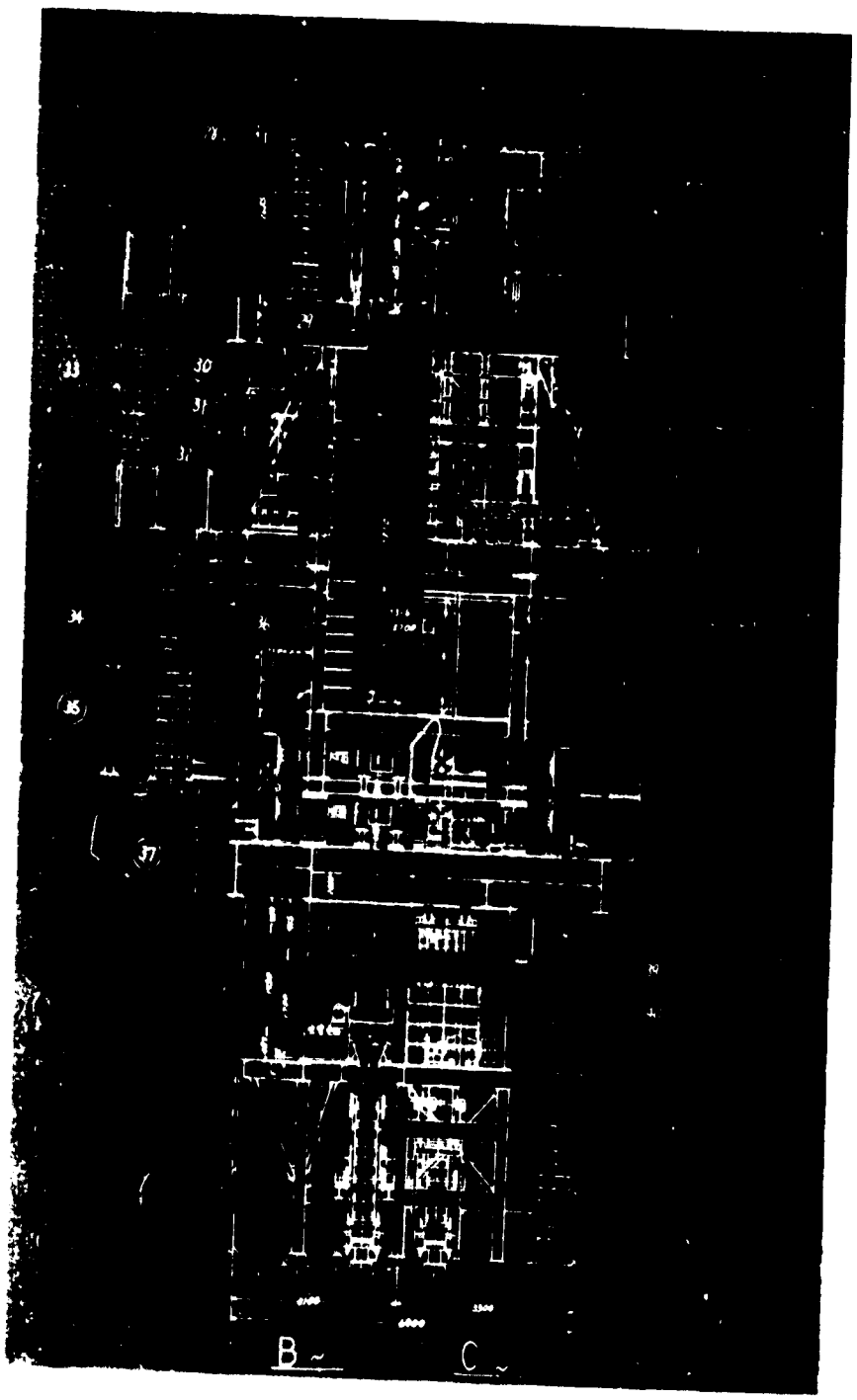


Fig. 2 General Assembly of 2 Strand Vertical Continuous Casting Machine, Sumitomo Metal, Osaka Works

Photo. 1 View of 2 Strand Vertical Continuous Casting Machine, Sumitomo Metal, Osaka Works

Table 2

Outline of Specification of Continuous Casting Machine at Sumitomo Metal, Osaka works.

Furnace	Basic Electric Arc Furnace
Ladle Capacity	80t
Type	Concast, Vertical
No of Strand	2
Sections of Billet	135 150 200 260㎜
Height	FL +8.2m -7.9m
Oscillation Stroke	6～50 ㎜
Oscillation cycle	40～70 /min
Oscillation Ratio	1 : 3
Cutting Device	Tourch
Annuel Capacity	30000 T

As the first continuous casting machine on a commercial scale in Japan this machine has operated without any trouble and has produced 2,000t to 3,000t/month of steels covering spring steel for automobiles and rolling stock as the principal product, machine-structural steel, bearing steel, structural alloy steel and stainless steel. Results of this successful operation were took notice for the industrial possibility of continuous casting of steel. Since then continuous casting has been rapidly accepted in Japan.

Using our wide experience of continuous casting of steel, we entered upon the construction of continuous casting machines not only for our own use, but also for other companies under the direction of Concast AG, our licensor. Till this day we have constructed 6 continuous casting machines, including our own machines. Besides, 4 machines are under construction. This figure means 40% of continuous casting machines in Japan, as seen in Table 3.

Table 3

Continuous Casting Machines Constructed by Sumitomo Metal.

No.	Steel works	Starting up	Type	No. of Strands	Ladle Capacity	Sections mm
1	Sumitomo Metal Industries Ltd, Osaka	(1955) 1960	Vertical	2	net ton 30	185~260φ
2	Yamato Iron & Steel Co. Ltd., Hikari	1960	Vertical	1	40	max 130×1200
3	Nippon Yakin Kogyo Co. Ltd.,	1965	Vertical	1	50	142×970~1270
4	Kokko Steel Works Ltd,	1966	Curved Mold	2	30	180 190φ
5	Yamato Steel Works Ltd,	1967	Curved Mold	1	50	150~250 ×800~1550
6	Sumitumo Metal Industries Ltd, Kokura	1967	Curved Mold	6	70	92 110φ
7	Kawasaki Steel Corporation, Mizushima	1968 June	Curved Mold	8	180	200×220~300 250×250~300
8	Yawata Iron & Steel Co. Ltd., Hikari	1968 Sep.	Vertical with bender	1	10~50	150~230φ 180~250φ
9	Nishin Seiko Co. Ltd., Himeji	1968 Sep.	Vertical	2	40	185 180×220 215×245
10	Sumitomo Metal Industries Ltd., Wakayama	1969 Jan.	Vertical	1	50~100	max 180×1600

According to this table continuous casting machines in operation and under construction include 4 slab machines and 6 billet machines, each having peculiar characteristics. We shall report particularly on the continuous casting machines for billets in the following.

3. Developments of Curved Mold Type Continuous Casting Machine

At the early period continuous casting machines are generally of vertical type, namely, all processes from pouring of molten steel into a mold to cut-off of a strand in optional length are practiced in the vertical line, as shown in Fig. 3A.

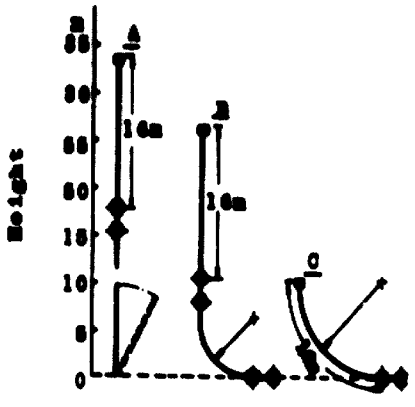


Fig. 3 Basic Types of Continuous Casting Machine.

With this type it takes much time for the solidification of steel owing to essentially low heat conductivity of steel. For this reason the height of a machine must be high, so that the building in which a machine is installed must be of considerable height or a deep pit must be dug under the ground. This brings a very high cost of construction. Continuous casting of steel has a large weak point in this, which brought delay of its development.

To remove this weak point many improvements have been attempted till this day. The first trial is that which is shown in Fig. 3B. According to this improvement molten steel is vertically withdrawn until it has been solidified and then the solidified strand is bent along a circular arc and after straightning by straightening rolls it is discharged in a horizontal position. Such a continuous casting machine is called a vertical bending type. By 90° bending along a circular arc after the solidification of steel cast the total height of the machine may be lowered to some extent, but it saves only several meters at the most. After then a new casting process in which a strand before complete solidification is bent in a circular arc was developed in Europe and since 1962 this process has quickly spread over the world. This continuous casting machine named "Model S" or curved mold type was developed by Concast and Mannesmann groups. As shown in Fig. 3C, this "Model S" or curved mold type takes the following course: molten steel is poured into a mold curved along a given circular arc and is withdrawn along the circular arc and then is completely solidified by passing through a curved cooling zone and after that the solidified strand is horizontally straightened at a position where the strand has passed 1/4 of the circular arc and lastly is discharged out of the machine. As the course from the metal level in the mold to complete solidification of the strand exactly corresponds to 1/4 circular arc, the height of the machine corresponding to this course is reduced to about two thirds ($2/\pi$), and, moreover, the height required for withdrawal, straightening, cut-off and discharge is completely unnecessary, for such working is carried out in the horizontal level. So that the total height of the machine becomes less than a half of that of the vertical type. Due to this fast the cost of construction, including the building, is more than 15% lower than the vertical type. Furthermore, this new type can be sufficiently installed in an existing plant, so that new construction of a building is not required.

Basing on experiences of vertical continuous casting machines our company proceeded with the development of the curved mold type continuous casting machine under the direction of Concast AG. In 1966 we constructed a curved mold type 2 strand continuous casting machine, as shown in Photo. 2, with the output rate of 30t/hr. at Kokko Steel Works Ltd. in Osaka. Table 4 shows an outline of specification of this machine.

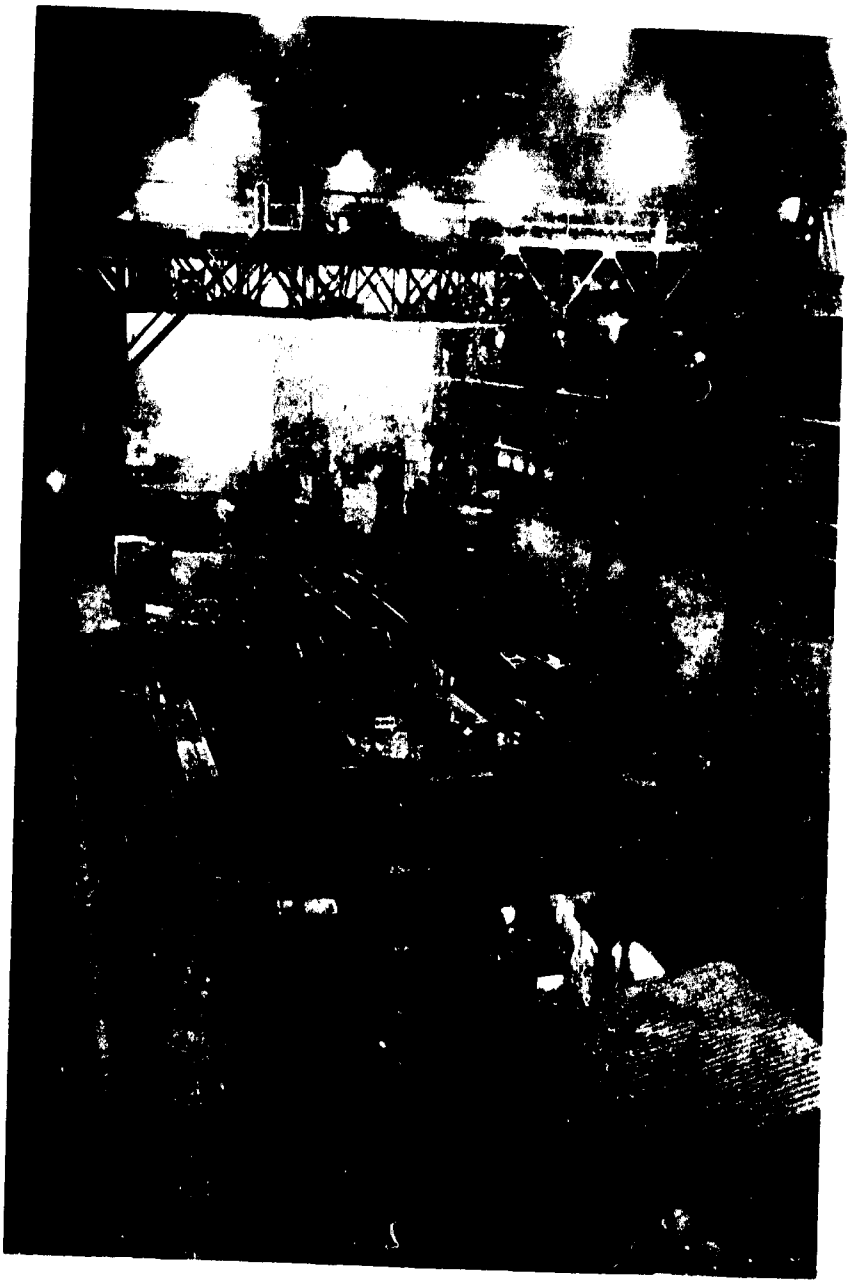


Photo. 2 View of 2 Strand Curved Mold Type Continuous Casting Machine, Kokko Steel Works Ltd.

Table 4.

Outline of Specification
of Continuous Casting Machine
at Kokko Stal works Ltd.

Furnace	Basic Electric Arc Furnace
Ladle Capacity	30 T
Type	Concast, Curved Mold
№ of Strands	2
Section of Billets	130 190■中
Height	FL +1.2m -8.0m
Bending Radius	8.5 m
Oscillation Stroke	0～30■
Oscillation cycle	40～70 /min
Oscillation Ratio	1 : 3
Cutting Device	Tourch
Annual Capacity	120000 T

This machine has 9m in its total height, so that it could be installed in the existing ingot-making building without any difficulty, and showed the advantage of this curved mold type. If the vertical type were adopted instead of curved mold type, the construction of a new building would be necessary because of the over 20m height of a machine. The following new ideas were adopted for the first curved mold type machine in Japan:

(1) This plant has 2 basic arc furnaces of 30t capacity and it was required to cast max. 16 heats per day by the continuous casting machine. To satisfy

this requirement it was necessary to shorten the preparatory time for casting. For this purpose the usual insertion of a dummy bar through pinch rolls and a roller apron was changed into the insertion from the upper part of a mold. Speaking in detail, first the dummy bar taken out of the machine is wound up on the operating floor and waits the completion of casting on a dummy bar car. When casting is completed and the ladle and tundish are removed, the inside of mold is cleaned and immediately after that the dummy bar car is moved on the upper part of the mold for inserting the dummy bar into it. At that time a cast strand remain still in the roller apron and is continuously withdrawn downward. By this method 20% of the preparatory time for casting could be saved.

(2) To enable continuous continuous casting of more than 2 heats the arrangement of the machine in plant was considered and the tundishes were arranged so as to be exchanged quickly. Besides, the refractories and nozzles to be able to cast for many hours were developed.

This machine started its operation in May, 1966 and since then it has run without any trouble. At present it continuously casts about 10,000t/month and succeeded in continuous continuous casting 6 heats during 7 hours.

4. Developments of Multistrand Continuous Casting Machine

Following the success in the curved mold type continuous casting machine of Kokko Steel, our company undertook the construction of a curved mold type multistrand continuous casting machine for our Kokura Iron Works. This machine is to cast small size billets with molten steel supplied from 70t L.D. converter. There were many difficult problems in the machine design and operation of this machine, as it is a multistrand (6 strand) machine and casts small billets below 110mm square. Design working of this difficult machine began in spring of 1966 and was carried forward very carefully, for there were few precedents of such type in the world. In our design working results of operation of Kokko Steel's curved mold type 2 strand machine which ran at that time were analysed from viewpoints of design and operation. Results of these analyses were taken in our machine design to insure a stable operation of the machine. Furthermore, the automatic control system was adopted in the plan as far as possible, considering future introduction of electronic computors into the control system. Table 5 shows a outline of specification of this machine and Photo. 3 is its outside view.

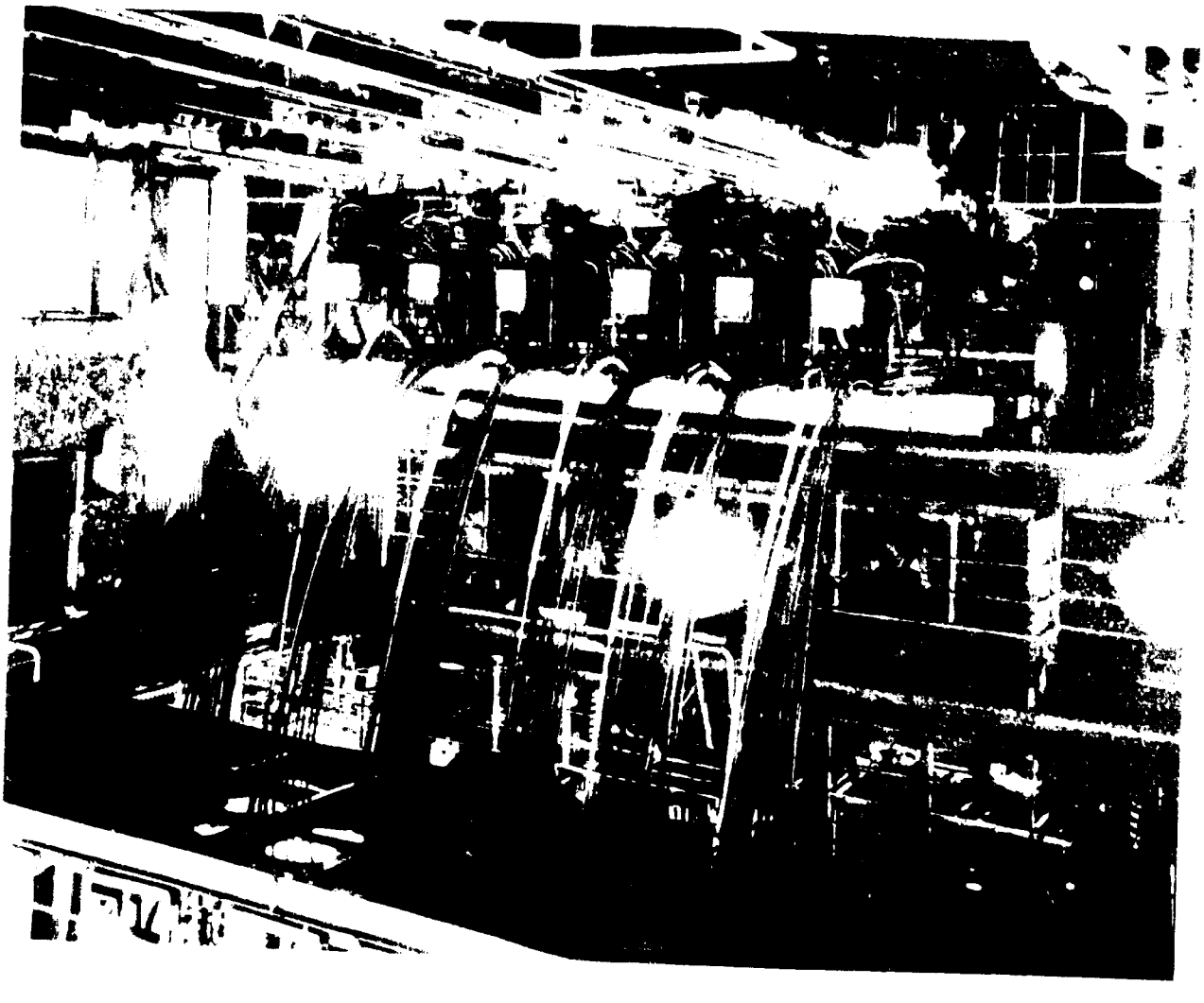


Photo. 3 View of 6 Strand Curved Mold Type Continuous Casting Machine, Sumitomo Metal, Kokura Works

Table 5

Outline of Specification of Continuous Casting Machine at Sumitomo Metal, Kokura works.

Furnace	L D Converter
Ladle Capacity	70 T
Type	Concast, Curved Mold
No of Strands	6
Section of Billets	92 110 mm
Height	FL +54m / 1.2m
Bending Radius	5.5 m
Oscillation Stroke	15～65 mm
Oscillation cycle	40～100/min
Oscillation Ratio	1 : 2.5
Cutting Device	Tourch
Annual Capacity	200000 T

Features of Kokura machine are as follows:

(1) The ladle has 2 stoppers. There are 2 tundishes from which molten steel flows into each 3 strands. This arrangement is made to prevent a temperature drop of molten steel in tundishes.

(2) Tundishes have no stopper. The casting speed is controlled by adjusting the molten steel level in each tundish.

(3) After the completion of casting each tundish is tilted on the spot and residual metal is removed from it to lengthen the life of its refractories.

(4) Foot rolls are provided just under the molds to prevent deformation of each strand.

(5) The roller apron can be easily replaced.

(6) The metal level in each mold is detected by radioactive rays. This method enables automatic driving of each mold at the start of casting and automatic control of the metal level in mold during casting.

(7) Opening and closing of ladle stoppers are automatically controlled by measuring weight of molten steel in tundishes in order to control casting at a given speed, in other words, to keep a constant metal level in tundishes.

(8) Quantity of secondary cooling water is automatically controlled by measuring the temperature of each strand to give it optimum cooling. These new trials above-mentioned achieved success and Kokura machine began its working in September, 1967, showing a very good start. As seen in Fig. 4, its output rate exceeded 10,000t/month after 3 months from the start. This indicates excellence of the machine. Since then it has run smoothly and skill of operator contributed to it, too. Since February, 1968 the machine has operated on 3 shifts. In April, 1968 its output exceeded 15,000t/month. It is expected to reach 20,000t/month from July.

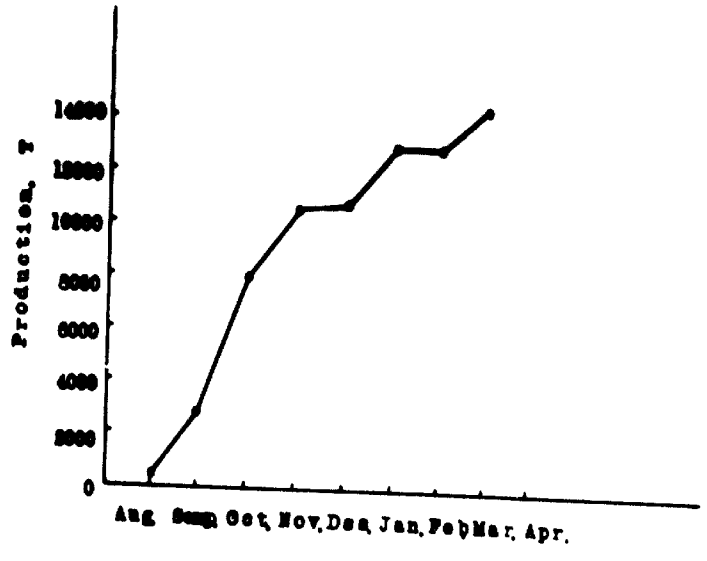


Fig. 4

Monthly production of Continuous Casting Billets at Sumitomo Metal, Kokura.

5. Qualities of Continuous Cast Billets and Finish Products

As already well-known, continuously cast billets have the better surface than the conventional ingot and an advantage of little segregation. These do not depend upon types of the continuous casting machine, whether it is of vertical type or curved mold type. The following examples of our products will elucidate that continuously cast billets are by no means inferior in quality to conventional ingot materials.

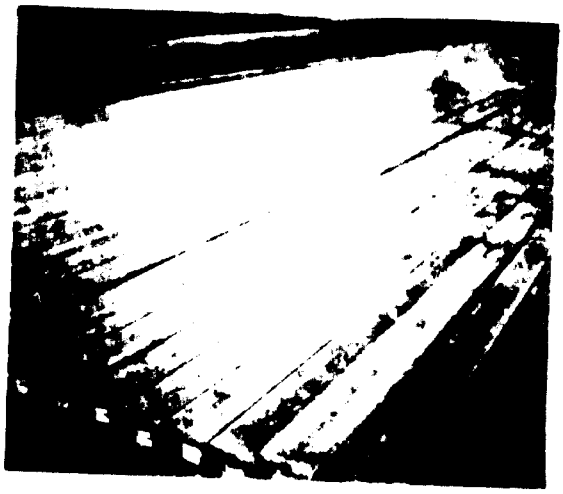


Photo 4. 110㎜φ Continuous Casting Billets, Carbon Steel.

Photo 5. Macrostructure and Sulphen print of Deforming Bar, 110㎜φ Continuous Casting Billet.

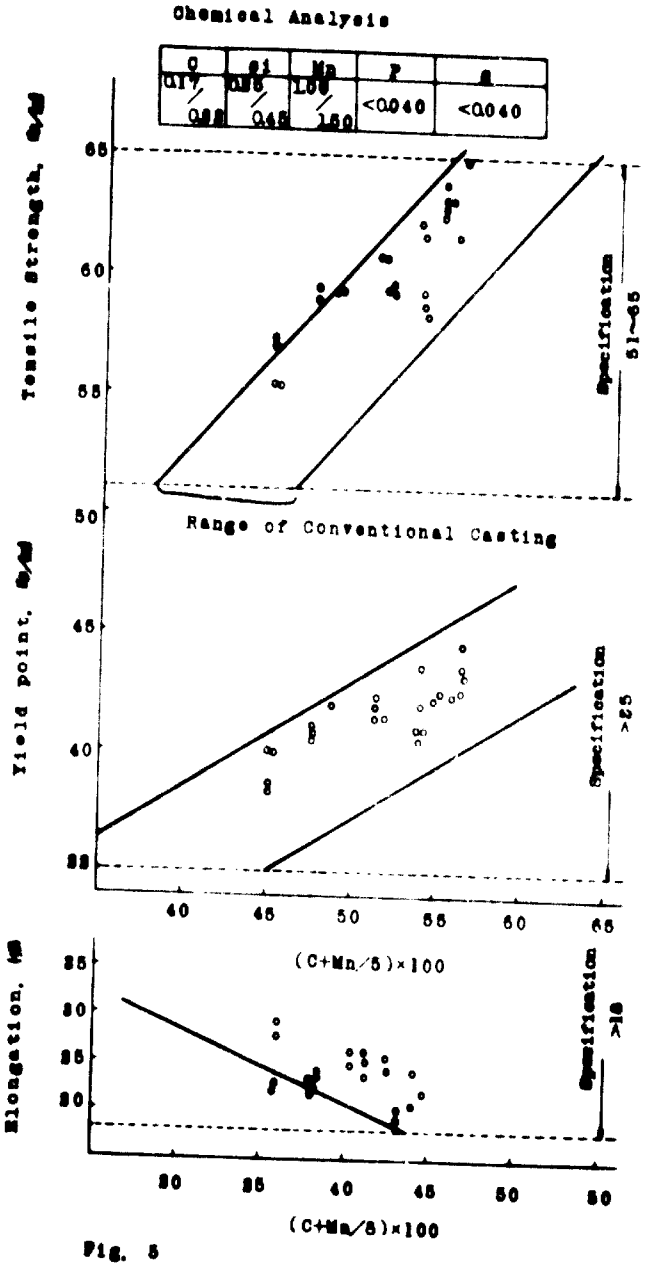


Fig. 5

Mechanical Properties of Deforming Bar made by Continuous Casting Billets.

Chemical Analysis

C	Si	Mn	P	S
0.75/0.90	0.15/0.35	0.60/0.80	<0.030	<0.035

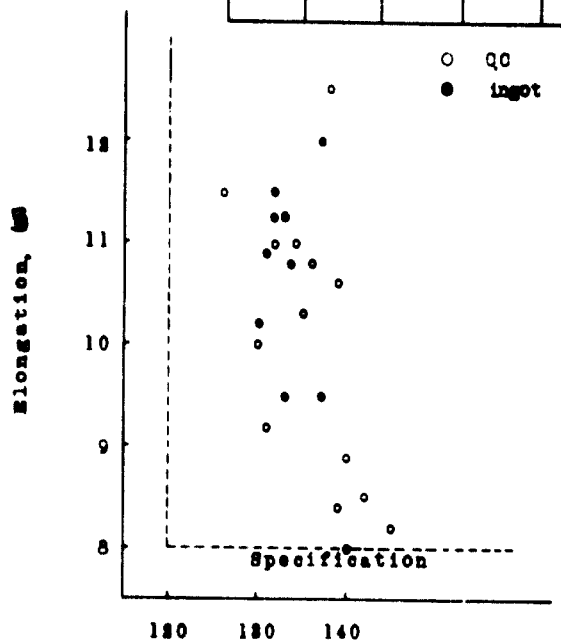


Fig. 6 Mechanical Properties of flat Spring (90mm×18mm) for Rolling Stock made by Continuous Casting Billet.

Photo 6. Macrostructure and Sulpher

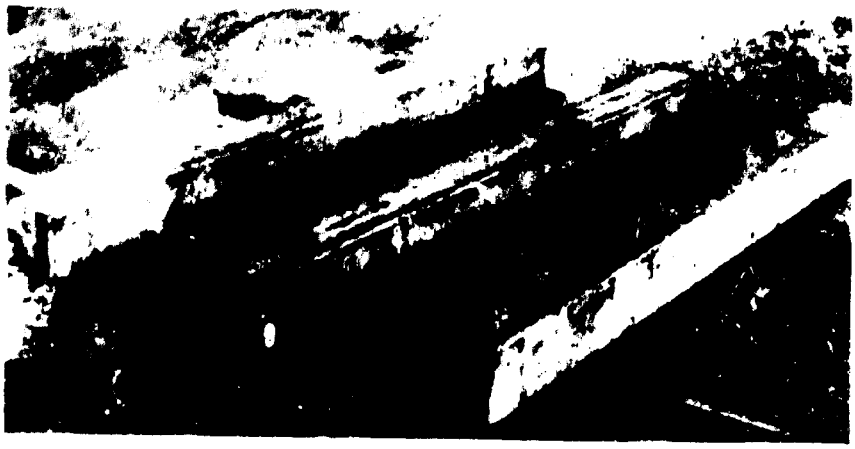
print of Deforming Bar.

Table 6

Inclusion of Spring Steel for Rolling Stock between Continuous Casting and Conventional Casting

(Section 90mm × 13mm)

	Continuous Casting				Conventional Casting			
	Type A Inclusion		Type B Inclusion		Type A Inclusion		Type B Inclusion	
	Cleanness	ab. Thickness (μ)	Cleanness	ab. Thickness (μ)	Cleanness	ab. Thickness (μ)	Cleanness	ab. Thickness (μ)
1	1.1	4.0	4.0	4.5	1.7	3.8	3.2	4.4
2	1.2	3.8	5.8	4.5	1.6	3.9	4.4	4.5



Phot 7. 190mm Continuous Casting Billets, Spring Steel.

Macrostructure

Sulpher Print

Chemical Analysis

C	Si	Mn	P	S
0.55/0.65	1.50/1.80	0.70/1.00	<0.035	<0.035

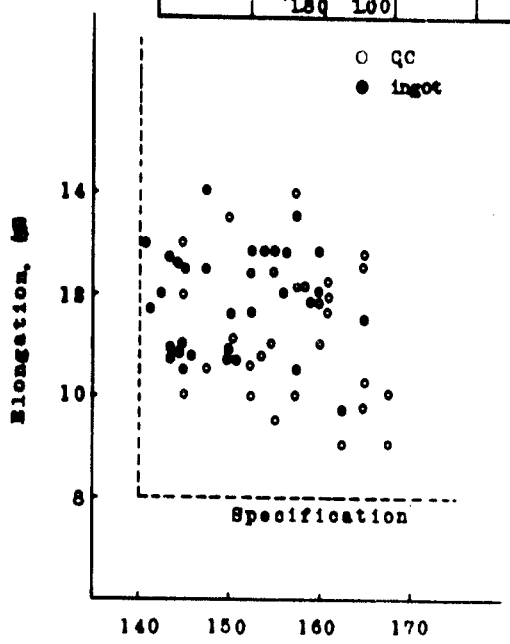


Fig. 7 Mechanical Properties of flat Spring (100mm×11mm) for Automobile made by Continuous Casting Billet.

(1) Deforming Bars

Kokura's 6 strand curved mold type continuous casting machine casts molten steel having the chemical composition shown in Fig. 5 into billets of 110mm sq. which are rolled into deforming bars of under 32mm round. They are good in mechanical properties, bending test and impact test and not inferior to conventional ingot materials in quality.
Photo. 4 and 5 shows appearance of billets, macrostructure of sections and sulphur prints. Further, Fig. 5 and Photo. 6 indicates mechanical properties to C eq. of 25mm round deformed bars rolled from a continuously cast billet of 110mm sq., macrostructure of section and sulphur print.

(2) Flat Springs for Rolling Stocks.

High carbon spring steel for rolling stocks shown in Fig. 6 was cast into 180mm sq. billets by our vertical 2 strand continuous casting machine of Osaka Steel Works and these billets were rolled into flat springs for rolling stock. Billets have satisfactory quality, as seen in surface condition, macrostructure of section and sulphur print of Photo. 7 and 8.
As to flat springs surface condition, mechanical properties, results of fatigue test, macrostructure, results of measuring non-metallic inclusions etc. are comparable with products rolled from conventional ingots.
Mechanical properties and results of measuring non-metallic inclusions are shown in Fig. 6 and Table 6.

(3) Flat Springs for Automobiles

Flat springs for automobiles with the chemical composition shown in Fig. 7 are by no means inferior to products of conventional ingot material. As an example mechanical properties of such flat springs are indicated in Fig. 7.

(4) Others

In addition to aboved-mentioned steels there are many other steel grades which may be cast by continuous casting. Castings of low alloy steel, stainless steel etc. are favorablly compared in quality with conventional ingot material.

6. Economic Profit of Continuous Casting

The remarkable development of continuous casting of steel is due to large economic advantages mentioned in the following:

(1) Simplification of Manufacturing Process

Generally speaking, the manufacture of rolled products of ingots takes the following course: Melting — Ingot-making — Equalizing Blooming — Reheating — Rolling. 3 out of such processes: ingot-making, equalizing and blooming can be replaced by one process of continuous casting.

Further, manufacturing rolled products directly of small ingots needs troublesome working for ingot mold casting such as preparation of molds, bricklaying of runner, preparation of feeder heads, drawing of molds after casting etc. But such working may be replaced by continuous casting in which molten steel is continuously cast without such troublesome working, so that the process is simplified to such the extent in continuous casting. Besides, such simplification brings on simplification of a steel plant. An example of our Kokura Iron Works will show such a simplified process, as seen in Table 7.

Table 7.

Comparision of Manufacturing process for Deforming Bar.

Continuous Casting	Conventional Casting
-	4800㎏ Ingot
-	Equalizing
-	Blooming
110㎜□ Billet	110㎜□ Billet
Heating	Heating
Rolling	Rolling
Deforming Bar	Deforming Bar

(2) Increase of Yield of Products

As continuous casting casts molten steel continuously, it need not use feeder heads and does not bring about scale loss and crop loss which are proper to blooming. Accordingly, the yield of products increases over 10%. In the case of our Kokura Iron Works the yield of oproducts has increased about 10%, as shown Table 8.

Table 8

Comparision of Yields between Continuous Casting and Conventional Casting.

(Deforming Bar)

	Continuous Casting (%)	Conventional Casting (%)	Difference (%)
Steel-Making			
charge to tap	93.9	93.9	
tap to Cast	97.2	96.5	
Cast to good billet	99.8	99.9	
Total	91.2	90.5	
Blooming	-	89.0	
Rolling	95.5	95.5	
Total	87.1	77.0	10.1

(3) Improved Working Environment and Decreased Personnel Expenses

It is said that conventional ingot mold casting is most painful working on account of a high temperature and dust. But this environment is considerably improved in continuous casting. Furthermore, a very few workmen can perform the operation due to mechanization and automation of the casting process.
The manufacturing cost can be considerably reduced owing to the above advantages. In our example it could cut down the cost 4% as compared with conventional ingot casting, as seen in Table 9.

Table 9.

Comparision of Billet Cost between Continuous Casting and Conventional Casting.

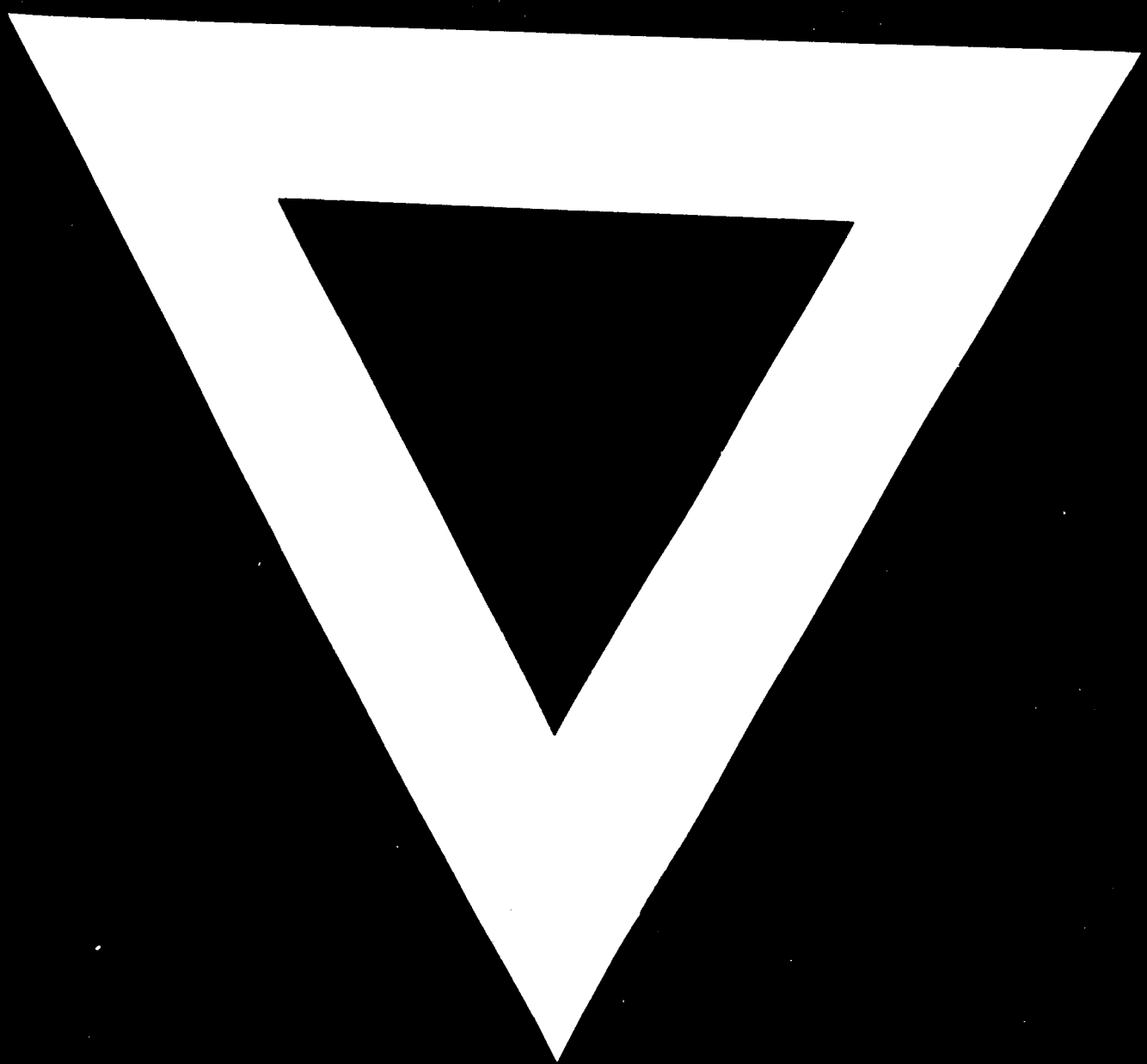
(In Percentage of Blooming Billet Costs)

	Continuous Casting (%)	Conventional Casting (%)	Defference (%)
Materials	83.9	83.6	+0.3
Operation	11.9	9.1	+2.8
(Furnace)	(5.0)	(4.9)	
(Casting)	(6.9)	(4.2)	
Inget Cost	95.8	92.7	+3.1
Blooming Cost	-	7.8	-7.8
Billet Cost	95.8	100.0	-4.2

7. Conclusion

Successfully industrialized continuous casting of steel is quickly spreading over the world as an epock-making process in place of conventional ingot casting. This is due to the established fact that this makes it possible to manufacture products, which are not inferior in quality to conventional products made of ingots, in cheaper cost.

Of course, it has passed only about 10 years since continuous casting of steel was industrialized, so that it may not be a completed process or installation. But we expect the future development of continuous casting of steel in the aspects of machine design as well as metallurgy and shall endeavour to promote it in future.



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