

⑫

EUROPEAN PATENT APPLICATION

⑰ Application number: **84110872.3**

⑸ Int. Cl.⁴: **B 22 D 11/16, B 22 D 11/06**

⑱ Date of filing: **12.09.84**

⑳ Priority: **19.09.83 JP 173837/83**
19.09.83 JP 173836/83

⑦ Applicant: **HITACHI, LTD., 6, Kanda Surugadai 4-chome**
Chiyoda-ku, Tokyo 100 (JP)

㉑ Date of publication of application: **24.04.85**
Bulletin 85/17

⑧ Inventor: **Nishino, Tadashi, 6-10-22, Kanesawa-cho,**
Hitachi-shi Ibaraki-ken (JP)
Inventor: **Kimura, Tomoaki, 4-6-8, Ohse-cho, Hitachi-shi**
Ibaraki-ken (JP)

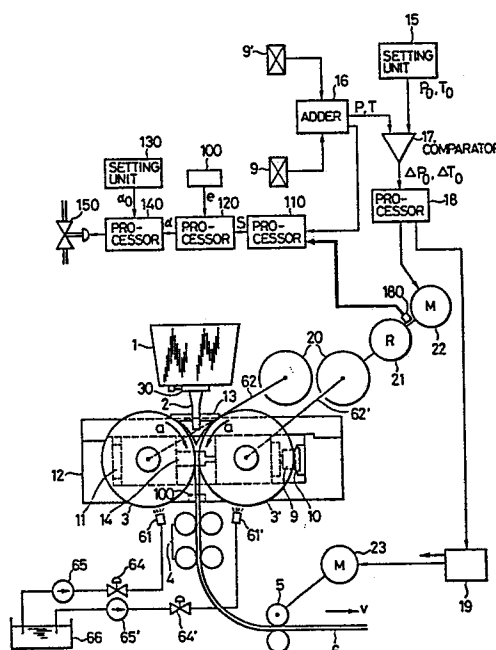
㉒ Designated Contracting States: **DE FR GB IT**

⑨ Representative: **Patentanwälte Beetz sen. - Beetz jun.**
Timpe - Siegfried - Schmitt-Fumian,
Steinsdorfstrasse 10, D-8000 München 22 (DE)

⑤4 **Manufacturing method and equipment for the band metal by a twin roll type casting machine.**

⑤7 A manufacturing equipment for band metal by the twin roll type casting machine, which is provided with a tundish (1) having a nozzle (2, 53) pouring molten metal and with a couple of rotating rolls (3, 3'; 50, 51) cooling the molten metal poured from the above nozzle (2; 53) to make the solidified crust (24, 24') and compressing the solidified crust to be able to manufacture continuously the band metal (6; 55) of the desired thickness. This is characterized as follows. It is equipped with the part material of the short side (13, 13'; 13a, 13a'), which is located in the face of the surface of the rolls (3, 3'; 50, 51) forming the long side of the section of the above molten metal and made up along the short side of the section of the molten metal by the heat resisting material of lower thermal conductivity than the rolls (3, 3'; 50, 51). And it is equipped with a detector (9, 9'), which detects the compressive load or equivalent quantity of state exerted when the above rolls (3, 3'; 50, 51) compress the solidified crust (24, 24') of molten metal formed on the each side of rolls (3, 3'; 50, 51). And it is equipped with a controller (15-17), which regulates the solidification time of molten metal in solidification range formed between the above twin rolls comparing the detected value from the above detector (9, 9') with the setup value. Moreover, it is

(Continuation next page)



equipped with a roll gap controller (140), which regulates the value of the narrowest gap between rolls (3, 3'; 50, 51) by moving the location of rolls so that the compressibility of solidified crust may become the desired plus value according to the detected value from the above detector (100).

Specification

Title of the Invention

MANUFACTURING METHOD AND EQUIPMENT FOR THE BAND METAL
BY A TWIN ROLL TYPE CASTING MACHINE

Background of the Invention

This invention is related to the continuous casting technology by twin rolls which manufactures the thin band metal from molten metal, especially to the manufacturing method and equipment by the twin roll type casting machine which is suitable for the manufacture of the thin band metal of excellent material quality.

Recently, it is demanded to develop a high speed casting machine in the domaine of the continuous casting. Because, if particularly high quality wide band steel of 3-10 mm in thickness can be manufactured directly by the continuous casting, the remarkable labour-saving or energy-saving can be achieved. However, till now, in order to manufacture the hot-working thin band metal, the slab of 150-250 mm in thickness made by continuous casting is reheated after the removal of defects on the surface and reduced to the desired thickness by the hot-working roughing-down mill and finishing mill. Therefore, the cost of equipment, reheating energy and rolling energy will become unnecessary, if a continuous casting machine for the thin band metal is invented.

1 As the manufacturing method of the thin band metal, the
Bessemer method, which is described on P.9-P.21 in "Handbuch
des Stranggiessens" by Dr. Erhard Herrmann (Published by
Aluminium Verlag GmbH, 1958), or the method described in
5 Japanese patent laid-open report, Shō55-No. 109549, is well
known. Especially, the Bessemer method is utilized in the
non-ferrous domain. But, it is not utilized in the ferrous
domain, which has high melting point and slow solidifying
rate, because the leakage of molten metal or the blocking
10 by solidification easily happens.

The solidifying rate depends on the coefficient of heat
transfer (α) between the cooling mold and the molten metal,
and the thermal conductivity (λ) of molten metal, as follows,

$$S = k\sqrt{t_0} \dots\dots\dots (1)$$

- 15 S : thickness of solidification (mm)
 k : coefficient of solidification (mm, min^{-1/2})
 t₀: cooling time (min)

In this formula, k depends on α and λ above mentioned,
and k = 20-25 in mold. By the way, the value of α varies
20 practically with the condition (roughness, and the kind and
thickness of painting) of the surface of a cooling roll.
Consequently, the thickness of solidification is not constant,
even if the cooling time t₀ is constant, so that solidified
cast metal can not always be tightly rolled between two
25 cooling rolls. Therefore, it is a practical obstacle of

1 quality in case of the continuous casting of band metal,
that the material quality is unequal.

-Summary of the Invention

5 It is the object of this invention to offer the
manufacturing method and equipment for the thin band metal
by the twin roll type casting machine, in which the thin band
metal of excellent material quality can be stably manufactured
keeping the rolling pressure of solidified crust constant
10 under control against the fluctuation of the solidifying rate
of molten steel.

This invention is related to the manufacturing method of
band metal by the twin roll type casting machine, in which
molten metal is poured between a couple of rotating rolls or
15 on the either roll and cooled by the twin rolls to be made
solidified crust on the surface of each roll and compressed
to the desired thickness between the rolls and thus the band
metal is continuously manufactured. The manufacturing method
of band metal by the twin roll type casting machine in this
20 invention is characterized as follows. It controls the
solidification time of molten metal in the solidification
range on the above roll so that the detected compressive
load or equivalent quantity of state, acting on the above
rotating rolls by the rolling reaction of each crust solidified
25 on the above both rolls when rolled between them, may be set

1 to the fixed value.

2 This invention is also a manufacturing equipment for
3 band metal by the twin roll type casting machine which is
4 provided with a nozzle pouring molten metal and with a couple
5 of rotating rolls. These rolls compress the solidified
6 crust, which is formed by cooling the molten metal poured
7 from the above nozzle, and can manufacture a band metal
8 continuously. This manufacturing equipment for a band metal
9 by the twin roll type casting machine is characterized as
10 follows. It is provided with a detector which detects the
11 compressive load or the equivalent quantity of state when
12 the above rolls compress the solidified crust of molten
13 metal formed on the each side of rolls and it has a controlling
14 system which regulates the solidification time of molten
15 metal in solidification range, which is formed between the
16 above twin rolls, comparing the detected value from the above
17 detector with the target value.

18 Thus this invention with the above system is able to
19 manufacture continuously thin band metals of excellent material
20 quality.

-Brief Description of the Drawing

21 Fig. 1 shows the outline of twin roll type continuous
22 casting machine for the thin band metal as an example for the
23 embodiment of this invention. Fig. 2 is the plan of Fig. 1,
24
25

1 and Fig. 3 shows explanatorily the formation of solidified
crust and compression between the cooling rolls in Fig. 1.
Fig. 4 shows a tundish and its surroundings in the other
example of this invention. Fig. 5 and Fig. 6 are the
5 outlines of the twin roll type casting machine in the other
examples of this invention. Fig. 7 is the outline of the
twin roll type continuous casting machine for thin band metal
in the one of other examples of this invention. Fig. 8 is the
plan of Fig. 7.

10

-Description of the Preferred Embodiment

This invention is based on the next knowledge. That is,
the compressive force at the compressive point, where the
solidified crust is pressed by the twin rolls, is determined
15 by the deformation resistance of cast metal (solidified crust)
and the thickness size of the cast metal formed between the
both rolls. The thickness of the cast metal is thicker in
case of fast cooling, while it is thinner in case of slow
cooling. Naturally, the compressive force at the narrowest
20 gap spot between twin rolls increases as the thickness of
cast metal does.

The deformation resistance of the cast metal is
essentially influenced by the internal temperature of the
cast metal and it is strong in case of fast cooling while it
25 is weak in case of slow cooling. Therefore, the internal

1 state or the thickness of the cast metal on the long side,
which is formed between the rolls, can be indirectly detected
by the strength of the compressive force. Namely, when the
reaction force of the cast metal acting on the cooling rolls
5 in time of compression or the rotary torque of the cooling
rolls is detected, the too large value of detection means that
the solidifying rate is fast and the too small value means
that the solidifying rate is slow. Consequently, if the
variation of rotation speed of the cooling rolls is controlled
10 according to the fluctuation of the detected level, the total
thickness of cast metal, which is formed on the each side of
rolls and reaches the compressive point, can be kept constantly
to the desired level in control. However, in this process,
if the solidified crust is also formed along the short side,
15 the thickness of the solidified crust on the short side is
deformed by the compression at the compressive point. In this
case, the compressive load increases as much, and therefore
the accurate size of the thickness of solidified crust on
the longside can not be calculated backward from the com-
20 pressive load.

Therefore, the mold is to be constructed so that the
refractory of small thermal conductivity, which is difficult
to form the solidified crust, may be applied to the short
side, while such material as metal of large thermal con-
25 ductivity may be applied to the long side. With this mold,

- 1 the solidified crust, which is formed along the long side or
the surface of the cooling rolls, is compressed, and the
compressive load of the cooling rolls, which is caused by the
compression, can be detected. Thus, the thin band metal of
5 excellent material quality is continuously manufactured by
controlling the solidification time of the molten metal in
the solidification range between the cooling rolls within
the adaptive value. And the above solidification time is well
controlled by controlling the rotation speed of the rolls.
- 10 Besides, even if the surface of the molten metal in the pool
surrounded by the both cooling rolls somewhat fluctuates,
the above controlling method gives the further effect avoiding
the influence by the fluctuation of the thickness of cast
metal at the same time. As it is not generally desirable in
15 the stable operation to vary much the rotation speed of the
cooling rolls, the surface control, which controls the dis-
charge of the molten metal by the detection of the reaction
force to the rolls or the rotation torque above mentioned, is
suitable for varying the compressive load as little as
20 possible by varying the surface of the molten metal in the
pool (or the depth of the pool of the molten metal).

The following explanation according to figures is on the
continuous casting machine for the thin band metal as an
example of this invention. In Fig. 1 and Fig. 2, the com-
25 position of the continuous casting machine is shown as an

1 example of this invention. Fig. 3 is a detail drawing showing
the compressed state of the solidified shell in the above
machine.

In Fig. 1 and Fig. 2, the molten steel is properly poured
5 from a ladle, which is not shown, to the tundish 1, and from
there into the pool of the molten metal through the immersion
nozzle 2 which is directly attached to the tundish 1. The
pool of the molten metal is surrounded with the cooling rolls
3, 3' composing twin rolls and the fixed plates composing the
10 short sides 13, 13' in the face of these both cooling rolls
which are made of the refractory of small thermal conductivity.
The cooling rolls 3, 3' are composed in order to stop the
rise of temperature of the rolls by the external forced
cooling of cooling water injection equipments 61, 61' sprinklin
15 on the surface of the rolls, or by the internal forced cooling
with the flow of cooling liquid in the rolls which is not shown
The cooling water is supplied from the cooling water tank 66
to the injection equipments 61, 61' through the pumps 65, 65'
and the control valves 64, 64'. The both ends of cooling
20 rolls are revolvingly supported by the bearing boxes 7, 7'
and 8, 8', which are fixed in the housings 12, 12'. The both
cooling rolls 3, 3' are driven respectively in the direction
of arrow a by the driving moter 22, reduction gear 21 and
gear distributor 20 in sequence. The thin band metal 6 is
25 formed from the molten metal in the pool to be cooled and

1 solidified through the gap of the cooling rolls 3, 3', and
pulled out by the pinch rolls 4, 5, and carried out to the
next process.

5 The cooling rolls 3, 3' are distributed in order to have
a gap between them, whose distance is equal to the desired
thickness of the thin band metal 6 (2-6 mm). They are located
so that the cooling roll 3 may be fixed by inserting the
liners 11, 11' between the bearing boxes 7, 7' and housings
12, 12', while the bearing boxes 8, 8' of the cooling roll
10 3' are located behind the load detectors 9, 9' and detect
the compressive reaction of the solidified cast metal. The
cylinders 14, 14' are located respectively between bearing
boxes of each side, namely between 7 and 8, and between 7'
and 8', and regulate the gap between the both bearing boxes
15 for setting the narrowest gap between these rolls.

Fig. 3 shows the solidification state of the molten metal.
The discharge Q of the molten steel, which is poured from the
immersion nozzle 2 to the pool of the molten metal, is
regulated by the flow control valve 30 etc. in order to keep
20 the surface of the molten metal 25 at the constant level.
The solidification of the molten metal starts at the spot d,
where the surface of the molten metal 25 touches the cooling
roll 3 (or 3'), and the cooling range L is from the spot d
to the spot b. The formation, solidification and compression
25 of the solidified crust 24, 24' is completed in this range

1 L. The solidifying crust 24, 24' grow respectively on each
cooling roll according to the above formula (1) $S = k\sqrt{t_0}$, and
join each other from the both sides at the spot c. When the
compression of these solidified crust 24, 24' is completed
5 between c-b, the thin band metal of excellent material
quality is realized. But the compressive force P (or torque
T) for the compression by rolling varies actually, because
the thickness of solidification S is not always constant by
the fluctuation of the surface of the molten metal 25 and
10 that of the coefficient of solidification k. Namely, the
thickness of solidification S is the function of the com-
pressive force P or torque T. $S \propto P, T$.

It means, if the compressive force P (or torque T) is
large, the thickness of solidification S is large comparing
15 with the narrowest gap e between rolls (Rolling is impossible
and slip begins in case of too large S), and if the compressive
force P (or torque T) is small on the other hand, the thick-
ness of solidification S is too small comparing with the
narrowest gap between rolls. In this extreme case, the
20 molten metal sometimes leaks past the cooling rolls as the
central part of the solidified crust is not yet solidified,
or the plate sometimes swells by the static pressure of the
molten steel past the cooling rolls. Therefore, the com-
pressive force P (or torque T) should be set to the fixed
25 value by regulating the circumferential speed of the cooling
rolls 3, 3' for the suitable rolling. That is, the com-

1 pressive force P or torque T is the function of the
circumferential speed v . $P, T = f(v)$. Here, the circumferen-
tial speed v of the cooling rolls 3, 3' is increased in case
of strong compressive force P (or torque T), while the
5 circumferential speed v is diminished in case of weak com-
pressive force P (or torque T). In the example of this
invention, the compressive force P is nearly equal to the
force compressing the solidified crust on the long sides or
the sides of the cooling rolls, because the solidified crust
10 grows little or very thinly on the short sides, as the
material of the parts utilized for the short sides 13, 13'
has much smaller thermal conductivity than the cooling rolls.

Next, the method of controlling the compressive force
of the solidified crust is explained in Fig. 1 and Fig. 2.

15 The load detectors 9, 9' detect the compressive reaction force
through the bearing boxes 8, 8' at the both sides of the
cooling roll 3', one of the both rolls 3, 3'. (Otherwise,
the rotating torque T can be detected by the driving shafts
62, 62' of the cooling rolls or by the amperage of the driving
20 motor 22, though this method is not illustrated.) This
detected values are added up by the adder 16 and compared
with the objective values P_o, T_o from the setup unit 15 by
the comparator 17. The driving speed of the cooling rolls
3, 3' is regulated so that the deviations $\Delta P, \Delta T$, which are
25 got as above described, may become zero. Namely, the directive

1 signal is output by the arithmetic unit 18 according to these
deviations and given to the driving motor 22 of the cooling
rolls 22 and the driving motor 23 of the pinch roll 5 which
pulls out the thin band metal 6. And the speed of the driving
5 motor 22 and the speed of the driving motor 23 are regulated
to synchronize so that the compressive force P or torque T
may be always kept in the objective range. Besides, in Fig.3,
as torque T is in proportion to the product of the compressive
force P by the length l of the compression range of the both
10 solidified crusts 24, 24', T and P are in linear relationship,
therefore the compressive force can be estimated by the either
value of them.

On the other hand, as P is in proportion with $l \cdot km$ in
Fig. 3, where km stands for mean deformation resistance, the
15 length l of the compression range of the solidified crust
can be calculated backward from the measured value of P or
torque T by measuring km previously.

As above described, the length l of the compression
range can be calculated backward from the measured value of
20 compressive force P or torque T , therefore if the circum-
ferential speed v of the cooling rolls 3, 3' is regulated
to keep P or T constant, the length l of the compression
range of the solidified crust can be kept to the objective
value under control.

25 The mean deformation resistance km of the material is

1 0.5-3 kg/mm², and it depends on the kinds of cast metal.
 As the length 1 of the compression range can be 100 mm in
 case of 750 mm in diameter of the cooling rolls 3, 3', the
 compressive force P, in casting of the thin band metal 6 of
 5 1,000 mm in width B, is calculated as follows, $P = k_m \cdot l \cdot Q_p \cdot B =$
 $2 \times 100 \times 1.2 \times 1,000 = 240$ ton in case of $K_m = 2$ kg/mm². Here, Q_p
 stands for compressive force function of rolling and $Q_p = 1.2$
 is nearly approved.

In Fig. 1 and Fig. 2, the controlling technology of the
 10 circumferential speed v of the cooling rolls 3, 3' is shown
 as the regulating method of the compressive force P of the
 solidified crust. However, the control of the surface level
 H of the molten metal in the pool of the molten metal can be
 the same effective measures as the above method. Fig. 4
 15 shows the above variant example of this invention centering
 on the tundish. In Fig. 4, the flow control valve 30 is
 assembled between the tundish 1 and immersion nozzle 2. The
 control valve 30 regulates the quantity of the molten metal
 poured through the above nozzle 2 into the pool of the molten
 20 metal, which is surrounded with the twin cooling rolls and the
 fixed plates 13, 13' on the short sides (not illustrated).
 This flow control valve 30 is assembled by the sliding plate
 31 with a port and the servo valve 32 which controls the area
 of the port of sliding plate 31 connecting with the above
 25 nozzle 2 by regulating the sliding distance of the above

- 1 sliding plate 31. The directive signal to the above servo
valve 32 is similar to what is shown in Fig. 2. The detected
valve of the compressive force P (or the driving torque T of
the cooling roll) of the solidified crust by the load
5 detectors 9, 9' is added up by the adder 16 and compared with
the objective value from the setup unit 15 by the comparator
17. And the height H of the surface level 25 of the molten
metal is regulated so that the difference between the total
detected value and the objective value may become zero.
10 Namely, the directive signal is output from the arithmetic
unit 38 according to this difference and given to the servo
valve 32 of flow control valve 30 so that the height of the
surface level 25 of the molten metal may be controlled and
the compressive force P or torque T may be always kept in
15 the objective value under control.

Although the detailed explanation will be described
later in the other example shown in Fig. 7 and Fig. 8, also
in the example of Fig. 1 and Fig. 2, the narrowest gap e of
the cooling roll 3, 3' is regulated in order to be able to
20 prevent the leak of the molten metal at the starting time and
in the time from starting to standing. In the equipment of
Fig. 1 and Fig. 2, the roll gap detector 100 for measuring the
narrowest gap between the rolls 3, 3' is set in the housing
12. And the arithmetic unit 110 is set, which calculates the
25 thickness S of the solidified crust 24 at the narrowest gap

1 between the rolls, as shown as the spot A in Fig. 3, from
the formula (1) according to the output of the adder 16
adding the detected value by the detector 9, 9'. The
arithmetic unit 120 is set to calculate the compressibility
5 α of the solidified crust by the twin rolls 3, 3' from both
the output S of the arithmetic unit 110 and the output e of
the roll gap detector 100 according to the formula (6) as
described later. And the arithmetic unit 140 is set to output
the operational routine corresponding with the equivalence of
10 the variation of the roll gap according to the desired value
from the setup unit 130 in order to keep the output α of the
arithmetic unit 120 to the plus desired value. And the
control valve 150 is set to control the quantity of the
working oil supplied to the oil-hydraulic cylinder 14
15 regulating the gap of the rolls 3, 3' according to the output
signal from the arithmetic unit 140. The operational method
of these controlling equipments for the gap of roll is
explained in the example of Fig. 7 and Fig. 8 as later
described. By the way, 180 is the speed detector to detect
20 the circumferential speed of the roll.

Next, the other example of this invention is explained.
In the casting method of Fig. 1, the cooling rolls 3, 3' are
directly touched by the molten metal, however, this invention
is also effective for such casting method that the cast metal
25 is squeezed and compressed at the spot A between the belts 40,

1 41 which are respectively rolled along the twin rolls as
shown in Fig. 5. In Fig. 5, the belts 40, 41 are guided
outside by the side rollers 42, 43 and endlessly continued.
Because the compressive load is caused at this compressed
5 spot A where the two rolls approach most nearly and the
solidified crust of the molten metal formed between the both
side of bolts is compressed although the belts 40, 41 wide
around the rolls. But, if the belts are driven as well as
the rolls, the load torque equals the total of the both torque
10 of the rolls and the belts as the torque is distributed to
the both sides of the rolls and the belts. And this invention
is also available in case that a belt winds arounds one of the
two rolls while the other is without a belt. At any rate,
this invention can be effective in case that a plate material
15 is manufactured in the way that the cast metal, which is formed
on the both side of a pair of rolls directly or through the
other parts such as a belt on the roll at the narrowest gap
between a pair of rolls, is compressed.

And this invention can be also available for all cases
20 pouring in every direction such as Hunter method pouring
horizontally on the twin rolls laid horizontally or a method
pouring upward from under the twin rolls.

It is also available for the case that the each diameter
of the twin rolls is different.

25 Furthermore, Fig. 6 shows another available example of

1 this invention. In Fig. 6 the molten metal is poured from
nozzle 53 on the larger roll 50 of a pair of rolls 50, 51 of
different size, and the solidified crust 54, which contains
half solidified or yet molten metal, is formed and thereafter
5 it is compressed and deformed between the rolls 50, 51 to be
made a thin plate 55. Also to this case, this invention can
be effectively applied, because the state of solidification
of the solidified crust 54, which comes to the compression
spot A of the narrowest part between the rolls, can be made
10 homogeneous if the compressive load is measured at the spot A.

In this case, it is preferable to synchronize the
circumferential speed control with the pouring control of
the molten metal 53.

According to every trial case of this invention above
15 described, the thin band metal of excellent internal quality,
being 1-6 mm thick and 500-1,600 mm wide, could be continuously
and stably manufactured at the casting speed of 10-100 m/min.

However, under the existing technology, the compressive
resistance increases at the compression spot of the twin rolls,
20 and the slip occurs between the cast metal and the rolls or the
rotation of the rolls stop, if the cooling speed is too fast
by the cooling rolls.

On the contrary, if the cooling speed is too slow, the
inside of the cast metal is not yet solidified even past the
25 compression spot, and the uncompressed part swells by the

1 static pressure of the molten steel, and sometimes the re-
melted cast metal leaks in the extreme case.

However, in the above example of this invention, the
solidified crust is compressed which is formed only on the
5 surface of the rolls corresponding to the long sides but is
not formed on the short sides, therefore, the thickness of
the solidified crust formed on the surface of the rolls can
be exactly estimated by measuring the compressive load, which
is the compressive force or compressive torque at the com-
10 pression spot, and is set to be a objective value for the
control of the operation. Consequently, the stable operation
of the continuous casting for thin band metal has been
realized, as such accidents as the leak of the molten metal
and the slip etc., which used to be the technical problems
15 so far, have not happened.

This invention gives the effect that the thin band metal
of excellent internal quality can be stably and continuously
manufactured, keeping the condition for the compression of
the solidified crust constant under control against the
20 fluctuation of the solidifying rate of the molten steel.

Next, as the other example of this invention, the
manufacturing equipment for the band metal by the twin roll
type casting machine is explained.

This casting machine is not only as effective as the
25 above casting machines, but also it prevents the leakage of

1 the molten metal during casting. First of all, the fundamental
substance of this invention is explained, before introducing
this example.

5 The gap e is set to be as narrow as about 0-0.5 mm at
the narrowest spot A of the rolls. As shown in Fig. 3, at
the beginning of casting. If the gap e at the spot A is
small, the molten metal does not leak out from the gap of
rolls or leaks very little, therefore the pool 25 of the
molten metal can be easily made up.

10 After the pool 25 has been made up, the molten metal is
cooled on the surface of the both side of rolls 3, 3', and
as the solidified crust is formed on each side of the rolls,
the gap e between the rolls is gradually opened to the desired
value according to the formation of the pool 25.

15 The thickness of the solidifications S of the molten
metal, which is cooled on the surface of a roll, can be given
by the following formula corresponding with the above (1).

$$S = k\sqrt{L/v} \dots\dots\dots (1)'$$

k is constant, usually $k=20-26$ mm/min $\cdot L$ in the formula
20 (1)' is the length of contact between the molten metal and
the roll, that is, the solidification range as shown in
Fig. 3. This length of contact increases according to the
depth of the pool H . The relation between L and H is given
in the following formula.

25
$$L = \pi D \sin^{-1} (H/R) / 360 \dots\dots\dots (2)$$

1 The molten metal should satisfy the next formula with
the roll gap e at the spot A, so as not to leak out from the
narrowest gap spot A.

$$2S = 2k\sqrt{L/v} > e \dots\dots (3)$$

5 In the formula (3), if the quantity of $(2S-e)$ can be
compressed at the spot A according to the rotation of the
rolls 3, 3', the safe operation can be realized preventing
the leakage of the molten metal.

Hence, in the example of this invention, the roll gap
10 e at the spot A is set to be narrow at the beginning of
casting when the depth of the pool H is small and this is
operated on condition that the formula (3) is satisfied.

The thickness of the solidified crust $2S$ is given by
the next expression.

15 $2S = e + \Delta S \dots\dots\dots (4)$

In the expression (4), ΔS represents the compressed
quantity of the solidified crust at the narrow gap spot of
twin rolls.

Therefore, α in the next expression is the compressibility
20 of the solidified crust by the twin rolls.

$$\alpha = (2S - e)/2S = \Delta S/2S \dots\dots (5)$$

The expressions (1) and (2) are put in the place of the
expression (5), then

$$\begin{aligned} \alpha &= 1 - e/2k\sqrt{L/v} \\ &= 1 - e/2k\sqrt{\frac{2 R \sin^{-1}(H/R)}{360v}} \dots\dots (6) \end{aligned}$$

25

1 In the expression (6), if it is not in case of $\alpha > 0$, the
molten metal, which is not yet solidified, remains past the
narrow gap spot of twin rolls. Namely, the molten metal
flows out at the beginning of pouring, and if α value is
5 minus, the molten metal remains past the narrow gap spot even
after the plate has been formed, and the thin solidified crust
swells by the static pressure of the molten metal, and there-
fore the excellent product can not be gained.

At the beginning of pouring, the depth of the pool of
10 molten metal is small and α of the expression (6) becomes
minus in case that the gap of the narrow gap spot between
rolls is large, and therefore the molten metal flows out.

Consequently, the casting starts after the gap e has
been set to be small at the beginning of pouring.

15 But, the depth of pool H in the expression (6) increases
rapidly to make up a pool, if the gap e is small.

On the other hand, α in the expression (6) need keep
to be plus as above described and it is preferable to be as
constant as possible. Because, if α becomes large, the
20 quantity to be compressed ΔS becomes large and therefore the
large load is needed for the rolls to compress between, and
if α increases all the more, the slip accident happens.

The value of α in the expression (6) can be kept con-
stant under control against the variable depth of pool H , if
25 the roll gap e is properly controlled to change according to

1 the variation of the pool depth H , or the circumferential
speed of roll v is also regulated with e so that the value
of α may be plus constant.

At any rate, at the beginning of pouring, the roll gap
5 is widened to the objective opening, controlling in the
expression (6) so as to be the desired plus value.

Next, the method in case of exchanging halfway the
manufacture of the thin plate of t_1 in thickness with that
of the thin plate of t_2 in standing operation is explained.

10 In standing operation, the pool depth H of the expression
(6) is kept to a certain value of upper limit in order to
make the most of the twin roll type casting machine. Then,
the circumferential speed of roll v need be controlled so that
the value of α of the expression (6) may be the desired plus
15 value, in order to move the location of the rolls to make a
roll gap e , corresponding to the desired thickness t .

Because, the molten metal remains past the narrow spot of
rolls as above described and the plate, which swells by the
static pressure of the molten metal, is manufactured, if
20 the value of α is minus. In the special case, the roll gap
 e may be regulated by moving the rolls under the control of
the pool depth H as well.

In short, the rolls are moved during the casting, keeping
the value of α in the expression (6) to the desired plus value
25 under control.

1 The value of α is selected as follows according to the various objects lest the molten metal should remain past the narrow gap spot A of rolls in the Fig. 2.

5 In case of the object only that the molten metal does not flow out past the spot A of Fig. 3 or remain inside the plate, the value of α_1 is selected as follows.

$$\alpha_1 = 0.05 \sim 0.1$$

10 It is selected to be the value equivalent to the error factor of the thickness of the solidified crust formed by the twin rolls. If the thickness of plate is nearly equal to the roll gap e , the quantity of compression ΔS can be given by the next expression through the expressions (4) and (5).

$$\Delta S = \alpha \cdot e / (1 - \alpha) \dots (7)$$

15 At the beginning of pouring, in case of $e = 0.5$ mm, $\alpha = 0.1$, and $\Delta S = 0.028$ mm.

 In the standing state, in case of $e = 3$ mm, $\alpha = 0.1$, and $\Delta S = 0.33$ mm.

20 In case of the other object that the strong compressive operation is necessary at the narrow gap spot of twin rolls in order to change the casting structure to the rolling structure, α_2 is properly selected between $\alpha = 0.1 \sim 0.6$.

 Also in this case, α_2 need be controlled to keep the value of α constant in order to equalize the quality of the rolling structure.

25 Now, the actual example of the above invention is

1 explained in Fig. 7 and Fig. 8. Fig. 7 is the front view,
and Fig. 8 is the plan of Fig. 7. In the figures, the molten
metal is poured from the nozzle 2 into between the two cooling
rolls 3, 3' so that the pool 25 of molten metal is made up.

5 Each flange 13a, 13a' is assembled around the two cooling
rolls 3, 3' as the part of short side, lest the molten metal
should leak out of the both ends of the rolls. The location
of these flanges 13a, 13a' is regulated in the axial direction
by the ring nuts 160, 160' so that the each end-face of the

10 flanges 13a, 13a' may tightly touch the each end-face of the
rolls 3, 3'. These rolls 3, 3' are borne by the bearing boxes
7, 7' and 8, 8' in the housings 12, 12', and either roll, e.g.
roll 3' is fixed to the housing 12, 12' through the load cells
9, 9'. And the arithmetic unit 110 calculates the thickness

15 S of the solidified crust 24 of the molten metal at the
narrowest spot A between the rolls, according to the expression
(1)' with the outputs of the speed detector 180 and the adder
16 which adds the detected values of this load cells 9, 9'.
Then, the arithmetic unit 120 calculates the compressibility

20 α of the solidified crust by the twin rolls at the narrowest
spot A, by the inputs of the above S and the value of gap
from the detector 100 of roll gap. And, the arithmetic unit
140 is composed which calculates the operational quantity to
regulate the optimum value of roll gap according to the setup

25 value of the setup unit 130 of compressibility, in order to

1 keep the above calculated compressibility to the desired plus value. Finally, as the motor 14a is operated according to the output of the above arithmetic 140, the value of the narrowest gap can be always kept to the optimum value under control.

5 While, another roll 3 is moved in order to regulate the narrowest gap e between the rolls 3, 3' by the worm gears 14b which comprise the moving equipment 14 assembled in the housing 12, 12'.

Namely, in this actual example, the spring 155 is set
10 between the bearing boxes of two rolls 3, 3', and the motor 14a, which comprises the moving equipment 14 against the spring tension, rotates the worm wheel 14e through the coupling 14c and the shaft 14d. The worm wheel moves the screw 14f, which moves the bearing box 7 to the neighboring
15 bearing box 8 through the pin 14g.

The gap e between rolls shown in Fig. 8 is set to be about 0~0.5 mm before the beginning of the pouring. The motor 14a starts to move at the beginning of pouring and regulates the gap e slowly to be a certain size of opening.

20 The automatic control method of the roll gap e regulating with the passage of time is preferably applied as follows.

The first method : when the solidified crust 24, which is formed between the both sides of rolls 3, 3', begins to be compressed at the narrowest spot A of the gap between the
25 rolls, the compression exerts the compressive load. As the

1 compressive load, the compressive force P , which parts the
rolls 3, 3', and the torque T , which drive the rolls 3, 3',
are exerted.

The relation between the compressive force P and the
5 torque T is represented by the next expression as 1 stands
for the compression length of the solidified crust 24.

$$T = k_0 P l \quad \dots\dots\dots (8)$$

k_0 : constant

And, the compressive force P is given by the next
10 expression.

$$P = k_m B l Q_p \quad \dots\dots\dots (9)$$

k_m : deformation resistance, Q_p : factor

Therefore, if the value of P or T is given, the
compression length l can be calculated backward by either
15 P or T .

Consequently, if the compressive force P is indicated by
the load cells 9, 9' in the Fig. 8, the compressive state of
the solidified crust 24 at the spot A in Fig. 3 is estimated.
Naturally, the compressive state can be estimated as well by
20 measuring the driving torque of the rolls 3, 3'. Hence, in
this method, the value of gap between the rolls is controlled
by regulating the location of the rolls so as to keep the
compressibility α of the solidified crust to the desired
plus value.

25 As above mentioned, the gap between the rolls may as

1 well be regulated estimating the compressive state by measruing
the compressive load. Naturally in this case, the circum-
ferential speed of roll can be regulated at the same time.
By this means, the value of α of the above expression (6) can
5 be kept to the desired plus value under control.

The second method is as follows, though it is not
illustrated. In Fig. 3, the opening of gap is regulated by
estimating the thickness of the solidified crust according
to the above expressions (1) and (2) measuring the height H
10 of the surface of the pool 25.

As a result of the above actual example, it could
decrease the leak of the molten metal at the beginning of the
pouring and lead to the safe operat;on to be able to regulate
the gap between the rolls while casting. And the wide plate
15 metal of 600~1,600 mm, which is 1 mm ~ about 6 mm thick,
became to be able to be cast. Moreover, it produces a good
effect that the operational efficiency is remarkable imprped,
as the thickness of plate can be automatically changed in the
middle of casting.

CLAIMS

- 1 1. The manufacturing method by the twin roll type
casting machine for the band metal, in which molten
metal is poured between a couple of rotating rolls or
an either roll and cooled by the twin rolls to be
5 made solidified crust on the surface of each roll and
compressed to the desired thickness between the twin
rolls, and thus the band metal is continuously manu-
factured, having the next characteristic.
- (i) It detects the compressive load or equivalent quantity
10 of state exerted on the rotating rolls by the rolling re-
action, when the solidified crusts formed on the both
rolls are rolled between the rolls,
- (ii) next, it controls the solidification time of molten metal
in the solidification range on the above rolls so that
15 the value of the above detected quantity of state may
become the fixed value.
2. The manufacturing method by the twin roll type casting
machine for the band metal according to claim 1, in
20 which the rotating torque of the rolls or the reaction
of the rolls exerted by the compression of the solidi-
fied crust can be detected as the above quantity of
state.

- 1 3. The manufacturing method by the twin roll type
casting machine for the band metal according to claim 1,
in which the solidification time control of the molten
metal in the solidification range on the above rolls
5 can be performed by the regulation of the rotating speed
of roll or the regulation of the level of the molten
metal.
4. The manufacturing method by the twin roll type casting
10 machine for the band steel according to claim 1, in which
at least either roll of the twin rolls can be moved to
another in the direction of radius in the middle of
casting in order to keep the compressibility of the
solidified crust under pressure to the desired value when
15 the above both rolls compress the solidified crust of
molten metal having been formed on the both rolls.
5. The manufacturing method by the twin roll type casting
machine for the band steel according to claim 1, in
20 which the opening of the narrowest gap of a pair of
rolls above mentioned is set to be smaller than the
desired thickness of band metal at the beginning of pou-
ring of the molten metal, next, the above rolls are
moved with the passage of time till the stationary
25 state so that the opening of the narrowest gap between
the above rolls may become the desired size of the
thickness of band metal.

1 6. A manufacturing equipment for band metal by the twin roll
type casting machine, which is provided with a tundish
(1) having a nozzle (2; 53) pouring molten metal and
with a couple of rotating rolls (3, 3'; 50, 51) cooling
5 the molten metal poured from the above nozzle (2; 53)
to make the solidified crust and compressing the soli-
dified crust to be able to manufacture continuously the
band metal (6; 55) of the desired thickness. This is
characterized as follows.

10 It is equipped with the part material of the short side
(13, 13'; 13a, 13a'), which is located in the face of
the surface of the rolls (3, 3'; 50, 51) forming the
long side of the section of the above molten metal and
made up along the short side (13, 13'; 13a, 13a') of
15 the section of the molten metal by the heat resisting
material of lower thermal conductivity than the rolls
(3, 3'). And it is equipped with a detector (9, 9')
which detects the compressive load or equivalent quan-
tity of state exerted when the above rolls (3, 3'; 50, 51)
20 compress the solidified crust (24, 24') of molten metal
formed on the each side of rolls (3, 3'; 50, 51). And
it is equipped with a controller (15 - 17), which re-
gulates the solidification time of molten metal in so-
lidification range formed between the above twin rolls
25 (3, 3'; 50, 51), comparing the detected value from the
above detector (9, 9') with the setup value.

- 1 7. A manufacturing equipment for band metal by the twin
roll type casting machine according to claim 6, in
which the above detector (9, 9') is the torque detec-
tor which detects the rotating torque of the rolls
5 (3, 3') or the quantity of state equivalent to the
compressive load.
8. A manufacturing equipment for band metal by the twin
roll type casting machine according to claim 6, in
10 which the above detector (9, 9') is the load detector
detecting the reaction force of the compressive rolls
when the rolls (3, 3') compress the solidified crust.
9. A manufacturing equipment for band metal by the twin
15 roll type casting machine according to claim 6, in
which the above controller (15 - 17) regulates the
rotating speed of the rolls (3, 3').
10. A manufacturing equipment for band metal by the twin
20 roll type casting machine according to claim 6, in
which the above controller (15-17, 32, 38, 30) controls
the surface level (25) of the molten metal poured from
the nozzle (2).
- 25 11. A manufacturing equipment for band steel by the twin
roll type casting machine according to claim 6, which
is provided with a moving equipment (14) and a roll

1 gap controller (140) as follows.

The moving equipment (14) can move the axle ends (62, 62') of at least either of the above twin rolls (3, 3') to the radial direction of another roll, and the roll
5 gap controller (140) regulates the narrowest gap between the above both rolls (3, 3') by operating the moving equipment (14) according to the detected value from the above detector (100).

10 12. A manufacturing equipment for band steel by the twin roll type casting machine according to claim 11, in which the above moving equipment (14) is connected with at least either of the neighbouring bearing boxes (7, 7', 8, 8') bearing respectively the axle ends (62, 62') of
15 both rolls (3, 3') disposed in the housings (12, 12'), and provided with the driving equipment (14a) for moving the location of the connected bearing boxes (7, 7', 8, 8').

FIG. 1

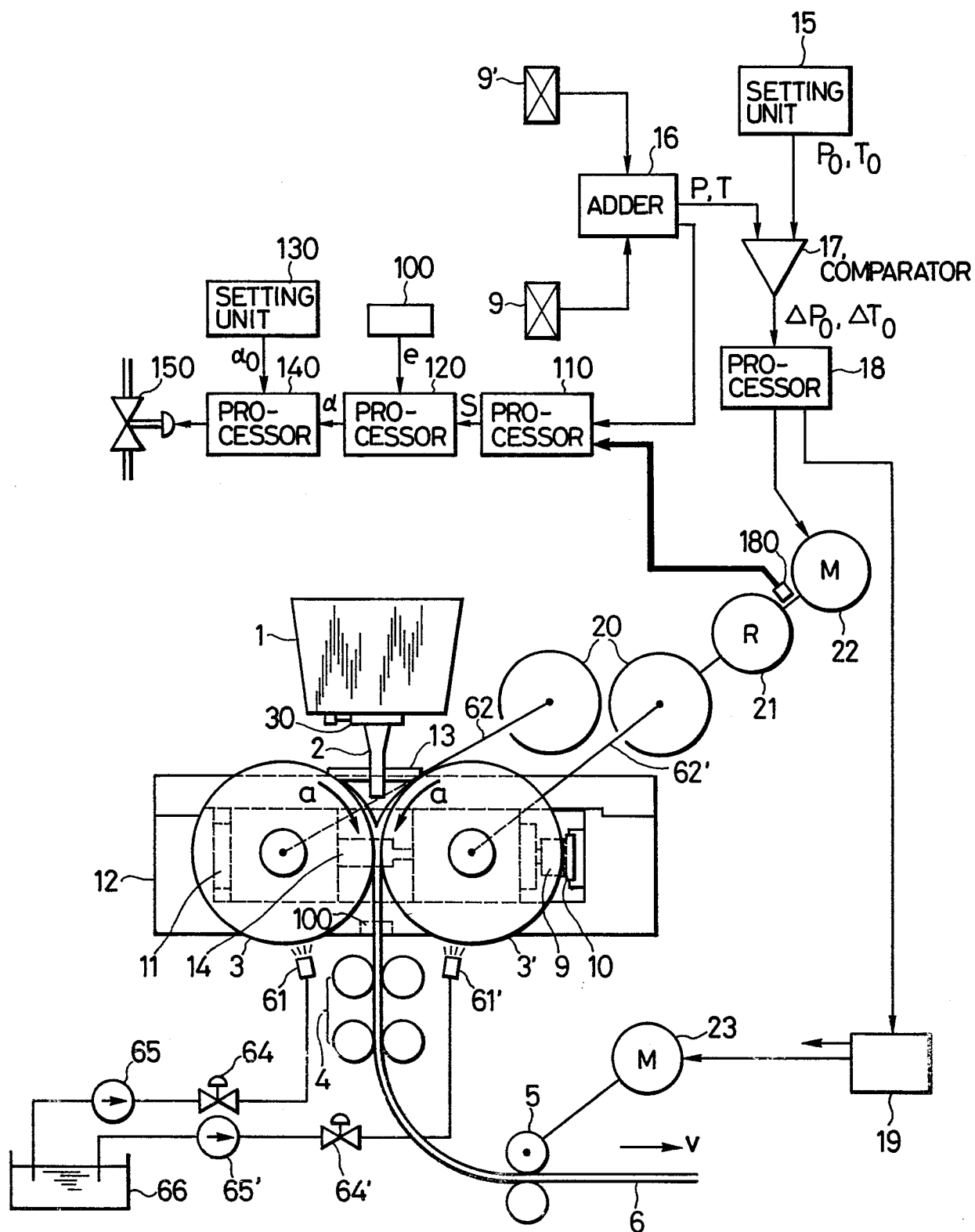


FIG. 2

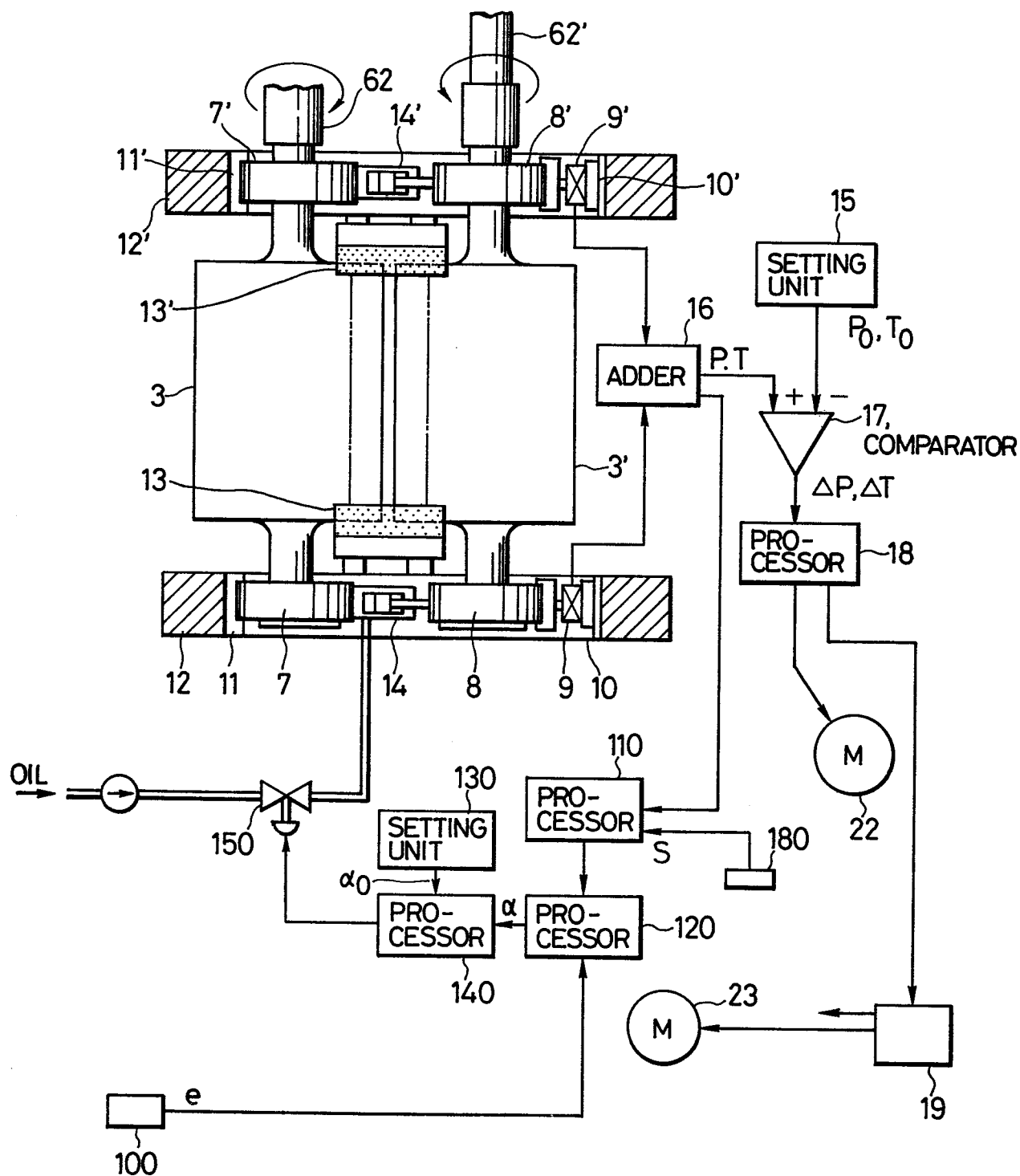


FIG. 3

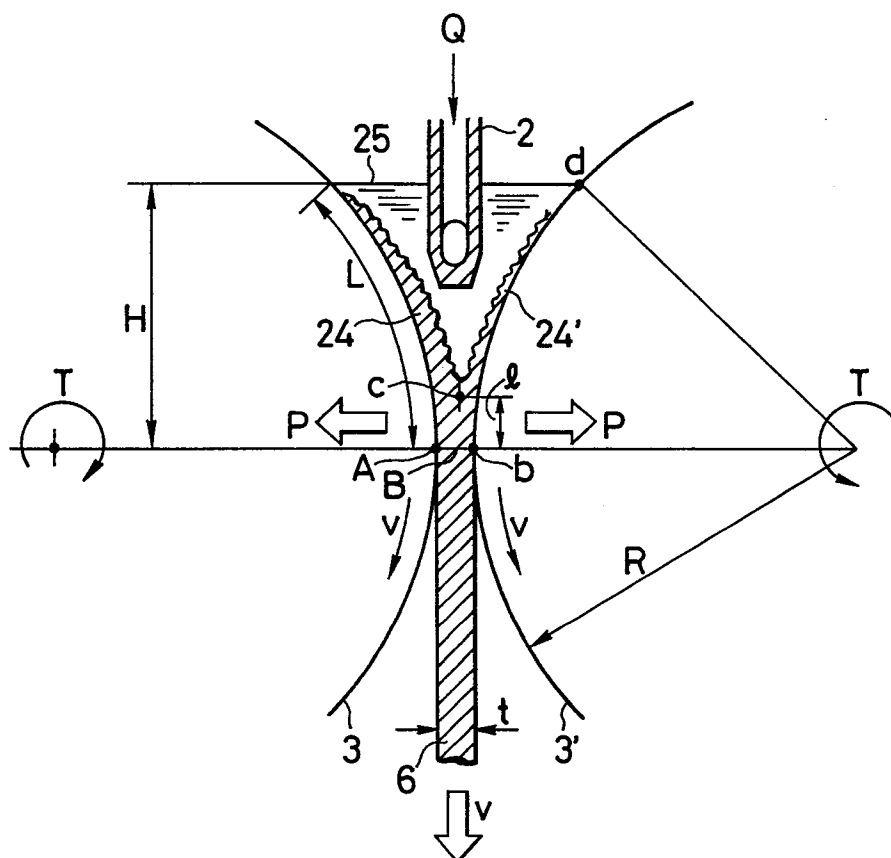


FIG. 4

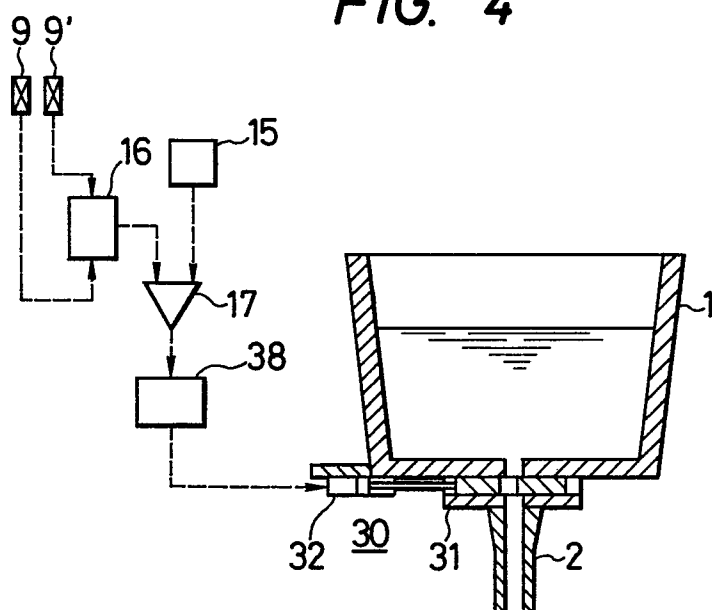


FIG. 5

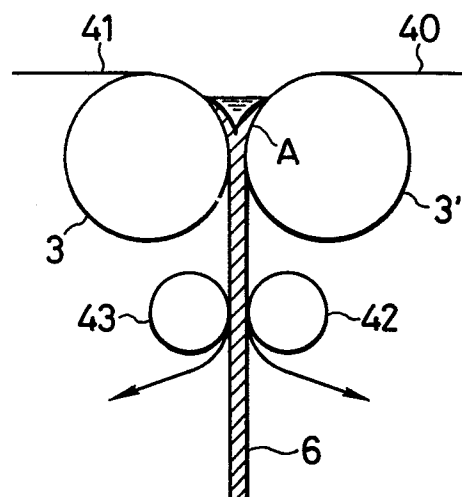


FIG. 6

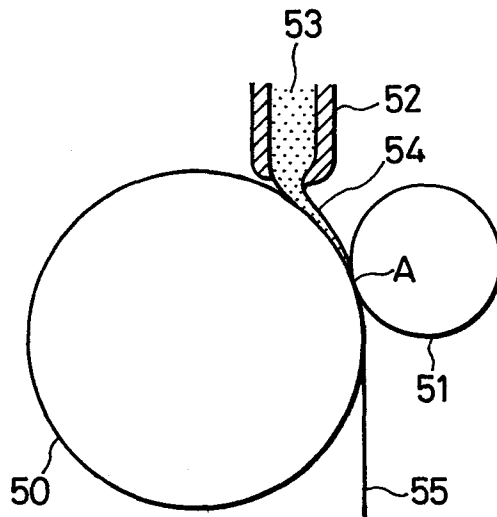


FIG. 7

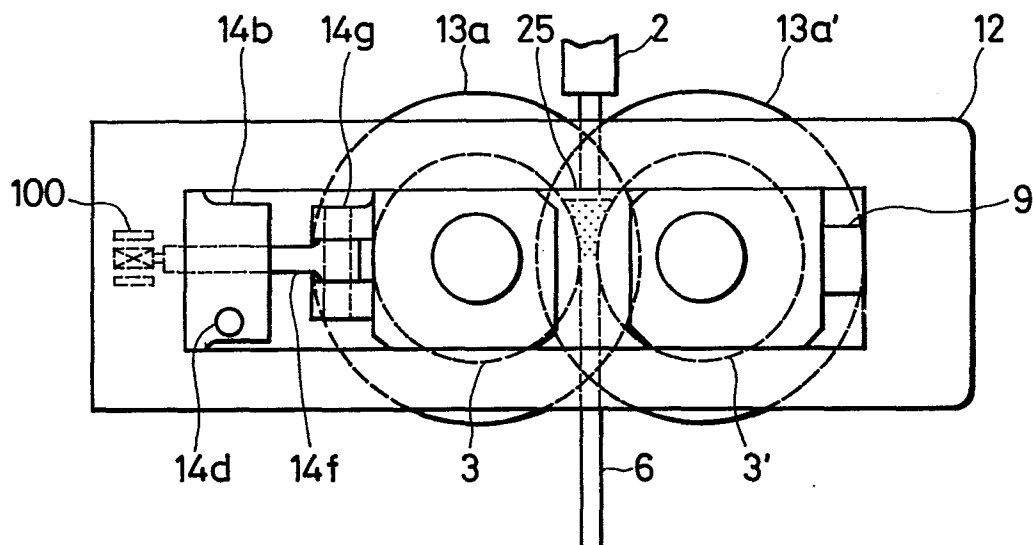
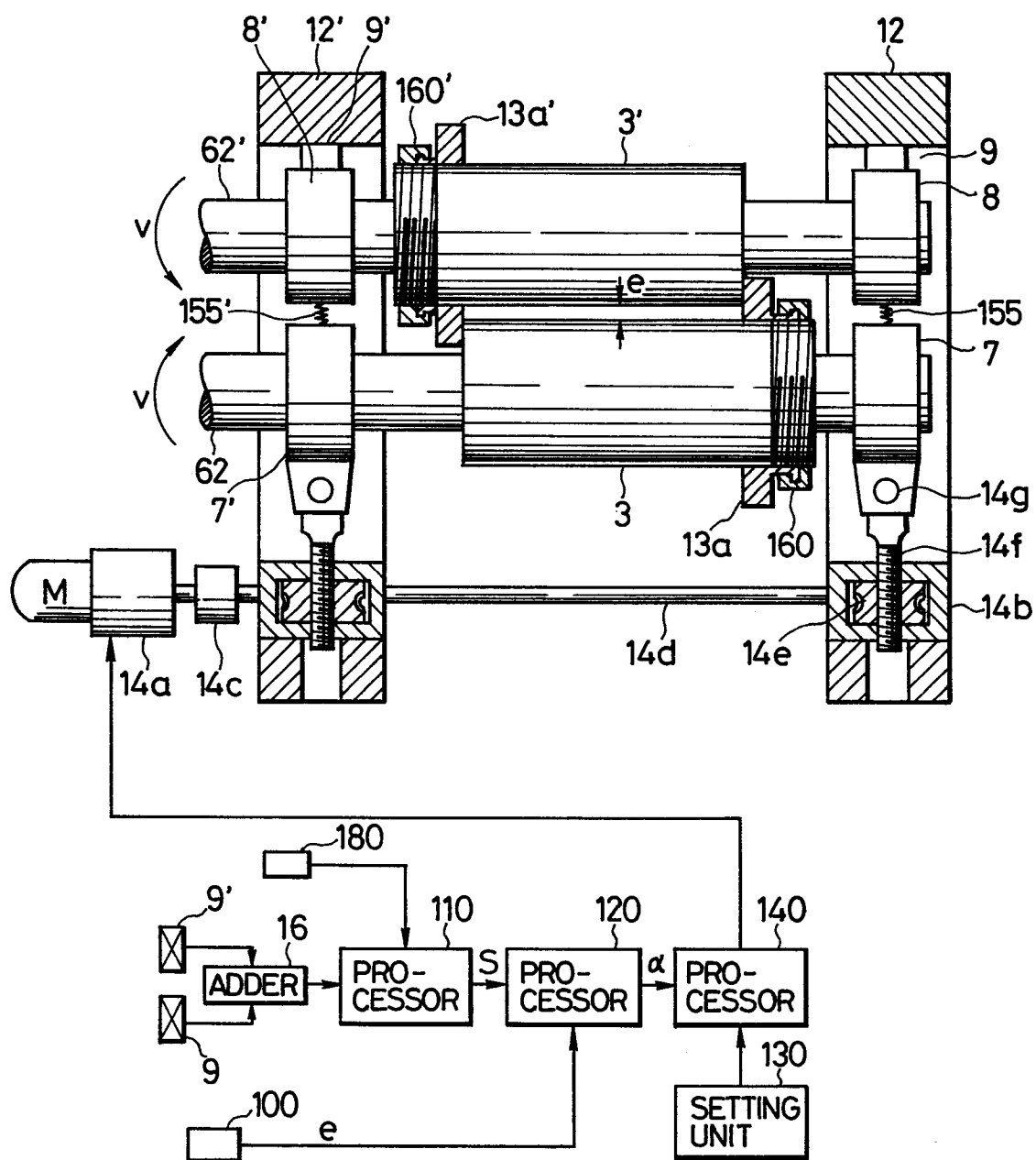


FIG. 8





European Patent
Office

EUROPEAN SEARCH REPORT

0138059
Application number

EP 84 11 0872

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	US-A-2 058 448 (HAZELETT) * Page 2, left-hand column, line 30 - right-hand column, line 14; page 2, right-hand column, lines 40-50; page 3, left-hand column, lines 27-35; page 5, left-hand column, line 58 - page 6, left-hand column, line 34; page 7, left-hand column, lines 26-36; page 9, left-hand column, line 36 - right-hand column, line 15 *	1-4, 6, 7, 9, 10	B 22 D 11/16 B 22 D 11/06
A	EP-A-0 047 218 (SCAL)		
A	US-A-3 587 708 (KHIMICH)		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			B 22 D 11/06 B 22 D 11/16 B 21 B 1/46 B 21 B 13/22
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 05-12-1984	Examiner SCHIMBERG J. F. M.
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			