



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.01.2002 Bulletin 2002/01

(51) Int Cl.7: **C21D 9/56, C21D 9/573**

(21) Application number: **01305480.4**

(22) Date of filing: **25.06.2001**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR**
Designated Extension States:
AL LT LV MK RO SI

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(30) Priority: **27.06.2000 JP 2000192378**

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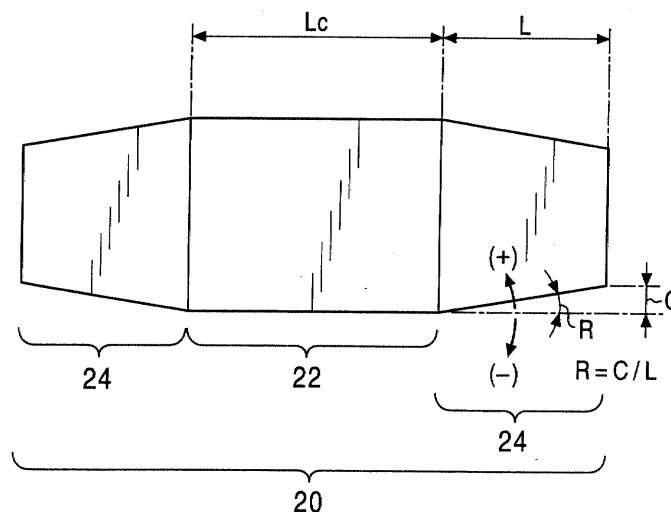
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(54) **Rolls for disposing at entry side or exit side of quenching zone of continuous annealing furnace and quenching zone unit using rolls**

(57) A roll (20) that can be disposed before and/or after a quenching zone (4) of a continuous annealing furnace is provided. The roll (20) has a predetermined profile satisfying $L_c \geq 0.7 \times W_{\min}$; $R = 0.1 \times 10^{-3}$ to $+0.2 \times 10^{-3}$; and $TR \geq 20$, wherein L_c represents the length (mm) of a flat portion (22) in the center of the roll (20), $W_{\min}$ represents the minimum width (mm) of a steel strip

(1), R represents the inclination of tapered portions (24) disposed at two sides of the roll (20), and TR represents the radius of curvature (m) of boundaries between the flat portion (22) and the tapered portions (24). The roll (20) can be used as a hearth roll (9) and/or a bridle roll (10) disposed at the entry side and/or the exit side of the quenching zone (4).

FIG. 5



Description

[0001] The invention relates to rolls disposed before and/or after a quenching zone of a continuous annealing furnace for continuously heat-treating strip, and to a quenching zone unit including the rolls.

[0002] As the size of automotive vehicles has increased in recent years, the width of steel strips has also increased. Moreover, from the point of view of preventing global warming, high-strength steel plates are increasingly employed to achieve a vehicular weight reduction by down-gauging the steel strips.

[0003] High-strength steel strips having increased widths and reduced thicknesses are being produced using continuous annealing furnaces. Continuous annealing furnaces are now required to treat a steel strip having an increased width ranging from 600 mm to 1850 mm and to 2100 mm in some cases.

[0004] Moreover, the annealing temperature of steel strips is further elevated, and, consequently, the steel strip passing through the furnace is further softened, resulting in increased amounts of defective products. For quality control, more precise control of the rapid cooling operation after annealing is required.

[0005] Because of these reasons, conventional processes are no longer sufficient for achieving stable operations of continuous annealing furnaces.

[0006] As shown in Fig. 4, an upright continuous annealing furnace for annealing steel strip comprises a heating zone 2 for heating a steel strip to a predetermined temperature to perform annealing, a soaking zone 3, and a cooling zone for cooling the high-temperature material, i.e., the steel strip 1, to room temperature.

[0007] The cooling zone normally comprises a plurality of furnace zones, namely, a quenching zone 4 (or "primary cooling zone") for rapid cooling the high-temperature steel strip, an over-aging zone 5, and a secondary cooling zone 6.

[0008] Before and after the quenching zone 4, i.e., at the entry side and the exit side of the quenching zone 4, hearth rolls and/or bridle rolls for feeding the steel strip 1 are provided. Moreover, bridle roll units 8 for preventing fluttering of the steel strip 1 inside the quench zone 4 are provided in many cases.

[0009] Herein, the term "quenching zone unit" includes the quenching zone 4 and the rolls, such as the bridle roll unit 8 disposed before and after the quenching zone 4.

[0010] Although the upright continuous annealing furnace shown in Fig. 4 includes the over-aging zone 5 and the secondary cooling zone 6, the over-aging zone 5 and the secondary cooling zone 6 may be omitted when applied to, for example, a molten metal plating line.

[0011] By employing the process of quenching a high-temperature metal strip in a quenching zone, the quality of the steel strip can be adequately controlled and the resulting products have both sufficient formability and sufficient strength. An exemplary steel strip being steel plates for vehicular bodies having a baking hardening property.

[0012] Known processes for quenching the steel strips include: a gas jet cooling process comprising cooling the atmospheric gas in the quenching zone using a heat exchanger, circulating the gas, and blowing cooled gas jet streams at high speeds on to the steel strips a roll cooling process comprising cooling rolls by placing cooling media into the rolls, which are pressed against a steel strip to quench the steel strip; a water quenching process using water as a cooling medium; and a mist cooling process.

[0013] Among these processes, the gas jet cooling process advantageously provides steel strips having satisfactory appearance and shapes after cooling. Moreover, the cost for the cooling equipment is relatively low. Thus, a high-speed gas jet cooling process, in which a temperature range of 300°C or more is quenched using a quenching zone including gas jet cooling equipment having a heat transfer coefficient of 170 W/(m²•°C) or more per surface, is now being performed. Herein, the phrase "a temperature range of 300°C or more is rapidly quenched" means that the temperature of the steel strip that is quenched is 300°C or more at the entry side of the quenching zone.

[0014] However, in the high-speed gas jet cooling process, the cooling air hitting the steel strip surfaces reaches connection sections, for example, the bridle roll unit, disposed between the heating zone and the cooling zone, thereby over-cooling the edge portions of the hearth rolls or the bridle rolls installed in the connection sections and generating large thermal crowns in the centers of these rolls. Consequently, the steel strip suffers from buckling in the width direction.

[0015] The following publications disclose means for solving this problem. Japanese Unexamined Patent Application Publication No. 56-65942 discloses that fluttering of steel strip is reduced by providing inner-furnace bridle rolls at the quenching zone entry side and increasing the tension of steel strip at a gas jet nozzle unit. However, operational experiences demonstrate that the buckling of steel strip at the inner-furnace bridle rolls disposed at the quenching zone entry side cannot be completely prevented.

[0016] Japanese Unexamined Patent Application Publication No. 60-40463 discloses a seal for preventing gas leakage from the connecting portion. However, when the seal for preventing gas leakage is applied to a high-speed gas jet cooling unit, the cooling gas hitting the steel strip surfaces leaks from the connecting units provided before and after the quenching zone, thereby generating a temperature distribution in the rolls disposed in the bridle roll units installed at the entry side and exit side of the quenching zone and resulting in the buckling of the steel strip. Accordingly, the bridle roll units require additional means for solving this problem. Otherwise, the edge portions of the rolls inside the

bridle roll unit are excessively cooled, large thermal crowns are developed in the centers of these rolls, and buckling occurs in the width direction of the steel strip.

[0017] Japanese Unexamined Patent Application Publication No. 6-93347 discloses that kinetic energy is reduced by disposing a sealing apparatus at an upper portion of a gas jet chamber of a quenching zone and injecting, from the sealing apparatus, a stream which flows in a direction opposing the stream at the surface of the steel strip. However, the sealing apparatus requires installation of a counter-stream injection apparatus and a seal roll, resulting in increased costs. Moreover, the operation thereof is complicated.

[0018] Japanese Unexamined Patent Application Publication No. 9-268324 discloses that in a quenching zone, the angle of a roll crown is adjusted so as to control the buckling threshold tension to be larger than the tension of the steel strip. However, in this continuous heat treating process, the rolls having a roll angle of the disclosed range do not come into satisfactory contact with the steel strip, resulting in slipping between the rolls and the steel strip.

[0019] Accordingly, the present invention addresses the above-described problems to achieve a high-speed gas jet cooling process without causing defects, such as buckling and meandering, even when rapid cooling is performed in a temperature range of 300°C or more and at a quenching zone having a jet cooling unit having a heat transfer coefficient per surface of 170 W/(m²•°C). The invention can achieve a reliable operation of a continuous annealing furnace by allowing a steel strip of a reduced gauge and an increased width to stably pass through the line. The invention also can solve problems such as decrease in yield, decrease in line speed, and shutdown.

[0020] An exemplary embodiment of the invention provides a roll to be disposed before or after a quenching zone of a continuous annealing furnace, satisfying the following relationships:

$$Lc \geq 0.7 \times W_{\min};$$

$$R = -0.1 \times 10^{-3} \text{ to } +0.2 \times 10^{-3};$$

and

$$TR \geq 20$$

wherein Lc represents the length (mm) of a flat portion in the center of the roll, W_{min} represents the minimum width (mm) of a steel strip, R represents the inclination of tapered portions disposed at the two sides of the roll, and TR represents the radius of curvature (m) of the boundaries between the flat portion and the tapered portions.

[0021] Another exemplary embodiment of the invention provides a quenching zone unit of a continuous annealing furnace, comprising at least one hearth roll and/or at least one bridle roll disposed at the entry side and/or the exit side of a quenching zone. The hearth roll and/or bridle roll comprises the above-described roll.

[0022] Another exemplary embodiment of the invention provides a quenching zone unit of a continuous annealing furnace, including at least one bridle roll unit having a plurality of rolls. The at least one bridle roll unit is provided at the entry side and/or the exit side of a quenching zone. Each of these rolls comprises the above-described exemplary roll.

[0023] Preferably, the roll closest to the quenching zone is a flat roll satisfying the relationships (i) R = 0 and (ii) TR = ∞.

[0024] Preferably, at least one pair of seal rolls is disposed at the entry side and/or the exit side of the quenching zone.

[0025] Reference is made, by way of example, to the accompanying drawings in which:-

Fig. 1 illustrates the vicinity of a quenching zone according to an exemplary embodiment of the invention;

Fig. 2 illustrates the vicinity of a quenching zone according to another exemplary embodiment of the invention;

Fig. 3 illustrates the vicinity of a quenching zone of a horizontal continuous annealing furnace;

Fig. 4 illustrates the structure of a continuous annealing furnace;

Fig. 5 shows an exemplary embodiment of a roll according to the invention;

Fig. 6 is a graph showing the relationship between a length Lc of the flat portion of a roll and a trouble ratio;

Fig. 7 is a graph showing the relationship between an inclination R of the tapered portion of a roll and a trouble ratio;

Fig. 8 is a graph showing the relationship between the length Lc of the flat portion of the roll at the entry side and the exit side of the quenching zone and problems regarding feeding;

Fig. 9 is a graph showing the relationship between the inclination R of the tapered portion at the entry side and the exit side of the quench zone and problems regarding feeding;

Fig. 10 is a graph comparing yield reduction rates of a conventional process and the process of the invention; and

Fig. 11 is a graph comparing operational efficiency reduction rates of the conventional process and the process

of the invention.

[0026] Preferred embodiments of the invention will be described with reference to the drawings.

[0027] Although the rolls of the invention can be preferably applied to the continuous annealing furnace shown in Fig. 4, the invention is not limited to this application. Rather, rolls according to the invention can be applied to a wide variety of continuous annealing furnaces having quenching zones.

[0028] The structures of a typical quenching zone and quenching zone units disposed before and after the quenching zone according to the invention will be described with reference to Fig. 1.

[0029] In Fig. 1, a quenching zone 4 includes a gas jet cooling apparatus 12 and performs quenching of a steel strip 1 fed into the quenching zone 4. In order to give a target tension to the steel strip 1 and to prevent fluttering of the steel strip 1 inside the quenching zone 4, bridle roll units 8 are disposed before and after the quenching zone 4. Seal rolls 11 are disposed inside the respective bridle roll units 8 to prevent the cooling gas ejected in the gas jet cooling apparatus 12 from entering the bridle roll units 8. Also, a heater 7 is provided in each of the bridle roll units 8 to prevent temperature drops inside the bridle roll units 8 and to maintain the temperature at a predetermined temperature. A plurality of hearth rolls 9 and bridle rolls 10 are provided inside each of the bridle roll units 8.

[0030] In Fig. 1, two of the hearth rolls 9 and three of the bridle rolls 10 are installed inside the bridle roll unit 8 located near the entry side of the quenching zone 4 and one hearth roll 9 and three of the bridle rolls 10 are installed inside the bridle roll unit 8 located near the exit side of the quenching zone.

[0031] The invention is, however, not limited to the particular configuration shown in Fig. 1. Other configurations can also be used as long as the steel strip 1 is provided with a target tension. For example, as shown in Fig. 2, the hearth roll 9 may also function as the bridle roll and the bridle roll unit 8 may be provided with three bridle rolls 10.

[0032] Furthermore, the invention can be applied to a horizontal continuous annealing furnace as shown in Fig. 3.

[0033] Embodiments of the invention can optimize the thermal crowns of the hearth rolls 9 and the bridle rolls 10 installed inside the bridle roll units 8 and prevent the steel strip 1 from slipping, buckling, and meandering by a desired tension applied to the steel strip.

[0034] The rolls installed after and before the quenching zone according to the invention can be applied to both the hearth rolls and the bridle rolls.

[0035] Next, a roll profile for achieving stable strip feeding without slippage of the steel strip will be described in detail.

[0036] As illustrated in Fig. 5, an exemplary roll 20 according to the invention can be disposed after or before the quenching zone. The roll 20 comprises a substantially flat portion 22 having a length L_c and tapered portions 24 having an inclination R . The flat portion 22 is sandwiched by the tapered portions 24, and the roll 20 is thereby symmetrical.

[0037] The roll crown has a convex shape. When the inclination R is negative, the roll crown has a concave shape. The inclination R is defined as the ratio of the value C , which equals half the difference in outer diameters between the beginning of the tapered portion and the end of the tapered portion, to the length L of the tapered portion, i.e., $R = C/L$.

[0038] According to the invention, the flat portion 22 does not necessarily need to be exactly flat. For example, the flat portion may have a gently curved surface having a radius of curvature of 100 m or more.

[0039] In order to specify preferred ranges of the invention, the relationship between the length L_c of the flat portion of the roll and the ratio of problems caused by slippage between the roll surface and the steel strip was examined. The results are shown in Fig. 6. In this examination, conditions such as the inclination R of the roll tapered portion and the radius of curvature at the boundary between the flat portion and the tapered portions were kept within preferred conditions according to the invention. Regarding cooling conditions, a temperature range of 300°C or more was quenched using a quenching zone including gas jet cooling equipment having a capacity of 170 W/(m²•°C) or more, reduced to a heat transfer coefficient per steel strip surface. The trouble ratio in the graph is normalized by the average of conventional operational data.

[0040] The examination shows that the preferred length of the flat portion (L_c) of the roll relative to the minimum strip width $W_{\min}$ of steel strip fed to the flat portion satisfies condition (1):

$$L_c \geq 0.7 \times W_{\min}$$

[0041] Next, the relationship between the inclination R of the tapered portion and the problem ratio caused by the slippage between the steel strip and the roll surface was examined. The results are shown in Fig. 7. Other conditions such as the length L_c of the flat portion of the roll, the radius of curvature of the boundary between the flat portion and the tapered portions, etc. were within the preferred conditions of the invention, and the cooling conditions were the same as those in the examination regarding Fig. 6. The trouble ratio is normalized by the average value of conventional operational data.

[0042] Accordingly, the range of the inclination R of the tapered portion preferably satisfies condition (2):

$$R = -0.1 \times 10^{-3} \text{ to } +0.2 \times 10^{-3}$$

[0043] Furthermore, the boundary between the roll flat portion and the tapered portions is preferably smooth and round without edges in order to prevent slipping and buckling of the steel strips. To smooth the boundary between the flat portion and the tapered portions of the roll, the radius of the curvature TR at the boundary is preferably 20 m or more. In other words, the curvature TR satisfies condition (3):

$$TR \geq 20$$

[0044] Next, based on the above-described parameters, the conditions which prevent buckling and meandering of the steel strip were investigated. The results are shown in Fig. 8. In Fig. 8, the horizontal axis indicates the entry side and the exit side of the quenching zone and the vertical axis indicates the length Lc of the roll flat portion. R and TR were set within the ranges of the invention. The graph shows whether buckling and/or meandering occurred in the steel strip fed therein. The cooling conditions were the same as those in the examination regarding Fig. 6. In the graph, circles (○) indicate that the steel strip had no defect and squares (□) indicate that buckling was observed in the steel strip. The speed of the strip line was set to a normal speed (100 to 300 m/min). No meandering was observed in the examination regarding Fig. 8.

[0045] Fig. 8 also demonstrates that condition (1):

$$Lc \geq 0.7 \times W_{\min}$$

is preferable.

[0046] Fig. 9 is a graph indicating the generation of buckling and meandering when a steel strip was fed. The horizontal axis in the graph indicates the entry side and the exit side of the quenching zone. The vertical axis in the graph indicates the inclination R of the tapered portion. The conditions such as Lc and TR were set within the preferred range of the invention. The cooling conditions were the same as those in the examination regarding Fig. 6. In the graph, circles (○) indicate the steel strip had no defect, triangles (Δ) indicate that meandering was observed, and squares (□) indicate that buckling was observed. The speed of the strip line was set to a normal speed (100 to 300 m/min).

[0047] Fig. 9 also demonstrates that condition (2):

$$R = -0.1 \times 10^{-3} \text{ to } +0.2 \times 10^{-3}$$

is preferable. This range is actually wider than the preferred range for preventing problems caused by slippage as shown in Fig. 7.

[0048] In order to prevent the steel strip from vibrating inside the quenching zone, bridle roll units are generally provided after and before the quenching zone to maintain the tension of the steel strip at the quenching zone at a high level. The rolls installed inside these bridle roll units are preferably the rolls within the preferred ranges of the invention so as to avoid problems, such as slipping, buckling and meandering, as described above. Under a high tension at the quenching zone, meandering is likely to occur when rolls have concave-shaped crowns, $R < 0$, whereas buckling is likely to occur when rolls have convex-shaped crowns, $R > 0$.

[0049] The optimum shape of the roll for avoiding these problems is a flat roll of $R = 0$ located substantially in the center of the preferred range shown in Fig. 9. In the flat roll, $TR = \infty$ (radius of curvature = 0). Other advantages of the flat roll are its ease of manufacturing and low manufacturing costs. In the bridle roll unit, the tension of the steel strips is relatively low at the roll closest to the quenching zone compared to the rolls at the preceding positions. In this respect, it is preferable that, among these bridle rolls, the one closest to the quenching zone be a flat roll of $R = 0$ and $TR = \infty$ and the preceding rolls be the rolls satisfying the conditions of the invention.

[0050] Preferably, the cooling gas injected into the quench zone is prevented from reaching inside of the bridle roll unit as much as possible. When a large amount of cooling gas passes through the connecting portion between the quenching zone and the bridle roll unit and reaches the bridle roll unit, the edges of the rolls inside the unit are excessively cooled, generating remarkable thermal crowns in the central portion of the roll. Thus, when the gauge of the strip is reduced, the probability of slipping and buckling becomes high.

[0051] In order to solve this problem, at least one pair of seal rolls is preferably installed in each of the connecting portions of the bridle roll units located at the entry side and the exit side of the quenching zone.

[0052] Table 1 shows profiles of the rolls of the invention as installed inside the bridle roll units disposed before and

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after the quenching zone of the upright continuous annealing furnaces. The profiles are defined as Lc and R, and show whether undesirable phenomena such as slipping, buckling, and meandering occur or not. In Table 1, "A" indicates neither slipping, buckling, nor meandering was observed; "B" indicates slipping, buckling, or meandering was occasionally observed; and "C" indicates slipping, buckling, or meandering was frequently observed.

5 **[0053]** The quenching zone had a gas jet cooling unit having a capacity of $170 \text{ W}/(\text{m}^2 \cdot ^\circ\text{C})$ or more reduced to a heat transfer coefficient per steel strip surface and was provided with a pair of seal rolls at the entry of the quenching zone. The temperature range of 300°C or more was quenched.

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Table 1

Sample	Width of Strip (mm)	$W_{\min}$	$W_{\max}$	Length of Flat Portion L_c (mm)	Inclination R of Tapered Portion ($\times 10^{-3}$)	Curvature Radius TR at Boundary (m)	Slipping	Buckling	Meandering	Reference
1	600	600	1600	700	0.2	20	A	A	A	Example
2	1000	600	1600	700	0.2	20	A	A	A	Example
3	1250	600	1600	700	0.2	20	A	A	A	Example
4	1600	600	1600	700	0.2	20	A	A	A	Example
5	600	600	1600	700	-0.05	20	A	A	A	Example
6	1000	600	1600	700	-0.05	20	A	A	A	Example
7	1250	600	1600	700	-0.05	20	A	A	A	Example
8	1600	600	1600	700	-0.05	20	A	A	A	Example
9	1000	700	2000	1000	0.0	∞	A	A	A	Example
10	1250	700	2000	1000	0.0	∞	A	A	A	Example
11	1600	700	2000	1000	0.0	∞	A	A	A	Example
12	1850	700	2000	1000	0.0	∞	A	A	A	Example
13	2000	700	2000	1000	0.0	∞	A	A	A	Example
14	1000	700	2000	800	-0.2	20	B	A	A	Comparative Example 1
15	1250	700	2000	800	-0.2	20	B	A	B	Comparative Example 1
16	1600	700	2000	800	-0.2	20	C	A	C	Comparative Example 1
17	1850	700	2000	800	-0.2	20	C	A	C	Comparative Example 1
18	1000	700	2000	800	0.4	20	B	B	A	Comparative Example 2
19	1250	700	2000	800	0.4	20	C	B	A	Comparative Example 2

Table 1 (continued)										
Sample	Width of Strip (mm)	$W_{\min}$	$W_{\max}$	Length of Flat Portion L_c (mm)	Inclination R of Tapered Portion ($\times 10^{-3}$)	Curvature Radius TR at Boundary (m)	Slipping	Buckling	Meandering	Reference
20	1600	700	2000	800	0.4	20	C	C	A	Comparative Example 2
21	1850	700	2000	800	0.4	20	C	C	A	Comparative Example 2

[0054] As can be understood from Table 1, in samples 14 to 17 (Comparative Example 1), the inclination R of the tapered portions of each of the rolls was negative; hence, significantly large concave crowns were formed, resulting in slipping and buckling of the steel strips.

[0055] In samples 18 to 21 (Comparative Example 2), the inclination R of the tapered portions of each of the rolls was positive; hence, significantly large convex crowns were formed, resulting in slipping and meandering of the steel strips.

[0056] Samples 1 to 13 are rolls according to the invention.

EXAMPLES

[0057] Operations were conducted using an upright continuous annealing furnace having a quenching zone unit including rolls of the invention disposed before and after a quenching zone.

[0058] The upright continuous annealing furnace had a $W_{\min}$ value of 700 mm and a $W_{\max}$ value of 1850 mm. The quenching zone unit used was that shown in Fig. 1. The quenching zone included a gas jet cooling apparatus having a capacity of $170 \text{ W}/(\text{m}^2 \cdot ^\circ\text{C})$ or more, reduced to a heat transfer coefficient per steel strip surface.

[0059] An operation according to the invention satisfied all conditions (1) to (3). That is, in the operation of the invention, all of the rolls used inside the bridge roll units were in conformity with conditions (1) to (3). The operations, each satisfying only one of conditions (1) to (3), were also performed and were compared to a conventional process.

[0060] In the operation according to the invention satisfying all of conditions (1) to (3), the rolls disposed before and after the quenching zone had the following profiles: $L_c = 1.0 \times 700$, $R = 0.05 \times 10^{-3}$, and $TR = 50 \text{ m}$.

[0061] In the operation satisfying only condition (1), the rolls disposed before and after the quenching zone had the following profiles: $L_c = 1.0 \times 700$, $R = 0.4 \times 10^{-3}$, and $TR = 10 \text{ m}$.

[0062] In the operation satisfying only condition (2), the rolls disposed before and after the quenching zone had the following profiles: $L_c = 0.5 \times 700$, $R = 0.05 \times 10^{-3}$, and $TR = 10 \text{ m}$.

[0063] In the operation satisfying only condition (3), the rolls disposed before and after the quenching zone had the following profiles: $L_c = 0.5 \times 700$, $R = 0.4 \times 10^{-3}$, and $TR = 50 \text{ m}$.

[0064] In the operation performed according to a conventional process, the rolls disposed before and after the quenching zone had the following profiles: $L_c = 0.5 \times 700$, $R = 0.5 \times 10^{-3}$, and $TR = 8 \text{ m}$.

[0065] Fig. 10 shows the relationship between each of the operation conditions and the decrease in yield of the products due to slipping, buckling, and meandering between the rolls and the steel strip. In the graph, the yield reduction rate is normalized by the amount of the defective product relative to the entire production in a conventional process.

[0066] When slipping, meandering, or buckling occur, the speed of the line must be reduced, resulting in a reduced production yield.

[0067] Improvements compared to the conventional process can be attained by satisfying one of conditions (1) to (3), but when all of these conditions are satisfied in combination as in the invention, decrease in yield can be significantly improved to approximately one-tenth of the conventional process.

[0068] Fig. 11 shows the relationship between each of conditions (1) to (3) and the operation efficiency reduction rate of the line caused by slipping, buckling, or meandering between the rolls and the steel strip.

[0069] Here, "operation efficiency" is defined as the ratio of the line speed calculated from the capacity of the equipment to the actual operation speed and is an indicator of the capacity in operation. In the graph, the operational efficiency reduction rate is normalized by an average value of the difference between a theoretical line speed calculated from capacity and an actual line speed of a conventional process.

[0070] When slipping, buckling, or meandering occurs, the speed of the line is decreased, resulting in a reduced treatment speed. It may be possible to continue the operation in such a state without major problems, but the operation efficiency will eventually be decreased, failing to achieve an expected production amount. If the problems are major, it becomes necessary to stop the line, decrease the temperature of the furnace, and dispose of the steel strips in the furnace, thus failing to achieve a predetermined production amount and decreasing the operation efficiency.

[0071] By employing the rolls of the invention, the operation rate of the upright continuous annealing furnace was improved by 0.1% on average and the operation efficiency reduction rate was lowered to one-fifth compared to the conventional process.

[0072] Also, occurrence of line shutdown, decrease in the line speed, and so forth due to slipping, buckling, and meandering were maintained at minimum levels, thereby significantly improving the production yield and operation efficiency of the furnace.

Claims

1. A roll for disposing at an entry side or an exit side of a quenching zone of a continuous annealing furnace, the roll

satisfying the following relationships:

$$L_c \geq 0.7 \times W_{\min};$$

$$R = -0.1 \times 10^{-3} \text{ to } +0.2 \times 10^{-3};$$

and

$$TR \geq 20$$

wherein L_c represents a length (mm) of a flat portion in the center of the roll,
 $W_{\min}$ represents a minimum width (mm) of a steel strip,
 R represents the inclination of tapered portions disposed at two sides of the roll, and
 TR represents the radius of curvature (m) of boundaries between the flat portion and the tapered portions.

2. A quenching zone unit of a continuous annealing furnace, comprising:

a quenching zone having an entry side and an exit side; and
at least one roll selected from the group consisting of hearth rolls and bridle rolls disposed at at least one of the entry side and the exit side of the quenching zone,

wherein the at least one roll comprises the roll according to claim 1.

3. A quenching zone unit of a continuous annealing furnace, comprising:

a quenching zone having an entry side and an exit side; and
at least one bridle roll unit comprising a plurality of rolls, the at least one bridle roll unit being disposed at at least one of the entry side and the exit side of the quenching zone,

wherein each of the plurality of rolls comprises the roll according to claim 1.

4. The quenching zone unit of a continuous annealing furnace according to claim 3, wherein a roll of the plurality of rolls that is closest to the quenching zone is a flat roll satisfying the relationships (i) $R = 0$ and (ii) $TR = \infty$.

5. The quenching zone unit of a continuous annealing furnace according to claim 2, 3, or 4, comprising at least one pair of seal rolls disposed at at least one of the entry side and the exit side of the quenching zone.

6. The quenching zone unit of a continuous annealing furnace according to claim 2, wherein said at least one roll comprises a roll closest to the quenching zone, which is a flat roll satisfying the relationship (i) $R = 0$ and (ii) $TR = \infty$.

FIG. 1

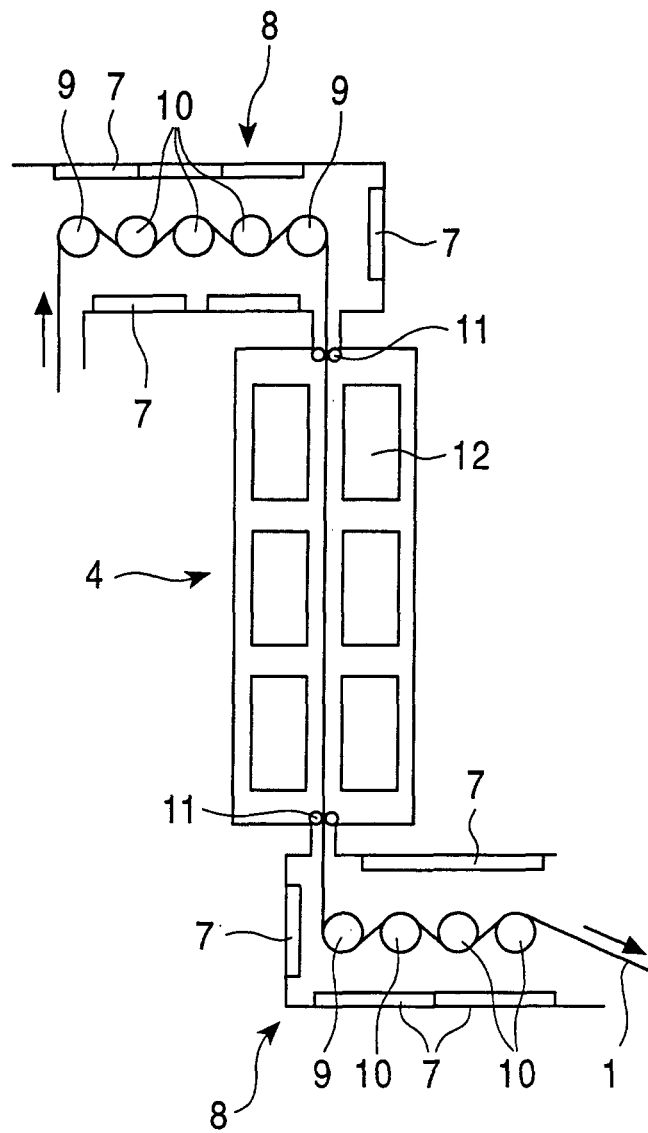


FIG. 2

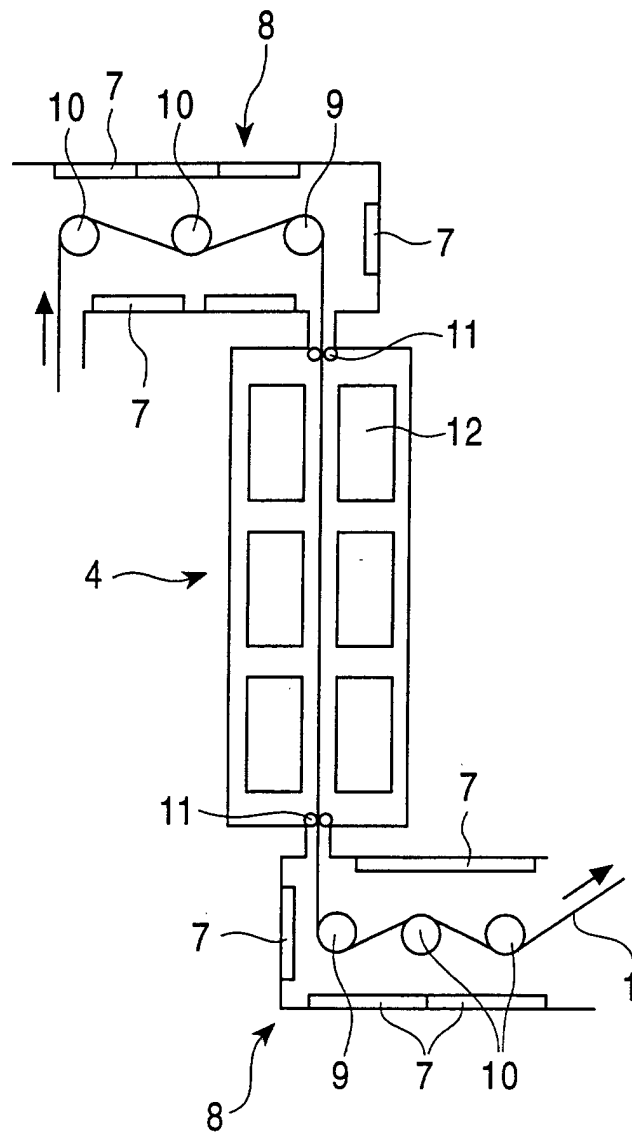


FIG. 3

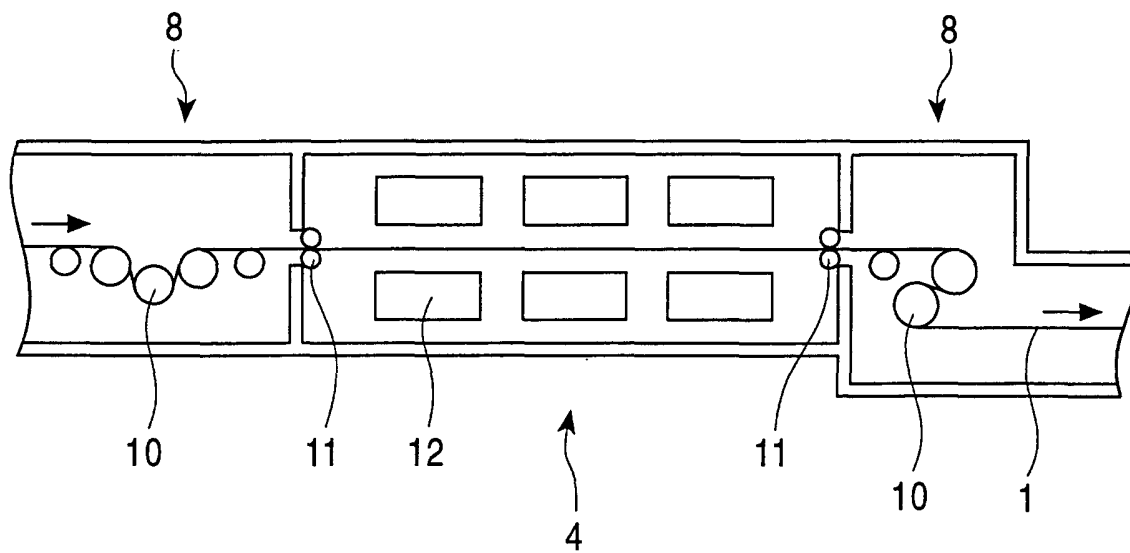


FIG. 4

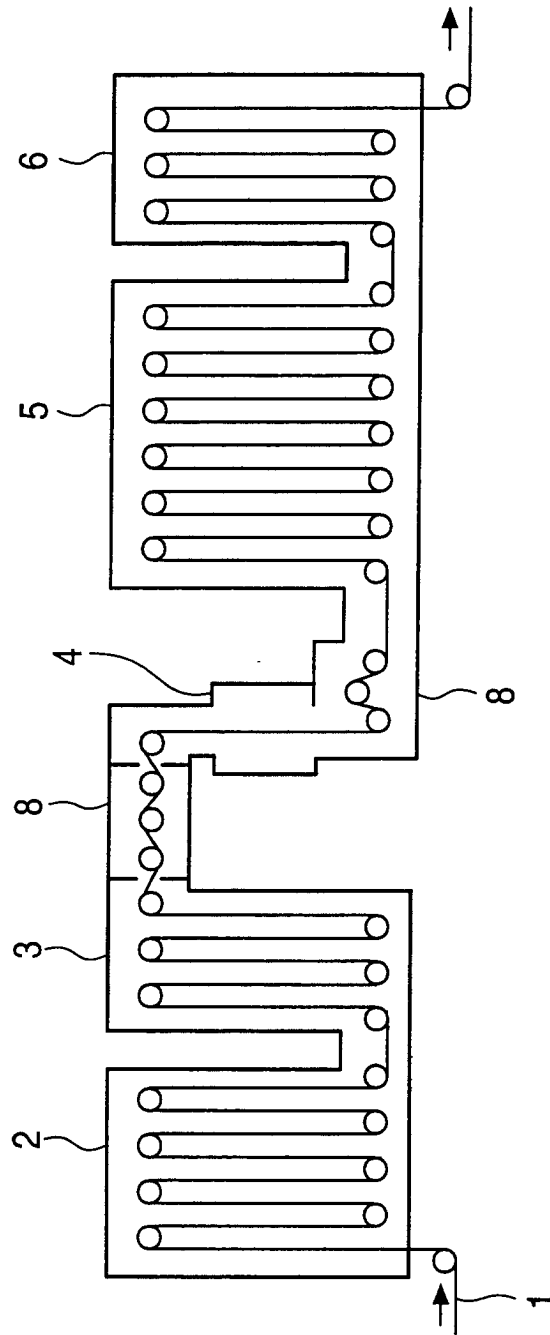


FIG. 5

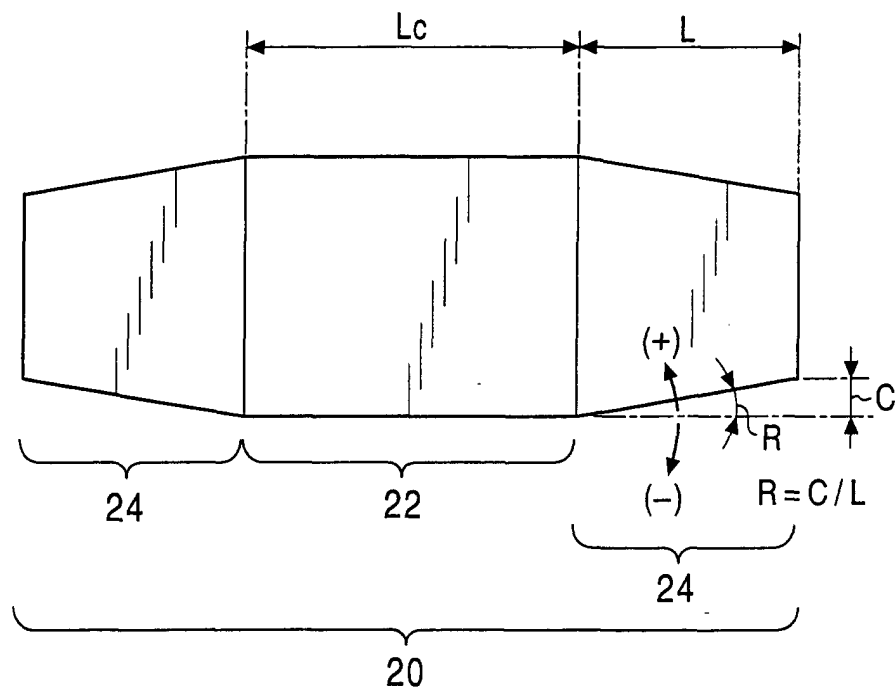


FIG. 6

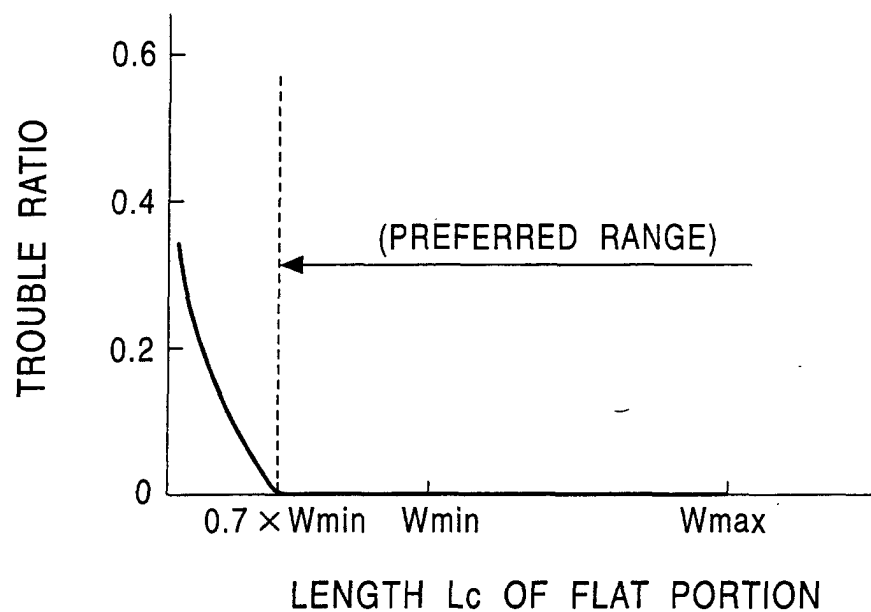


FIG. 7

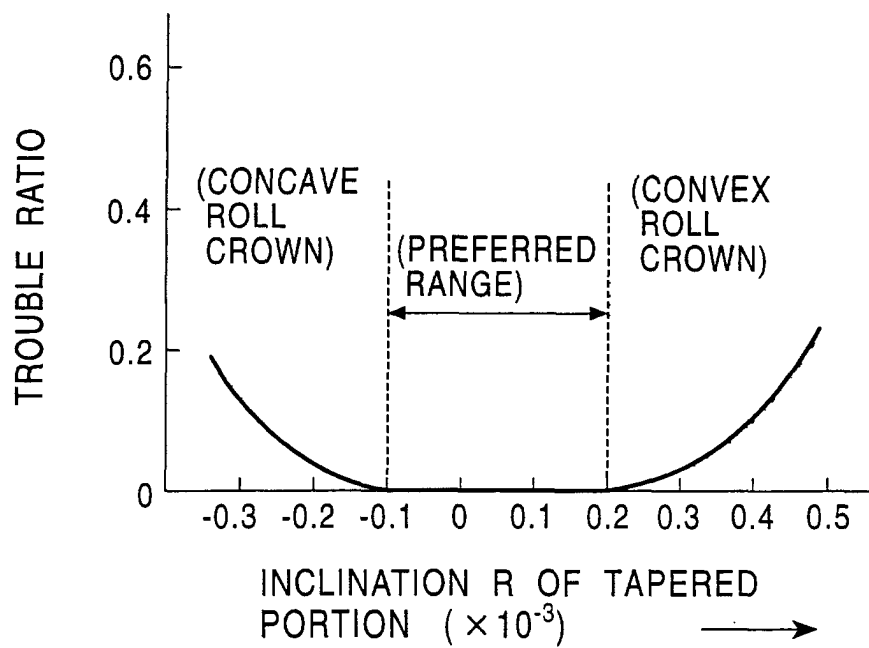


FIG. 8

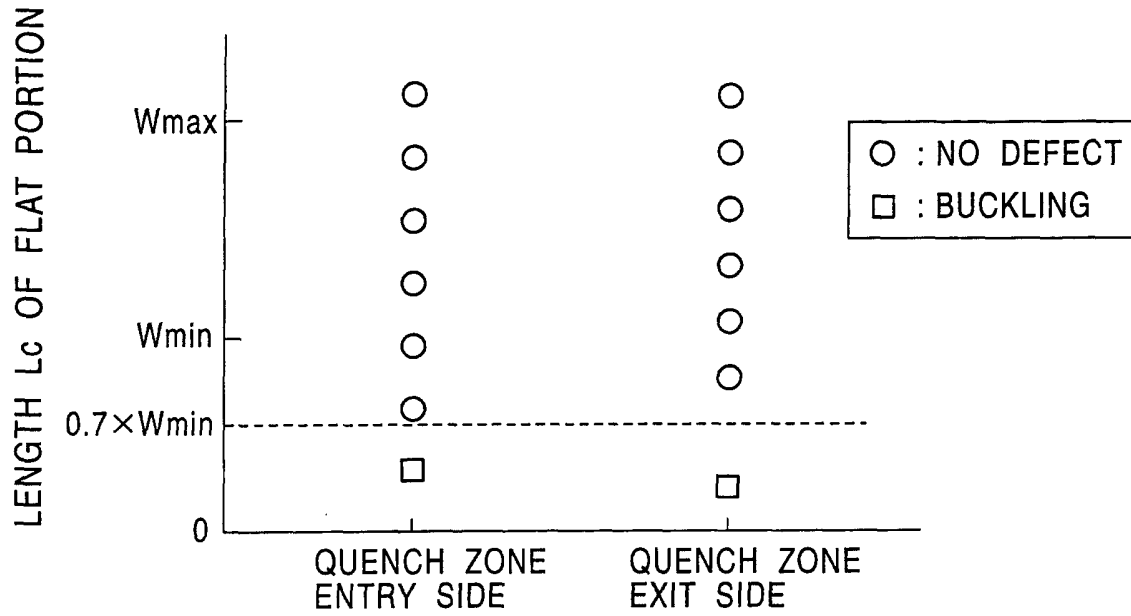


FIG. 9

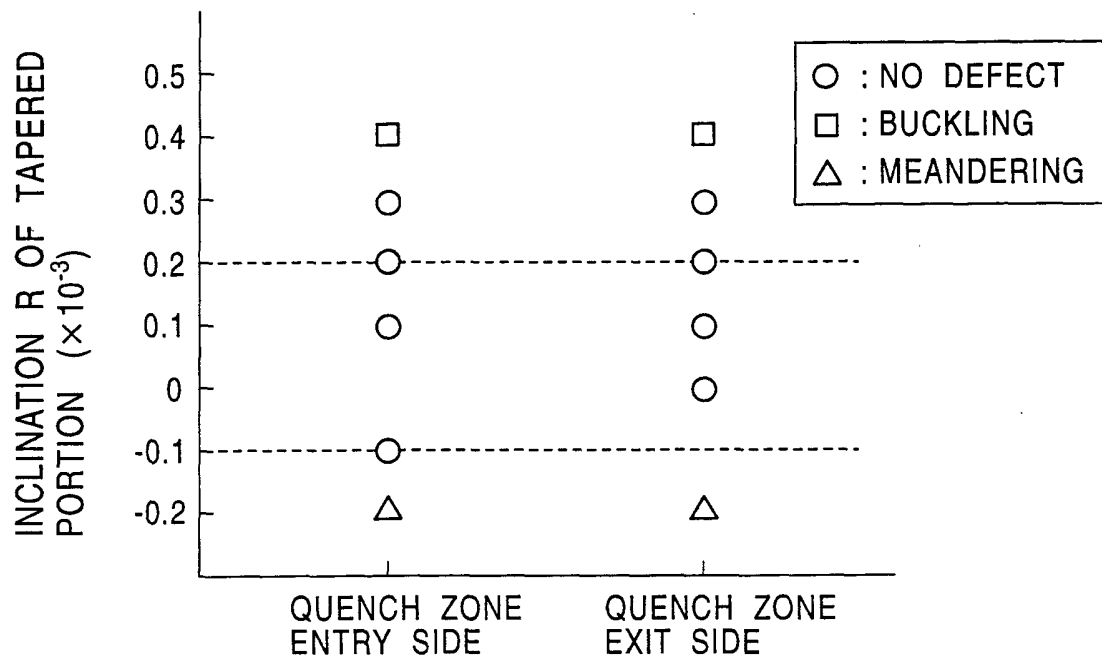


FIG. 10

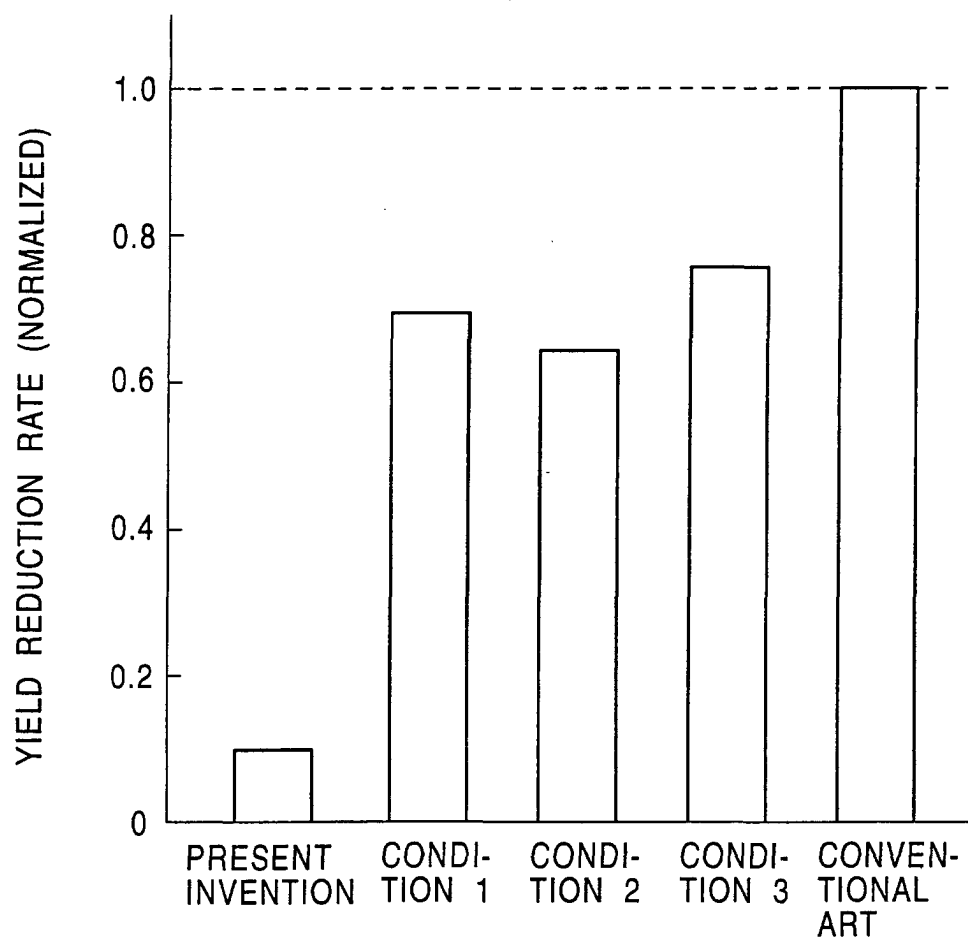
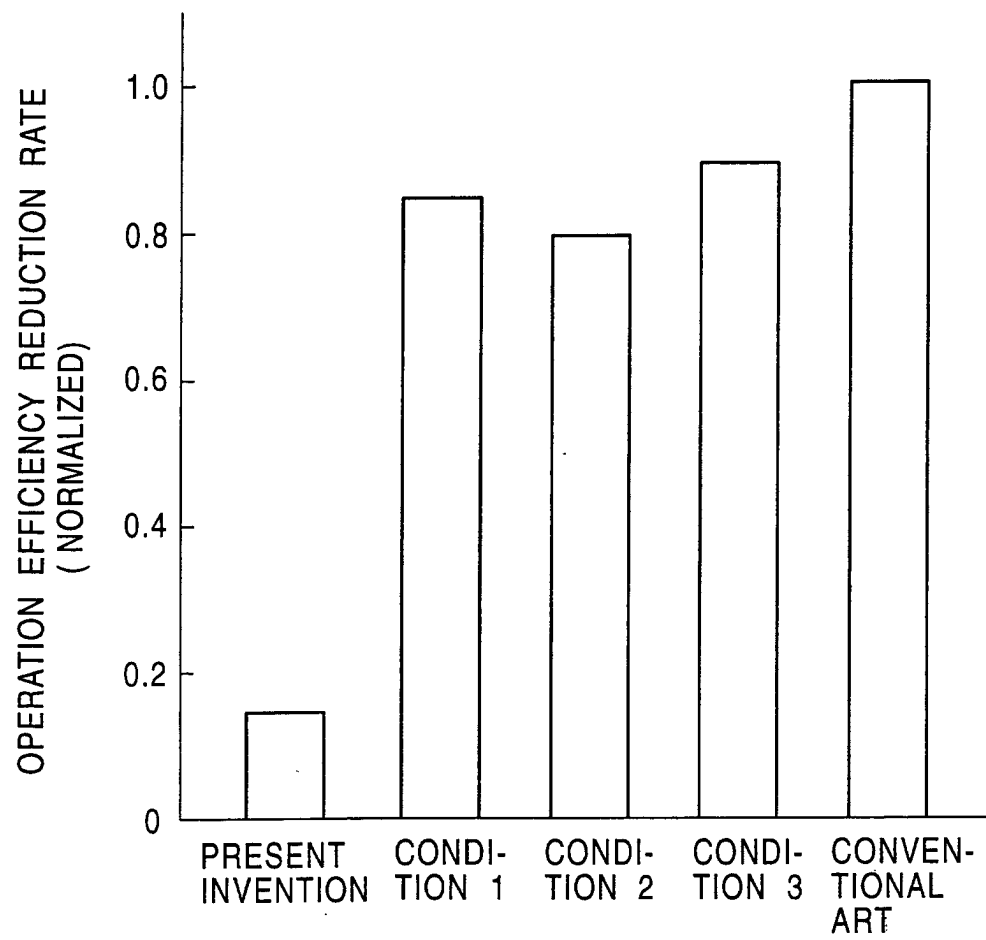


FIG. 11





European Patent
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EPC FORM 1503 03 82 (P4/C01)

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