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(54) **Continuous annealing method for deep drawable extra-low carbon steel.**

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EP-A- 0 112 027
DE-A- 2 942 338
DE-B- 2 056 313
US-A- 3 385 946

The Making, Shaping and Treating of Steel, 9th Edition, USS, 1971, page 977

PATENT ABSTRACTS OF JAPAN, vol. 6, no. 180 (C-125)(1058), 14 September 1982; & JP-A-57 94524 (Nippon Kokan) 12-06-82

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EP 0 211 681 B1

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Description

This invention relates to a method for continuously annealing an extra-low carbon steel for deep drawing. More particularly, it relates to a method which optimises the excellent mechanical properties of extra-low carbon steel by considering the heating phase as being of prime importance in furnace structure instead of the conventional view in which the most important section is the cooling zone.

The production of deep drawable steel sheets through a continuous annealing process has previously been disclosed in Japanese Patent Application Publication No. 47-33409. As shown by a symbol (a) in Fig. 5, the essence of this technique lies in the fact that a coiled steel sheet, obtained after hot and cold rolling, is heated to a higher temperature, soaked at this temperature for a given time, rapidly cooled down to about 400 °C, held at about 400 °C for 1-3 minutes and then cooled down to room temperature. Furthermore, as described in the above article, there is a technique wherein a low carbon steel is annealed by merely cooling, following heating and soaking, as shown by a symbol (b) in Fig. 5. In any case, the steel sheets annealed by the above heat cycle are rigid and are not fit for use as deep drawable steel sheets.

Thus the only presently available equipment for annealing low carbon steel operates according to a cycle of heating → soaking → rapid cooling → overaging. In such a conventional technique for continuously annealing low carbon steel, to produce a deep drawable steel sheet, it is well-known that the cooling step is most important in the continuous annealing process. That is, it is necessary to control the rapid cooling and overaging conditions, and further slow cooling conditions, prior to the rapid cooling or final cooling conditions after overaging. Therefore, serious problems arise in the continuous annealing of low carbon steel in how to effectively maintain such an ideal but complicated cooling cycle during actual operation, or how to design equipment capable of producing the steel sheet in high efficiency from a process incorporating the above heat cycle.

DE-OS-2942338 discloses a method of producing non-ageing cold rolled steel strip having excellent deep-drawability from low carbon Al-killed steels. The non-ageing cold-rolled steel is obtained by a continuous heat-treatment which does not require an over-ageing treatment. It is, however, essential to soak the strip at a temperature in the range from 680 °C to 900 °C prior to cooling.

US-A-3385946 is concerned with the initial heating stage in a continuous annealing process and discloses a method for continuous annealing a low carbon steel tinplate strip. The strip is heated to a temperature which is below its recrystallisation temperature. A rapid heating means is then employed to perform the final heating of the strip to the annealing temperature (which is above its recrystallisation temperature) in the final stages associates with the annealing of the strip.

Until now the continuous annealing equipments required for the production of deep drawable steel sheets have been designed and constructed on the basis of the aforementioned technical knowledge. Consequently, the cooling portion in all the existing continuous annealing equipment for the production of deep drawable steel sheets is a rate-determining portion of the equipment. The operation and control processes thereof are planned so as to preferentially achieve the desired cooling conditions.

On the other hand, it is known that when using an extra-low carbon steel having a carbon content of C≅0.002%, less than a tenth of that of the conventional low carbon steel in which C≅0.04%, the overaging treatment becomes unnecessary. However, it is considered that there is no essential difference between low carbon steel and extra-low carbon steel insofar as the heating and soaking steps are concerned. Therefore, the conventional annealing furnace designed for the low carbon steel has been applied to the production of extra-low carbon steel until now. However, the excellent mechanical properties of extra-low carbon steel cannot be exploited at all in such a furnace, and additionally there are several disadvantages inherent in this method of processing.

When the low carbon steel is treated in the conventional continuous annealing apparatus for deep drawable steel sheets, as shown in Fig. 4, control of the rapid cooling rate and overaging is most important. In order to accurately control these factors the temperature at the beginning of the rapid cooling or at the outlet side of a soaking zone should be constant. However, as the sheet travelling speed, sheet gauge or the like changes, the temperature in the heating zone varies as shown by symbols (i), (ii) and (iii) in Fig. 4a. In extreme cases, a sheet heated in the heating zone to a higher temperature than that required in the soaking zone is gradually cooled in the soaking zone, as shown in the symbol (i) of Fig. 4a, instead of remaining at constant temperature in the soaking zone.

Experiments performed by the inventors in connection with the above observations revealed several salient points. Thus, an extra-low carbon steel containing 0.0025 wt% of C, 0.08% wt% of Mn, 0.01 wt% of Si, 0.010 wt% of P, 0.005 wt% of S, 0.04 wt% of Aℓ, 0.002 wt% of N and 0.035 wt% of Ti was melted and continuously cast into a slab, which was hot rolled and cold rolled to obtain a steel sheet of 0.8 mm in final gauge. This sheet

was heated at various temperatures, soaked for a period of 0-120 seconds and then subjected to a skin pass rolling. The elongation of this treated sheet was measured and the results are shown in Fig. 2, wherein numerical values described in circles are values of elongation (%). Referring to Fig. 2, it can be seen that elongation increases with an increase in heating temperature, but there is only a slight increase in elongation in all cases at the relatively low heating temperature of 750 °C, even when this temperature is held for a long time. However, the soaking time has no influence at heating temperatures above 800 °C, although the measured elongation increases markedly in comparison with that at 750 °C. A similar tendency is observed with other properties such as yield strength, tensile strength etc.

Secondary work embrittlement, following annealing at 850 °C, was examined and the results obtained are shown in Fig. 2 (symbol o shows no embrittlement and symbol x shows occurrence of embrittlement). One consequence of the results obtained in Figure 2, is that cracking does not occur even at -80 °C when the soaking time is zero, whereas if soaking is carried out for a time of not less than 30 seconds, the embrittlement temperature is as high as not less than -50 °C. This fact, confirms that it is better to make the soaking time as short as possible.

Further, the aforementioned cold rolled sheet (of 0.8 mm final gauge) was heated to various temperatures at a heating rate of 35 °C/sec and rapidly cooled at a cooling rate of 30 °C/sec. Thereafter the r-values (Lankford value) were measured and the results are shown in Fig. 3. As seen from Fig. 3, the r-value tends to increase as the annealing temperature rises in the case of low carbon steel, but the change of r-value is not so large. However, when the annealing temperature reaches 850 °C, the growth of austenite phase increases to obstruct the growth of crystal grains and hence the r-value tends to decrease. On the contrary, the r-value tends to considerably increase as the annealing temperature rises in the case of extra-low carbon steel.

From these results, the inventors have discovered that the control of maximum heating temperature is most important for obtaining a given product from extra-low carbon steel without controlling the soaking time.

When annealing extra-low carbon steel in the conventional continuous annealing apparatus on the basis of the above knowledge, the steel sheet is annealed according to the changed heat cycle as shown in the symbols (i), (ii) and (iii) of Fig. 4a in the heating zone, as previously mentioned. Thus even when the temperature at delivery side of the soaking zone is constant, different maximum temperatures occurring in the heating zone may result in changed mechanical properties (as a result of variations in sheet travelling speed, sheet gauge or the like).

Since the extra-low carbon steel becomes very soft at high temperature, the risks of producing surface defects and coil breakage increase with the increase in holding time at the high temperature, thus sufficient care must be taken.

It is an object of the invention to solve all of the aforementioned problems in the manufacture of extra-low carbon steel sheets and to provide a continuous annealing method capable of precisely controlling the intended heating temperature.

According to the present invention there is provided a method of continuously annealing sheet material of extra-low carbon steel for deep drawing comprising the steps of heating and cooling the sheet material wherein the sheet material is heated from room temperature to a temperature above its recrystallisation temperature, the temperature of the heated sheet is regulated by rapid heating to a desired maximum temperature, said maximum temperature being determined by the steel composition, within an accuracy of ±10 °C, rapidly cooled without soaking after reaching said maximum temperature and the rapidly-cooled sheet material is finally cooled to room temperature.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made by way of example only, to the following drawings in which:-

Fig. 1a is a diagram showing a heat cycle in the apparatus used in the present invention;

Fig. 1b is a schematic view of an embodiment of the apparatus used in the present invention;

Fig. 2 is a graph showing influences of soaking time and heating temperature on elongation;

Fig. 3 is a graph showing an influence of annealing temperature on r-value;

Fig. 4a is a diagram showing a heat cycle in the conventional continuous annealing apparatus;

Fig. 4b is a schematic view of the conventional continuous annealing apparatus;

Fig. 5 is a diagram showing heat cycle in the conventional annealing; and

Fig. 6 is a graph showing changes of properties when the travelling speed of the decoiled sheet is changed in the course of the continuous annealing.

The apparatus used in the present invention is largely different from the conventional apparatus shown in Fig. 4 in that the overaging zone is omitted and a temperature regulating zone is provided instead of the soaking zone. According to the present invention, it is intended to positively control the temperature while heating the steel sheet in the temperature regulating zone, so that the tempera-

ture regulating zone is required to have a fairly large heating capacity and a good response. In this case, the heating capacity per unit length of steel sheet in the temperature regulating zone is necessary to be larger than that of the heating zone or preheating zone. Furthermore it is essential that the temperature accuracy is at least ±10 °C even at a non-steady portion. For this purpose, a means for directly blowing a high-temperature non-oxidizing gas to the steel sheet, a means for directly heating the steel sheet by application of current, a means for using a radiant tube at a temperature higher than that usually used and so on are adopted to the temperature regulating zone. Further the temperature regulating zone has the function of correcting the control of mechanical properties and change of components by the annealing temperature, or the function of correcting the temperature of the steel sheet by the sheet travelling speed or change of sheet gauge, whereby the intended maximum temperature of steel sheet can be controlled with good precision. Moreover, the feature that the steel sheet is partially cooled in the course of the heating is effective for achieving the object of the invention.

After the steel sheet is heated to the intended maximum temperature in the temperature regulating zone as shown in symbols (i), (ii), (iii) or (iv) of Fig. 1a, it is rapidly cooled without passing through the overaging zone. In this case, a gas jet cooling, roll cooling or a combination thereof is suitable as a cooling means. Moreover, consideration of the mechanical properties hardly restricts the cooling rate and it may be determined mainly by the circumstances of the installation and its operation since the special treatment of rapid cooling-overaging is not required.

The reason why the steel sheet is rapidly cooled after the temperature reaches the intended ultimate temperature is due to the fact that improvements in mechanical properties are no longer expected when the soaking time becomes long as shown in Fig. 2 and conversely risks such as abnormal growth of crystal grains, degradation of properties and frequency in occurrence of operational troubles such as heat buckle, pick-up and so on increase.

In order to further enhance the heat efficiency, a preliminary heating zone may be arranged before the heating zone, or the heating zone may be divided into plural furnace bodies, which do not injure the effect of the invention. Further, the feature that the cooling zone is divided into two or more cooling furnace bodies for enhancing the cooling efficiency also does not injure the effect of the invention.

According to the invention, when using an extra-low carbon steel as a sheet material, various mechanical properties can be obtained from the same sheet material or the mechanical properties of a non-steady portion in the sheet material can be made uniform by accurately controlling only the heat annealing temperature in the continuous annealing treatment. In particular, the invention can advantageously realize the following facts:

(1) Steel sheet having very uniform mechanical properties can be obtained by controlling the heating temperature in accordance with any change of chemical composition;

(2) The degradation of mechanical properties in the outer and inner portions of hot rolled coils can be compensated for by local high-temperature heating;

(3) The temperature change of steel sheet due to the change of sheet gauge or sheet travelling speed can be prevented; and

(4) The formation of products having given mechanical properties from the same material. For example, when the sheet travelling speed of the extra-low carbon steel (C:0.0015%, Ti:0.055%) is changed in the course of the annealing as shown in Fig. 6, the r-value, hot coiling temperature and heating temperature can uniformly be maintained over substantially the whole length of the sheet.

Example

In a conventional continuous annealing apparatus, having a throughput such that the product of the sheet gauge (mm) and the sheet travelling speed (mpm) is about 400, the heating capacity of the heating zone (burner capacity) was about 40×10^6 kcal/hr. On the other hand, the soaking zone only had a heating capacity compensating for the dissipation of heat from the furnace body and its burner capacity was a tenth of that of the heating zone.

On the contrary, the heating capacity of the temperature regulating zone according to the present invention is at least twice that of a conventional soaking zone by using a super-high temperature radiant tube having a furnace temperature above 1100 °C together with a high temperature gas jet, which corresponds to $10 \sim 20 \times 10^6$ kcal/hr. In particular, when considering the heating capacity per unit length of steel sheet, the heating capacity of the temperature regulating zone is more than that of the heating zone.

As mentioned above, according to the present invention, the intended heating temperature of the deep drawable extra-low carbon steel can be accurately controlled to obtain a steel sheet having no variation in mechanical properties. Further, the heat efficiency can be enhanced by arranging the preliminary heating zone before the heating zone.

These features of the present invention result in very marked improvements.

Claims

1. A method of continuously annealing sheet material of extra-low carbon steel for deep drawing comprising the steps of heating and cooling the sheet material wherein the sheet material is heated from room temperature to a temperature above its recrystallisation temperature, the temperature of the heated sheet is regulated by rapid heating to a desired maximum temperature, said maximum temperature being determined by the steel composition, within an accuracy of ±10 °C, rapidly cooled without soaking after reaching said maximum temperature and the rapidly-cooled sheet material is finally cooled to room temperature.

2. A method as claimed in claim 1 wherein said steel is partially cooled in the course of the heating to regulate the desired maximum temperature.

Patentansprüche

1. Verfahren zum kontinuierlichen Tempern von Blechmaterial aus tiefziehfähigem Stahl mit besonders niedrigem Kohlenstoffgehalt, umfassend die Schritte: Erhitzen und Kühlen des Blechmaterials, wobei das Blechmaterial von Raumtemperatur auf eine Temperatur über dessen Rekristallisationstemperatur erwärmt wird, die Temperatur des erwärmten Bleches durch schnelles Erhitzen auf eine gewünschte Höchsttemperatur eingestellt wird, die Höchsttemperatur sich aus der Stahlzusammensetzung ergibt, und zwar mit einer Genauigkeit von +/- 10 °C, und nachdem die Höchsttemperatur erreicht wurde, das rasche Kühlen ohne Benässen erfolgt, und schließlich das schnell gekühlte Blechmaterial auf Raumtemperatur gekühlt wird.

2. Verfahren nach Anspruch 1, wobei der Stahl unter dem Erhitzen partiell gekühlt wird, um die gewünschte Höchsttemperatur einzustellen.

Revendications

1. Procédé pour recuire en continu un matériau en feuille d'acier en teneur extra-basse en carbone pour emboutissage profond, comprenant les étapes qui consistent à chauffer et refroidir le matériau en feuille, caractérisé en ce que le matériau en feuille est porté de la température ambiante à une température supérieure à sa température de recristallisation, en ce que la température de la feuille chauffée est régulée par chauffage rapide à une température maximale désirée, ladite température maximale étant déterminée par la composition de l'acier, avec une précision de ± 10 °C, en ce qu'elle est ensuite rapidement refroidie sans maintien en température après avoir atteint ladite température maximale et en ce que le matériau en feuille rapidement refroidi est enfin refroidi à température ambiante.

2. Procédé selon la revendication 1, caractérisé en ce que ledit acier est partiellement refroidi lors de la phase de chauffage pour réguler la température maximale désirée.

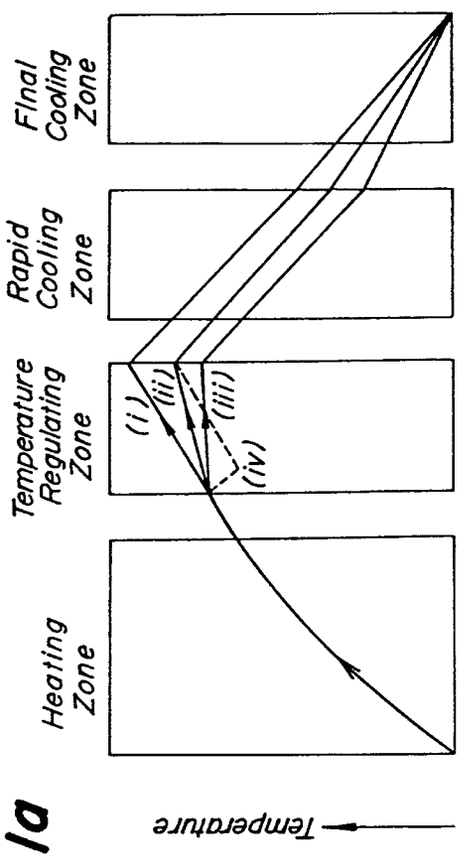

Heating Zone
Temperature Regulating Zone
Rapid Cooling Zone
Final Cooling Zone
(i)
(ii)
(iii)
(iv)
Temperature

FIG. 1a

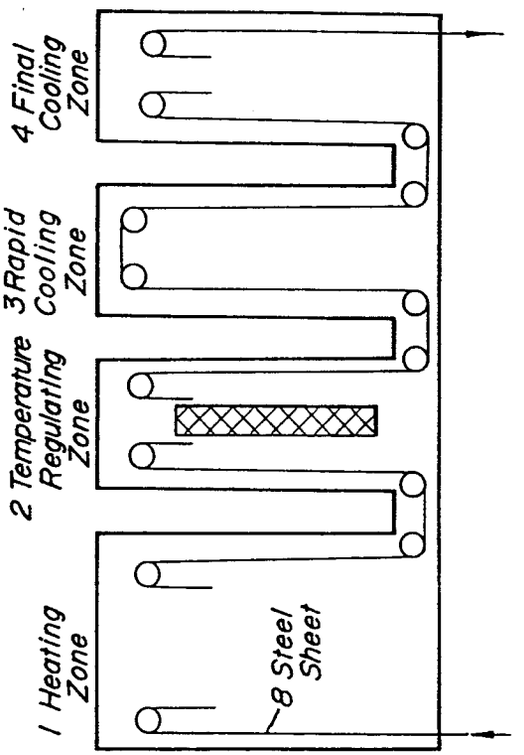

1 Heating Zone
2 Temperature Regulating Zone
3 Rapid Cooling Zone
4 Final Cooling Zone
8 Steel Sheet

FIG. 1b

FIG_2

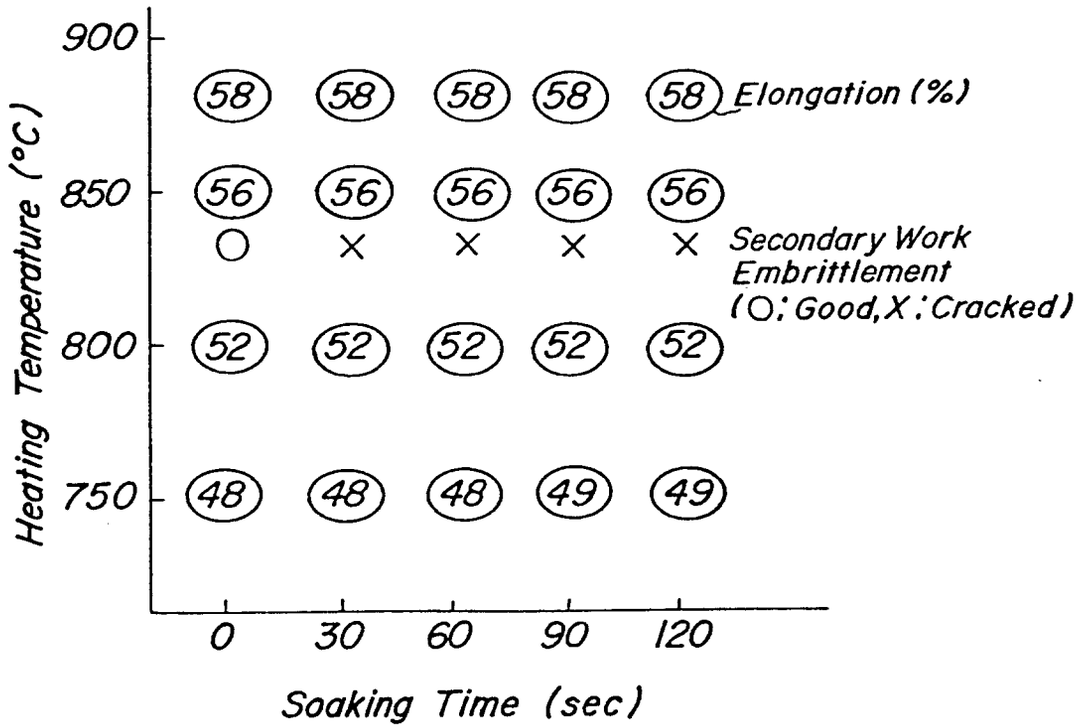

900
850
800
750
Heating Temperature (°C)
58 58 58 58 58 Elongation (%)
56 56 56 56 56
○ × × × ×
Secondary Work Embrittlement (○: Good, X: Cracked)
52 52 52 52 52
48 48 48 49 49
0 30 60 90 120
Soaking Time (sec)

FIG_3

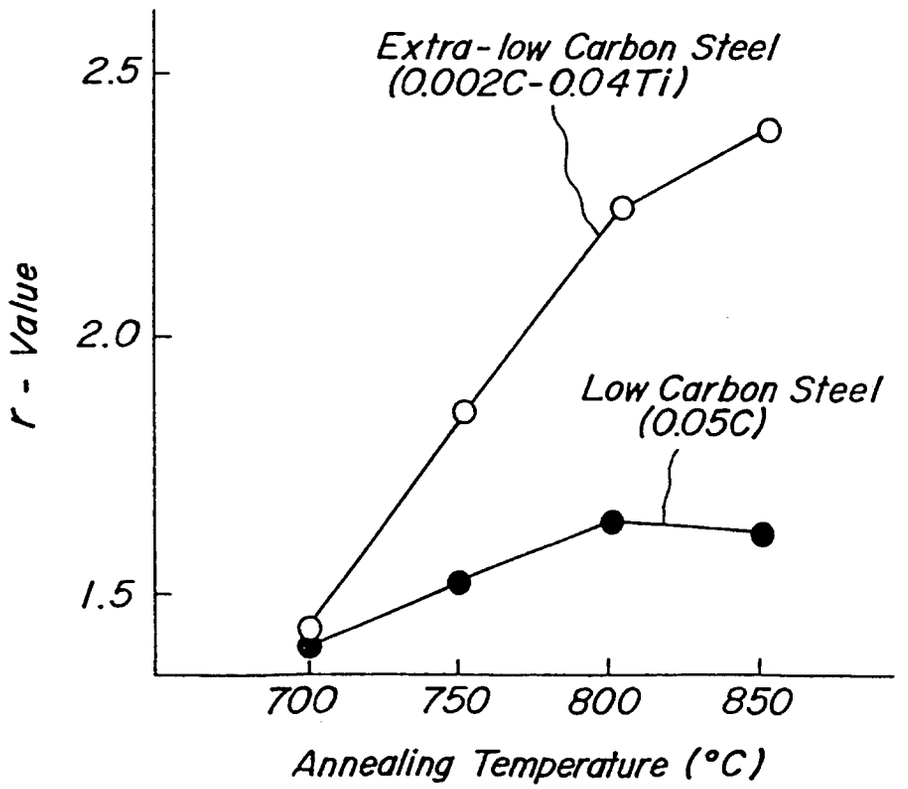

2.5
2.0
1.5
r - Value
Extra-low Carbon Steel (0.002C-0.04Ti)
Low Carbon Steel (0.05C)
700 750 800 850
Annealing Temperature (°C)

FIG.4a PRIOR ART

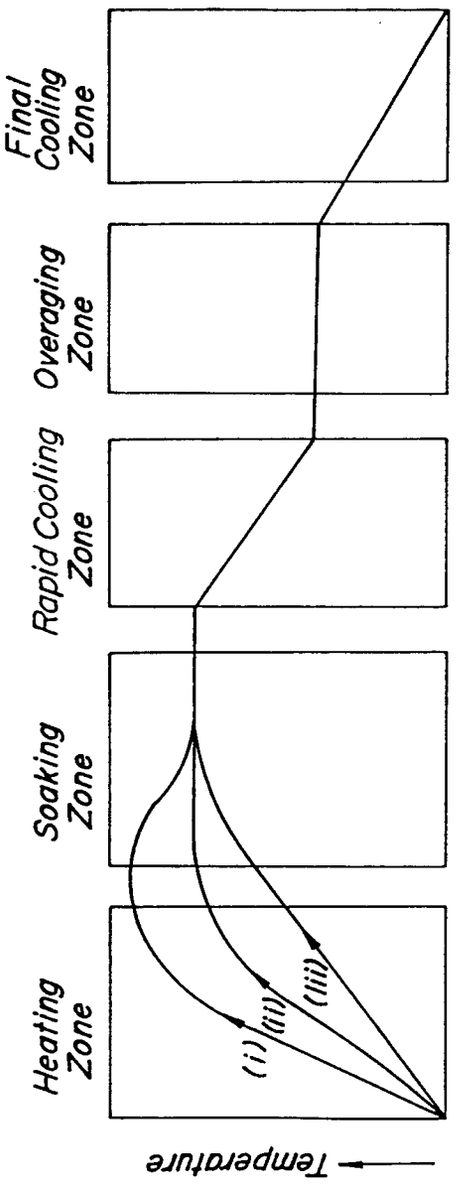


FIG.4b PRIOR ART

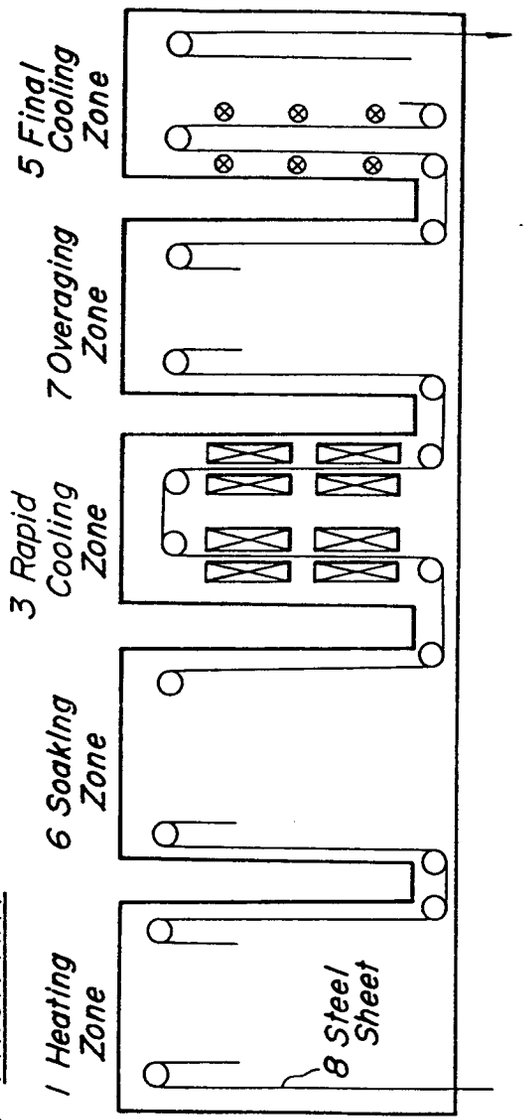


FIG_5

PRIOR ART

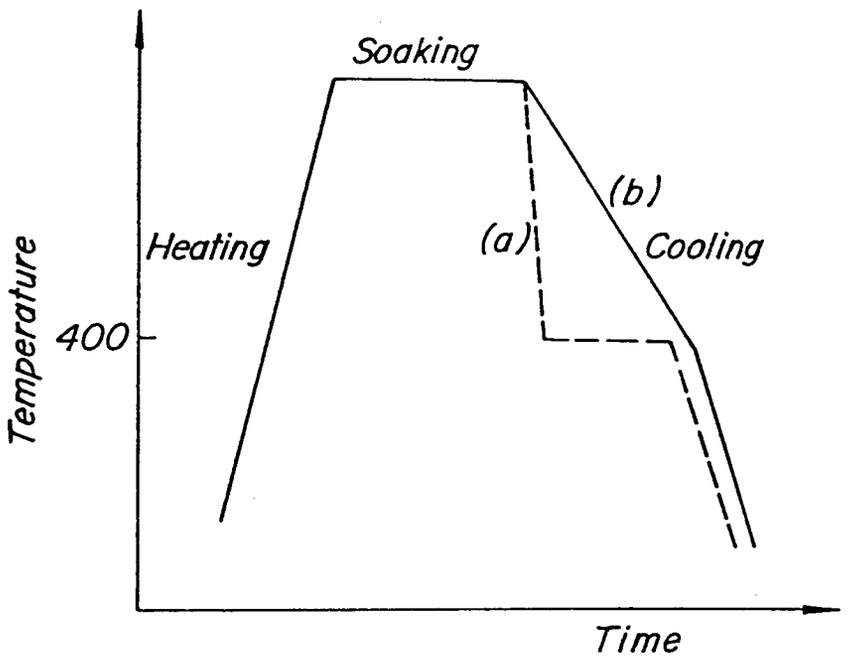
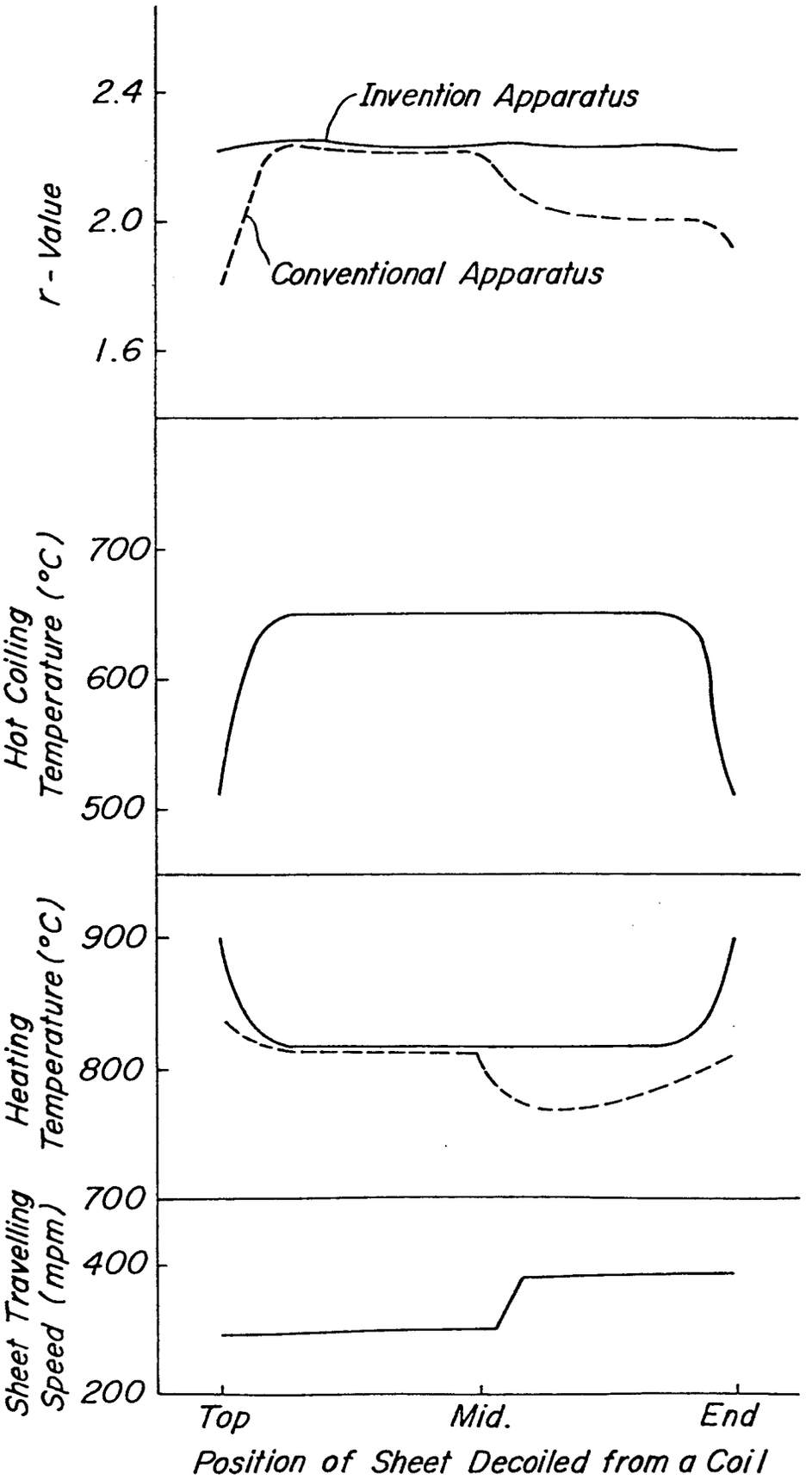


FIG_6


2.4
2.0
1.6
r - Value
Invention Apparatus
Conventional Apparatus
700
600
500
Hot Coiling Temperature (°C)
900
800
Heating Temperature (°C)
700
400
200
Sheet Travelling Speed (mpm)
Top
Mid.
End
Position of Sheet Decoiled from a Coil