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(54) **Process for terminating anode effects during the production of aluminum.**

(57) The invention relates to a method of quenching (or terminating) anode effects which arise during the production of aluminum by fused salt electrolysis in a cell containing a molten electrolyte including alumina and a plurality of carbon-containing anodes dipping into the electrolyte. The method involves dividing at least 25% of the total number of anodes into groups of adjacent anodes located at different positions longitudinally of the cell, moving at least one of the groups upwardly and the remainder downwardly to "pump" the cell, the upwardly moving groups alternating with the downwardly moving groups in the longitudinal direction of the cell, and adding alumina to the cell. The anodes are returned to their original operating positions and, if the anode effect has not been quenched, are again moved in the same or opposite pattern. High quenching efficiency can be achieved by the method of the invention with minimal variations in the surface level of the molten electrolyte.

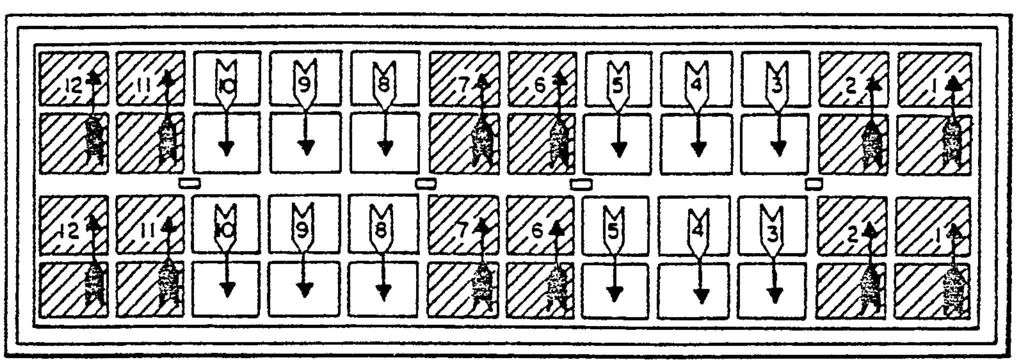

FIG. I

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Process for terminating anode effects during the production of aluminum

This invention relates to a process for quenching or terminating so-called "anode effects" which occur when aluminum is produced from alumina by electrolysis.

The electrolytic reduction of alumina is normally carried out in a Hall-Heroult cell which comprises an elongated shallow container lined with a conductive material., such as carbon, used to form a cathode. The container holds a molten electrolyte, normally cryolite containing about 2-6% by weight of dissolved alumina, and a number of carbon anodes dip into the electrolyte from above. When direct current is passed through the cell, molten aluminum is formed and descends to the bottom of the cell where it forms a pool acting as the cell cathode. Oxygen gas is also liberated and this tends to oxidize the carbon anodes and thereby forms carbon dioxide and/or carbon monoxide. Since the anodes are gradually consumed and since a generally constant anode-cathode spacing must be maintained, lifting apparatus is provided above the cell to enable the anodes to be raised, lowered and eventually replaced.

In one type of cell, namely the Soderberg cell, only one large carbon anode is provided which almost completely covers the upper surface of the cell. In another type of cell, namely the prebake cell, a large number of smaller anodes are provided and arranged in longitudinal and transverse rows referred to as the anode panel. Normally there are two longitudinal rows of anodes arranged symmetrically on each side of the longitudinal cell axis. The spacing between the two rows along the cell axis is referred to as the centre channel. The number of tranverse rows is variable according to the size of the cell, but there are normally up to fifteen, usually 8 to 15, such rows, all of which are normally equally spaced from each other.

During operation of such electrolytic cells, the electrolyte is held at a temperature in the range of 950-980 °C in order to keep the electrolyte and aluminum in a molten state. The temperature is lower at the electrolyte surface which solidifies to form a solid crust. The electrolyte may also solidify adjacent to the cell walls where the temperature also tends to be lower. As electrolysis proceeds, the concentration of alumina in the electrolyte falls and more is added by periodically breaking the crust in limited places and adding the alumina from above.

The concentration of alumina declines most rapidly in the region of the electrolyte immediately beneath the anodes. When the concentration in these regions falls to about 2% by weight or less, the so-called anode effect is observed. This manifests itself as a high voltage (up to around 40 volts) and the appearance of fluorocarbons in the anode gas. The anode effect is explained in detail in such publications as Aluminum Electrolysis Fundamentals of the Hall-Heroult Process, 2nd Edition, by K. Grjotheim et al, Aluminum Verlag, 1982, pp 264-283; and Aluminum Smelter Technology, 2nd Edition, by K. Grjotheim and B. J. Welch, Aluminium Verlag, pp 116-118, the disclosures of which are incorporated herein by reference. The anode effect is disadvantageous for a number of well-known reasons explained in the above publications and attempts are usually made to terminate or "quench" this effect as quickly as possible.

Quenching is conventionally carried out by (a) breaking the crust and adding alumina to the cell, and (b) sweeping the gas from beneath the affected anodes by vigorous stirring of the electrolyte, which also helps to distribute the alumina from the feeding points into the whole volume of the cell. Wooden poles or gas lances were traditionally used to stir the electrolyte under the anodes, but attempts have been made in the last few years to develop more effective and automated techniques. For example, Canadian Patent 1,148,892 issued on June 28, 1983 to Saksvikrønning et al. (which relates to a Soderberg type of cell) discloses the idea of tilting and rocking the single anode to sweep away the unwanted gases and to mix the cell contents. However, this is not really suitable for use in prebake cells because the numerous anodes of the latter type of cell are spaced too closely for individual tilting and because complex equipment would be required.

In prebake cells, "pumping" has been carried out by moving the whole anode panel downwards by a certain distance and later moving it up again. The disadvantage of this method is that there is a considerable raising of the electrolyte level when the anode panel moves down, leading to crust penetration by the molten electrolyte and to spillage. In order to avoid this, cathodes with deep cavities had to be designed, leading to increased capital costs. The quenching efficiency of this procedure has usually been in the range of 70-90% (number of anode effects successfully quenched relative to the total number arising during operation of the cell) depending largely on the maximum permitted downward travel of the anode panel. Higher efficiencies in the range of 90-95% can only be obtained in cells having deep cathode cavities.

Our prior U.S. Patent No. 4,414,070 to Spence which issued on November 8, 1983 discloses a quenching procedure which is suitable for prebake cells and which can be carried out without the need for deep cathode cavities. Apparatus is disclosed which permits the anodes to be raised or lowered individually and the patent teaches that one group of anodes can be raised while another group is lowered in order to pump the cell contents without affecting the surface level of the molten electrolyte. Spence suggests that all anodes on one longitudinal side of the cell could be raised while all anodes on the other longitudinal side could be lowered (pivoting around the longitudinal axis of the cell), or that all anodes at one end of the cell could be raised while all those at the opposite side could be lowered (pivoting around the transverse axis of the cell), or further that one quarter of the anodes in one corner could be raised while those in the diagonally opposed quarter could be lowered (a so-called "kitty corner" action). While these procedures are effective, the efficiency with which anode effect quenching can be achieved is not as high as we would have hoped and is usually in the range of 80-90%.

Consequently, an object of the present invention is to provide a process for quenching or terminating the anode effect which can be carried out with improved efficiency.

Further study of anode movements using the type of equipment disclosed by Spence has shown that quenching efficiencies can be remarkably improved if a number of small groups of anodes interdispersed in the longitudinal direction of the cell are moved in opposite directions, and the present invention is based on this finding.

According to the invention there is provided a method of terminating an anode effect occurring during the production of aluminum in an electrolytic cell containing a molten electrolyte including alumina and having a plurality of carbon-containing anodes arranged in at least two longitudinal rows and at least three transverse rows forming an anode panel, said method comprising: adding alumina to the electrolyte; dividing at least 25% of the total number of anodes into groups of adjacent anodes located at different positions in the longitudinal direction of the cell, each group containing at least two anodes but no more than one third of the total number of anodes; initially moving at least one of said groups in a first vertical direction from an original operating position, moving the remaining groups in an opposite vertical direction from an original operating position, wherein said group(s) moved in said first vertical direction and said group(s) moved in said opposite vertical direction alternate with each other in the longitudinal direction of the cell; returning said anodes to their original operating positions; and repeating or reversing said movements of the anode groups until said anode effect is quenched.

The pattern of movement required by the present invention ensures that only a relatively small number of adjacent anodes forming a group moves in the same direction at the same time within a particular area of the cell while anodes neighboring the group either do not move at all or move in the opposite direction. This has the advantage that, breakage of the crust is minimized since widespread up and down forces are not exerted on the crust. On the other hand, the invention ensures that the pumping action is maximized because anode movement takes place at various positions along the cell and the opposed direction of movement of longitudinally neighboring groups causes efficient mixing of the added alumina with the electrolyte. There may also be some electromagnetic stirring of the cell contents as a result of the anode movements.

The invention, at least in its preferred forms, can provide a quenching efficiency of up to 99% and can quench anode effects in short periods of time, e.g. less than one minute. Other advantages are that there is a low loss of energy (e.g. 10-20 millivolts equivalent per anode effect day), and variations in the bath level can be minimized or eliminated altogether.

The arrangement of the anode groups and the type of anode movements contemplated according to the present invention are exemplified as follows. Each group must contain at least two adjacent anodes and preferably contains no more than six adjacent anodes. The adjacent anodes of each group preferably form one or more entire transverse rows although this is not essential. When the groups do consist of entire transverse rows, adjacent anodes on each side of the longitudinal centreline of the cell always move in the same direction and this tends to minimize breakage of the crust over the centre channel, which breakage can result in pieces of the crust falling into the electrolyte causing sludging of the cathode floor and an unnecessary loss of heat.

The alternating arrangement of the groups means that each group of anodes which initially moves up is positioned between two groups that initially move down, and vice versa, except at the extreme ends of the cell. Of course, when less than 100% of the anodes are caused to move, then immobile anodes may separate "up" groups from "down" groups, at least in some parts of the cell.

While as few as 25% of the anodes may be caused to move, either up or down, preferably at least 40% are caused to move and, most desirably, all of the anodes are caused to move.

The groups of anodes may be moved simultaneously or sequentially in a continuous or stepwise manner. The number of anodes raised at a given time may equal the number of anodes lowered, with the distance of travel being the same, so that there is no change of electrolyte level in the cell. This, however, is by no means essential because small variations in the electrolyte level, either up or down, can normally be tolerated and may even be beneficial in some cases. The pattern of anode movement clearly should not be such as to cause unacceptable degrees of movement of the electrolyte level. When the anodes are moved in such a way as to cause quite large changes in the electrolyte level, the group(s) of anodes designated to move upwardly should preferably be moved first in order to prevent electrolyte overflow.

All of the "up" groups may be raised at the same time and simultaneously or subsequently all of the "down" groups may be lowered. Alternatively, the different "up" groups may be raised at different times (e.g. producing a "ripple" effect along the cell) and the different "down" groups may be lowered in the same way.

As noted above, the anodes may be moved either up or down continuously or in steps (i.e. short rapid movements with pauses between them). If the movement is stepwise, the stepwise motions of all of the anodes may be simultaneous or alternatively may be completely independent.

As will be well understood by persons skilled in the art, there is a maximum distance of travel, both up and down, beyond which the anodes should not be moved. The maximum down travel might be beyond the short-out point because shorting may be desired in some cases (e.g. it is a radical way to quench an anode effect that does not respond to the method of the invention). On the other hand, the upward movement should not remove the anode from the electrolyte and, particularly, should not let the anode break free of the crust. This causes a greater amount of current to flow through the other anodes and can result in catastrophic heating and even explosion.

After the anodes have been moved through their maximum distance of travel in either the up or down directions, the anodes are returned to their original operating positions (i.e. their positions prior to the appearance of the anode effect). The anodes may be returned with the same, but opposite, pattern of motion and at the same speed that they were moved away from the original operating position (e.g. if they were initially moved in a stepwise fashion, they may be returned in a stepwise fashion). Alternatively, the anodes may be returned with a different pattern of motion and/or at a different speed.

If the anode effect has not been quenched upon the completion of one cycle of anode motion, one or more other cycles may be carried out until quenching results. The pattern of motion of the anodes in the subsequent cycle(s) may be the same as, or opposite to, the pattern in the first cycle. That is, the "up" anodes and the "down" anodes of the first cycle may move in the same, or alternatively in the opposite, initial directions.

Although the pattern of motion of the electrodes is often reversible as described above (i.e. the groups which initially move upwardly from the original operating position, may instead be moved downwardly and vice versa), it may sometimes be desirable to ensure that the electrodes at the extreme longitudinal ends of the cell never move downwardly from the original operation position. This is because the electrolyte may "freeze" adjacent to the end walls and the resulting solid electrolyte may extend partially beneath the end electrodes so that downward movement of the electrodes might result in damage either to the electrodes themselves or to the electrode supporting structure.

The alumina may be added to the cell in the conventional manner, e.g. by breaking the crust (normally at the centreline of the cell) and adding the alumina to the liquid electrolyte. The pumping effect of the anodes quickly distributes the added alumina throughout the cell. The quantity of alumina added may again be the amount conventionally used. The alumina addition does not have to be simultaneous with the commencement of the anode movement. For example, the alumina may be added shortly before the anodes are moved or alternatively there may be a delay of 10 to 20 seconds, or even more, before the alumina is added. Naturally, the sooner the alumina is added, the sooner quenching is likely to begin.

The speed with which the anodes are moved is not particularly critical to the success of the invention. A slow speed requires more time for the quenching effect to take place and therefore faster speeds are preferable. However, the movement should not be so fast as to produce damage to the crust or spillage of the electrolyte.

The method of the invention requires an anode supporting structure capable of moving different groups of anodes in different directions either simultaneously or sequentially. The apparatus described in our U.S. Patent 4,414,070 to Spence, the disclosure of which is incorporated herein by reference, is suitable for this purpose because it provides individual up and down movement of the anodes for all of the anodes of the anode panel. However, a less complex apparatus could physically interconnect the electrodes of individual groups or of all the "up" groups and all the "down" groups for simultaneous movement.

The pattern of anode movement, as well as the maximum distances of anode travel may be computer controlled, which is particularly easy to arrange when using the apparatus described in the patent referred to above.

Preferred embodiments of the invention are described in more detail below with reference to the accompanying drawings, in which:

Figs. 1 to 3 are schematic representations of electrolytic cells in plan view showing anode blocks and indicating their initial directions of movement by means of arrows and shading.

In the embodiment shown in Fig. 1, the anodes of a cell having two longitudinal rows and 12 transverse rows are divided into groups consisting of four and six anodes (the drawing shows individual anode blocks, two of which in the transverse direction form a single anode as will be appreciated by persons skilled in the art). When an anode effect develops, the groups consisting of four anodes are initially moved upwardly from their original operating positions and the groups consisting of six anodes are initially moved downwardly, as shown. Upon reaching their maximum distance of travel in the up or down direction, the direction of movement is reversed and the anodes are returned to their original operating positions. During this procedure, alumina is added to the cell through a hole made in the crust along the centre channel. If the anode effect has not been satisfactorily quenched by the indicated anode motion, the procedure may be repeated, with the anodes moving in the same initial directions indicated in the Figure or in the opposite directions, and the anodes again returned to their original operating positions. The procedure may be repeated any number of times until the anode effect is suitably quenched.

The anodes of the three "up" groups (i.e. those in rows 1-2, 6-7 and 11-12) may all be moved simultaneously or they may alternatively be moved sequentially (to produce a "ripple" effect along the cell). The movement may be continuous or step wise, i.e. in small increments. The same is true of the movement of the "down" groups (i.e. the anodes in rows 3-4-5 and 8-9-10). The "up" and "down" groups may be moved simultaneously or sequentially.

Preferably, the number of anodes moving up equals the number of anodes moving down at any particular time so that the electrolyte level remains the same as it was when the electrodes were in the original positions. However, as indicated above, small variations in the electrolyte level are permissible, and so virtually any continuous or sequential anode movement pattern can be adopted, provided the anodes initially move in the directions indicated.

The pattern shown in Fig. 1 can be reversed, i.e. the "up" groups can be made "down" groups and *vice versa*.

Fig. 2 shows an alternative movement pattern for the cell of Fig. 1 and Fig. 3 shows a preferred movement pattern for a cell having 9 transverse rows. Again, the movement can be continuous or stepwise, simultaneous or sequential and the direction of initial movement can be reversed.

The effectiveness of the present invention is demonstrated by the following Example.

Example

A Hall-Heroult cell (Apex cell) having two longitudinal rows of anodes and twelve transverse rows was equipped with a superstructure capable of producing individual anode movements, and the cell was operated in the normal way until anode effects developed. Attempts were then made to quench the anode effects by particular anode movement patterns coupled with the addition of alumina.

The results are shown in Table 1 below from which it can be seen that the results achieved by the present invention are remarkably superior to the results obtained by other procedures.

TABLE I

Plant results for automatic anode effect quenching						
Method	Total number of anode effects	Quenching success		Average anode effect duration (s)	Average duration of high voltage (s)	Average contribution of anode effects to equivalent voltage per pot-day* (mV)
		No.	%			
Descent of the whole anode panel	389	295	75.8	402	180	28
Descent of anodes on one side with ascent of anodes on the other side	135	113	83.8	246	84	23
According to this invention, pattern of Figure 1	392	389	99.3	120	60	13

* Days without the anode effect are not included in the average.

When all the anodes on one side of the cell were moved downwards and all the anodes on the other side of the cell were moved upwards, besides the low quenching efficiency, another problem was present: the crust in the centre channel fell into the bath in 17% of the quenching attempts.

Claims

1. A method of terminating an anode effect occurring during the production of aluminum in an electrolytic cell containing a molten electrolyte including alumina and having a plurality of carbon-containing anodes arranged in at least two longitudinal rows and at least three transverse rows forming an anode panel, by adding alumina to the electrolyte and raising and lowering different ones of said anodes to cause distribution of the added alumina in said electrolyte, characterized in that
at least 25% of the total number of anodes is divided into groups of adjacent anodes located at different positions in the longitudinal direction of the cell, each group containing at least two anodes but no more than one third of the total number of anodes;
at least one of said groups is initially moved in a first vertical direction from an original operating position;
the remaining groups are moved in an opposite vertical direction from an original operating position, wherein said group(s) moved in said first vertical direction and said group(s) moved in said opposite vertical direction alternate with each other in the longitudinal direction of the cell;
said anodes are returned to their original operating positions; and
said movements are repeated or reversed until said anode effect is quenched.

2. A method according to Claim 1 characterized in that each anode group contains no more than six electrodes.

3. A method according to Claim 1 characterized in that each anode group contains no more than four electrodes.

4. A method according to Claim 1, Claim 2 or Claim 3 characterized in that said groups forms at least 40% of the total number of anodes.

5. A method according to any preceding claim characterized in that all of said anodes are divided into said groups.

6. A method according to any preceding claim characterized in that all of said groups are moved simultaneously.

7. A method according to any one of Claims 1 - 5 characterized in that said anode groups are moved sequentially.

8. A method according to any preceding claim characterized in that said alumina is added substantially simultaneously with said initial movement of said groups.

9. A method according to any one of Claims 1 to 7 characterized in that said alumina is added subsequently to said initial movement of said groups.

10. A method according to claim 1, claim 2 or claim 3 characterized in that there is an even number of transverse anode rows, said anodes are divided into groups containing 4 anodes and groups containing 6 anodes, said groups alternating in the longitudinal direction of the cell, and wherein all of said groups containing 4 anodes are initially moved in said first direction and all of said groups containing 6 anodes are moved in said opposite direction.

11. A method according to claim 1, claim 2 or claim 3 characterized in that there is an even number of transverse anode rows and said anodes are divided into groups of two at extreme longitudinal ends of the cell and groups of four between said longitudinal ends, and wherein said groups of two and alternate groups of four are initially moved in said first direction and the remaining groups of four are initially moved in said second direction.

12. A method according to claim 1, claim 2 or claim 3 characterized in that there is an odd number of transverse anode rows and the anodes are divided into groups consisting of single anode rows and wherein groups at extreme ends of the cell and alternate groups therebetween are initially moved in said first direction, and the remaining groups are initially moved in said second direction.

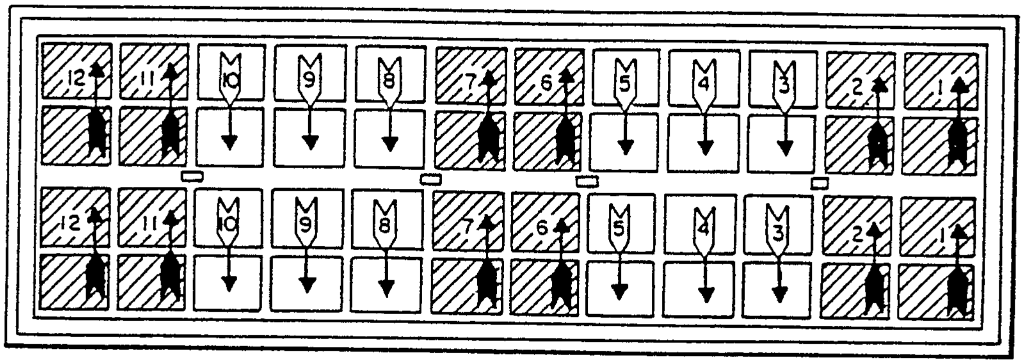

FIG. 1

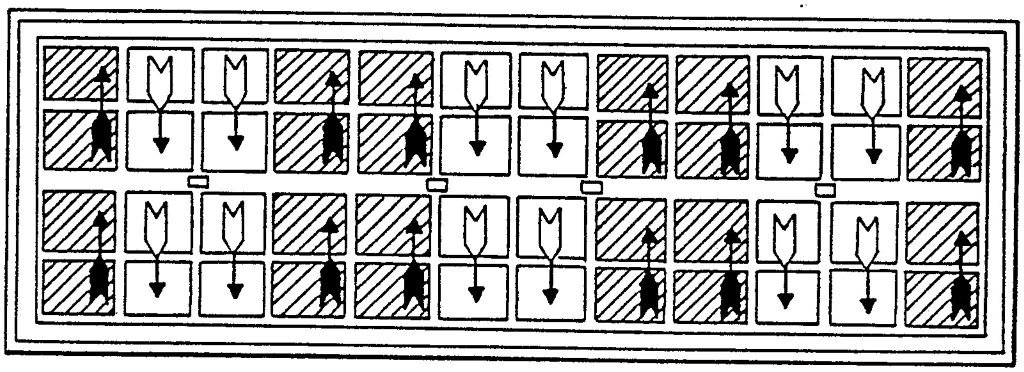

FIG. 2

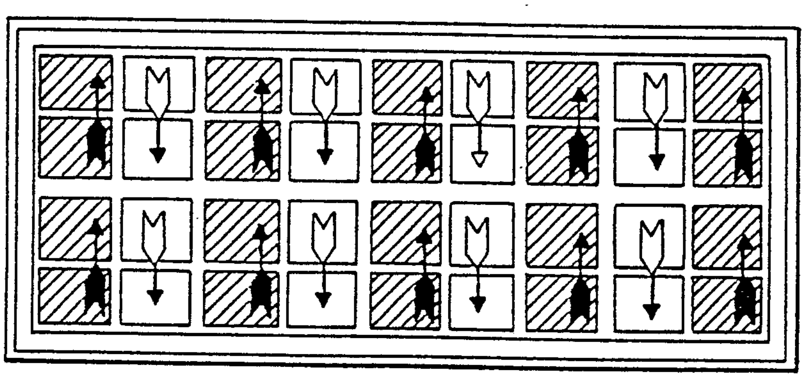

FIG. 3

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EUROPEAN SEARCH REPORT

Application number EP 89307626.5

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)
A	US - A - 4 039 419 (BUSE) * Column 5, lines 29-39 *	1	C 25 C 3/12 C 25 C 3/20
A	FR - A - 2 083 362 (INSTITUTUL POLITEHNIC) * Claims 1,4 *	1	
D,A	EP - A1 - 0 086 593 (ALCAN) * Abstract *	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl 4)
			C 25 C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	07-11-1989	LUX

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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E : earlier patent document, but published on, or after the filing date
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