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(71) Applicant: **ALLUMINIO ITALIA S.p.A.**
Piazza Marconi No. 25
I-00144 Roma-Eur(IT)

(72) Inventor: **Solinas, Giancarlo c/o ALLUMINIO ITALIA S.p.A.**
Piazza Marconi, 25
I-00144 Roma-Eur(IT)

(74) Representative: **Ferri, Antonio**
c/o BREVETTI EUROPA S.r.l. Piazza Bernini 6
I-20133 Milano(IT)

(54) Method and apparatus for electric current supply of pots for electrolytic production of metals, particularly aluminium.

(57) Method and relevant apparatus for the electric current supply to pots for the electrolytic production of metals, particularly aluminium, arranged in side-by-side or end-to-end relationship and electrically connected in series, consisting in carrying most of the electric current in the circuit of said series of pots by means of conductors all having the same cross-section and being always combined, in the individual circuit sections, in couples of the same length, all said couples of conductors being furthermore symmetrically positioned with respect to the transverse median vertical plane and/or to the longitudinal median vertical plane of the single pots in the series.

By the present invention, and in compliance with the objects thereof, a high compensation and the total symmetrization (with respect to the vertical median planes) of the components of the induction magnetic field in the single pots of the series and, by consequence, the minimization and the total symmetrization of the effects of the magnetic forces operating in the molten areas of said pots are achieved.

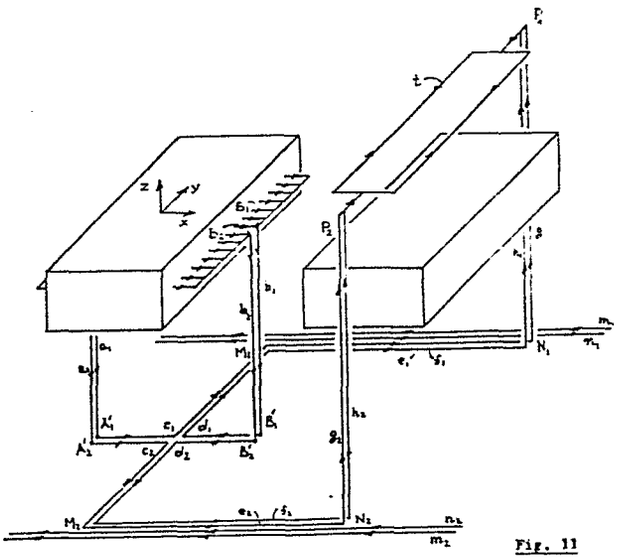

Fig. 11

EP 0 084 142 A2

Method and apparatus for electric current supply to pots for electrolytic production of metals, particularly aluminium

The present invention relates to a method and relevant apparatus for the electric current supply to pots for the electrolytic production of metals, in particular for the production of aluminium, said pots being connected in series and arranged transversally or longitudinally.

Background of the invention

As is known, aluminium is commercially produced in pots electrically connected in series by electrolytic reduction of alumina dissolved in molten cryolite, each of said pots essentially consisting of a rectangular crucible having the cathode (formed by joined carbon blocks which embody iron cathode bars) on the bottom, while the anodes (consisting of separate carbon blocks connected by iron yokes to aluminium anode rods) hang vertically over each pot and are immerged in the elctrolytic molten bath of cryolite-alumina. The aluminium produced by electrolysis deposits onto the cathode, under said molten bath.

The electrical connection in series is accomplished by connecting, by means of aluminium conductor bars, the cathode outputs of an upstream pot with the anode bus bar of the adjcining downstream pot, said upstream and downstream positions being referred - as is usually conventional - to the prevailing current direction in the pot-line.

Generally, in the plants for the electrolytic production of aluminium, the pots of the pot-line are arranged, from a geometrical point of view, on one or more parallel rows, and are oriented in each of such rows in a so-called end-to-end relationship, or in a so-called side-by-side relationship, depending on whether the long side of said pots is arranged parallelly or perpendicularly to the predominant direction of the current in the series.

Each of the two arrangements (end-to-end and side-by-side) exhibits own typical known advantages and drawbacks of various kind ,but for both said arrangements the electric current carried by whole conductor system (i.e.:the anodes,the molten electrolyte and metal,the cathodes and the outer bus bar system) generates magnetic fields of comparatively high intensity, which cause in the electrolysis bath as well as in the molten metal, due to the interaction with the current flowing through said fluids, forces of electromagnetic nature dissymetrically distributed.

Said magnetic fields and consequent forces (which are the more intense, the higher is the current intensity involved, being also known that at present the tendency of the technique is to construct pots operating at 150-200 kA and over) cause serious disturbances to the behaviour of the pots, with related detrimental effects on the technical-economical results of the electrolysis process.

More particularly, said disturbances and detrimental effects may be summarized as follows :

- Localized erosions in the frozen ring of electrolytic bath and in the side lining materials of the pots, with consequent non-homogeneous operation of the pots and possible damages to the pot iron shell, such erosions and damages leading of course to a shortening of the life of said pots. The above-mentioned drawbacks are imputable chiefly to the motions induced in the bath and in the metal by the electromagnetic forces (the forces acting on the two individual fluids being, furthermore, different as to magnitude and distribution), therefrom resulting extended horizontal vortexes asymmetrically arranged with respect to the median axes of the pots and characterized by high peripheral speeds;

- Forming of waves of comparatively considerable amplitude on the bath-metal interface surface, such waves causing local reductions of the current efficiency as well as occasional short-circuits between cathodic metal and anode, with consequent high power specific consumption. Said forming of waves (which is strictly connected with the vorticose motions mentioned hereinabove) is prevailingly due to the dynamic friction interaction between the two above-said fluids in motion, said interaction bringing about phenomena of local accumulation of the mass of molten metal with respect of the bath and vice-versa.

With a view to obviating the drawbacks and disturbances cited hereinbefore, several methods and apparatus have been proposed (such as, e.g., the ones described in U.S. patents 3 969 213 and

4 132 621), which however are generally complicated or such as not to satisfactorily reduce the effects of the abovesaid magnetic forces.

Summary of the invention

Thus, the object of this invention is to provide an improved method and a relevant apparatus for the electric current supply to pots for the electrolytic production of metals, in particular aluminium, capable of minimizing the detrimental effects of the magnetic forces acting on the electrolysis pots, said pots being electrically connected in series, and arranged side-by-side or end-to-end on one row or more rows.

This and still other objects, which will be more clearly apparent to those skilled in the art from the detailed description given hereinbelow, are achieved, according to the present invention, by a process consisting in carrying most of the current in the circuit of said pot line by means of conductors having all the same cross-section and being always associated, in each section of the circuit, in couples of equal length, all said couples of conductors being furthermore arranged symmetrically to the median vertical longitudinal and/or transverse plane of the single pots of the series, and being, the reverse bus bars to the rectifier station - they too divided into symmetrical pairs of equal length and cross-section - being positioned side by side, over the whole extension of the series, with the bus bars which direct-

ly connect each couple of succeeding pots.

The double symmetrical current paths so provided permit to obtain a high compensation and the total symmetrization (with respect to both median vertical planes of said pots) of the magnetic field components and, by consequence, a total symmetrization of the magnetic forces induced by the interaction of said magnetic field with the pot current.

Said symmetrization of forces, in itself extremely advantageous for the purposes of a uniform distribution in the pot of the effects of said forces, is coupled, due to the particular arrangements of the conductors adopted in the invention, to a marked difference in the behaviour and action of said forces in respect of the prior art, what results, on the whole, in a substantial decrease of the abovesaid undesired drawbacks and detrimental effects in the above-mentioned pots and relevant electrolytic process.

In fact, both the stress action on the side lining of the pot by the fluids in motion, and the "ondulation" of the bath-metal interface become practically homogeneous and are considerably reduced (in the four sectors into which each pot in question may be imagined to be divided by said two median vertical planes), the whole resulting in an excellent stability of the operation of said pots , in a sensible improvement of the current efficiency and in a substantial energy saving.

Brief description of the drawings

The invention, as schematically illustrated hereinbefore and the relevant advantages are described hereinafter more in detail, making reference to figures 1 to 11 for plants with side-by-side pots, and to figures 12 to 18 for plants with end-to-end pots.

Said figures schematically show some arrangements of the conductors intended for carrying the current in plants for the electrolytic production of metals, in particular aluminium, figures 1 to 3 and 12 to 14 referring to conventional arrangements, while figures 4 to 11 and 15 to 18 refer to arrangements according to the present invention. More particularly, with reference to the side-by-side pots :

- figure 1 shows the arrangement, in a plan view,of a pot line and relevant bus bar conductors in a known conventional plant, in which said line extends on two parallel rows;
- figure 2 shows more in detail a conventional supply scheme to a downstream pot C_V by the corresponding upstream pot C_M of the same row;
- figure 3 shows a simplified scheme relating to a conventional plant of the"mono-row"type in which, as the pots are arranged on a single row, the closing of the series circuit is secured by two independent reverse bus bars;
- figure 4 shows a simplified scheme concerning a plant with side-by-side arrangement according to the present invention, in which, by way of example, the pot-line

extends on two parallel rows;

- figure 5 shows a scheme of a type of arrangement of the conductor bus bars according to this invention and referred to as "cross symmetrical arrangement". (In this figure, like in the following figures 6 to 10 and 16-17, the bus bars lying underneath the bottom plane of the pots are indicated with dashed lines);
- figure 6 shows a variant of the arrangement of fig.5, referred to as "rhombus symmetrical arrangement";
- figure 7 shows a scheme of another type of arrangement of the conductor bus bars according to the present invention, referred to as " corridor symmetrical arrangement";
- figure 8 shows a variant of the arrangement of fig. 7, referred to as " hexagon symmetrical arrangement";
- figure 9 shows a scheme of another type of arrangement of the conductor bus bars according to the present invention, referred to as " rectangle symmetrical arrangement";
- figure 10 shows a scheme of still another arrangement of the conductor bus bars according to the present invention, referred to as "sheaf symmetrical arrangement;
- figure 11 shows, finally, - in axonometric projection - the whole electric circuit of the cross arrangement as per figure 5 (for the sake of illustrative completeness, the drawing shows also the series reverse bus bars).

Making now reference to the pots arranged in end-to-end relationship :

- figure 12 shows the arrangement, in a plan view, of a series of pots and relevant bus bars in a known conventional plant, in which said series extends on two parallel rows;
- figure 13 shows in greater detail a known conventional scheme of the supply to a downstream pot C_V by the corresponding upstream pot C_M, the two pots being positioned in the same row;
- figure 14 shows a simplified scheme relating to a known plant of the "mono-row" type in which, since the pots are arranged on a single row, the closing of the series circuit is secured by two independent reverse bus bars;
- figure 15 shows a simplified scheme concerning a plant with the end-to-end arrangement according to the invention in which, by way of example, the pot-line extends on two parallel rows;
- figure 16 shows a scheme of a type of arrangement of the conductor bus bars according to the present invention, referred to as "sheaf symmetrical arrangement";
- figure 17 shows a scheme of another type of arrangement of the conductor bus bars according to the present invention, referred to as "corridor symmetrical arrangement";
- figure 18 finally shows - in axonometric projection - the whole electric circuit of the corridor arrangement of figure 17 (for the sake of illustrative completeness, the drawing shows also the series reverse bus bars).

Detailed description of the invention

Referring to the above figures, there is completed hereinbelow the illustration of the known technique, and is provided, in comparison with said technique, a detailed description of the present invention.

As is known, the magnetic forces $\vec{F}$ which influence the behaviour of an electrolytic pot are generated by the interaction of the magnetic induction field $\vec{B}$ created by the currents flowing through the outer and inner conductors (in respect of the pot), with the current density field $\vec{J}$ existing inside the molten areas of the pot (more specifically : bath and metal) according to the vectorial relationship

$$\vec{F} = \vec{J} \times \vec{B}$$

wherein both $\vec{F}$ and $\vec{J}$ and $\vec{B}$ are intended in general to be functions of the point of observation, being such point referred - in the present case - to an orthogonal reference system having the center coinciding with the center of the cathode plane of the pot (metal bottom), the x axis directed as the general flow of the current in the potline, the y axis arranged at 90° counterclockwise and the z axis directed upwards.

At the design and assembling stages there is usually devised and carryed out a perfect geometrical-structural symmetry of the pot with respect to its two median vertical planes, such geometry and structure theoretically securing a symmetrical distribution of the current, and therefore of $\vec{J}$, inside the cavity containing the fluids (bath and metal).

A possible dissymmetry in the magnetic force field

$\vec{F}$ in said cavity is therefore substantially ascribable to field $\vec{B}$. Such dissymmetry is a consequence, in turn, of the dissymmetry of the outer conductor bus bar system of the pot, since the inner conductors (from the anode rod system to the cathode block) are usually symmetrically arranged.

In the conventional known plants for electrolytic production of aluminium there are two prevailing types of dissymmetry of the field $\vec{B}$: one is typical of the bi-row (or multi-row) plants and is due to the presence and consequent influence of a pot row in respect of the other row (adjoining row), since in said two rows the electric current carried by the bus bars flows in opposing directions,as is shown in figures 1 and 12.

The electric current which flows - with direction parallel to x - through the adjoining row causes in the pots of the other row a systematic unbalance of the field $\vec{B}$ with respect to the median vertical plane xz ("transversal plane" in the transversally arranged pots and "longitudinal plane" in the longitudinally arranged pots).

The second type of dissymmetry, as is shown in figures 2 and 13, is conversely due to the non-symmetrical arrangement of the conductor bus bars and of the currents with respect to the plane yz,i.e.to the median vertical plane of the single pot perpendicular to the direction of the current in the row ("longitudinal plane" for transversally arranged pots and "transversal plane" for longitudinally arranged pots), and causes an unbalance of field $\vec{B}$ between the upstream and the down

stream halves of the pot.

In the known mono-row pot-lines (as is shown in figures 3 and 14), the former of said two types of dissymmetry is not present.

The same may apply to the pot-lines (either mono-row or multi-row) according to the present invention, since (as figures 4 and 15 show) the effect of the adjoining row - which is actually only the effect caused by the conductor bus bars of such row which are parallel to x and carry the current from each pot to the succeeding one - is completely annulled by the presence of the reverse bus bars positioned side-by-side thereto. Therefore, for the purpose of eliminating the drawbacks and detrimental effects cited hereinabove, reference is to be made in the present case only to the second type of dissymmetry mentioned hereinabove.

In the connections between pots of the known conventional type (particular reference is to be made to figure 2 for the case of pots arranged side-by-side, and to figure 13 for the case of pots arranged end-to--end) it is apparent that the arrangement of the bus bars is remarkably dissymmetrical with respect to median vertical plane yz (namely between upstream and downstream).

Such dissymmetry concerns above all, and with serious effects in terms of the generated magnetic field, the direction of the current flowing in the bus bars parallel to x, said direction being oriented exclusively from upstream to downstream (and therefore being completely absent, for restoring the symmetry , any corres-

ponding bus bars directed from downstream to upstream).

Furthermore, although with different alternatives connected with different schemes of collecting the currents carried by the output cathode bars, the total current carried on the two sides of the row from the two sets of cathode bus bars parallely to the x direction is never constant , as is clearly apparent from the examples illustrated in the above-mentioned figures 2 and 13.

Turning now to the detailed description of the present invention - in the form of preferred but not exclusive embodiments thereof - particular reference is made to figures 5 through 11 (with greater detail in figure 11) for pots arranged side-by-side and to figures 16 through 18 (with greater detail in figure 18) for pots arranged end-to-end.

Pots arranged side-by-side :

a) The total current carried by the output cathode bars is always symmetrically collected in four equal portions along the two long sides of the pot and conveyed through the cathode bus bars to the four points A_1, A_2, B_1, B_2 symmetrical with respect to the two median vertical planes of the pot, said points being positioned

- for the arrangements as per figures 5 and 6 : at the four cathode outputs closest to the transversal median plane;

- for the arrangements as per figures 7 and 8 : at four intermediate cathode outputs on the four half long sides;

- for the arrangements as per figures 9 and 10 : at the four cathode outputs farest from the transvers-

al median plane.

b) The current so conveyed is carried downward by means of two couples of conductors a_1, a_2; b_1, b_2 (fig. 11) of equal length and cross-section, preferably vertically arranged and symmetrically positioned with respect to the two median vertical planes, up to the four symmetrical points A_1', A_2', B_1', B_2' (fig. 11) arranged on a plane (hereinafter referred to as "lower plane") lying beneath the bottom of the pot and parallel to the reference plane xy.

The level at which said lower plane is positioned has no relevant influence on the distribution and magnitude of the magnetic forces in the bath and in the metal, at least from a certain value onward.

For example, the difference - in terms of induced forces - is minimum from a level of -1.5 m to a level of -2.0 m with respect to the plane xy.

c) The current so carried to the four abovesaid points A_1', A_2', B_1', B_2' is conveyed by two couples of conductors of equal length and cross section c_1, d_1; c_2, d_2, preferably horizontal, which follow symmetrical paths with respect to median vertical planes xz and yz - according to the abovesaid alternative "cross arrangement " (fig. 5), "rhombus arrangement" (fig.6), "corridor arrangement" (fig.7), "hexagon arrangement" (fig. 8), " rectangle arrangement" (fig. 9) - to two points M_1, M_2 of the longitudinal median plane, symmetrical with respect to the transversal median plane, being it also possible to assemble said points M_1, M_2 to a single point M - in the "sheaf arrangement" alternative (fig. 10) - corresponding to the vertical projection of the pot

centre on the lower plane.

d) From said points M_1, M_2 (or M), by means of two couples of side-by-side conductors e_1, f_1; e_2, f_2 of same length and cross-section, the current is carried, parallelly to the general flow of the current in the series, from the longitudinal median plane of the upstream pot to the longitudinal median plane of the downstream pot, up to the points N_1, N_2 (or N in figure 10), substantially homologous - when taking into consideration the connection in series of all the pots - to the aforesaid points M_1, M_2 (or M).

e) From said points N_1, N_2 (or N), by means of two couples of side-by-side conductors g_1, h_1; g_2, h_2 (figure 11) of same length and cross-section, the current is carried upward - according to paths symmetrical with respect to the two vertical median planes - up to the anode bus bar t in the two symmetrical points P_1, P_2 (fig. 11), said anode bus bar being so symmetrically supplied at the heads of the pot.

f) The total feeding current I which, coming from the rectifier station, supplies the first pot in the series is distributed (at least from a certain point onward) in four equal portions in two parallel couples of side-by-side conductors of equal length and cross-section, said couples being lined, up to the intersection points with the longitudinal median plane of the abovesaid first pot, with the aforecited couples of conductors e_1, f_1; e_2, f_2, so that a "continuous" is practically obtained from the rectifier station to the longitudinal median plane of the

last pot in the series, such "continuous" being represented by two couples of side-by-side conductors, each couple carrying,in the x direction, a current equal to I/2.

g) The four reverse bus bars are divided into two couples m_1,n_1; m_2, n_2 (fig. 11) of equal length and cross-section, arranged allthrough the potline and up to the rectifier station in proximity of and parallelly to the two cited couples representing the "continuous" mentioned in point f) above, each of said couples of reverse bus bars carrying a current equal to I/2 having a direction opposite to the general flow direction of the current in the potline, wherefore a complete compensation between the current feeding the series and the reverse current is provided in the four couples of said conductor bus bars; as a consequence thereof, the magnetic field generated by them is fully annulled and, therefore, any cause of dissymmetry due to the currents with respect to the longitudinal vertical planes of the pots is removed.

Pots arranged end-to-end :

h) The total current carried by the output cathode bars,always symmetrically collected - by means of the cathode bus bars - in two halves at middle points A, B of the sides of the pot,is carried downward - by means of a couple of conductors a, b of equal length and cross-section belonging to the transversal median plane, symmetrically positioned with respect to the longitudinal median plane - up to a

plane lying, optionally, underneath the pot bottom (hereinafter referred to as "lower plane") in two points C, D symmetrically arranged with respect to the longitudinal median plane. In the "sheaf arrangement" of figure 16, said two points C, D are assembled in a position corresponding to the vertical projection of the pot centre; in the "corridor arrangements" of figures 17 and 18, the two points are separated, being respectively outside (figure 17) or at (figure 18) the vertical projections of abovesaid points A, B.

i) From said points C, D - by means of a couple of conductors c, d of equal length and cross-section - the current is carried, according to a path parallel to the general direction of the current in the series, from the transversal median plane of the upstream pot to the transversal median plane of the downstream pot, up to points C', D', which are substantially homologous - when taking into consideration the connection in series of all the pots - to the aforesaid points C,D. In the "sheaf arrangement" alternative of figure 16, said conductors c, d are positioned side-by-side.

l) From the abovesaid couple of points C', D' - by means of a couple of conductors a', b' of equal cross-section , which follow paths parallel to the preceding couple of conductors a, b (and therefore having the same length of the latter and being likewise symmetrically arranged with respect to the longitudinal median plane) - the current is carried again -from said lower plane- to the level of the cathode outputs of the pots, till reaching,

at the long sides of the downstream pot, the two points A', B' ,which are substantially homologous to the two points A, B of the upstream pot.

Taking into account the connection in series of the pot-line there are by consequence - in a same pot - two couples of side-by-side conductors (namely a, a'; b, b') symmetrically arranged,on the transversal median plane, with respect to the longitudinal median plane; furthermore - within each couple - the two conductors carry the same currents (equal exactly to I/2),but directed in opposing directions.

m) From preceding points A', B' - by means of two conductors e, f (anode risers) of equal length and cross-section, and arranged on the transversal plane, which follow symmetrical paths with respect to the longitudinal median plane - the current is finally carried upward, up to anode bus bar t, at points E, F (figure 18), so that such anode bus bar is symmetrically supplied in correspondence of the central points of the long sides of the pot.

n) The total feeding current I which, coming from the rectifier station, flows to supply the first pot in the series, is divided (at least from a certain point onward) into two equal portions on a couple of parallel conductors of equal length and cross-section, said couple being lined, up to the intersection points with the transversal median plane of the abovesaid first pot, with the cited couple of conductors c, d, so that a "continuous" is practically provided from the rectifier station

to the transversal median plane of the last pot in the series, such "continuous" consisting of a couple of conductors parallel to direction x, each carrying a current equal to I/2.

o) The reverse current is carried by two conductors m, n (fig. 18) of equal length and cross-section, arranged along the all pot-line and up to the rectifier station close and parallelly to the two conductors constituting the "continuous" mentioned in point n) above, each of said reverse conductors carrying a current equal to I/2 having a direction opposite to the general direction of the current in the series, wherefore a complete compensation between feeding current and reverse current is obtained in the two couples of abovesaid conductors; as a consequence thereof, the magnetic field generated by them is completely annulled, and any cause of dissymmetry of the currents with respect to the transversal vertical planes of the pots is therefore eliminated.

From what has been explained and exemplified herein before there are apparent the advantages of the present invention, which are listed and illustrated in the following :

I) The conductors utilized for carrying the cathode current can have uniform cross-sections in the whole plant. This depends on the fact (clearly evidenced by figures 11 and 18) that from the current collecting points at the long sides of each single upstream pot up to the joins to the anode bus bar of the adjoining downstream pot, the conductors - having the same length and cross-section in the single sections -

follow total paths of equal length and a constant current equal to I/2 flows therein on each side of the row.

In the prior art, conversely (for example according to the arrangement of figures 2 and 13), the connection between upstream pot and downstream pot is provided by conductors which follow paths of different length and carry different currents, what forces - in order to secure the electrical balance of the pot - to utilize conductors with different cross sections.
Besides, the calculation of these sections, due to the presence of parasite contact resistances of various types in the circuits, is often affected by errors which involve non-homogeneity in the output of current from the pot, especially between upstream and downstream.

The utilization of the abovesaid uniform cross-section, extensible, on the basis of what illustrated at points f), g), n) and o) hereinabove, also to the separate bus bars from and to the rectifier station, involves undeniable technical advantages and economical saving as regards design, assembly and maintenance.

II) The working floor of the pots is left fully free - in all of the alternatives - with the exception of the space required for the anode risers. This results in advantages and simplifications with regard to the operation of the mechanical equipments around the pots.

III) The ordered and simple geometrical arrangem-

ent of the conductors results in a simplification of the bar system assembly and disassembly operations, as well as in a uniformity and homogeneity of access to the outer walls of the iron pot-shell under operative conditions (for example, for accomplishing measurements and checks).

IV) The presence of only one direct connection between the median planes yz of two succeeding pots facilitates the by-pass operation of one or more pots which need to be separated from the remaining pots in the series (a comparison should be made with the more complex situation existing in the case of the known arrangements of figures 2 and 13).

V) The conductor arrangement adopted reduces to the essential the portions of outer conductors which are unshielded, from a magnetic point of view, by the steel xhell of the pot.

Furthermore it should be noted that a beneficial and symmetrical shielding action is exerted by the iron structures employed for the containment and support of the pot-shell on the conductors, if any, placed underneath the bottom of the pot.

VI) The double geometrical and structural symmetry of the steel shell and of the totality of conductors secures, finally, a double symmetry of the steel shell shielding action.

VII) The symmetrical distribution of the "residual" conductors (i.e. the ones which determine a non identically null field) with respect to the two median vertical planes (therefore, a "doubly symmetrical" distribution) causes in the bath and in

the metal "doubly" and totally symmetrical distributions of the magnetic induction field $\vec{B}$ and of the magnetic forces field $\vec{F}$, what generally involves a uniform operation of the pot in the four portions whereinto it may be imaginarily supposed to be divided by the abovesaid median vertical planes, the unbalances between upstream and downstream and between right side and left side (with respect to the general direction of the current flow in the series) having been eliminated.

VIII) The "doubly" symmetrical distribution of the magnetic forces in the pot leads to a "doubly" symmetrical distribution of the horizontal velocity field in the bath and in the metal, with consequent:

- elimination of the extended asymmetrical horizontal vortexes typical of the pots with conventionally arranged conductors;
- generalized reduction of the velocities in the metal;
- reduction of the waves amplitude at the bath--metal interface.

Thus, while eliminating, on one side, both erosion and damages of the side linings , it becomes possible, on the other side, - by lowering the anode--cathode distance - to reduce the power dissipation in the bath due to the Joule effect (and therefore the ohmic drop of the pot), still simultaneously improving the current efficiency.

IX) There is obtained a substantial absence of abnormal behaviours in the pots placed at the beginning

and at the end of the series - as is found in the known conventional plants - because the magnetic effects induced by each pot in the adjoining ones are extremely reduced.

This fact permits also to avoid known extensions (for magnetic compensation) of the bus bars connected to the terminal pots of the rows.

X) In the side-by-side pots, the conductor arrangements, as previously described and illustrated in figures 4 through 11, cause a considerable reduction, in all the area of the molten metal, of the detrimental portion of the longitudinal component of the magnetic force , such detrimental portion being expressed by $-J_x B_z$, where J_x is the transversal component of current density $\vec{J}$ and B_z is the vertical component of magnetic induction $\vec{B}$. Such reduction has a considerable practical advantage as it permits to the pot to operate -without any harmful effects - with a transversal horizontal component J_x of the current by far higher than the one existing in the conventional pots. This permits to sensibly reduce the height of liquid metal deposit in the pot, with consequent saving in the deferred costs for the metal.

XI) In the end-to-end pots, the side-by-side arrangement of conductors in countercurrent allthrough the bus bar system - from the points collecting the cathode outputs in correspondence of the centers of the long sides of the upstream pot up to the homologous points on the long sides of the downstream pot -secu

res the total elimination of the magnetic effects caused by said conductors. In other words, the "residual" magnetic field (i.e.: non identically null field) is only the one generated by outer portions of cathode by the bars, running along the pot long sides, by the risers, by the anode bus bar and by the conductors inside the pot; all the abovesaid conductors being symmetrically arranged with respect to both median vertical planes.

It should be pointed out, in particular, that there is eliminated the magnetic field generated (in the conventional plants) by the currents parallel to y, carried by the conductors arranged in the corridors between one pot and the succeeding one, such currents - as is known - causing very high values of the vertical magnetic field at the heads of the pots.

It should be also noted in particular that, as the anode risers are placed in correspondence of the middle points of the pot long sides, there is a lowering - with respect to the known arrangements - of the transversal component By of the magnetic field, which is responsible for the detrimental longitudinal forces, against a rising of the longitudinal component Bx, responsible for the less harmful transversal forces.

XII) In the end-to-end pots, the conductors arrangements (as previously described and illustrated in figures 15 through 18) involve the practical elimination - in the fluid areas of metal and of bath -

of the harmful total longitudinal component of the magnetic force, expressed now by $F_x = J_y B_z - J_z B_y$, such practical elimination being due to the simultaneous sensible reduction of the values of B_y and B_z.

In particular, in the whole area of molten metal, an almost total elimination of term $J_y B_z$ is obtained, such term representing the product of the transversal component of the current by the vertical component of the magnetic field. Said elimination of $J_y B_z$ permits the pot to operate -without detrimental effects- with a transversal component of the current J_y much higher than the one existing in the known conventional pots. This entails the possibility of remarkably reducing the liquid metal deposit inside the pot, with a consequent appreciable saving in the deferred costs for the metal.

XIII) In the plants with pots arranged end-to-end - where the compensation of the current carried by the cathode bus bar system is in any case total- it is not necessary to carry the current on a "lower plane", as it is possible to eliminate (fig. 18) the conductor sections a, b, a', b' in order to place the sections c, d (and consequently the reverse conductors m, n of the series) all at the level of the cathode outputs plane, so as to provide a variant of the conductors' arrangement as per fig. 17, referred to as "plane symmetrical arrangement". (Such arrangement, or scheme, is represented once again by fig. 17, provided also the conductors indicated in dashed lines are imagined to be

positioned on the plane of the cathode outputs). Such variant results - for said longitudinally arranged plants - to be the most advantageous from the point of view of the use and consequent requirement of aluminium conductor bars, because in said variant such conductor bars are reduced to the absolutely essential.

The present invention, which is mainly and predominantly deviced for plants equipped with single reverse conductors symmetrically arranged side-by-side to feeding conductors, can be advantageously applied also to plants in which the potline, arranged on two or more parallel rows (figures 1 and 12) does not have, according to the conventional schemes, said reverse conductors arranged in countercurrent. In such case, however, the benefits induced by the symmetrical arrangement of the cathode bus bars around a single pot are attenuated due to the permanence of asymmetries in the magnetic field, and by consequence in the field of forces, with respect to the median vertical planes of the pot.
For said case, the asymmetry with respect to plane xz caused by the "adjoining row" (this being a known problem common to all the normal bi-row or multi-row plants) can be corrected - as is known - by separate compensation circuits (as is disclosed, for example, in U.S. patent 3,616,317).

As regards the asymmetry with respect to plane yz caused by the current flowing in the conductors connecting the median planes of adjoining pots perpendicular to the general direction of the current in the

series, it is to be pointed out, however, that, due to the fact that said conductors are equivalent to two unique conductors in which costant current I/2 flows along all the length of the series, their effect is systematic and uniform. In other words, the magnetic field generated by such conductors is constant along a straight line parallel to axis x, wherefore the effects of greater unbalance of the magnetic field between upstream and downstream existing in the known conventional arrangements (for example the ones of figures 2 and 13) are eliminated.

Additionally, the optional positioning of the aforesaid conductors underneath the pot bottom (on the"lower plane") ensures in any case - as compared with the conventional known plants - a sensible reduction of the vertical magnetic field.

Finally, it is to be noted that the symmetrical arrangement of the conductors according to the present invention always provides the advantages indicated at points I) through V) hereinabove also in the case of plants in which the potline is arranged on two or more rows and the circuit does not have single reverse conductors arranged side-by-side symmetrically to the feeding conductors.

The invention, as is described and illustrated hereinbefore and claimed hereinbelow, may be modified with technically equivalent elements, but all included in the scope of the inventive concept of the invention. In particular, each single conductor may be splitted into two conductors, each of which having a cross-sec-

tion equal to half of said single conductor.

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Method and apparatus for electric current supply to pots for electrolytic production of metals, particularly aluminium

Claims

1. A method for the electric current supply to pots for the electrolytic production of metals, particularly aluminium, arranged in side-by-side or end--to-end relationship and connected in series on one or more rows, capable of minimizing the magnetic effects in said pots, characterized in that it comprises carrying most of the current in the circuit of said pot series by means of conductors all having the same cross-section and being always combined, in the single circuit sections, in couples of equal length, all said couples of conductors being furthermore symmetrically positioned with respect to the median vertical longitudinal and/or transversal plane of the single pots in the series.

2. A method according to claim 1, characterized in that the current carried by the reverse conductors of the series, which follows a path parallel to but directed in opposite direction with respect to the general direction of the current in the series, is distributed in equal portions on couples of conductors of equal length, said conductors being symmetrically arranged with respect to the vertical median plane parallel to the general direction of the current in the series and being placed externally and close to the corresponding couples of feeding conductors, furthermore the cross-section of said reverse conductors beeing

always the same and equal to the cross-section of the feeding conductors, including those which feed the current to the first pot in said series.

3. A method according to claim 1, in which the pots are arranged side-by-side, characterized in that :
- the total cathode output current of each single pot in the series is symmetrically assembled in four equal portions along the four half long sides of said pot and is conveyed - by means of cathode bus bars - to four points symmetrically positioned with respect to both median vertical planes - longitudinal and transversal, respectively - of said pot; whereafter
- from said four points, the current is carried downward - by means of four conductors of equal length and cross-section, symmetrically arranged with respect to both said median vertical planes - up to four points lying on a "lower plane" underlying and parallel to the bottom of said pot, said four points resulting to be symmetrically positioned with respect to the abovesaid two median vertical planes; whereafter
- the current is conveyed - by means of two couples of conductors of equal length and cross-section which follow preferably horizontal paths symmetrically arranged with respect to the aforesaid median vertical planes - to two points in the median longitudinal plane, such points resulting to be symmetrically arranged with respect to the median transversal plane, such points being furthermore optionally coincident;

whereafter

- from the abovesaid two points - by means of two couples of side-by-side arranged conductors of equal length and cross-section, optionally combined to form a single sheaf - the current is carried, parallelly to the general direction of the current in the series, up to the longitudinal median plane of the adjoining downstream pot, being said plane intersected by said conductors in two points substantially homologous to the aforecited preceding points; and finally

- the current is carried upward - by means of two couples of side-by-side arranged conductors of equal length and cross-section which extend symmetrically with respect to the median transversal plane of the abovesaid downstream pot - up to the level of the anode bus bar, in order to allow the symmetrical supply to said bus bar in correspondence of the median area of the heads of said pot.

4. A method according to claim 3, characterized in that the current carried by the cathode bus bars, once conveyed to said four symmetrical points of the long sides of each single pot, is directly carried - by means of four conductors of equal length and cross-section which follow prevailingly horizontal paths outside the outline of the pot, said paths being furthermore symmetrical with respect to the two median vertical planes - to two points of the median longitudinal plane, said two points resulting to be symmetrically arranged with respect to the median

transversal plane and placed outside the heads of said pot, and said two points belonging, furthermore, to the plane of the cathode outputs or to a plane close thereto, in order to permit the prevailing part of the conductors carrying the cathode current to extend on a plane substantially coincident with the plane of the cathode outputs.

5. A method according to claim 1 in which the pots are arranged end-to-end, characterized in that :

- the current carried by the cathode output bars of each single pot in the series is symmetrically collected on the four half long sides of the pot and is carried, by means of four identical cathode bus bars, to two collecting points belonging to the transversal median plane and symmetrically positioned with respect to the median longitudinal plane; whereafter

- the current, from the two aforesaid collecting points, is carried - by means of a couple of conductors of equal lenght and cross-section, which, on the median transversal plane, are symmetrically arranged with respect to the longitudinal median plane - up to two symmetrical points of the median transversal plane, optionally lying on a "lower plane" underlying the bottom of the pot, such points being furthermore optionally coincident; where after

- from the aforesaid points - by means of a couple of conductors of equal length and cross-section, optionally arranged side-by-side - the current is carried, parallelly to the general direction of the current in the series, up to the median transversal plane of the

adjoining pot in downstream position,being this plane intersected by said conductors in two points substantially homologous to the preceding points; whereafter

- the current is carried - by means of a couple of conductors of equal length and cross-section which, on the transversal plane of the downstream pot,are parallelly arranged to the abovesaid conductors on the transversal plane of the preceding upstream pot (and therefore have the same length of the latter and are equally symmetrically arranged with respect to the median longitudinal plane) - up to two points of the long sides of said downstream pot, which are substantially homologous to the two above-mentioned collecting points of the upstream pot; finally

- the current is carried upward - by means of two conductors of equal length and cross-section which, on the median transversal plane, are symmetrically arranged with respect to the longitudinal median plane - up to the anode bus bar of said downstream pot in correspondence of the median areas of the long sides.

6. A method according to claim 5, characterized in that the current carried by the output cathode bars once conveyed by means of the cathode bus bars to said two symmetrical points at the half sides of each single pot, is directly carried - by means of two conductors of equal length and cross-section, parallel with the general direction of the current in the series and symmetrically arranged with respect to the median longitudinal plane - to the two homologous points of

the transversal plane of the adjoining downstream pot, in order to permit the prevailing part of the conductors carrying the cathode current to extend on a plane substantially coincident with the plane of the cathode outputs.

7. An apparatus for the electric current supply of pots for the electrolytic production of metals, particularly aluminium, according to the method as claimed in any of the preceding claims, characterized in that it consists of conductors all of equal cross-section and always combined, in the single sections of the circuit, in couples of equal lenght, all said conductors being furthermore divided into couples positioned always symmetrically with respect to the median longitudinal and/or transversal vertical plane of the single pots in the series, furthermore, the reverse conductors to the rectifier station - they too divided into symmetrical couples of equal cross-section and length - being side-to-side arranged along the total extension of the series to the feeding conductors which directly connect each couple of succeeding pots.

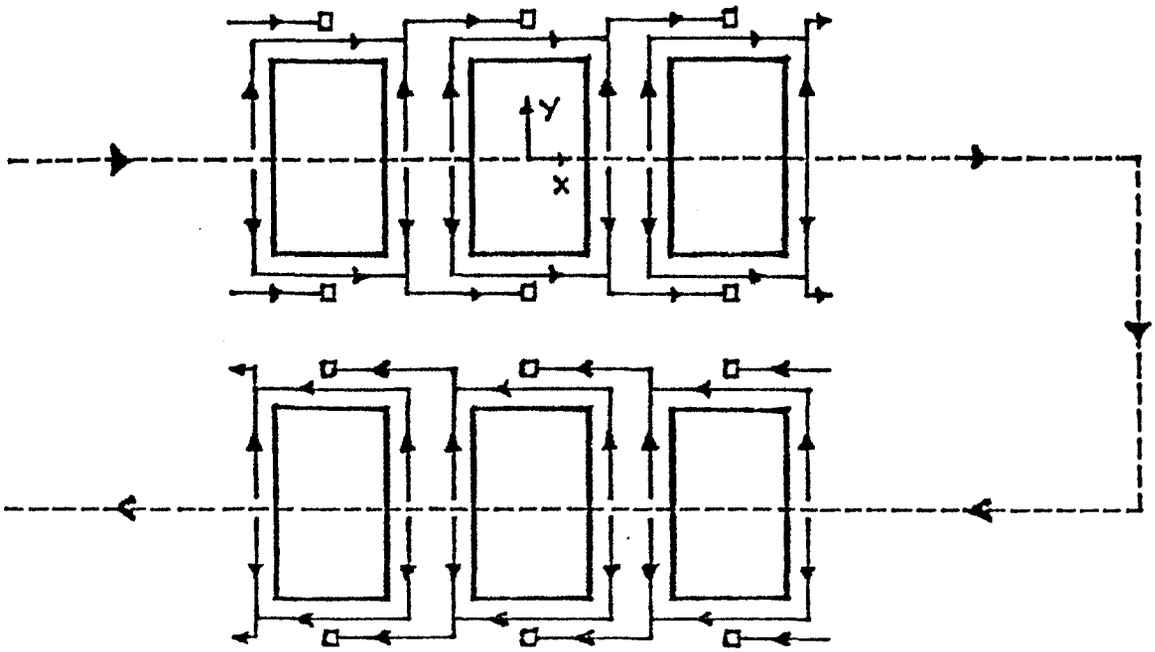


Fig. 1

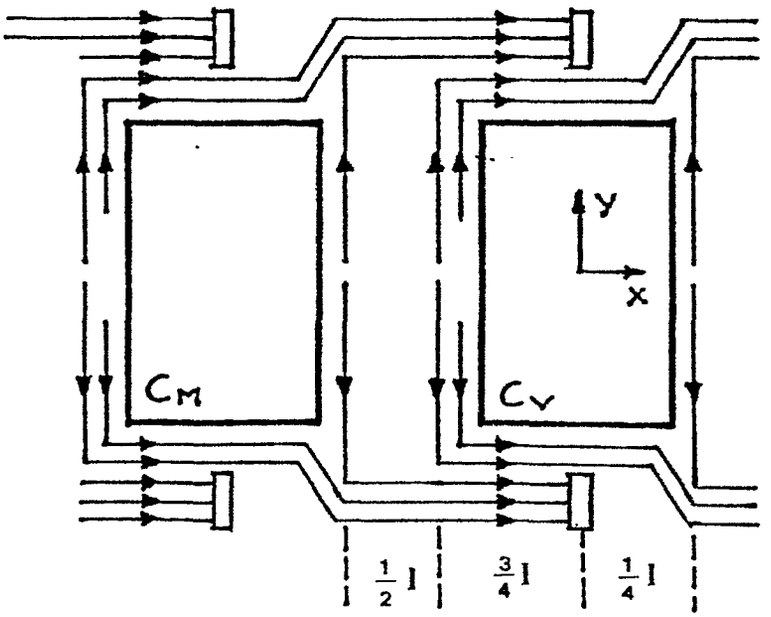


Fig. 2

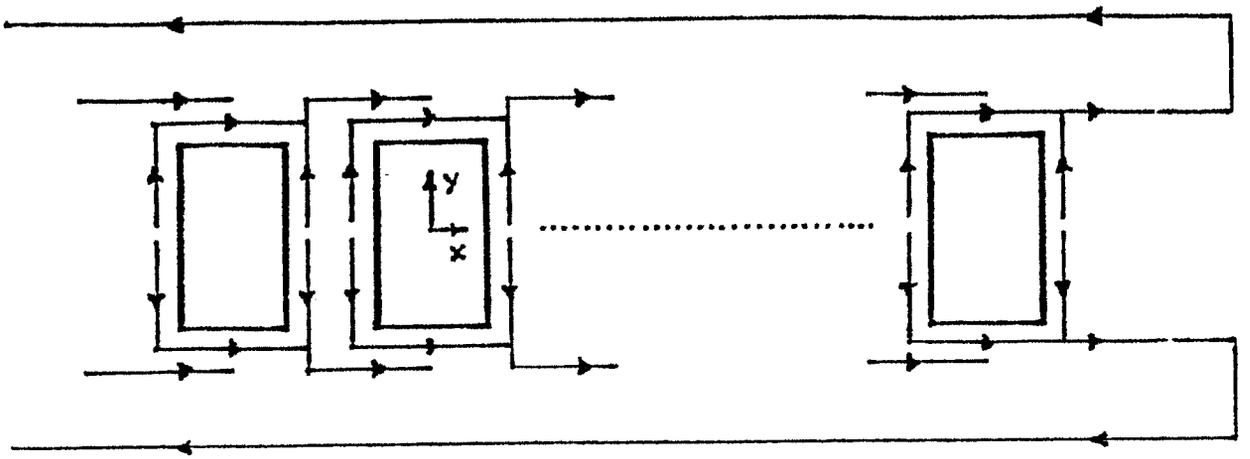


Fig. 3

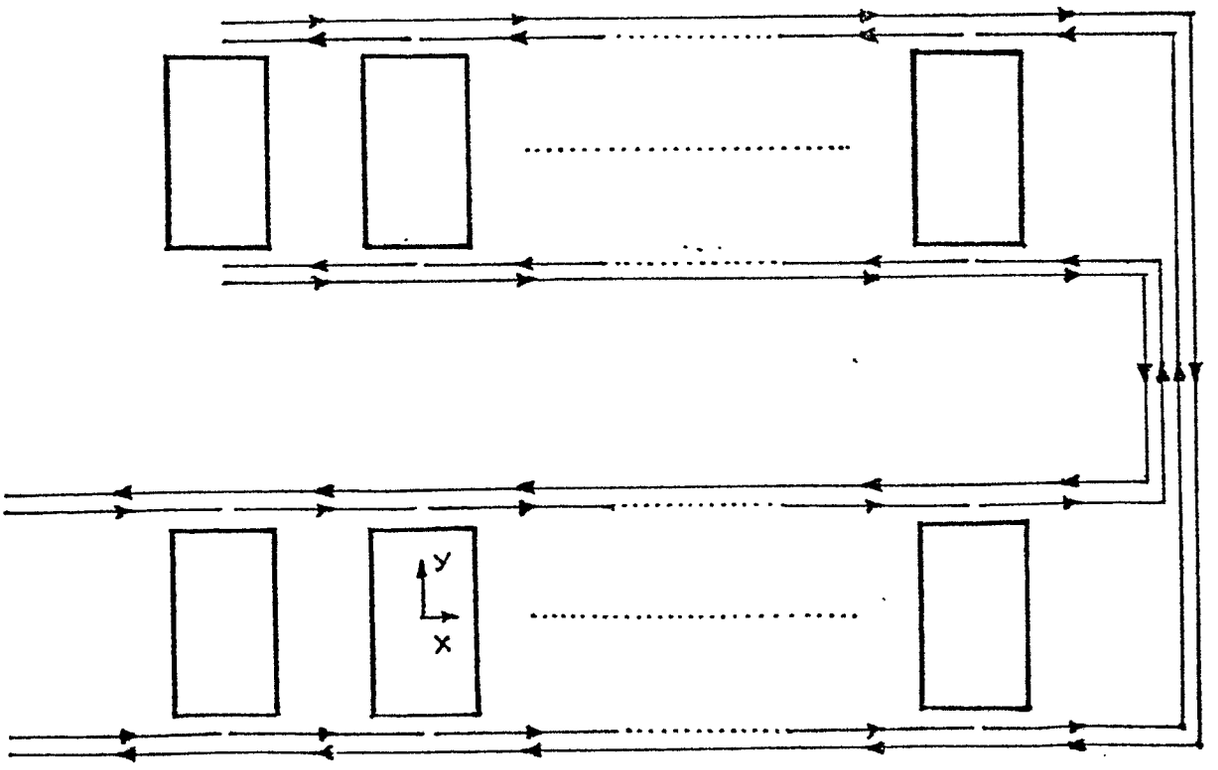


Fig. 4

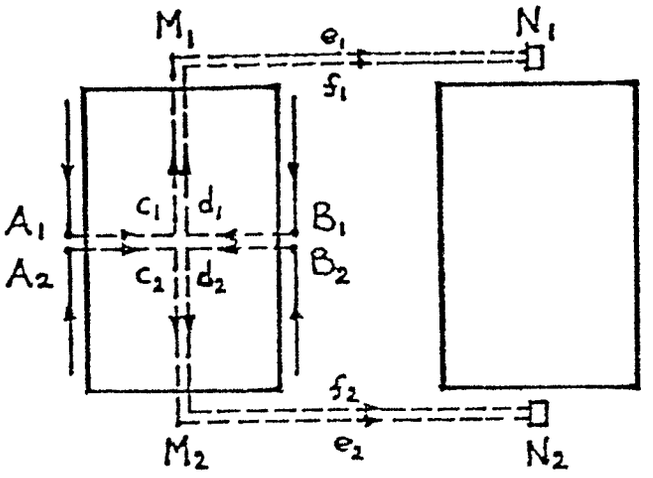


Fig. 5

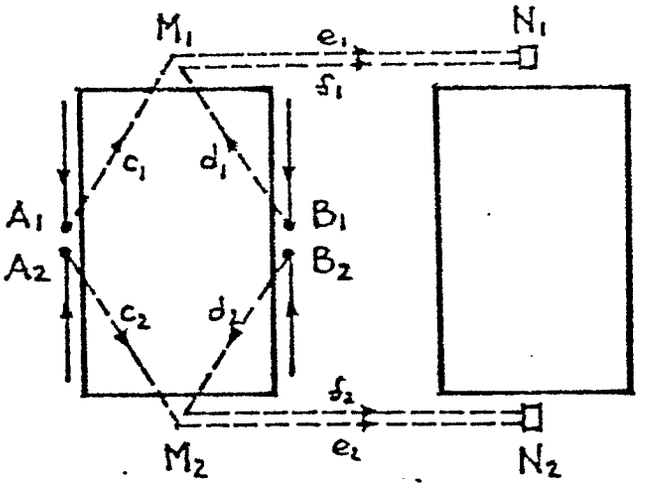


Fig. 6

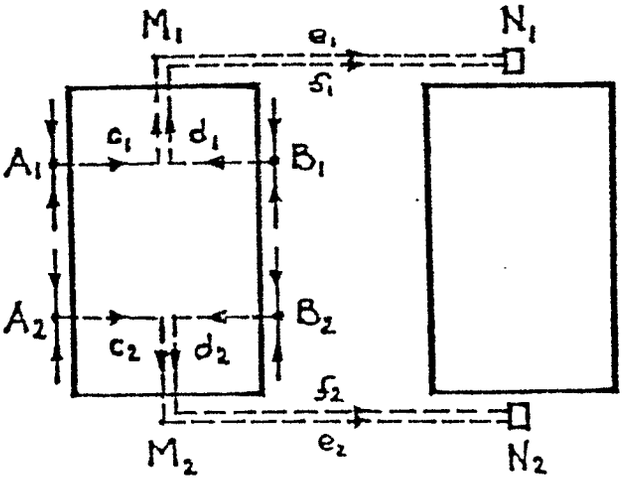


Fig. 7

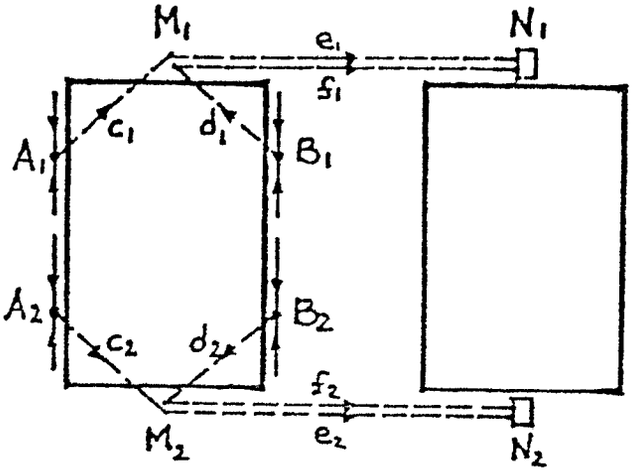


Fig. 8

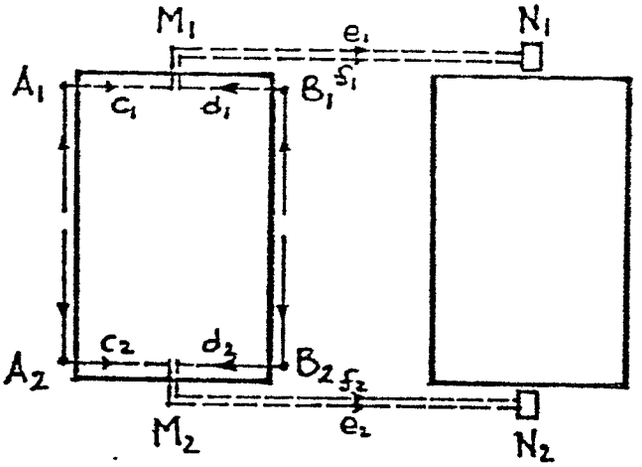


Fig. 9

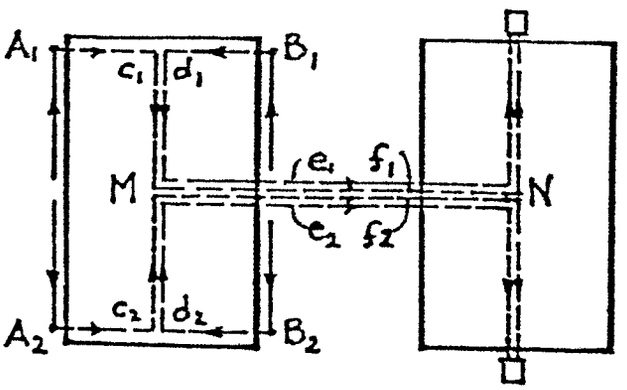
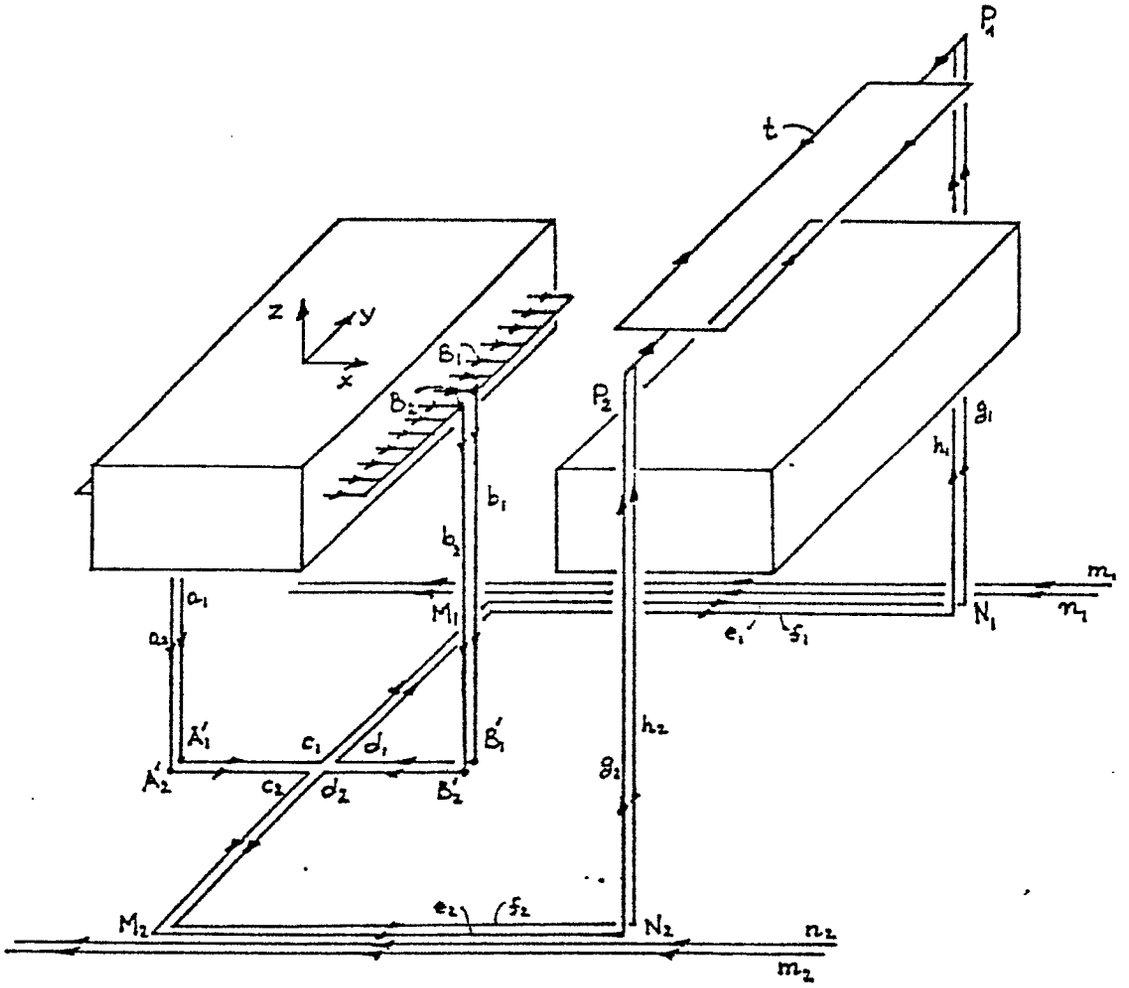


Fig. 10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B2
P2
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b2
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n1
e1
f1
A'1
c1
d1
B'1
h2
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n2
m2

Fig. 11

6/9

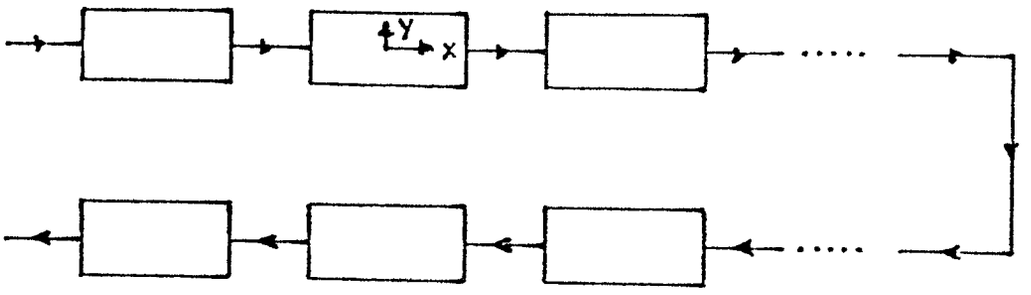

Fig. 12

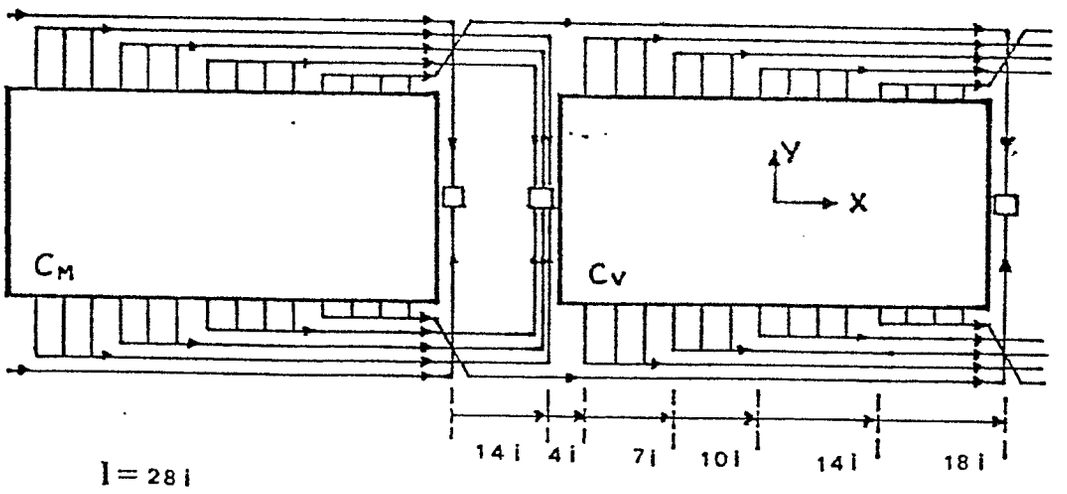

Fig. 13

7/9

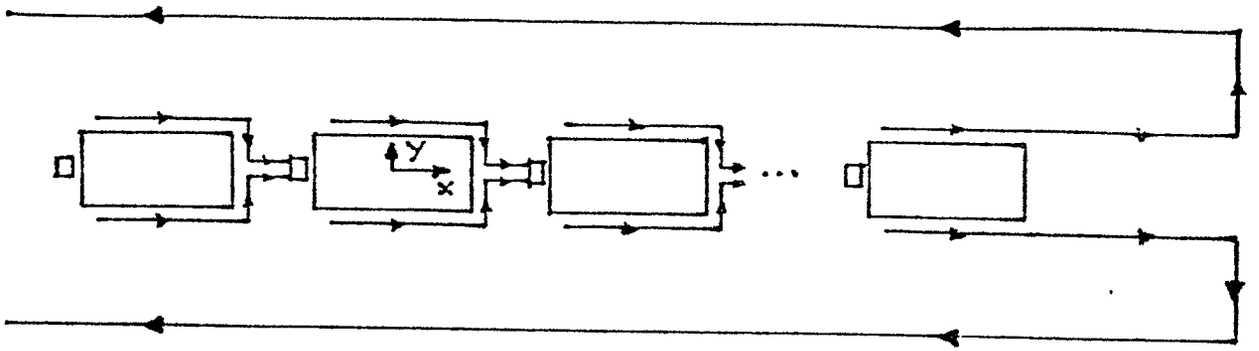

Fig. 14

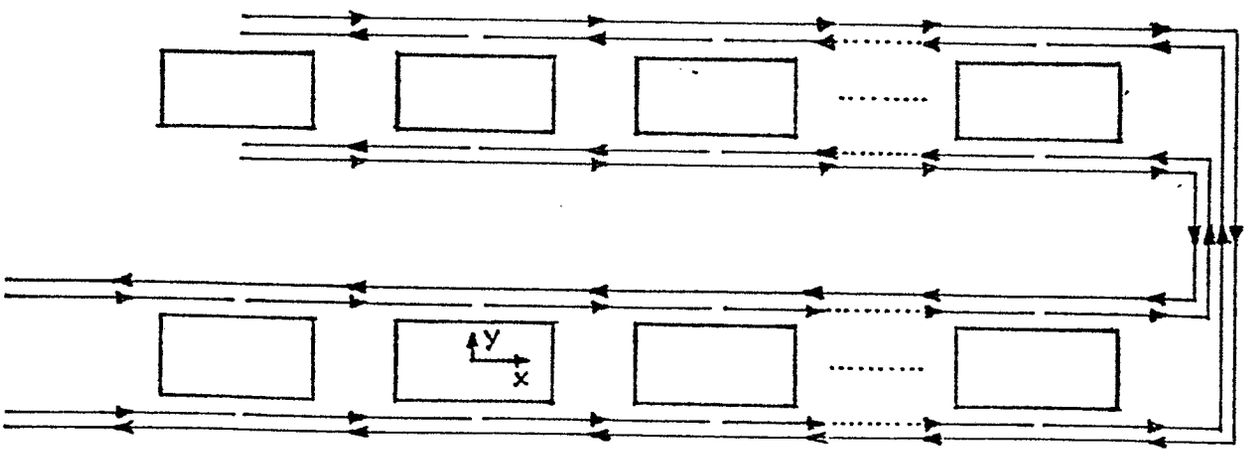

Fig. 15

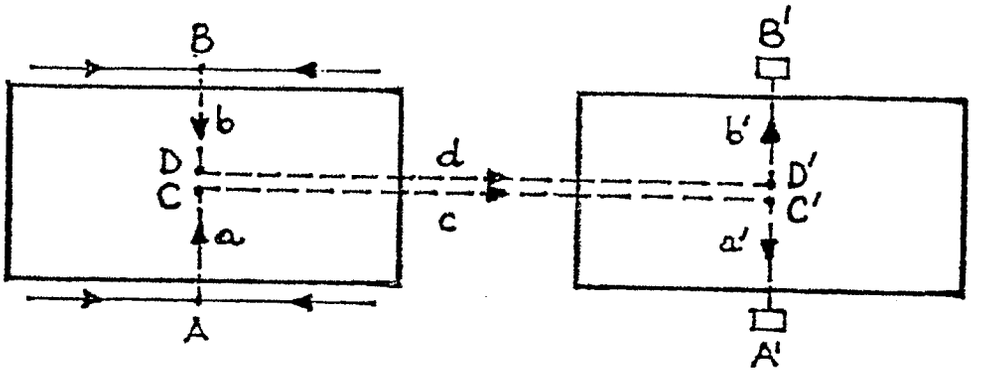

Fig. 16

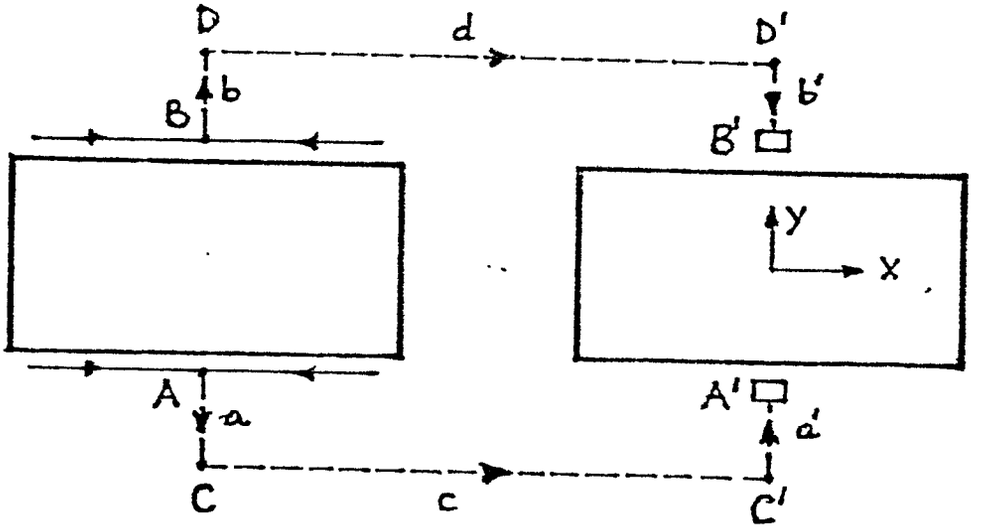

Fig. 17

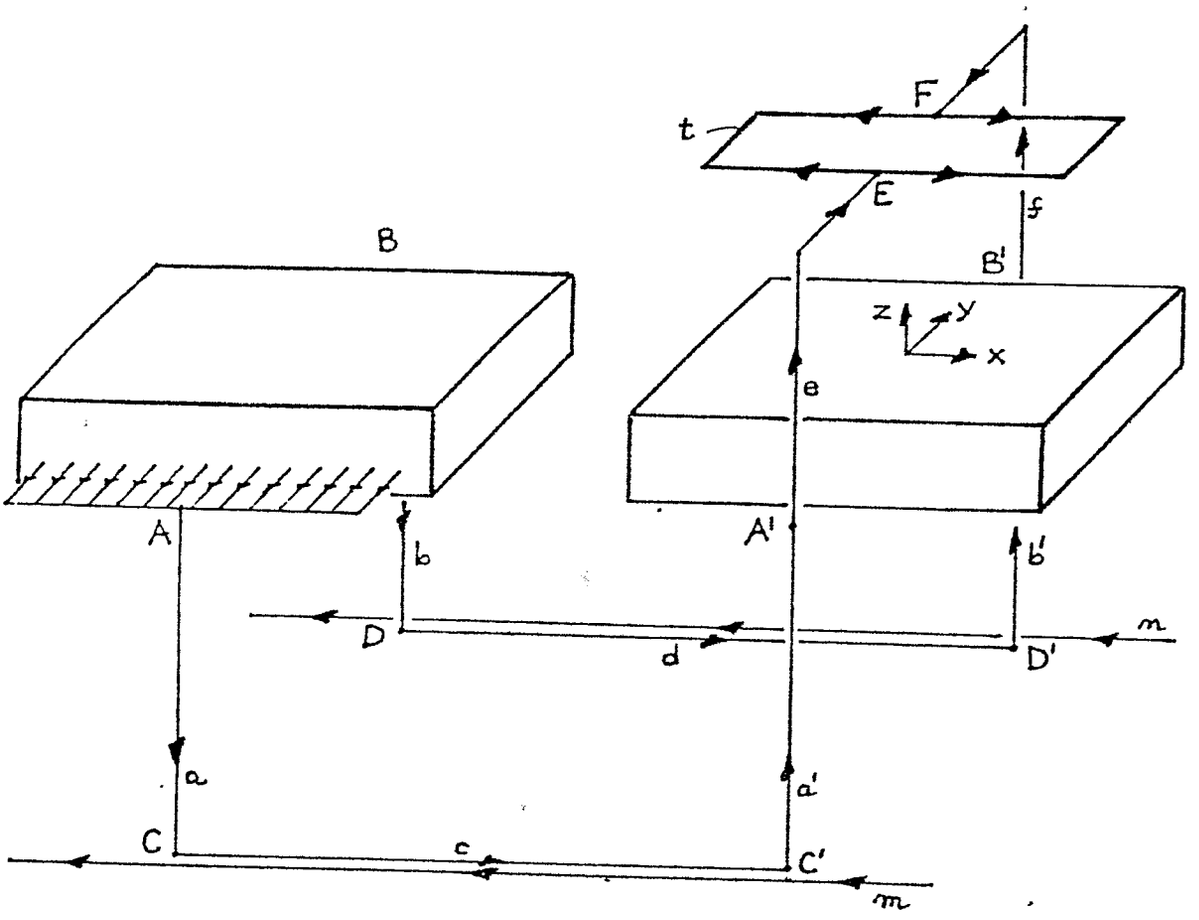

Fig. 18