CONVENTION APPLICATION FOR A PATENT.

I, WE SWISS ALUMINIUM LTD., A COMPANY ORGANISED UNDER THE LAWS OF SWITZERLAND, OF CHIPPS (CANTON OF VAIS), SWITZERLAND

HEREBY APPLY FOR THE GRANT OF A PATENT FOR AN INVENTION

ENTITLED DEVICES FOR CONTINUOUS HORIZONTAL CASTING

WHICH IS DESCRIBED IN THE ACCOMPANYING COMPLETE SPECIFICATION.

THIS APPLICATION IS MADE UNDER THE PROVISIONS OF THE PATENTS ACT 1952/60

AND IS BASED ON AN APPLICATION FOR A PATENT OR SIMILAR PROTECTION MADE IN

SWITZERLAND ON 19TH DECEMBER, 1977 UNDER NO. 15604/77

OUR ADDRESS FOR SERVICE IS C/O PHILLIPS, ORMONDE & FITZPATRICK,
367 COLLINS STREET,
MELBOURNE,
VICTORIA 3000

DATED THIS 27TH DAY OF NOVEMBER, 1978

SWISS ALUMINIUM LTD
COMMUNWEALTH OF AUSTRALIA

Patents Act

DECLARATION FOR A PATENT APPLICATION

42690

In support of the 1970 Convention application made by

SWISS ALUMINIUM LTD

hereinafter called "applicant(s)"

for an

invention entitled "...

Devices for Continuous Horizontal Casting

Paul Douady, Procurist of

Swiss Aluminium Ltd., of Chippis,

Switzerland

I, the applicant(s)

(or, in the case of an application by a body corporate)

declare to make this declaration on behalf of

the applicant(s).

I am/We are the actual inventor(s) of the invention.

I am/We are not the actual inventor(s) for which the application is made.

Josef Morianz of Austrian nationality

of Steinacherstrasse 11

CH-8308 Illnau, Switzerland

do solemnly and sincerely declare as follows:

1. I am/We are the applicant(s).

2. I am/We are the actual inventor(s) of the invention.

or, where the applicant(s) is/are not the actual inventor(s)

Applicant is the assignee of the inventor in respect of the invention

(Note: Paragraphs 3 and 4 apply only to Convention applications)

3. The basic application(s) for patent or similar protection on which the application is based is/are identified by country, filing date, and basic applicant(s) as follows:

Switzerland on 19th December 1977

by Schweizerische Aluminium AG, the alternative name of Swiss Aluminium Ltd.

4. The basic application(s) referred to in paragraph 3 hereof was/were the first application made in a Convention country in respect of the invention the subject of the application.

Declared at Neuhausen am Rheinfall

Dated 27th November 1978

Paul Douady

To: The Commissioner of Patents
2. Device for continuous horizontal casting metals, particularly aluminium and its alloys, using a casting trough, holding furnace or the like having in a wall near the bottom an outlet onto which an opening provided in the lower part of a disc-shaped nozzle connects up in the direction of casting as a transition to a mold, in which device the said outlet is in the form of a trumpet-shaped taper opening up towards the inside of the trough and the lower surface of the opening is curved saddle-shaped above the level of the surface of the floor of the trough.
Complete Specification for the invention entitled:

"DEVICES FOR CONTINUOUS HORIZONTAL CASTING"

The following statement is a full description of this invention, including the best method of performing it known to applicant(s):
Device for Continuous Horizontal Casting

The invention concerns a device for continuous, horizontal casting of metals, particularly aluminum and its alloys, using a casting trough, a holding furnace or the like having in one wall near the bottom a tapping hole which connects up to a nozzle opening situated in the lower part of a disc-shaped nozzle by means of which the molten metal is transferred to the mold.

The components used for the melt transfer system in horizontal casting are generally made of refractory materials in some versions in combination with nozzles made of graphite or another suitable material, or of insulated or plasma coated metal. The outlet for the melt is situated near the floor of the holding furnace or casting trough and connects up with the opening in the lower part of the nozzle; the exceptions here are systems for casting special shapes - for example U-shaped rails, tubes, box-shaped sections - and the central pouring system with built-in baffle plates.

When casting round ingots, there is a channel-shaped part with refractory lining connected up to the nozzle which is in the form of a disc with a circular opening in it. The metal leaves the trough via that nozzle on its way to the mold, the nozzle opening forming an abrupt transition, as
a result of its position with respect to the inner face of
the mold. Such systems can be employed only for certain
products which have to meet normal quality standards since
there are frequently surface flaws such as, for example,
differences in the quality of the upper and lower surfaces
of the ingot, open or concealed shuts, - in particular in
the upper region - laps, bleeding, roughness and surface
segregation. Inside the ingot there can be clusters of
particles, a so-called marble structure, internal cracks
and dross. One can also find coring, an inhomogeneous struc-
ture in the form of onion-like solidification rings, an
inhomogeneous sump with striations, and a tendency for twinn-
ed or feathery crystals to form. It is therefore impossible
to guarantee uniform quality.

In the US-PS Patent specification 3 381 741 a simple arc-
shaped slit is disclosed as a nozzle-like opening in the
wall of a casting trough, which however also suffers from
the above mentioned and further disadvantages.

With this in mind the inventor set himself the task of im-
proving a device of the kind mentioned at the beginning,
avoiding the known shortcomings and, in particular, making
it possible to produce by continuous horizontal casting
defect-free ingots without pronounced structure and with
completely satisfactory surface quality.
This object is achieved by way of the invention in that the opening in the nozzle, as viewed in end view, is approximately banana-shaped or is in the form of a tapering slit with at least one approximately arc-shaped, curved, contoured part and presents, at least in the region of a vertical axis through the centre of the nozzle, a suitable run-out surface with a shape in the direction of casting which surface runs stepless into the inner face of the casting mold.

By way of comparison with the methods of horizontal continuous casting known up to now, where, as a result of the geometry of the metal feed system, there is an artificial meniscus, and therefore changes in the casting parameters - e.g. higher casting rate or temperature which normally eliminate cold shuts in vertical DC casting - do not help, the transfer of metal from the nozzle to the mold is improved and carried out smoothly by means of the device of the invention viz. the diffusive-like design of the nozzle slit or opening providing the run-out surface, and the direct connection of the inner face of the mold to the run-out surface at the same time avoiding the formation of a meniscus.

According to another feature of the invention the favourable range for the angle of the nozzle run-out surface lies between 0° and 45°, preferably between 10° and 35°, whereby the lower limit of 0° comes into consideration only for the
beginning and the end part of the run-out surface, and
the upper limiting value of 45° and the preferred limits of
10° and 35° refer to the average inclination over the whole
length of the run-out surface.

It has been found favourable to hollow out the face of the
nozzle body facing the mold and this in fact over such a
width that the free edge of the wall of the hollow space
comes to lie in line with the edge of the inner face of
the mold. This face of the hollow space which serves to
guide or lead the molten metal flowing to the mold is use-
fully conical in shape and is at an angle of at most 45°,
preferably 10° to 35° to the long axis of the casting de-
vice and therefore to the inner wall of the mold. Usefully
this conical surface is connected up to the base of the
hollow space via a curve e.g. circular shaped section. This
last mentioned surface can be flat or curved concave and
forms the actual end face of the nozzle body. It is also
possible to make the whole of the wall surface of the hollow
space one curve. The tangent to this surface in the immediate
vicinity of the mold should then be at an angle of 0°-45°,
preferably 10°-35°. In general the value 0° applies at most
to the last millimetres of the wall of the hollow space,
near the mold. The space, or chamber, described here func-
tions as a hot melt reservoir before the entrance to the
mold. As a result of this special design of the wall of the
hollow space which acts as metal guiding or leading surface, which connects up smoothly, without any steps, to the inner wall of the mold, raising of the molten metal and therefore the formation of an artificial meniscus is prevented all around. As a result of these two measures, cold shuts are avoided, also in case of alloys which are difficult to cast, and there is a considerable reduction in the incidence of surface flaws; the result is a uniform, smooth ingot surface, free of cold shuts, surface tears, oxide inclusions and oxide skin. By the provision of the banana-shape of the nozzle slit which is suitable for casting round ingots or the like, a purposeful locally different feed of metal is achieved, viz., in the region of the plane of vertical symmetry of the ingot, where, at the top and the bottom, the surface and structural flaws occur most, more metal and therefore more heat being supplied there than at the sides.

Within the thickness of the nozzle body, as was already mentioned, the run-out surface of the nozzle opening is inclined in the direction of casting; with the provision of the above mentioned space, its wall surface, or leading surface, usefully forms the outer part of the run-out surface. Advantageously, the run-out surface forms an elongated S-curve as viewed in longitudinal section. Over the rest of the periphery of the slit its wall changes over, via a curved part, into the outlet end face of the nozzle body.
Even if no cold shuts are to be feared at this place removed from the cold mold, these curves produce a quiet laminar flow without any of the troublesome turbulence which would lead to flaws in the upper part of the ingot.

The described, selected banana-shape of the nozzle slit with the inclined run-out surface prevents, in particular, the formation of clusters of particles and the formation of regions of variable structure over the cross section of the ingot, such as can be observed in conventionally cast ingots, viz. in the form of a uniform structure with relatively little feature to it in the upper half of the ingot and under this a zone of "marble structure" and also an even lower lying zone with clusters of particles in particular in the lowest portion of the ingot.

The favourable effect of the banana-shaped nozzle slit with inclined run-out surface connected to the hollow space of the nozzle front end can be increased by means of a further development of the invention in that the opening in the trough has a trumpet-shaped taper towards its inside, as viewed in cross section, the lower contour of the opening, as viewed in longitudinal section, thereby forming a saddle above the level of the trough floor.

In another preferred embodiment of the invention, the upper
longitudinal contour of the trumpet-shaped, tapering inlet is approximately in the form of one half of a catenary curve.

Usefully the opening with the trumpet-shaped inlet taper is situated in a special, separable part of the trough which can be changed any time without difficulty, in particular when an opening of a different size is required. It has also been found favourable for handling purposes to make the component containing the opening out of a refractory material and to construct it together with the nozzle, if desired also with the mold, as a single unit.

Further advantages and features of the invention are revealed in the following description of preferred exemplified embodiments and with the help of the drawings viz.,

Fig. 1 the partly sectioned longitudinal view of equipment for horizontal continuous casting;

Fig. 2 an enlarged perspective view of part of fig. 1, as viewed in the direction of the arrow III in fig. 1;

Fig. 3 a detail of a further exemplified embodiment, enlarged over the scale used in fig. 1;

Fig. 4 the end view of a part of fig. 3, as viewed in the direction of the arrow V;
Fig. 5 the enlarged end view of a nozzle with slit-shaped opening;

Fig. 6 the cross section through fig. 5 along the line VII-VII;

Fig. 7 a sketch of part of a polar coordinate system for calculating the closed curve shown in fig. 8;

Fig. 8 the enlarged contour of the nozzle opening, enlarged over the scale in fig. 5;

Fig. 9 the schematic, enlarged longitudinal section through a part of the nozzle.

An equipment for horizontal continuous casting of ingots or billets B with little structure has a casting trough G and a belt-like transfer table 2 in line downstream from the outlet or outlets 1 of the trough comprising substrate bars 3 which lie transverse to the direction of casting t and are moved in the casting direction t by the links 4 of a pair of chains 6. The drive 7 for the chains 6 is positioned at the end of the casting belt 2 away from the trough; towards the outlet 1 the lower part 6 of the chain belt is raised and in fact raised at an angle w of about 30° between two guiding sprocket-wheels 8, 9 over a distance m - measured
on a horizontal projection. After passing over the zenith 10 of the upper guide sprocket-wheel 9 the substrate sections 3 which are then pulled along by the upper part 6, of the chain on a plurality of rails 11 which lie in the casting direction t and in turn are supported by I-beams 12. The latter are provided with a layer 13 to allow easy sliding and therefore to prevent friction between the rails 11 and the substrate sections 3.

The walls 20 of the trough G are provided with a layer 22 of refractory material - with insulation 21 between the walls 20 and refractory lining 22; likewise the floor 23 of the trough is made of a refractory layer over the surface 24 of which the melt - not shown in the drawing - flows into the outlet opening or openings. 1.

The opening 1 of length n in the trough G is situated in a unit 27 made out of refractory material, the outer part 28 of which is situated between steel ribbing 29. Connecting up to this outer part 28 is a disc-shaped nozzle 30, the opening 31 in which is below the centre Z - as specified by the nozzle axis M - and together with the opening 1 of length n creates a pouring channel 32 of total length q.

Between the nozzle 30 and the neighbouring part 28 of the insert 27 there is a heat resistant seal 33. Downstream of
the nozzle 30 there is a mold 34 which is connected to the nozzle 30 by means of bolts. In figure 1 the connections for oil and water supply to the mold 34 are indicated by the numerals 37 and 38.

The diameter \( d \) of the mold recess also determines the breadth of a dummy block 40 which has a conical part 41 pointing counter to the direction of casting and which is moved into the mold recess before the start of the casting operation; the metal ingot which forms is drawn out of the mold 34 with this dummy block 40.

As shown in figures 5 and 6, the inlet side 45 to the nozzle 30 facing the trough G is in the form of a smooth uninterrupted surface; the outlet side 46 facing the direction of casting on the other hand has a ring-shaped edge 47. This edge forms the hollow space or chamber which acts as a warm melt reservoir before the entrance to the mold. The wall of the ring-shaped part 47 facing this hollow space forms the so-called wall surface of the hollow space, or leading surface, which features here a conical region 48 which changes over to a curve 49 in the flat run-out surface 46. The mold 34 lies against the end face of the ring-shaped part 47 in such a way that its inner face connects to the wall 48 of the hollow space, as shown in fig. 3.
In the end view shown in fig. 5 the nozzle opening 31 is a curved, banana- or mouth-shaped slit near the lower edge of the nozzle 30, as viewed when installed. The lower edge K of the opening 31 in the inlet side 45 facing the trough is vertically a height h higher than the sharp edge K₁ at the ring-shaped part 47 of the nozzle 30. The inclination u of the run-out surface Q is approximately 15° in fig. 6; in other exemplified embodiments it is 15 to 30°; advantageously it should not be less than 10°.

In the case of a nozzle or mold radius R (in centimetres) the lowest point Sₖ of the nozzle opening, on the inlet side 45 of the nozzle, is at a distance r₀ below the centre Z of the nozzle (see fig. 7), whereby r₀ is from 0.5·R to 0.9·R, preferably from 0.65·R to 0.8·R. The geometry of the slit 31 on both sides of the nozzle 30 can be described by a Fourier series, in polar coordinates (radius vector q, angle γ) with centre Sₖ (fig. 7).

In this Fourier series the relation \( q_L = \frac{N}{N} \cdot L \) is used, where N is the total number of measurements and N was chosen to be 30 i.e. measurements were made at 6° intervals, L is the number of measurement: \( L = 0, 1, \ldots, N-1 \), and \( q_L \) is the angle corresponding to the measurement in question.

The radius vector \( q_L \) for each measurement is then obtained.
from the following approximation formula:

\[ f_L = \frac{R}{9} \sum_{k=0}^{\infty} A(k) \cdot \cos (K \cdot 2 \varphi_L) \]  

(equation I)

in centimetres.

The coefficients for an opening of maximum, minimum and preferred size were worked out both for the inlet and the outlet sides of the nozzle. These are presented in the following table:

<table>
<thead>
<tr>
<th>Table</th>
<th></th>
<th>minimum size</th>
<th>maximum size</th>
<th>Preferred sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>A (K)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>minimum</td>
<td>maximum</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Inlet side</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (0)</td>
<td>+ 3,160</td>
<td>+ 6,050</td>
<td>+ 3,793</td>
<td>+ 4,116</td>
</tr>
<tr>
<td>A (1)</td>
<td>+ 0,677</td>
<td>- 1,064</td>
<td>- 0,189</td>
<td>+ 0,310</td>
</tr>
<tr>
<td>A (2)</td>
<td>- 1,241</td>
<td>+ 3,644</td>
<td>- 1,942</td>
<td>- 1,745</td>
</tr>
<tr>
<td></td>
<td>- 1,387</td>
<td>- 0,719</td>
<td>- 1,059</td>
<td>- 1,272</td>
</tr>
<tr>
<td>Outlet side</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (0)</td>
<td>+ 5,303</td>
<td>+ 7,308</td>
<td>+ 6,045</td>
<td></td>
</tr>
<tr>
<td>A (1)</td>
<td>- 0,764</td>
<td>- 1,534</td>
<td>- 0,981</td>
<td></td>
</tr>
<tr>
<td>A (2)</td>
<td>- 2,204</td>
<td>- 4,002</td>
<td>- 2,621</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 0,624</td>
<td>- 0,344</td>
<td>- 0,846</td>
<td></td>
</tr>
</tbody>
</table>

By using equation I a banana-shaped design is obtained for the various openings, as shown in fig. 8. The approximation
of the Fourier equation leads however to an irregular shape in the middle of the upper part of the curve which is to be corrected by the contour \( F \), as shown in fig. 8. Between the maximum and minimum sizes there are average sizes which are similar in shape and come into question as the contours for the inlet and outlet sides of the nozzle opening 31. The values of \( A(K) \) mentioned in the table hereabove are valid for a diameter of the nozzle or of the mold of 9 cm. However the factor \( \frac{R}{9} \) in equation I gives the correction for all other values of \( R \) automatically.

As seen from the centre \( Z \) of the nozzle, the opening sizes so obtained for the inlet side of the nozzle extend within an angle of about 90 to 180°, preferably of above 120° ± 15°.

In particular, it is possible to design the nozzle opening, as shown in fig. 5. On the inlet side of the nozzle the opening 31 is delimited: - below by an arc-shaped curve \((K)\) the centre of which coincides approximately with the centre of the nozzle, - above by an arc-shaped curve of a larger radius and having its centre above the centre \( Z \) of the nozzle, - and at the side by two arcs of smaller diameter. This results in the banana-shaped opening which narrows towards its ends. In this nozzle, shown in fig. 5, the opening size on the inlet side of the nozzle extends within an angle of 120°, as seen from the centre \( Z \) of the nozzle.
In this version the lower curve or edge K runs parallel to the contour of the conical surface 48 with the edge K₁. Between the curves, or edges, K and K₁ there is the run-out surface Q which is in the form of an elongated S-curve as shown in longitudinal section in fig. 6.

The difference in height h between the edges K and K₁, as shown in fig. 6, is 10 - 35 mm, preferably 16 - 25 mm, in nozzles having a total thickness (including the edge 47) of about 50 mm. For thicker or thinner nozzle bodies these limits of h may vary proportionally.

A particularly favourable longitudinal contour for the run-out surface of the nozzle slit 31 at its lowest point is obtained from the equation expressed in cartesian coordinates:

\[
f = \sum_{K=0}^{4} B_K \cdot X^K \quad \text{(equation II)}
\]

where f is the relevant vertical distance between a point on the contour and a horizontal H shown in fig. 9, and X is the relevant horizontal distance to the end face of the edge 47.

If f and X are expressed in centimetres, the following values hold for the coefficients B_K:
\[
\begin{align*}
B_0 &= +0.0588 \\
B_1 &= -0.0454 \\
B_2 &= +0.6459 \\
B_3 &= -0.1744 \\
B_4 &= +0.01325
\end{align*}
\]

These values for B lead, for a nozzle plate of total thickness of 48 mm, to a vertical difference h of 24.6 mm between the edges K and K. A flatter or steeper run-out surface within the usable h-values of 15 to 35 mm is achieved, if the relevant f-values of one of each curve is reduced or increased by up to 40%. On both sides of the vertical symmetry plane the run-out surface, as viewed in longitudinal section, exhibits a similar or approximately similar path.

The overall shape of the opening 1 and the nozzle slit 31 can be seen from figs 2 and 3:

On the inside 25 of the trough there is an almost oval funnel edge 50 of a height i above the floor 24 of the trough corresponding approximately to the length n of the opening 1. The opening 1 narrows symmetrically with respect to a vertical plane from this funnel edge 50.

The longitudinal section as in fig. 3 shows the upper edge 51 of the opening 1 in the unit 27, approximately in the
form of a catenary curve which runs relatively flat in the outer part 28 of the unit 27 and in the most part of the nozzle 30.

The lower face of the opening 1, 32, beginning from the trough end, rises at a gentle slope 52 to then form an approximately horizontal part 53, and then inside the nozzle 30 falls steeply by an amount h as a run-out surface. This produces together with the incurvature in cross section a saddle shape for the said lower face.

Due to the shape of the nozzle opening 31, the hot stream of the molten metal is directed obliquely onto the lower part of the inner face of the mold, with the result that:

the coarse clusters of floating crystals which sink under the force of gravity to the lower part of the sump are redissolved or made smaller by remelting, and therefore the region of the pasty zone is made narrower,

the natural thermal convection is to a large extent compensated in that the lower part of the sump is fed by the hot melt stream and the upper part of the sump lies away from the stream, this resulting in a large equalisation of temperature within the sump.
In the region where the effect is mainly desired, the pouring slit 31 presents also its greater width and allows the passage of more hot melt and therefore of more heat. In this way, the formation of clusters or agglomeration of particles as well as of a "marble" structure can be avoided. The laminar flow is maintained everywhere; there is neither turbulence nor dead spaces or corners. The sump geometry is symmetrical and the cross section of the billet or ingot B consequently has a completely homogeneous structure.

The trumpet shape of the unit 27 in the trough G results in an optimum flow of metal towards the nozzle and to a further diminution of the "marble" structure caused by dead zones and turbulence; there is only laminar acceleration up to the nozzle 30.

Furthermore, due to this trumpet shape, stationary metal (cold melt) is avoided in the trough G, which cold melt, if appearing and allowed to flow into the sump, would cause so-called pre-solidification and produce clusters.

Smooth, uniform, defect-free ingot surfaces are obtained by means of a relatively simple shape of nozzle 30 which can be produced at no extra expense and requiring only little time for fitting into place.
The melt feed system described is particularly suitable for casting round ingots or the like. This melt feed system can however also be used for casting rectangular rolling ingots and other sections. Also for such shapes it appears that particular regions of the ingot cross section, particularly near the edges, require more heat, that is a larger hot melt feeding than other regions. Accordingly it will be possible to dispose the wider part of the pouring slit not in the middle of the slit as this is required for round ingots or the like, but in the side parts of the slit, and also to form the run-out surface in order to direct more metal to the exposed regions. Besides that all prescriptions relating to the spacing or chamber and its leading surface on the end face 46 of the nozzle as well as to the position of the mold with respect to the nozzle remain valid.
The claims defining the invention are as follows:

1. Device for continuous horizontal casting metals, particularly aluminum and its alloys, using a casting trough, holding furnace or the like having in a wall near the bottom an outlet onto which an opening provided in the lower part of a disc-shaped nozzle connects up in the direction of casting as a transition to a mold, in which device for casting round ingots or the like the opening in the nozzle is, in end view, in the form of an approximately banana- or mouth-shaped slit tapered towards its ends, with at least an approximately arc-shaped, curved, contoured part and, at least in the region of the vertical plane of symmetry of the nozzle, is provided with a run-out surface sloping down in the direction of casting and running without any step into the inner surface of the mold.

2. Device for continuous horizontal casting metals, particularly aluminum and its alloys, using a casting trough, holding furnace or the like having in a wall near the bottom an outlet onto which an opening provided in the lower part of a disc-shaped nozzle connects up in the direction of casting as a transition to a mold, in which device the said outlet is in the form of a trumpet-shaped taper opening up towards the inside of the trough and the lower surface of the opening is curved saddle-shaped above the level of the surface of the floor of the trough.

3. Device according to claim 1, in which the nozzle opening on the inlet side of the nozzle has a contour of a form as expressed in polar coordinates with radius $R_L$ and angle of inclination $\varphi_L$ by the following approximation formula:

$$
S_L = \frac{R}{9} \sum_{K=0}^{3} A(K) \cdot \cos(K \cdot 2\varphi_L) [\text{cm}]
$$

wherein $R$ is the radius of the nozzle, expressed in centimetres, and the Fourier coefficients $A(K)$ have the following values:

<table>
<thead>
<tr>
<th></th>
<th>smaller opening size</th>
<th>larger opening size</th>
<th>preferred opening sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A(0)$</td>
<td>+ 3,160</td>
<td>+ 6,050</td>
<td>+ 3,793</td>
</tr>
<tr>
<td>$A(1)$</td>
<td>+ 0,677</td>
<td>- 1,064</td>
<td>- 0,189</td>
</tr>
<tr>
<td>$A(2)$</td>
<td>- 1,241</td>
<td>- 3,644</td>
<td>- 1,942</td>
</tr>
</tbody>
</table>

where $\varphi_L$ and $R_L$ are defined by the following values:

$$
\varphi_L = \frac{2}{3} \sum_{K=0}^{3} A(K) \cdot \cos(K \cdot 2\varphi_L) [\text{deg}]
$$

and

$$
R_L = \frac{R}{9} \sum_{K=0}^{3} A(K) \cdot \cos(K \cdot 2\varphi_L) [\text{cm}]
$$

wherein $R$ is the radius of the nozzle, expressed in centimetres, and the Fourier coefficients $A(K)$ have the following values:

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</tr>
</tbody>
</table>
the so calculated curve being to be smoothed in the middle of its upper part, wherein the smaller size curve and the larger size curve represent the limits of the range for suitable opening contours of similar shape.

4. Device according to claim 1 or 3, in which the nozzle opening on the outlet side of the nozzle has a contour of a form as expressed in polar coordinates with radius $\psi_L$ and angle $\phi_L$ by the following approximation formula:

$$\psi_L = \frac{R}{9} \cdot \sum_{K=0}^{3} A(K) \cdot \cos(K \cdot 2 \psi_L) \text{ [cm]}$$

wherein $R$ is the radius of the nozzle in centimetres and the Fourier coefficients have the following values:

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<tbody>
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<td>opening</td>
<td>opening</td>
<td></td>
</tr>
<tr>
<td>size</td>
<td>size</td>
<td>size</td>
<td></td>
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<td>-1,534</td>
<td>-0,981</td>
</tr>
<tr>
<td>A(2)</td>
<td>-2,204</td>
<td>-4,002</td>
<td>-2,621</td>
</tr>
<tr>
<td>A(3)</td>
<td>-0,624</td>
<td>-0,344</td>
<td>-0,846</td>
</tr>
</tbody>
</table>

the so calculated curve being to be smoothed in the middle of its upper part, wherein the smaller size curve and the larger size curve represent the limits of the range for suitable opening contours of similar shape.

5. Device according to at least one of the claims 1 to 4, in which the opening of the nozzle is symmetric to the vertical plane of symmetry of the nozzle.

6. Device according to claim 1, in which the opening is diffusive in form in the direction of casting.

7. Device according to at least one of the claims 1 to 6, in which the run-out surface of the nozzle opening presents in longitudinal cross section the form of an elongated S-curve.

8. Device according to claim 7, in which the run-out surface of the nozzle opening presents at least in the lowest region, in longitudinal cross section, a shape as expressed in cartesian coordinates, by the approximation formula:

$$f = \sum_{K=0}^{4} B_K \cdot X^K$$
wherein \( f \) is the vertical distance, in centimetres, of the contour at any given point from a horizontal, the distance in centimeters of that point to the extreme outlet face of the nozzle, and \( B_K \) is a coefficient with values as follows:

\[
\begin{align*}
B_0 &= +0.0588 \\
B_1 &= -0.0454 \\
B_2 &= +0.6459 \\
B_3 &= -0.1744 \\
B_4 &= +0.01325
\end{align*}
\]

and the value of the factor \( a \) is 0.6 to 1.4, preferably 0.8 to 1.2.

9. Device according to at least one of the claims 1 to 8, particularly according to claim 2, in which the upper contour of the outlet opening, as viewed in section through its middle, is approximately half of a catenary curve in appearance.

10. Device according to at least one of the claims 1 to 9, particularly according to claims 2 and 9, in which at least the trumpet-like entry taper in the opening is contained in a special insertable part of the casting trough or the like.

11. Device according to at least one of the claims 1 to 10, in which the wall part penetrated by the opening is made of refractory material and is combined with the nozzle to make a built-in unit.

12. Device according to at least one of the claims 1 to 11, in which a circumferential projecting ring-shaped edge is provided on the outlet side of the nozzle, this ring-shaped edge defining a chamber before the mold entrance, and the surface of this ring-shaped edge, towards the said chamber, running all around without any step into the inner surface of the mold.

13. Device according to claim 12, in which the surface of the ring-shaped edge, towards the chamber, goes into the bottom surface of the chamber over an incurved surface portion, which may be followed, in direction of the mold, by a conically shaped surface.

14. Device according to one of the claims 1 to 13, in which the tangent to the surface of the ring-shaped edge, towards the chamber, and of the run-out surface of the nozzle opening, makes, near the mold, an angle of 0° to 45°, preferably of 10° to 30°, with the common axis of the nozzle and of the mold.
15. Device according to one of the claims 1 to 14, in which the run-out surface of the nozzle opening runs smoothly into the surface of the ring-shaped edge, towards the chamber, at least in the part of this last surface near the mold.

16. Device according to one of the claims 1 to 15, in which for casting ingots of rectangular cross section the widest portions of the nozzle opening are provided not in the middle, but near or at the side ends of this opening.

DATED: 18th December, 1978.

PHILLIPS ORMONDE AND FITZPATRICK
Attorneys for:
SWISS ALUMINIUM LTD.

David C. Fitzpatrick
Fig. 1
Fig. 5

Fig. 6