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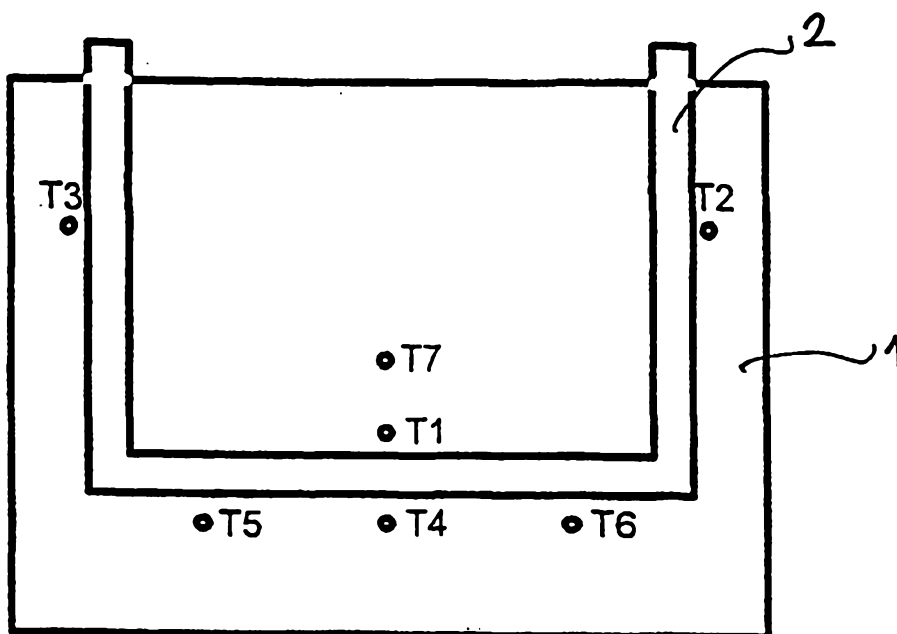


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<p>(21) International Application Number: PCT/FI99/01030 (22) International Filing Date: 14 December 1999 (14.12.99) (30) Priority Data: 982770 22 December 1998 (22.12.98) FI (71) Applicant (for all designated States except US): OUTOKUMPU OYJ [FI/FI]; Riihitontuntie 7, FIN-02200 Espoo (FI). (72) Inventors; and (75) Inventors/Applicants (for US only): HUGG, Eero [FI/FI]; Aamukuja 4 H, FIN-02200 Espoo (FI). KOJO, Ilkka [FI/FI]; Malmen 140, FIN-02430 Masala (FI). MÄKINEN, Pertti [FI/FI]; Suulotintie 35, FIN-28610 Pori (FI). KOOTA, Raimo [FI/FI]; Virkkala, FIN-29250 Nakkila (FI). (74) Agent: OUTOKUMPU OYJ; Patent Services, P.O. Box 27, FIN-02201 Espoo (FI).</p>		<p>(81) Designated States: AU, BR, CA, CN, DE, ES, IN, JP, KR, KZ, MX, PL, PT, RU, SE, TR, US, YU, ZA, Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published With international search report.</p>

(54) Title: PYROMETALLURGICAL REACTOR COOLING ELEMENT AND ITS MANUFACTURE



(57) Abstract

The invention relates to a method of fabricating a pyrometallurgical reactor cooling element with flow channels. In order to enhance heat transfer capability, the wall surface area of the flow channel, which is traditionally round in cross-section, is increased without increasing the diameter or length of the channel.

PYROMETALLURGICAL REACTOR COOLING ELEMENT AND ITS MANUFACTURE

Field of the Invention

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The present invention relates to a cooling element for pyrometallurgical reactors and its method of manufacture.

Background of the Invention

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The refractory of reactors in pyrometallurgical processes is protected by water-cooled cooling elements so that, as a result of cooling, the heat coming to the refractory surface is transferred via the cooling element to water, whereby the wear on the lining is significantly reduced compared with a reactor which is not cooled. Reduced wear is caused by the effect of cooling, which brings about forming of so called autogenic lining, which fixes to the surface of the heat resistant lining and which is formed from slag and other substances precipitated from the molten phases.

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Conventionally, cooling elements are manufactured in a number of ways. Primarily, elements are manufactured by sand casting, where cooling pipes made of a highly thermal conductive material such as copper are set in a sand-formed mould, and are cooled with air or water during the casting around the pipes. The element case around the pipes is also of highly thermal conductive material, preferably copper. This kind of manufacturing method is described in e.g. GB patent no. 1386645. One problem with this method is the uneven attachment of the piping acting as cooling channel to the cast material surrounding it. Some of the pipes may be completely free of the element case around it and part of the pipe may be completely melted and thus fused with the element. If no metallic bond is formed between the cooling pipe and the rest of the case element around it, heat transfer will not be efficient. Again if the piping melts completely, that will prevent the flow of cooling water. The casting properties of the cast material can be improved, for example, by mixing phosphorous with the copper to improve the metallic bond formed between the piping and the cast material, but in that case, the heat transfer properties (thermal conductivity) of the copper are significantly weakened by even a small addition.

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Another method of manufacturing cooling elements for pyrometallurgical reactors is where glass tubing in the shape of a channel is set into the cooling element mould, which is broken after casting to form a channel inside the element.

US patent 4,382,585 describes another, much used method of manufacturing cooling elements, according to which the element is manufactured for example from rolled or forged copper plate by machining the necessary channels into it. The disadvantages with this method are the dimensional limitations (size) and the high cost.

The ability of a cooling element to receive heat can be represented by the following formula:

$Q = a \times A \times \Delta T$, where
Q = amount of heat being transferred [W]
a = heat transfer coefficient between flow channel wall and water [W/Km²]
A = heat transfer surface area [m²]
 ΔT = difference in temperature between flow channel wall and water [K]

Heat transfer coefficient *a* can be determined theoretically from the formula

$Nu = a D / \lambda$
λ = thermal conductivity of water [W/mK]
D = hydraulic diameter [m]

Or $Nu = 0.023 \times Re^{0.8} Pr^{0.4}$,
where
 $Re = wD / \eta$
w = speed [m/s]
D = hydraulic diameter of channel [m]
ρ = density of water [kg/m³]
η = dynamic viscosity
Pr = Prandtl number []

Thus, according to the above, it is possible to influence the amount of heat transferred in a cooling element by influencing the difference in temperature, the heat transfer coefficient or the heat transfer surface area.

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The difference in temperature between the wall and the tube is limited by the fact that water boils at 100°C, when the heat transfer properties at normal pressure become significantly worse due to boiling. In practice, it is more advantageous to operate at the lowest possible flow channel wall temperature.

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The heat transfer coefficient can be influenced largely by changing the flow speed, ie. by affecting the Reynolds number. This is limited however by the increased loss in pressure in the tubing as the flow rate increases, which raises the costs of pumping the cooling water and pump investment costs also grow considerably after a certain limit is exceeded.

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A conventional method of increasing the heat transfer surface area is by either increasing the diameter of the cooling channel and/or its length.

20 The cooling channel diameter cannot be increased unrestrictedly in such a way as to be still economically viable, since an increase in channel diameter increases the amount of water required to achieve a certain flow rate and also the energy requirement for pumping. Furthermore, the channel diameter is limited by the physical size of the cooling element, which for reasons of
25 minimizing costs, is preferably made as small and as light as possible. Another limitation on length is the physical size of the cooling element itself, i.e. the quantity of cooling channel that will fit in a given area.

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Summary of the Invention

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According to a first aspect of the present invention, there is provided a cooling element for a pyrometallurgical reactor, the cooling element comprising a wrought, highly thermally conductive metal plate having at least one cooling water flow channel of generally circular cross section machined in the metal plate, the surface of the channel having threads or grooves machined therein.
35 Preferably, the wrought metal plate is a copper plate. Preferably, the threads or grooves are rifling grooves. Preferably, the threads or grooves are rifling

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grooves machined by an expanding mandrel.

According to a second aspect of the present invention, there is provided a method of manufacturing a cooling element for a pyrometallurgical reactor, the method including the steps of:

- 5 (a) providing a wrought, highly thermally conductive metal plate;
- (b) machining at least one cooling water flow channel of generally circular cross-section in the metal plate; and
- 10 (c) machining threads or grooves in the surface of the at least one cooling water flow channel. Preferably, the threads or grooves are rifling grooves. Preferably, the threads or grooves are rifling grooves machined in the surface of the at least one cooling water flow channel by an expanding mandrel.

15 According to a third aspect of the present invention, there is provided a pyrometallurgical reactor having a cooling element as described above.

Brief Description of the Drawings

20 Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a principle drawing of the cooling element used in the tests, Figure 2 shows a cross-sectional profile of the test cooling element, 25 Figures 3a – 3d indicate the temperature inside the element at different measuring points as a function of melt temperature. Figure 4 presents the heat transfer coefficient calculated from the measurements taken as a function of the melt, and Figure 5 presents the differences in temperature of the cooling water and the 30 channel wall at different cooling levels for normalized cooling elements.

Detailed Description of the Drawings

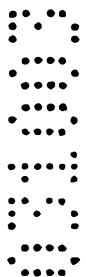
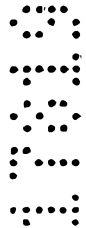
Example

35 The cooling elements relating to the present invention were tested in practical tests, where the bottom of said elements A, B, C and D were immersed in about

1cm deep molten lead. Cooling element A had a conventional smooth-surfaced flow channel, and this element was used for comparative measurements. The amount of cooling water and the temperatures both before feeding the water into the cooling element and afterwards were carefully measured in the tests.

- 5 The temperature of the molten lead and the temperatures inside the cooling element itself were also carefully measured at seven different measuring points.

Figure 1 shows the cooling element 1 used in the tests, and the flow channel 2 inside it. The dimensions of the cooling element were as follows: height 300
10 mm, width 400 mm and thickness 75 mm. The cooling tube or flow channel was situated inside the element as in Figure 1, so that the centre of the horizontal part of the tube in the figure was 87 mm from the bottom of the element and each vertical piece was 50 mm from the edge of the plate. The horizontal part of the tube is made by drilling, and one end of the horizontal
15 opening is plugged (not shown in detail). Figure 1 also shows the location of temperature measuring points T1 – T7. Figure 2 presents the surface shape of the cooling channels and Table 1 contains the dimensions of the test cooling element channels and the calculatory theat transfer surfaces per metre as well as the relative heat transfer surfaces.



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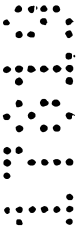


Table 1

	Diameter mm	Flow cross-sectional area mm ²	Heat transfer surface / 1m m ² /1m	Relative heat transfer surface area
A	21.0	346	0.066	1.00
B	23.0	415	0.095	1.44
C	23.0	484	0.127	1.92
D	20.5	485	0.144	2.18

Figures 3a - 3d demonstrate that the temperatures of cooling elements B, C and D were lower at all cooling water flow rates than the reference measurements taken from cooling element A. However, since the flow cross-sections of the said test pieces had to be made with different dimensions for technical manufacturing reasons, the efficiency of the heat transfer cannot be compared directly from the results in Figures 3a - 3d. Therefore the test results were normalised as follows:

Stationary heat transfer between two points can be written:

$$Q = S \times \lambda \times (T_1 - T_2), \quad \text{where}$$

Q = amount of heat transferred between the points [W]

15 S = shape factor (dependent on the geometry) [m]

λ = thermal conductivity of the medium [W/mK]

T_1 = temperature of point 1 [K]

T_2 = temperature of point 2 [K]

20 Applying the above equation to the test results, the following quantities are obtained:

Q = measured thermal power transferred to cooling water

λ = thermal conductivity of copper [W/mK]

T_1 = temperature at bottom of element as calculated from tests [K]

25 T_2 = temperature of water channel wall as calculated from tests [K]

S = shape factor for a finite cylinder buried in a semi-infinite medium (length L, diameter D) shape factor can be determined according to the equation

$$S = 2\pi L / \ln(4Z/D) \quad \text{when } Z > 1.5D,$$

z = depth of immersion measured from the centre line of the cylinder [m].

The heat transfer coefficients determined in the above way are presented in Figure 4. According to multivariate analysis a very good correlation is obtained between the heat transfer coefficient and the water flow rate as well as the amount of heat transferred to the water. The regression equation heat transfer coefficients for each cooling element are presented in Table 2.

Thus a [W/m^2K] = $c + a \times v$ [m/s] + $b \times Q$ [kW].

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Table 2

	C	A	b	r^2
A	4078.6	1478.1	110.1	0.99
B	3865.8	1287.2	91.6	0.99
C	2448.9	1402.1	151.2	0.99
D	2056.5	2612.6	179.7	0.96

To make the results comparable, the cross-section areas of the flow channels were normalized so that the amount of water flow corresponds to the same flow rate. The flow channel dimensions and heat transfer surface areas normalized according to the flow amount and rate are presented in Table 3. Using the dimensions given in Table 3 for cases A', B', C' and D' and the heat transfer coefficients determined as above, the temperature difference of the wall and water for normalized cases regarding the flow amount were calculated as a function of water flow rate for 5, 10, 20 and 30 kW heat amounts with the equation

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$$\Delta T = Q / (a \times A)$$

Table 3

	Diameter mm	Flow cross-sectional area mm ²	Heat transfer surface / 1m m ² /1m	Relative heat transfer surface area
A*	21.0	346	0.066	1.00
B*	21.0	346	0.087	1.32
C*	19.2	346	0.120	1.82
D*	15.7	346	0.129	1.95

25

The results are shown in Figure 5. The figure shows that all the cooling elements manufactured according to this invention achieve a certain amount of heat transfer with a smaller temperature difference between the water and the cooling channel wall, which illustrates the effectiveness of the method.

- 5 For example, at a cooling power of 30kW and water flow rate of 3 m/s, the temperature difference between the wall and water in different cases is:

Table 4

	ΔT [K]	Relative ΔT [%]
A'	38	100
B'	33	85
C'	22	58
D'	24	61

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When the results are compared with the heat transfer surfaces, it is found that the temperature difference between the wall and the water needed to transfer the same amount of heat is inversely proportional to the relative heat transfer surface. This means that the changes in surface area
15 described in this invention can significantly influence the efficiency of heat transfer.

Claims:

1. A cooling element for a pyrometallurgical reactor, the cooling element comprising a wrought, highly thermally conductive metal plate having at least one cooling water flow channel of generally circular cross section machined in the metal plate, the surface of the channel having threads or grooves machined therein.

2. A cooling element as claimed in claim 1 wherein the wrought metal plate is a copper plate.

3. A cooling element as claimed in claim 1 or claim 2 wherein the threads or grooves are rifling grooves.

4. A cooling element as claimed in claim 1 or claim 2 wherein the threads or grooves are rifling grooves machined by an expanding mandrel.

5. A cooling element for a pyrometallurgical reactor, the cooling element being substantially as herein described with reference to the accompanying drawings.

6. A method of manufacturing a cooling element for a pyrometallurgical reactor, the method including the steps of:

(a) providing a wrought, highly thermally conductive metal plate;

(b) machining at least one cooling water flow channel of generally circular cross-section in the metal plate; and

(c) machining threads or grooves in the surface of the at least one cooling water flow channel.

7. A method as claimed in claim 6 wherein the threads or grooves are rifling grooves.

8. A method as claimed in claim 6 wherein the threads or grooves are rifling grooves machined in the surface of the at least one cooling water flow channel by an expanding mandrel.

9. A pyrometallurgical reactor having a cooling element as claimed in any one of claims 1 – 5.

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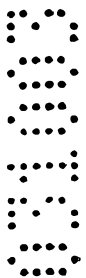
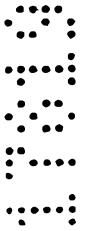
Dated this 2nd day of October 2003

Outokumpu Oyj

By its Patent Attorneys

GRIFFITH HACK

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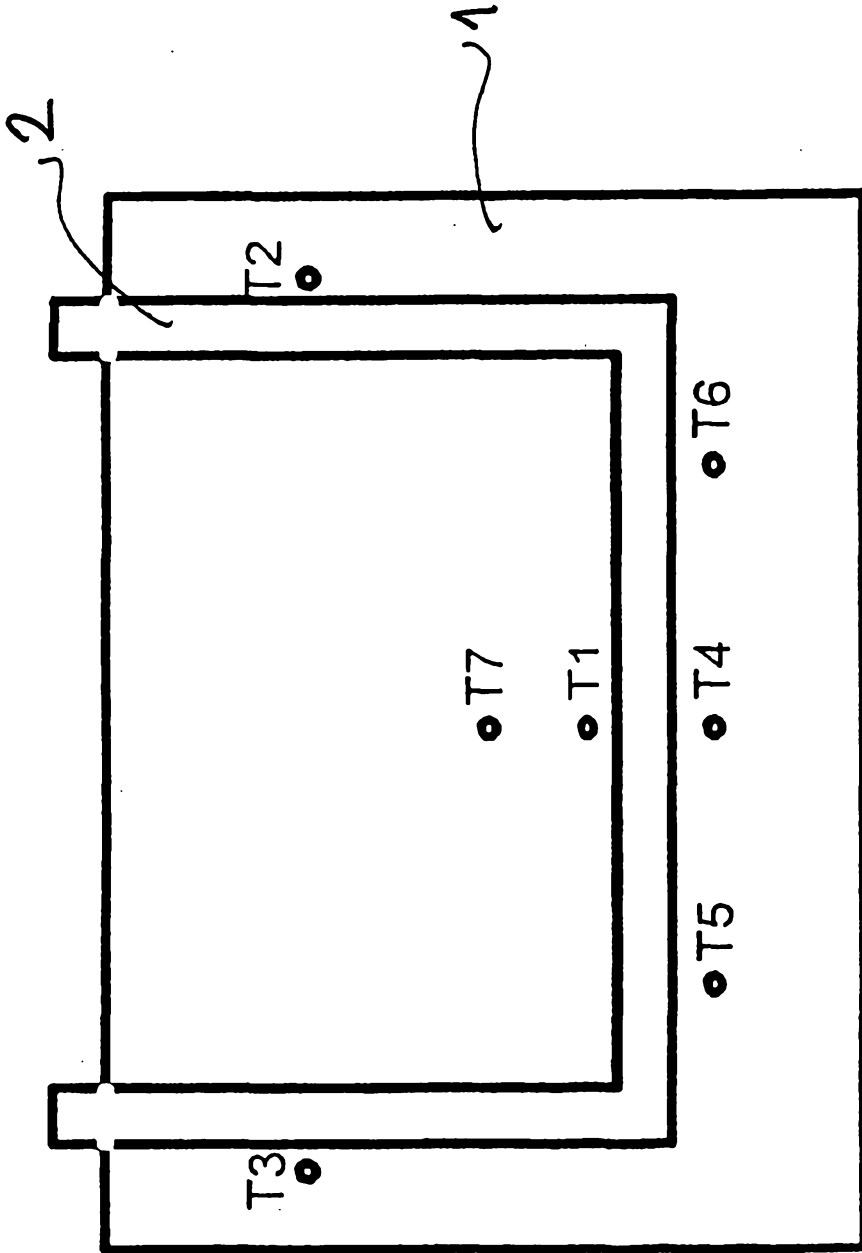


FIG. 1

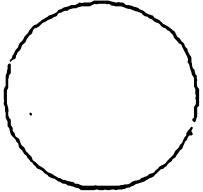
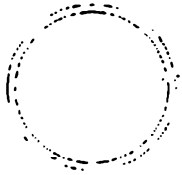
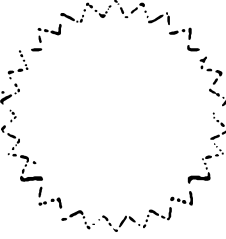
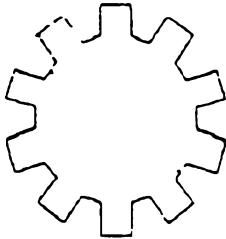
 <p>A: SMOOTH SURFACE</p>	 <p>B: SCREW THREAD</p>
 <p>C: DRAFTED V-GROOVE</p>	 <p>D: SLIP CAST GROOVE</p>

FIG. 2

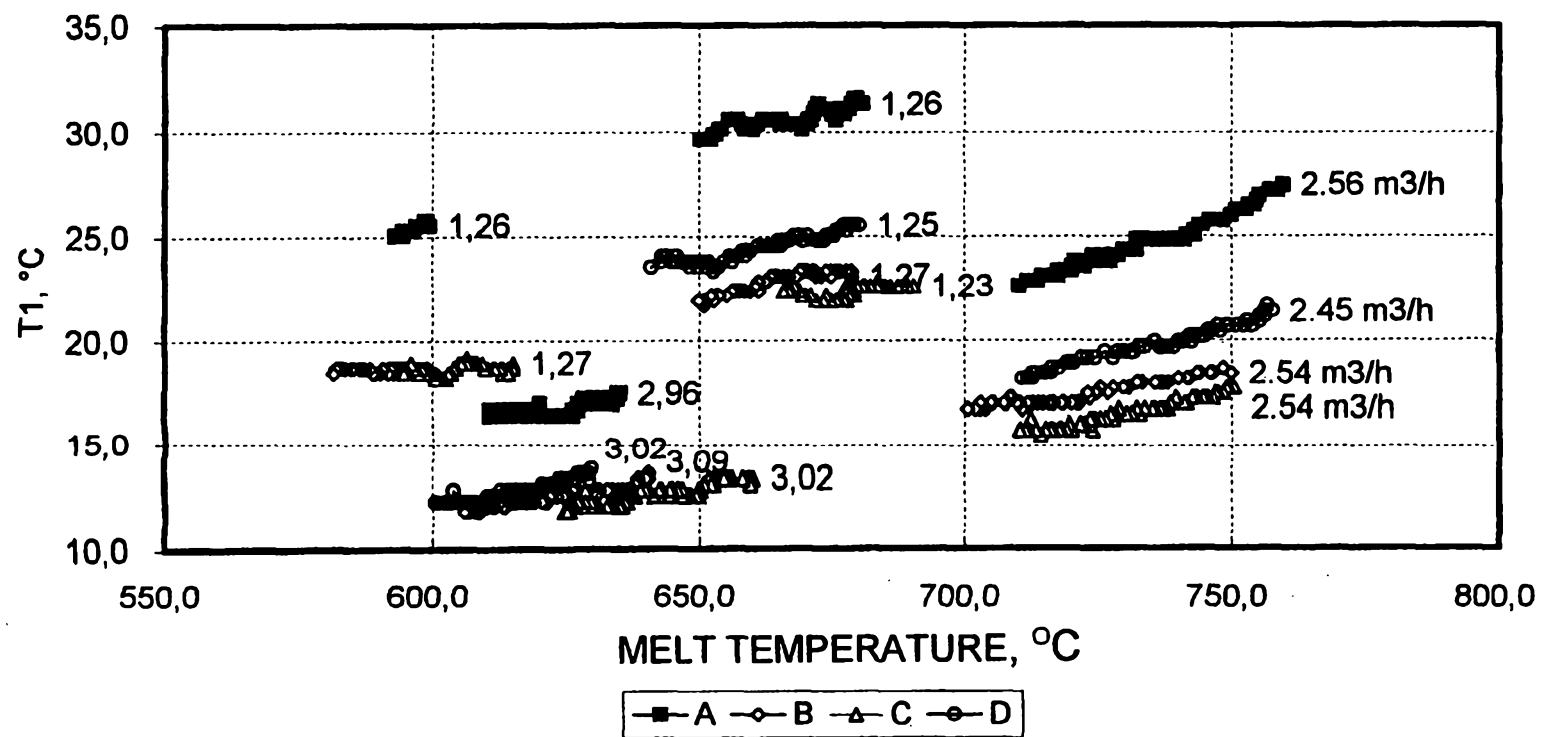


FIG. 3a

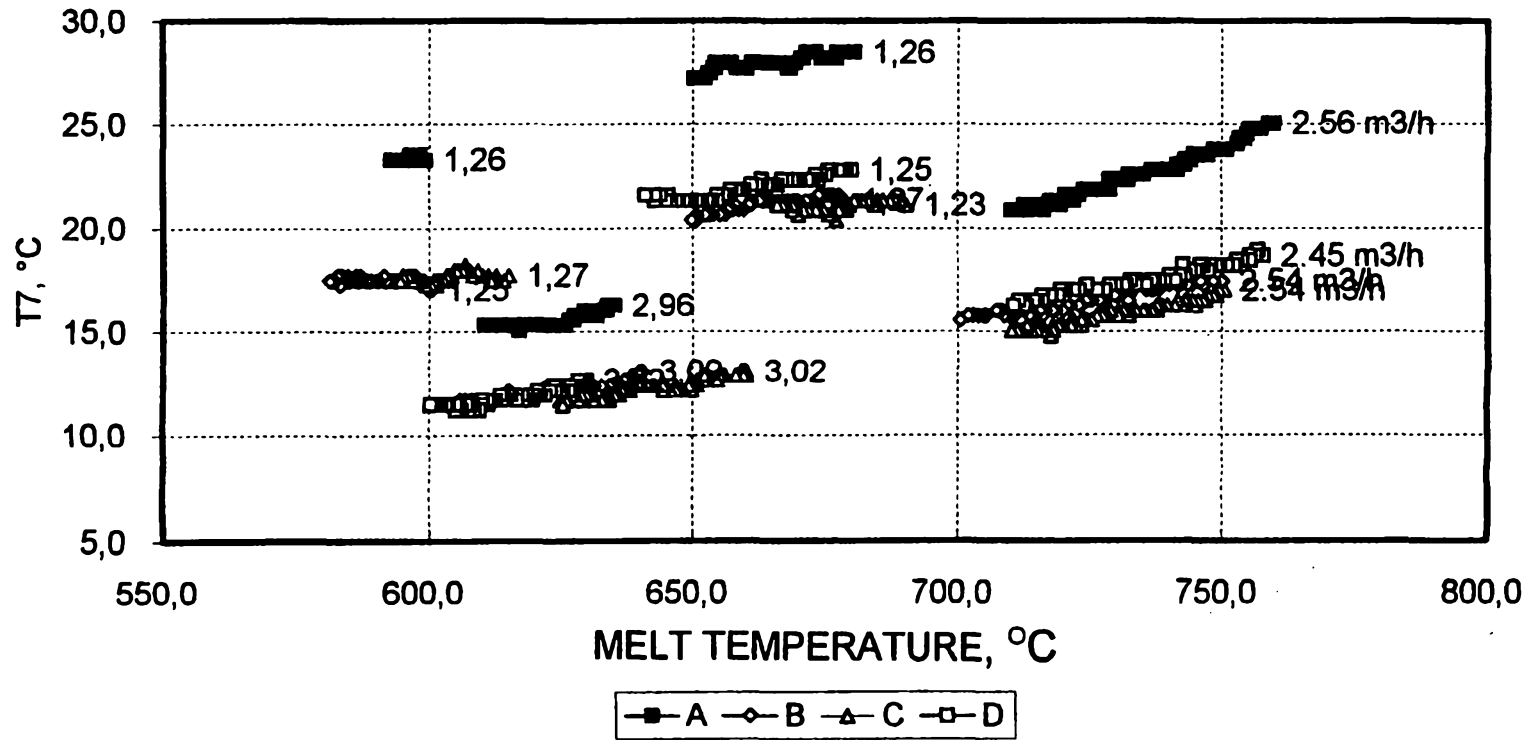


FIG. 3b

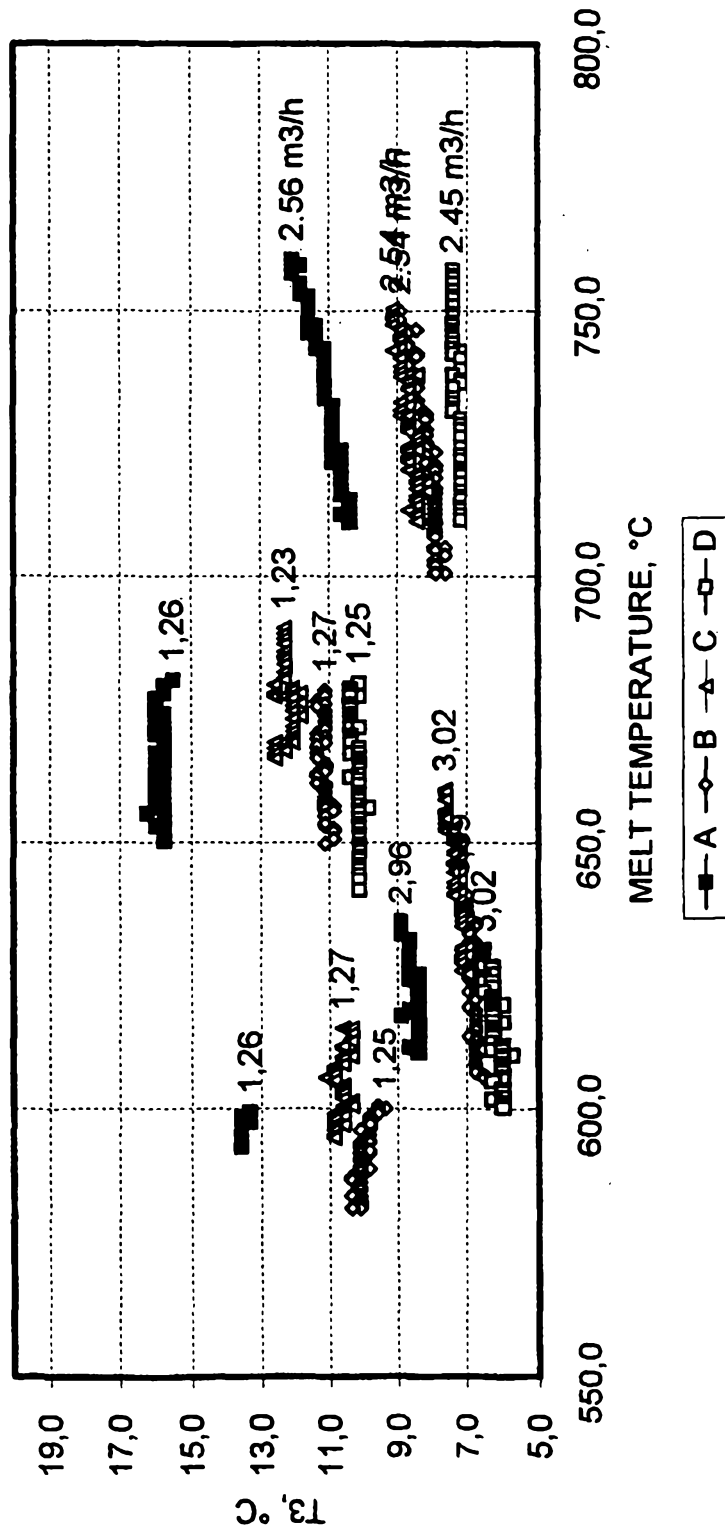


FIG 3C

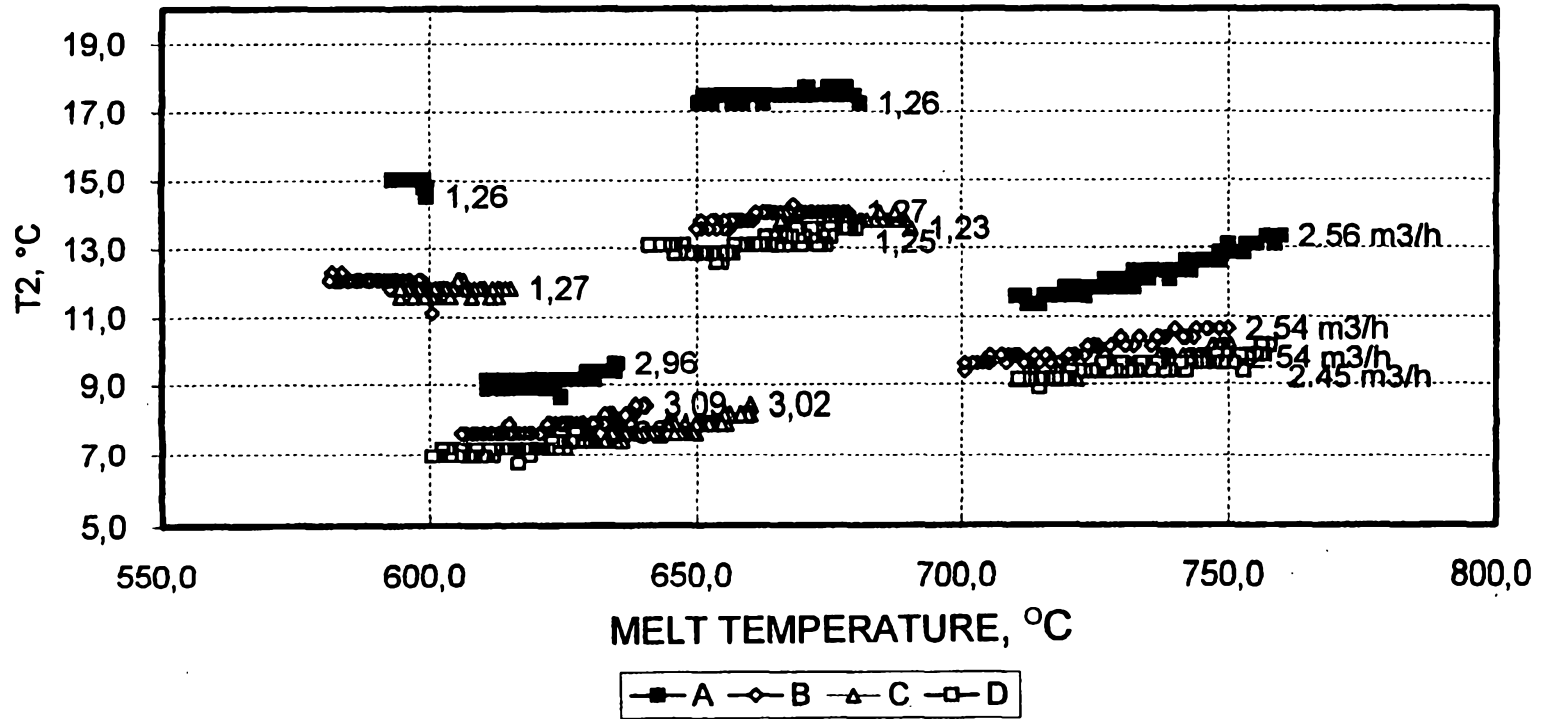


FIG. 3d

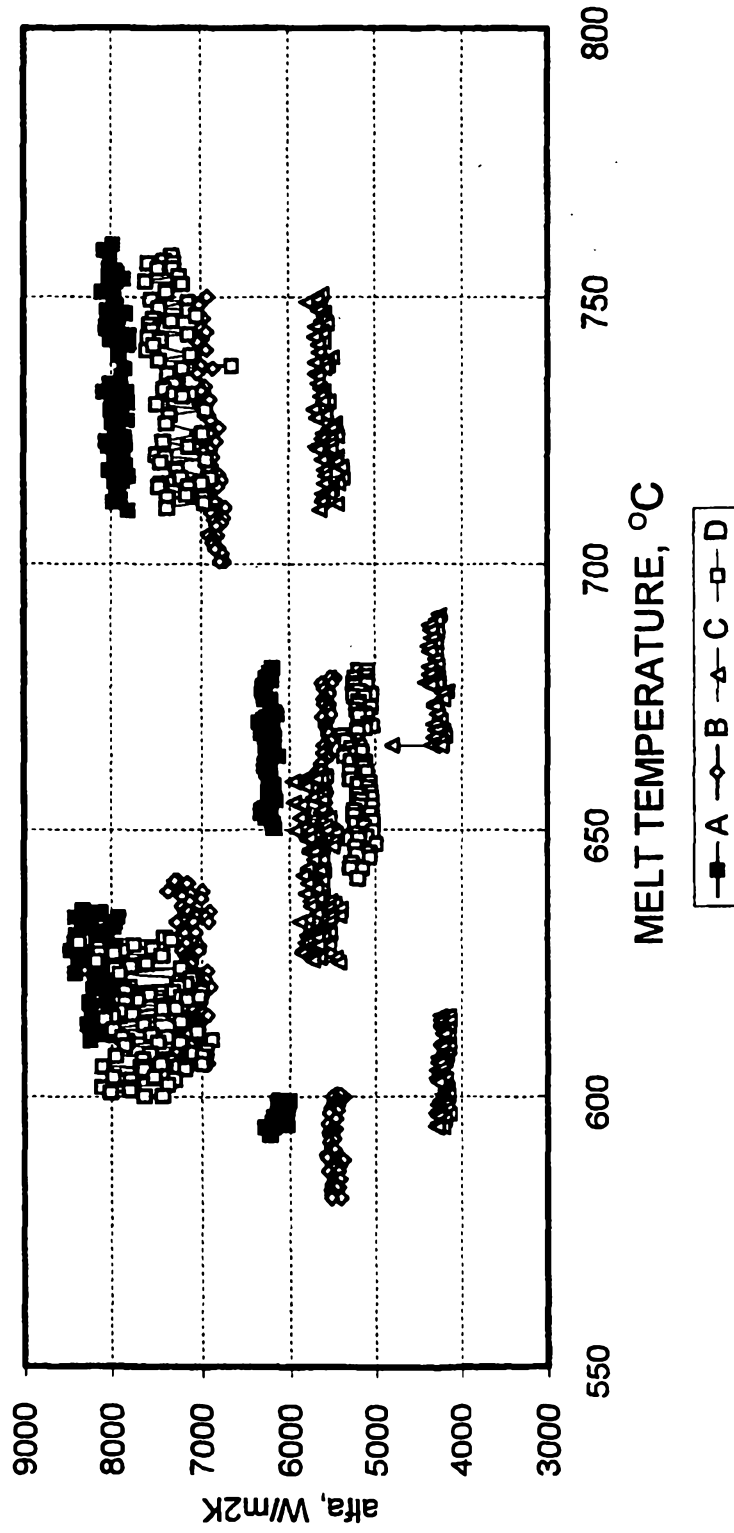


FIG. 4

THE TEMPERATURE DIFFERENCE BETWEEN THE WATER AND THE WATER CHANNEL WALL

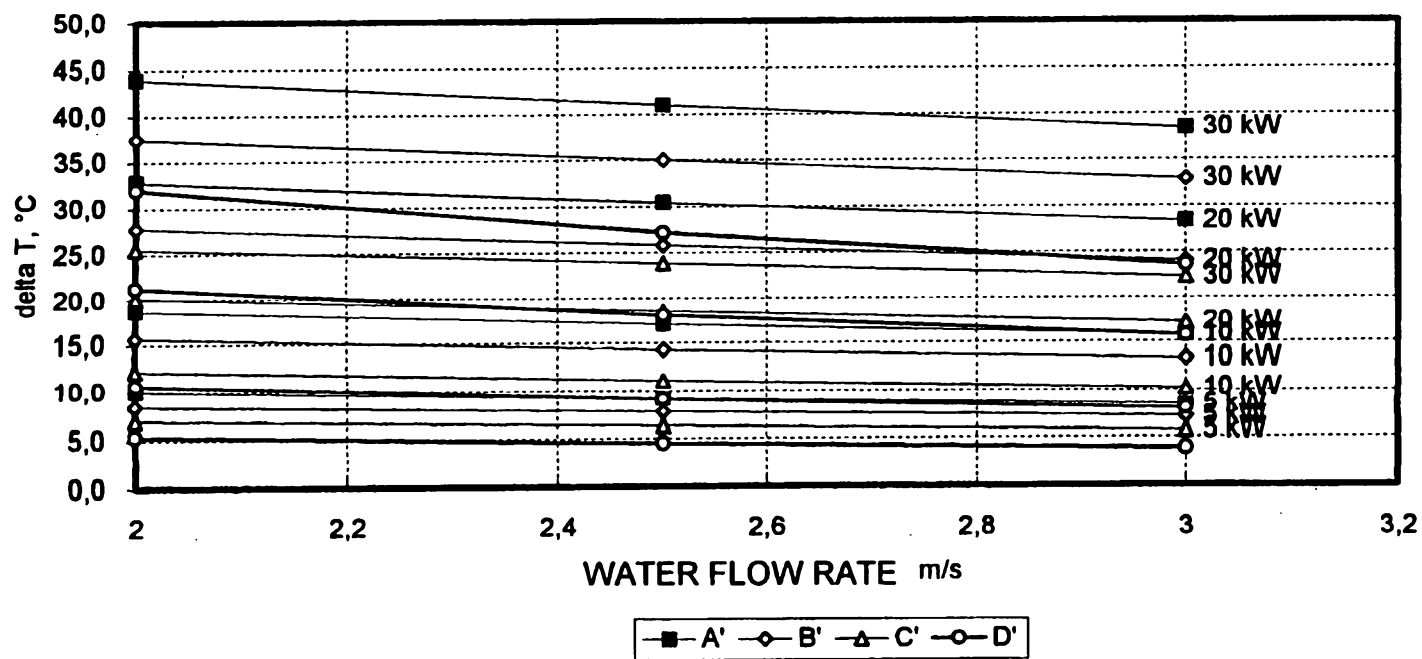


FIG. 5