

(12) STANDARD PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. **AU 2010232000 B2**

(54) Title
A method and a mixing station for mixing of bulk solid materials with broad particle size distribution

(51) International Patent Classification(s)
B01F 3/18 (2006.01) **B01F 13/10** (2006.01)
B01F 5/00 (2006.01) **B01F 15/02** (2006.01)

(21) Application No: **2010232000** (22) Date of Filing: **2010.03.26**

(87) WIPO No: **WO10/114381**

(30) Priority Data

(31)	Number	(32)	Date	(33)	Country
	20091342		2009.03.31		NO

(43) Publication Date: **2010.10.07**

(44) Accepted Journal Date: **2016.02.25**

(71) Applicant(s)
Norsk Hydro ASA

(72) Inventor(s)
Karlsen, Morten;Dyroy, Are;Hjelle, Vidar

(74) Agent / Attorney
Phillips Ormonde Fitzpatrick, L 16 333 Collins St, Melbourne, VIC, 3000

(56) Related Art
US 4358207 A
CN 86103783 A



(51) International Patent Classification:

B01F 3/18 (2006.01) **B01F 5/00** (2006.01)
B01F 13/10 (2006.01) **B01F 15/02** (2006.01)

(21) International Application Number:

PCT/NO2010/000113

(22) International Filing Date:

26 March 2010 (26.03.2010)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

20091342 31 March 2009 (31.03.2009) NO

(71) Applicant (for all designated States except US): **NORSK HYDRO ASA** [NO/NO]; N-0240 Oslo (NO).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **KARLSEN, Morten** [NO/NO]; Årdalsveien 19, N-6884 Øvre Årdal (NO). **DYRØY, Are** [NO/NO]; Ånnerødveien 27, N-3920 Porsgrunn (NO). **HJELLE, Vidar** [NO/NO]; Hjelle Gård, N-6884 Øvre Årdal (NO).

(74) Agent: **BERG, André**; Intellectual Property Department, Hydro Aluminium AS, N-0240 Oslo (NO).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: A METHOD AND A MIXING STATION FOR MIXING OF BULK SOLID MATERIALS WITH BROAD PARTICLE SIZE DISTRIBUTION

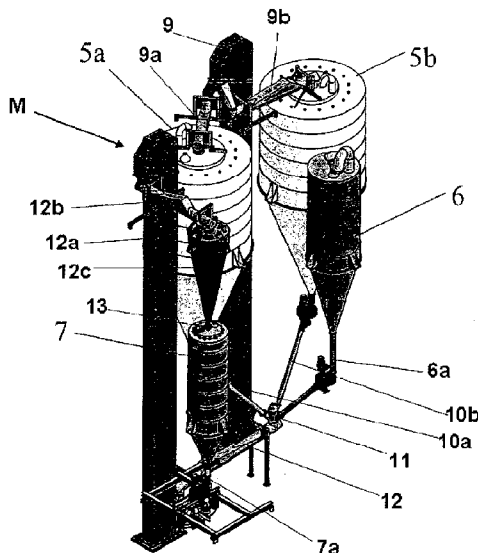


Fig. 5

(57) Abstract: A method and a station for mixing bulk solid material, in particular for mixing at least two materials (A, B) where at least one of these materials (A) has a broad particle size distribution. The material (A) is homogenized in a first mixer (5a, 5b) before being mixed together with material (B) in a second mixer (7). The material (A) is homogenized in a gravimetric mixer (5a, 5b) with plural chambers and which is discharged in accordance to the mass flow principle. The materials (A) and (B) are preferably mixed in a gravimetric mixer (7) with plural chambers and is further discharged in accordance to the mass flow principle. The material (A) is substantially crushed bath material. The material (B) is primary and/or secondary alumina that mixed with (A) will be used as recycled anode cover material (ACM).

WO 2010/114381 A1



Published:

— *with international search report (Art. 21(3))*

A method and a mixing station for mixing of bulk solid materials with broad particle size distribution

5 The present invention relates to a method and a station for mixing materials, such as bulk solids materials that have broad particle size distribution. In particular, the invention relates to preparation of anode covering material (ACM) in aluminium industry. Such material is used in electrolysis cells having prebaked anodes, as a covering material on the top and at the sides of the anode blocks as an encapsulating layer above the
10 electrolytic bath.

A reference herein to a patent document or other matter which is given as prior art is not to be taken as an admission that that document or matter was known or that the information it contains was part of the common general knowledge as at the priority date
15 of any of the claims.

ACM is a mixture of crushed bath and alumina, primary alumina and/or secondary alumina, in a ratio dependent of the electrolysis technology at the actual site. Such material can consist of a substantial amount of recycled material, for instance bath and/or
20 crust material grabbed out of electrolysis cells when replacing anodes or material removed from butts in a rodding facility.

In most existing installations for mixing of crushed bath and alumina to make ACM, mechanical mixers are used, mostly ordinary batch mixers or just metering plural material
25 streams by screw conveyors at the desired mixing ratio onto belt conveyors. To apply an ACM with homogenous particle distribution is important for heat balance in the cell.

A starting point for the development of the present invention is that crushed bath from aluminium electrolysis cells is a material that will segregate very easily, due to broad
30 particle distribution. Therefore, the methods have to be chosen in such a way that it will counteract segregation. To achieve this, the basic philosophy of homogenization is applied. This will reduce variation in the material stream, which otherwise would have to be corrected by the operator of the mixing apparatus or station. The installation as it is anticipated, will homogenize the incoming material flow, and at any time deliver a material
35 that has improved material properties with regard to homogenisation (even/constant particle size distribution (PSD)).

A correctly configured apparatus for mixing materials, such as a silo, can give as good, and in some cases better mixtures than what can be achieved by ordinary mechanical mixers. The reason for this is that a silo can mix or homogenize a lot larger quantities than what is possible with an ordinary mixer per unit time.

Based on the theories of Andrew W. Jenike: Gravity Flow of Bulk Solids, Bulletin 108, Utah University (1961), there is known how to design flow pattern defined as mass-flow and funnel-flow.

- 5 A silo consists normally of a parallel section and a converging section (hopper). By dividing the parallel section of a silo into several chambers by internal walls, and then fill them one by one and empty them simultaneously (in accordance to the principles of mass-flow), a mixing/homogenisation will take place. Commonly, such silo can be denoted gravimetric mixer.

10

In order to explain this concept, the easiest way is to show by an example how it works. Imagine that 300 samples are collected from the flow into the silo, evenly distributed in time. The average here: arithmetic mean (Average), and the standard deviation (Stot), are then calculated, giving the variation with time of the ingoing material, see Table 1. If

15 the samples in Table 1 are filled into a conventional mass-flow silo (without internal chambers) and then discharged, the variation (standard deviation) described by Stot in Table 2 will be the same.

Sample #	Conventional silo
1	7,25
2	7,63
3	14,71
4	12,95
5	7,78
6	7,63
7	15,54
8	8,58
9	10,61
10	15,61
	
291	6,21
292	15,17
293	11,65
294	9,12
295	5,15
296	9,09
297	15,21
298	7,10
299	8,90
300	10,70
Average	10,37
S _{tot}	3,23

20

Table 1. Example of input samples

Sample #	Conventional silo
1	7,25
2	7,63
3	14,71
4	12,95
5	7,78
6	7,63
7	15,54
8	8,58
9	10,61
10	15,61
	
291	6,21
292	15,17
293	11,65
294	9,12
295	5,15
296	9,09
297	15,21
298	7,10
299	8,90
300	10,70
Average	10,37
S _{tot}	3,23

Table 2. Example of calculations concerning homogenisation

5

To demonstrate the effect of gravimetric mixing in a silo, one can theoretically divide the silo mentioned above into for instance 10 chambers. These chambers are filled one by one with the same material as in Table 1, and a new chamber starts to fill up for each 30 samples.

10

When material is removed from the outlet of the silo, all chambers will be emptied in parallel or simultaneously, as a consequence of the mass-flow principle in contrast to funnel flow as in previous example. The samples in the various chambers will be mixed with each other. If 30 samples are collected during discharge, the first sample will ideally be an average of sample 1, 31, 61, and 271 from Table 1, the second will be the average of 2, 32, 62, and 272, and so on, as shown in Table 2. The standard deviation after discharge will then be what is given by Table 3.

15

Chamber01	Chamber02	Chamber03	Chamber04	Chamber05	Chamber06	Chamber07	Chamber08	Chamber09	Chamber10	Average
7,25	5,12	12,60	7,70	13,77	12,25	5,74	14,91	11,30	8,48	9,91
7,63	5,05	6,39	7,66	15,30	6,92	5,08	7,26	12,54	5,98	7,98
14,71	5,11	10,48	9,84	5,87	6,31	8,64	10,40	15,61	15,48	10,25
12,95	10,25	15,90	13,87	9,72	12,42	11,58	15,38	12,87	13,03	12,80
7,78	11,26	5,96	7,19	15,36	10,65	9,46	11,78	9,77	7,29	9,68
7,63	11,87	5,50	11,43	5,80	8,08	6,98	15,11	6,16	9,35	8,79
15,54	5,87	12,31	8,74	9,47	11,99	15,07	11,55	12,46	12,67	11,57
8,58	8,73	6,65	11,78	6,17	13,95	8,62	12,04	11,62	14,22	10,24
10,61	13,37	8,34	14,04	11,79	8,99	11,72	15,71	7,00	5,52	10,71
15,61	10,37	14,58	15,17	5,32	9,58	9,10	9,97	13,79	6,66	11,02
11,11	8,40	9,57	12,11	10,00	6,06	10,31	12,12	7,71	15,17	10,26
14,96	12,49	13,94	15,23	11,84	14,09	10,44	10,30	5,23	15,08	12,36
11,16	10,81	9,46	9,01	12,25	13,45	15,05	13,48	11,82	6,48	11,30
7,26	9,46	7,07	12,49	9,83	6,73	12,19	14,87	6,23	6,66	9,30
13,07	8,65	6,72	8,59	10,47	12,25	7,37	10,02	5,49	11,21	9,38
10,38	9,26	15,76	10,15	13,47	6,61	12,43	10,70	6,47	11,41	10,66
8,32	5,29	6,71	12,25	14,16	7,81	7,69	15,22	8,45	8,22	9,41
12,37	5,20	10,43	13,74	7,76	14,78	14,61	13,09	12,15	8,80	11,29
5,41	7,41	9,18	13,67	14,16	14,35	14,58	10,06	15,08	5,48	10,94
5,51	6,30	7,30	9,36	5,45	5,50	12,23	8,04	8,76	15,27	8,37
9,31	12,45	7,34	14,63	8,37	10,48	11,32	7,61	15,28	6,21	10,30
11,95	9,16	7,12	7,05	5,15	15,61	9,00	13,18	8,07	15,17	10,15
7,15	11,85	12,95	13,25	5,65	12,54	6,11	15,73	15,80	11,65	11,27
14,68	6,22	11,87	13,08	10,40	15,81	10,39	8,26	11,78	9,12	11,16
15,50	12,30	6,54	12,68	8,00	5,90	15,19	8,93	5,62	5,15	9,58
6,80	7,19	5,21	10,86	15,73	5,80	7,54	6,01	12,51	9,09	8,67
14,60	15,37	7,69	13,69	6,76	15,53	14,57	9,82	12,49	15,21	12,57
6,23	11,15	8,00	7,34	6,65	14,93	13,78	7,15	14,97	7,10	9,73
13,18	12,91	14,46	7,82	10,43	9,69	13,54	10,83	9,18	8,90	11,09
12,34	9,24	9,83	10,82	5,87	8,35	15,13	9,71	12,48	10,70	10,45
Average										10,37
S _{tot}										1,18

Table 3. Example of calculations concerning homogenisation when using several chambers in a silo

- 5 The 30 first samples are filled in the first column of the table, the next 30 in the second column, and so on. Collecting 30 samples during discharge will give the samples shown by the last column, named Average, which are averages of the corresponding numbers in the corresponding samples distributed in the 10 chambers.
- 10 As is clearly seen from Tables 1 and 3, the standard deviation S_{tot1} of the samples from the filling is considerably larger than the standard deviation S_{tot2} of the samples collected during discharge. In this case the standard deviation is reduced by 68% from filling to discharge of the homogenizing silo. It can be shown theoretically that a homogenizing silo consisting of N chambers, on average will reduce the standard deviation from filling to
- 15 emptying by a factor of the square root of N ($\sqrt{N}$).

This means that the homogenizing effect improves with increasing number of chambers, but as the number of chambers increases, the effect of an extra chamber diminishes asymptotically.

In order to make such a chamber silo to work, a correct design of the chambers is essential, at the same time as also the silo itself has to be correctly designed.

The example given above is illustrated in Fig. 1. As shown in the Figure, the samples associated with conventional silo vary a lot throughout the sampling sequence. If the homogenizing silo of 10 chambers is used, the variations in the discharged material are considerably reduced, as indicated by the curve associated with a 10 chamber silo.

According to the present invention there is provided a method for mixing bulk solid material, more precisely for mixing at least two materials (A, B) where at least one of these materials (A) has variations in particle size distribution, and whereby said material (A) is homogenized in a first gravimetric mixer with plural chambers, wherein

the material (A) is entered into a central filling tube of the mixer and then successively into each chamber, where the filling tube has openings or slots with various vertical extensions towards the respective chambers, before being discharged and mixed together with material (B) in a second mixer.

According to the present invention there is also provided A mixing station (M) for bulk solid materials, more precisely for mixing at least two materials (A, B) where at least one of these materials (A) has variations in particle size distribution, comprising a first mixer which is a gravimetric mixer formed as a silo with an upper part having plural chambers where the material (A) is fed into said chambers for homogenisation of the material (A), wherein

the mixer has a central filling tube provided with several openings or slots with various vertical extensions towards the said chambers, where the material (A) is entered into the central filling tube and further successively to each chamber through said openings, before being discharged and entered into a second mixer for mixing material (A) with material (B). In accordance with the invention it is possible to recycle and handle anode covering materials and further mix the material with secondary and/or primary alumina or other material in an efficient and little energy consuming manner.

In accordance to specific embodiments of the invention, it relates to a method and a station for mixing bulk solid material, in particular for mixing at least two materials (A, B) where at least one of these materials (A) has a broad particle size distribution. The material (A) is homogenized in a first mixer (5a, 5b) before being mixed together with material (B) in a second mixer (7). The material (A) is homogenized in a gravimetric mixer

(5a, 5b) with plural chambers and which is discharged in accordance to the mass flow principle. The materials (A) and (B) are preferably mixed in a gravimetric mixer (7) with plural chambers and is further discharged in accordance to the mass flow principle. The material (A) is substantially crushed bath material. The material (B) is primary and/or secondary alumina that mixed with (A) will be used as recycled anode cover material (ACM).

In the following the present invention shall be described by examples and figures where:

- 10 Fig. 1 discloses a sample variation of a conventional silo compared with a homogenizing silo having 10 chambers,
- Fig. 2 discloses in perspective, a cut through view along I-I of a mixer divided into chambers
- Fig. 3a discloses a central filling tube of the mixer in Fig. 2, seen in perspective,

Fig. 3b discloses in part a perspective view of the cylindrical part of the mixer, divided in 16 chambers,

Fig. 4 discloses a frontal, cross sectional view of the mixer of Fig. 2,

Fig. 5 discloses a mixing apparatus or station in accordance to the present invention.

5

The present invention is based upon the principles of mass-flow in multi chamber silos, where the silos have a mixing function, i.e. hereinafter named mixer. In Figure 2 and 4, there is shown three main items of a mixer. First of all there is a central filling tube 1 arranged in one cylindrical part 9 of the mixer. The filling tube has one inlet opening 1'. In the lower, converging part of the mixer, the hopper 2" has arranged two static flow promoters 2, 2' inside. The outlet is indicated at reference sign 3.

10

The central filling tube 1 is shown in more details in Fig. 3a. As shown in the Figure, there are several openings or slots as indicated by 8, 8'... in the tube having various vertical extensions, thus distributing the material successively into corresponding chambers 4, 4'... as indicated in Figure 3b. During filling of materials into the central filling tube, the slots in the tube will distribute materials to each chamber successively, due to the arrangement of the slots.

20

The cylindrical part 9 of the mixer is in more detail disclosed in Fig. 3b, where the upper part of the filling tube 1 is disclosed together with chambers 4, 4'. Slots 8, 8' in the filling tube communicates with the chambers 4, 4'. Line I-I along internal dividing walls 20, 28 indicates the same cut through plane as that of Fig. 2 and 4.

25

As shown in Fig. 4, that is a frontal view of Fig. 1, the filling tube 1 is arranged in the cylindrical part of the mixer having openings or slots 8, 8' allowing material filled into the filling tube 1 to be distributed into the various chambers of the mixer.

During removal of materials from the silo, the static flow promoters 2, 2' are designed to support that materials are removed from the chambers in accordance with the mass flow principle, and consequently these will discharge simultaneously, hence mixing/ homogenising the bulk solid filled into the mixer.

Utilising the theory above and a mixer in accordance with that, a mixing station M is set up as shown in Figure 5. The mixing station in accordance to this example has two main mixers 5a, 5b that receives the most segregating bulk solids from a vertical conveyor 9, via inlet conveying means 9a, 9b. In this example crushed bath is the most segregating

35

bulk solids. The mixers are of the same type as described in the previous example (Fig. 2-4).

- 5 The mixers are operated in such a way that when 5a is being filled, mixer 5b is in its discharge mode. This operational method is essential to make the multi chamber mixer concept work. This because it has been observed that filling the mixer while it is in discharging modus will disturb an optimal operation of the silo with regard to homogenisation.
- 10 Materials from mixer 5a or 5b via discharge conveying means 10a, 10b are then in proper ratio filled together with less segregating powder such as primary and/or secondary alumina transported from a silo 6 via conveying means 6a into a conveying system 12, 12a, 12b, 12c. The conveying system comprises a horizontal conveyor 12, a vertical conveyor 12a, one inlet conveying means 12b and one hopper reservoir 12c. The outlet
- 15 13 of the hopper reservoir conveys the material into a gravimetric mixer 7. The mixer 7 is working by the principles of the above described multi chambered silo, and is discharged in accordance with the mass flow principle. In operation, the mixer 7 is filled completely up. It is discharged completely for further transport into the process.
- 20 Throughout the description and claims of the specification, the word "comprise" and variations of the word, such as "comprising" and "comprises", is not intended to exclude other additives, components, integers or steps.

The claims defining the invention are as follows:

1. A method for mixing bulk solid material, more precisely for mixing at least two materials (A, B) where at least one of these materials (A) has variations in particle size distribution, and whereby said material (A) is homogenized in a first gravimetric mixer with plural chambers,

wherein

the material (A) is entered into a central filling tube of the mixer and then successively into each chamber, where the filling tube has openings or slots with various vertical extensions towards the respective chambers, before being discharged and mixed together with material (B) in a second mixer.
2. A method in accordance to claim 1, wherein the material (A) is discharged in accordance to the mass flow principle.
3. A method in accordance to claim 1 or 2, wherein the materials (A) and (B) are mixed in a gravimetric mixer.
4. A method in accordance to claim 3, wherein the materials are mixed in a mixer with plural chambers and is further discharged in accordance to the mass flow principle.
5. A method in accordance to any one of claims 1 to 4, wherein the material (A) is substantially crushed bath material.
6. A method in accordance to any one of claims 1 to 5, wherein material (A) is mixed with material (B), which is primary and/or secondary alumina, to produce anode cover material (ACM).
7. A mixing station (M) for bulk solid materials, more precisely for mixing at least two materials (A, B) where at least one of these materials (A) has variations in particle size distribution, comprising a first mixer which is a gravimetric mixer formed as a silo with an upper part having plural chambers where the material (A) is fed into said chambers for homogenisation of the material (A),

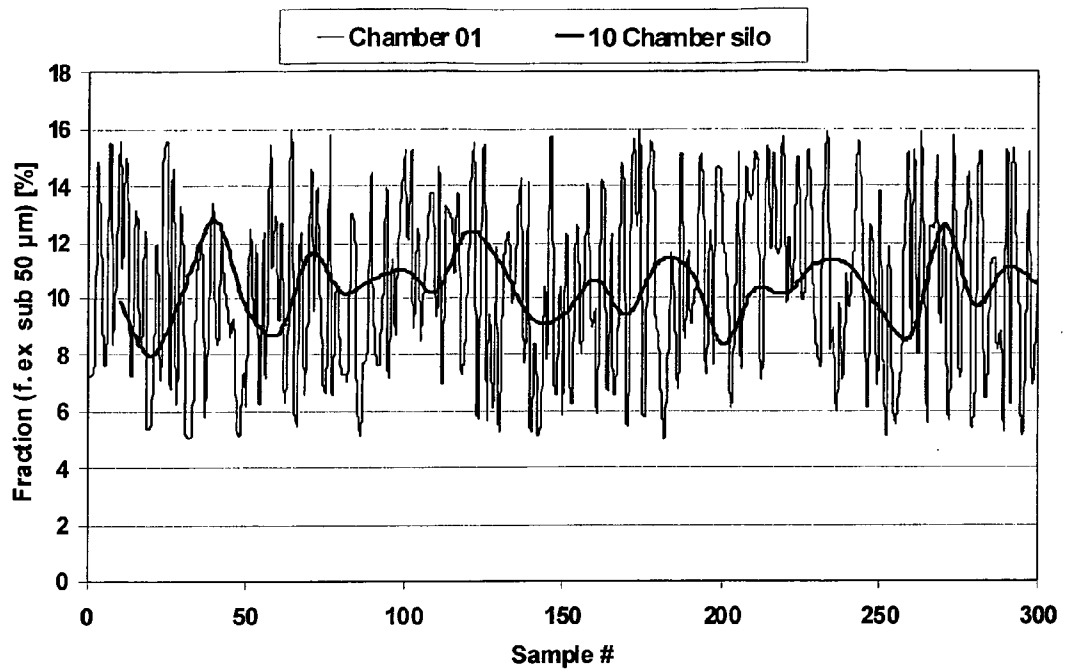
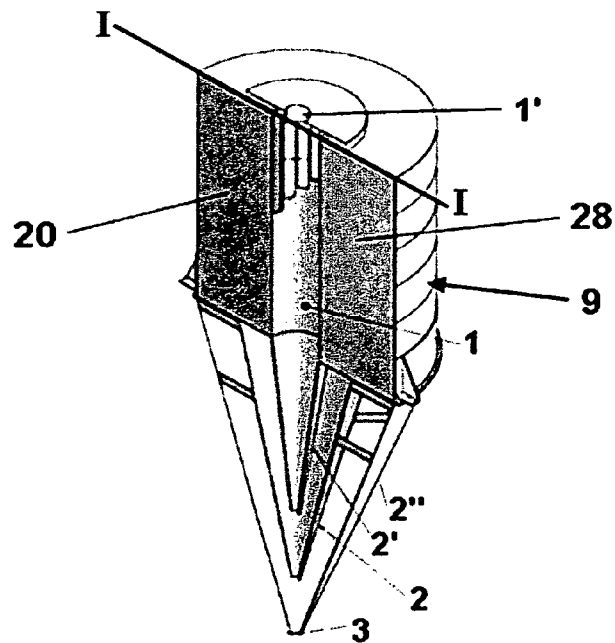
wherein

the mixer has a central filling tube provided with several openings or slots with various vertical extensions towards the said chambers, where the material (A) is

entered into the central filling tube and further successively to each chamber through said openings, before being discharged and entered into a second mixer for mixing material (A) with material (B).

- 5 8. A mixing station in accordance to claim 7, wherein the mixer comprises a converging lower part with an outlet and further being provided with static flow promoters inside.
- 10 9. A mixing station in accordance to claim 7, wherein the second mixer is a gravimetric mixer formed as a silo with an upper part having plural chambers where the material is fed sequentially into said chambers.
- 15 10. A mixing station in accordance to claim 9, wherein the second mixer comprises a converging lower part with an outlet and further being provided with static flow promoters inside.
- 20 11. A mixing station in accordance to any one of claims 7 to 10, wherein the station comprises a third mixer for homogenisation of material (B) before mixing with material (A).
- 25 12. A mixing station in accordance to any one of preceding claims 7 to 11, wherein the mixers are of a mass flow type.
13. A mixing station in accordance to anyone of preceding claims 7 to 12, wherein the material (A) is substantially crushed bath material.
14. A mixing station in accordance to any one of preceding claims 7 to 13, wherein the material (B) is substantially primary and/or secondary alumina.
- 30 15. A mixing station in accordance to any one of preceding claims 7 to 14, wherein the mixed material is used as anode covering material (ACM).

1/4

**Fig. 1****Fig. 2**

2/4

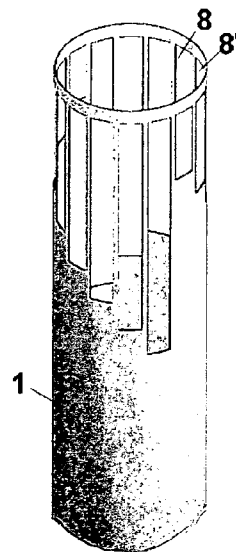


Fig. 3a

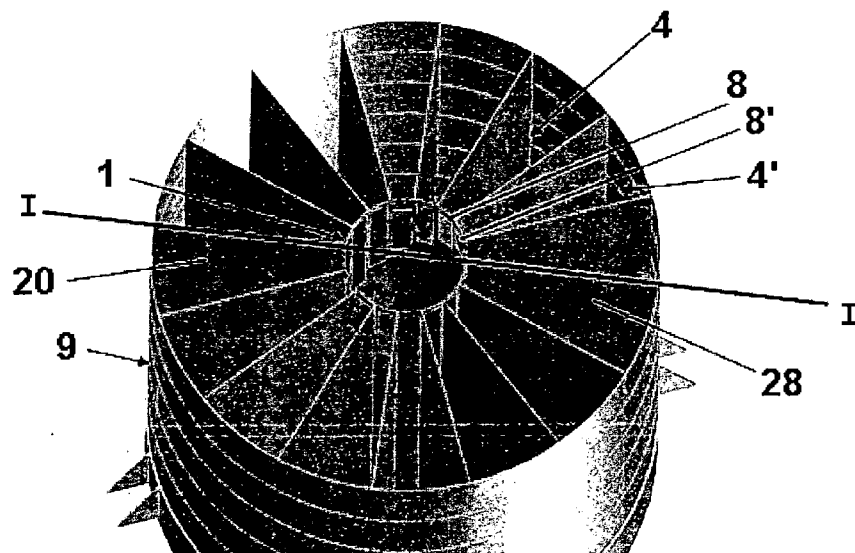


Fig. 3b

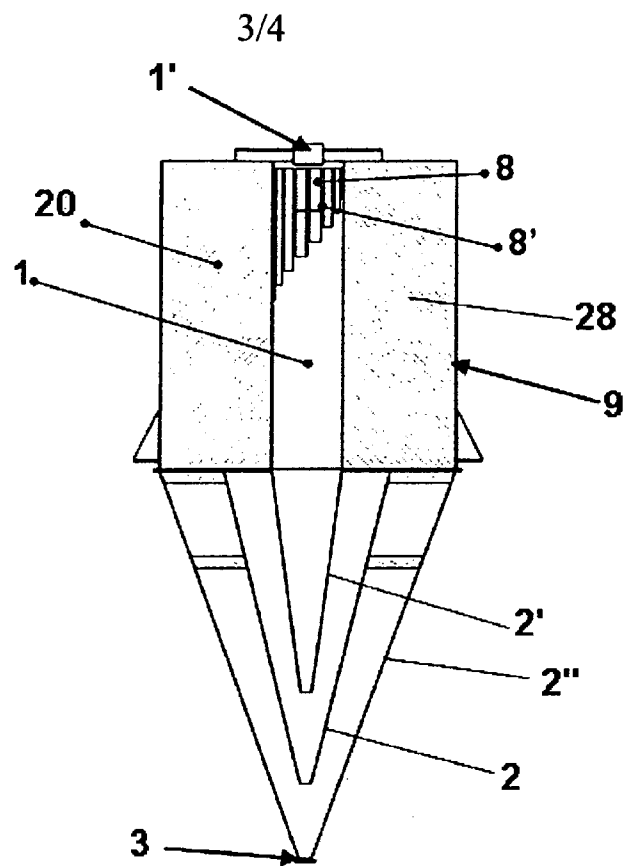


Fig . 4

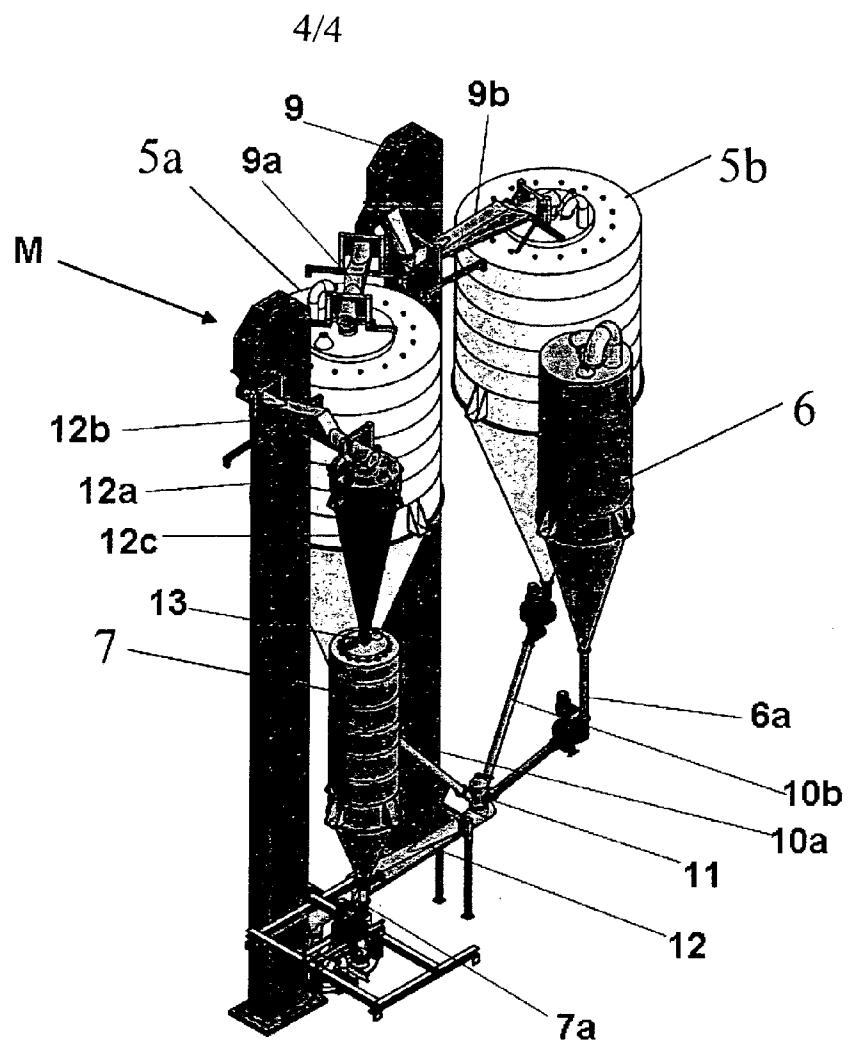


Fig. 5