BODY PREPARATION

Technological aspects and plant-engineering solutions

Comparison between the continuous cylindrical and conical mills

Author:
ETTORE CAVAZZUTI

SUMMARY

1) INTRODUCTION

The analysis herein concerns the technical-plant engineering aspects of the body preparation plant for porcelainized stoneware, with particular attention to the most innovative and performing sections of the plant.

We have chosen to analyse the plant for porcelainized stoneware since it is the most complex technological process about and with the hardest product to mill, as it requires a higher degree of refining compared to other ceramic products.

The body preparation plant, together with the press charging system, is the heart of the production line of porcelainized stoneware, as it is indeed in these two sections that the most crucial procedures are carried out, which characterise the quality, on one hand, and the appearance on the other, of the final product.

Our research will take a thorough look at the part of plant that goes from the storage of the raw materials through to the outlet from the spray dryer, including also the storage of the spray-dried product.

2) CLASSIC PLANT LAYOUT

In highly developed tile manufacturing countries, for a porcelainized stoneware production plant to be advantageous, it must ensure a daily production rate of at least 5.000 sq.m.: if the production rate reaches or exceeds 10.000 sq.m./day, then the plant becomes even more advantageous, with lower production costs thanks to the improved management, also favoured by the greater scale economy.

The classic layout of a body preparation plant for porcelainized stoneware is articulated as follows:

2.1) Feeding and batching of the raw materials

Following various experiences, the most convenient feeding line for medium/large plants envisages the loading of various components, separately, in suitably sized box feeders.

The products are batched by means of weighing belts and the mills are fed continuously.

Plastic raw materials, due to the fact that they may have a rather high moisture content, are loaded in box feeders, equipped with extractor, by a metal belt and then crushed down to a maximum size of 40÷50 mm.

Hard raw materials are loaded in box feeders by a rubber extractor belt and are usually fed at a maximum size of 2÷3 mm.
For special cases, hard raw materials, refined up to 200 µ, can be used to increase the mill production rate.

2.2) Wet grinding

The mixture of raw materials is stored in the mill pre-charging hopper and fed to the mill continuously.
A weighing belt ensures the pre-set flow rate. Water, deflocculant and grinding media are fed simultaneously and continuously.
The obtained slurry for porcelainized stoneware production contains 31÷32% of water and has a residue of less than 1% with screen of 10.000 mesh/cm² equal to a 63 µ opening.

2.3) Sieving and storage of the slurry

The slurry is sieved through a screen of 1.600÷2.200 mesh/cm², then, after the iron-removing process, it is stored in proper tanks equipped with stirrer.

2.4) Preparation of the pigments and colouring of the slurry

Over the years, the slurry colouring process has been studied in order to find a solution that is not too complex but that, at the same time, envisages the use of acceptable amounts of pigments.
The most popular process is the production of the neutral base slurry, then the pigment is continuously added before the spray-drying phase.
The pigment is previously dissolved in water with the addition of a small amount of slurry or Kaolin.

2.5) Spray-drying and storage of the dried product

The possibly coloured slurry is dried in the spray dryer and is then sent to the storage bins after a pre-sieving cycle.
The various colours of dried powders are produced in different lots, corresponding to the capacity of each silo.
The plant must be washed each time the colour is changed.

2.6) Treatment of the spray-dried product and production of special grains

The dried product of various colours obtained in the spray dryer has an average grain size of 300÷400 µ and is suitable to produce mono-chrome or poly-chrome tiles with the typical "salt and pepper" effect.

If special grains, in terms of size or colour, are to be added to the mixture of powders, then a specific system is to be installed to produce these grains, which will then be stored until they are sent to the press.

2.7) Transport of the dired product to the press

The dried powders in the various colours and in the various sizes are conveyed to the batching and mixing systems, installed before the various presses, by means of a system of conveyor belts.

This conveyance system, due to the complexity of the plant and to the ever-increasing number of possible combinations, has been a tricky problem for years and has conditioned the plant versatility.

Thanks to the introduction of remote-controlled mobile silos it is now possible to manufacture simpler and much more versatile installations.

2.8) Preparation of the mixtures and feeding of the press

To avoid the much feared problems of "de-mixing" and in order to ensure greater versatility, factories now tend to prepare the mixture of powders right before the press, by installing dedicated lines that can feed each press with various powders and mixtures by means of an automatic equipment to load the mould cavities.

The flow sheet of "Enclosure 1" schematises the process through to the storage section of base slurry.

3) <u>TECHNOLOGICAL AND PLANT-ENGINEERING TRENDS</u>

If we should reconsider the technological and plant-engineering aspects that even a mere 4 to 5 years ago were considered to be "untouchable" in the body preparation plant for porcelainized stoneware, we would realise once again how risky it is to take rigid decisions that, due to the unforeseeable nature of the development of the technological process, can be proved wrong at any time.

It was indeed taken for granted that to be able to produce good quality stoneware, the following principles were a MUST:

a) Milling with discontinuous mills and colouring of the mixture in the mill.

b) Production of a second so-called “Super white” body obtained using noble raw materials added with zirconium silicate.

Now, however, continuous milling has prevailed over in the production of technical porcelainized stoneware and just one good quality body is produced with residue of 10.000 mesh/cm² around 0.7÷1% and the colouring is performed continuously at the spray dryer inlet.
The so-called “Super white” body is obtained just like any other colour, starting from the base slurry and adding zirconium silicate.

With the introduction of glazed porcelainized stoneware, the tendency is to produce a second body of lower quality with residue at 10.000 mesh/cm² around 1.3÷1.5%.

When drawing the layout of the plant, one tends to make separate and independent production lines for each of the two bodies.

When choosing the continuous mill, preference goes to the medium/large sizes (100, 125 and 165 cu.m.); smaller capacities (60-80 cu.m.) are only chosen when alumina grinding media are used.

As to the spray dryer, the tendency is to install at least 2 machines to produce separately the base and the coloured mixtures.
Medium/large sized spray dryers are used for the base product, with evaporating capacity up to 10.000÷12.000 l/h. Machines with maximum evaporating capacity of around 5.000÷7.000 l/h are used to produce coloured grains, due to the frequent washing cycles involved.

As we have already mentioned in the previous chapter, the tendency is to always use mobile silos to transfer the dried product to the press. Another important novelty in this specific field of the plant is the so-called "Technological tower", which not only simplifies the conveying system but also allows the grain and the mixture of coloured grains to be prepared directly on the press, thus completely eliminating the much feared problem of "de-mixing".

This system makes the plant remarkably flexible and avoids having to install complex, expensive and rigid conveying systems.

4) CONTINUOUS MILLING WITH THE CYLINDRICAL MILL

The greater amount of hard materials in the body and the greater milling fineness required are fundamental factors which, combined with a congenital rigidity of the plant, have postponed the diffusion of the continuous milling process in plants for porcelainized stoneware.

Despite all this, however, considering that continuous milling has proved to be extremely advantageous compared to discontinuous milling, the continuous milling process has completely replaced the discontinuous milling process in new plant for porcelainized stoneware production.

The classic continuous milling plant conformation for porcelainized stoneware is made up substantially of a continuous cylindrical mill with a number of chambers charged with grinding media in top quality silica, having a specific weight of 2,75 kg/dm^3 with decreasing dimensions.

The illustration of "Enclosure 2" represents a continuous cylindrical mill with 3 chambers.

The heavy grinding stones of variable size are put in the first chamber to rapidly crush the material, then smaller spheroid-shaped grinding media are put in the next chambers to break the material down further to the desired fineness.

This type of plant, processing a classic body for porcelainized stoneware containing hard materials measuring less than 3 mm, allows an hourly production rate of 12 to 13 tons of dry product with a maximum residue of 1% at 63µ net meshes. This body, added with suitable thinning substances (0,3÷0,5%), contains about 31÷32% of water.

When rubber linings were introduced with lifter bars fitted in a blade conformation, the so-called "segregating effect of the grinding media" enabled to reduce the milling chambers from 3 to 2, thus eliminating one of the intermediary diaphragms.

The illustration of "Enclosure 3" shows the continuous cylindrical mill with 2 chambers, with lining in the first chamber of the "segregating effect" type.

The high investment costs, unsubstantiated by a relatively low production capacity of the milling plant, convinced the user and the plant engineer to try to increase the production rate of the plant, in the attempt to reduce the amortisation time or, in any event, to reduce production costs.

The use of high-density alumina balls, having a specific weight of 3,5÷3,6 kg/dm^3 has given good results which we are going to explain hereafter.

Various solutions have been tested, starting from adding high-density alumina balls to the silica grinding pebbles (especially in the second and third chamber) through to the complete replacement of the same with high-density alumina balls in one or more chambers.

The increase in the production rate (that can be documented), in continuous mills with two chambers with "segregating effect" lining in the first chamber, is found in the case of the complete replacement of the silica grinding pebbles with high-density alumina ones in the last chamber: this increase is 14÷15% and therefore the production rate of a 165 m^3 size mill has improved up to 14÷15 ton/h.

The results that may be obtained with the use of 100% high-density alumina grinding media have been evaluated, at a research level.
We don't think we are far off when we say that a further increase of 18÷20% is possible compared to the production rate obtained using high-density alumina grinding balls in the third chamber alone.
Under these conditions, a 165 cu.m. suitably dimensioned mill should reach production rates around 17÷18 ton/h.

Obviously the possibility of using grinding media with a greater specific weight would meet with objective application difficulties, due to the considerable increase in the mass involved and to the consequent use of higher powers in the existing plant that has been designed for the use of lighter grinding media.

The higher consumption of grinding stones in the milling process for porcelainized stoneware causes more frequent stops compared to those already found in the milling process for single-fired products and further enhances the semi-continuous milling cycle of the continuous cylindrical mill, creating considerable production losses compared to what should be obtained if the mill would not be stopped.

The table of "Enclosure 4" shows the real average production rate obtained with continuous cylindrical mills in the milling process for porcelainized stoneware. As a comparison, the production rate that can be obtained with the same mills processing bodies intended for the production of single-fired tiles is also given.

5) <u>CONTINUOUS MILLING WITH THE CONICAL MILL</u>

The conical mill is a truncated-cone-shaped continuous-drum-type mill with decreasing section towards the outlet (Enclosure 5), covered by a patent registered by ICF INDUSTRIE CIBEC SPA in all countries around the world.

Thanks to the conical form of the shell, the *grinding media are spontaneously segregated* inside the mill according to their size, so that the larger stones concentrate in the larger sections where the material is let into the mill, whereas the smaller stones are gradually distributed towards the outlet.

Thus, *without the use of intermediary diaphragms,* the larger balls crush the larger-sized material let in, whereas the smaller ones, with reduced interstitial spaces, crush the partially ground material flowing towards the outlet.

The spontaneous segregation of the grinding media according to their size is an advantage of outstanding importance of the conical mill compared to the continuous cylindrical mill. The possibility of eliminating the intermediary "walls" does indeed lead to the following additional advantages:

- *Increase in the useful internal volume of the mill* (equal to 4% for a 100 m^3 mill).
- *Reduction of the energy dissipated due to the collision of the grinding balls* against the intermediary walls.
- *Increase in the milling efficiency* since the grinding media are arranged according to a segregating and not casual logic.
- *Possibility of feeding the grinding balls together with the material*, without stopping the mill.

*This last advantage ensures the actual continuity of the milling process and promotes the conical mill as a real and true continuous mill (*whereas the cylindrical mill is a semi-continuous one, or rather intermittent, as it has to be stopped every now and again to fill-up with grinding media) *and it is the effective continuity of the process to be the main advantage of the continuous conical mill:* in fact, together with the profits gained in production coming from the lack of stops of the plant to re-fill the grinding stones, this fact means that the process parameters of the plant are perfectly constant, which is impossible with the continuous cylindrical mill.

The illustration of “Enclosure 6” compares the flow rate/time and residue/time diagrams of a conical mill and a cylindrical mill of the same size processing the same type of body for porcelainized stoneware production.
While the values examined in the conical mill are absolutely constant in time, there is a continuous decrease in the milling power in the cylindrical mill, due to the progressive reduction in the grinding media.
In both diagrams of the continuous cylindrical mill the stop time of the plant to re-fill the grinding charge is clearly noticed, enhancing the intermittent operation of the plant itself.

The comparative research carried out has confirmed the superiority of the conical mill compared to the cylindrical one, enhancing higher production rates of the conical mill of up to 16,4% and lower specific energy consumptions by 6,5%.

These advantages remain unaltered even when the cylindrical mill is equipped with the rubber lining with the so-called “segregating effect” of the grinding media.

Considering the outstanding advantages, the continuous conical mill has become very popular both in the milling process of materials intended for single-fired and mono-porous tile production and in the milling process for porcelainized stoneware production.

6) THE USE OF HIGH-DENSITY ALUMINA GRINDING BALLS IN THE CONTINUOUS CONICAL MILL

Recently, considering the increasing offer on the market and the increasingly convenient prices of high-density alumina grinding balls, in order to better exploit the milling plant, ICF has decided to use in its continuous conical mills lined in rubber the 100% alumina grinding charge also in the milling process of materials for porcelainized stoneware.

For this purpose a range of "super-reinforced" continuous conical mills has been designed that includes 40-50-65-80-100 and 125 cu.m. mills with production capacities between 5,0 and 15,7 ton/h of dry product milled to a residue lower than 1% at 63 µ.

In a milling plant of materials for porcelainized stoneware with continuous conical mill equipped with high-density alumina grinding charge, the investment costs and the running costs are lower than those of the same plants where silica grinding media are used.

The table of "Enclosure 7" shows the actual average production rates obtained with continuous conical mills in the milling of materials for porcelainized stoneware both with silica grinding pebbles and with high-density alumina grinding charge.

7) FINAL COMMENTS

The body preparation plant for the porcelainized stoneware confirms to be the heart of the production line of porcelainized stoneware, together with the press charging system.

The fundamental role of continuous milling is confirmed in the body preparation plant.

The continuous conical mill ascertains its superiority compared to the cylindrical mill even if the latter is equipped with "segregating effect lining". The validity of the conical mill is further confirmed considering that, following the introduction of the conical mill, the cylindrical mill exploits a tricky mechanical solution connected to factors that change in time, such as the wear & tear of the lifter bars, in the attempt to bring the performance up to the par with those given spontaneously by the continuous conical mill.

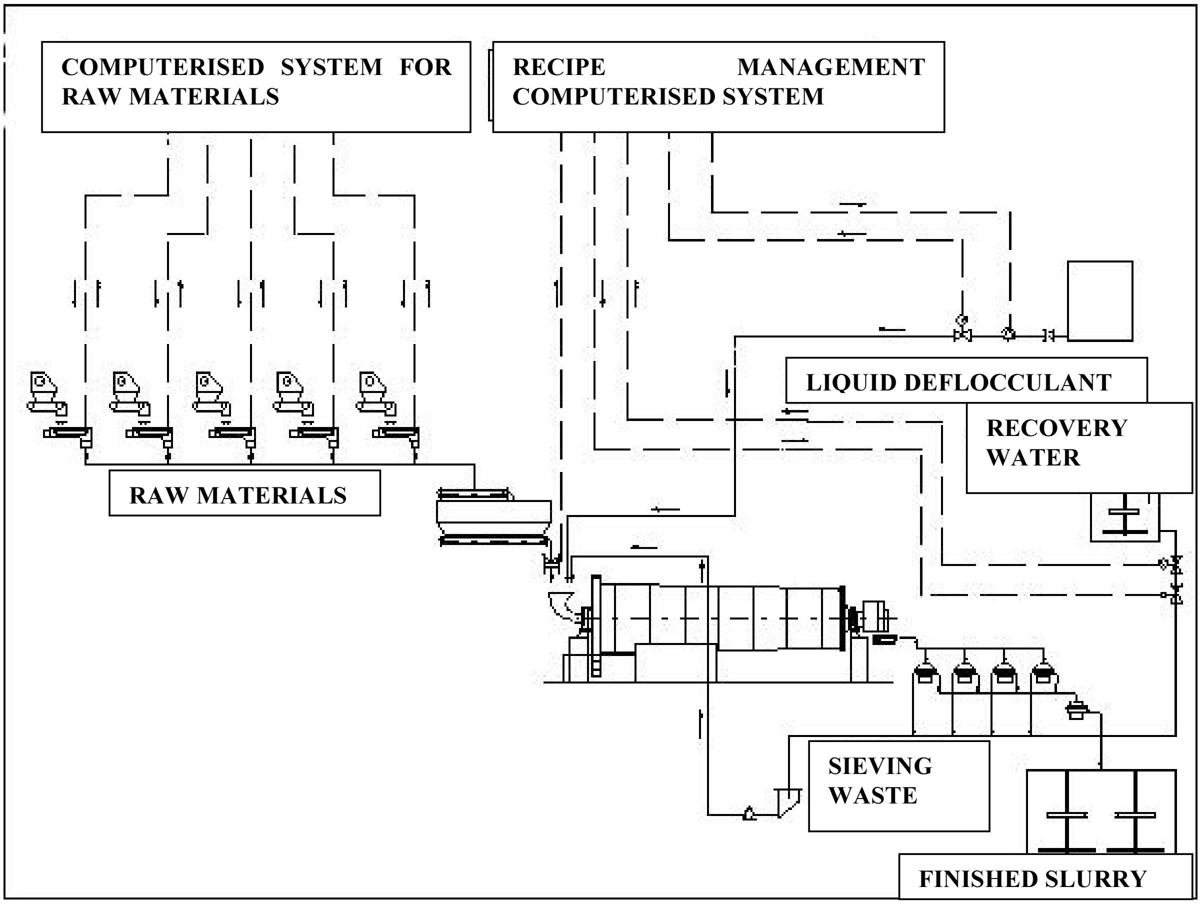
The growing availability on the market and the increasingly convenient prices of high-density alumina grinding media allow this type of grinding charge to be used further a field: in particular, when it is used together with the continuous conical mill, higher production rates are obtained with lower specific energy consumptions.

The introduction of remote-controlled mobile silos and of the so-called "Technological towers" permit to the plant to become even more versatile, even in that section which has for years been a troublesome problem for the plant.

I.C.F.-INDUSTRIE CIBEC S.p.A.
VIA SICILIA,10
41053 MARANELLO (MO)-ITALY

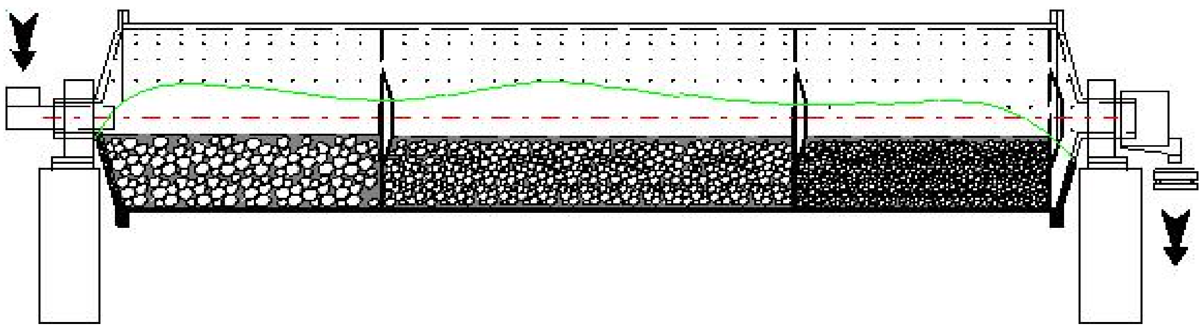
TEL. +39-0536941038
FAX +39-0536943454
E-mail: icf@icf.it
http://www.icf.it

CAP SOC. € 1.000.000,00 I.V.-C.F./P.IVA N.00284950367-C.C.I.A.A. N. 156998 - TRIB.MO N. 6850-MECC. N. MO 004620



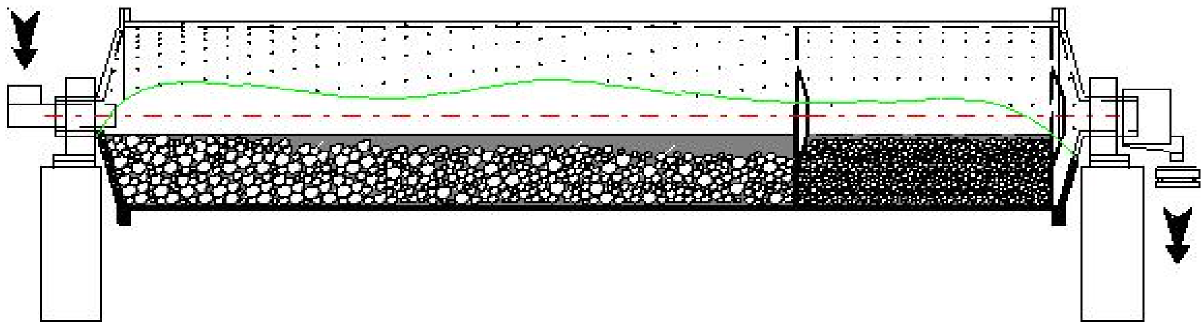
FLOW SHEET OF THE MILLING PLANT
WITH CONTINUOUS CONICAL MILL

ENCLOSURE 1



**CONTINUOUS CYLINDRICAL MILL
WITH 3 CHAMBERS**

ENCLOSURE 2



CONTINUOUS CYLINDRICAL MILL WITH 2 CHAMBERS AND LINING WITH "SEGREGATING EFFECT" IN 1st CHAMBER

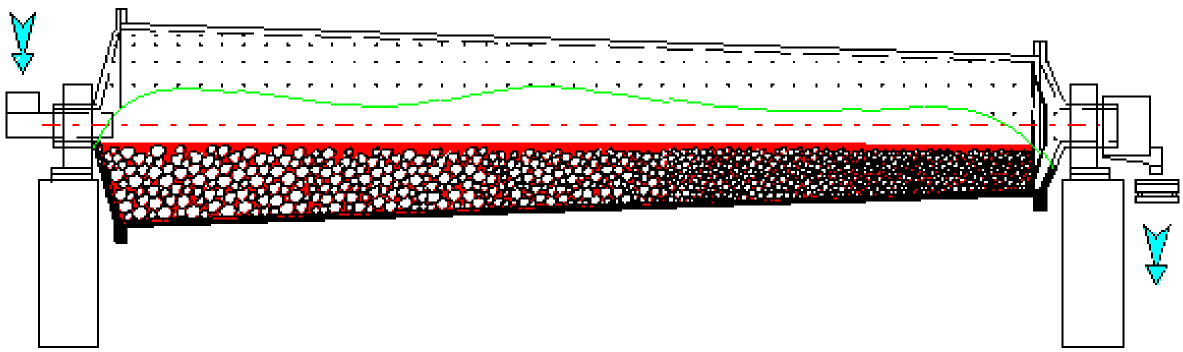
ENCLOSURE 3

ACTUAL AVERAGE PRODUCTION RATE IN TON/HOUR OF THE CONTINUOUS CYLINDRICAL MILLS WITH TWO CHAMBERS

TYPE OF MILL	SINGLE-FIRED * TILES	PORCELAINIZED STONEWARE **	
	Silica grinding stones	Silica grinding stones	Grinding media: Silica 1st chamber Alumina2nd chamber
CBM 50	8	4	4,6
CBM 75	12	6	6,8
CBM 100	16	8	9,2
CBM 125	20	10	11,5
CBM 160	26	12,5	14,5

* Milling residue at 63µ =< 5%
** Milling residue at 63µ =< 1%

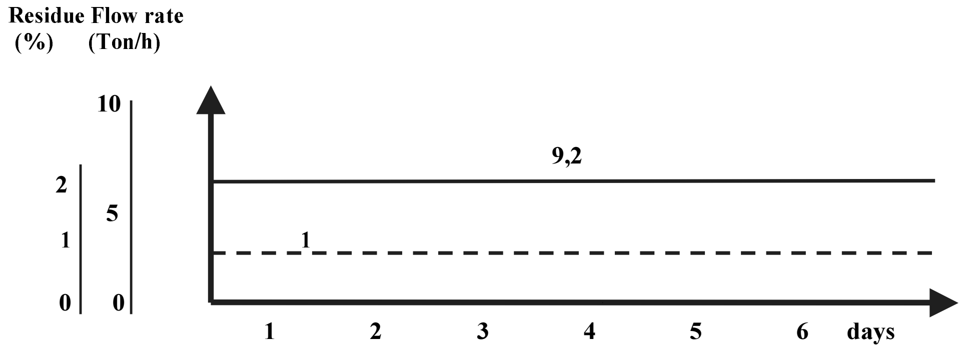
ENCLOSURE 4



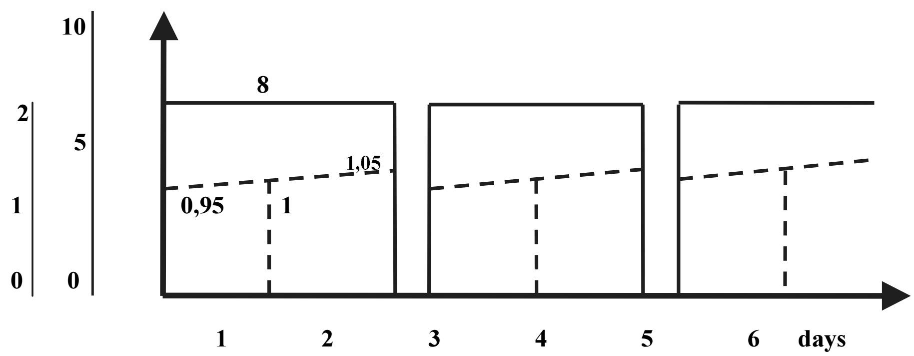
CONTINUOUS CONICAL MILL

ENCLOSURE 5

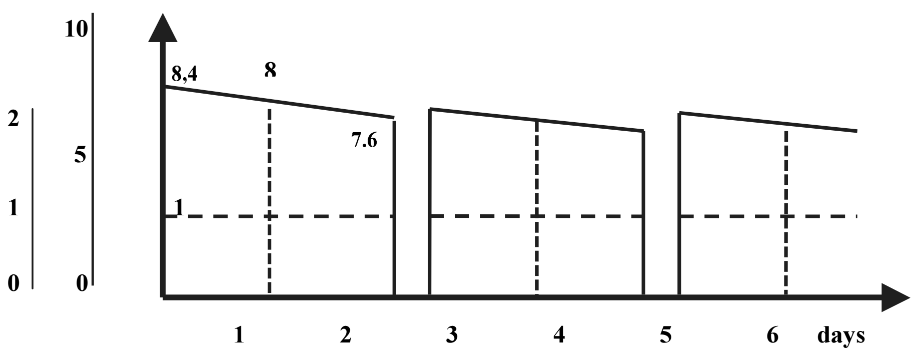
COMPARATIVE DIAGRAMS, FLOW RATE AND RESIDUE, BETWEEN CONTINUOUS CONICAL AND CYLINDRICAL MILLS OF 100 M³ CAPACITY WITH SILICA GRINDING STONES



CONTINUOUS CONICAL MILL



CONTINUOUS CYLINDRICAL MILL
Operation with constant production



CONTINUOUS CYLINDRICAL MILL
Operation with constant residue

ENCLOSURE 6

ACTUAL AVERAGE PRODUCTION RATES IN TON/HOUR OF THE CONTINUOUS CONICAL MILLS

Type of mill	SINGLE-FIRED TILES *	PORCELAINIZED STONEWARE**	
	Execution N Silica grinding stones	Execution N Silica grinding stones	Execution RR Alumina grinding balls
40/C	7,2	3,6	5,0
50/C	9,0	4,5	6,3
65/C	12,0	6,0	8,2
80/C	14,8	7,4	10,3
100/C	18,4	9,2	12,6
125/C	23,0	11,5	15,7

*** Milling residue at 63 μ = < 5%**
**** Milling residue at 63 μ = < 1%**

ENCLOSURE 7