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GB 2261938 A **GB 2236747 A**
GB 0555757 A **JP 090145031 A**

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(54) Abstract Title**: Production of lightweight aggregates using olivine sand**

(57) A method of producing lightweight aggregates comprises the steps of introducing a feed stream comprising a mixture of granular and powdered materials into a heating chamber of a kiln and applying heat to the chamber, where the mixture of powdered and granular materials includes olivine sand. A kiln for the production of lightweight aggregates is also disclosed, comprising a generally cylindrical heating chamber 10, the heating chamber being disposed for rotation about its axis 'X'. The heating chamber has an inlet end into which material to be treated can be introduced at charge feed tube 36, and an outlet end from which treated material is removed at charge outlet duct 38. The axis is disposed such that it is tilted upwardly from the horizontal in the direction from the inlet end to the outlet end. Typically, the tilt of the heating chamber may be in the range of 6° to 8°. Preferably, the kiln processes a mixture of expansible aggregate and refractory powder. The tilt causes the aggregate to move through the heating chamber at a rate that is greater than that of the refractory powder, so minimising stiction of material within the kiln.

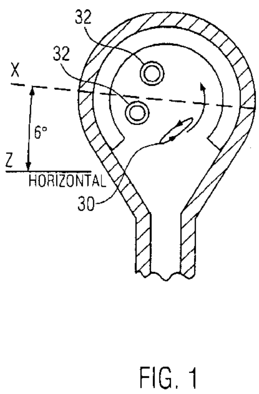

FIG. 1

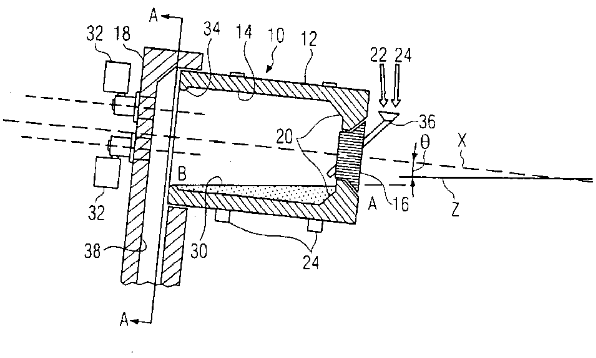

FIG. 2

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 2007.

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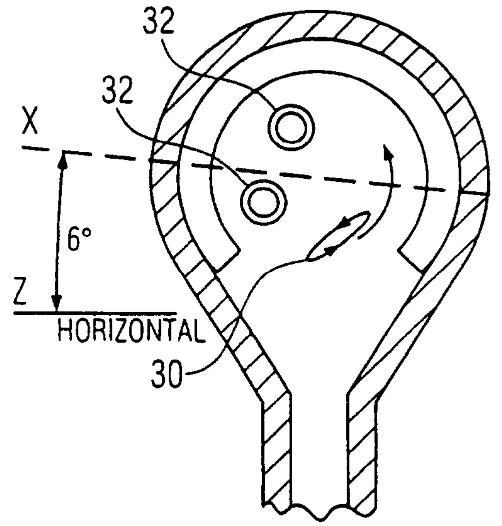
32
32
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FIG. 1

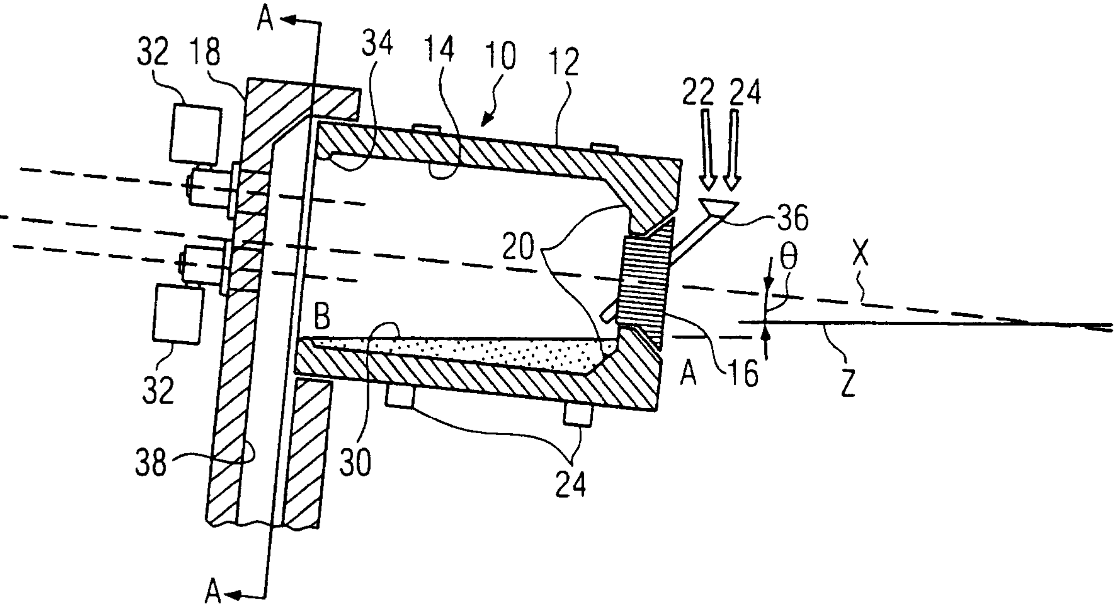
A
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FIG. 2

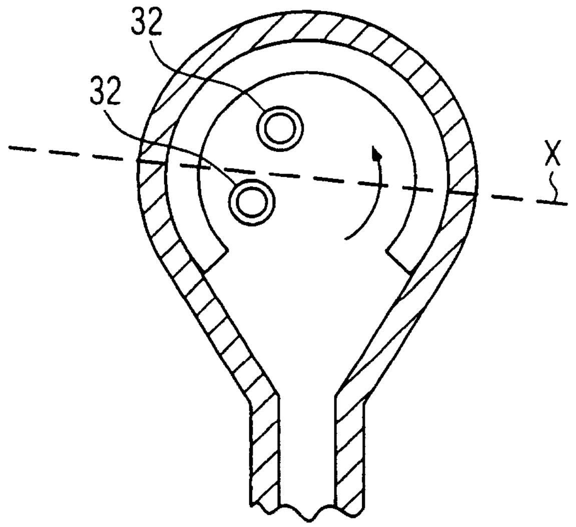

FIG. 3

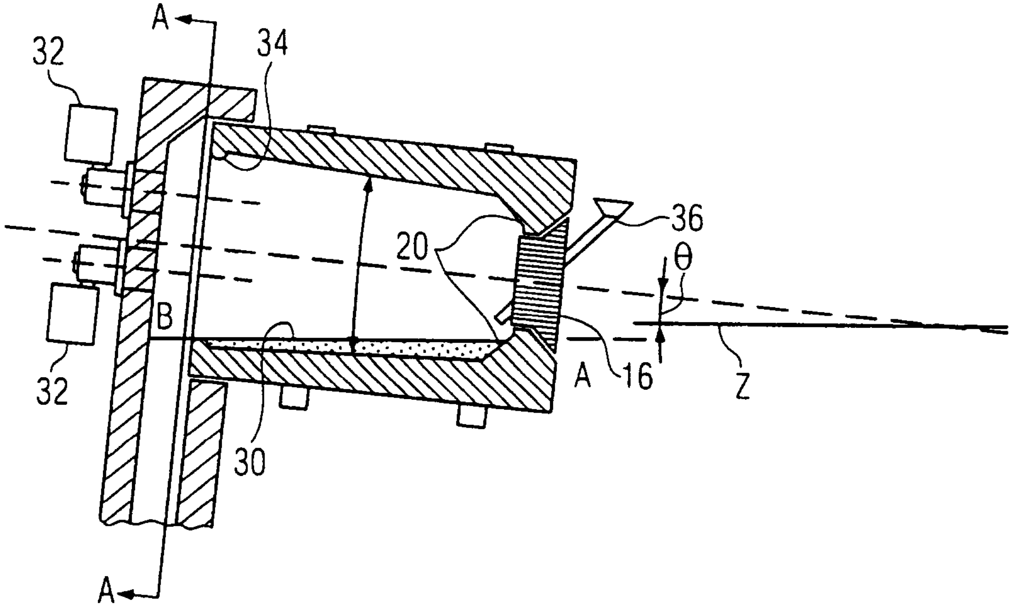

FIG. 4

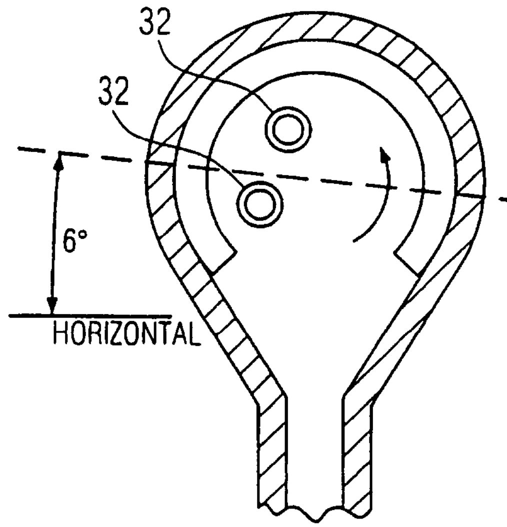

FIG. 5

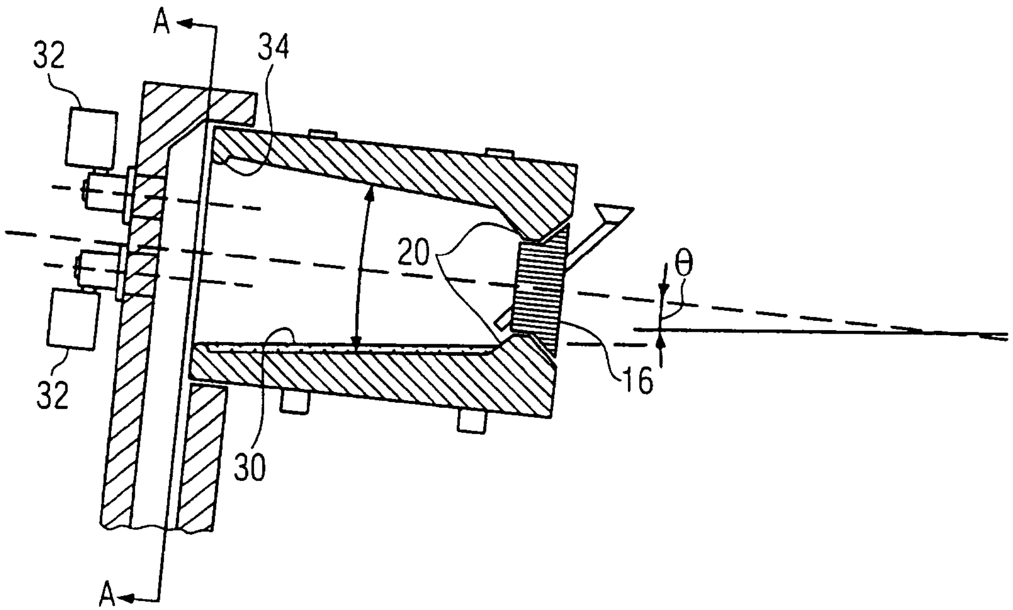

FIG. 6

Production of lightweight aggregates using olivine sand

This invention relates to heat treatment of expansible materials in the production of lightweight aggregates by use of a rotary kiln.

It is well known that lightweight aggregates can be and are produced commercially by suitable heat treatment of certain mineral and rock materials. These include clays, shales and slates of suitable chemical and mineralogical composition. High temperatures are necessary, at or near to fusion in the range of say 1000°C to 1300°C depending on the material. There is a large amount of information available on the subject and production has been, and still is, carried out predominantly by use of rotary kilns. The feed material for the kiln is usually in particulate form, as size graded chippings in the case of slates and shales, or as pellets in the case of clays. Sizes are typically in the range 4 mm to 20 mm.

Feed material from the pre-kiln stockpile will almost certainly be wet or damp and will need to be dried. In the case of pellets, almost invariably water is a necessary component for their formation. Such drying can be part of the rotary kiln process or can be effected by various means external to the kiln itself, usually using lower grade heat (i.e., at lower temperature) generated by the heating process. A common arrangement is that of two separate rotary kilns in tandem, with a drying/preheating kiln discharging into a high temperature bloating kiln. Usually the bloating kiln speed of rotation is considerably higher than that of the low temperature kiln. This invention and the discourse which follows relates to the high temperature rotary kiln part of the process.

In the case where the feed consists of pellets, typically water contents are of the order of 20% to 30% by weight. Some 35% to 50% of the total heat energy supplied has to be expended in evaporating this water before serious heating to high temperature can commence. In the case where the feed is chippings, these will most usually be taken from an outdoor stockpile and again drying will be necessary. However, then the chippings will only be surface wet or damp (typically, less than 2% water by weight) and drying will be comparatively easy with minimal energy consumption when compared with that required for pellets.

With all of these materials, the actual expansion process takes place towards the end of heating whereat the material is nearing its fusion temperature. At these high temperatures, the surface of each particle starts to fuse and thus becomes sealed and impervious; then as heat penetrates to raise the internal temperature, gases are produced which cannot easily escape. Such gases act upon the material which has now entered a plastic state, and these are then able to expand the particles by the formation of a multitude of gas pockets. Once expansion has occurred, it is important to remove the expanded material as rapidly as practicable from the heating zone so that the expanded structure will be preserved on cooling. The result will then be a porous aggregate with a relatively hard impervious skin highly suitable for lightweight aggregate concrete. Noting the foregoing, rapid heating at the final stage to expansion is highly desirable to maximise the effect.

Inherent in the process is the need for the material to be softened and brought into the plastic state at or near to its fusion temperature. In this state, when treating some expansible materials, the particle surfaces tend to become sticky and then there is a strong tendency for the particles to agglomerate, and also there tends to be sticktion to the refractory lining. This then prevents an orderly transit of material through the expansion zone and has proved to be a serious problem. The degree of sticktion varies according to the material and is very much temperature-dependant and at the temperatures needed to achieve full expansion, sticktion often renders rotary kiln treatment unworkable with many materials that would otherwise be highly suitable. The problem tends to be severe when treating slate or shale chippings, yet some of these materials have excellent expansion properties an d are abundantly available.

With ever-tightening energy supplies, there is a strong case for using chippings as feed, particularly if some means of overcoming the sticktion problem could be devised thereby maximising production by volume.

There are two known methods of alleviating the sticktion problem as below.

The kiln operating temperature in the expansion zone is carefully controlled and restricted so that sticktion is just avoided, but then the product is not fully expanded. Typically, the bulk density of these aggregates would be in the range 600 kg/m^3 to 900 kg/m^3. This tends to be accepted practice, particularly in the U.S.A where the product has a strong market.

Alternatively, a refractory powder with a much higher fusion temperature is used as a cohesion inhibitor. The particle size is usually 0.5 mm to 2.0 mm. Suitable powders could be, for example, high purity silica sand, calcined bauxite, crushed and graded scrap refractories and so on. It is important that, besides having a much higher fusion temperature, that the powder does not tend to sinter and attach itself to the refractory lining or have any reaction chemically with the material under treatment. The particle shape is also important in that even in the absence of chemical reaction, sharp type powder particles tend to embed themselves in the softened material being treated. This leads to the powder sticking to the material and possibly difficulty in effecting recovery and separation of the powder from the aggregate after treatment. The selected powder being itself unaffected at the expansion temperature, has the effect of keeping the kiln lining clean and the sticky particles under expansion separate. The powder may be added with the feed or introduced later at or near the expansion zone. Most of the powder (if suitable) can be recovered from the kiln and can thus be recycled in the process. Experiment has shown that olivine sand (magnesium iron silicate) to be highly effective as a powder for this purpose, and is used in preferred embodiments.

With regard to the second of the above techniques, in order achieve the best expansions, generally higher operating temperatures are needed and the increased sticktion effect has to be counteracted by using more and more powder. This can result in the proportion of powder being as high as 60% or more of the feed by weight. All this powder is of necessity heated to the operating temperature, (1200°C for example). This adds to fuel costs and is clearly not optimal. Generally, addition of powder at 25% is considered to be feasible, but then the expansion potential of the material is often not fully exploited; all that fuel for a product which is not as low in density as it could be. For example, the bulk density of the product might be 450 kg/m^3 to 500 kg/m^3 compared with a potential of 350 kg/m^3. Since lightweight aggregates are sold by volume, the advantage of obtaining full expansion is obvious.

An aim of this invention is to provide means and method for avoiding sticktion by creating a safe workable regime within a kiln with only a modest throughput of powder and which is not so limited by operating temperature as heretofore.

This invention provides means for substantial improvement in the refractory powder method of alleviating the sticktion problem. The thrust of the invention is to provide a pool or bed of refractory powder within a rotary kiln, and then to force the particulate material under treatment to transit therethrough leaving the powder substantially *in situ*.

Any deposit of particulate material of size range for example 4 mm to say 12 mm would contain interstitial or void space, amounting to some 50% of the total volume For example, at 50% void space, 1m^3 of particulate material of size 4mm to 12mm in a container would consist of 0.5 m^3 of actual solid material and 0.5 m^3 which is void space. The addition of 0.5 m^3 powder would then be sufficient to fill all the void space Mixes are possible with greater proportions of powder up to 100% of the total space, with corresponding reductions in the proportion of the aggregate sized material. Conversely, the aggregate sized material can never occupy the void space, 50% in this instance. The corollary of this is that in any mix whether it is stationary or agitated the larger material cannot displace the smaller powder occupying void space, 50% in this instance; but the powder can displace the larger sized material up to totality

In a rotary kiln situation the contents of solids is in a constant state of tumbling, a form of agitation. The properties of mixes of materials of substantially different particle size, as stated above can be used to advantage in a rotary kiln containing particulate expansible material and refractory powder. Refractory powders are usually heavy and have a high bulk density and this is helpful.

As mentioned in the introduction, production is often separated into two units; one for drying and preheating and then the material moves on to the expansion or bloating kiln. Material exiting the preheat unit would typically be at a temperature of anything from say 200°C to 600°C (e.g., 350°C). A kiln embodying the invention could be fed with cold material so long as it is dry, but almost invariably in practice the feed would be that exiting a drying and preheating unit typically at temperatures mentioned above. Such dryers/preheaters are generally used to recover heat at lower temperatures from the system as a whole, for instance from exhaust gases exiting a bloating kiln, hot exhaust air from a product cooler and any other heat source that might otherwise be wasted. A bloating kiln embodying this invention will tend have a small length to diameter ratio and heat transfer will be predominantly radiant as disclosed in patent publications notably GB-A-2276438 of the present inventor.

According to an aspect of the invention there is provided a rotary bloating kiln, characterised in that the inclination is reversed with the feed end being lower than the discharge end with the internal dimensions and geometry being such that a quantity or charge of particulate solids of substantially different particle size in the form a mixture of aggregate sized expansible material and refractory powder can be retained in the kiln whilst particulate material of both particle sizes is fed in each at its own fixed rate at the feed end, without spillage out at the feed end, so that heated particulate material of both sizes leaves the discharge end of the kiln each at its own same fixed rate.

When the angle of reverse tilt, that is to say the angle of the axis of rotation to the horizontal is increased to 5° or more, the rate of infeed of refractory powder can be reduced to just a small fraction of the feed rate of the larger particle sized material whilst maintaining as contents a mixture in which practically all the interparticulate void space of the larger sized material is occupied by powder. Powder is retained and the larger sized material is forced to move by displacement through what is effectively a pool of powder. Both powder and aggregate material contribute to this effect. The powder displacement component is influenced by kiln rotational speed, such that an increase in speed leads to a more rapid transit for larger components towards the discharge. The movement of the material in a kiln embodying the invention results in a great reduction in the sticktion problem associated with known kilns.

The quantity of retained particulate material can be varied by adjustment of the angle of reverse inclination and can be increased near to the limit which is the point where material will start to spill out at the feed end. The design is such that the particulate material is made to reside in one quadrant and is kept in a rapid tumbling motion and if necessary ribs can be incorporated in the refractory to promote this without lifting and dropping. Burners and attendant flues can be provided at one end or at both ends and heat transfer will tend to be radiant and by contact with the lining. The burners are positioned to be remote from the charge, approximately diametrically opposite to its position.

By way of amplification: two separate streams of particulate material of substantially different size, expansible material and refractory powder are fed into the kiln. As these materials tumble down in the motion caused by rotation, they try to move towards the feed end by reason of reversed tilt, but the position they previously occupied will already be occupied by incoming feed and the materials are thus forced along progressively towards discharge by displacement. When the angle of reverse tilt is increased sufficiently to about 5°, the larger sized material still travels through the kiln at its fixed rate, so does the powder in relation to its feed rate, except that the rate of powder infeed can be reduced to a minimal amount down to a small fraction; for example, 5% of the feed rate of the larger material with the kiln still being flooded with powder filling all the interparticulate void space. In the rapid tumbling motion of the regime, the larger-sized material cannot effectively displace the powder. Conversely, the powder can and does displace the larger material towards discharge. In the extreme case, when the feed of larger material is stopped and a small flow of powder is maintained, the larger material is displaced in its entirety leaving the kiln full of powder. The angle of reverse tilt of the axis of rotation is important in achieving this effect. Experimentation has found that the angle is preferably in excess of 5° to be particularly effective. Angles below 5° work, but powder retention diminishes and flow rates of powder must be increased to maintain a powder full situation. In operation the degree of tumbling is preferably controlled by adjustment of kiln speed to be at least sufficient to produce almost a fluid regime in the charge of particulate solids, such that the charge has a substantially level upper surface along the kiln length.

In embodiments in which the internal profile of the kiln is retained in cylindrical form and the reverse tilt angle is in excess of 5°, then even with a short length kiln the quantity retained will be quite large, which for any set feed rate will involv a correspondingly longer residence time to effect the necessary heating. Adjustment of tilt angle will determine the quantity retained, but it is preferable not to reduce this the 5° necessary for effective powder retention. Larger angles of reverse tilt, for example, in excess of 8°, can cause material to spill out of the feed end as the level reaches the depth of the end wall of the rotating part of the kiln. Working within these two constraints means that adjustment of angle to vary quantity retained is limited.

From another aspect, this invention provides a kiln for production of lightweight aggregates comprising a generally cylindrical heating chamber, the heating chamber being disposed for rotation about its axis, and the heating chamber having an inlet end into which material to be treated can be introduced and an outlet end from which treated material is removed, wherein the axis is disposed such that it is tilted upward from horizontal in the direction from the inlet end to the outlet end

This can provide the advantageous operational features, as described above.

In typical embodiments the tilt of the axis is in the range 5.5° to 7.5°, for example, it may be approximately 6°

In some embodiments, the heating chamber has an internal volume that is generally cylindrical. In alternative embodiments, the heating chamber has an internal volume that increases in diameter in a direction from the inlet end to the outlet end. Typically, the diameter increases at a generally constant rate of taper. The included angle of taper is typically less than twice the angle of tilt of the axis. Thus, the lower surface of the heating chamber is either horizontal or slopes down towards the feed end. A lip may extend radially into the internal volume at a location adjacent to the outlet end. The size of the lip can be chosen to effect a step change in the quantity of material retained within the kiln and the depth to which the material can accumulate at the bottom of the heating chamber.

In order to heat the chamber, one or more burners direct hot combustion gasses into the heating chamber. Advantageously, the burners are regenerative, and operate in a co-operating pair. This is a particularly energy-efficient arrangement. The burners are typically located close to the outlet end of the heating chamber. For example, the burners may extend through a structure that closes the outlet end of the heating chamber. Flues are provided as appropriate.

From a yet further aspect, this invention provides a method of production of production of lightweight aggregates comprising steps of: introducing a feed stream comprising a mixture of granular or powdered materials into the heating chamber of a kiln according to any preceding claim, while simultaneously rotating the heating chamber and applying heat to the chamber.

During treatment, the material forms a pool of material within the kiln. Due to the tilt of the axis of the kiln, the pool generally has a depth that decreases with distance from the inlet end. During treatment, as a result of the tilt of the axis, and their comparatively large particle size, the expansible material is caused to transit through the chamber.

In a typical embodiment, the feed stream contains material to be expanded and a refractory powder to reduce the tendency of particles of the material to be expanded to coalesce. For example, the feed stream may include a mixture of slate or shale chippings (the material to be expanded) and bauxite or olivine sand (the powder). Typically, the slate chippings have a particle size of less than 15 mm – for example, in the range 4 mm to 12 mm.

Advantageously, the slate chippings (or other material to be expanded) are preheated prior to their introduction into the heating chamber. This may be to a temperature substantially below that of their fusion temperature – typically in the range 200°C to 600°C (e.g., 350°C) for slate.

The powder typically has a particle size that is considerably less than that of the material to be expanded. For example, olivine sand has a particle size in the range 0.5 mm to 2 mm.

The mass flow rate of powder in the feed stream is approximately 5% of the mass flow rate of expansible material once steady operating conditions have been established. (Initially, the amount of powder may be greater than this to establish an accumulation of powder to be formed within the chamber.)

In cases where the expansible material is slate, the mixture is typically heated to a temperature of approximately 1200°C. This temperature may be different for other expansible materials.

During expansion, the mixture typically travels from the feed end to the outlet end of the heating chamber where it exits the heating chamber. The rate at which the expansible material travels through the heating chamber is typically much greater than the rate at which the powder travels through the heating chamber. This allows the consumption of the powder to be considerably less than is possible in known methods.

A further feature of the invention that can have application beyond the apparatus disclosed is the use of olivine sand to promote expansion of lightweight aggregates in a kiln. For example, olivine sand may be employed in the methods and apparatus disclosed in GB-A-2236747, GB-A-2261938 and others. It has been found that this material can be surprisingly effective

Embodiments of the invention will now be described in detail, by way of example, and with reference to the accompanying drawings, in which:

Of Figures 1 to 6, odd-numbered figures show an end view and even-numbered figures show a cross-section of a respective one of three embodiments of the invention.

Each embodiment comprises a generally hollow cylindrical chamber 10. The axis X is inclined to the horizontal Z at an angle θ. The chamber has a feed end, to the right in the figures, and an outlet end to the left The chamber is formed from a steel outer case 12 lined with refractory and insulating material 14. The refractory material 14 forms a heat-resistant surface that forms the surface with which the material being processed makes contact.

The chamber 10 is supported from below on rollers (not shown) that engage with tyres 24 carried on the outer surface of the chamber 10. The supporting rollers, drive and arrangements to take axial thrust are not shown as these are a normal matter of design. The complete device of the whole of kiln is set a working angle with $\theta = 6°$. Provision is made so that the angle of tilt of the whole can be adjusted from the horizontal to a maximum angle, in this embodiment, of $\theta = 8°$. In operation adjustments between just $\theta = 6°$ and $\theta = 7°$ will easily suffice. However the design provides for $\theta = 0°$ to completely empty the kiln if ever necessary, and the $\theta = 8°$ provision is normally just to give some extra margin for operation in unusual conditions. Again, the accommodation of the angles of tilt is a matter of engineering design and the manner of achieving the requirements will not be discussed here further.

The chamber 10 is closed at the feed end by an end wall 16 and by a hood 18 at the outlet end, both being lined with refractory and insulating material. The end wall 16 and the hood 18 each serve to house burners, instrumentation feed tube and other ancillary components. The end wall 16 and the hood 18 are stationary – they do not rotate with the chamber 10. A charge feed tube 36 extends through the end wall through which charge material can be introduced into the chamber 10. An outlet duct 38 carries material leaving the chamber away from the kiln.

In the various embodiments, the shape of the internal surface of the refractory is selected to achieve different movement of the material in the chamber 10. Reduction of charge size is desirable and preferred in keeping with short residence time and the benefits of rapid heating. Alteration of the internal profile from cylindrical to a tapered form, tapering towards the feed end can achieve this reduction, giving a step change in the quantity or charge of particulate solids retained. The amount of taper (included angle between opposed refractory surfaces) can be anything from 0° the cylindrical case shown in Figure 2, up to twice the angle of tilt of the axis X, in which case the lower refractory surface would be horizontal.

The profiles of the refractory 14 as shown in Figures 2, 4, and 6 should serve to illustrate this. In all the three cases shown, the angle of reverse tilt of the axis X is 6°. In Figure 2, the refractory is cylindrical, in Figure 4 the included angle is intermediate chosen in this case to be 8° and in Figure 6 the included angle is 12°. In the third case at the bottom the refractory surface is horizontal. The step change in size of the charge or pool 30 of particulate material retained is clearly shown in the figures

In operation, the kiln will be rotating and the particulate material will position itself in the lower quadrant substantially diametrically opposite the burners 32 Thus when the kiln is rotating, the contents pool 30 as drawn is not strictly accurate, in spite of this however, each figure is still representative enough of what would happen in practice to illustrate the effect of tapering the refractory surface towards the feed end. A larger included angle could be selected, but there would be no advantage. A circumferential lip 34 can be provided in the refractory at the discharge end. This has the effect of increasing the size of the charge retained and helps to retain powder at the point of discharge. Such a lip is often provided when the degree of taper chosen in the design approaches the usual maximum of twice the reverse tilt angle. The angle of taper must be decided at the design stage and at full production scale this angle will have been determined as a result of piloting trials. Once the taper angle is fixed, adjustment of contents of retained particulate material as necessary to provide control in operation, can still be effected by adjustment of tilt angle. As already explained such adjustment may only be possible over 1 to 2°, but this will be sufficient to have a significant effect on contents retained. Consider an angle increase of just 1° subtended over a length of 6m. This would give a tapering increase in bed depth from zero at the discharge end up to some 100mm at the feed end, involving a large amount of material, in excess of what might be needed for fine tuning and kiln operation.

To reduce the charge size and shorten the residence time in keeping with the benefits of rapid heating, the preferred arrangement tends towards that shown in Figure 6, that is to say a refractory taper angle between opposite faces of twice the operational mean angle of reverse tilt. A small depth circumferential lip is provided in the refractory at the discharge end. An example of the preferred arrangement will now be described by reference to Figure 5 and 6.

The figures show the position of a co-operating pair of regenerative burners 32. Such burners are well known for their high combustion efficiency, obtained by extracting heat from combustion products and using the same to provide a high degree of preheat to the incoming combustion air. They achieve exceptional heat recovery at high temperature; a notoriously difficult goal. The direction of rotation ensures that the charge 30 of particulate material will reside in the lower quadrant approximately diametrically opposite the burners. In section A-A, the position of the charge 30 is shown only to illustrate its position relative to the kiln axis. In this position, the charge 30 is remote from the passage of combustion gases penetrating the length of the kiln, passing from one burner 32 to the other in a set sequence Heat transfer to the charge 30 is almost entirely radiant and by direct contact with the refractory lining 14.

The profile of the refractory 14 is tapered at an included angle of 12° towards the feed end and at the discharge end a shallow lip 34 is provided as an integral part of the refractory 14.

In light of trials on a pilot scale, and extrapolating the results with calculations, the following example shows the kiln operating in steady state producing lightweight aggregate.

Again with reference to Figures 5 and 6, the kiln rotor 10 has internal dimensions and geometry as below:

- Diameter at discharge end, just before the lip 34: 4.0 m, tapering at included angle of 12° to 2.8 m over a length of 6.0 m. At the discharge end, the lip 34 is part of the refractory with radial depth 0.1 m.

- At the feed end, the end wall 20 of the rotor refractory has a radial depth of 0.6 m. Thus, the diameter of the aperture to accept the stationary feed end plug 4 is 1.6 m. The refractory of the plug is radially smaller to provide a working clearance.

An important feature of the geometry is that at the 6° reverse tilt angle the end wall is substantially higher than the discharge lip over all angles of reverse tilt provided for in the design. That is, point A is substantially higher than B under all operational circumstances. The end plug 16, being stationary during operation, is fitted with a feed tube 36 for the material under treatment and refractory powder. The feed end plug 16 houses temperature sensors for the burner control system; these are not shown. Regenerative burners 32 are housed in the hood 18 and these burners are provided with full automatic control to maintain an operating temperature of 1200°C. The penetration of burner gases is effective along the length of the kiln, resulting in a substantially uniform process temperature along the kiln length. The maximum output of the burners is approximately 4.6MW. The burners have turn-down capability to limit their output to about 10% of the maximum. Separate feed streams 22 for slate chippings of size 6 mm to 12 mm) and 24 for olivine sand as refractory powder (0.5 mm to 2.0 mm). The actual feeders are not shown. The slate chippings are preheated to 350°C employing heat from the production system mainly that derived from cooling the hot aggregate exiting the kiln. The olivine powder is fed in cold.

With regard to kiln contents in this example, at the chosen mean angle of reverse tilt of 6°, the following data obtains, as far as can be ascertained, and represents a good approximation.

Angle	Volume of retained particulates. m^3	Percentage increase(decrease) on the 6°case
5.5°	0.3	(37)
6°	0 48	N/A
6.25°	0 57	18
6.5°	0 66	34
7°	0 84	75
7.5°	0.93	94

Thus, a range of angular adjustment of just 1.75° will alter the volume contents by something threefold. Volume retained reflects the mass of particulate solids retained. The ability in the preferred arrangement to be able to control the kiln contents to such an extent in percentage terms for a relatively small angular adjustment is an important feature. In any realistic operating situation, where the production rate is say 50% or more of the maximum, residence time is dependant on flow rate of both solids and the contents. The aim is to work up the production rate to an acceptable level prudently short of the maximum capacity of the burner system. For any set feed rate of expansible material there will be an optimum residence time and this is obtainable mainly by adjustment of tilt angle. The embodiment allows a great deal of control to be achieved.

Control features of the embodiment are summarised as below:

- Feed rate of slate chippings and to an extent their entry temperature.
- Feed rate of refractory powder.
- Operating temperature.
- Contents or size of charge by volume and thereby by mass.
- Speed of rotation and thus the degree of agitation and the tumbling regime, and thereby also the displacement effect of powder with its influence on residence time of the expansible material.
- Burner system output, automatic control response features, proportional, derivative etc.

Again with reference to Figure 5 and 6, operating conditions in steady state, a typical production rate and regime will now be described.

Operating temperature 1200°C.

Feed rate of slate chippings (4 mm to 12 mm) preheated to 350°C, 10000kg /hour

Feed rate of olivine sand (0.5 mm to 2.0 mm) cold, 500kg / hour. 5% of slate rate

Residence time of slate chippings variable 2 to 6 minutes altered by tilt angle and kiln rotational speed. (This parameter is difficult to determine by mass as density reduces in transit. This estimate is based on partially expanded bulk density of 800 kg/m^3. The powder fills void space irrespective of the tilt angle Its residence time will also alter, but this is not relevant to operation of the embodiment. The residence times quoted have sufficient latitude to accommodate variations in the assumption of 800 kg/m^3.

Bulk density slate feed 1200 kg/m^3.

Bulk density expanded product 375 kg/m^3.

Bulk density olivine sand powder 1800kg/m^3.

Casing losses from steelwork 3 kW/m^2 over surface area 200 m^2 = 600 kW. Note that 3 kW/m^2 is conservatively high

Slate power requirement 350°C to 1200°C. =	1977 kW.
Olivine power requirement 0°C to 1200°C =	175 kW.
TOTAL POWER	2752 kW
Approximate BURNER INPUT at efficiency 75%	3.7 MW

(c. 80% of max burner output 4.6 MW).

This gives an energy cost per tonne of 1332MJ or 500 MJ/m^3.

As a result of a proportion of the powder remaining in the kiln, the slate charge is mixed with powder at approximately 1:1 by volume for a powder input of just 5% In a conventional kiln, sloping towards discharge, powder would have to be added at a rate of at least 100% to get the same effect.

In a further example the temperature is raised to 1230°C. By reason of sticktion of the olivine powder to the product in transit, even though the powder is specially selected for its inertness and particle shape, more powder is needed to compensate. The powder rate is increased to 20%, 2000 kg/hour. On cooling, the powder is easily separable from the expanded product. The energy requirement is increased but the product is lighter at 320 kg/m^3, thus offsetting the energy increase. Figures are given below.

operating temperature 1230°C.

Feed rate slate preheated to 350°C as before	10000 kg/hour.
Feed rate olivine, cold: 20% of slate rate.	2000 kg/hour.
Residence times, slate and bauxite bulk densities as before.	
Casing losses, substantially unaltered.	600 kW
Slate power requirement marginally up to	2047 kW
Bauxite power requirement increased to	715 kW
TOTAL POWER	3362 KW
BURNER INPUT at 75% efficiency	4.5 MW

Now 96.5% of maximum burner output, would be prudent to reduce output.

Energy cost per tonne now 1620 MJ or 517 MJ/m^3.

Many variations are possible within the scope of this invention. Such variations would relate mainly to kiln internal geometry and dimensions, angle of taper, depth and profile of lip at discharge, perhaps no lip at all and so on. Operational experience and routine experience will lead to optimisation and determination of the best internal profile for subsequent kilns.

The main point to emphasise is that all variants will rely on the principles enunciated in the foregoing; that is creating a regime in the kiln that allows larger sized material to transit through the kiln whilst leaving a reservoir of powder sized refractory material substantially *in situ*, all made possible by reverse tilt and the forcing of solids of differing particle size to move through by progressive displacement.

Claims

1. A method of production of lightweight aggregates comprising steps of: introducing a feed stream comprising a mixture of granular and powdered materials into a heating chamber of a kiln and applying heat to the chamber, wherein the mixture of powdered and granular materials includes olivine sand.

2. The method of claim 1, wherein the olivine sand has a particle size of 0.5 mm to 2 mm.

3. A method of production of production of lightweight aggregates substantially as herein described with reference to the accompanying drawings.

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Application No:	GB0725358.6	**Examiner:**	Gareth Davies
Claims searched:	1	**Date of search:**	29 April 2008

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 2	GB2261938 A (KYFFIN) - see whole document, especially page 11 lines 5-11, and figure 1; noting kiln (10) and feed chutes (19, 20).
A	-	GB2236747 A (GREAVES) - see whole document, especially page 6 paragraph 1, and figure 1.
A	-	GB555757 A (GOLDSCHMIDT) - see whole document.
A	-	JP09145031 A (EBARA) and WPI Abstract Accession No. 1997-353579 [33] - see abstract and figure 1.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

F4B

Worldwide search of patent documents classified in the following areas of the IPC

C04B; F27B

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, TXTE

International Classification:

Subclass	Subgroup	Valid From
C04B	0020/06	01/01/2006
F27B	0007/00	01/01/2006