Jan. 4, 1966 S. H. VAUGHAN, JR 3,227,430

REFRACTORY STRUCTURE FOR A ROTARY KILN

Filed June 24, 1964

4 Sheets-Sheet 1

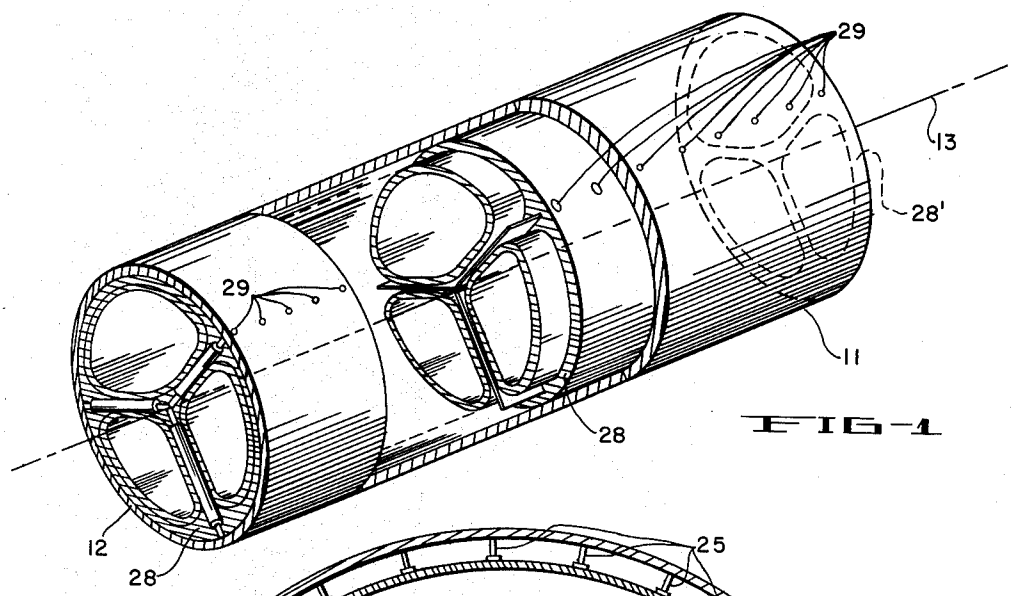


FIG-1

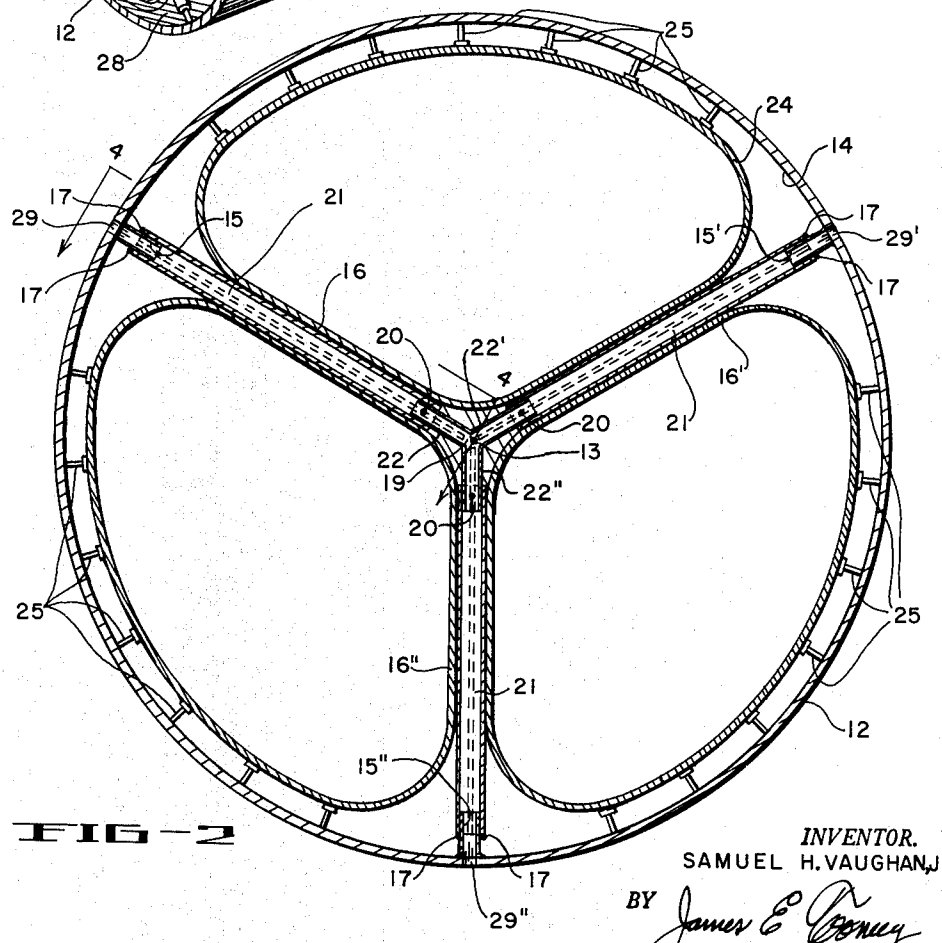


FIG-2

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REFRACTORY STRUCTURE FOR A ROTARY KILN

Filed June 24, 1964 4 Sheets-Sheet 2

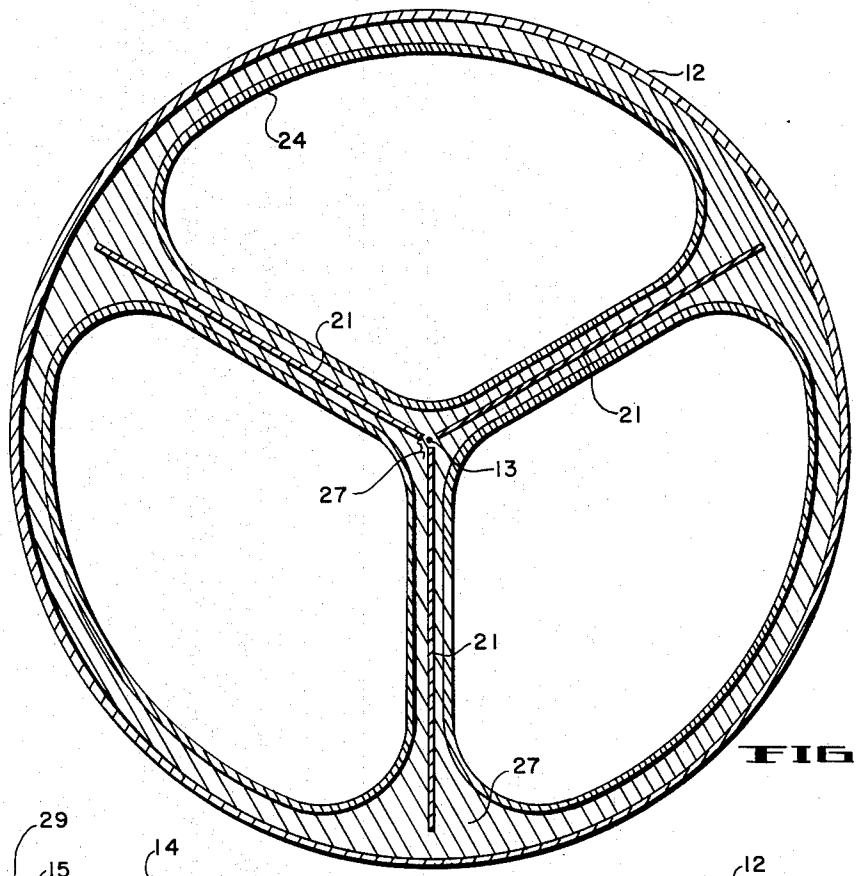


FIG-3

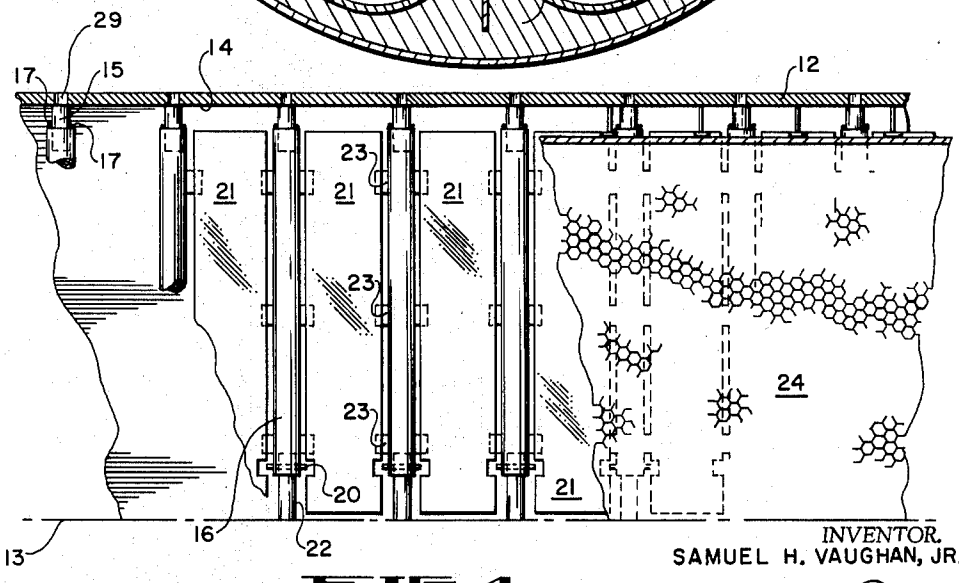


FIG-4

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Jan. 4, 1966 S. H. VAUGHAN, JR 3,227,430

REFRACTORY STRUCTURE FOR A ROTARY KILN

Filed June 24, 1964 4 Sheets-Sheet 3

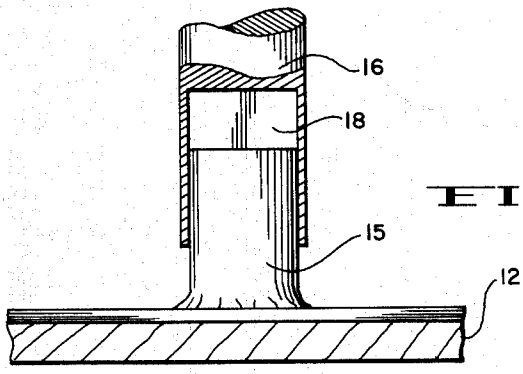


FIG-6

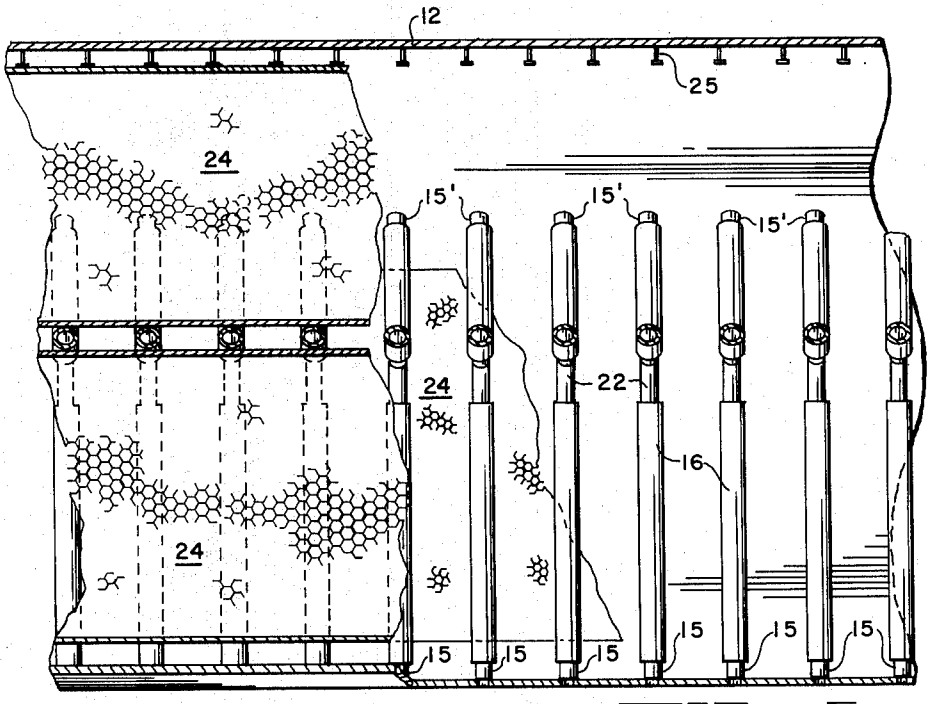


FIG-5

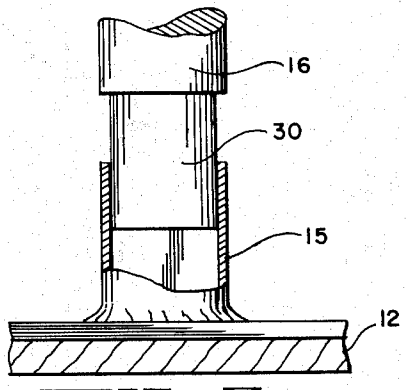


FIG-7

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REFRACTORY STRUCTURE FOR A ROTARY KILN

Filed June 24, 1964 4 Sheets-Sheet 4

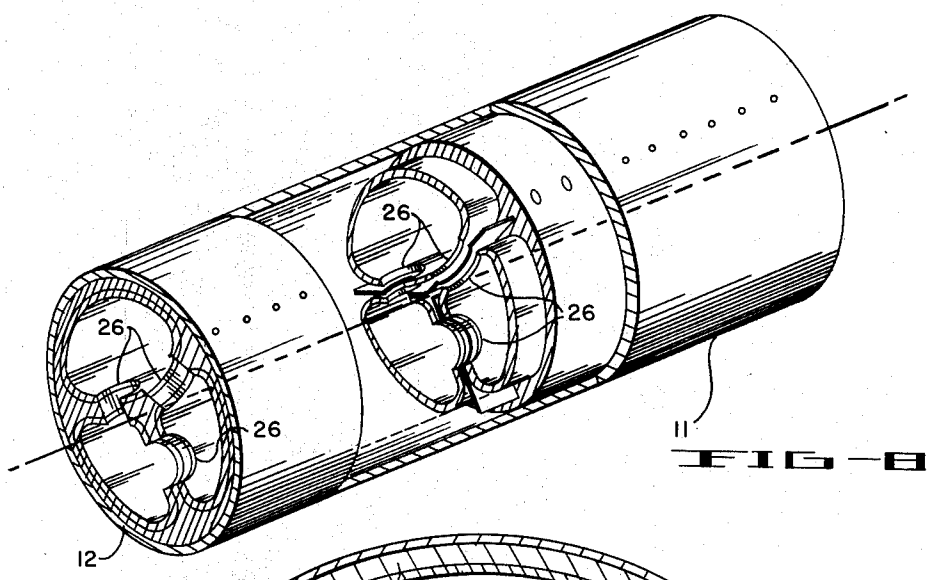


FIG-8

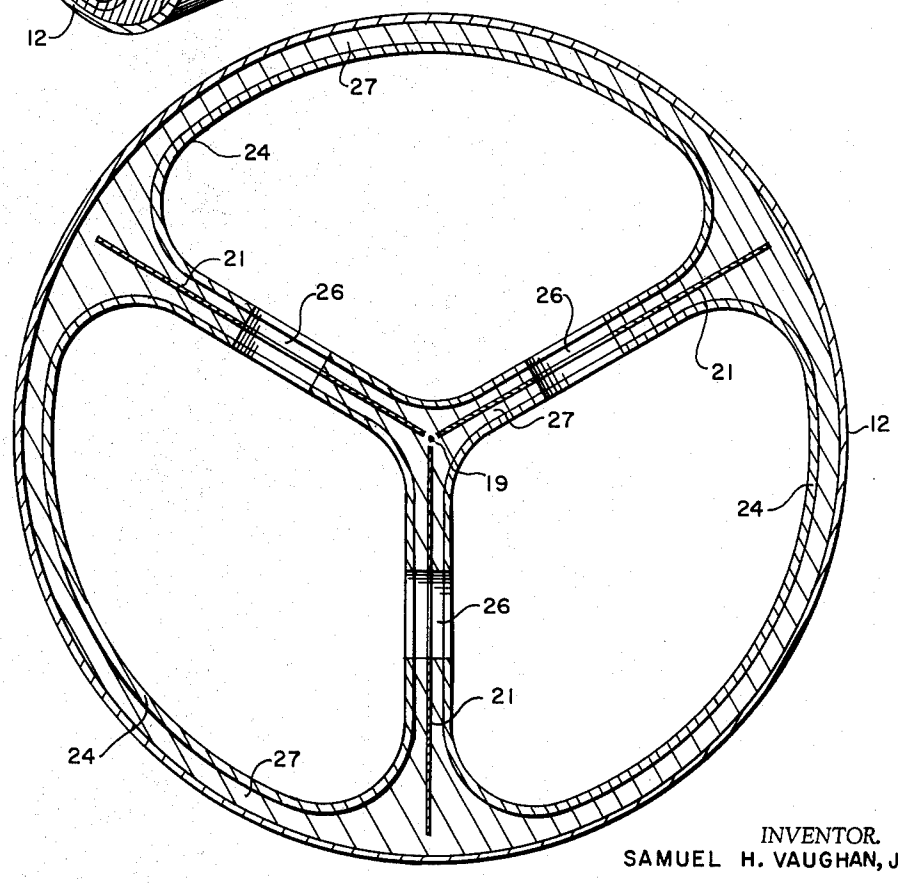


FIG-9

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United States Patent Office 3,227,430
Patented Jan. 4, 1966

3,227,430

REFRACTORY STRUCTURE FOR A ROTARY KILN

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Filed June 24, 1964, Ser. No. 377,543
8 Claims. (Cl. 263—33)

This invention relates to rotary kilns and particularly to internal structures for such kilns.

In a rotary kiln, generally comprising a refractory lined, elongated metal cylinder or tube with its longitudinal axis inclined at a small angle to the horizontal, material to be treated is fed to the kiln at its upper end and a burner or other source of heat is directed into the kiln at its lower end. As the kiln is rotated about its longitudinal axis, the material to be treated flows by gravity down the length of the kiln, passing out the hot or lower end of the kiln. During its passage through the kiln, the material undergoes physical or chemical changes or both.

One of the important processes taking place in a rotary kiln is the heating of material in the upper or cooler end of the kiln by the hot gases passing up the kiln from the burner. It is desirable to extract as much heat from the hot gases as possible since any heat not extracted is carried out of the kiln by the outgoing gases and may be wasted.

Various means have been suggested to increase the efficiency of heat transfer between the hot gases and the material in the kiln. For example, it is known to insert chains in the cold or upper end of the kiln. It is also known to insert lifters in the lining of the kiln to raise the material being treated as the kiln rotates and allow it to drop back through the hot gases. It has also been suggested to insert longitudinal walls or dividers into the cooler end of the kiln to divide the kiln into two or three or more parallel sections or segments or passages, thus increasing the amount of contact between the material being treated and the hot gases.

Such walls or dividers as heretofore constructed suffer from several disadvantages. For one thing, they have usually been made from preformed refractory shapes and the problem of building straight walls within a circular kiln has necessitated the use of many specially shaped pieces assembled in precisely the correct relationship. Not only is it expensive to form the particular special shapes required for such a structure, but it is also difficult and time consuming for workmen assembling such a structure to place each special shape in its correct position in the structure. Another disadvantage of prior art divider or wall structures is that they are relatively rigid and have a tendency to crack and break under the stresses induced by flexure of the kiln as it rotates. As will be understood by those skilled in the art, the shell of a rotary kiln, ideally circular, actually assumes an oval shape under its own weight and the weight of its lining, the long axis of the oval being horizontal and the short axis vertical. As the kiln rotates, the long and short axes remain fixed relative to the earth but move relative to a given point in the kiln, thus causing flexing or bending of different parts of the kiln.

It has now been found that it is possible, by the structure of this invention, to build an internal heat exchanger structure in a rotary kiln which comprises refractory-retaining means or reinforcement made of metal and a monolithic refractory placed by gunning, casting, or the like. The structure according to this invention is relatively easy and simple to assemble and install, provides mobility or flexibility in the structure to accommodate the flexing of the kiln as it rotates, and also permits the passing of air or other cooling fluid through passages within the

internal structure itself, thus cooling the structure and tending to prolong its life.

The invention will be best understood from the following description taken in conjunction with the drawings, in which:

FIGURE 1 is a perspective view of a rotary kiln, partly broken away, showing the general arrangement of the heat exchanger structure of this invention;

FIGURE 2 is a cross section view of a rotary kiln according to the invention taken perpendicular to the longitudinal axis of the kiln and showing the metal framework of the internal heat exchanger structure;

FIGURE 3 is a cross sectional view similar to FIGURE 2 but slightly displaced along the axis of the kiln and showing the refractory material in place;

FIGURE 4 is an elevational view, partially broken away, along the line 4—4 of FIGURE 2;

FIGURE 5 is a longitudinal cross-section view similar to FIGURE 4 but showing an embodiment of the frame structure of the present invention wherein interior plates are omitted;

FIGURE 6 is a cross sectional view of one embodiment of a support means according to this invention;

FIGURE 7 is a cross sectional view of another embodiment of a support means according to this invention;

FIGURE 8 is a perspective view similar to FIGURE 1 but showing an alternative embodiment; and

FIGURE 9 is a sectional view similar to FIGURE 3 but showing the embodiment of FIGURE 8.

In erecting the structure of the present invention within a rotary kiln **11** having an external metal shell **12** and longitudinal axis **13**, there are attached to the inside of the metal shell **12** a plurality of support means such as projections or studs or lugs **15**. The lugs **15** are of metal, preferably ferrous metal, and are attached to the metal shell **12** by welding or threads or other suitable means as desired. The lugs or projections **15** are spaced from each other and are disposed in rows running generally longitudinally of the kiln, the number of rows depending upon the number of radial sections into which the kiln is to be divided. Thus, for example, in the drawings a division of the kiln into three sections is shown. In this embodiment, then, there are three rows of lugs **15** affixed to the interior surface **14** of shell **12** for the distance along the kiln over which it is desired to construct the heat exchanger structure.

It will be understood that the heat exchanger structure according to this invention is spaced from the upper end of the kiln and continues for any desired distance along the length of the kiln. In a preferred embodiment, such structure terminates less than half-way down the kiln from the upper end or, in other words, extends from adjacent the cold end to not over about one-half the length of the kiln. It will be understood that the interior of the kiln can, alternatively, be divided into two or into four or more radially disposed sections within such structures. Generally, however, it is preferred to divide the kiln into at least three such sections therein. In a preferred embodiment, each row of lugs **15** along the inside of the metal shell **12** is disposed parallel to the longitudinal axis **13**, and the rows then are also parallel to each other. However, the rows of lugs **15** can be disposed at an angle to the axis **13** when it is desired to make a spiral or twisted heat exchanger structure.

Mounted on each of the lugs **15** is a metal spoke **16** having its outer end disposed adjacent lug **15** and its inner end disposed adjacent the longitudinal axis **13** of the kiln **11**. Preferably, spoke **16** is slidably mounted on lug **15**, as, for example, by making at least the end portion of the spoke hollow and of such an inside diameter that it will receive the end of the lug **15**. For convenience in

construction of the heat exchanger of this invention, spoke **16** can, after being placed over lug **15**, be temporarily secured to the lug **15**, as by tack-welds **17**. While continuous welds can be made at the junction between spokes **16** and corresponding or associated lugs **15**, it is preferred that only a temporary, breakable joint, for example tack weld **17**, be made at this point so that the temporary joint will be broken under the stresses in the rotating kiln, thus effecting a mounting of spokes **16** on lugs **15** such that spokes **16** are slidable in the direction of their length with respect to lugs **15**. This slidable mounting gives a mobility or resilience to the entire structure which enables it to withstand strains due to flexure during rotation of the kiln.

The inner end of each spoke **16** is attached to an arm **22** of a central connector **19** which can comprise, for example, as shown in the drawings, three tubular pieces of metal joined at the center, as by welding, to form a central connector having three outwardly extending arms **22**. These arms are preferably spaced from each other at equal angles. For instance, in a three-section heat exchanger arms **22** are spaced 120° from each other. It is preferred that the spokes **16** be pivotally attached to arms **22** of central connector **19** whereby the outer end of an arm **22** is disposed within the hollow end of spoke **16** and is pivotally connected thereto by pin **20** which passes through suitable, aligned apertures in **22** and in **16** and which is provided with suitable keys or cap nuts to retain it in position. The pivotal or pin joints between the spokes **16** and central connectors **19** add to the flexibility of the heat exchanger structure. Most preferably the pins **20** are placed so that their axes are substantially parallel to the longitudinal axis **13** of the kiln **11**.

The element disposed between a support means or projection **15** and central connector **19** is suitably a rod, which is termed herein a "spoke". This element in one embodiment is hollow, but in another embodiment, shown in FIGURE 6, is solid and is provided at each end with hollow portions, one of which fits over the end of projection or lug **15** and the other or opposite end portion over the end of arm **22** of central connector **19**. In still another embodiment, shown in FIGURE 7, the support means **15** is a tubular piece of metal and the spoke **16** terminates in a tongue **30** of reduced cross-section with respect to the cross-section of the main body of the spoke. This tongue is disposed within tubular support means **15** and is movable with respect thereto as the kiln shell **12** flexes with the rotation of the kiln.

For ease and economy of construction and for uniform operation of the kiln, it is preferred that central connectors **19** lie substantially on the longitudinal axis **13** of the kiln **11** and that, consequently, spokes **16** be all of substantially the same length and all lie or extend substantially perpendicular to the metal shell **12** of kiln **11** and to its axis **13**. Also for ease of construction, it is preferred that corresponding lugs in the different rows, i.e., the first, second, etc. lugs, be placed on the same circumference, or the same periphery of the same circular cross-section, of the rotary kiln **11**. That is to say, by the word "circumference" is meant the line of intersection between the shell of the kiln and a plane perpendicular to the longitudinal axis **13** of the kiln **11**. Also, it is generally desirable that the rows of lugs be equally spaced about the circumference of the kiln. When corresponding lugs **15** in each row are placed on the same circumference of the kiln **11**, the spokes **16** attached to the lugs **15** on one circumference will all lie in the same plane and be aligned with the mating arms **22** of the central connector **19**. Thus, a single central connector **19** can be used to join all three spokes. While the central connector **19** joining these spokes can be joined, if desired, to the central connector **19** connecting the next adjacent set of spokes **16**, it is preferred, for convenience in construction, that the central connectors **19** not be connected with each other.

It will be understood that the corresponding lugs **15** in different rows can lie on different circumferences of the kiln **11**. In this event, spokes **16** will not meet at the same point along the longitudinal axis **13** and the central connector **19** can be a continuous means, e.g. a rod or pipe, with projections or arms **22** extending at appropriate points. However, it will generally be found that such a construction is less convenient to assemble and more expensive than the above-described central connector **19**.

Between spokes **16** attached to adjacent lugs **15** in a given row are preferably placed plates **21**. These plates extend from adjacent inner surface **14** of metal shell **12** of the kiln **11** to adjacent the longitudinal axis **13** of kiln **11**, and from adjacent one spoke **16** to closely adjacent the neighboring spoke **16**. They are attached to each spoke **16**, for example by fingers **23** attached to spoke **16** and to plate **21**, as by welding or bolting.

It will be seen that the spokes **16** attached to the lugs **15** in a row form a corresponding row of spokes. To the outer side of each spoke **16** in such a row is attached, for example by welding, a layer of apertured metal sheet such as metal mesh **24**. The mesh shown, as an example only, in the drawings has openings of hexagonal configuration. This mesh is placed on each side of each row of spokes **16**, and can extend from end to end of such spoke. However, it is preferred that the mesh **24** extend in a continuous curve along the sides of a row of spokes **16**, over and past the central connector **19**, and along the facing sides of an adjacent row of spokes **16**. It is further preferred that the metal mesh **24** extend in a continuous curve over and past the outer ends of the spokes **16** in each row and continue in spaced relationship with the metal shell **12** of the kiln **11**. For example, the mesh is spaced from the shell **12** by means of T-bolts or anchors **25** attached to the interior of the shell **12** and spaced from each other longitudinally and transversely. Thus, it will be seen that, in the most preferred embodiment, each radial section or passage into which the rotary kiln **11** is divided by the heat exhanger structure of this invention is continuously lined with metal mesh **24** attached to spokes **16** and anchors **25**, forming a smooth, continuous lining for each section. It will be seen that the above described metal structure divides the kiln into three adjacent radial sections and forms a reinforcing structure for receiving refractory material.

After the metal structure has been erected within the kiln, the space between the metal mesh **24** and the kiln shell **12** and between the two layers of metal mesh **24** attached to each side of the rows of spokes **16** is filled with monolithic refractory material, for example by gunning or casting or ramming the refractory material, preferably a plastic refractory, into the spaces. The spaces will be filled with refractory material up to the outer or exposed surface of the metal mesh **24**. The term "outer surface" of the mesh is intended to mean the surface facing the enclosed or central space of the radial section. In other words, the monolithic refractory surface is flush with the outer surface of the metal mesh **24**. It will be understood that this monolithic refractory material, for example a fireclay gunning mix, is preferably of a type which sets to a hard coherent structure at room temperature and which is of such a composition that it remains hard and coherent at the operating temperatures of the rotary kiln **11**, such monolithic refractory materials being well known in the art.

It will be seen that a special advantage of plates **21** is to retain the monolithic refractory material during its placement, for example by gunning. Thus, if plates **21** were not present, there would be a tendency for the monolithic refractory, when it is gunned, to pass through both thicknesses of metal mesh **24** and be wasted. In an alternative embodiment, however, the metal mesh can be used without lining plates such as plates **21**. In this case a shield, for example, can be placed at one face of the double mesh wall and refractory gunned or cast into the

space between the mesh sheets from the opposite face of the mesh.

It will be understood that the ends **28** and **28'** of the heat exchanger structure within the rotary kiln **11** can be finished with metal mesh **24** attached to the metal shell **12** of the kiln **11** and to the end surface of the spokes **16** at the end of each row of spokes, the monolithic refractory **27** being brought out flush with the surface of this metal mesh **24** at the ends **28** and **28'**, whereby the mesh is embedded in the refractory.

Generally, for ease of construction, the lugs **15** in each row, and correspondingly the spokes **16** in each row, will be spaced from each other along the row at equal intervals, but in another mode of carrying out this invention the lugs and correspondingly the spokes are spaced from each other at irregular or nonequidistant intervals, if desired.

In one embodiment of the invention, shown in FIGURE 2, the structure is such that air or other cooling fluid can pass from outside the metal shell **12** of the kiln **11** through the metal framework of the heat exchanger structure. Circulation of air or other cooling fluid is possible because the metal shell **12** of the kiln **11** has holes **29** placed so as to register with the openings of lugs **15**, which are tubular elements. Likewise each spoke **16** is a hollow pipe and the central connector **19** is made of three joined, hollow arms **22** opening into or registering with each other at the center of this element. Thus, the structure provides a continuous passage from hole or aperture **29'** through hollow lug **15'**, hollow spoke **16'**, and hollow arms **22'** of central connector **19** through which cooling air or other fluid may be passed, either by natural convection or by artificially created pressure, on through arm **22''**, spoke **16''** and tubular support element **15''** and out through aperture **29''** in shell **12**.

In the alternative embodiment shown in FIGURES 8 and 9, ports or holes or openings **26** are placed in the dividing walls of the heat exchanger structure. The effect of these holes is to impart additional motion to the material travelling through the kiln and increase the heat exchange between the material and the hot gases. This structure allows the product being treated to not only travel down the kiln longitudinally, but also be transferred or exchanged between compartments on its journey down the kiln. This additional motion imparted to the product or material being treated effects a slowing down of the material to get better heat exchange.

It will be understood that the metal parts of the heat exchanger structure can be made of any suitable metal, for example steel. For the load bearing parts of the structure, lugs **15**, spokes **16**, and central connectors **19**, 25% chrome steel is particularly suited to the elevated temperatures encountered in a rotary kiln. While circular spokes **16** are shown in the drawings, it will be understood that square, rectangular, or other cross-sectional forms can be used. While preferred embodiments of the structure have been shown and described, it will be understood that other forms of the invention are possible within the scope of the appended claims.

Having described the invention,

What is claimed is:

1. In a rotary kiln having a metal shell longitudinally inclined to the horizontal and an upper end and a lower end, a heat exchange structure disposed within said shell and comprising a metal reinforcing frame work comprising a plurality of generally longitudinal rows of outer support means affixed to the interior surface of said shell, a central support means disposed at the axis of said kiln, a plurality of rows of connector means disposed between said rows of outer support means and said central support means, each of said connector means being connected with one member of said row of outer support means and with said central support means, apertured metal sheet disposed over said outer support means, said central support means and said connector means and defining a plurality of radially disposed interior sections of said kiln; and refractory material disposed within said apertured metal sheets and embedding substantially all of said support means.

2. A heat exchange structure according to claim **1** wherein said outer support means are lugs, said connector means are spokes slidably connected to said lugs, and said refractory material is a plastic refractory.

3. A heat exchange structure according to claim **2** wherein said structure includes dividing walls having ports disposed therein permitting access from one radial section to another of said sections.

4. In a rotary kiln havng a metal shell and a longitudinal axis, an internal structure comprising: studs attached to the interior of said shell, said studs being located in rows; spokes having inner and outer ends; central connectors, the outer ends of said spokes being mounted on said studs and the inner ends of said spokes being attached to said central connectors, said spokes forming rows corresponding to the rows of studs; metal mesh attached to the spokes in each row; and monolithic refractory filling the space between the surfaces of the mesh and the spokes to which the mesh is attached.

5. In a rotary kiln having a metal shell and a longitudinal axis, an internal structure comprising: studs attached to the interior of said shell, said studs being located in rows said rows being substantially equally spaced about the circumference of the kiln shell; spokes, all of substantially equal length, having inner and outer ends; central connectors, the outer ends of said spokes being mounted on said studs so that said spokes are slidable in the direction of their length with respect to said studs, said spokes lying radially with respect to the kiln axis, the inner ends of said spokes being pivotally attached to said central connectors, said spokes forming rows corresponding to the rows of studs; plates disposed between and attached to the spokes mounted on adjacent studs in a row; metal mesh attached to both sides of the spokes in each row; and monolithic refractory filling the space between the surfaces of the mesh and the spokes to which the mesh is attached.

6. In a rotary kiln having a metal shell and a longitudinal axis, an internal structure comprising: studs attached to the interior of said shell, said studs being located in rows running substantially longitudinally of said kiln, said rows being substantially equally spaced about the circumference of the kiln shell, corresponding studs in each row being located on substantially the same circumference of the kiln shell; spokes, all of substantially equal length, having inner and outer ends; central connectors, the outer ends of said spokes being mounted on said studs, said spokes lying radially with respect to the kiln axis, the inner ends of said spokes attached to corresponding studs on the same circumference of the kiln shell being attached to a common connector, said spokes forming rows corresponding to the rows of studs; metal plates disposed between and attached to the spokes mounted on adjacent studs in a row; metal mesh attached to both sides of the spokes in each row, said mesh extending from the vicinity of the outer ends of the spokes in each row to the vicinity of the inner ends of said spokes in each row, past the central connectors and to the vicinity of the outer ends of the spokes in an adjacent row said mesh also extending past the outer ends of the spokes into spaced relationship with the kiln shell, the mesh on facing sides of adjacent rows of spokes and on the intervening kiln shell forming a continuance structure; and monolithic refractory filling the space beween the surfaces of the mesh and the spokes to which the mesh is attached and the space between the mesh and the kiln shell.

7. In a rotary kiln having a metal shell and a longitudinal axis, an internal structure comprising: studs attached to the interior of said shell, said studs being located in rows running substantially longitudinally of said kiln, said rows being substantially equally spaced

about the circumference of the kiln shell; spokes, all of substantially equal length, having inner and outer ends; central connectors, the outer ends of said spokes being mounted on said studs so that said spokes are slidable in the direction of their length with respect to said studs, said spokes lying substantially radially with respect to the kiln axis, the inner ends of said spokes being pivotally attached to a central connector, the axis of said pivotal attachment being substantially parallel to the kiln axis, said spokes forming rows corresponding to the rows of studs; metal plates disposed between and attached to the spokes mounted on adjacent studs in a row; metal mesh attached to both sides of the spokes in each row, said mesh extending from the vicinity of the outer ends of the spokes in each row to the vicinity of the inner ends of said spokes in each row, past the central connectors and to the vicinity of the outer ends of the spokes in an adjacent row, said mesh also extending past the outer ends of the spokes into relatively closely spaced relationship with the kiln shell, the mesh on facing sides of adjacent rows of spokes and on the intervening kiln shell forming a continuous structure; and monolithic refractory filling the space between the surfaces of the mesh and the spokes to which the mesh is attached and the space between the mesh and the kiln shell.

8. In a rotary kiln having a metal shell and a longitudinal axis, an internal structure comprising: studs attached to the interior of said shell, said studs being located in rows said rows being substantially equally spaced about the circumference of the kiln shell and corresponding studs in each row being located on substantially the same circumference of the kiln shell; spokes, all of substantially equal length, having inner and outer ends;

central connectors, the outer ends of said spokes being mounted on said studs, said spokes lying substantially radially with respect to the kiln axis, the inner ends of said spokes attached to corresponding studs on the same circumference of the kiln shell being attached to a common central connector, said spokes forming rows corresponding to the rows of studs; metal mesh attached to the spokes in each row, said mesh extending from the vicinity of the outer ends of the spokes in each row to the vicinity of the inner ends of said spokes in each row, past the central connectors and to the vicinity of the outer ends of the spokes in an adjacent row, said mesh also extending past the outer ends of the spokes into spaced relationship with the kiln shell, the mesh on facing sides of adjacent rows of spokes and on the intervening kiln shell forming a continuous structure; and monolithic refractory filling the space between the surfaces of the mesh and the spokes to which the mesh is attached and the space between the mesh and the kiln shell; said spokes, said studs, and said central connectors being hollow and interconnected, and the kiln shell having holes at the points of attachment of the studs whereby cooling fluid can pass from outside the kiln in toward the axis of the kiln through certain of said spokes and out from the axis of said kiln through others of said spokes.

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