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REFRACTORY TILE SYSTEM FOR BOILER TUBE/HEAT EXCHANGERPROTECTION

10

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to refractory tube blocks which protect metallic waterwall tubes from hot and highly corrosive furnace gases, while at the same time maintaining good heat conductivity.

2. Background Information

Refractory tiles have long been used for the protection of boiler walls in waste incinerators and other heat exchanger applications. The primary function of the tiles has been to shield the steel alloy boiler walls, which typically include waterwall tubes and membranes or webs disposed therebetween, from the temperature, erosion, and corrosion by acid vapor attack associated with boiler operation. These conditions are generated by the combustion process occurring within the boiler. For example, municipal solid waste (MSW)

5 facilities incinerate trash and garbage in furnaces at
temperatures of up to about 1400°C. In order to recover
the valuable energy produced in these MSW plants, water
is passed through metallic waterwall tubes adjacent to
the furnace and converted to steam by the high
10 temperatures. The steam produced in the tube assembly is
then used to power a turbine-driven electric generator.
However, the MSW plant also produces gaseous products
which, if allowed to contact the metal wall, would
chemically attack the walls. The purpose of the
15 refractory tiles has been to prevent direct attack of the
walls by gaseous products and still allow the tubes to be
sufficiently heated to efficiently generate steam. The
primary purpose of the tiles is thus to extend tube wall
lifetime expectancy.

20 Refractory tiles for boiler tube protection have
traditionally been fabricated from a material such as
silicon carbide (SiC). These tiles typically are
provided with a substantially planar face with a
contoured back surface sized and shaped to match the
25 contour of the tube wall. Such tiles generally have been
fabricated as a variant of one of three configurations,
namely bolted tiles; hanging tiles, such as disclosed in
U.S. Patent No. 4,768,447 to Roumeguere; and modified
hanging tiles also known as slotted or T-slotted tiles

5 such as disclosed in U.S. Patent No. 5,243,801 to Aiken,
et al. and in WO 97/09577 to Zampell Advanced Refractory
Technologies, Inc. The U.S. 4,768,447, U.S. 5,243,801
and WO 97/09577 references are fully incorporated by
reference herein.

10 As shown in Figs. 1 and 2, bolted tiles 10 are
generally provided with a square or rectangular face 12
adapted for orientation towards an interior of the
boiler. A hole penetrates through the thickness of the
tile in the approximate center of the face 12. A
15 countersunk region 34 typically exists within the hole or
bore 30 to act as a seat for a nut 28. In a typical
installation, a stud or threaded bolt 24 is welded to a
membrane region 16 between two tubes 18 in the boiler
wall 62. The contoured back surface 14 of the tile 10
20 includes accurate portions 20 sized and shaped to
receivably match the profile of the tube wall 19 and
allow for close contact therewith.

The tile is installed by fitting the stud through
the hole and securing the tile in position with a washer
25 28 and nut 26 threaded onto the stud. A cap (not shown)
is then typically mortared in place over the hole to
minimize the amount of gas that can flow through
clearance between the standard hole to the backside of
the tile. A layer of mortar (not shown) is typically

5 applied between the tile and the wall 62, and between adjacent tiles, to form a rigid structure which serves to help secure the tile in position and to substantially prevent gas from flowing between and/or behind the tiles.

An advantage of using a bolted tile configuration is
10 that the tiles are relatively easy to install and may be installed on substantially any surface of the boiler, including vertical and overhanging surfaces.

A disadvantage of such bolted tiles is associated with tile failures. These tiles usually have a 2 to 4
15 year life expectancy due to stud failure. When the studs fail, the tiles tend to fall off of the walls, leaving the boiler tubes exposed to the incinerator atmosphere. The cause of failure in the studs was previously believed to have been due to high temperature acid corrosion. In
20 particular, it was believed that the acids penetrated the tile through the stud hole to attack the stud. The corrosion was believed to be severe on the stud due to its high operating temperature (believed to be 1000°C or more). Also, cracking of the tiles was a common
25 occurrence, and believed to have been generated by overstressing the stud.

One attempt to address the disadvantages associated with bolted tile systems has included the use of hanging tiles. As shown in Figs. 3 and 4, hanging tiles 45

5 typically utilize an anchor/hook or short stud 37 to hang
the tile on the membrane 16 of the boiler wall 62, with
gravity utilized to maintain the tile in close proximity
to the boiler wall 62 for good heat transfer. This tile
45 is a modification of the bolted tile in that one or
10 more holes 30' project from the back surface 14' of the
tile toward the hot face 12, but do not fully penetrate
the hot face. This provides the tile with a closed face,
to theoretically improve acid corrosion resistance. A
layer of mortar (not shown) is typically installed
15 between the tile 45 and the boiler wall 62, as well as
between adjacent tiles to form a rigid, substantially gas
and ash impermeable structure.

A variation of this hanging tile arrangement
utilizes the tiles 45 in conjunction with an air sweep
20 system. In this variation, no mortar is installed behind
the tiles to leave a gap between the tiles and the boiler
wall. A flow of air is fed through this gap to help
minimize acid corrosion of the wall.

An advantage of hanging tiles in general is the
25 relative ease of installation and replacement. A
disadvantage of such hanging tile arrangements is that
the tiles generally cannot be installed on non-vertical
walls, as the tiles tend to fall off their anchors.
Also, tiles have been known to lift off of their anchors

5 during operation due to thermal expansion, etc.
Moreover, the above described air sweep system tends to
disadvantageously increase the expense of the tile system
relative to configurations utilizing mortar. Heat
transfer between the tiles and wall also may be
10 disadvantageously reduced due to the insulative (i.e.,
relatively low thermal conductivity) characteristic of
air layers.

Turning to Fig. 5, modified hanging tiles 50 have
been developed in an attempt to address the drawbacks
15 associated with the hanging tiles becoming dislodged from
their anchors or hooks. Examples of such modified
configurations are commonly known as mushroom bolt, tube-
welded fin anchor, and T-slot tiles. These tiles 50 are
typically hybrids of bolted tiles and hanging tiles,
20 incorporating a closed tile face 12' with an anchor 52
that has a substantially T-shaped profile, to effectively
capture the tiles and allow them to be installed on both
vertical and overhanging surfaces.

These tiles 50 are generally installed with a layer
25 of mortar between the tile and the boiler wall, as well
as between adjacent tiles. The purpose of the mortar is
to help secure the tiles by providing a rigid attachment
and to provide a barrier to resist penetration of ash and
corrosive gas between and behind the tiles.

5 An advantage of these modified tiles 50 is that they
may be installed on nominally any boiler surface.
Disadvantages of the tiles 50 include difficulty of
manufacture since they incorporate a blind (i.e.,
discontinuous) slot 54 projecting laterally into the tile
10 from an edge thereof. Also, the tiles may be physically
weaker due to the complexity of the blind slots 54.
Moreover, individual tiles generally cannot be replaced
without removing a entire row of tiles.

 An additional approach intended to address the
15 drawbacks of the above-described configurations has
included use of the hanging tiles 45 in combination with
a resilient material 48 installed between opposed
recesses or grooves 49 as shown in Figs. 3 and 4. This
approach tends to facilitate installation and replacement
20 of the tiles relative to tile systems utilizing
conventional rigid mortar. While this approach may
operate satisfactorily in some applications, the
resilient material 48 disadvantageously provides little
resistance to corrosive gas flow and thus tends to be
25 undesirable for use in particularly corrosive
environments such as found in MSW boilers.

 Still further, many of the approaches discussed
hereinabove utilize a fibrous compressible material or
mortar at periodic tile intervals to serve as expansion

5 joints. For example, such material may be used every 7
to 15 tiles in a manner familiar to those skilled in the
art of masonry (i.e., such as commonly utilized in
fabrication of concrete sidewalks, etc.) These joints
however, tend to disadvantageously permit the passage of
10 acids and other corrosive materials therethrough, to
enable corrosion of the underlying boiler wall.
Additionally, the useful life of tile systems having such
expansion joints have not been shown to be appreciably
greater than similar tile configurations not having such
15 expansion joints.

Thus, a need exists for an improved refractory tile
system that addresses drawbacks associated with the prior
art.

20

SUMMARY

A significant aspect of the present invention is the
recognition of the problem responsible for many of the
failures of the prior art systems. It was recognized
25 that these failures were generated by both bowing of
individual tiles (as used herein, "micro-scale" bowing)
and collective bowing of multiple tiles (as used herein,
"networked" or "macro-scale" bowing) as shown in Fig. 8.
Referring to Fig. 9, micro-scale bowing generates forces

5 F which transfer through the rigid mortar (not shown) to adjacent tiles to thus generate a macro-scale bowing effect. The macro-scale bowing applies sufficient tensile stress to the studs to cause failure. In this regard, it was heretofore believed that any significant
10 dimensional instability of the tiles was primarily limited to thermal expansion generated by exposure to elevated boiler temperatures. Moreover, it was believed that any bowing was limited to individual tiles.

Contrariwise, the present invention is based on the
15 recognition that thermal gradients experienced by individual tiles during boiler operation (i.e., the difference between the temperature at the hot face 112' and the back 114' as shown, for example, in Fig. 7) were greater than previously suspected, and exerted a greater
20 influence on the dimensional instability of the tiles than the aforementioned thermal expansion. It was then realized that bowing generated by the thermal gradient tended to transfer stresses through the rigid mortar disposed between adjacent tiles to effectively magnify
25 the effects of individual tile bowing as a function of the square of the length of the tile network. This phenomenon is described by the following equation:

$$\delta = \alpha L^2 \Delta T / (8t)$$

5 where δ = cumulative deflection, α = the coefficient of
thermal expansion, L is the length of the tile array, ΔT
is the difference between temperatures at opposite faces
of the tiles and t is the tile thickness.

It has also been discovered that oxidation on the
10 hot face on the tiles occurring over time creates "hot
spots" which tend to exacerbate the temperature gradient
across the tile to further contribute to the micro-scale
bowing effect. In this regard, it has been found that the
macro-scale bowing serves to accelerate the oxidation,
15 thus initiating a self-perpetuating cycle that serves to
accelerate the decay of the tiles. For example, optimum
operating temperature of the hot face of SiC tiles may be
approximately 500 to 600 degrees C. Oxidation at this
temperature has been found to be minimal and to not
20 substantially affect tile life. However, it has been
found that oxidation progresses rapidly in the event the
hot face reaches or exceeds about 750 degrees C and
continues to accelerate rapidly as the temperature
increases further. An aspect of the present invention
25 was thus the recognition that the macro-scale bowing
serves to separate the tiles from the boiler wall,
forming an air gap which generally reduces the heat
transfer from the back of the tile to the wall. This

5 decrease in heat transfer effectively increases the
temperature at the hot face beyond the preferred
operating temperature range. The macro-scale bowing
eventually has the effect of raising the hot face
temperature to the oxidation promoting temperature of 750
10 degrees C or more. The oxidation in turn, tends to
further increase the temperature gradient which as
discussed hereinabove, tends to further exacerbate the
macro-scale bowing, thus forming a self-perpetuating,
deleterious cycle.

15 Thus, as prior art tile configurations have been
developed to minimize acid penetration (i.e., the blind
hole mounting of hanging and modified tiles 45 and 50),
they have neither identified, nor addressed the
aforementioned bowing condition. These prior
20 configurations continue to make use of rigid mortar
around the tiles, to thus permit macro-scale bowing to
occur.

It was similarly realized that the failure of the
above-referenced expansion joints to generate any
25 substantial benefit was due in part to the failure to
recognize the networked bowing phenomena and rather
attempt to compensate only for relatively benign thermal
expansion effect. This failure is indicated not only by
the relative paucity or infrequency of the expansion

5 joints (i.e., utilized only once every 7-15 tiles), but also by the frequent use of conventional mortar disposed within at least a portion of the expansion joint.

Initial steps in developing the present invention included completion of a first finite element model (FEM) of a conventional 18cm x 18cm bolted tile to assess the cause of cracking in the tiles during operation. This analysis revealed the presence of stresses in the tile due to thermal gradients. It also revealed that the individual tiles bow as a function of the thermal gradients. The initial result of this analysis was to increase the thickness of the tile to increase the tile strength.

After this first analysis was completed, a second finite element model was completed to predict the thermal profiles through the tile thickness and along the length of the stud. At an assumed incinerator operating temperature of 1370°C, this model predicted that the studs were operating at temperatures above 800°C, which is the maximum use temperature for most stainless steel.

25 Failed studs were then retrieved from an incinerator. Analysis of the studs revealed that they had been stretched approximately 6mm prior to failure. This indicated that the studs were placed under a tensile

5 load, and thus were not failing by acid corrosion alone, but rather by stress-corrosion. It was thus determined to examine the cause of the stress on the studs.

Moreover, during retrieval of the failed studs, it was observed that blistered areas of tiles existed.

10 These blisters were approximately 10 tiles by 10 tiles in area, and were displaced into the boiler.

A third finite element model was initiated to study the phenomenon of tile bowing and tensile stress. As previously mentioned, the first FEM indicated that bowing
15 of individual tiles, or micro-scale bowing, occurred due to thermal gradients. This bowing, however, was of insufficient magnitude (0.3 mm) to have caused the 6mm deformation observed in the studs.

In the third FEM, a 7 by 7 array of tiles was
20 modeled, assuming that the mortar would act as a rigid material. The results of the analysis indicated a networking effect among the tiles which generated a significant bow of over 25mm. Additionally, stress analysis indicated that the networked (macro-scale)
25 bowing applied sufficient tensile force to the studs to cause them to stretch to the fracture point.

To confirm the finite element model, a test panel of instrumented tiles was installed in an incinerator. Data collected from the test panel indicated that the tiles

5 bow on a macro-scale during operation, with the magnitude of the bow being approximately 4mm after 1 year in service. Extrapolation of the rate of bowing indicates that the tile will displace 8mm (the displacement assumed to be necessary for stud failure) approximately 2.5 years
10 from the start of the test. This corresponds well with the previous service lifetime observations from bolted tiles.

Thus, according to an embodiment of this invention, a refractory tile system for use on a wall of a boiler
15 includes a plurality of tiles having a floating fastener system engagable with the wall to maintain the tiles in spaced, movable relation to one another. The tiles are sized and shaped to provide a gap between adjacent ones of the tiles, the gap being sufficient to accommodate
20 dimensional changes of the tiles exhibited during exposure to operational temperatures of the boiler. A corrosion barrier is disposed between the tiles and the wall.

In a second aspect of the present invention, a
25 refractory tile system for use on a wall of a boiler includes a plurality of tiles disposed on the wall in spaced, movable relation to one another. The tiles are sized and shaped to provide a gap between adjacent ones of the tiles, the gap being sufficient to substantially

5 prevent macro-scale bowing of the tiles during exposure to operational temperatures of the boiler. A corrosion barrier is disposed between the tiles and the wall to substantially prevent corrosion of the wall.

In a third aspect of the subject invention, a method
10 is provided for increasing the useful life of a wall of a boiler. The method includes the steps of:

(a) providing a plurality of tiles having a floating fastener system engagable with the wall to maintain the tiles in spaced, movable relation to one
15 another;

(b) sizing and shaping the tiles to provide a gap between adjacently wall-mounted ones of the tiles, the gap being sufficient to accommodate dimensional changes of the tiles exhibited during exposure to
20 operational temperatures of the boiler;

(c) disposing a corrosion barrier on the wall; and

(d) engaging the floating fastener system with the wall, wherein the tiles are superposed with the wall with the corrosion barrier disposed therebetween.

25 The above and other features and advantages of this invention will be more readily apparent from a reading of the following detailed description of various aspects of the invention taken in conjunction with the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a bolted refractory tile of the prior art;

10 FIG. 2 is a cross-sectional view taken along 2-2 of the refractory tile of Fig. 1;

FIG. 3 is a side elevational cross-sectional view of a hanging refractory tile of the prior art;

15 FIG. 4 is a top elevational cross-sectional view of the hanging refractory tile of Fig. 3;

FIG. 5 is a perspective, partially exploded view, with portions broken away, of a modified refractory tile of the prior art, disposed for engagement with a boiler wall;

20 FIG. 6 is a view similar to that of Fig. 2, including a top elevational view of an embodiment of the refractory tile system of the present invention;

FIG. 7 is a view similar to that of Fig. 6, of an other embodiment of the refractory tile system of the
25 present invention;

FIG. 8 is a perspective view of an array of prior art refractory tiles bowed on a macro-scale as identified pursuant to the present invention;

5 FIG. 9 is a schematic cross-sectional view similar to that of Fig. 2, of a portions of a pair of adjacent refractory tiles of the prior art, with portions shown in phantom to indicate improvement due to bowing;

 FIG. 10 is a view similar to that of Figs. 6 and 7,
10 of still an other embodiment of the refractory tile system of the present invention;

 FIG. 11 is a side elevational exploded view of portions of the refractory tile system of FIG. 11;

 FIGS. 12-15 are perspective views of the refractory
15 tile system of FIGS. 10 and 11, of various steps taken during installation of a refractory tile according to the present invention;

 FIG. 16 is an elevational schematic representation of a series of conventional bolted tiles of Figs. 1 and 2
20 installed in a boiler for test;

 FIG. 17 is a graphical representation of test results generated by bolted tiles of FIG. 16; and

 FIG. 18 is a graphical representation similar to that of FIG. 17, of test results generated by tiles of
25 the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 Referring to the figures set forth in the
accompanying Drawings, the illustrative embodiments of
the present invention will be described in detail
hereinbelow. For clarity of exposition, like features
shown in the accompanying drawings shall be indicated
10 with like reference numerals and similar features as
shown in alternate embodiments in the Drawings shall be
indicated with similar reference numerals.

Where used in this disclosure, the term "axial" when
used in connection with an element described herein,
15 shall refer to a direction relative to the element, which
is substantially parallel to the central axis a of tube
18 (i.e., Fig. 7) when the element is disposed in
engagement with a tube 18 as shown in Figs. 6, 7, 10 and
14. The term "transverse" refers to a direction
20 substantially orthogonal to the axial direction.

Turning now to Fig. 6, in one embodiment of the
present invention, a refractory tile system 60 includes a
barrier layer coating 61 applied to the wall 62 (i.e.,
membrane 16 and tube wall 19) of a boiler of an
25 incinerator or heat exchanger. The barrier layer 61 is
adapted to provide acid and salt corrosion resistance at
the normal operating temperatures of the boiler. An
example of such a coating is a phosphate bonded SiC
barrier layer such as PC-1022™ available from Norton

5 Company of Worcester, Massachusetts. Advantageously,
this material provides relatively good corrosion
resistance and thermal conductivity. Refractory tiles 66
are then fastened to the tube wall 62 in superposed
relation with the wall 62 utilizing a floating attachment
10 mechanism 68. The tiles 66 are fabricated from any
suitable refractory material known to those skilled in
the art, such as, for example silicon carbide (SiC) or
other ceramic materials capable of withstanding the
temperatures (as high as approximately 1400°C) experienced
15 within the boiler of a MSW incinerator/heat exchanger,
and the like.

The floating attachment mechanism 68 provides the
tiles 66 with a relatively high degree of freedom of
movement relative to the tube wall 62 to accommodate
20 micro-scale bowing of the tile. As discussed
hereinabove, the micro-scale bowing has been found to be
generated by the relatively large temperature gradient
(typically about 200 to 600°C or more) experienced by such
tiles. As also discussed, this temperature gradient has
25 been found to have a substantially greater effect on the
dimensional instability of the tiles than the elevated
temperature per se, particularly in light of the
networking effect in which bowing increases as a square

5 of length of the tile array. Each tile 66 is effectively isolated from adjacent tiles by providing a predetermined gap 70 therebetween of sufficient size to effectively prevent macro-scale bowing which has been found to be generated by networking. As shown in Fig. 9, this
10 networking phenomena is generated by the pressure or force F exerted by the tiles upon one another through the rigid mortar (not shown) when micro-scale bowed.

Turning back to Fig. 6, the gap 70 is preferably formed by contoured peripheral edges 72 which are sized
15 and shaped to form a spaced, shiplapped joint between adjacent tiles 66. This shiplapped configuration advantageously serves to provide an obstructed line-of-sight between the tiles to inhibit penetration of ash or other contaminants through the gap 70 during operation of
20 the boiler. Moreover, a compressible fibrous mortar (not shown) may be disposed in the gap or channel 70 between each adjacent tile to further inhibit ash or other contaminant penetration. An example of such a suitable compressible fibrous mortar is known as Topcoat 2600™
25 available from Unifrax Corporation of Niagara Falls, New York. In the event such a compressible mortar is used, the gaps 70 are sized in combination with the known compressibility of the particular compressible mortar selected, so as to maintain any force transfer between

5 tiles at a magnitude low enough to substantially prevent the occurrence of macro-scaled bowing when the individual tiles are disposed in their maximum micro-scale bowed condition. For example, tiles shaped substantially as shown in Fig. 7 having a rectangular face 112' extending
10 approximately 30cm x 20cm, should have gaps 70' extending at least approximately 6mm from adjacent tiles.

In the embodiment shown, floating attachment mechanism 68 includes rails 74 having a plurality of flexible arms 76 with convex terminal ends 78 adapted to
15 engage similarly sized recesses 80 disposed in the tiles 66. Arms 76 are thus biased into releasable engagement with tile 66 to facilitate installation and removal thereof. Moreover, the resiliency of the arms 76 serves to fasten the tile 66 to the wall 62 in a manner which
20 permits the tile 66 to move or "float" relative to the wall 62 in response to dimensional changes of the tile 66 generated by thermal gradients and elevated mean temperatures. In this regard, the floating attachment mechanism 68 enables the tile 66 to move with at least
25 three degrees of freedom (i.e., along three mutually orthogonal axes x, y and z, as shown) relative to the wall 62. Moreover, in addition to translation along the x, y and z axes, the tile may rotate around a tube 18 and/or bow towards or away from a tube 18. The rail 74,

5 including arm 76 and convex terminal end 78 are preferably fabricated from a flexible, corrosion resistant material, such as stainless steel.

As also shown, the face 112 of the tile 66 may be provided with a contoured geometry which substantially
10 matches the contour of the wall 62 to provide the tile with a relatively uniform thickness t .

Turning now to Fig. 7, an alternate embodiment of the present invention is shown as tile system 60'. This embodiment is substantially similar to the tile system 60
15 shown in Fig. 6, while utilizing a substantially planar face 112' and an alternate floating engagement mechanism 68'. As shown, this fastener system 68' is in many respects similar to fastener system 68 of Fig. 6, though utilizing approximately 50 percent fewer arms 76'.

20 Although embodiments of floating mechanism 68 and 60' have been shown, it should be recognized by those skilled in the art that substantially any mounting mechanism capable of securing a tile to a wall 62 of a boiler in a manner which permits the tile to expand
25 and/or bow on a micro-scale without generating the macro-bowing effect as set forth hereinabove, may be utilized without departing from the spirit and scope of the present invention. In this regard, for example, a rigid mounting arrangement may be used in lieu of the flexible

5 arms 76 and 76', as long as sufficient clearance is provided between the mounting hardware and the tile to enable the aforementioned dimensional changes to occur nominally without applying excessive force or stress to the mounting hardware and/or adjacent tiles.

10 One example of such an alternate arrangement may include provision of one or more pins 82 (shown in phantom) fabricated from stainless steel or the like, which are insertable into substantially oversized bores 84 (shown in phantom) disposed within in the tile and
15 which extend substantially parallel to the tile face 112. The pin 82 is in turn, secured to the wall 62 in any convenient manner known to those skilled in the art, (not shown). In this manner, the tile may be secured to the wall 62 with sufficient clearance to effectively "float"
20 relative to the wall as discussed hereinabove.

Turning now to Figs. 10 and 11, an additional embodiment of the present invention is shown as tile system 60". This tile system 60" is substantially similar to the tile systems 60 and 60' shown in Figs. 6
25 and 7, while using an alternate floating engagement mechanism 68". As shown, this fastener system 68" is in many respects similar to fastener system 68' of Fig. 7, though the arms 76" are substantially "C" shaped for

5 engagement with substantially semi-cylindrical slots or recesses 80" of the tile 66" as shown.

Referring to Fig. 11, the slots 80" of tile 66" include upper slots 81 and lower slots 83, which extend axially inward from upper and lower edges 116 and 118, respectively, of tile 66". The upper slot 81 preferably extends an axial distance d1 from upper edge 116 that is greater than axial distance d2 of lower slot 83, to facilitate installation of the tile 66" as discussed hereinbelow. As also shown, the upper and lower surfaces 15 116 and 118 are chamfered, preferably at an angle α of approximately 30 to 60 degrees, at their intersection with the slots 81 and 83 to further facilitate installation of the tiles 66" as discussed below. In a preferred embodiment, angle α is approximately 45 degrees 20 as shown.

Turning now to Figs. 12-15, the method of installing a tile 66" is shown. Referring to Fig. 12, a tile 66" is installed by placing the upper surface 116 of the tile between the upper and lower arms 76", in substantial 25 axial alignment therewith. This orientation may be accomplished by disposing a portion of the upper surface 116 in surface-to-surface engagement with the tubes 18 as shown. Turning to Fig. 13, the surface 116 of tile 66"

5 is moved axially upwards as indicated by arrow a, while the lower surface 118 is pivoted closer to the tubes 18 as shown by arrow b. This action serves to slide the upper slot 81 (Fig. 11) into receiving engagement with one set of (i.e., the uppermost) arms 76" as shown. This
10 movement is continued until the tile clears the lower arms 76" to permit the tile 66" to be moved into substantially parallel alignment with the tubes 18 as shown in Fig. 14. The tile then may be translated axially towards an adjacent pre-installed tile 66" (i.e.,
15 in direction c) to receivably engage lower arms 76" within lower slots 83 (Fig. 11). This translation preferably continues until the lower arms 76" engage the proximal end 120 (Fig. 11) of the slots 83. At this point, the adjacent tiles 66" will be disposed in their
20 desired spaced, shiplapped orientation as shown in Fig. 15, to complete the installation. Additional tiles 66" (not shown) then may be installed in a similar manner.

The following illustrative examples are intended to demonstrate certain aspects of the present invention. It
25 is to be understood that these examples should not be construed as limiting.

EXAMPLES

Example 1 - Comparison

5 A series of conventional bolted tiles of the general
type shown in Figs. 1 and 2 were installed in a furnace
in a pattern as shown in Fig. 16. Tiles labeled A, B, C,
and D were instrumented with LVDTs (linear variable-
displacement transducers) to measure the displacement of
10 these tiles away from the tube walls during normal
furnace operation. As shown, tiles B and D were located
in a tile array portion that included a conventional
flexible mortar (the above-referenced Topcoat 2600™)
between adjacent tiles. Turning to Fig. 17, the output
15 of the LVDTs indicate that the instrumented tiles were
displaced nearly simultaneously with one another,
providing evidence that macroscale bowing was taking
place. (The differences in displacement magnitude
indicated by the plots were apparently due to variations
20 in location of the LVDTs within the tiles.) Note, LVDT 5
located on Tile B malfunctioned and thus is not shown in
Fig. 17.

Example 2

25

An array of tiles of the present invention was
mounted in a boiler for test. The tiles were configured
and mounted in the boiler in a manner substantially as
shown and described hereinabove with respect to Fig. 7,

5 including use of a barrier material between the boiler wall and the tiles, and Topcoat 2600™ between adjacent tiles. Selected tiles indicated as A, B, C, D, E, and G were instrumented with LVDTs in the manner described in Example 1. As shown in Fig. 17, the output of these
10 LVDTs show that the tiles were displaced independently from one another, in a manner contrary to that shown in Example 1. These test results thus indicate that these tiles of the present invention accommodated individual (micro-scale) bowing, without generating macroscale
15 bowing.

Although the attachment mechanisms 68, 68' and 68" enable the tiles 66, 66' and 66" to move or "float" relative to the wall 62, the skilled artisan will
20 recognize that the mechanisms 68, 68' and 68" preferably maintain the tile 66 as close as possible to the surface of the tube 18 to maximize heat transfer through the tile 66 to the tube.

Moreover, the aforementioned hanging tile and
25 modified hanging tile systems discussed hereinabove may be utilized in combination with the present invention. Furthermore, a conventional bolted tile fastener arrangement as also discussed hereinabove may be modified to provide additional clearance between the stud and bore

5 to permit the tile to float relative to the wall to thus
be usable in combination with the corrosion barrier and
the gap between adjacent tiles of the present invention.

The foregoing description is intended primarily for
10 purposes of illustration. Although the invention has
been shown and described with respect to an exemplary
embodiment thereof, it should be understood by those
skilled in the art that the foregoing and various other
changes, omissions, and additions in the form and detail
15 thereof may be made therein without departing from the
spirit and scope of the invention.

Having thus described the invention, what is claimed
is:

CLAIMS

1. A refractory tile system for use on a wall of a boiler, the system comprising:
a plurality of tiles having a floating fastener system engagable with the wall to maintain said tiles in spaced, movable relation to one another;
said tiles being sized and shaped to provide a gap between adjacent ones of said tiles, said gap being sufficient to accommodate dimensional changes of said tiles exhibited during exposure to operational temperatures of the boiler; and
a corrosion barrier disposed between said tiles and the wall.
2. The refractory tile system of claim 1, wherein said fastener system maintains said tiles in spaced, moveable relation to the wall.
3. The refractory tile system of claim 2, wherein said tiles are sized and shaped to provide a gap between at least a portion of said tiles and the tube wall sufficient to accommodate said dimensional changes.



4. The refractory tile system of claim 1, wherein said gaps are sufficient to accommodate dimensional changes of said tiles due to exposure to a temperature gradient and exposure to a mean temperature experienced during operation of the boiler.
5. The refractory tile system of claim 4, wherein said temperature gradient is within a range of about 200-600 degrees C and said mean temperature is within a range of about 500 to 1400 degrees C.
6. The refractory tile system of claim 5, wherein said tiles are maintained close enough to the wall of the boiler to maintain said temperature gradient within said range of about 200-600 degrees C.
7. The refractory tile system of claim 6, wherein at least a portion of said tiles is maintained in superimposed contact with at least a portion of said corrosion barrier, and said portion of said corrosion barrier is maintained in superimposed contact with at least a portion of the wall.
8. The refractory tile system of claim 1, wherein said



floating fastener system comprises a tab disposed on one of said wall and said tiles, and a receptacle disposed on an other of said wall and said tiles, said member and said receptacle being adapted for mutual engagement with sufficient clearance to maintain said tiles in said moveable relation.

9. The refractory tile system of claim 8, wherein said floating fastener system comprises a hanging tile system.
10. The refractory tile system of claim 8, wherein said floating fastener system comprises a T-slotted tile system.
11. The refractory tile system of claim 1, wherein said floating fastener system comprises a tab disposed on one of said wall and said tiles, and a receptacle disposed on an other of said wall and said tiles, said member and said receptacle being adapted for mutual engagement with sufficient resiliency to maintain said tiles in said moveable relation.
12. The refractory tile system of claim 1, wherein said



receptacle comprises at least one slot, said at least one slot extending in an axial direction.

13. The refractory tile system of claim 12, wherein said at least one slot extends inwardly from an edge of said tile, said edge being chamfered relative to the edge of said tile.
14. The refractory tile system of claim 13, wherein said at least one slot comprises first and second slots extending inwardly from opposite edges of said tile, said first slot extending approximately twice as far as said second slot from respective opposite edges.
15. The refractory tile system of claim 13, wherein said chamfer extends approximately 30 to 60 degrees relative to a transverse direction.
16. The refractory tile system of claim 1, wherein said floating fastener system provides said tiles with at least one degree of freedom of movement relative to the wall.



17. The refractory tile system of claim 16, wherein said floating fastener system provides said tiles with at least two degrees of freedom of movement relative to the wall.
18. The refractory tile system of claim 17, wherein said floating fastener system provides said tiles with at least three degrees of freedom of movement relative to the wall.
19. The refractory tile system of claim 1, further comprising a compressible material disposed in said gap.
20. The refractory tile system of claim 19, wherein said compressible material inhibits passage of contaminants into said gap.
21. The refractory tile system of claim 20, wherein said compressible material comprises a fibrous mortar.
22. The refractory tile system of claim 1, wherein said barrier comprises a fluid.



23. The refractory tile system of claim 22, wherein said fluid comprises a gas flowing between said tiles and the wall.
24. The refractory tile system of claim 22, wherein said fluid comprises a coating applied to the tube wall.
25. The refractory tile system of claim 24, wherein said coating is adapted to adhere to the wall and to be free from adherence to said tiles.
26. The refractory tile system of claim 25, wherein said coating comprises a membrane.
27. The refractory tile system of claim 26, wherein said coating comprises phosphate bonded silicon carbide (SiC).
28. The refractory tile system of claim 1, wherein said tiles further comprise peripheral surfaces sized and shaped to form a spaced, shiplapped joint between said adjacent ones of said tiles.



29. The refractory tile system of claim 5, wherein said mean temperature is within a range of about 750 to 1200 degrees C.
30. A refractory tile system for use on a wall of a boiler, the system comprising:
a plurality of tiles disposed on the wall in spaced, movable relation to one another;
said tiles being sized and shaped to provide a gap between adjacent ones of said tiles, the gap being sufficient to substantially prevent macro-scale bowing of said tiles during exposure to operational temperatures of the boiler; and
a corrosion barrier disposed between said tiles and the wall to substantially prevent corrosion of the wall.
31. A method for increasing the useful life of a wall of a boiler, said method comprising the steps of:
(a) providing a plurality of tiles having a floating fastener system engagable with the wall to maintain said tiles in spaced, movable relation to one another;



(b) sizing and shaping said tiles to provide a gap between adjacent ones of said tiles, said gap being sufficient to accommodate dimensional changes of said tiles exhibited during exposure to operational temperatures of the boiler;

(c) disposing a corrosion barrier on the wall; and

(d) engaging the floating fastener system with the wall, wherein the tiles are superposed with the wall and the corrosion barrier is disposed therebetween.