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Musser

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[54] **DESIGNING AND BUILDING FURNACE STRUCTURES WITH SINGLE SIZE BRICK**

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[52] **U.S. Cl.** **52/80,** 52/245, 52/575, 52/608, 110/99, 52/89

[51] **Int. Cl.** **E04b 1/32,** F23m 5/02

[58] **Field of Search** 110/99, 99 A; 52/89, 608, 575, 52/245, 80; 263/46

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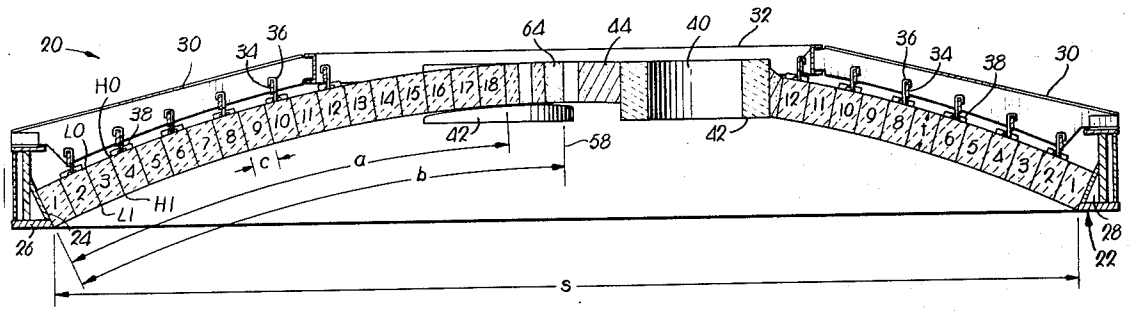
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[57] **ABSTRACT**

An electric furnace roof or other generally circular structure is formed by concentric rows of bricks disposed side by side in each row. Each brick is the same size throughout the entire structure or individual sections thereof and is tapered to present a pair of opposed, non-parallel sides, the single size being determined in accordance with the innermost radius of the inner row to permit such radius, or a preselected smaller radius, to be turned by bricks oriented in the regular position with the larger width across the taper at the outer periphery of the row. In order to turn the greater radii of the remaining, outer rows, certain of the bricks in each row are reversed to place the larger width at the inner periphery of the respective row. The number of reversed brick in each row is determined mathematically by initially assuming the existence of imaginary reversed bricks expanded in size to equalize the widths of all bricks, both real and imaginary, of a given row at the outer periphery thereof. A digital computer is programmed to provide output including the numbers of brick or each row in both regular and reversed positions, from input comprising design dimensions and conditions of the structure to be built.

10 Claims, 5 Drawing Figures



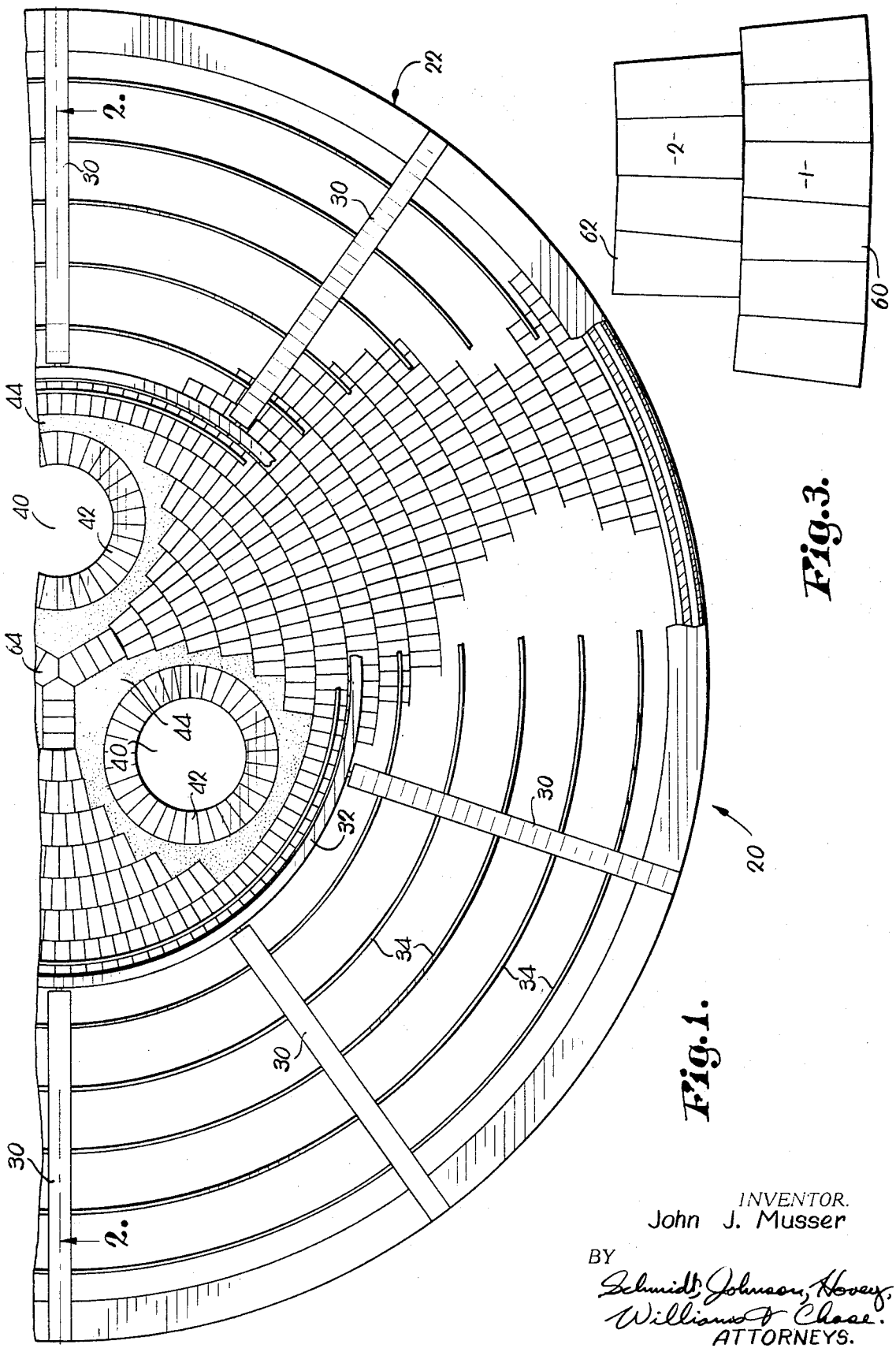


Fig.3.

Fig.1.

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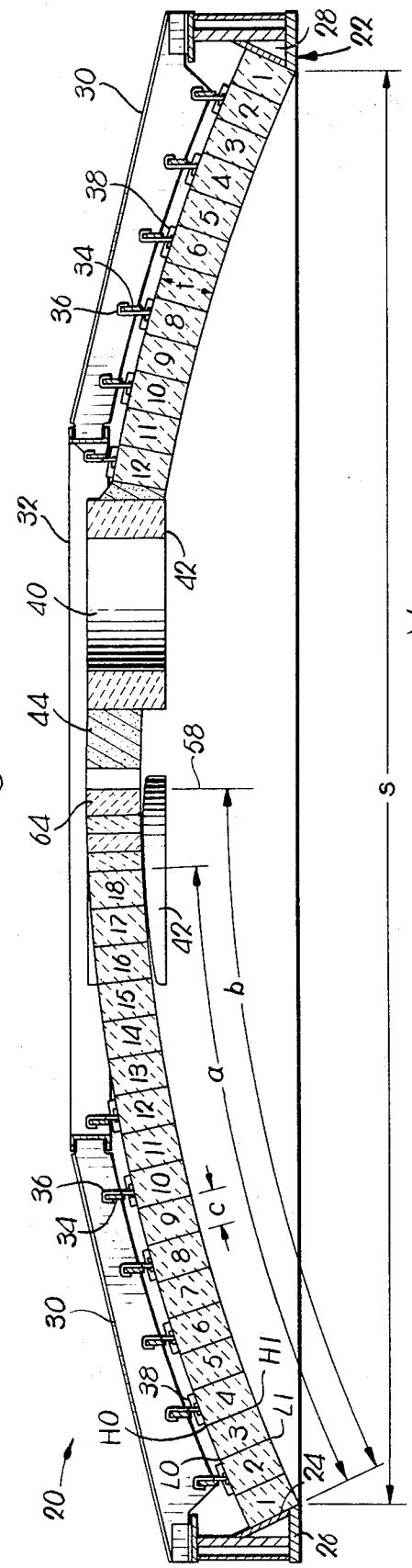


Fig.2.

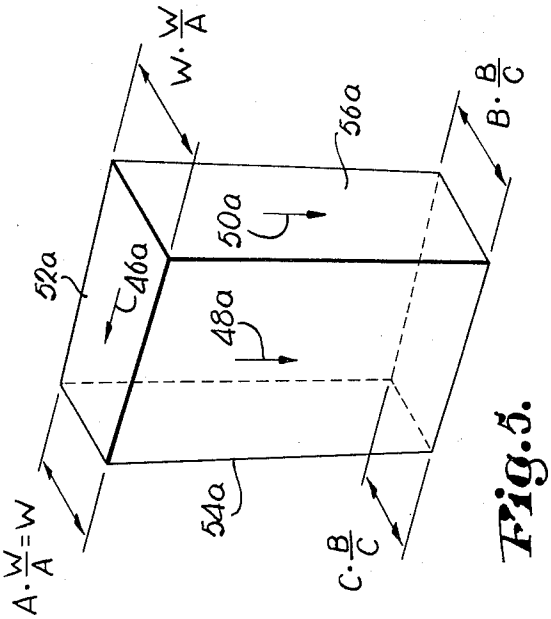


Fig.3.

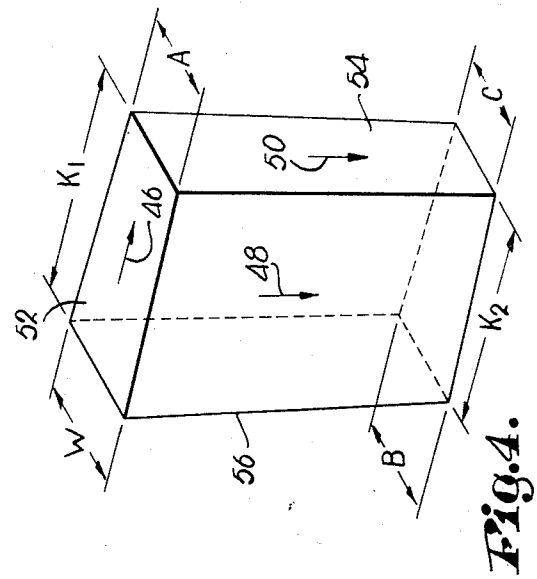


Fig.4.

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DESIGNING AND BUILDING FURNACE STRUCTURES WITH SINGLE SIZE BRICK

This invention relates to structures, such as electric furnace roofs for example, of generally circular configuration, either flat or dome shaped, formed by concentric rows of tapered bricks or other structural elements laid side by side in each row, and to a method and system of designing and building such structures utilizing a brick of only one size in a given structure or section thereof.

The roofs of electric furnaces are commonly dome shaped and constructed of concentric rows of bricks of various sizes and shapes laid side by side in each row. It is presently the practice to utilize a number of different sizes and shapes of brick in order to accommodate the various radii of the concentric rows. Since the roof of an electric furnace in use may fail after only a short period of furnace operation, a second, preconstructed roof is usually maintained on a standby basis for immediate use upon roof failure. It may be appreciated, therefore, that the construction of new roofs is a continuing and necessary function at the furnace site, requiring both a large brick inventory and the necessary labor to complete the construction within the time limits dictated by the desire for nearly continuous furnace operation.

A current development in this art is the introduction of the triple tapered brick, which facilitates construction of the roof by accommodating the dome configuration (normally a section of a sphere or nearly so) to thereby compensate for the arch of the dome as well as the various radii of the concentric rows. The taper of the brick which enables the radius of each annular row to be turned by bricks laid side by side is referred to as the arch taper and is, therefore, the basic design consideration of the brick configuration. The taper of each major side of the brick is referred to as the key taper, and the taper of the end faces is known as the wedge taper in a triple tapered brick. Bricks with a single taper to turn a radius are employed in flat structures formed by concentric rows of bricks, and also find application in the construction of electric furnaces.

From the foregoing, it may readily be seen that the minimization of standing brick inventory and the time required for roof construction is important from the standpoints of both economy and convenience. Accordingly, the primary object of the present invention is to reduce the required inventory and facilitate the rapid construction of furnace roofs or other generally circular structures (i.e., flat or dome shaped having a circular or elliptic perimeter) formed by concentric rows of bricks or similar structural elements disposed side by side in each row.

Furthermore, it is an important object of this invention to provide a method of designing and building generally circular structures as aforesaid with tapered bricks or similar structural elements of a single size, thereby reducing to a minimum the standing brick inventory required for the construction of replacement structures.

Another important object of this invention is to provide a method as above utilizing single size brick to regular and reversed positions within each row in order to enable the annular rows of various radii to be formed.

Still another important object of the invention is to provide such a structure having concentric rows of bricks laid in both regular and reversed positions, wherein every brick throughout the structure or a section thereof is of a single size and shape except for changes in brick thickness that may be desired for reinforcement purposes.

Yet another important object of the invention is to provide a method of and system for determining the total number of bricks required in a structure as aforesaid, and determining the number of regularly positioned and reversed bricks in each row, to the end that the bricks may ultimately be laid in building the structure without the need for trial and error methods and with assurance that the design curvatures will be followed and the rows closed by brick within allowed tolerances.

Additionally, it is an important aim of the invention to provide a method and system as aforesaid having sufficient accuracy in the brick number and position determinations to permit the bricks to be laid without the use of mortar, and with only the insertion of expansion shims between adjacent bricks at intervals around the row being required.

In the drawings:

FIG. **1** is a partial, top plan view of an electric furnace roof constructed in accordance with the teachings of the present invention;

FIG. **2** is a vertical sectional view taken along line 2—2 of FIG. 1;

FIG. **3** is a fragmentary, greatly enlarged, diagrammatic, top plan view of two adjacent rows of brick illustrating the regular and reversed positions of individual bricks;

FIG. **4** is a diagrammatic, perspective view of a triple tapered brick; and

FIG. **5** is a diagrammatic, perspective view of the brick of FIG. 4 shown in a reversed orientation and illustrated with imaginary dimensions for a purpose to be discussed in the following detailed specification.

THE FURNACE ROOF

An electric furnace roof constructed in accordance with the teachings of the present invention, broadly designated by the reference numeral **20,** is adapted for use with a cylindrical electric furnace (not shown) having an open top that presents an upper peripheral edge spanned by the roof **20.** The roof structure includes an annular, peripheral skewback **22** presenting an inclined supporting surface **24** and a flat base **26,** the latter overlying the upper edge of the furnace. An annular passageway **28** of triangular cross-sectional configuration is formed within the skewback **22** and carries a suitable coolant such as water.

The top of the skewback **22** supports the outer ends of a number of radially extending beams **30,** the inner ends thereof being secured to an annular channel **32** which presents a hub member concentric with the skewback **22.** Accordingly, particularly from viewing FIG. **1,** it may be seen that the radial beams **30** define spokes between the channel **32** and the skewback **22,** a number of circular, concentric stringer bars **34** being carried by the beams **30.** In viewing FIG. **2,** it may be seen that the bars **34** have hangers **36** suspended therefrom which are utilized to support alternate rows of bricks forming the main portion of the roof structure. **12** annular, concentric, full rows of bricks are illus-

trated and designated in FIG. 2 by the numbers 1 through 12. Each of the bricks is encased in steel, the steel casings of the bricks of the even number designated rows being provided with upstanding loops 38 presenting eyes that receive the respective hangers 36. The rows of bricks are self-supporting without mortar, the outer periphery of row 1 being in engagement with and supported by the inclined surface 24 of the skewback 22. For clarity of illustration, the hangers 36 and loops 38 of the underlying brick casings are not shown in FIG. 1. Reference may be made to Alvis et al., U. S. Letters Patent No. 3,385,241, owned by the assignee herein, for a detailed illustration of the manner of suspending the encased bricks from the stringer bars 34.

Three electrode openings 40 are provided in the central portion of the roof 20 for the purpose of receiving the electrodes of the furnace which extend downwardly thereinto through the openings 40. Due to the presence of the electrode openings 40, rows of bricks designated 13 through 18 (either cased or uncased) are partial rows interrupted by such openings. Each of the openings 40 is surrounded by a ring of brick 42 that defines a cylindrical sleeve or collar through which the electrode extends. A plastic ram material 44 serves as a filler between the ring brick 42 and the partial rows of roof brick 13–18.

FIG. 2 reveals that the roof 20 is dome shaped, the roof brick thereof being laid to define substantially a section of a sphere. Accordingly, a triple tapered brick is utilized to accommodate the dome configuration and is illustrated diagrammatically in FIG. 4. The arch taper is illustrated by the arrow 46, the key taper is represented by the arrow 48, and the wedge taper is represented by the arrow 50. Each of the arrows points in the direction of convergence of the taper of that particular face of the brick. Accordingly, the maximum width of the triple tapered brick is at one corner thereof and is illustrated by the dimension W, which is also the maximum width of the upper face 52 of the brick shown in FIG. 4. The minimum width of the upper face 52 due to the arch taper is represented by the dimension A. The brick of FIG. 4, as will be discussed hereinafter, is in the "regular" position with its narrower end face 54 being the inner face of the brick as it is placed in the row. The inner face 54 tapers from the dimension A to a minimum dimension C; likewise, the opposite, outer end face 56 tapers from the dimension W to a dimension B. The arch taper represented by the arrow 46 is, of course, due to the presence of nonparallel major sides of the brick, the bricks in each row being laid in side-by-side relationship to form the annular row configuration clearly seen in FIG. 1. It will be desired to also employ expansion shims of asbestos or other compressible material at regular intervals between adjacent bricks as is the present practice in the art, such shims not being seen in the drawings due to the relatively small scale. Additionally, expansion shims between the end faces of bricks of adjacent rows may also be utilized.

Each of the bricks of the rows 1 through 18 is of the same size and shape although the rows are of different circumference and, therefore, differ in the radius that must be turned in order to form a given row. The term "radius" as used herein with respect to an annular row of bricks is understood to mean the radius of the annulus formed by such row as viewed in plan (FIG. 1), or the perpendicular, radial distance from the center line 58 (FIG. 2) of the roof to a given point in such row. In order to form all of the rows from the single size brick, certain of the bricks in each row are reversed in orientation in order to accommodate the particular radius. This is illustrated in FIG. 3 where six bricks of the outermost row 1 and four bricks of the next row 2 are shown diagrammatically. The brick 60 in row 1 and the brick 62 in row 2 are reversed so that the maximum dimension W of its upper face is now at the inner periphery of the respective row rather than the outer periphery thereof. The nonparallel major sides of the bricks abut one another, thus the radius turned in a given row by the presence of reversed bricks is increased in proportion to the number of such reversed bricks utilized. For a circular row, the reversed bricks are interspersed at equal intervals among the bricks therein in the regular position. It should be noted that the nonparallel sides of the brick have an equal amount of angularity and thus present a uniform taper configuration.

In order to design and build the roof 20, the number of bricks in each row in both regular and reversed positions must be determined. Furthermore, prior to such determination, the single brick size appropriate to the dimensions of the particular roof structure must be ascertained in order to assure that the single size will be capable of forming the various rows of differing radii. The determination of the appropriate brick size will be discussed hereinafter, it being assumed for the moment that the proper size has been ascertained and that, therefore, the number of bricks in each row and the orientation thereof are to be determined. These determinations are effected by a digital computer which is programmed and supplied with input as set forth hereinafter.

COMPUTER INPUT

The computer, assuming that the size of the brick has been ascertained, is provided with the following input in accordance with the dimensions of the particular roof structure to be designed and built:

1. Inside radius of dome.
2. Thickness of dome.
3. Inside span of dome.
4. Number of rows of brick (including two additional rows over the actual number to allow for brick shims within each row).
5. Row after which the first row shim is to be inserted.
6. Number of rows before next row shim.
7. Number of brick along each row between brick shims.
8. Length K_1 of outside face of an individual brick.
9. Thickness of brick and row shims.
10. Dimensions W, A, B, and C of an individual brick.

It should be understood that the above reference to "brick shims" refers to expansion shims inserted between adjacent bricks in a given row, while the reference to "row shims" refers to expansion shims inserted between the inner and outer peripheries of adjacent rows. Both brick shims and row shims are of the same thickness.

Referring to FIG. 2, the inside radius of the dome is the radius of the spherical surface defined by the inside faces of the brick of rows 1–18 (the calculation is concerned only with roof brick and not with the relatively

small quantity of electrode ring brick **42**). The thickness of the dome is the distance between the inside and outside faces of the brick along an extension of the inside radius of the dome, and is designated t in FIG. **2.** The inside span of the dome is designated *s*.

Row shims may, for example, be inserted after every other row, the first shim being inserted after row **2** (i.e., between rows **2** and **3**). Thus, two would be the number of rows before the next row shim is inserted (i.e., between rows **4** and **5, 6** and **7,** etc.). Brick shims within each row would be inserted as required by design considerations, such as every fourth brick, in which case four would be the number of brick along each row between shims.

The length of the outside face of an individual brick is the length of the upper face **52** or **52***a* shown in FIGS. **4** and **5** and designated K_1. The dimension W of each brick in the regular position is the low outside width thereof, the term "low" being relative to the arch of the dome. For purposes of clarity, the low outside width of a brick in row **3** is designated by the reference character L0 in FIG. **2.** The dimension A of each brick in the regular position is the high outside width HO thereof, the dimension B is the low inside width LI, and the dimension C is the high inside width HI.

If dictated by the design considerations of a particular roof structure, the computer input may also include the outside dimension of fill brick to be laid against the supporting surface **24** of the skewback **22.** Fill brick is not utilized in the exemplary design illustrated in FIG. **2,** except as may be needed in the ram material **44** at the crown **64** of the dome above the row **18** of roof brick.

Now assuming that a suitable brick size for the above input is not known or in instances where it is desired to determine the optimum brick size, the same input as set forth above is provided with the omission of the dimensions A, B, and C. The dimension W (oftentimes a standard width for bricks of this type equal to three inches) is supplied and the computer is programmed to determine A, B, C, and K_2 which, in effect, is a determination of the arch taper **46,** the key taper **48,** and the wedge taper **50** (FIG. **4**). K_2, as indicated, is the length of the inside face and is less than K_1 as a result of the key taper **48** (K_1 is oftentimes a standard length equal to six inches). In practice the optimum brick size may first be determined, and then a standard size selected that is nearest the optimum size. Supplying the computer with the W, A, B, and C dimensions of the selected size, a recomputation then reveals whether the error introduced is within acceptable tolerances. Such error will be the extent to which each annular row is either not completely closed or provided with excess brick. A deviation of less than 2 ½ in a row having a circumference on the order of 1000 inches is well within the acceptable range and may be readily realized in practice.

THE SOLUTION

In order to determine the optimum brick size and/or the number of regularly positioned and the number of reversed brick required to form each row, the circumferences are computed of circles having their centers at the center line **58** and radii equal to the perpendicular distances from the center line **58** to the low outside (LO), high outside (HO), and high inside (HI) corners of the brick of each row. The circumference at the low inside (LI) corner of the brick of each row may also be computed and used in determining the acceptability of any error introduced at the LI corner. Additionally, when determining the optimum brick size, the circumferences of circles having radii equal to the distances from center line **58** to the low outside (LO), high outside (HO), low inside (LI), and high inside (HI) corners of the brick of the innermost row of the roof **20** if such roof had twenty rows instead of eighteen are computed, as will be discussed hereinafter. (Except where row shims are inserted, the HO corners of brick of a lower row will abut the LO corners of brick of the next higher row, and likewise for the inside dimensions, resulting in a number of common circumferences.) For example, beginning with row **1** and utilizing the input set forth hereinabove, noting that one-half the included angle of the dome is designated *b* in FIG. **2**:

$$\sin b = (s/2)/(\text{inside radius of dome})$$

circumference at LO $= 2\pi$ (inside radius of dome $+ t$) (sin b)

circumference at LI $= 2\pi$ (inside radius of dome) (sin b)

angle c in degrees formed by brick in each row = [length of outside brick face]/[2π (inside radius of dome $+ t$)] $\cdot$ 360°

circumference at HO $= 2\pi$ [inside radius of dome $+ t$] [sin $(b-c)$]

circumference at HI $= 2\pi$ [inside radius of dome] [sin $(b-c)$]

The above is repeated for the remaining rows, utilizing sin $(b\text{-}2c)$ for the HO and HI circumferences of row **2,** etc., and allowing for insertion of row shims in subsequent row calculations. The approximate angle in degrees formed by such shims, i.e., between the opposite faces of an individual shim, is equal to the shim thickness times 360° divided by the spherical circumference such as represented by 2π (inside radius of dome $+ t$).

Assuming that a determination of the optimum brick size is desired, the number of bricks in the regular position required for the innermost row of the roof **20** if such roof had twenty rows instead of 18 is first ascertained. This is the meaning of input No. **4** listed hereinabove, it being understood that the brick shims occupy space that would otherwise be filled with brick and thus a smaller than actual minimum row circumference must be assumed to allow for the insertion of the shims. Accordingly, the LO circumference of the imaginary innermost row divided by the dimension W equals the number of bricks in the regular position required. Dimension A equals the HO circumference of the imaginary innermost row divided by the aforesaid number of bricks; dimension B equals the LI circumference of the imaginary innermost row divided by the number of bricks; and dimension C equals the HI circumference of the imaginary innermost row divided by the number of bricks.

Having determined the optimum brick size or utilizing the W, A, B, and C dimensions of a selected brick size, the determination of the number of bricks in the regular position, the number of bricks in the reversed position, and the number of brick shims for row **1,** for example, is next computed.

To aid in visualizing and making this computation, it is convenient to employ, as a computational tool, the concept of an assumed hypothetical brick, hav-

ing expanded dimensions related in predetermined manner to the dimensions of the real bricks actually to be used in building the roof and to further assume in certain steps of the computation that such imaginary bricks are all reversed in orientation with respect to the regularly oriented real bricks.

Such an imaginary brick of expanded dimensions is depicted in FIG. 5 in a reversed orientation as compared with the real brick shown in FIG. 4. The same reference numerals are employed on corresponding parts in FIG. 5 as in FIG. 4, with the addition of an "*a*" notation. The imaginary reversed brick is regarded as expanded in size to an extent to equalize its outer dimension across the arch taper at the top face **52***a* with the outer dimension across the top face **52** of the regularly positioned real brick. In order to effect this hypothetical expansion in the imaginary brick to be considered for computational purposes, the dimension A is increased by the factor W/A so as to equal W, which is the same as the maximum width W of the regularly positioned real brick. This is indicated by the dimensional legends in FIG. 5, and the expansion factors for the width of the imaginary brick at the other corners thereof are likewise indicated. Accordingly, the width that is W in the real brick is assumed to be W(W/A) in the imaginary brick, the width that is B in the real brick is assumed to be B(B/C) in the imaginary brick, and the width that is C in the real brick is assumed to be C(B/C) in the imaginary brick.

It may be appreciated from the foregoing that the imaginary reversed brick has an outer end face **54**a of the same width as the outer end face **56** of the regularly positioned real brick, i.e., W at its upper end and B at its lower end. Having thus hypothetically equalized the dimensions of all of the bricks (both regularly positioned real and reverse positioned imaginary) assumed for purposes of the initial computation to be disposed along the outer periphery of a given row, calculation of the number of ultimately real bricks to be required in regular and reversed positions is materially simplified. It should be understood that, having initially determined the proper real brick size, it is then next assumed, for computational purposes, that all of the annular rows of brick will contain bricks in both orientations, with the regularly disposed bricks of the dimensions of the real brick and the reversed bricks assumed to be of the imaginary expanded dimensions. Therefore, the next determination is to ascertain the number of regularly positioned real bricks and the number of reversed imaginary bricks for each row, which is then followed by conversion of the calculated number of imaginary reversed bricks into the number of real reversed bricks actually required to form the row, it being understood, of course, that the roof is ultimately constructed only of real bricks in both the regular and reversed positions.

To illustrate the computation for a given row, and assuming that it is desired to use brick shims spaced with four bricks therebetween to allow for expansion when the bricks are heated (input No. 7 above), and letting T represent the shim thickness, the computational procedure is as follows:

approximate number of brick shims = (LO circumference)/(4W + T)

total number N of real bricks in regular position and imaginary expanded bricks in reversed position = [LO circumference − (T · number of brick shims)]/W

It will be remembered that the width of real brick in the regular position and the width of imaginary, expanded brick in the reversed position are both equal to W at the outer periphery of the row. Furthermore, the larger outside dimension across the arch taper of the reversed, imaginary brick is at the inner periphery of the row and equals W (W/A) as illustrated in FIG. 5. Continuing,

HO circumference − (T · number of brick shims) = length of inner periphery P of the row to be occupied by brick

$D_e = W\ (W/A)$

Therefore,

number N_1 of real bricks in regular position = $(ND_e - P)/(D_e - A)$

The foregoing computation of P is repeated utilizing the HI circumference, thus D_e becomes equal to B (B/C) and C replaces A in the expression for N_1. The two values for N_1 so obtained are averaged. Continuing further,

number of imaginary expanded bricks in reversed position = N − average N_1

number N_2 of real bricks in reversed position = W/A (N − average N_1)

The values thus obtained for the number of brick shims, the average number N_1 of real bricks in the regular position, and the number N_2 of real bricks in the reversed position are rounded to the nearest whole number. The procedure is repeated for the remaining rows **2–18.** If desired, the bricks of the partial rows **13–18** may be uncased and brick and row shims omitted, with appropriate changes in the computer input for the computations for these rows to allow for the absence of the casings as well as the omission of the shims.

By way of review, it should be noted that at the outset it is realized that certain of the bricks in each row will necessarily be in reversed positions, but the number of such bricks is not known. Still without knowing the number of reversed bricks, each such brick is mathematically assumed for computational purposes to undergo an imaginary change in its dimensions to an extent to equalize the dimensions of all of the bricks at the outer periphery of the row. This enables the number of both real bricks in the regular position and imaginary bricks in the reversed position required to hypothetically form the row to be readily determined. Then, knowing the extent of the imaginary dimensional change, the number of real bricks in the regular position is derived. It is then a matter of subtraction to determine the number of imaginary bricks assumed, and from this figure the number of real bricks actually to be required in the reversed position may be derived by compensating for the imaginary dimensional change that was assumed at the outset of the computations.

A suitable program for a general purpose digital computer based on the input and solution hereinabove is not set forth herein since the preparation of such program is well within the capabilities of one having ordinary skill in the computer programming art and appropriate source languages. The computer, when programmed in accordance with the teachings of the pres-

ent invention, constitutes a means of determining the single brick size capable of accommodating the dimensions of the structure to be built, and a means of determining the numbers of regularly positioned and reversed bricks required in a given row. Through looping techniques in the programming, the computer repeats the brick number determinations in order to successively determine the numbers of regularly positioned and reversed bricks required in each of the rows, thus the computer output comprises all of the information necessary to form the various rows of the structure of differing radii.

It may be appreciated that the roof **20** may now be rapidly constructed since the number of bricks in the regular position and the number of bricks in the reversed position in each row, together with the number of brick shims, are known prior to the actual laying of the rows of bricks. To form a circular row, the reversed bricks are interspersed among the regularly positioned bricks at equal intervals as the bricks are laid. In the partial rows **13–18,** a predetermined number of bricks is omitted from each row due to the presence of the electrode openings **40** and surrounding ring brick **42** and ram material **44.** Accordingly, the exact number of single size roof brick for the rows **1–18** is known prior to construction of the roof **20,** thus the necessary brick inventory may also be accurately determined and controlled. In the event that uncased bricks are utilized in the partial rows **13–18,** the composite inventory will comprise single size brick, cased for rows **1–12** and uncased for rows **13–18.**

In the design and building of a structure having an elliptic rather than a circular perimeter, the same basic approach to the solution is utilized except that the determination is mathematically more complex due to the varying radius of the elliptic perimeter. The reversed bricks would be interspersed among the regularly positioned bricks at varying intervals to form the ellipse. Furthermore, it is evident that the teachings of the present invention are equally applicable to a flat structure of circular configuration as well as the dome-shaped structure described and illustrated herein, in which case the brick or other structural element need only be provided with a single taper (corresponding to the arch taper **46** illustrated in FIG. **4**) to form the flat, circular rows.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. A generally circular composite structure, such as an electric furnace roof or the like, comprising:

means for presenting a generally circular, central portion of said structure;

a plurality of tapered structural elements of a single shape and size,

each of said elements having a tapered top, a tapered bottom, a wide end, a narrow end, and a pair of opposed sides converging toward each other from said wide end toward said narrow end,

said elements being arranged in a plurality of generally annular rows having a common central axis, including an innermost row and at least one outer row, with said sides of each element facing toward the sides of the adjacent elements in the same row,

at least certain of said elements in each row being regularly oriented with said narrow ends thereof facing inwardly toward said central portion,

there being other of said elements in each outer row that are reversely oriented with said wide ends thereof facing inwardly toward said central portion,

defining a generally annular, outer main portion of said structure around said central portion thereof; and

support means for holding said elements in said arrangement and orientations thereof.

2. A structure as set forth in claim **1,** wherein said support means requires no mortar, and includes generally annular means around the outer extremity of and circumferentially confining said outer main portion.

3. A structure as set forth in claim **1,** wherein said reversely oriented elements are interspersed at substantially equal intervals among said regularly oriented elements in each outer row.

4. A structure as set forth in claim **1,** wherein there are a plurality of said rows in the outer main portion, and the number of said reversely oriented elements per row increases as the outer extremity of said outer main portion is approached.

5. A structure as set forth in claim **1,** wherein the shape and size of said elements, the total number of said elements in all of said rows, the total number of said elements in each row, the number of regularly oriented elements in each outer row, and the number of reversely oriented elements in each outer row are each predetermined by computation prior to assembly thereof in said arrangement and orientation.

6. A structure as set forth in claim **1,** wherein said central portion includes at least one generally sector-shaped portion comprising:

a plurality of tapered structural pieces of a single shape and size,

each of said pieces having a tapered top, a tapered bottom, a wide end, a narrow end, and a pair of opposed sides converging toward each other from said wide end toward said narrow end,

said pieces being arranged in a plurality of generally partially annular rows having a common central axis, including a row adjacent said outer main portion with said sides of each piece facing toward the sides of the adjacent pieces in the same row,

at least certain of said pieces in each row thereof being regularly oriented with said narrow ends thereof facing inwardly,

there being other pieces in at least said outermost row thereof, that are reversely oriented with said wide ends thereof facing inwardly.

7. A structure as set forth in claim **6,** wherein said elements and said pieces are both of the same, single shape and size.

8. A structure as set forth in claim **1,** wherein said sides and said ends are also tapered and are bounded by edges converging toward each other from said top toward said bottom, whereby said structure has generally spherical curvature to present a dome configuration.

9. A composite structure comprising:

a plurality of tapered structural elements of a single shape and size,

each of said elements having a tapered top, a tapered bottom, a wide end, a narrow end, and a pair of opposed sides converging toward each other from said wide end toward said narrow end,

said elements being arranged in at least one row having inner and outer edges of substantially circular curvature with said sides of each element facing toward the sides of the adjacent elements, a first plurality of said elements in said one row being regularly oriented with said narrow ends thereof facing inwardly,

a second plurality of said elements in said one row being reversely oriented with said wide ends thereof facing inwardly; and

support means for holding said elements in said arrangement and orientation thereof.

10. A generally annular composite structure comprising:

a plurality of tapered structural elements of a single shape and size, each of said elements having a tapered top, a tapered bottom, a wide end, a narrow end, and a pair of opposed sides converging toward each other from said wide end toward said narrow end,

said elements being arranged in a plurality of generally annular rows having a common central axis, including an innermost row and at least one outer row, with said sides of each element facing toward the sides of the adjacent elements in the same row,

at least certain of said elements in each row being regularly oriented with said narrow ends thereof facing inwardly,

there being other of said elements in each outer row that are reversely oriented with said wide ends thereof facing inwardly; and

support means for holding said elements in said arrangement and orientations thereof.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,788,015 Dated January 29, 1974

Inventor(s) JOHN J. MUSSER

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 54, after "2-1/2", insert -- inches -- .

Column 6, line 20, "2τ" should read -- 2π -- .

Signed and sealed this 13th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.

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