Sept. 22, 1953 R. P. HEUER ET AL 2,652,793

REFRACTORY FURNACE ROOF BRICK RESISTANT TO SPALLING

Filed Oct. 30, 1948 6 Sheets-Sheet 1

Fig. 1.

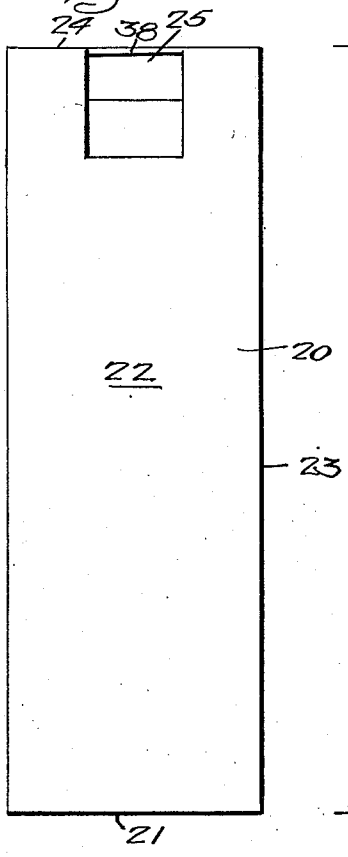


Fig. 2.

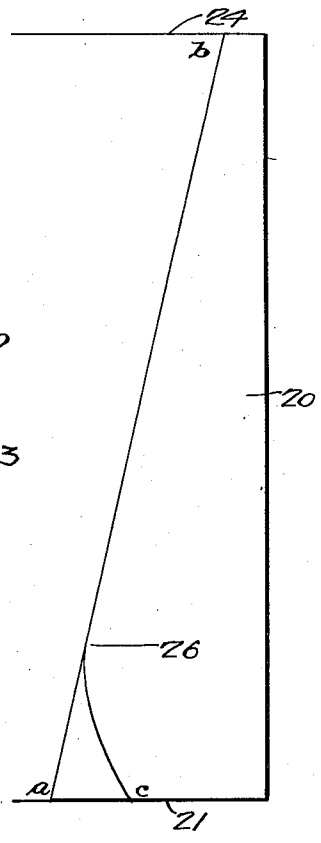
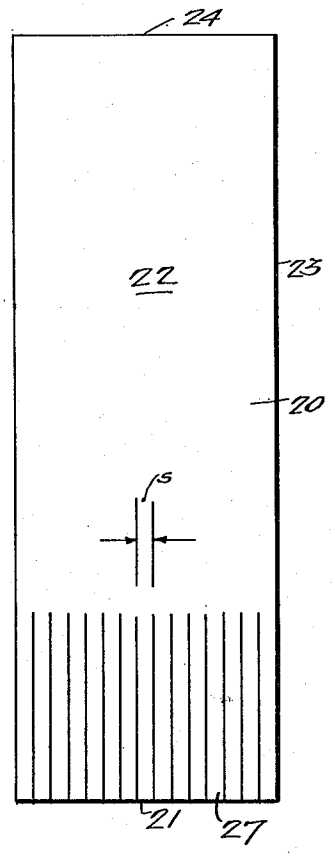


Fig. 3.



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Sept. 22, 1953 R. P. HEUER ET AL 2,652,793

REFRACTORY FURNACE ROOF BRICK RESISTANT TO SPALLING

Filed Oct. 30, 1948 6 Sheets-Sheet 2

Fig. 4.

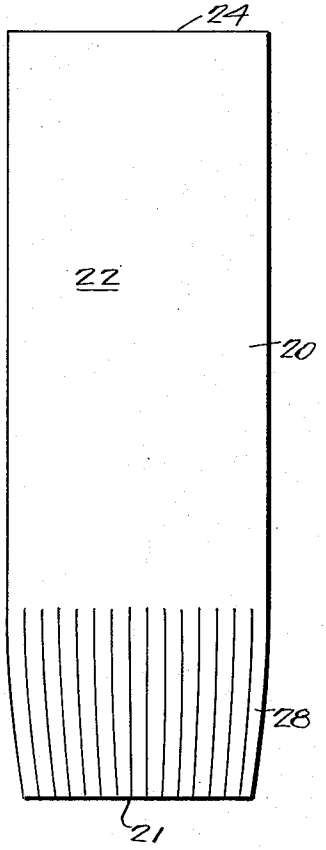


Fig. 5.

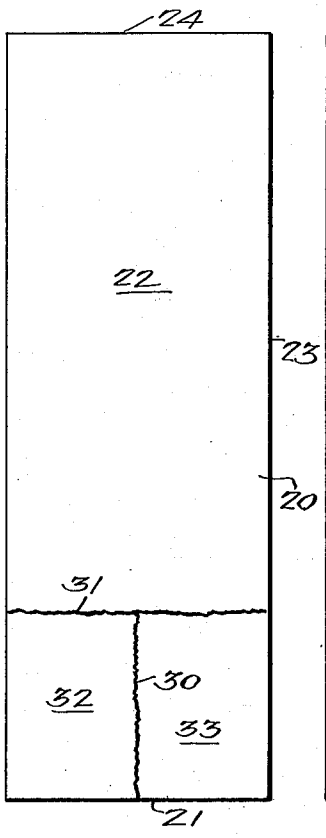
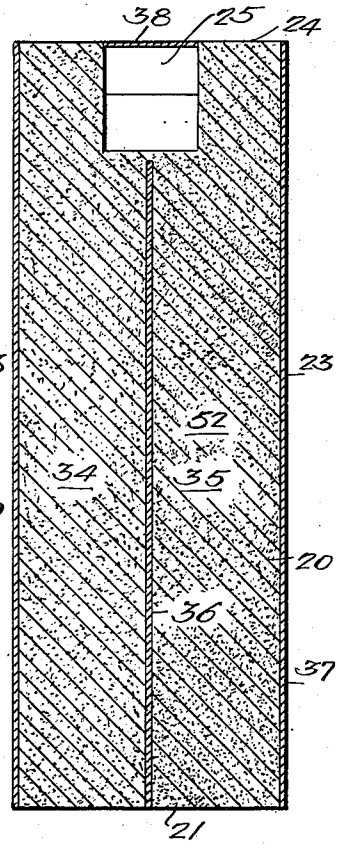


Fig. 6.



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Sept. 22, 1953 R. P. HEUER ET AL 2,652,793

REFRACTORY FURNACE ROOF BRICK RESISTANT TO SPALLING

Filed Oct. 30, 1948 6 Sheets-Sheet 3

Fig. 7.

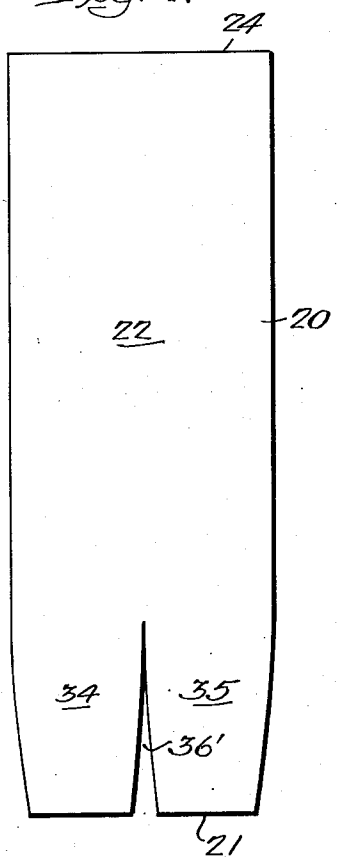
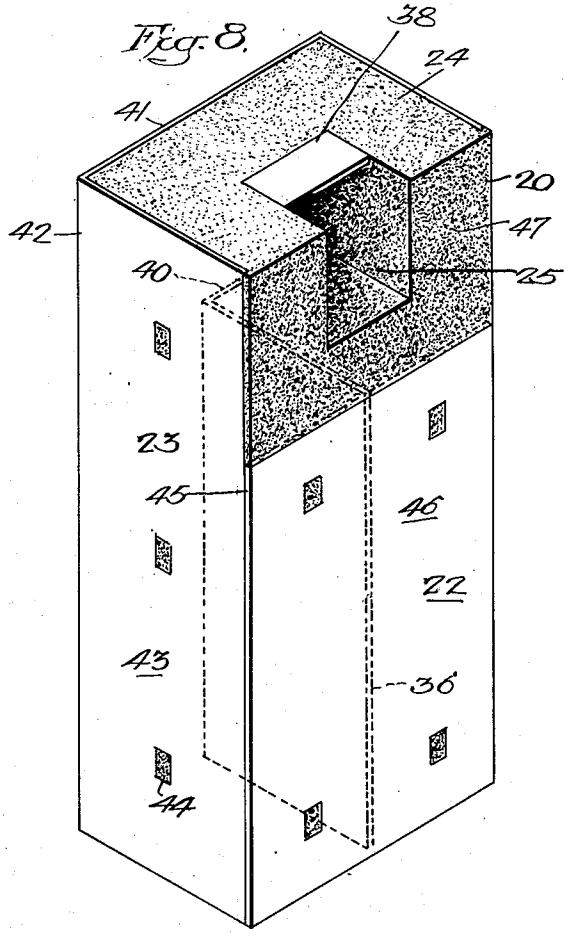


Fig. 8.



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Sept. 22, 1953 R. P. HEUER ET AL 2,652,793

REFRACTORY FURNACE ROOF BRICK RESISTANT TO SPALLING

Filed Oct. 30, 1948 6 Sheets-Sheet 4

Fig. 9

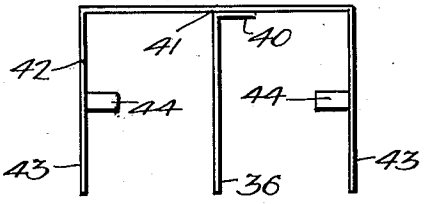


Fig. 11

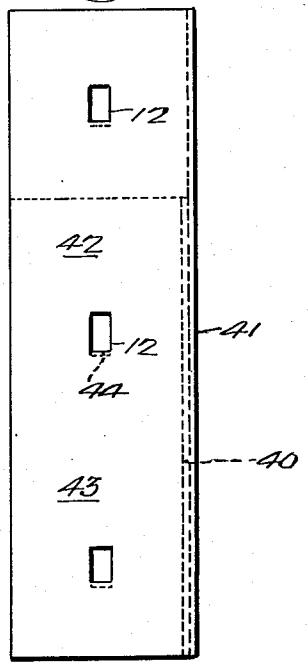


Fig. 10

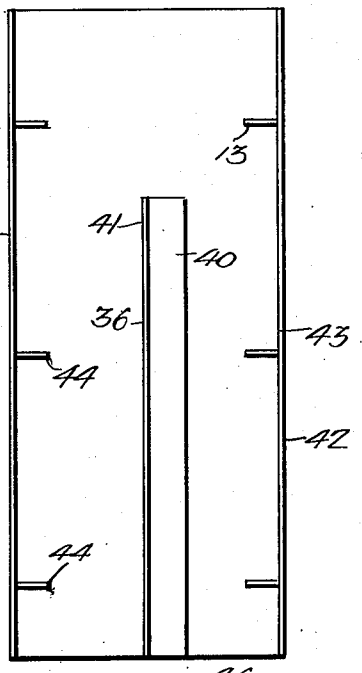


Fig. 13

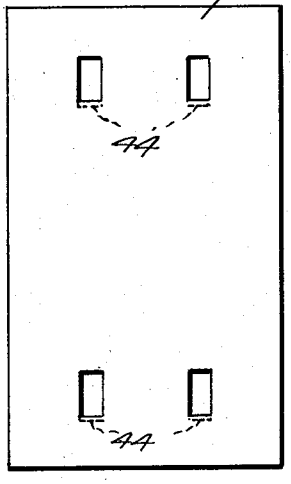
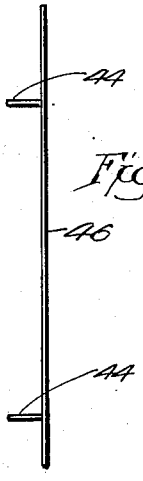


Fig. 12



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Sept. 22, 1953 R. P. HEUER ET AL 2,652,793

REFRACTORY FURNACE ROOF BRICK RESISTANT TO SPALLING

Filed Oct. 30, 1948 6 Sheets-Sheet 5

Fig. 17

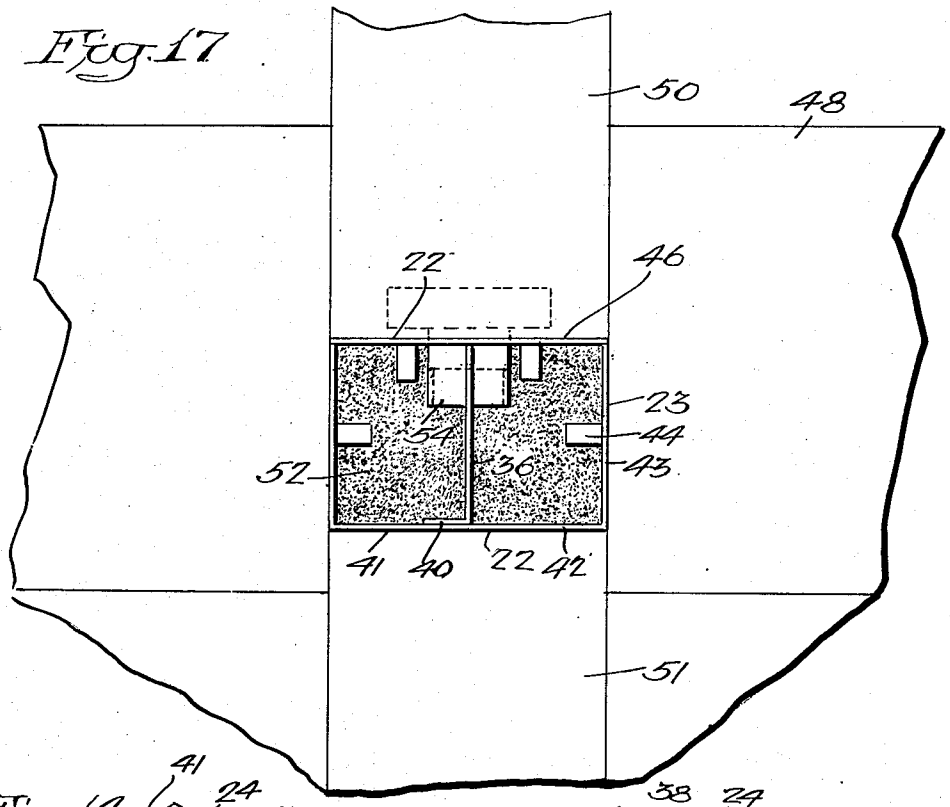


Fig. 14

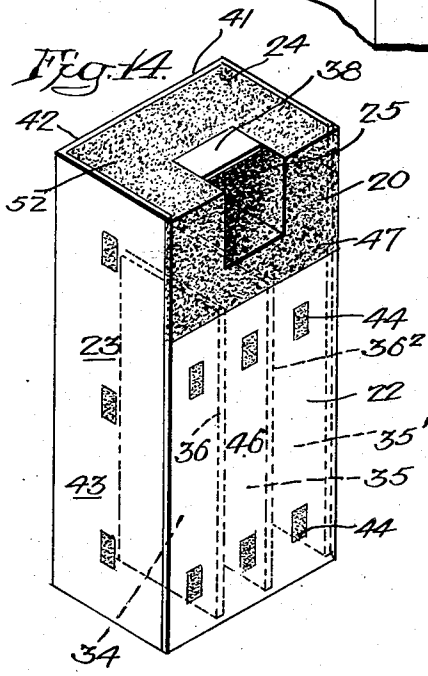
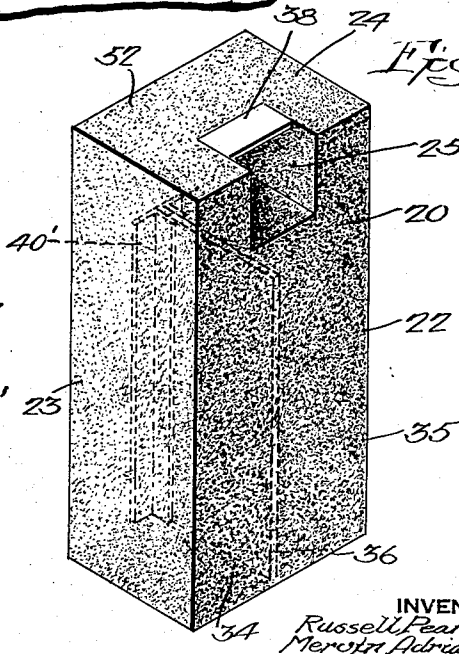


Fig. 15



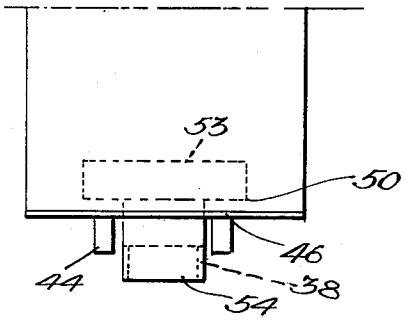
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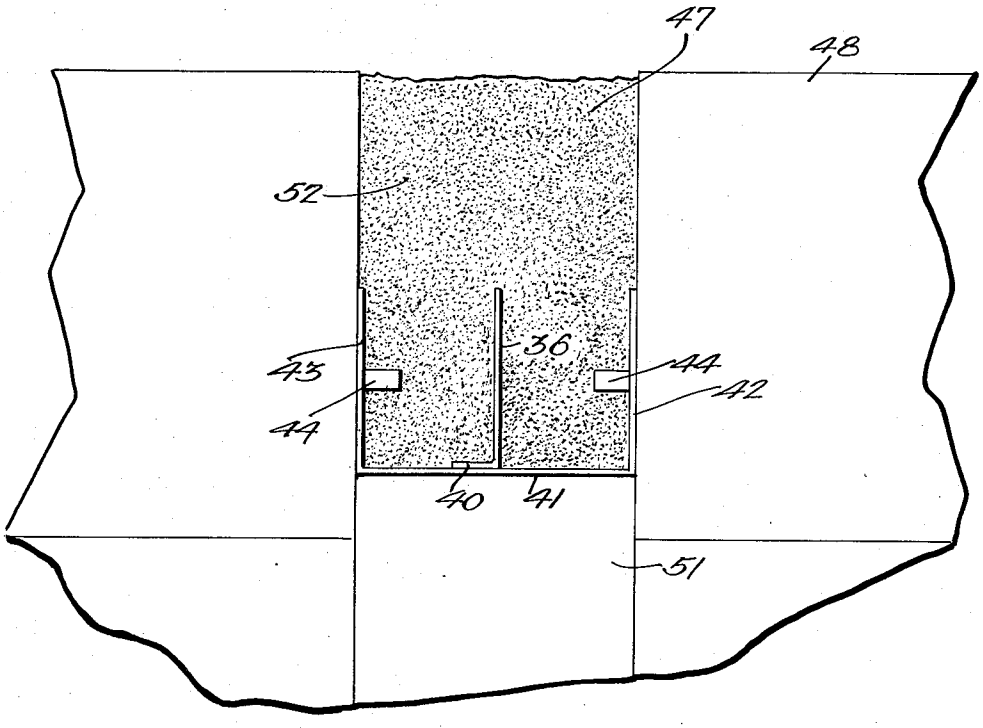
Sept. 22, 1953 R. P. HEUER ET AL 2,652,793

REFRACTORY FURNACE ROOF BRICK RESISTANT TO SPALLING

Filed Oct. 30, 1948 6 Sheets-Sheet 6

Fig. 16





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UNITED STATES PATENT OFFICE

2,652,793

REFRACTORY FURNACE ROOF BRICK RESISTANT TO SPALLING

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Application October 30, 1948, Serial No. 57,454

5 Claims. (Cl. 110—99)

1

The present invention relates to the manufacture of brick having unusually high resistance to spalling and particularly to such brick intended for use in suspended roofs or supported wall construction of furnaces.

This application has been divided, and claims on the process of molding a refractory brick have been inserted in co-pending application for Process of Molding Refractory Brick Having Spacer Plates, Serial No. 375,094, filed August 19, 1953.

A purpose of our invention is to mould basic refractory brick under high forming pressure and concurrently with the moulding to imbed in the brick an oxidizable metallic spacer which effectively subdivides the brick internally in a direction which will resist spalling.

A further purpose is to imbed such an oxidizable metallic spacer in a plane parallel to the major axis of the brick and/or parallel to one of the longitudinal faces of the brick, thereby subdividing the brick into a plurality, suitably two, comoulded cells.

A further purpose is to provide cellular brick of this character with a socket or other engagement at one end of its major axis by which the brick can be hung or otherwise supported so that a temperature gradient in the brick cell exists along the major axis.

Further purposes appear in the specification and in the claims.

In the drawings we have chosen to illustrate a few only of the numerous embodiments in which our invention appears, choosing the forms shown from the standpoints of convenience in operation, satisfactory illustration and clear demonstration of the principles involved.

Figure 1 is a diagrammatic side elevation of a conventional brick intended for suspended arch use in vertical position, the lowermost edge of the brick in this view being exposed to high temperature.

Figure 2 is a diagrammatic illustration showing the length of the brick of Figure 1 plotted as ordinate and the temperature at any point when in furnace roof service plotted as abscissa to the left of the right hand edge of the brick as shown. The curve thus gives temperature gradient.

Figure 3 is a diagrammatic side elevation similar to Figure 1 with the brick broken up into elements to illustrate the spalling behavior.

Figure 4 is a diagrammatic side elevation similar to Figure 3, in which the behavior of the laminae in Figure 3 is illustrated.

2

Figure 5 is a diagrammatic side elevation similar to Figure 1 showing the action of the brick in spalling.

Figure 6 is a central longitudinal section parallel to a side face showing the preferred brick made in accordance with the present invention.

Figure 7 is a side elevation similar to Figure 4 showing the spalling behavior of the brick of Figure 6.

Figure 8 is a perspective showing a brick according to the invention intended for suspended roof or supported wall construction, and having its principal side faces covered with metallic spacers, with a metallic spacer also imbedded in the brick.

Figure 9 is a top plan view of a U-shaped spacer and an internal cell separating spacer according to the invention.

Figure 10 is a front elevation of Figure 9.

Figure 11 is a side elevation of Figure 9.

Figure 12 is a side elevation of a spacer plate used on the side opposite to the base of the U-shaped spacer plate.

Figure 13 is a front elevation of Figure 12.

Figure 14 is a perspective of a brick according to the invention, having three cells.

Figure 15 is a perspective of a brick according to the invention having cells but without spacer plates on the lateral faces.

Figure 16 is a diagrammatic central vertical section showing a moulding press by which the brick of the invention is moulded and illustrating the method of moulding. The end portion of the mould box is removed to permit seeing the interior.

Figure 17 is a view similar to Figure 16 showing the moulding press in closed position, whereas Figure 16 shows the moulding press in open position.

In the drawings like numerals refer to like parts throughout.

Describing in illustration but not in limitation, and referring to the drawings:

In the construction of many types of furnaces to be used at high temperatures, such as open hearth steel furnaces, it is desirable to form the roof of suspended refractory brick and to employ mechanically supported construction for certain downtake walls. The refractories used for this purpose consist of the various basic refractories, of which the most widely used are chrome ore, magnesite, chrome-magnesite and magnesite-chrome. It is customary to lay the brick with oxidizable metallic spacers in the joints. Frequently such basic brick are used without previ-

ous kiln firing and in such cases the metallic spacers are desirably applied to the brick at the time of forming the brick.

In service of this character, failure of the refractory is primarily by spalling away of the brick at the hot end due to the temperature changes which the hottest part of the brick experiences in the cyclic or intermittent operation of the furnace. The changing temperatures cause the brick to expand and contract rapidly, and eventually the brick fracture and spall off along planes which are parallel to the exposed faces of the brick and located about one inch from the hot end.

This spalling causes premature failure of the roof before failure has occurred from other causes.

The reason for spalling of the basic brick in an open hearth furnace roof will be understood more clearly by reference to Figures 1 to 5 inclusive.

Figure 1 shows a brick **20** having a lower face or hot end **21**, a side face **22**, an edge face **23** and a cold end **24** provided with a hanger opening or other recess **25** for suspending the brick. The vertical or lateral faces of the brick are protected from the heat of the furnace by adjacent brick. The lower or hot face **21** may exhibit a temperature of 3000° F. at the time the finished heat of steel is tapped from the open hearth furnace.

A thermal gradient then prevails along the longitudinal axis of the brick as shown by the line *ab* in Figure 2, the temperature being indicated by the abscissa distance from the right hand edge of the brick. After the furnace is tapped, the furnace doors are opened, the fuel is shut off and a large quantity of cold charge is placed in the furnace. As a result the hot face of the brick cools rapidly and its temperature may fall 1000° F. or more. The line *cb* in Figure 2 represents schematically the new condition. Since the cooling is relatively rapid, most of the temperature change is confined to the hot end of the brick. At some interior point such as **26** there is relatively little loss in temperature.

After charge of the furnace is completed, the fuel is again supplied to the furnace and the hot face of the brick rises in temperature until the gradient shown by the line *ab* is again established. This operating cycle is repeated again and again. The brick are thus subjected to repeated strains and finally fractures develop and the hot faces of the brick spall off. The new hot faces thus formed are subjected to a similar treatment and gradually the brick are destroyed.

Figure 3 aids in understanding the mechanism by which these spalling cracks develop. In this figure the heated end of the brick shown in Figure 1 is represented as consisting of a number of elements of thickness S across the width of the brick. Each strip **27** thus represented will extend from one edge to the other of the brick over a distance of 2½ inches.

If each element **27** were free to act independently when the temperature at the hot end falls from T_1 to T_2, the dimension S would decrease in amount equal to $Sc\ (T_1-T_2)$, where c represents the coefficient of expansion. In the actual brick, however, each element **27** is firmly attached to its neighboring element throughout the lengths and widths of the elements.

In order to maintain this continuous structure, the individual elements must undergo strains in

amounts sufficient to compensate for the change $Sc(T_1-T_2)$. This is accomplished in two ways. Tensile stresses are set up across the hot face of the brick, which increase the thickness of the individual elements. In addition, the adherence of each element to its neighbor tends to conform the adjoining elements to each other. This conformation plus the tensile strain tends to compensate for $Sc\ (T_1-T_2)$. The resulting assembly of the strained elements is indicated at **28** in Figure 4.

The tensile stress acting across the hot face may rise to a value which the refractory material cannot stand, whereupon a crack **30** will result at about 90 degrees to the hot face as shown in Figure 5. The deformation of the elements at the edge of the brick may exceed the strain which the refractory is capable of standing, whereupon a crack **31** (Figure 5) will start and then gradually work its way across the brick. Cracks similar to **30** and **31** are commonly observed in actual practice. As a result of such cracks, portions such as **32** and **33** of the brick separate and fall off as spalls. Of the two types of cracks indicated, the cracks **31** are more destructive.

In the foregoing study, only the forces caused by cooling have been considered. Upon rapid heating, compressive forces are set up across the face of the brick. Deformation of the individual brick elements also occurs, but in an opposite direction to the deformation caused by cooling. If the compressive forces are large enough they may cause shearing stresses and consequent cracking of the refractory. In basic refractory roofs these shear cracks are seldom observed. However, the effect of deformation of the brick elements upon heating supplement the destructive deformation caused by cooling and may therefore accelerate failure.

We have observed that the presence of metallic spacers attached to the sides of the brick during forming of the brick minimizes the tendency of cracks to form at the surface due to the strains set up by heating and cooling. The exact nature of the action of the metallic spacers in preventing crack formation is not entirely clear. It is, however, evident that the spacers exert a skin effect in avoiding crack origin and propagation.

The spacers are usually made of ordinary low carbon steel, although they can be made of any oxidizable constructional material which will operate at the temperature at the hot end of the refractory. It will be evident of course that the spacers need not be oxidizable at room temperature as long as they oxidize at furnace temperature, and therefore stainless steel, such as the 18% chromium 8% nickel grade or the 16% chromium grade or other alloys of iron and chromium may be used.

The heat of the furnace oxidizes the spacer at the hottest part of the brick and the iron or other metallic oxide formed reacts with the basic material present in the refractory, suitably magnesia or impurities in chrome ore. The resultant product welds together and forms a monolithic structure which definitely resists crack formation.

Our studies indicate that the strain set up at the surfaces of the brick due to heating and cooling are greater if the transverse dimensions of the brick are greater. This will be evident by reference to Figure 4. This is one reason why it is customary to limit the maximum dimensions of the brick to definite prescribed figures.

By making the transverse dimensions of the brick smaller, the strains can be made smaller, but this advantage is offset by the difficulties inherent in increasing the number of individual brick.

We have discovered that improved resistance to spalling is obtained by imbedding in the brick at the time of moulding, one or more oxidizable metallic spacer plates which are placed in a plane or planes parallel to the major axis of the brick and preferably approximately parallel to one of the longitudinal faces of the brick, thereby subdividing the brick into co-moulded cells of smaller dimensions, which can be heated and cooled with less strain at the outer surface. The same mysterious action of the spacer plate which minimizes the crack formation when the plate is located at the edge of the brick likewise minimizes crack formation at the edges of the cells within the brick. Therefore, spalling resistance is decreased due to a combination of the cellular effect on account of reduced dimensions subjected to strain, and the skin effect exerted by the oxidizable metallic spacer subdividing the cells.

While the partition wall between the cells should extend a major portion of the distance across the brick at the hot end (and most desirably at least three quarters of such distance), it will be understood that there may be some remaining cross connection between the refractory where the partition does not fully extend across the brick. Likewise while the cell should run the major length of the brick, it will be understood that considerable benefit will be evident if the partition is located at the hot end and extends for a distance of even two or better three inches from the hot end. Naturally for best results the cells should be separated for the major portion of the length of the brick beginning at the hot end.

In making up the brick, the brick mix employed may, for example, be magnesia or refractory material high in magnesia, such as dead-burned magnesite or electrically fused magnesia. It is important that the refractory material be of a basic nature, since certain refractories such as silica would react with the metallic spacer when they oxidized and would form fusible slags, destroying the roof. Chromite may be used instead of material high in magnesia. For instance mixtures of chromite with magnesia, containing for instance 75% of chromite and 25% of dead-burned magnesite, may be used. The amount of chromite present may be decreased for example to a composition containing 25% chromite and 75% of dead-burned magnesite. Any other suitable basic refractory composition may be employed.

To the basic refractory material, bonding substances should be preferably added to secure a bond without kiln firing. Organic binders such as sulphite pitch, dextrin, glue, gum arabic, or inorganic binders such as water solutions of magnesium sulphate, magnesium chloride, sodium dichromate, sodium silicate and the like may be used. The amount of binder used should be sufficient to form a brick which is mechanically strong without kiln firing. Normally the binder will be of the order of 1% on the weight of the brick, and will seldom exceed 2% on the weight of the brick, excluding the metal parts (the water is not included in this percentage), and never exceed 5%.

The pressure of moulding the brick will in any case exceed 1000 pounds per square inch (70.3 kilograms per square centimeter), and preferably exceed 5000 pounds per square inch (351.5 kilograms per square centimeter) and will most desirably exceed 10,000 pounds per square inch (703 kilograms per square centimeter).

Where reference is made herein to a brick it is intended to include the standard rectangular shape as well as any suitable block or other shape, provided with any suitable contour or attachment to engage a suitable hanger or support if any.

A suitable brick according to the present invention is illustrated in Figure 6, provided with cells **34** and **35** separated by a metallic spacer plate partition **36**. Metallic spacer plates **37** are provided at the lateral faces of the brick (Figure 6). The top of the hanger recess **25** is closed by the base of the U of an inverted U-shaped metallic support **38** comoulded in the brick.

The behavior of the brick of Figure 6 after repeated reheating is indicated in Figure 7, where each of the cells **34** and **35** undergoes strain separately and the partition line **36'**, where the iron oxide from the spacer plate has formed, protects the edges of the cells against crack formation.

Figure 8 illustrates the preferred embodiment of the brick in accordance with the invention. The partition wall **36** between the cells has at one edge a flange **40** which is suitably attached as by welding to the base **41** of the U of the U-shaped oxidizable metallic spacer plate **42**, having sides **43** which extend along the edges of the brick. The sides **43** may diverge slightly from parallelism if desired, even in a rectangular brick. Interlocking tabs **44** are lanced or otherwise formed from the spacer plate and extended inwardly to imbed in the brick.

The sides of the U are desirably short enough so that a thin line of refractory **45** exists on the edges adjoining a spacer plate **46** which closes the open space of the U and extends over the portion of the side of the brick opposite to the base of the U below the hanger recess. Interlocking tabs **44** are also lanced or otherwise formed from the plate **46**. It is usually not necessary to extend the plate **46** over the portion **47** of the brick adjoining the mouth of the hanger opening.

It will be seen in Figures 8, 10 and 14 that the partition spacer desirably does not extend fully to the cold end of the brick, in order to avoid interference with the hanger recess.

In some cases it may be desirable to use more than two cells, and in Figure 14 a brick is shown having cells **34**, **35** and **35'** separated by spacer plates **36** and **36²**, each of which is suitably secured to the base of the U of the plate **42**.

Figure 15 illustrates a brick similar to Figure 8 without spacer plates at the outside, and shows that the cellular construction can be employed even where spacer plates are not used on the lateral faces. A broadened base **40'** on the partition spacer is provided to hold it in the mould.

Figures 16 and 17 illustrate a desirable manner of moulding the brick. It is preferable to use a hydraulic press, although any other suitable press may be used. The material need not be formed by a steady forming pressure but may be formed by repeated impacts or blows delivered by falling weights, pneumatic hammers or the like.

Figures 16 and 17 show a mould assembly having a mould opening **47** of the desired brick size contained in the mould box **48**. The opening is closed by upper and lower dies **50** and **51**. Both dies are desirably movable. The forming pres-

sure may be supplied as by a hydraulic cylinder acting on the upper die **50**.

The brick is formed on its side with the longitudinal axis transverse to the plane of the paper in Figures 16 and 17. At the start of the pressing cycle as shown in Figure 16, the upper and lower dies are in retracted position and the mould is empty. The U-shaped spacer plate **42** with the attached partition plate **36** is placed in the bottom of the mould with the bottom of the U resting on the bottom die **51** and the arms **42** of the U as well as the partition spacer plate **36** upstanding.

The basic refractory **52** in the form of a mix is placed in the mould. The opposing spacer plate **46** is attached to the upper die **50** with the interlocking projections **44** downwardly directed. The spacer plate **46** is desirably temporarily held in place on the upper die by a magnetic chuck **53**, although adhesive or any other suitable attachment may be employed. The upper die has a plug **54** which forms the hanger recess and desirably carries any metallic parts relating to hanging such as the U element **38** associated therewith. To mould the brick the dies are closed to the position shown in Figure 17. Thereupon the upper die **50** is withdrawn and the lower die **51** is raised to eject the brick from the mould. The cycle is then ready for repeating.

The moulded brick are dried for about twenty-four hours, after which they are ready for use.

It will be evident that the spacer plates are secured to the brick by comoulding.

The spacers are desirably made of metallic sheet or plate of about $\frac{1}{8}$ inch thickness, although thinner or thicker spacers may be used. Spacers thicker than $\frac{1}{4}$ inch are not recommended because of the tendency of the metal to melt out rather than oxidize. Spacers thinner than $\frac{1}{64}$ inch are not recommended.

In view of our invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of our invention without copying the process and structure shown, and we, therefore, claim all such insofar as they fall within the reasonable spirit and scope of our claims.

Having thus described our invention what we claim as new and desire to secure by Letters Patent is:

1. A unitary basic refractory brick of elongated shape having support means adjacent one end and an oxidizable metallic spacer plate in comoulded relation to the refractory extending longitudinally through the interior of the brick for part only of the length of the brick and extending across the brick and partially separating the brick into refractory blocks on either side, there being refractory brick material extending unitarily across a transverse edge of the spacer plate between the blocks adjacent the end having the support means.

2. A unitary basic refractory brick of elongated shape having support means adjacent one end, an oxidizable metallic spacer plate in comoulded relation to the refractory extending longitudinally through the interior of the brick for part only of the length of the brick and extending across the brick, and partially separating the brick into refractory blocks on either side, there being refractory brick material extending unitarily across a transverse edge of the spacer plate between the blocks adjacent the end having the support means, and an oxidizable metallic spacer plate on one of the lateral faces of the brick comoulded therewith.

3. A unitary basic refractory brick of elongated shape having a hanger connection adjacent one end, and an oxidizable metallic spacer plate in comoulded relation to the refractory extending longitudinally through the interior of the brick for part only of the length of the brick and extending across the brick and partially separating the brick into refractory blocks on either side, there being refractory brick material extending unitarily across a transverse edge of the spacer plate between the blocks adjacent said one end.

4. A unitary basic refractory brick of elongated shape having support means adjacent one end, a first oxidizable metallic spacer plate in comolded relation to the refractory extending longitudinally through the interior of the brick for part only of the length of the brick and extending across the brick and partially separating the brick into refractory blocks on either side, there being refractory brick material extending unitarily across a transverse edge of the spacer plate between the blocks adjacent the end having the support means, and a second oxidizable metallic spacer plate secured to the first plate, located on a lateral face of the brick and comolded with the brick.

5. A unitary basic refractory brick of elongated shape having support means adjacent one end, a first oxidizable metallic spacer plate in comolded relation to the refractory extending longitudinally through the interior of the brick for part only of the length of the brick and extending across the brick and partially separating the brick into refractory blocks on either side, there being refractory brick material extending unitarily across a transverse edge of the spacer plate between the blocks adjacent the end having the support means, and a second oxidizable metallic spacer plate of U-shape on one lateral face and parts of two other lateral faces of the brick, having the base of the U united to the first oxidizable metallic spacer plate, the second oxidizable metallic spacer plate being comolded with the brick.

RUSSELL PEARCE HEUER.
MERVIN ADRIAN FAY.

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