United States Patent [19]

Silverstone et al.

[11] **3,918,517**

[45] **Nov. 11, 1975**

[54] **REGENERATIVE HEAT EXCHANGER MATRIX**

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[73] Assignee: **Caterpillar Tractor Company,** Peoria, Ill.

[22] Filed: **Sept. 3, 1974**

[21] Appl. No.: **502,897**

[52] **U.S. Cl.** ..... **165/10;** 29/157.3 R; 29/202 R; 29/445; 423/344; 106/69

[51] **Int. Cl.** **F28d 19/04**

[58] **Field of Search** ..... 165/10, 9.1–9.4; 29/157.3 R, 202 R, 445

[56] **References Cited**

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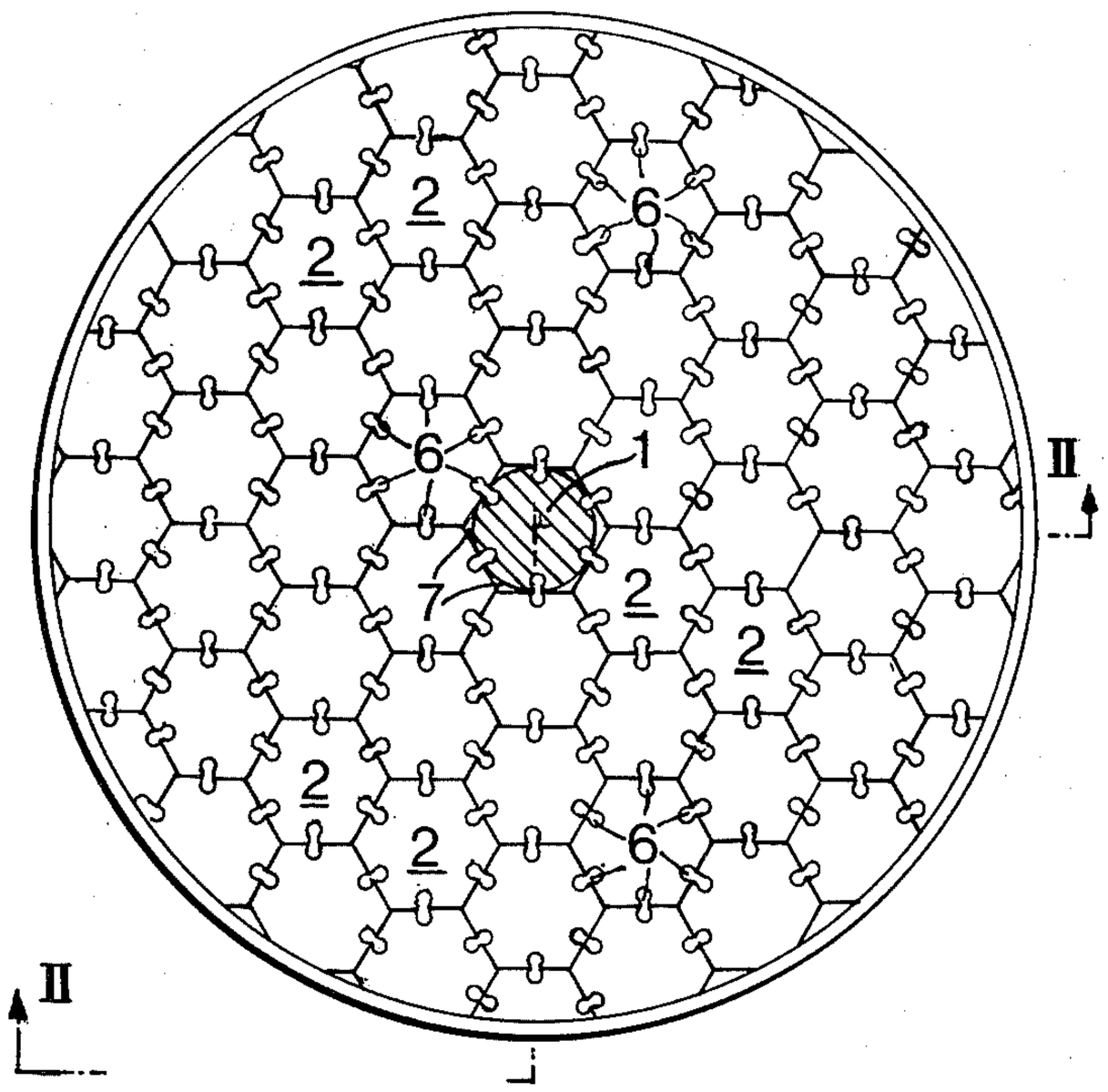
Primary Examiner—Albert W. Davis, Jr.
Attorney, Agent, or Firm—Gifford, Chandler & Sheridan

[57] **ABSTRACT**

A regenerative heat exchanger matrix comprising a multiplicity of blocks of a porous ceramic material having substantially flat side faces arranged side-by-side with adjacent side faces abutting and held together by a key member inserted into sockets formed in each of the abutting side faces. The blocks may be bonded together additionally to using the key members. The strength of the bonds between adjacent blocks may be selected to permit stress to be relieved by controlled fracture at the bonds, the blocks remaining connected together by the key members.

9 Claims, 4 Drawing Figures



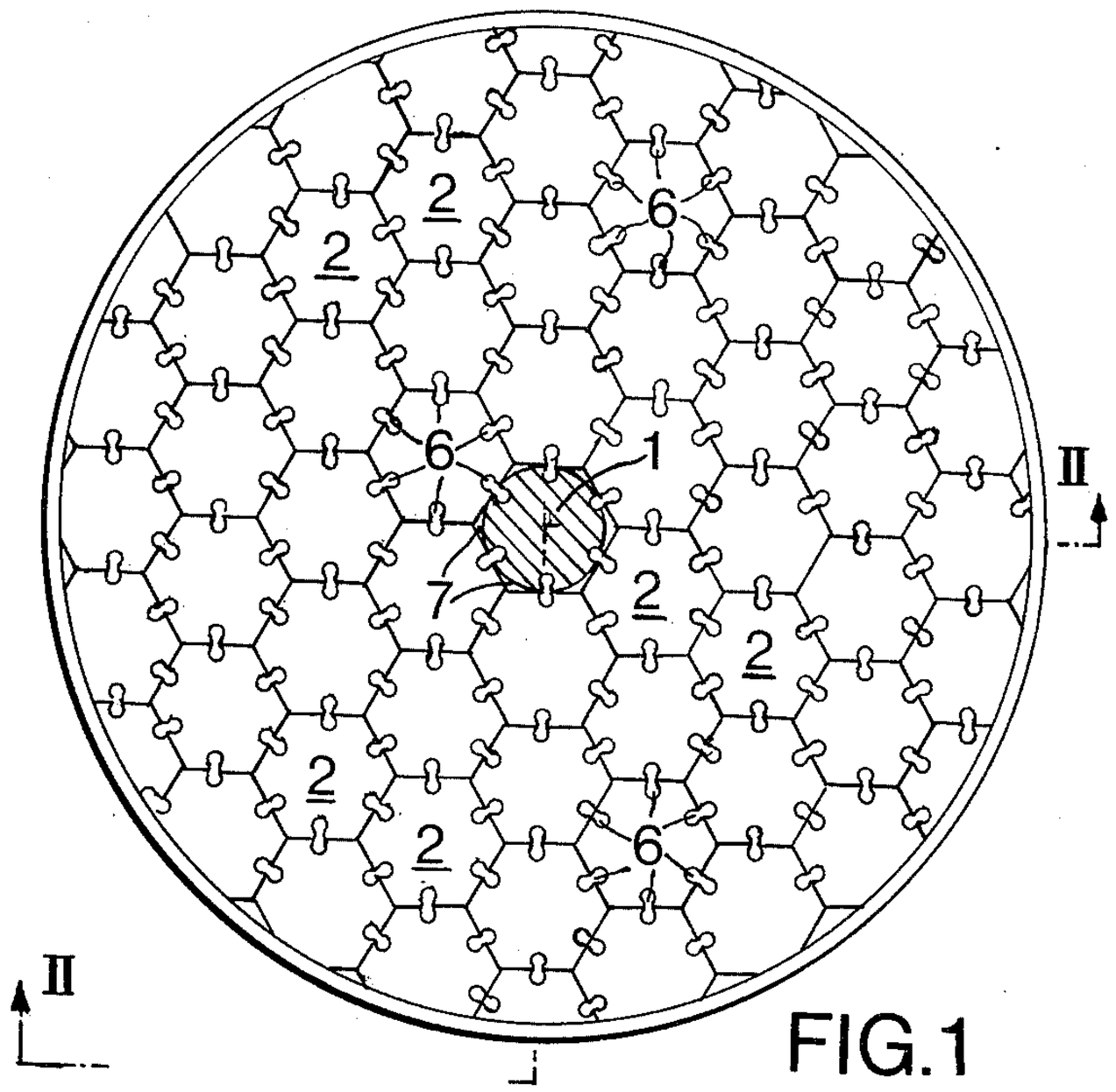


FIG.1

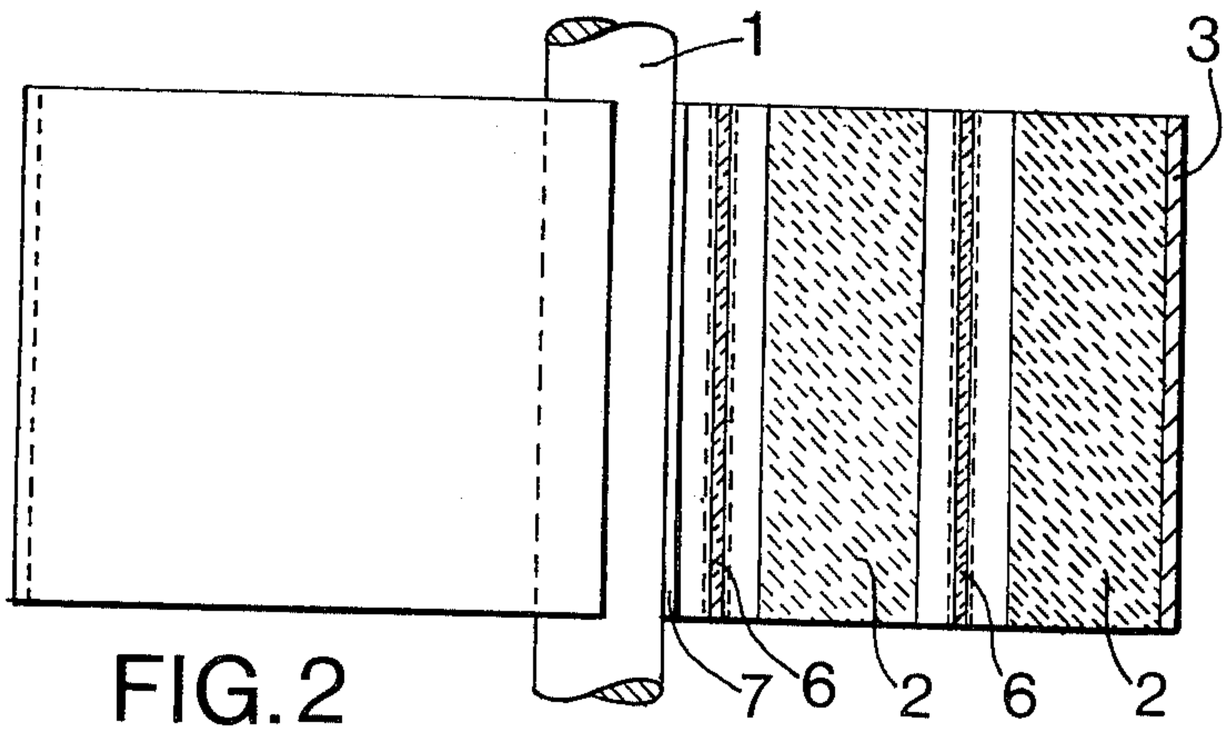


FIG.2

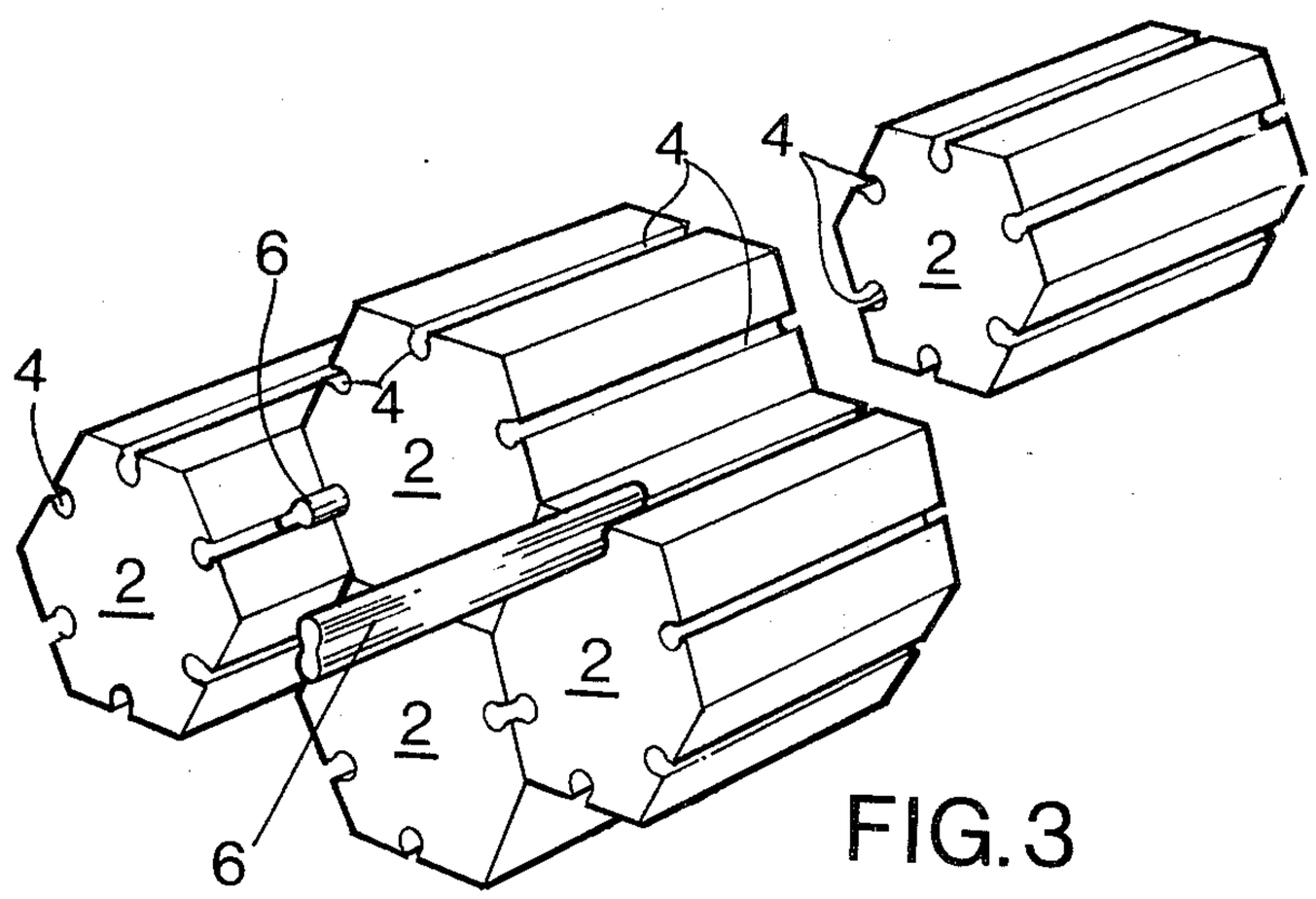


FIG. 3

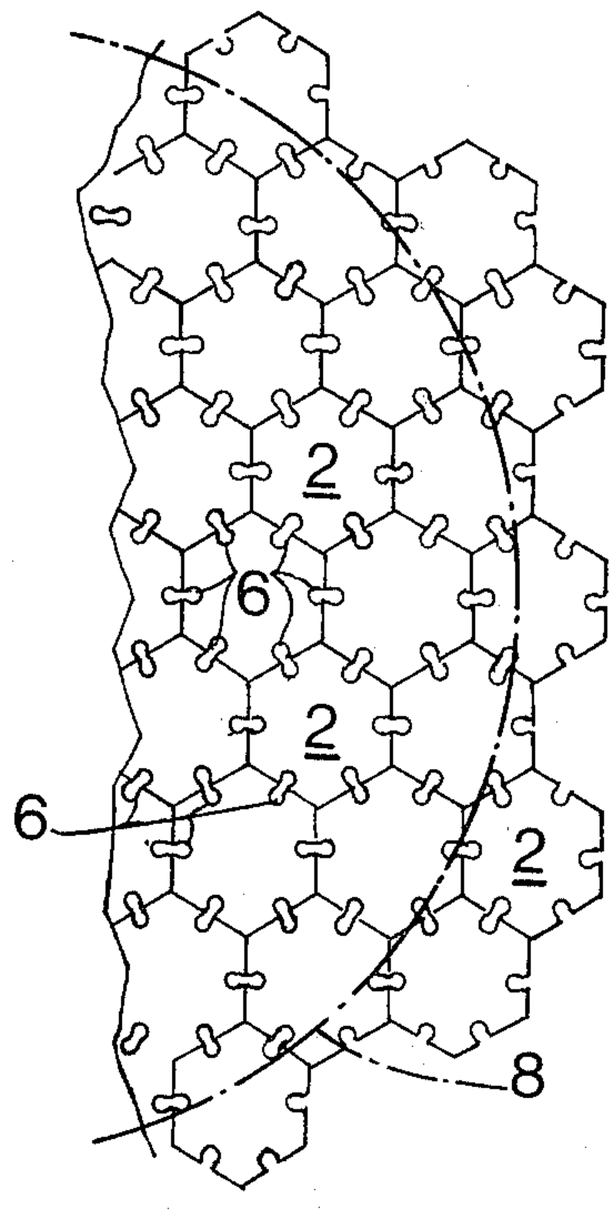


FIG. 4

REGENERATIVE HEAT EXCHANGER MATRIX

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a regenerative heat exchanger matrix.

2. Description of the Prior Art

A ceramic material such as silicon nitride is often used for the construction of a matrix of a rotary regenerative heat exchanger. Silicon nitride has a relatively high co-efficient of expansion and under high operating temperatures, stresses may occur in a matrix formed from a monolithic block of the material, resulting in fracture of the matrix. An object of the invention is to provide a matrix construction in which the tendency to fracture is reduced.

SUMMARY OF THE PRESENT INVENTION

According to the invention, a heat exchanger matrix comprises a multiplicity of blocks of a porous ceramic material having substantially flat side faces arranged side-by-side with adjacent side faces abutting and held together by a key member inserted into sockets formed in each of the abutting side faces.

The key member engaging between each pair of abutting side faces is conveniently a pin which is inserted into aligned sockets in the abutting side faces and extends between opposite end faces of the pair of blocks in a direction substantially parallel with the longitudinal axis of the assembled matrix.

The sockets when aligned and the pin may be cylindrical or be of any other suitable shape in cross-section. For example, each pin may be of dumb-bell shape in cross-section, that is it may be of the shape of an oval having a constriction intermediate its ends. The sockets and the pins may be tapered in the longitudinal direction of the blocks and/or the pins may have end portions extending beyond the end faces of the blocks to enable the said end portions to be peened or up-set.

The blocks may be bonded together in addition to being keyed together by the key members. Certain of the bonds between abutting faces of adjacent blocks may be weaker than others or they may all be of low strength, whereby stress can be relieved along the weaker or low strength bonds by failure of said bonds, the blocks remaining connected together by the key members.

The invention also includes a method of constructing a matrix from a multiplicity of blocks of a porous ceramic material and having substantially flat side faces by arranging the blocks side-by-side with adjacent side faces abutting and securing adjacent blocks together by inserting key members into sockets formed in each of the abutting side faces.

The method may include the step of additionally bonding adjacent blocks together. Certain of the bonds between abutting faces of adjacent blocks may be made weaker than others or they may all be of low strength, as aforesaid.

Conveniently the blocks may be made of silicon nitride or a similar material. Where the material is silicon nitride, the blocks may be formed with the sockets for receiving the key members before nitriding of the block material is effected. Each block may be separately nitrided or the blocks may be assembled in the "green" state and keyed to adjacent blocks by the key members, the assembled blocks then being nitrided to effect bonding between the blocks. The key members may also be made of silicon nitride and are separately nitrided prior to the assembling of the matrix, or they may be made of the green material and then be nitrided in situ with the remainder of the assembly.

BRIEF DESCRIPTION OF THE DRAWING

By way of example, a disc-like matrix for a rotary regenerative heat exchanger, and a method of making the matrix, are now described with reference to the accompanying drawing, in which:

FIG. 1 is an end view of the assembled matrix;

FIG. 2 is a section on the line II—II in FIG. 1;

FIG. 3 is an exploded view of several matrix blocks and showing key members therefor, drawn to a larger scale then that of FIGS. 1 and 2, and

FIG. 4 shows a portion of an assembled matrix and illustrates a stage in the manufacture of the matrix.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

The matrix is formed from a central shaft 1 or hub portion, surrounded by a multiplicity of hexagonal cross-section blocks 2 of porous silicon nitride or of green silicon-based material which is subsequently nitrided to form silicon nitride. The blocks 2 are closely packed side-by-side to form the complete matrix. The radially outermost blocks are later machined in situ as will be explained with reference to FIG. 4 or they are pre-shaped to form a circular profile. The assembled blocks may be bounded by a rim portion 3 or the rim may be machined, as described hereinafter with reference to FIG. 4. Before assembly the blocks 2, which may be extruded or cast, are formed with longitudinally-extending grooves 4, (see FIG. 3) constituting the aforesaid sockets, in each side face of every block 2. On assembly of the blocks 2 to form the disc-like matrix, the grooves 4 in abutting side faces will be in registration one with the other to form together a longitudinally-extending passageway of dumb-bell shape in cross-section, i.e., having a cross-section of oval shape constricted intermediate its ends. After assembly of at least a pair of the blocks 2, correspondingly-shaped key members 6 are inserted into the passages formed by the grooves 4 to hold the blocks together. The method of connecting adjacent blocks 2 together by the key members 6 is illustrated in FIG. 3. The key members 6 and the grooves 4 may be tapered to enable the key members 6 to be locked by wedging action in the grooves 4 or the key members 6 may extend beyond one or both of the end faces of the matrix and there be peened or up-set. Instead of the key members and passages being of dumb-bell shape in cross-section, cylindrical pins and semi-cylindrical grooves forming cylindrical passages may be employed. The pins may be locked against axial movement by providing tapered pins and grooves or by peening or up-setting the ends. Pins and grooves of any other suitable complementary cross-sectional shape may be employed.

The blocks 2 may be cured and be separately machined and nitrided or the green blocks may be assembled, machined to form a circular cross-section matrix or to receive a rim 3, and, the end faces of the matrix are machined, if necessary, and then the whole matrix is nitrided. The key members 6 may be made of the green material and be separately nitrided or nitrided in the whole matrix after assembly.

By nitriding an assembled matrix in the green condition, bonds may be formed by the nitriding process between abutting side faces of the blocks. By making the bonds between certain of the blocks, or all of them, of low strength, stresses can be relieved in the matrix during its use by causing fracture of the bonds between blocks in a controlled manner, thereby avoiding uncontrolled fracture or shattering of the matrix as in monolithic constructions of matrix. The key members **6** maintain the blocks **2** together even when the bonds between blocks have fractured and so complete failure of the matrix would not occur.

Although in the foregoing description the blocks **2** are of hexagonal shape in cross-section, other cross-sectional shapes of block, for example triangular or square may be employed, the central hub shape, where a hub is required, may be complementary to that of the blocks. Alternatively where a central shaft **1** is provided, the shaft may be keyed to adjacent blocks **2** by key members **6** as illustrated in FIGS. **1** and **2.** Where the block assembly is nitrided after assembling the blocks in the green condition, the material to be nitrided may be used to fill the spaces **7** between the innermost blocks and the shaft **1** or a circular hub member.

FIG. **4** shows how a matrix may be assembled from blocks to an irregular peripheral shape and then be machined to a circular profile indicated at **8,** conveniently before nitriding, in the case of silicon nitride. The circular profile may be fitted with a rim, such as **3** in FIG. **1.**

What we claim as our invention and desire to secure by Letters Patent of the United States is:

1. A regenerative heat exchanger matrix comprising a multiplicity of blocks of a porous ceramic material having substantially flat side faces arranged side-by-side with adjacent side faces abutting and a plurality of key members by which adjacent blocks are held together, each said key member being inserted into sockets formed in each of the abutting side faces.

2. A matrix as claimed in claim **1** in which each key member engaging between each pair of abutting side faces is a pin which is inserted into aligned sockets in the abutting side faces and extends between opposite end faces of the pair of blocks in a direction substantially parallel with the longitudinal axis of the assembled matrix.

3. A matrix as claimed in claim **2** in which each pair of sockets when aligned and the co-acting pin are of substantially dumb-bell shape in cross-section, that is in the shape of an oval having a constriction intermediate its ends.

4. A matrix as claimed in claim **2** in which each pair of sockets when aligned and the co-acting pins are of circular shape in cross-section.

5. A matrix as claimed in claim **2** in which the sockets and the pins are tapered in the longitudinal direction of the blocks.

6. A matrix as claimed in claim **2** in which the pins have end portions extending beyond the end faces of the blocks to enable said end portions to be peened.

7. A matrix as claimed in claim **1** in which adjacent blocks are bonded together in addition to being keyed together by said key members.

8. A matrix as claimed in claim **7** in which certain of the bonds between abutting faces of adjacent blocks are weaker than others.

9. A matrix as claimed in claim **7** in which the bonds are weak, whereby said bonds can readily fail to relieve stress, the blocks remaining connected together by the key members.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,918,517

DATED : November 11, 1975

INVENTOR(S) : Calfin Eric Silverstone et al

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

--Foreign Application Priority Data
Sept. 5, 1973 United Kingdom 41706/73--

Signed and Sealed this

twenty-fourth Day of *February 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,918,517
DATED : November 11, 1975
INVENTOR(S) : Calvin Eric Silverstone et al

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

Change the assignee to read:
--Caterpillar Tractor Co.--

Signed and Sealed this

Thirteenth Day of July 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks