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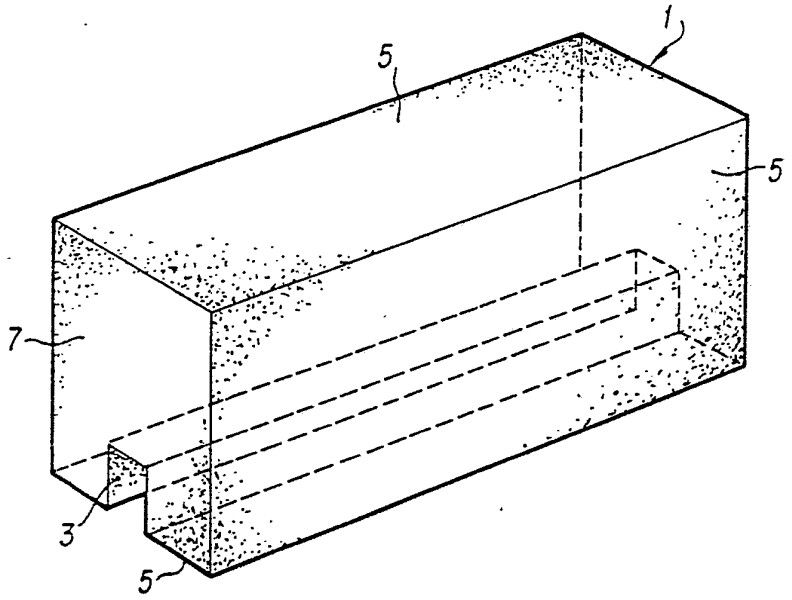
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(54) Title: SYSTEM FOR CONVERTING WASTE MATERIALS INTO USEFUL PRODUCTS




(57) Abstract

A system for converting waste materials including solid refuse and microbial refuse into useful products for fuel and agricultural applications. A mixture of solid refuse and sewage sludge having a predetermined mixture content is compacted under controlled pressure conditions to form substantially rectangular-shaped blocks (1), each of which is provided with an open air channel (3) across at least one face (5) thereof to provide enhanced air circulation through a stack of such blocks so that efficient and complete aerobic fermentation of the biodegradable materials is realized.

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# SYSTEM FOR CONVERTING WASTE MATERIALS INTO USEFUL PRODUCTS

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention generally involves the conversion of biodegradable waste materials. More specifically, the invention relates to the production of useful products from a mixture of solid refuse and sewage sludge through enhanced aerobic fermentation.

### 2. Description of the Prior Art

The biological decomposition of organic materials through aerobic fermentation and thermal rotting is a well known natural process which has been utilized to advantage in converting municipal and industrial waste products into stable and useful materials. For example, biodegradable mixtures of vegetation and manure have produced soil conditioners and fertilizers. Fuel products suitable for combustion in furnaces and stoves have also been made from mixtures of solid refuse and sewage sludge which have been compacted into discrete shapes and decomposed through aerobic fermentation.

In order for a mixture of waste materials to undergo aerobic fermentation, the mixture must include a microbial organic component. For complete aerobic fermentation of a biodegradable mixture to be realized in a minimum of time, it is essential that the mixture be

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provided with sufficient air circulation therethrough to confine the fermentation process to one that is achieved entirely by aerobic bacteria. Biological decomposition in the absence of sufficient air circulation is accompanied by the evolution of gases having undesirable odors produced through the putrifaction of the organic material by anaerobic bacteria which reproduce and thrive in the absence of oxygen.

The prior art has clearly recognized that air circulation is critical for proper aerobic fermentation of biodegradable materials and has addressed this problem through various proposals. For example, the aerobic fermentation of large masses of waste materials has been achieved by cracking or splitting such masses at spaced intervals to facilitate air circulation therethrough. Tunnels or air passageways have been provided in block-shaped masses for this same purpose. Forced circulation of air through the mass has also been proposed.

Because of the heterogeneous nature of waste materials making up biodegradable mixtures, particularly with regard to size and shape of the individual materials, it has heretofore proven extremely difficult to form masses or discrete bodies of such mixtures into desired shapes having efficient air circulation characteristics. This problem is particularly acute in the making of compacted blocks of various configurations wherein the blocks must be piled or stacked prior to undergoing decomposition while maintaining structural integrity and permitting clear air circulation between and through the blocks.

## SUMMARY OF THE INVENTION

The present invention provides an improved system of achieving efficient and complete aerobic fermentation of biodegradable mixtures to produce discrete shapes that are particularly useful as a fuel product in combustion applications. This is achieved by forming a precursor mixture of waste materials that includes a mixture of a solid refuse and a microbial source, such

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as raw sewage sludge, having a moisture content of from about 50-55% by weight. The mixture is compacted into discrete shapes, preferably of substantially rectangular or block configuration, each of which includes an open air channel formed in at least one face thereof, whereby the ratio of the total transverse cross-sectional area of the block to the transverse cross-sectional area of the air channel is in the range of from about 6 to 31. The blocks are then stacked in a spaced manner, with the spacings between adjacent blocks and air channels defining a pluarlity of open air circulation passageways between and through the blocks in three dimensions.

It is an object of the invention to provide an efficient and simple system for achieving complete aerobic fermentation of a biodegradable mixture of waste materials.

It is another object of the invention to provide an improved system for converting a mixture of solid refuse and raw sewage sludge into useful products.

It is a further object of the invention to provide a means for enhancing aerobic fermenation of stacked shapes formed from biodegradable mixtures of waste materials.

It is yet another object of the invention to provide an improved system for rapidly and economically producing a source of quality fuel for combustion purposes.

These and other objects and advantages of the present invention will become apparent to those skilled in the art by reference to the following description of the preferred embodiments thereof when taken in conjunction with the accompanying drawings wherein like reference characters refer to like elements throughout the views.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a perspective view of a block made according to the invention depicting an open air channel formed along one longitudinal face thereof;

FIGURE 2 is an end elevational view of the block depicted in FIGURE 1;

FIGURE 3 is an end elevational view depicting a plurality of the blocks shown in FIGURE 1 stacked according to the invention on a pallet for undergoing aerobic fermentation;

FIGURE 4 is a top view of the stack of blocks depicted in FIGURE 3, partially broken away at one corner to show the orientation of individual block layers.

FIGURE 5 is an end elevational view of a second embodiment of a block made according to the invention depicting an open air channel having a triangular cross-sectional configuration; and

FIGURE 6 is an end elevational view of a third embodiment of a block made according to the invention depicting an open air channel having a semicircular cross-sectional configuration.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is advantageously practiced by utilizing a mixture of waste materials which include solid refuse and raw sewage sludge, both of which are readily obtained from municipal and industrial sources. The solid refuse is generally characterized by the inclusion of cellulosic and fibrous materials which serve as binders for maintaining the structural integrity of the blocks formed according to the invention. The solid refuse also provides a desired porosity to the block to facilitate oxygenation of the mixture for enhanced aerobic decomposition. The sewage sludge provides the necessary microbial source for effecting the aerobic fermentation process.

The solid refuse, such as wood chips, sawdust

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and paper wastes, is derived from municipal and industrial sources and initially reduced to a workable particle size by utilizing conventional shredding and grinding apparatus. The particulated solid refuse is then subjected to standard separation treatment during which inert solids such as metals, ceramics, glass and the like are removed.

The microbial component is preferably raw sewage sludge, though other suitable organic materials, such as animal and septic tank wastes may also be utilized to advantage in practicing the invention. The raw sewage sludge is generally derived from municipal sewage disposal plants in a partially dehydrated condition, with the moisture content being in the range of from about 75-80% by weight.

The particulated solid refuse and sewage sludge are mixed in such desired proportions so as to result in a mixture having a moisture content in the range of from about 50-55% by weight. The mixture is then compacted or molded into block form by utilizing conventional concrete block molding machines that are well known in the art. For example, suitable machines of this type are manufactured by the Besser Company of Alpena, Michigan 49707. During the compacting or molding of the decomposable mixture, it is important that the molding pressure be such as to provide a density of about 30-40 pounds per cubic foot, preferably 33-37 pounds per cubic foot, in order to assure sufficient porosity in the molded product for maximum oxygenation of the mixture.

The molded blocks are then stacked on pallets, preferably in the open atmosphere, and permitted to undergo undisturbed aerobic bacteria fermentation and thermal rotting during which the blocks are self-dehydrated. The blocks normally complete fermentation at about seven to twenty-one days, with the final dehydrated moisture content being in the range of from about 15-40% by weight. If the blocks are ultimately used for combustion purposes, increased fuel value is realized in proportion to decreased final moisture content. Thus, for fuel applications, it

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is preferable to permit the blocks to undergo undisturbed fermentation and thermal rotting for a time period of about twenty-one days, thereby resulting in dehydration to a final moisture content in the range of from about 15-20% by weight.

In order to assure complete aerobic fermentation of a stack of the blocks, it is critical that sufficient air circulation be provided between and through the blocks in order to achieve maximum oxygenation of the bacteriological reaction. This is made possible through the discovery that it is critical to provide an open air channel across at least one face of the block wherein the ratio of the cross-sectional area of the block to the cross-sectional area of the air passageway across a transverse plane must be within a certain range in order to provide structural integrity and maximum air circulation. This ratio is independent of either size or cross-sectional configuration of either the block or the air channel. For example, a rectangular-shaped block may be provided with an open air channel along one longitudinal face, with the cross-sectional configuration of the passageway being substantially triangular, rectangular or semi-circular.

A block 1 made according to a preferred embodiment of the invention is depicted in FIGS. 1 and 2. In this embodiment, block 1 is of a substantially rectangular configuration and provided with an open air channel 3 which extends along the entire length of a longitudinal face 5 of block 1. Under certain circumstances, it may also be desirable to dispose channel 3 longitudinally or transversely across one or more longitudinal faces 5 of block 1, or even across a transverse face 7 thereof. While the transverse cross-sectional configuration of channel 3 as shown in FIG. 2 is substantially rectangular, it is understood that such configuration may assume a variety of designs, including semicircular, triangular, square or any other geometrical configuration deemed suitable for the practice of the invention.

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In order for block 1 to achieve full aerobic decomposition of the biodegradable mixture making up same, it is critical that the cross-sectional area of channel 3 be of a certain size relative to the total cross-sectional area of transverse face 7, the latter area being determined by multiplying the height and width of block 1. If the cross-sectional area of channel 3 is too small, sufficient air ciruclation therethrough will not be realized, thereby resulting in improper and inefficient fermentation. If the cross-sectional area of channel 3 is too large, the natural characteristics of the mixture making up block 1 will not afford sufficient structural integrity and strength to permit the necessary manual and mechanical handling of block 1. This latter problem cannot be overcome by merely compacting the mixture making up block 1 into a denser product since porosity is destroyed and oxygenation of the mixture is hindered when the density of block 1 exceeds about 30-40 pounds per cubic foot.

Thus it has been discovered that in order to realize the basic advantages of structural integrity, sufficient oxygenation for proper fermentation of the biodegradable mixture, and adequate air circulation for efficient and complete fermentation, block 1 must be designed in accordance with an optimum relationship between the cross-sectional areas of block 1 and air channel 3. This relationship has been established in the form of a ratio of the total cross-sectional area of block 1 to the cross-sectional area of air channel 3, taken across a common transverse plane, as being within the range of about 6 to 31.

The manner in which a plurality of blocks 1 undergo complete and efficient aerobic decomposition in accordance with the invention shall be described with reference to FIGS. 3 and 4. As shown therein, a plurality of blocks 1 are placed in a stack 9 and disposed on a pallet 11 or similar device for supporting stack 9 in a raised manner to permit air circulation across the bottom thereof. As seen in FIG. 3, individual blocks 1 forming

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the lowermost layer of stack 9 are disposed endwise with spacings 13 between adjacent blocks. The second layer of stack 9 is disposed lengthwise across the first layer with spacings 15 being provided between transverse end faces 7 of adjacent blocks. The third layer is disposed on top of the second layer in the same orientation as the first layer, with succeeding layers being alternated in this manner so that the longitudinal axes of the blocks of each layer are perpendicular to the longitudinal axes of blocks forming adjacent layers.

As seen in FIG. 4, the manner in which stack 9 is formed places air channels 3 of blocks 1 in coaxial alignment to define continuous air passageways 17 that extend completely through stack 9 in two directions and for each layer of blocks 1. Therefore, air circulation is provided for stack 9 through passageways 17 and spacings 13 and 15 in three directions, as generally indicated by arrows A, B and C in FIGS. 3 and 4. Since stack 9 realizes complete air circulation therethrough, maximum oxygenation of the biodegradable mixture making up blocks 1 is provided, thereby resulting in complete aerobic fermentation and thermal rotting of blocks 1 in the most efficient manner possible.

Another embodiment of a block made in accordance with the invention is shown in FIG. 5 wherein a rectangular block 19 is provided with an air channel 21 having a substantially triangular-shaped cross-sectional configuration. A third embodiment of the invention is shown in FIG. 6 wherein rectangular block 23 is provided with an air channel 25 having a substantially semicircular-shaped cross-sectional configuration. As previously indicated, the respective ratio of the transverse cross-sectional areas of their respective air channels 21 and 25 is within the preferred optimum range of 6 to 31.

By was of example, a block was made in accordance with the invention and having the general configuration of block 1, with a height of 9 inches, width of 7 inches and length of 23 inches. The air channel had a

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height of 2 inches, a width of 1.5 inches and a length of 23 inches. The transverse cross-sectional area of the block is the product of its width and height or 63 square inches. The transverse cross-sectional area of the air channel is the product of its width and height or 3 square inches. Thus, the ratio of these areas is 63/3 or 21, a value which is intermediate the optimum range of 6 - 31 and represents a preferred embodiment of the invention. The block of this example was tested for combustion characteristics and revealed a fuel value of about 9000 BTU's per block, a value which is substantially equal to that for a grade 3 subbituminous coal having a low sulfur emission. From this value, it can be reasonable stated that one ton of these blocks should produce sufficient energy value as to equal approximately 2.8 barrels of oil.

It is to be understood that the embodiments of the invention herewith shown and described are to be taken as preferred examples of the same, and that various changes in the shape, size and arrangement of parts and compositions may be resorted to, without departing from the spirit of the invention or scope of the subjoined claims.

I CLAIM:

1. A process for efficiently converting municipal and industrial refuse into useful products through aerobic fermentation comprising:

a) forming a compactible mixture having a given moisture content from a source of solid refuse and a source of microbial refuse;

b) molding the compactible mixture into a substantially block shape having at least one planar face and an open channel across the planar face, wherein the ratio of the cross-sectional area of the block to the cross-sectional area of the channel is within the range of about 6 to 31; and

c) permitting the block shape to undergo aerobic fermentation and thermal rotting to reduce the given moisture content.

2. The process of Claim 1 wherein the given moisture content of the compactible mixture is within the range of about 50-55% by weight.

3. The process of Claim 1 wherein the compactible mixture is molded to a density within the range of about 30-40 pounds per cubic foot.

4. The process of Claim 1 wherein the given moisture content of the compactible mixture is reduced through aerobic fermentation and thermal rotting to a level within the range of about 15-25% by weight.

5. The process of Claim 1 wherein the block shape is substantially rectangular in configuration and further including the step of forming a stack from a plurality of the block shapes to permit air circulation through a plurality of passageways defined by coaxially aligned channels of adjacent blocks.

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6. The process of Claim 5 wherein the block shapes are stacked with spacings between the longitudinal sides of adjacent blocks whereby the spacings and passage-ways permit air circulation through the stack from three directions.

7. The process of Claim 1 wherein the block shapes are permitted to undergo aerobic fermentation and thermal rotting for a period of time within the range of about 7 to 21.

8. The process of Claim 1 wherein the microbial source is sewage sludge.

9. A fuel element of substantially block shape formed from an aerobically fermented mixture comprising a solid refuse and a microbial refuse wherein the block shape includes at least one planar face having an open channel formed therein, with the ratio of the cross-sectional area of the block to the cross-sectional area of the channel being within the range of about 6 to 31.

10. The fuel element of Claim 9 wherein the microbial refuse is sewage sludge.

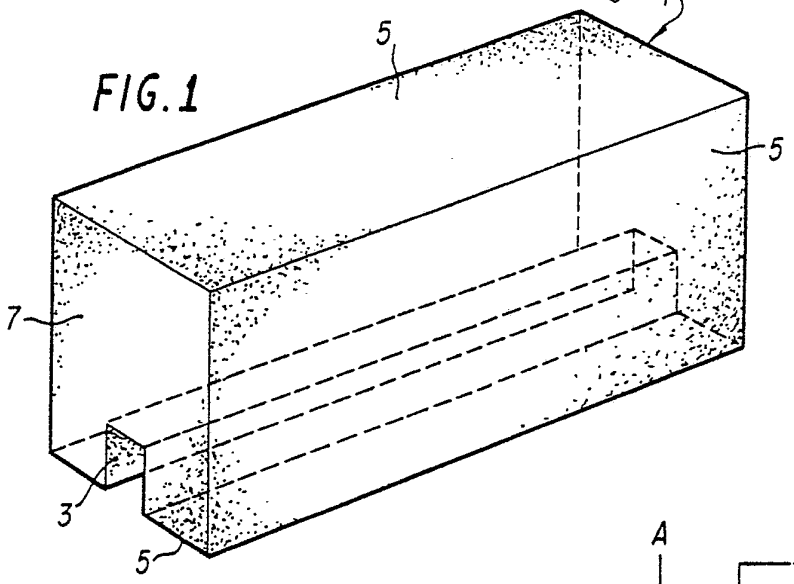
11. The fuel element of Claim 9 wherein the cross-sectional areas are each substantially rectangular in configuration.

12. The fuel element of Claim 9 wherein the cross-sectional area of the open channel is substantially triangular in configuration.

13. The fuel element of Claim 9 wherein the cross-sectional area of the open channel is substantially semicircular in configuration.

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FIG. 1



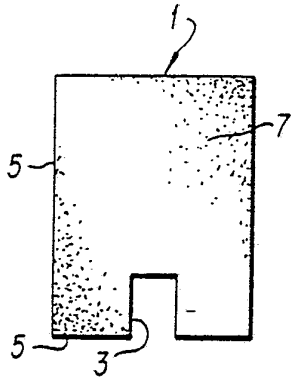




FIG. 2

FIG. 3

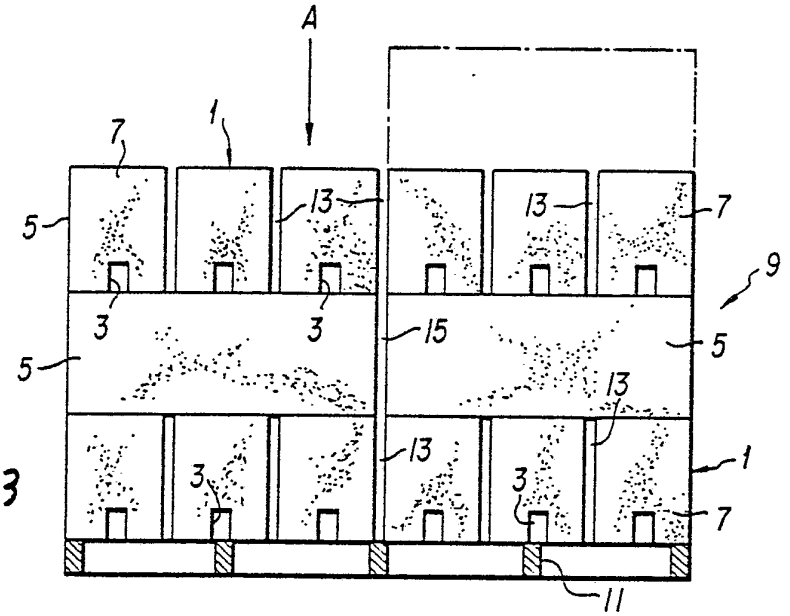
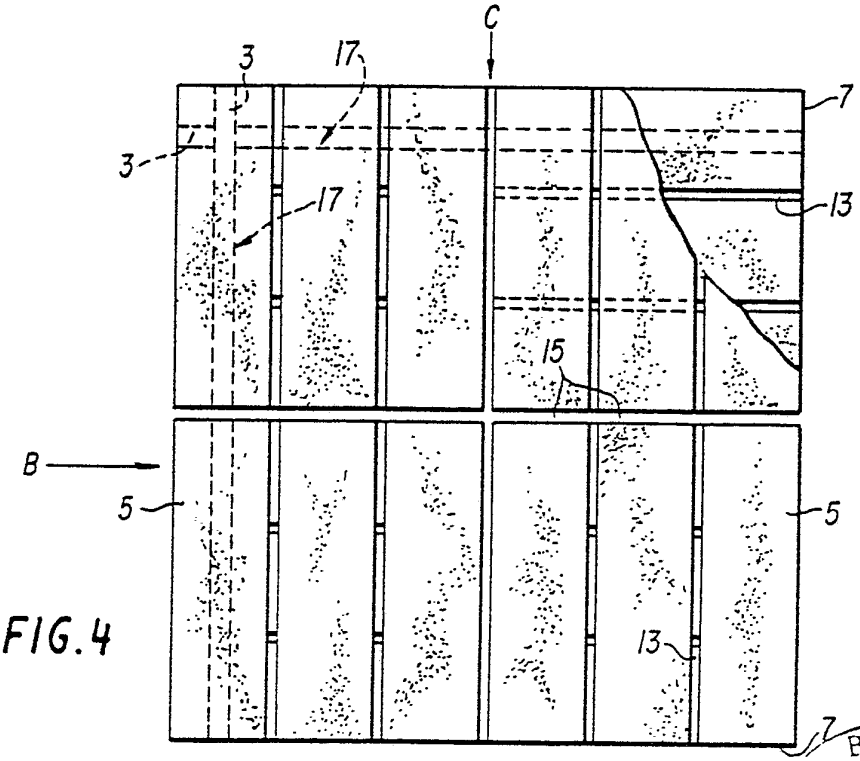



FIG. 4




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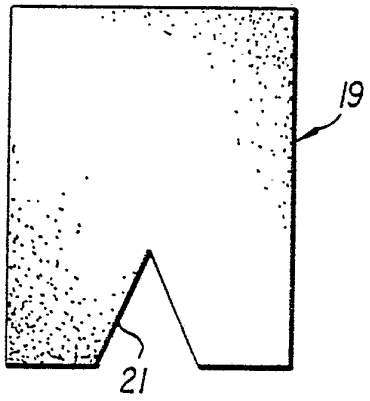



FIG. 5

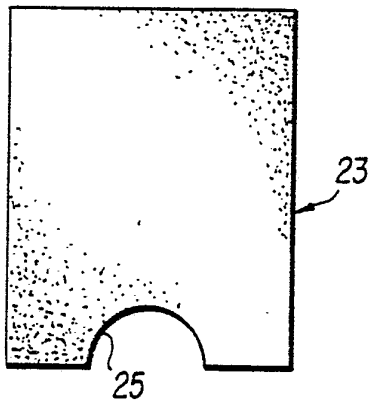



FIG. 6

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# INTERNATIONAL SEARCH REPORT

International Application No PCT/US 81/00504

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL. (IPC)[3] C10L 5/46, C10L 5/36
US. CL. 44/1D

## II. FIELDS SEARCHED

Minimum Documentation Searched [4]

| Classification System | Classification Symbols |
|---|---|
| US | 44/1D, 10A, 14 |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

## III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

| Category * | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No. [18] |
|---|---|---|
| X | N, Brikollare Process Brochure, cited by Applicant in U.S. Serial No. 182,045, 2 Sheets. | 1-13 |
| X | US, A, 620,186, Published, 28 February 1899, Sendlein | 1-13 |
| X | US, A, 44,342, Published, 20 September 1864, Sawyer | 1-13 |
| X | US, A, 3,298,821, Published, 17 January 1967, Pierson | 1-13 |
| X | US, E, 15,417, Published, 25 July 1922, Beccari | 1-13 |
| A | US, A, 4,043,764, Published, 23 August 1977, Loas | |
| P, A | US, A, 4,203,376, Published, 20 May 1980, Hood | |

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## IV. CERTIFICATION

| Date of the Actual Completion of the International Search [2] | Date of Mailing of this International Search Report [2] |
|---|---|
| 15 JULY 1981 | 16 JUL 1981 |
| International Searching Authority [1] | Signature of Authorized Officer [20] |
| ISA/US | Carl F. Dees<br>CARL F. DEES |

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