(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 November 2000 (30.11.2000)

PCT

(10) International Publication Number
WO 00/71257 A1

(51) International Patent Classification[6]: B02C 13/04

(21) International Application Number: PCT/US99/10457

(22) International Filing Date: 24 May 1999 (24.05.1999)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **ANDELA TOOL & MACHINE, INC.** [US/US]; 493 State Route 28, Richfield Springs, NY 13439 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **ANDELA, James** [US/US]; 776 County Highway 24, Richfield Springs, NY 13439 (US). **ANDELA, Cynthia** [US/US]; 776 County Highway 24, Richfield Springs, NY 13439 (US).

(74) Agent: **DE ANGELI, Michael**; Suite 330, 1901 Research Boulevard, Rockville, MD 20850 (US).

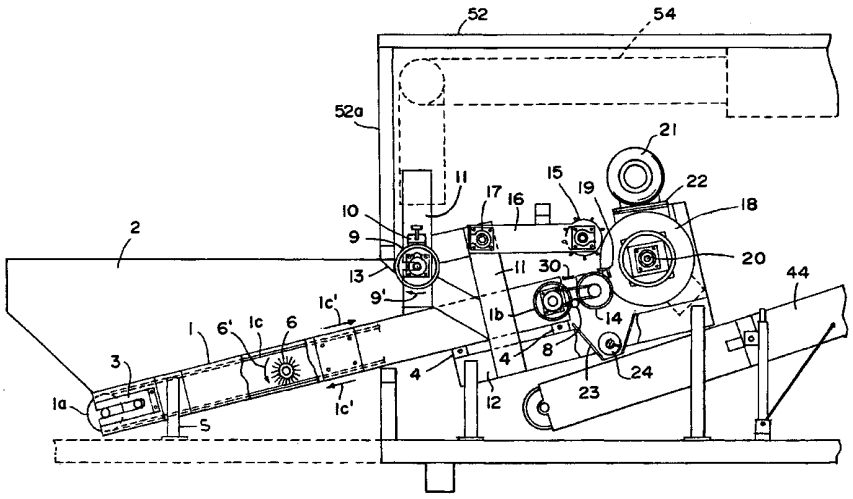
(81) Designated States *(national)*: AU, CA, IL, JP, KR, US.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: REDUCER AND SEPARATOR FOR PREPARING GYPSUM BOARD AND OTHER PRODUCTS FOR RECYCLING



(57) Abstract: An apparatus for preparing planar composite materials such as gypsum board for recycling comprises an infeed mechanism (1, 2) for receiving large quantities of scrap material and feeding these into a reduction unit (40). The reduction unit (40) comprises powered infeed rollers (14, 15), a breaker bar (19), and a rotating hammer assembly (18). As scrap gypsum board is fed over the breaker bar (19), the hammmers (60) reduce it in such a way that the paper is left in relatively large scraps, while the gypsum is essentially granular or powdered. The materials can then be separated using a simple size-based technique. The same machine can also be used, with only minor modification, for separating aggregate from asphalt substrate in recycling the materials of asphalt shingles. The impactors (63) are preferably of single-link (62) type, and are designed for ready replacement in the event of wear or damage.

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REDUCER AND SEPARATOR FOR PREPARING GYPSUM BOARD AND OTHER PRODUCTS FOR RECYCLING

Field of the Invention

This invention relates generally to recycling gypsum board, and in particular to an apparatus for reducing scrap gypsum board and separating it into its components for recycling. This same apparatus could also be used to prepare other composite materials, such as asphalt shingles, for recycling.

Background of the Invention

Scrap gypsum board is generated in large quantities in the manufacturing process, as a result of waste from new construction and modular home manufacturing, and through the demolition or de-construction of existing structures. Because gypsum board is generally relatively inexpensive, new construction in particular tends to generate large quantities of waste, as there is little incentive to use the material efficiently. Similarly, historically there has been little incentive to recycle scrap gypsum board. Accordingly, large quantities of scrap gypsum board require disposal, normally in landfills.

More recently, interest in gypsum board recycling has increased as the "tipping fees" paid to dispose of materials in landfills have increased, providing increased financial incentive for recycling the material. Moreover, regulatory pressure to keep scrap gypsum board out of landfills has increased recently, particularly in Japan, as it has become

well known that under certain circumstances scrap gypsum board can react with moisture in the landfill and generate a malodorous toxic gas. Gypsum board manufacturers also have limited space for storing scrap gypsum board on their property and need to recycle waste to limit future disposal issues.

Gypsum board is comprised of gypsum encased between two layers of paper, or between layers of paper and vinyl. (Reference herein to the "paper" component of gypsum board should be understood to include this optional vinyl layer.) By weight, gypsum board is comprised of approximately 90% gypsum and 10% paper. To successfully recycle this material, the gypsum needs to be separated from the paper. When separated, the gypsum can be used in place of the raw material or virgin gypsum as a soil amendment or agricultural additive, in new gypsum board manufacturing, in cement manufacturing, and as a substitute for new gypsum in a number of other uses. The paper can also be used in composting or agricultural applications.

Thus, as used herein, to "prepare scrap gypsum board for recycling" involves reduction of large pieces, e.g., up to full sheets of scrap gypsum board, into smaller pieces, detaching the gypsum from the paper, and separating the gypsum from the paper, for separate collection and efficient reuse.

Existing equipment for separating gypsum board into gypsum and paper includes:

1) A device that compresses the gypsum board in some manner, such that the paper can be lifted or removed from the gypsum. This device has not been applied on a commercial scale and has only been demonstrated with a small prototype. A serious limitation on the utility of this device is the necessity for feeding gypsum boards or portions thereof one at a time, that is, it would be preferable to provide a recycling machine for gypsum board that can accept a continuous stream

of the material for recycling.

2) Gypsum board has also been reduced using existing construction debris grinders and hammer mills. Tub grinders and similar construction grinders can process large quantities of gypsum board at one time, but the dust generated during grinding is excessive and the open design of the grinders make the collection and control of the dust a problem. Hammer mills and grinders also tend to reduce the paper equally with the gypsum so that the mixed paper and gypsum are difficult to separate. If the paper is substantially reduced, or fiberized, the recycling of the gypsum as a raw material substitute is compromised.

It therefore would be desirable to provide a machine for receiving scrap pieces of gypsum from a truck, conveyor belt, or the like, reducing large pieces of gypsum into smaller pieces, dividing the paper from the gypsum, and separating the mixed paper and gypsum from one another.

Similar concerns exist concerning recycling of asphalt roofing shingles, which typically comprise an asphalt substrate to which is adhered a fine gravel "aggregate", for foot traction and appearance. Large amounts of used shingles are generated in reroofing, of course; other sources of abundant scrap desirably to be recycled include factory scrap and new shingles left over after a roofing job. As above, it would be desirable to reduce large pieces of the shingle material into smaller pieces, divide the aggregate from the substrate, and separate larger and smaller pieces of the shingle substrate from one another and from the aggregate for recycling.

Objects of the Invention

It is therefore an object of the invention to provide a machine that can accept a steady flow of pieces of gypsum board

and efficiently separate the gypsum board into paper and gypsum, so that both components can be effectively reused.

More specifically, it is an object of the invention to provide a machine capable of accepting a large quantity of scrap gypsum board, for example, so that several cubic yards may be dumped in an input hopper by a loader, and efficiently separating the paper and gypsum components thereof for reuse.

It is a further object of the invention to provide equipment for accepting large quantities of asphalt shingles, reducing the shingles, separating the substrate into larger and smaller pieces, and similarly separating the aggregate from the asphalt substrate.

Summary of the Invention

The gypsum board reducer of the invention, broadly speaking, comprises an infeed mechanism for receiving large quantities of scrap gypsum and feeding these into a reduction unit. The reduction unit comprises powered feed rollers, a breaker bar, and a rotating hammer assembly. As the material is fed over the breaker bar, the hammers reduce it in such a way that the paper is left in relatively large scraps, while the gypsum is essentially granular or powdered. The materials can then be separated using a simple size-based technique. The same machine can also be used, with only minor modification, for reducing asphalt shingles, and separating aggregate from the asphalt substrate, permitting recycling of the materials of asphalt shingles. Reference herein to various aspects of the apparatus for recycling gypsum board according to the invention should be understand to include use of the apparatus for recycling asphalt shingles, and other materials, unless specifically stated to the contrary.

Machines according to the invention can be manufactured

in relatively small sizes and be hand-fed in some applications, for example, when small quantities of scrap gypsum on a construction site must be separated. The invention may also be implemented by machines having a large capacity, e.g., for a centralized processor/recycler, who wants to load material with a mechanical loader and wants to process ten to twenty tons/hour of material.

In the smaller embodiments, the gypsum board reducer will be integrated with separation and dust control equipment, and the complete device may be mounted on a trailer for easy movement between job sites. The larger-capacity gypsum board reducers will typically form part of a stand-alone system comprising a hopper to receive large quantities of material to be prepared for recycling, conveyors to move the gypsum board from the hopper into the reducer and to move the reduced gypsum board to separation equipment, and a dust control system providing collection at selected points. In the latter embodiment, the gypsum board reducer has a wide feed belt with receiving hopper for loading scrap gypsum board. A leveling device limits the height of the gypsum on the belt as it is conveyed into the gypsum board reducer, and the spacing of opposed infeed rollers of the gypsum board reducer can be varied corresponding to variable height loads on the infeed belt. Water sprays may be provided in either case to keep the dust down. The same machine can be used for preparing asphalt shingles for recycling.

Other aspects of the invention are discussed more fully below.

Brief Description of the Drawings

The invention will be better understood if reference is made to the accompanying drawings, wherein:

Fig. 1 represents a side view of a relatively high-capacity embodiment of the gypsum board recycling system of the invention;

Fig. 2 represents a perspective view thereof;

Fig. 3 shows a side view of the reduction mechanism;

Fig. 4 shows a side view of a hand-fed embodiment of the invention;

Fig. 5 shows a perspective view of a typical impactor and breaker bar assembly; and

Fig. 6 shows an alternative impactor assembly in detail.

Description of the Preferred Embodiments

Referring now to Figs. 1 and 2 simultaneously, as mentioned these are side and perspective views, respectively, of a system according to the invention in a relatively large embodiment capable of processing 10 - 20 tons/hour of scrap gypsum board. The unit comprises a hopper 2, for receiving large quantities of scrap; an infeed conveyor 1; a reduction unit 40, wherein the gypsum board is reduced to scraps of paper and various small pellets, chunks, grains, or powders of gypsum; a trommel separation unit 42, where the gypsum and paper are separated from one another; a takeaway conveyor system 44 conveying the mixed reduced materials from the reduction unit 40 to the separation unit 42; and bins 46, 48, and 50, typically for collecting finely-divided gypsum, coarse gypsum, and paper. The entire assembly, apart from infeed hopper 2, can be housed in a containment structure 52 provided with a dust collection system 54. In the embodiment shown, the infeed end of the system rests on the ground, with bins 46, 48, and 50 in a pit, and a support wall 56 supporting the exit end of the system, but of course other arrangements are possible.

Referring now to Fig. 3, one end of a slightly inclined

or flat infeed conveyor 1 extends out one end of the containment structure 52, for receiving the scrap gypsum board for recycling. The conveyor width can range from 30" to 120". Hopper 2 is provided over the outside end of conveyor 1 to receive loads of material deposited directly by a loader, or to receive material from a separate conveyor infeed system.

The infeed conveyor 1 comprises a belt 1c and tail and head rolls, 1a and 1b respectively, with adjustable take-ups 3 on at least the tail end for adjustment of belt tension and tracking. The frame of conveyor 1 is attached to the frame of reducer 4 at two points near the head end of the conveyor 1. The tail end of conveyor 4 can be supported by support legs 5 and/or be braced to the containment structure 52, depending on the length of the conveyor.

A rotating brush assembly 6 continually cleans the back of the conveyor belt 1c to keep gypsum from building up on the back of the belt 1c. The brush 6 is mounted between two bearings mounted on the outside of the conveyor frame. A slot in the conveyor frame allows the bearings to be adjusted to keep the brush in contact with the belt 1c as it wears. The brush is driven by a ½ HP motor mounted on the inside of the frame and connected with a drive sprocket and chain assembly.

The head roll 1b of the conveyor is driven with the same motor and gear reducer (not shown) that drives a bottom infeed roll 14; the motor and gear reducer assembly is directly attached to the infeed roll shaft at one end, and a sprocket and chain drive 8 connects the conveyor head pulley 1b and the bottom feed roll 14. Variable speed controls with a reversing option allow the operator to adjust the infeed conveyor speed for different types of gypsum board or other materials and for the size of the load, and to reverse the direction of operation to clear jams if necessary.

As it is desirable to permit loads of gypsum board to be dumped directly into the hopper, so that an irregular pile will be formed, and as the reduction operation is performed more uniformly if a relatively regular mass of scrap material is presented to the reducing mechanism, a leveling device is preferably provided. The leveling device consists of a driven leveling roller 9 supported on each end by bearings and extending across the full width of the infeed conveyor belt 1c. The bearings are an integral part of an adjustable take-up assembly 10 providing several inches of adjustment in the spacing of the leveling roller 9 from the belt 1c. The take-up assembly 10 is attached to support arms 11 extending upward on either side of the infeed conveyor frame and attached to the reducer frame 12. The leveling roller 9 is powered by a motor and gear reducer (not shown) attached directly to the shaft on one end of the roll. As shown by arrows 9', 1c', the direction of rotation of leveling roller 9 is such that its surface facing the belt 1c moves in the direction opposite the surface of the belt, so that scrap that does not fit between the leveling roller and the belt is prevented from entry. Stated differently, the direction of rotation of the leveling roller is such that material piled too high on belt 1c is urged back toward the hopper 2.

The leveling roller 9 has a surface textured for traction, effectively leveling the scrap. The textured surface may include a number of ridges about 1/4" high arranged to form a series of broad chevron or "V-shaped" ridges extending around the surface of the leveling roller, forming an auger pattern. The auger pattern is arranged to move the material from the center toward the edges of the belt for uniform feed into the reducer. Since the scrap material tends to be piled higher in the center of the belt, the driven

leveling roller 9 is effective in leveling the scrap and spreading it across the width of the belt. The distance between the top of the infeed belt and the bottom of the leveling roll, adjusted by the take-up assembly 10, determines the infeed rate of the material; arranging these components such that the clearance between the infeed belt and the leveling roller can be adjusted between about four and about nine inches is appropriate.

If the gypsum board reducer is in a container, as in the large-capacity embodiment of Figs. 1 - 3, the front wall 52a of the container is extended down to be closely spaced from the front surface of the leveling roller 9, as shown in Fig. 3. A wedge-shaped scraper 13 is provided, with a working edge closely juxtaposed to the surface of the leveling roller 9, as shown in Fig. 3, to prevent scrap from being drawn over the upper surface of leveling roller 9. Scraper 13 may be made of a hardened steel to limit wear, and may be made readily replaceable.

Thus, the space between the leveling roller 9 and the belt 1c defines the upper and lower edges of the opening through which the material will go into the gypsum reducer, while the opposed vertical edges thereof are defined by the enclosure 52. Accordingly, all scrap material will go through an infeed opening the area of which is defined by the width of the belt and the distance between the bottom of the leveling roller and the top of the conveyor infeed belt.

After passing under the leveling device, the material is conveyed into the infeed rollers. See Figs. 3 and 5. The bottom infeed roller 14 extends across the full width of the infeed opening, is about 10 inches in diameter, and rotates about an axis defined by fixed bearings attached to the reducer frame 12. As mentioned above, the motor and gear reducer

assembly (not shown) that drives the infeed conveyor 1 also drives the bottom infeed roller 14, with a chain and sprocket assembly 8 at one end. The surface speed of bottom infeed roller 14 is slightly faster than the surface speed of the infeed conveyor 1, so as to pull the scrap material off the infeed conveyor and into the reducer. The speed of this motor and gear reducer assembly is variable, to allow adjustment for different types and thicknesses of material.

The top infeed roller 15 also extends across the full width of the infeed opening, and is also about 10 inches in diameter, but rotates about an axis defined by two bearings mounted on parallel pivoting arms 16. The pivoting arms 16 rotate about a shaft and bearing assembly 17 attached to a support structure 11 extending upward from the reducer frame 12 on either side of the infeed conveyor. Accordingly, the top infeed roller 15 rests on the scrap passing beneath it, so as to provide constant traction between the scrap and the bottom infeed roller 14, so that scrap material is fed into the reducer at relatively constant feed rate and feed pressure, despite considerable variation in the depth of the material load on the infeed belt 1c. Positive stops limiting the upward movement of the arms 16 prevent the top infeed roller 15 from riding up over a pile of material that is deeper than the width of the opening into the reducer. In a successfully tested embodiment, the upper infeed roller is a heavy tubular member, and gravity alone forces it into engagement with the scrap to be reduced.

The top feed roller 15 is directly driven with a motor and gear reducer assembly attached to the pivoting arm 16 on one side, and has a textured surface, formed, e.g., by threading bolts into its surface at spaced intervals, but allowing their heads to protrude by on the order of ½", to aggressively engage

the material, so as to forcefully feed the material into the reducer. The bottom feed roller 14 has a smooth surface to allow for the closest interface possible between the roller and the top of the infeed conveyor belt where they meet. A flat "wiper" plate 30 may be disposed between the head end of conveyor belt 1c and the bottom infeed roller 14. The infeed rollers 14 and 15 compress the scrap gypsum board and are driven so as to feed the scrap into the reducer 40 at an even rate.

The gypsum scraps are reduced in a steel reducer barrel 18, typically 16, 24, or 30" in diameter, a few inches longer than the infeed belt is wide, and having a long infeed opening that extends almost the full length of the barrel along one side, and is 3 - 12" high. An L-shaped breaker bar 19 extends the length of the infeed opening; one leg of the L extends downwardly inside the infeed opening, while the other leg of the L extends toward and nearly touches the lower infeed roller 14, so that the material passes over and is supported by the breaker bar 19 as it enters into the reducer barrel 18. Mounted within the barrel is a hammer shaft 20 to which are mounted a number of replaceable hammer/link impactors 60, each comprising a base member 61, a link 62, and a hammer 63. Fig. 6 shows an alternative construction of impactors 60.

The hammer shaft 20 is driven in the direction indicated, and is located so that the hammers 63 swing just clear of the breaker bar, missing it by a clearance C. The hammers 63 accordingly impact and break off whatever portion of the gypsum board B overhangs the breaker bar, as shown. The gypsum is divided from the paper in this process, because the gypsum tends to fracture and break into particulates of various size upon impact, while the paper tends to be folded and torn into scraps. The feed rate of the scrap gypsum board and the rate

of rotation of the hammers are such that the board advances on the order of 1/4 - 1 inch per revolution; since there is only one hammer at one position along the shaft (preferred in order that bolts can extend through the shaft to allow replacement of the impactors 60; see Fig. 6) any portion of the board B protruding over the edge of the breaker bar will be impacted again by the same hammer a revolution later.

Observation suggests that the uppermost layer of paper in Fig. 4, which is first impacted, tears more or less above the edge of the breaker bar 19 upon impact of the hammer, so that it and much of the gypsum are immediately torn off. Little gypsum remains adhered to the upper shred of paper. Any gypsum that remains adhered to the lower shred of paper, then lying against and over the breaker bar, being relatively brittle, is normally stripped from the paper from in one or two revolutions, while it may be another revolution or two before the remaining shred of paper is torn off. However, the invention is not to be bound by this theory of operation, nor any other.

Accordingly, in the reducer 40 the larger pieces of the gypsum board are reduced to smaller pieces, and the gypsum and paper are substantially divided from one another; however, the paper and gypsum are still mixed, and must be separated in a subsequent operation.

The reducer barrel 18 is lined with a replaceable tubular liner of wear-resistant steel held in place with spring-back pressure. Two removable round end plates, one at each end of the barrel 18, provide access to the barrel liner and hammer/link impactors 60 mounted on the shaft; the end plates are also lined with replaceable liners of wear-resistant steel. The hammer/link impactors 60 can also be accessed and replaced by reaching through the rectangular infeed opening.

The impactors 60, comprising flexible hammer/link assemblies as noted above, are attached to a central rotating shaft 20. Shaft 20 preferably rotates in two heavy duty spherical bushings, mounted outside reducer barrel 18 on offsets and protected by "slinger" seals to protect against fines. Further seals are provided where the shaft 20 passes through reducer barrel 18. The impactor shaft 20 is driven by a motor 21, with a sheave and belt drive between the motor and impactor shaft. The motor is mounted on top of the reducer frame with an adjustable motor mount 22, so that the drive belt can be tightened as required.

As mentioned, as the scrap gypsum board B passes over the stationary breaker bar 19 into the path of the rotating impactors 60, the impactors 60 hit the board protruding over the breaker bar, strip the gypsum from the paper, and break down the material. In one embodiment, the hammer/link impactors are attached to the shaft in opposing auger patterns. One half of the impactor shaft has the impactors arranged in a spiral pattern that tends to bring the material from one end of the shaft towards the middle of the shaft, while the other half of the shaft has the impactors arranged in a similar auger pattern, but reversed, so that these impactors tend to bring material from the opposite end of the shaft to the middle of the shaft. The opposing auger action of the impactors thus brings the material from the ends of the barrel towards the center of the barrel, for exit out a central discharge opening in the bottom of the barrel. It is also within the scope of the invention to arrange the impactors in a single-direction auger pattern, and arrange for discharge at one end of the barrel.

A vacuum-driven dust collection system is provided, as indicated at 54; enclosure of the impactor assembly in barrel

18 further assists in reducing the spread of dust. Water sprays (not shown) may also be incorporated for the same reason.

Where the infeed conveyor transfers material to the bottom feed roller, a small amount of material tends to adhere to the top of the conveyor belt and drop down between the end of the conveyor 1 and the bottom feed roller 14; some material also falls between the bottom feed roller 14 and the breaker bar 19. A collection hopper 23 is attached to the bottom of the reducer to catch the material that thus falls down on either side of the bottom infeed roller. An auger conveyor 24 at the bottom of the hopper 23 comprises opposing augers, arranged similarly to the impactors, so as to feed the fine material toward the center and out the bottom of the collection hopper. The take-away conveyor 44 (or the container for reduced material in the smaller-capacity embodiment of Fig. 4) therefore extends under the reducer far enough to receive material discharged from both the collection hopper 23 and the reducer barrel 18.

The reduced material, essentially a mixture of particulates of gypsum and scraps of paper, is then conveyed by takeaway conveyor 44 to the separator unit 42. As shown in Fig. 1, this essentially comprises a conventional trommel separator, that is, a barrel 69 driven by a motor 73 to rotate about an axis slightly below horizontal (from its input end, on the left in Fig. 1), so that the material tends to move from left to right in the trommel. Sets of holes 70, 71 are formed extending around the cylindrical surface of the trommel barrel; the holes 70 toward the inlet are smaller than those disposed toward the outlet end, so that the smaller particulates, i.e., fine gypsum particulates, fall out first, into a first bin 46. A second section of mid-sized holes 71 may follow, so that larger gypsum particulates fall out next, into a second gypsum

bin 48, followed by an open or slotted section 72, whereby the paper scraps fall into a bin 50 for paper. A spiral baffle 74 may be provided within the trommel barrel, providing adequate residence time of the mixed reduced components, and providing reliable separation.

More particularly, good results have been obtained if the smaller holes 70 are ½" in diameter, the second group of holes 71 are 5/8" in diameter, and a series of relatively large slots are formed on the rightmost end of the trommel. In general it is found that 95 - 99% of the gypsum collected in practice of the invention is in the form of particulates less than 5/8" in size, and most of the paper is larger than 5/8" in size. Typically the gypsum thus collected contains about 1% paper and the paper about the same amount of gypsum. It has also been found useful to incorporate a magnetic head pulley 44a on the takeaway conveyor 44, to remove any ferrous nails and the like; a bin 76 is disposed under the head end of the conveyor, so that when the belt is pulled off the surface of the magnetic head pulley, the ferrous items fall into bin 76.

Fig. 4 shows a smaller, hand-fed embodiment of the device, which can also be used to prepare asphalt shingles for recycling by reducing the shingles, separating the asphalt and aggregate components thereof, and separating larger and smaller pieces of the asphalt.

The Fig. 4 embodiment again includes a driven infeed conveyor 80, driven upper and lower infeed rolls 81 and 82, and a reducer 83, comprising a barrel 84, a rotating impactor shaft 85 carrying a number of hammer/link impactor assemblies 86, and a breaker bar 87. These components may be somewhat more than four feet wide, so as to accept standard widths of gypsum board without pretreatment. The mechanism of reduction of the scrap and the separation of the gypsum and paper is essentially as

above. The reduced materials fall through a discharge opening in the bottom of the barrel 84, down a chute 90, and onto a reciprocating-screen separator 92 of generally conventional design. This unit comprises at least one screen 94 that is driven to oscillate, and which is perforated by holes sized to pass the smaller gypsum particulates and retain the paper scraps; accordingly, the gypsum particulates fall through screen 94, and are collected in a first bin 96, while the paper scraps are conveyed by the oscillation of screen 94 to its edge and eventually fall into a second bin 95. A collection hopper 91 catches any materials that do not enter barrel 84. The reducer is enclosed as shown at 98, to reduce the spread of dust; a vacuum dust collection system is provided as indicated at 99 to remove dust as it is created. Water sprays as indicated at 97 may also be provided, for the same reason.

The same machine can be used to prepare asphalt shingles for recycling, that is, to reduce the asphalt substrate into small pieces, divide the substrate from the aggregate, and separate the aggregate from the asphalt pieces. It may be desirable to remove the barrel surrounding the impactor assembly in thus processing asphalt shingles. Dust presents less difficulty when processing asphalt shingles, and removing the barrel limits heat within the machine; when the asphalt gets too hot, the pieces tend to stick to one another, interfering with their separation.

Fig. 6, comprising Figs. 6(a) and (b), shows an alternative construction of the impactors 60, wherein the link 62 comprises a pair of spaced members fixed to one another so as to define a rigid member having two pivot points, thus being correctly termed a "link". Fig. 6 (a) shows the assembly of the impactors 60 to the shaft 20, in a view parallel to the axis of shaft 20, while Fig. 6(b) shows a view transverse to

the same axis. Each impactor 60 includes an end member 132, a unitary rigid link 100, and a hammer 130. Members 120 and 122 are rigidly joined to one another by screws 124, threaded into solid bushing members 126, 128 so as to form a unitary rigid link 100. Hammer 130 fits around the distal bushing 128. The size of the aperture in hammer 130 receiving bushing 128 is sufficiently loose that the hammer pivots freely about the bushing and can move angularly slightly. The width of hammer 130 is also slightly less than the length of bushing 128 so as to allow the hammer freedom to move between members 122 and 120. The end member 132 fits similarly over bushing 126 and between members 122 and 120, for similar reasons. The end member, link, and hammer are all fabricated of hardened steel, for durability in service.

As shown in Fig. 6(b), end member 132 is formed to define an arcuate surface 132a for mating with the outer cylindrical surface of the drive shaft 20. Preferably, the end member 132 is affixed to the shaft 20 by bolt 134 extending radially through the center of shaft 20 and into threaded hole 132b formed in the end member 132. The shaft 20 is spot-faced or counterbored as indicated at 20a to conveniently receive the head of bolt 134. The particular advantage of this attachment structure is that a person desiring to replace a worn or damaged impactor assembly 60 simply unscrews bolt 134, discards the worn or damaged impactor 60, and immediately threads a new impactor assembly 60 into place. The assembly is complete when bolt 134 is tightened. This replacement process can be carried out very rapidly and requires a minimum amount of tools or skill. Given that impactors 60 are relatively high wear items, their ready replacement is a great convenience to their users.

It is necessary to secure screws 124 in place so that they do not back out of bushings 126, 128 and allow the link and

hammer to become disassembled. One simple means for doing so would be to tack- or spot-weld the screws to members 120, 122. However, as mentioned, the hammers, the link members, the bushings, and the end members are all preferably fabricated of hardened steel materials for durability in the very difficult service of pulverizing gypsum board and other materials. It is well understood in the art that it is undesirable to weld such hard materials as this destroys or damages their surface hardness. Therefore, small bores 136 are provided adjacent the countersunk bores in members 120, 122 for receiving the heads of flat-head screws 124, so as to be disposed just under the sharply beveled peripheral edges of the heads of screws 124, as shown. These bores 136 are provided so that a mechanic using a punch can deform the edge of the heads of screws 24 downwardly into bores 136, preventing screws 124 from unscrewing due to vibration experienced in service. This expedient provides a simple and reliable means of preventing screws 124 from becoming unscrewed that does not require tack-welding the screws to the members 120, 122.

The choice between the Fig. 6 embodiment of the impactors and that shown in Fig. 5, where the hammer and end members are bifurcated to receive a link that is a single steel member, is to be made by evaluating the usual engineering concerns. In processing of gypsum board, shreds of paper can be trapped between the hammer and the members of the link of the Fig. 6 embodiment, preventing their free swinging. The Fig. 5 embodiment appears to be somewhat more efficient in reduction of gypsum board, as this jamming does not occur often. However, the Fig. 5 embodiment requires machining of the bifurcated parts, and a suitably tough, impact-resistant steel must be used for the hammers, as they tend to swing back and impact the links; this does not occur in the Fig. 6 embodiment,

as the hammers can swing freely between the spaced members of the links.

The embodiments disclosed herein have been discussed for the purpose of familiarizing the reader with the novel aspects of the invention. Although preferred embodiments of the invention have been shown and described, many changes, modifications and substitutions may be made by one having ordinary skill in the art without necessarily departing from the spirit and scope of the invention as described in the following claims.

We Claim:

1. A machine for preparing planar composite materials such as gypsum board for recycling by reducing the materials and separating the materials into their constituents, comprising:

a powered infeed conveyor, for feeding materials to be prepared for recycling to a reduction device,

a reduction device, for reducing relatively large planar pieces of material to be prepared for recycling into smaller pieces, and for substantially dividing said smaller pieces into their constituents, such that a first of the constituents is provided as relatively larger pieces than the other(s) of said constituents; and

a separation unit for separating said relatively larger and relatively smaller constituents from one another;

wherein said reduction device comprises:

a drum-shaped hollow barrel having an inlet aperture disposed adjacent to said infeed conveyor, and an outlet aperture disposed in its bottom surface;

an impactor assembly operatively mounted within said first barrel, said impactor assembly comprising a central rotatable cylindrical shaft supported by bearings at first and second ends of said shaft, said bearings being fixed with respect to said barrel, and further comprising a plurality of impactors secured to an exterior surface of said cylindrical shaft;

a motor connected to said first impactor assembly such that said impactor rotates within said barrel; and

a breaker bar arranged with respect to said inlet aperture and said impactor assembly such that said materials to be prepared for recycling are fed by said conveyor over said

breaker bar, such that portions thereof protruding over said breaker bar are impacted by said impactors, whereby said materials are reduced and the constituents thereof substantially divided.

2. The machine of claim 1, wherein each of said plurality of impactors consists of an end member having a part-cylindrical end surface for mating with said exterior surface of said shaft, a single elongated rigid link pivotally attached at a first end to said end member, and a hammer portion pivotally attached to a second end of said link.

3. The machine of claim 2, wherein each said link comprises a single member or two parallel members joined at opposed ends thereof by first and second means pivotally joining said link to said end member and said hammer, respectively.

4. The machine of claim 3, wherein said link comprises two parallel members, and said first and second means pivotally joining said link to said end member and said hammer each comprise generally tubular bushing members received between said parallel members, said end member and said hammer each having bores formed therethrough for fitting over said bushings and being confined between said parallel members.

5. The machine of claim 4, wherein said bushing members have threaded bores formed in opposed ends thereof for receiving screws securing said parallel members to said bushings.

6. The machine of claim 4, wherein said screws are

flathead screws having heads defining sharply beveled peripheral edges, and wherein said parallel members are provided with bores situated such that said peripheral edges may be readily deformed so as to protrude into said bores, locking said screws in place.

7. The machine of claim 2, wherein said apertures in said end members are threaded for receiving bolts extending through said radial bores in said shaft for securing said impactors to said shaft.

8. The machine of claim 1, wherein said divided materials are conveyed from said reduction device to said separation unit by a powered conveyor.

9. The machine of claim 8, wherein said separation unit comprises a trommel separator.

10. The machine of claim 8, wherein said reduction device, said separation unit, and said powered conveyor extending therebetween are enclosed within a housing.

11. The machine of claim 10, wherein said housing is provided with dust-collection means.

12. The machine of claim 1, further comprising a hopper disposed above a head end of said powered infeed conveyor, for receiving bulk quantities of said material to be prepared for recycling.

13. The machine of claim 1, further comprising a leveling roller disposed over said powered infeed conveyor to level

material to be prepared to be recycled across the inlet of said reduction device.

14. The machine of claim 1, further comprising a pair of opposed infeed rollers, rotating about generally horizontal axes, and disposed between a tail end of said powered infeed conveyor and said reduction device, for urging said material to be prepared to be recycled into said reduction device.

15. The machine of claim 14, wherein at least one of said pair of infeed rollers is provided with protruding members, to increase the force whereby said roller urges said materials to be prepared to be recycled into said reduction device.

16. The machine of claim 14, wherein said at least one of said pair of infeed rollers provided with protruding members is the upper of said pair of infeed rollers.

17. The machine of claim 14, wherein the upper of said pair of infeed rollers is mounted on a pair of pivoted arms, arranged such that said upper roller can move vertically to accommodate different thicknesses of materials passing between said pair of infeed rollers.

18. A replacement impactor for a machine for preparing gypsum board and like planar composite materials for recycling, consisting of:

an end member for being secured to a rotating shaft of a reducing apparatus, said end member having a part-cylindrical end surface for mating with a cylindrical exterior surface of said shaft, said end member having an aperture extending

therethrough for receiving a bolt securing said replacement impactor to the shaft;

a single elongated rigid link, pivotally attached at a first end to said end member; and

a hammer portion, pivotally attached to a second end of said single elongated rigid link.

19. The replacement impactor of claim 18, wherein said link comprises two elongated parallel members joined at opposed ends thereof by first and second means pivotally joining said link to said end member and said hammer, respectively.

20. The replacement impactor of claim 19, wherein said first and second means pivotally joining said link to said end member and said hammer each comprise generally tubular bushing members received between said parallel members, said end member and said hammer each having bores formed therethrough for fitting over said bushings and being confined between said parallel members.

21. The replacement impactor of claim 20, wherein said bushing members have threaded bores extending therethrough for receiving screws securing said parallel members to said bushings.

22. The replacement impactor of claim 21, wherein said screws are flathead screws having heads defining sharply beveled peripheral edges, and wherein said parallel members are provided with bores situated such that said peripheral edges may be readily deformed so as to protrude into said bores, locking said screws in place.

23. The replacement impactor of claim 18, wherein said apertures in said end members are threaded for receiving bolts extending through radial bores in said shaft for securing said flails to said shaft.

24. A conveniently relocatable machine for preparing planar composite materials such as gypsum board for recycling by reducing the materials and separating the materials into their constituents, comprising:

a powered infeed conveyor, for feeding materials to be prepared for recycling to a reduction device,

a reduction device, for reducing relatively large planar pieces of material to be prepared for recycling into smaller pieces, and for substantially dividing said smaller pieces into their constituents, such that a first of the constituents is provided as relatively larger pieces than the other(s) of said constituents; and

a separation unit for separating said relatively larger and relatively smaller constituents from one another;

wherein said reduction device comprises:

a drum-shaped hollow barrel having an inlet aperture disposed adjacent to said infeed conveyor, and an outlet aperture disposed in its bottom surface;

an impactor assembly operatively mounted within said first barrel, said impactor assembly comprising a central rotatable cylindrical shaft supported by bearings at first and second ends of said shaft, said bearings being fixed with respect to said barrel, and further comprising a plurality of impactors secured to an exterior surface of said cylindrical shaft;

a motor connected to said first impactor assembly such that said impactor rotates within said barrel; and

a breaker bar arranged with respect to said inlet aperture

and said impactor assembly such that said materials to be prepared for recycling are fed by said conveyor over said breaker bar and are impacted by said impactors, whereby said materials are reduced and the constituents thereof substantially divided.

25. The machine of claim 24, wherein each of said plurality of impactors consists of an end member having a part-cylindrical end surface for mating with said exterior surface of said shaft, a single elongated rigid link pivotally attached at a first end to said end member, and a hammer portion pivotally attached to a second end of said link.

26. The machine of claim 24, wherein said separation unit for separating said relatively larger and relatively smaller constituents from one another comprises and oscillating-screen separation unit disposed directly beneath the outlet aperture in said barrel of said reduction device.

27. The machine of claim 24, wherein said reduction device and said separation unit are enclosed within a housing.

28. The machine of claim 27, wherein said housing is provided with dust-collection means.

29. The machine of claim 24, wherein said powered infeed conveyor, said reduction device, and said separation unit are mounted on a road trailer for convenient transport.

30. The machine of claim 29, wherein bins for collection of said separated materials are also mounted on said trailer.

31. The machine of claim 24, wherein said barrel is removable for processing of asphalt shingles and like materials.

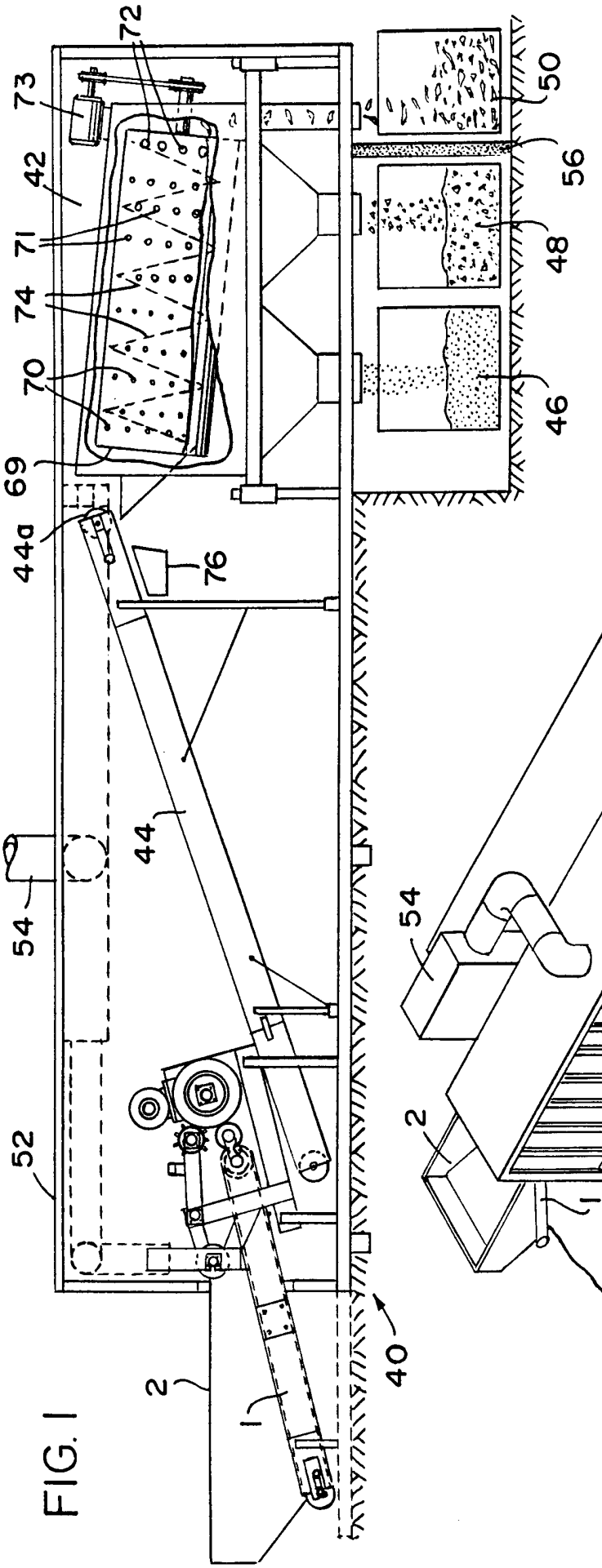
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FIG. 1

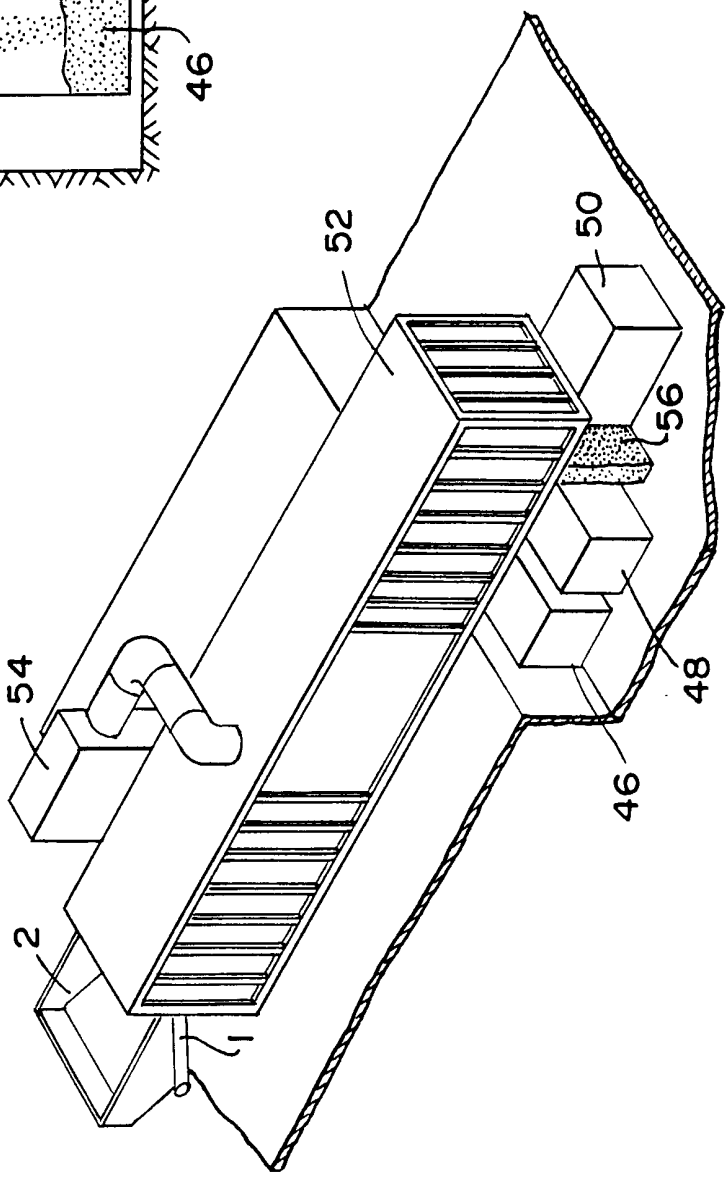
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FIG. 2

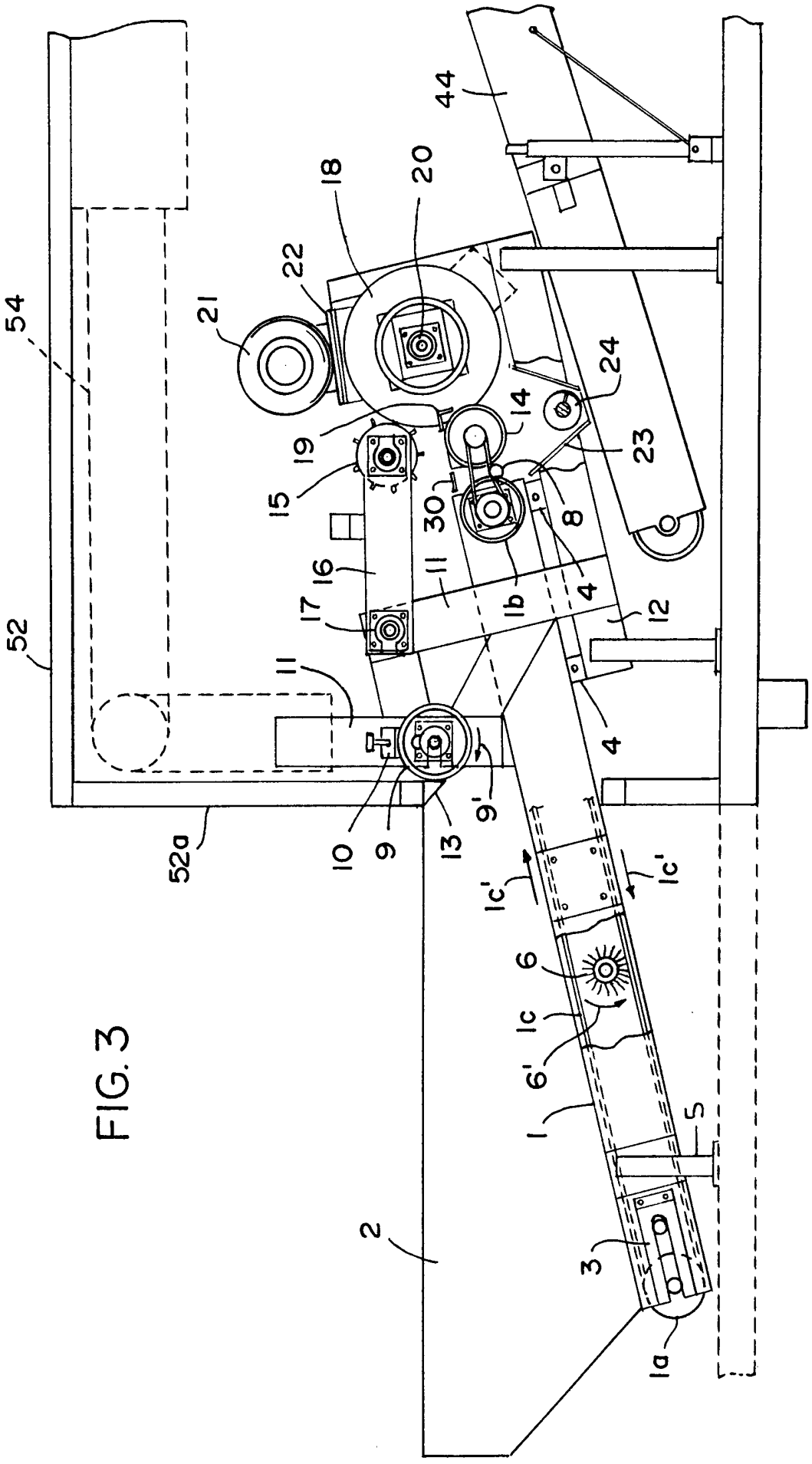
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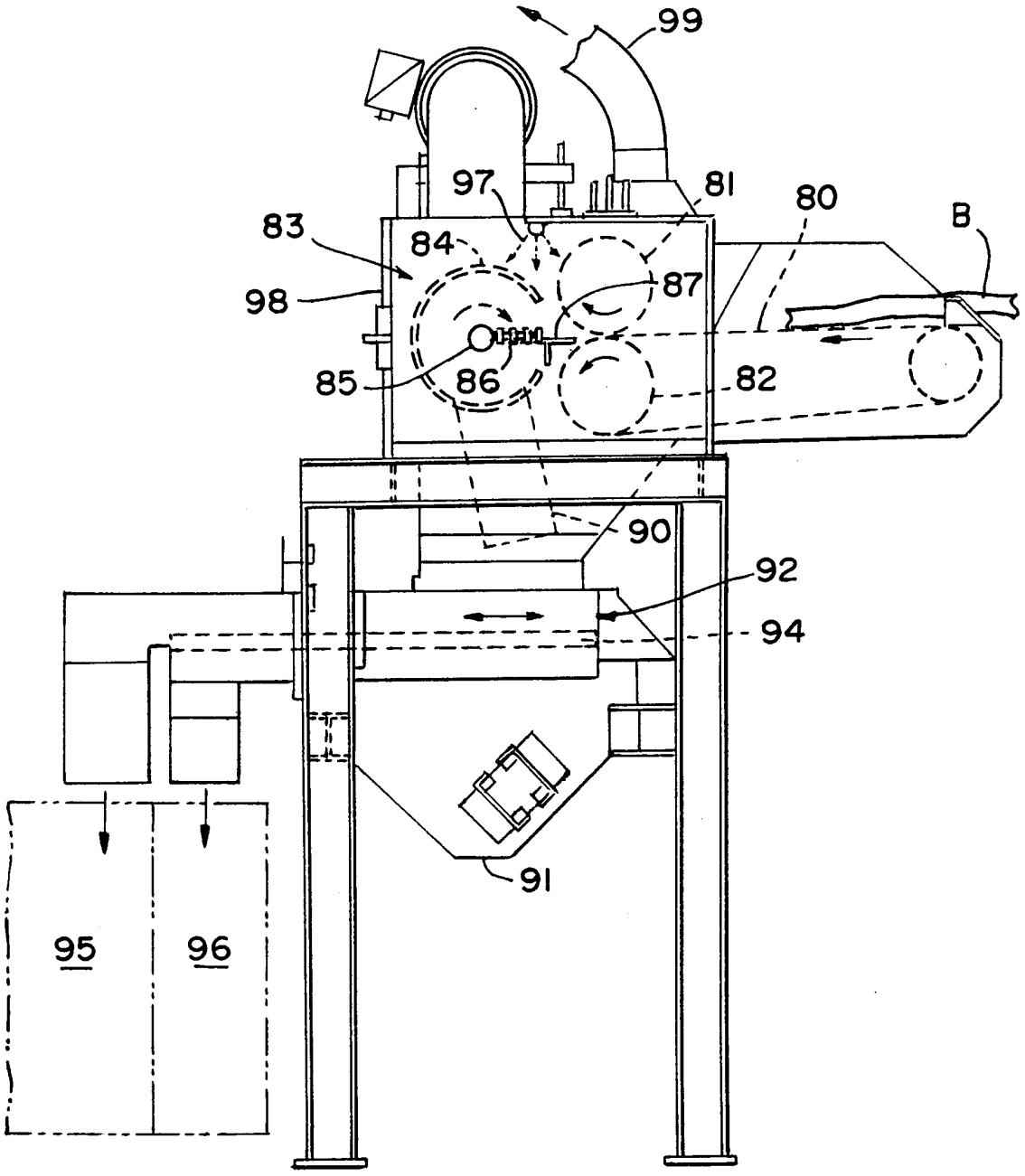
FIG. 3

FIG. 4



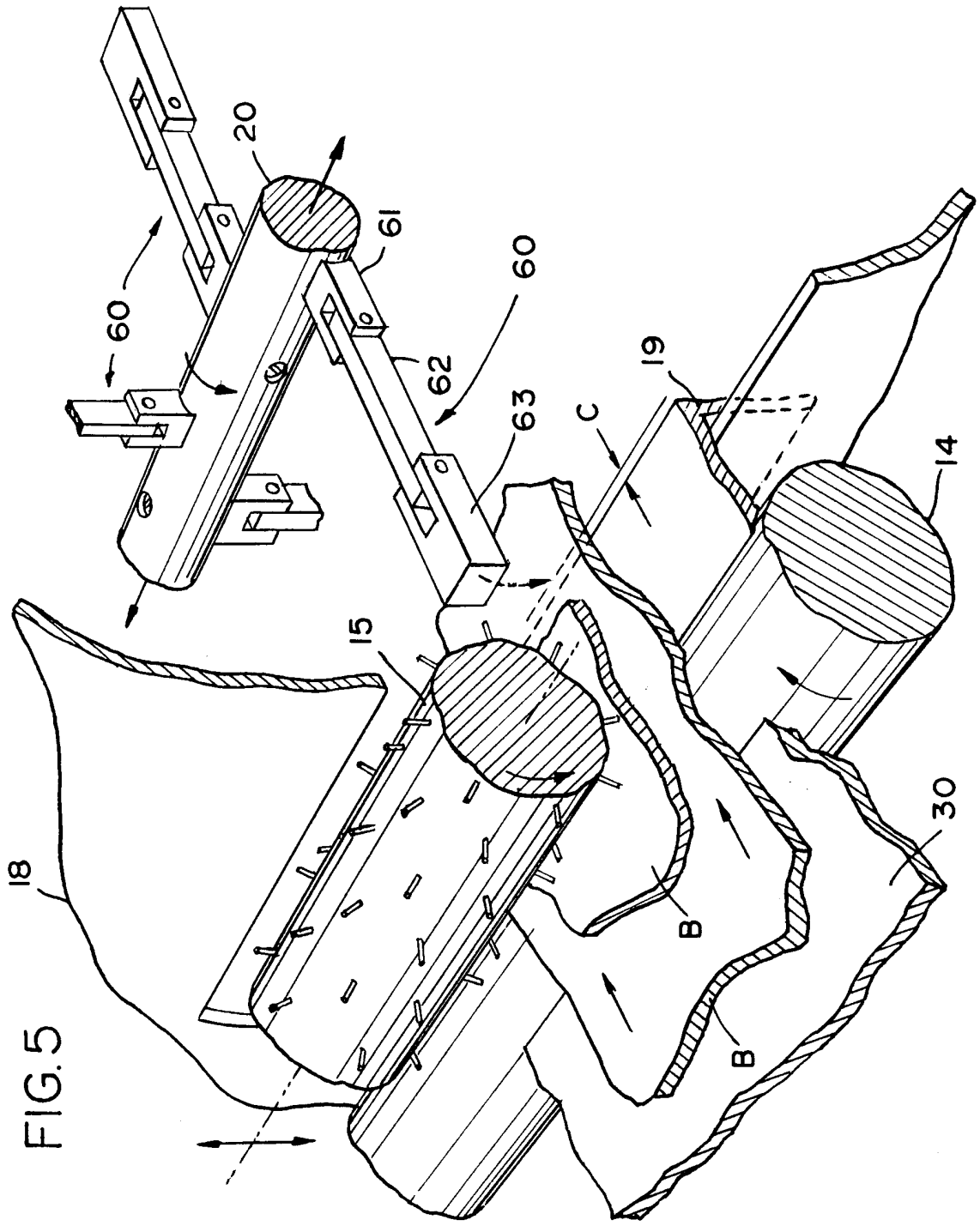


FIG.5

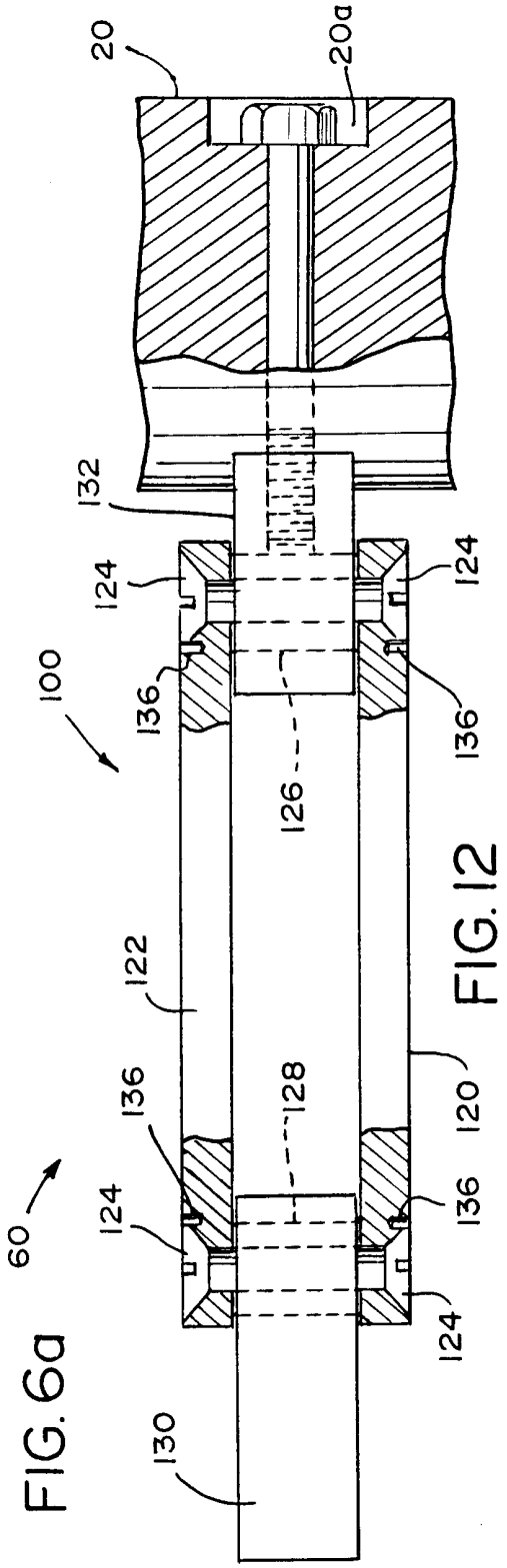


FIG. 6a

FIG. 12

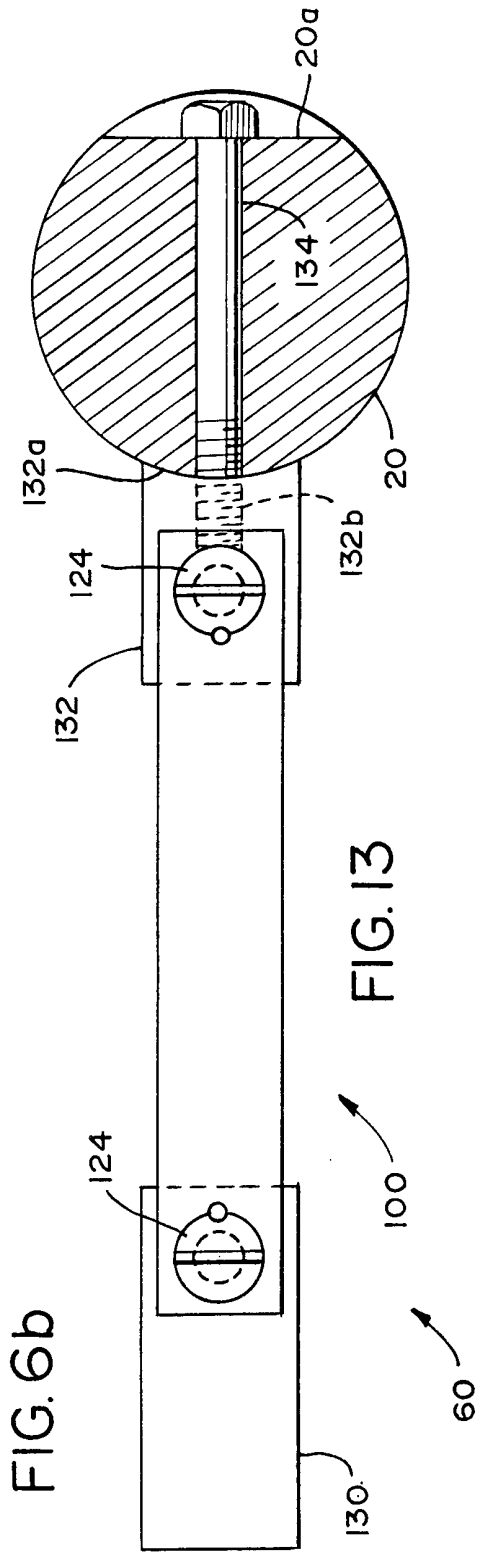


FIG. 6b

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/10457

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :BO2C 13/04
US CL :241/186.35, 194, 280
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 241/79, 186.35, 189.1, 194, 280, DIG. 38

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,193,597 A (STRONG) 16 March 1993, see entire document.	1,7-17,24 & 26-31
Y	US 4,060,961 A (ANDERSON et al) 06 December 1977, see entire document.	2-6 & 25
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X		18-23
A	US 4,801,101 A (DREYER et al) 31 January 1989.	1-31
A	US 5,887,808 A (LUCAS) 30 March 1999.	1-31
A	US 5,183,213 A (KNEZ, JR.) 02 February 1993.	1-31
A	US 5,829,690 A (DESCHAMPS) 03 November 1998.	1-31

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
04 AUGUST 1999	17 AUG 1999

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	JOHN M. HUSAR Sheila Veney Paralegal Specialist Technology Center 3700
Facsimile No. (703) 305-3230	Telephone No. (703) 308-1790

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/10457

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,593,096 A (HARKER et al) 14 January 1997.	1-31
A	US 5,577,672 A (HOLMES) 26 November 1996.	1-31
A	US 3,252,276 A (BREWER) 24 May 1966.	1-31