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Snaper

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(54) **AUTOGENOUS IMPACT MILL THAT REDUCES SIZE OF FRIABLE MATERIAL**

(71) Applicant: **Alvin A. Snaper**, Las Vegas, NV (US)

(72) Inventor: **Alvin A. Snaper**, Las Vegas, NV (US)

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**

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B02C 13/09	(2006.01)
B02C 13/28	(2006.01)
B02C 23/16	(2006.01)
B02C 23/26	(2006.01)
B02C 23/24	(2006.01)
B02C 23/28	(2006.01)

(52) **U.S. Cl.**
CPC ***B02C 13/08*** (2013.01); ***B02C 13/09*** (2013.01); ***B02C 13/2804*** (2013.01); ***B02C 23/16*** (2013.01); ***B02C 23/24*** (2013.01); ***B02C 23/26*** (2013.01); ***B02C 23/28*** (2013.01); *B02C 2023/165* (2013.01)

(58) **Field of Classification Search**
CPC B02C 13/08; B02C 13/09; B02C 13/2804; B02C 13/284; B02C 23/26; B02C 23/28; B02C 13/095
USPC 241/56–57, 66; 209/130
See application file for complete search history.

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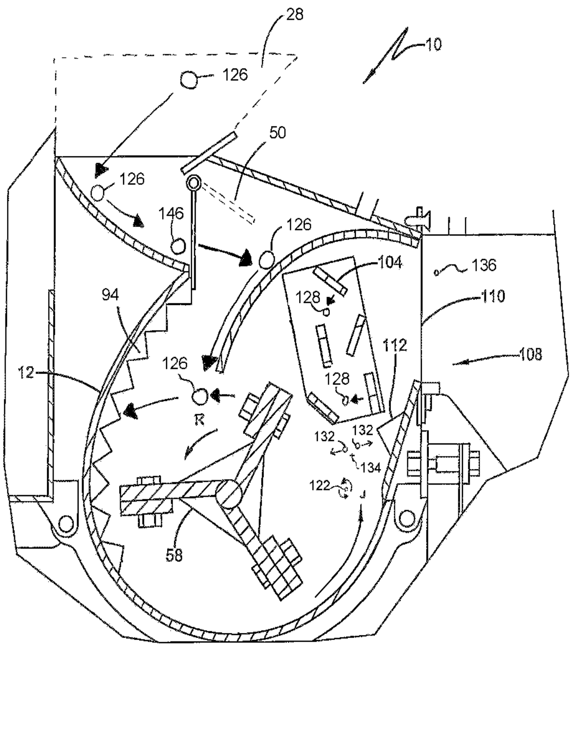
Primary Examiner — Nhat Chieu Q Do
(74) *Attorney, Agent, or Firm* — Ralph E. Jocke; WALKER & JOCKE

(57) **ABSTRACT**

An autogenous impact mill (**10**) is operative to size reduce friable material particles processed through operation of the mill. At least one impeller (**58**) rotatable within an interior area (**44**) of a housing (**12**) of the mill is operative to produce one or more air jets. The air jets are operative to suspend material particles using the Coanda Effect. Other particles moved by the air jets bounce off ricochet bars (**74**) and impact suspended particles so as to break and reduce the particles to a suitable size to pass through a screen (**110**) to an outlet opening (**42**).

22 Claims, 13 Drawing Sheets



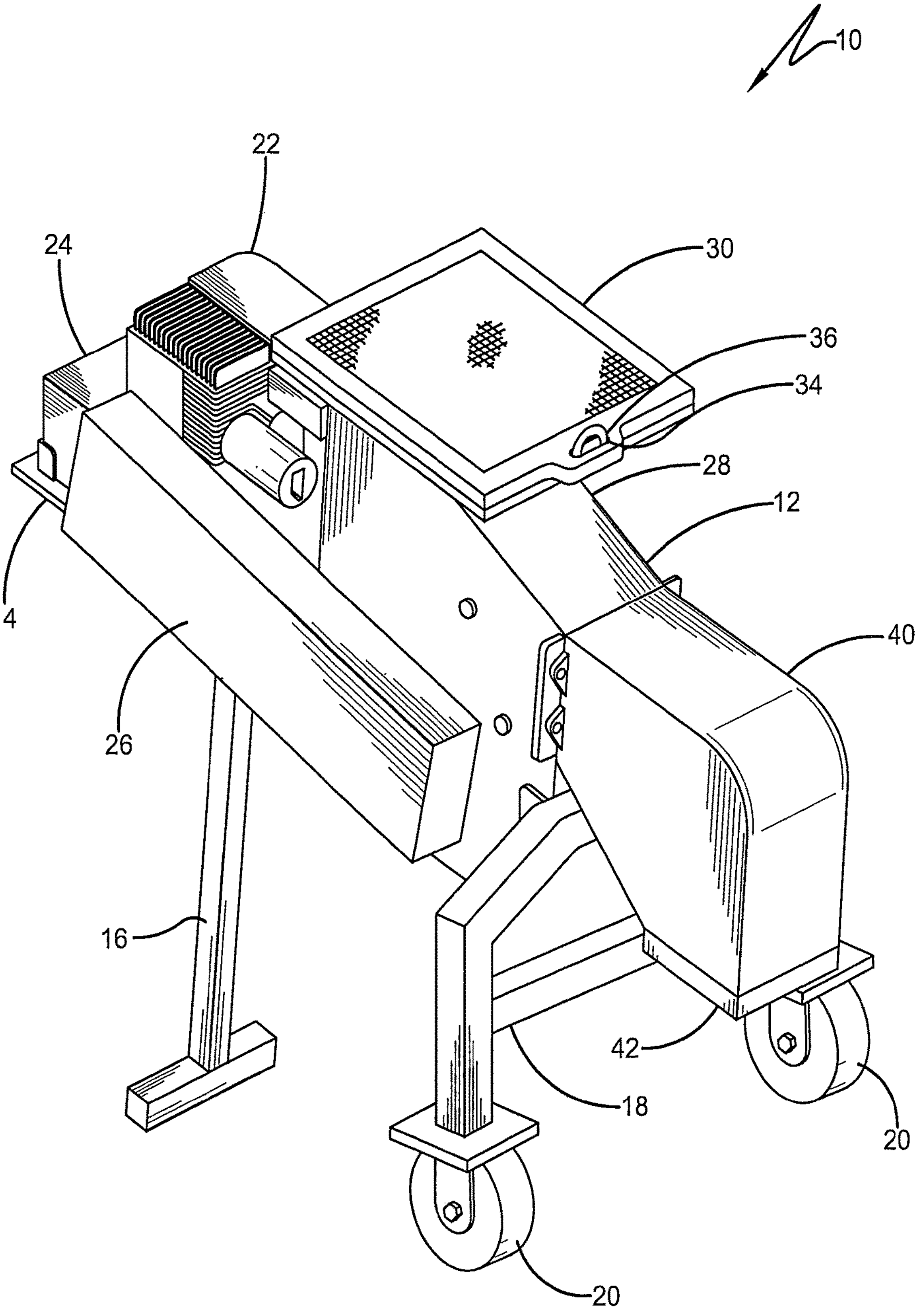


FIG. 1

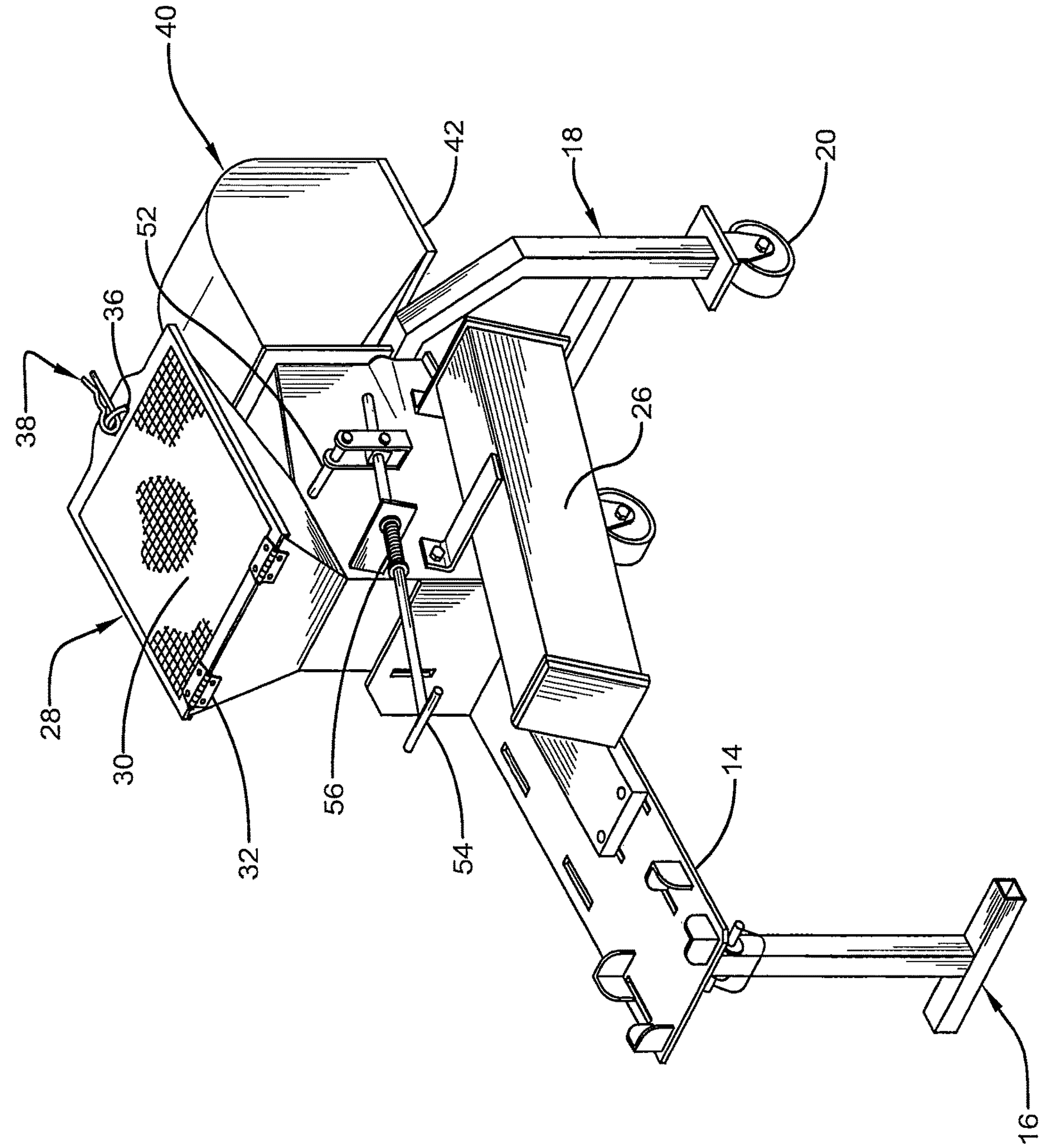


FIG. 2

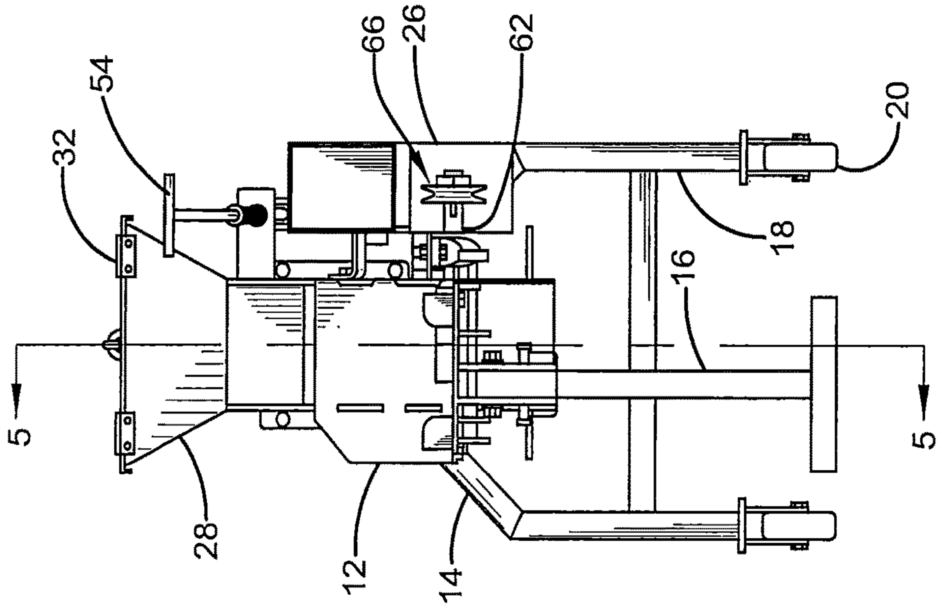

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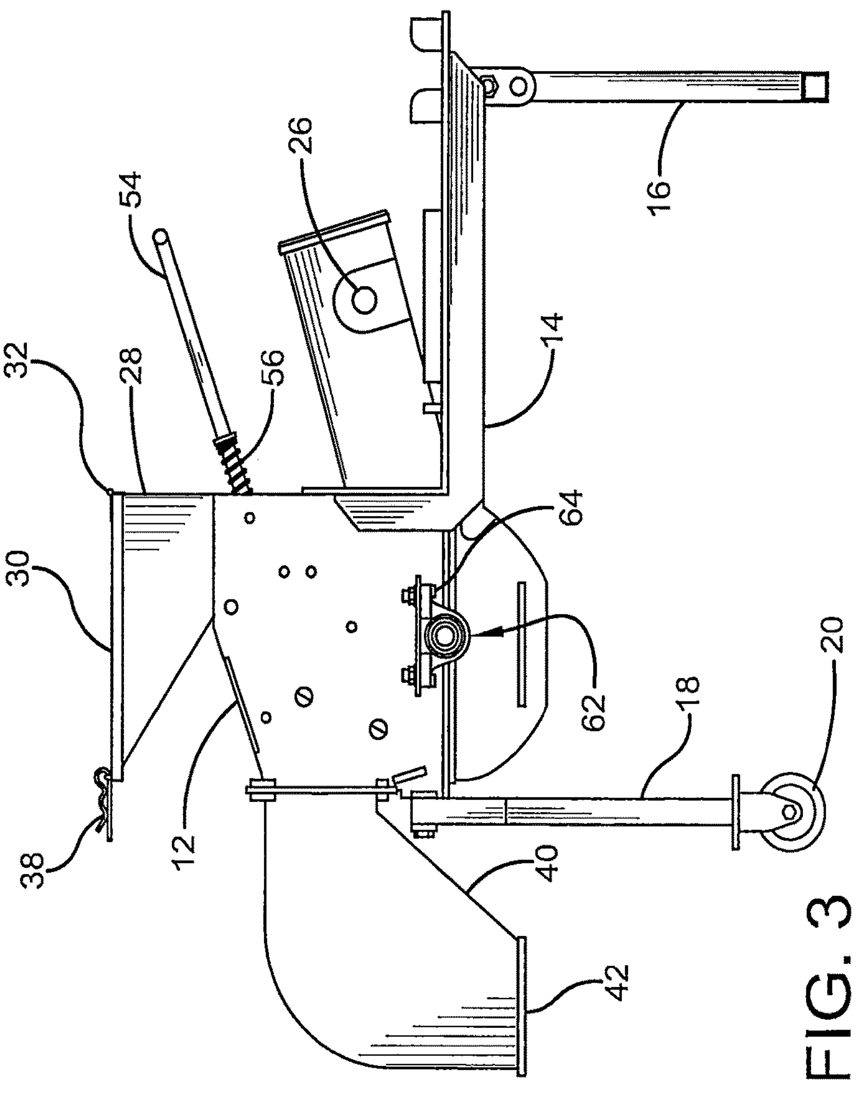
FIG. 4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38
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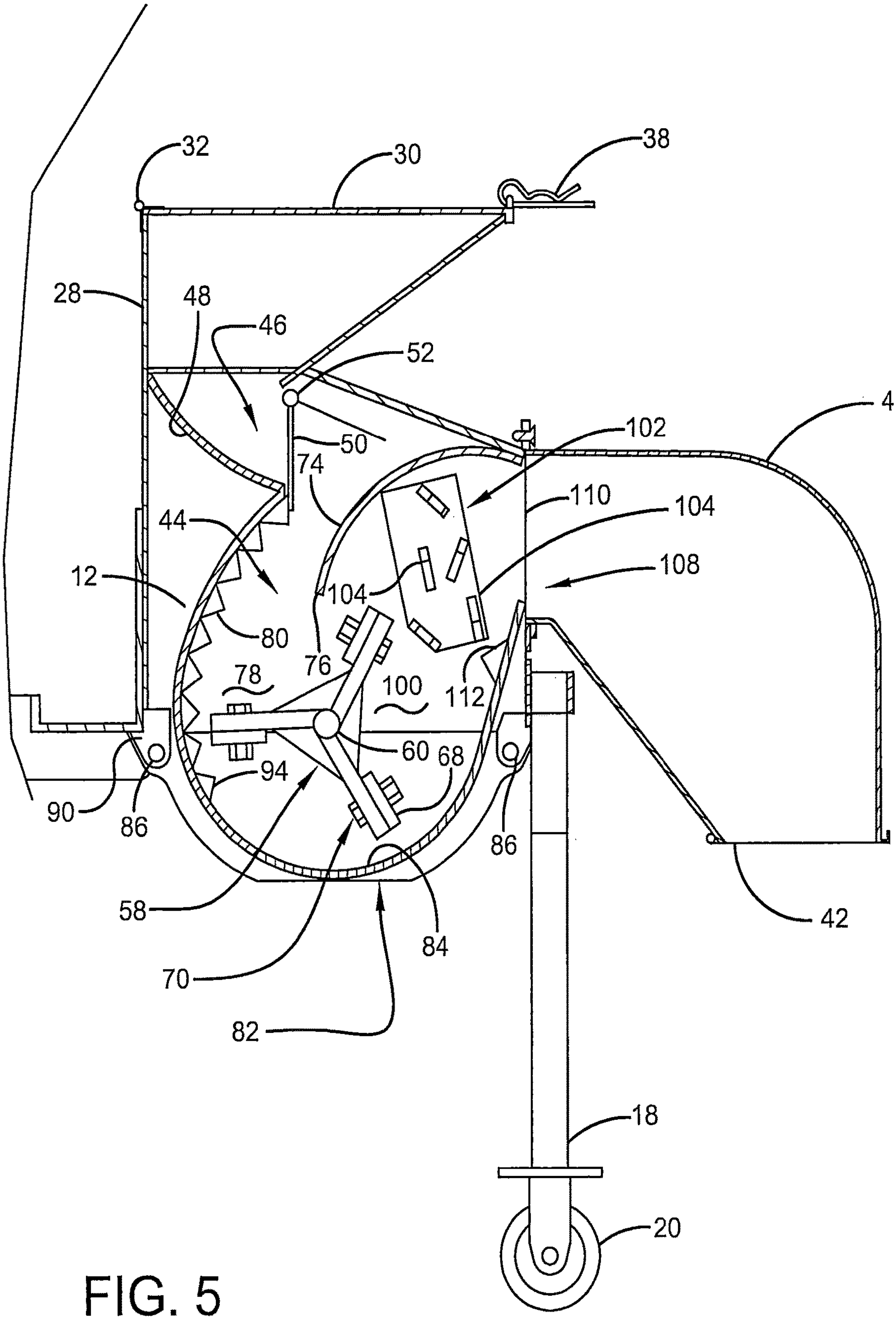
56
62
64

FIG. 3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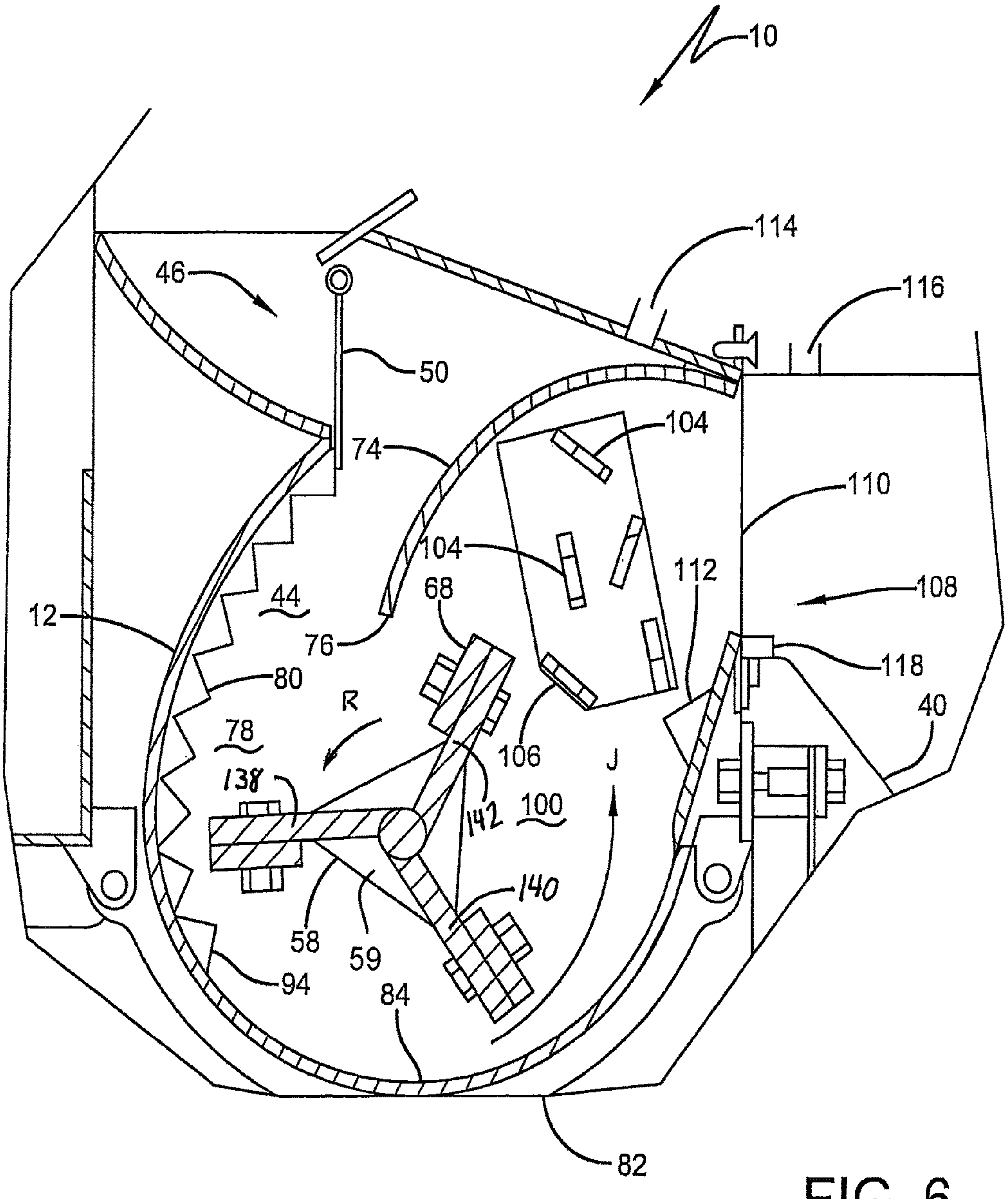
30
38
28
48
46
52
40
102
50
74
110
104
44
108
12
104
80
76
78
100
112
60
68
94
90
86
86
58
84
42
70
82
18
20

FIG. 5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114
116
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50
104
74
110
104
112
108
68
44
12
76
118
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40
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106
78
138
142
100
J
140
58
59
94
84
82

FIG. 6

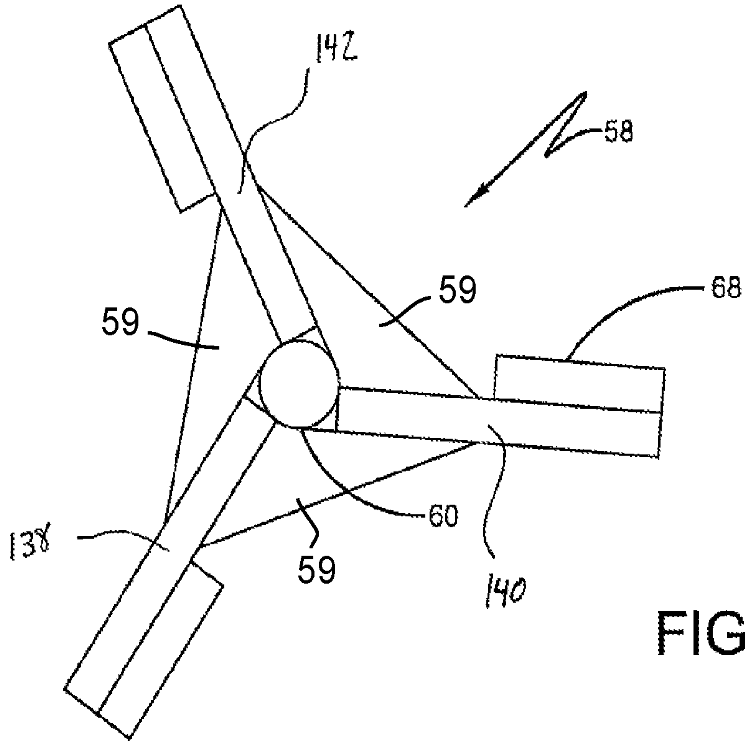


FIG. 7

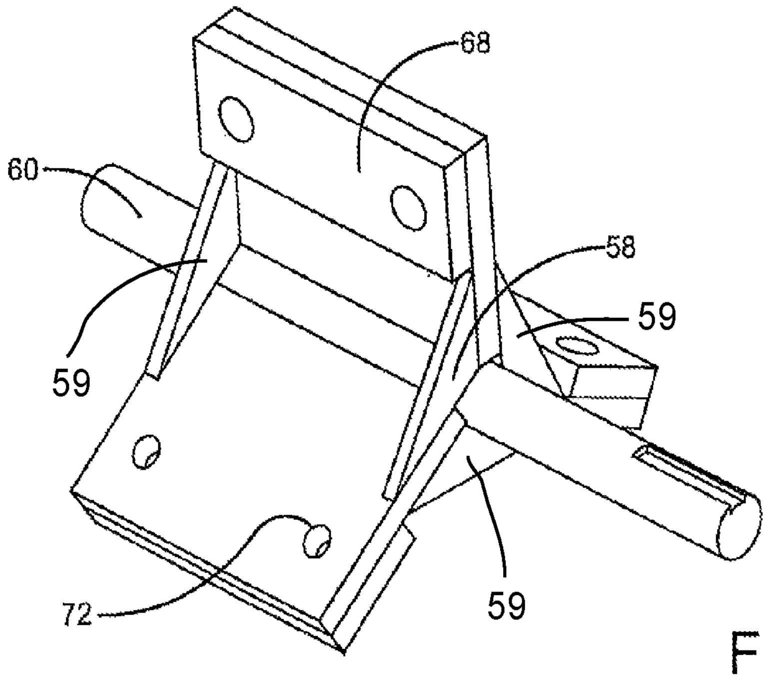
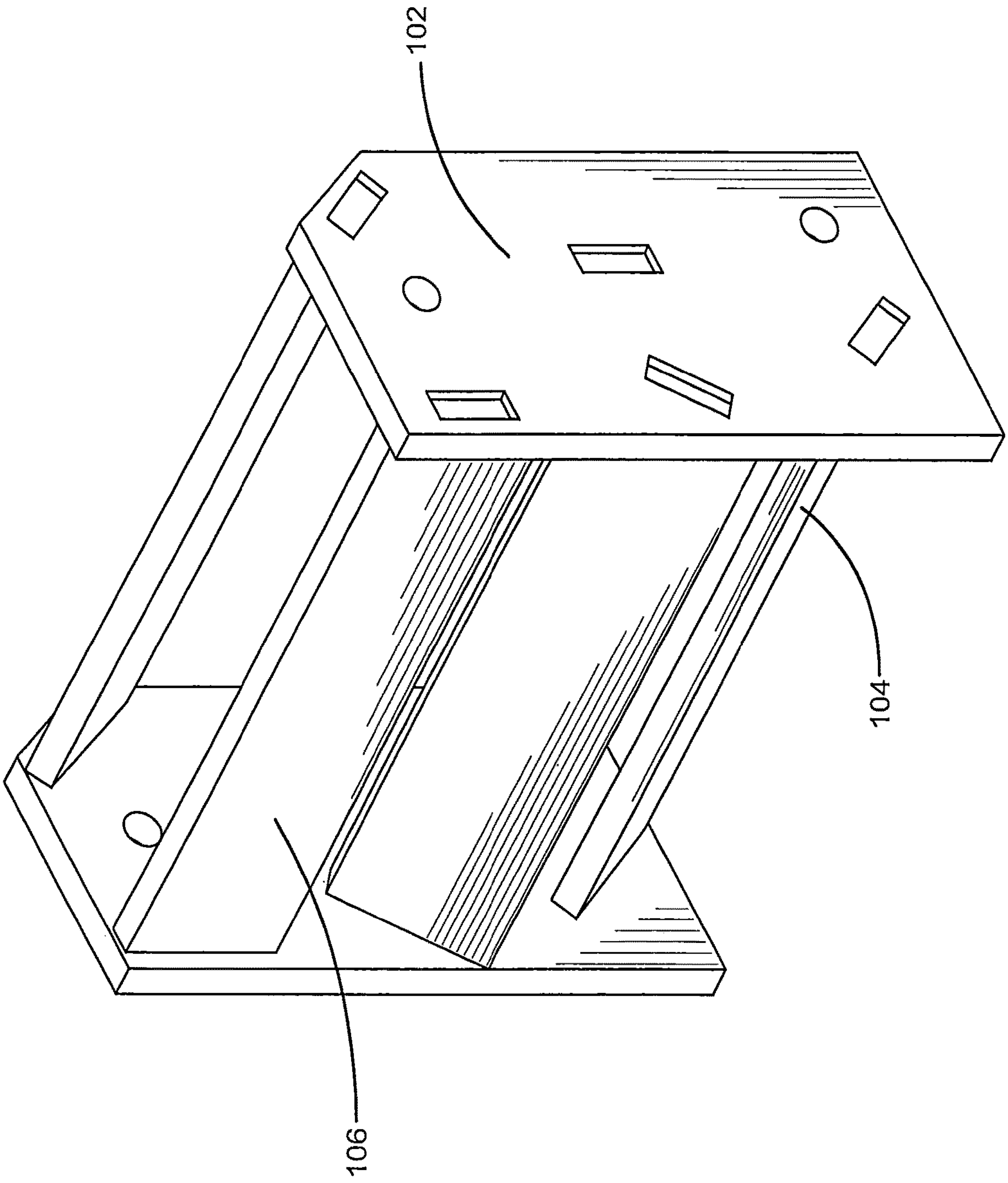


FIG. 8

FIG. 9



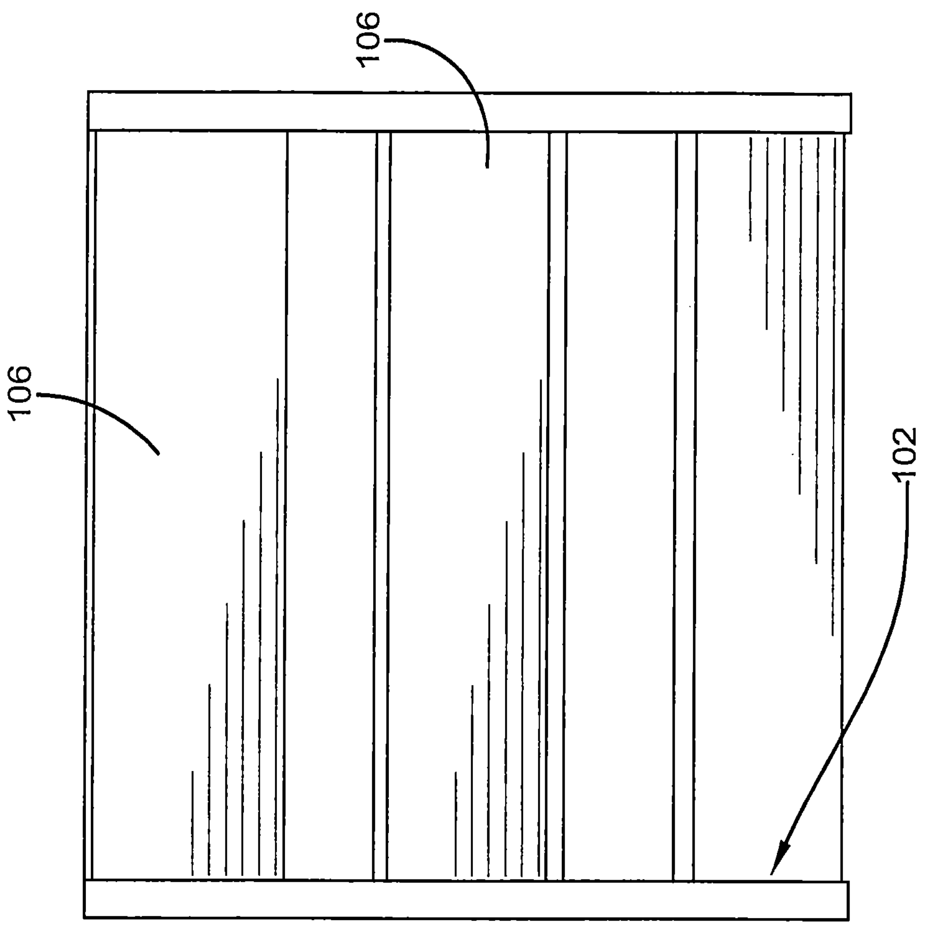


FIG. 11

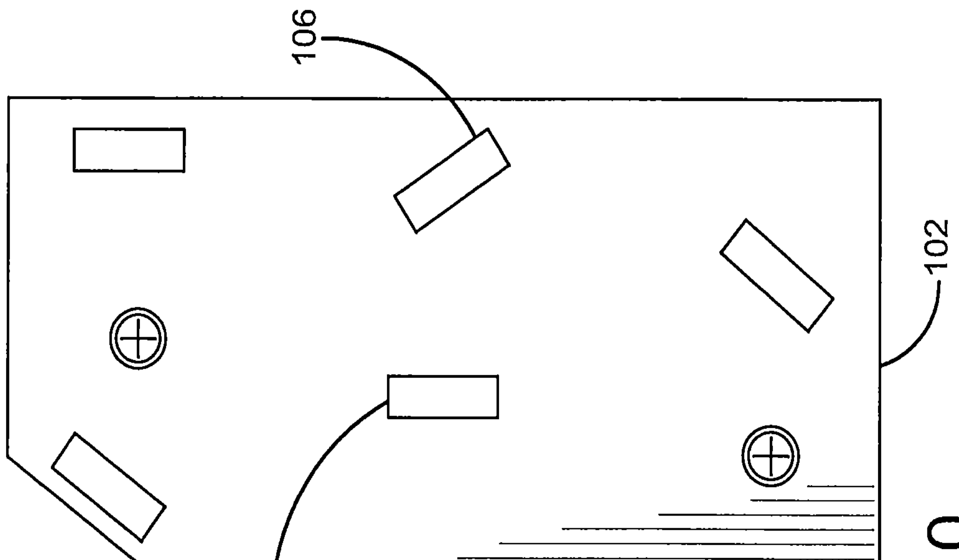


FIG. 10

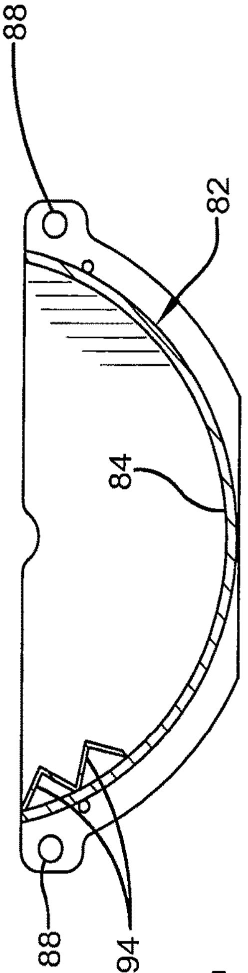


FIG. 13

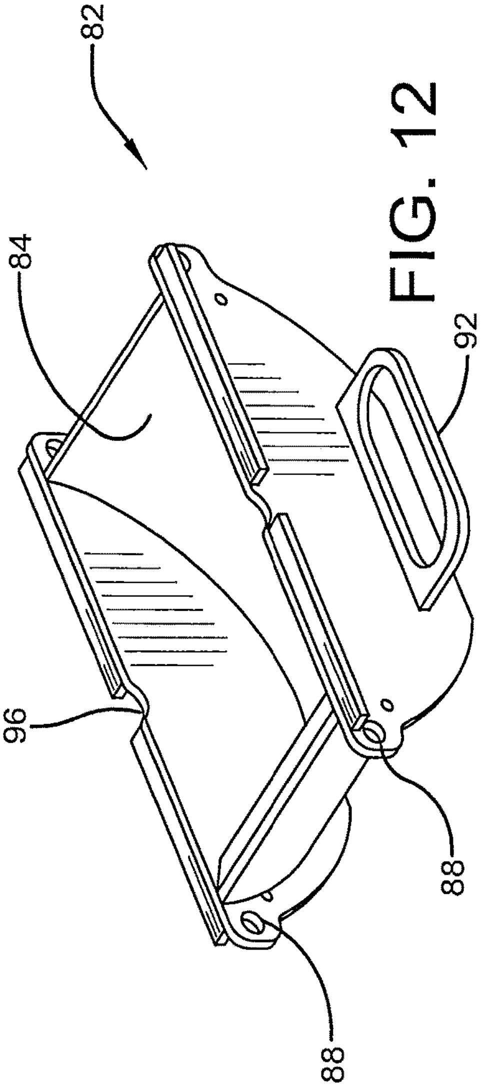


FIG. 12

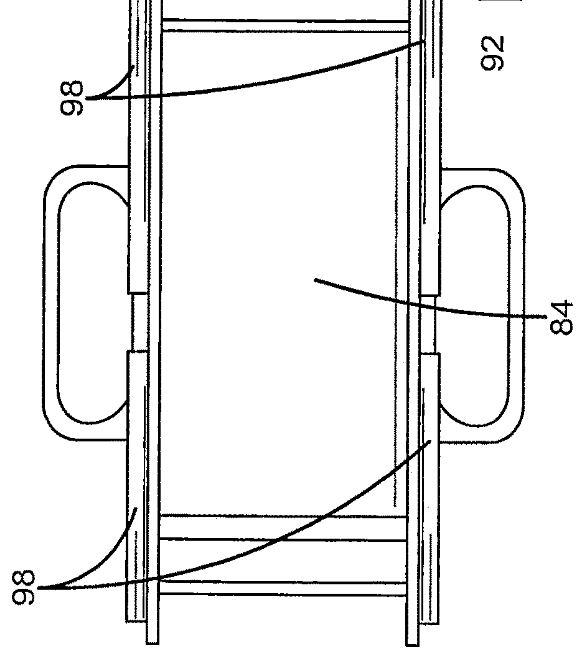
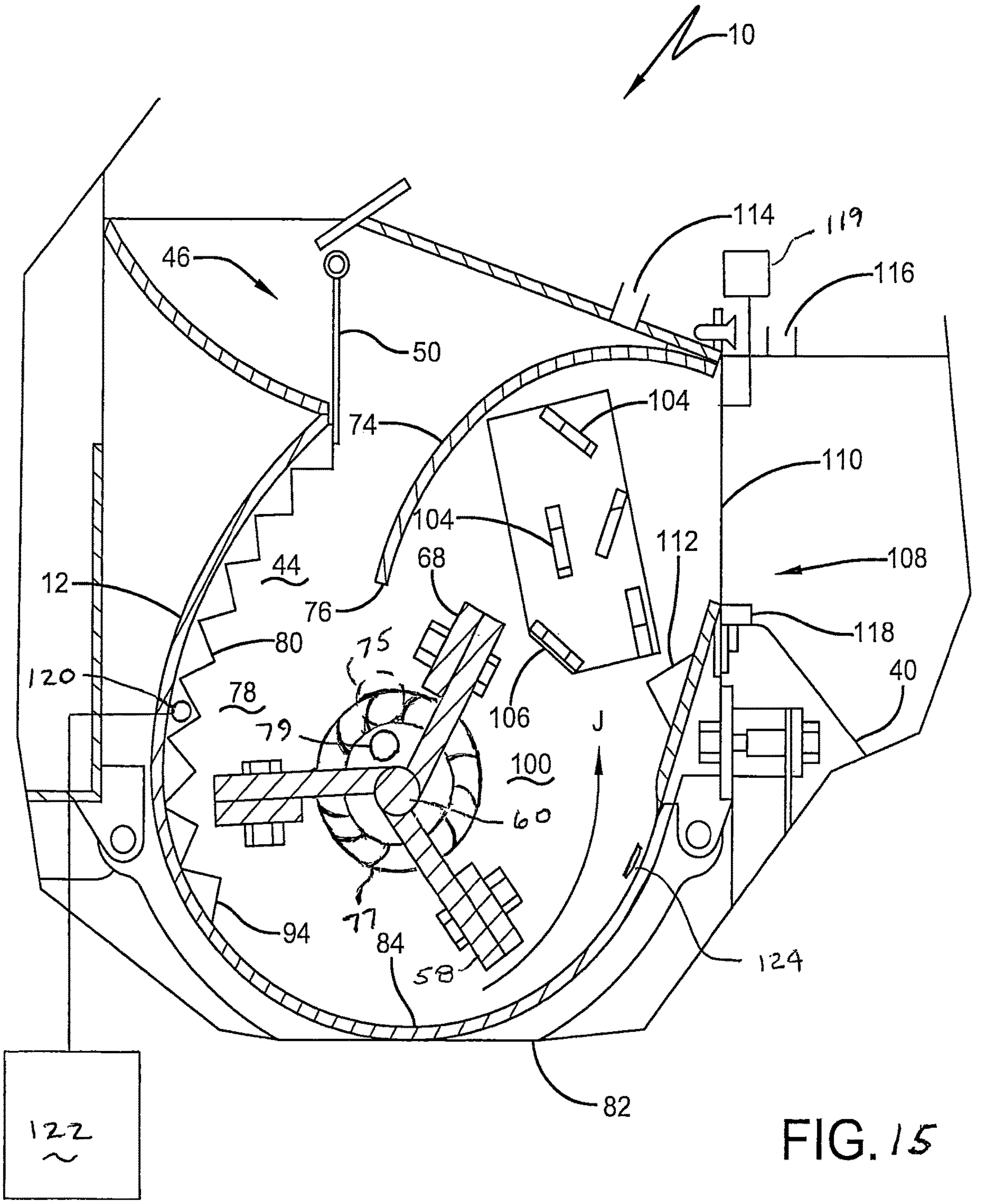


FIG. 14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114
119
116
46
50
104
74
110
104
68
112
108
44
12
76
118
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78
106
79
J
100
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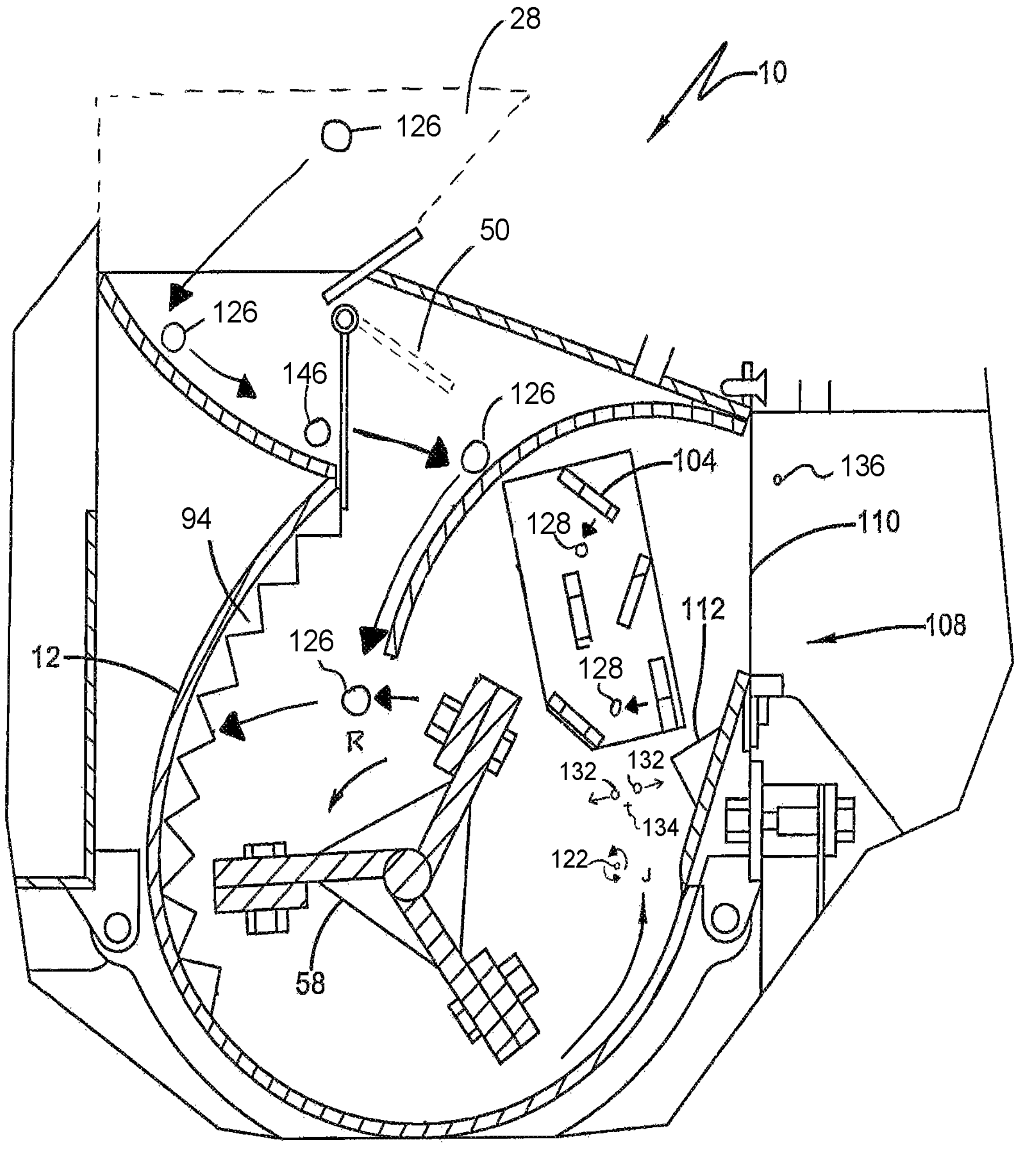
94
77
84
58
124
82
122

FIG. 15


28
10
126
50
126
146
126
104
136
128
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94
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12
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R
132
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134
122
58

FIG. 16

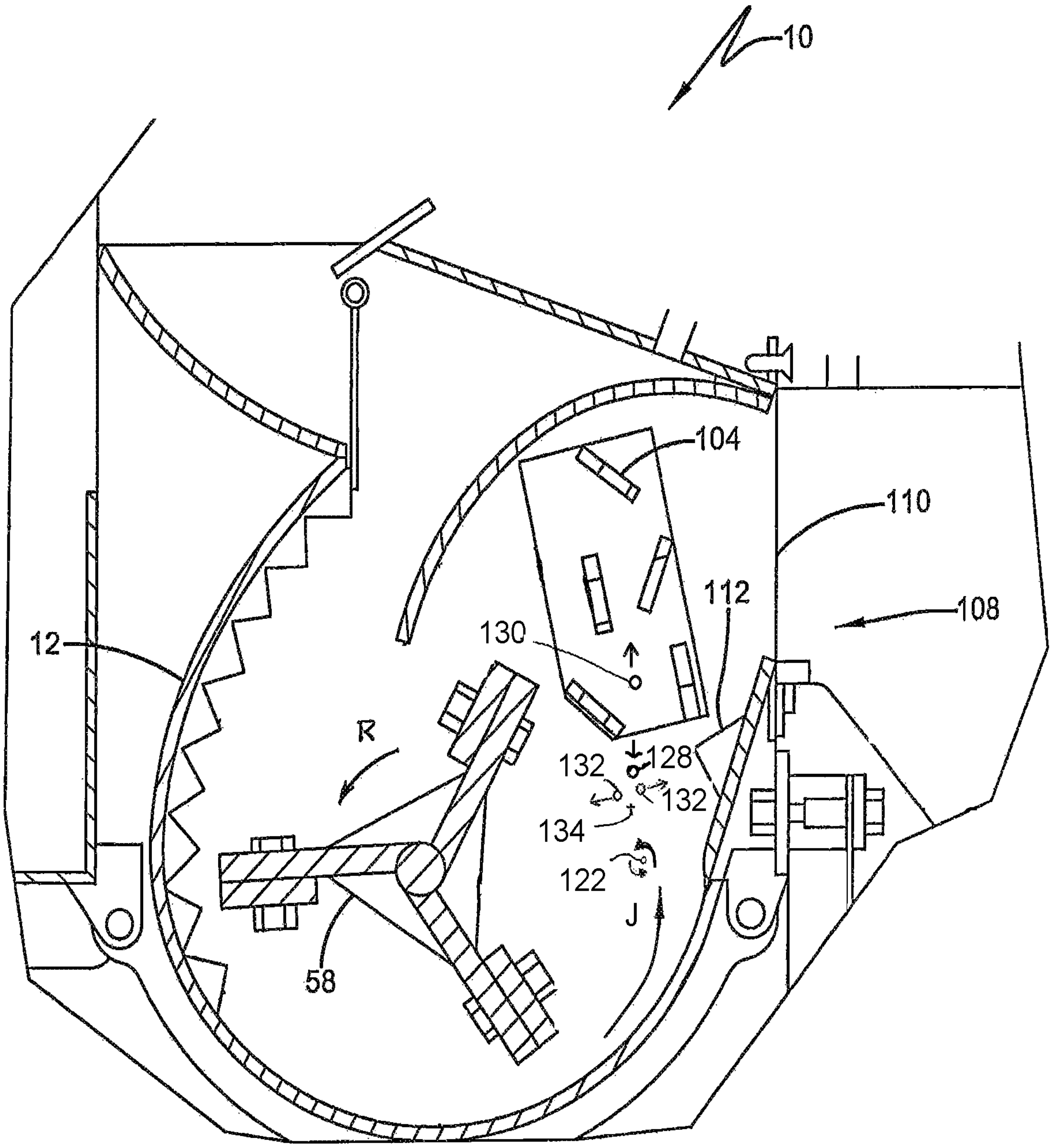
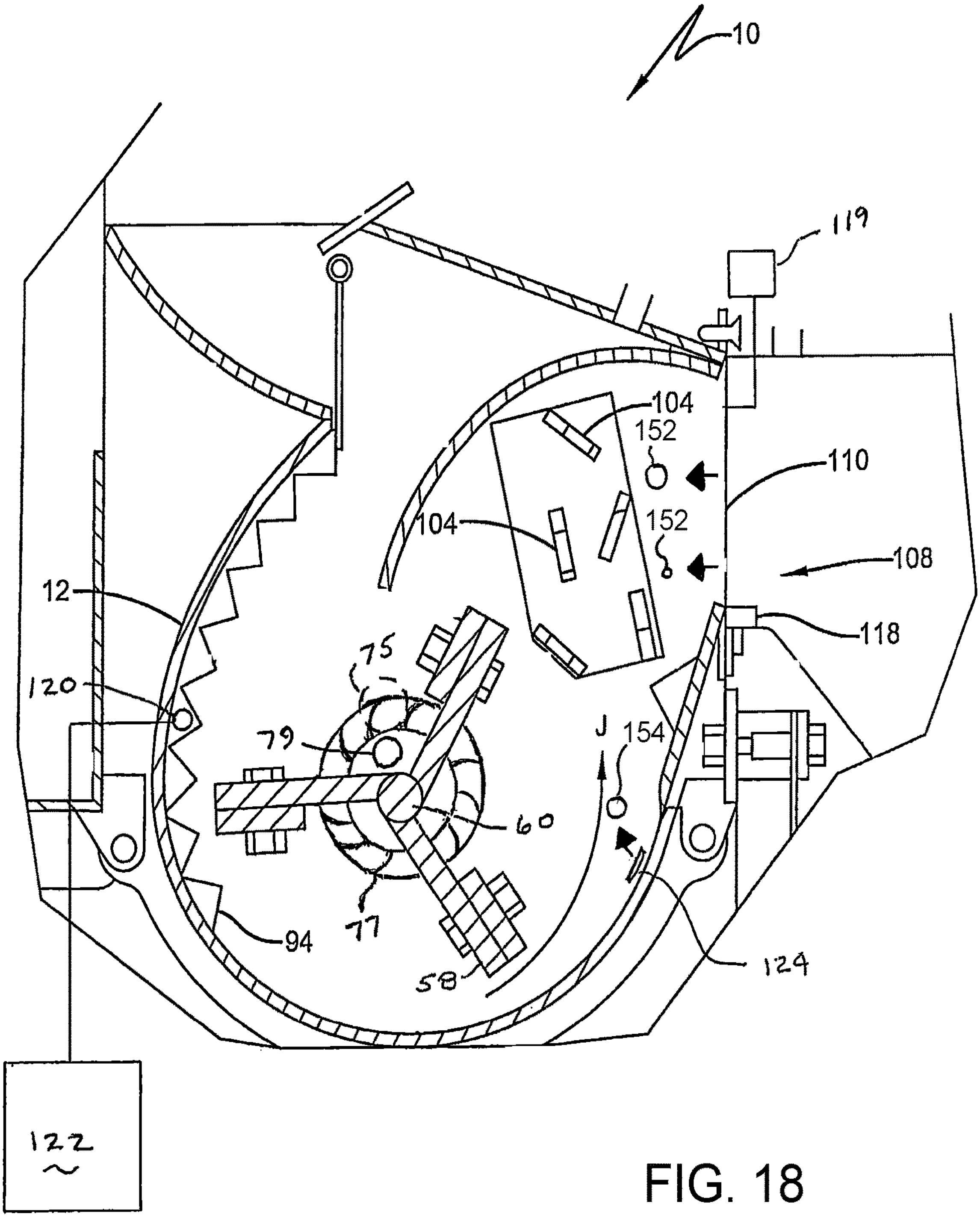


FIG. 17


10
119
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152
110
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154
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94
77
124
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122

FIG. 18

AUTOGENOUS IMPACT MILL THAT REDUCES SIZE OF FRIABLE MATERIAL

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 15/464,776 filed Mar. 21, 2017 which has been granted as U.S. Pat. No. 11,045,812, which claims priority pursuant to 35 USC § 119 (e) of U.S. Provisional Application Ser. No. 62/318,920 filed Apr. 6, 2016.

TECHNICAL FIELD

Exemplary embodiments relate to milling devices that are used to reduce the size of friable material particles. Exemplary embodiments relate to an autogenous impact mill that reduces the size of material particles through impacts with particles suspended in air via the Coanda Effect.

BACKGROUND

Various types of devices are known for processing materials in ways that reduce the size of larger material particles to a desired smaller particle size. Such milling devices are known to act on the material using pulverizing or grinding devices to reduce the size of particles of the material to a desired level. Such known milling devices may require considerable energy input, suffer wear from the required impacts and other forces necessary to pulverize the material particles, and may not produce material particles of a consistent size.

Such prior milling devices may benefit from improvements.

SUMMARY

Exemplary embodiments described herein include an autogenous impact mill that is operative to size reduce friable material particles that are processed through operation of the mill. Exemplary embodiments include a mill having a housing which bounds an interior area. The interior area includes at least one impeller that is rotatable within the interior area. Rotation of the at least one impeller is operative to produce at least one air flow jet within the interior area.

Exemplary embodiments include in cross section a plurality of ricochet bars within the housing on a first lateral side of the at least one impeller. A plurality of fracture plates extend within the housing on an opposed lateral side of the at least one impeller from the side having the ricochet bars. A removable concave lower pan portion extends below the at least one impeller and between the lateral sides of the interior area.

Pieces of the friable material to be processed by the mill are placed in a loading chute. The material pieces pass through an entrance opening into the interior area of the housing. The at least one impeller is operative to engage the material pieces and cause them to be propelled into impacting engagement with the fracture plates to reduce the material pieces to a smaller size. At least one impeller produces at least one air jet within the housing that extends away from the lower concave portion. The at least one jet extends toward the plurality of ricochet bars and an exit opening from the housing. Material particles are suspended by the at least one air jet due to the Coanda Effect. Other material particles are propelled by the at least one jet into the ricochet bars. Particles bounce off ricochet surfaces of the ricochet bars and impact the suspended particles. The impacts between the suspended particles and the particles that ricochet from the ricochet bars breaks the particles into smaller pieces.

In an exemplary arrangement, a screen is positioned adjacent the exit opening from the housing. The screen includes a plurality of screen openings having a screen opening size. Particles that are smaller than the screen opening size are enabled to pass through the screen openings and exit the interior area of the device through a delivery chute. Particles that are too large to pass through the screen openings are prevented by the screen from exiting the interior area and are further processed therein until the size of the particles is sufficiently reduced to enable the particles to leave the interior area through the screen.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a top rear left perspective view of an autogenous impact mill of an exemplary embodiment.

FIG. **2** is a top right perspective view of the impact mill, absent the motor.

FIG. **3** is a right plan view of the exemplary mill.

FIG. **4** is a front plan view of the exemplary mill.

FIG. **5** is an enlarged cross-sectional view taken along line **5-5** in FIG. **4** showing the interior area of the housing.

FIG. **6** is a further enlarged view of the interior area of the housing including a representation of the action of the at least one impeller to produce at least one air jet.

FIG. **7** is a side view of an exemplary impeller without the impeller head fasteners.

FIG. **8** is a perspective view of the exemplary impeller of FIG. **7**.

FIG. **9** is a perspective view of an exemplary assembly of ricochet bars.

FIG. **10** is a side view of the exemplary ricochet bars.

FIG. **11** is a front view of the exemplary ricochet bars.

FIG. **12** is a perspective view of the exemplary removable concave lower pan portion of the housing.

FIG. **13** is a cross-sectional view of the lower pan portion.

FIG. **14** is a top view of the exemplary lower pan portion.

FIG. **15** is an enlarged view of the interior area of an alternative embodiment.

FIG. **16** is a further enlarged view of the interior area of the housing including a representation of material particle positions, collisions, and movements in the housing interior area.

FIG. **17** is a further enlarged view of the interior area of the housing including a representation of material particle positions, collisions, and movements in the housing interior area.

FIG. **18** is an enlarged view of the interior area of an alternative embodiment including a representation of material particle positions, collisions, movements, and repulsions in the housing interior area.

DETAILED DESCRIPTION

Referring now to the drawings and particularly to FIG. **1**, there is shown therein an exemplary embodiment of an autogenous impact mill generally indicated **10**. The exemplary mill includes a housing **12**. The housing **12** is supported on a frame **14**. The exemplary frame **14** includes a front support **16** and a rear support **18**. The exemplary rear support includes casters **20** that facilitate the portability of the mill. In the exemplary embodiment, the frame supports a motor **22** such as an internal combustion engine. The exemplary frame **14** further supports other components associated with the mill such as a battery **24**. A guard **26** is positioned to overlie a belt, chain or other moving drive members that operatively connect the motor and the powered components within the housing **12**. It should be noted that in many of the drawings presented herein, the engine and other components supported by the frame have been omitted to facilitate describing the structure of the mill.

The exemplary embodiment of the mill further includes a loading chute **28**. The exemplary loading chute **28** is used to receive pieces of friable material that are to be processed and reduced in size through operation of the mill, represented by material pieces **126** in loading chute **28** as shown in FIG. **16**. The exemplary loading chute includes a top opening that can be selectively covered by a hinged screen **30**. The screen enables air flow therethrough. The hinged screen **30** is movably mounted on hinges **32** as shown in FIG. **2**. The hinged screen **30** further includes an opening **34** through which a loop or other fastening member **36** may extend when the screen is in a closed position. As shown in FIG. **2**, the exemplary loop is sized for accepting a removable pin **38** or other suitable fastening device for holding the screen **30** in a closed position. As can be appreciated in the exemplary embodiment, the hinged screen can be closed and secured by the pin **38** when the mill **10** is operating to avoid the risk of material flying out of the top of the loading chute **28**.

The exemplary embodiment further includes a delivery chute **40**. The exemplary delivery chute **40** includes a downward directed outlet opening **42**. The outlet opening is configured to pass particles of material that have been processed by the mill out of the delivery chute and into a suitable holding bin or other suitable receptacle for receiving the processed material particles.

As shown in vertical cross section in FIGS. **5** and **6**, the housing **12** includes an interior area **44**. An entrance opening **46** to the interior area extends below the loading chute **28**. A guide plate **48** includes a concave surface that directs material pieces in the loading chute toward the entrance opening.

In the exemplary embodiment, a valve plate **50** is selectively movable in the entrance opening. The valve plate **50** is movable between a closed position which is shown in solid lines in FIGS. **5** and **16** and an open position which is shown in FIG. **5** in phantom. In the exemplary arrangement, the exemplary valve plate is rotatable on a pivot shaft **52** responsive to manual actuation of a lever **54**. In the exemplary embodiment, a spring **56** biases the lever outward such that the valve plate **50** is rotationally biased toward the closed position. Manually moving the lever **54** against the biasing force of the spring **56** operates to cause the pivot shaft **52** to rotate the valve plate **50** toward the open position. As can be appreciated, the movement of the lever **54** enables controlling the delivery of material pieces from the loading chute into the interior area of the housing. This enables the operator of the exemplary mill to avoid overloading the mill so that it is not bogged down with excess material entering the interior area of the housing. As shown in FIG. **16**, material pieces **146** near the entrance opening **46** are stopped from entering the housing interior area when the valve plate **80** is in the closed position. Of course it should be understood that this approach is exemplary and in other embodiments, other approaches may be used.

In the exemplary embodiment, at least one impeller **58** is rotatably mounted in the interior area. In the exemplary embodiment, the impeller **58** is rotatable with a shaft **60**. The shaft **60** is supported on bearings **62** which are attached to the housing **12** through suitable fasteners **64**. The impeller shaft **60** is driven by the motor **22** rotationally driving a suitable pulley **66** or other suitable rotating member that is attached to the shaft **60**. In other embodiments multiple impellers that rotate on one or more shafts may be utilized.

In an exemplary embodiment, the rotatable impeller **58** includes a plurality of angularly disposed outer peripheral heads **68**. In some exemplary embodiments the impeller heads may include generally flat continuous planar leading faces that extend generally horizontally across the majority of the interior area of the housing. In other embodiments the impeller heads may have a contoured configuration. Such contours may have curved surfaces that tend to direct impacting particles toward the transverse central area of the housing interior. As shown in FIGS. **6** and **7**, the exemplary impeller heads **68** are attached to radially extending arms **138**, **140**, and **142** of the impeller through suitable fasteners **70**. The fasteners **70** extend through suitable openings **72** which extend through the impeller heads and arms to hold the components in engagement. In some exemplary embodiments, as shown in FIGS. **6-8**, the exemplary arms **138**, **140** and **142** may extend radially outward beyond the shaft **60** a distance greater than three times the diameter of the shaft **60**. Additionally, in some exemplary embodiments, the exemplary arms **138**, **140**, and **142** may be further supported by support braces **59**. As shown in FIGS. **6-8**, the exemplary support braces **59** extend angularly intermediate of and in fixed operative engagement with each of the angularly adjacent pair of arms, and are disposed entirely radially inwardly of the respective outer peripheral impact heads **68**. Of course it should be understood that this arrangement is exemplary and in other embodiments, other arrangements may be used. For example in other exemplary embodiments, the impeller heads may include contours that cause greater air movement. This may include causing greater air flow in a counterclockwise direction as shown within the interior of the housing in the direction of movement of the radially outward ends of the impeller heads. Further in some exemplary arrangements, the impeller may additionally include in operative connection therewith, fan blades that enhance desired air flow properties, such as suitable speeds and directional flows within the housing. For example in some arrangements such as is shown in FIG. **15** fan blades **77** may rotate with the shaft **60**. The fan blades may be configured to direct air flow in the circular direction of rotation of the impeller heads **68**. The airflow may also be directed toward the horizontally transverse middle area of the housing **12** so as to reduce the collection of material on the transverse sides of the housing. In some exemplary arrangements a manifold **79** extending coaxially with or otherwise adjacent to the shaft may be used to draw air from outside of the housing into selected areas of the housing interior in proximity to the fan blades and/or the impeller heads. For example air may be delivered from outside the housing into an area radially within the arc of rotation of the fan blades and/or impeller heads to achieve circumferential and radial acceleration of such incoming air by the fan blades and/or impeller heads to create higher volumes and speeds of air flows within the housing. Further in some arrangements the rate of outside air flow into the housing interior from the outside may be controlled by an external flap valve **75** or similar structure to tailor the air flow to the properties and amount of material processed by the mill. Of course numerous different approaches may be used.

The interior area **44** of the housing **12** further includes a guide plate **74**. The guide plate **74** includes a convex surface that extends below the entrance opening **46**. The guide plate terminates at an inward end **76**. The inward end **76** is positioned such that the impeller heads **68** pass in close proximity thereto as the impeller rotates within the housing. In the exemplary embodiment, the impeller rotates in a counterclockwise direction as shown during operation as represented by Arrow R in FIG. **6**. Opening the valve plate **50** moves the valve plate initially closer to and then further away from the guide plate **74**.

In the exemplary embodiment the interior area on a first lateral side of the impeller generally indicated **78** is bounded by a plurality of fracture plates **80**. In the exemplary embodiment the fracture plates are arranged at convergent angles and terminate in a plurality of disposed inwardly pointed apexes in cross section. As later explained, the fracture plates are configured to be impacted by pieces of friable material that are propelled by engagement with the heads of the impeller toward the apexes and fracture plates to facilitate the breaking up of such material pieces. Of course it should be understood that the exemplary arrangement of fracture plates **80** is but one of numerous arrangements that may be used for this purpose.

The exemplary housing **12** includes a removable concave lower pan portion **82**. Lower pan portion **82** is bounded inwardly by a concave surface **84** that extends below the impeller **58**. The exemplary embodiment of the lower pan portion **82** which is shown in greater detail in FIGS. **12-14** is releasably connected to the housing **12** through pins **86**. Pins **86** removably extend through openings **88** in the pan portion and ears **90** on the housing. In exemplary arrangements, suitable clips are utilized for holding the pins **86** in engagement with the pan portion and the housing during operation. For example in some exemplary arrangements the fracture plates may be configured so that the apexes extend generally horizontally across generally the entire interior area of the housing. In other arrangements the fracture plates may include offset apex structures or other structures such as pyramids, spikes or other configurations that will fracture the material particles on impact and then enable the fractured particles to disengage from the structures against which they are impacted.

As shown in FIGS. **12-14**, the exemplary lower pan portion includes a pair of opposed handles **92**. Handles **92** facilitate removal and installation of the lower pan portion. The exemplary lower pan portion further includes fracture plates **94** which serve the same function as fracture plates **80** higher up on side **78** of the interior area. The fracture plates **94** have a similar configuration as fracture plates **80** and are attached to the concave surface **84**. In the exemplary embodiment, the removable concave lower pan portion includes recesses **96** through which the shaft **60** extends. The sides of the pan portion further include flanges **98** which are configured to be in generally abutting relation with corresponding lower surfaces of the housing. The flanges enable the removable concave lower pan portion to be in generally tight engagement with the housing when the pan portion is mounted thereto so as to prevent the escape of material from between the housing and the pan.

The interior area **44** of the housing **12** further includes a second lateral side generally indicated **100** that in vertical cross section of the housing is on the opposed side of the impeller **58** from the first side **78**. A housing **102** is mounted on the second side **100**. Housing **102** includes a plurality of ricochet bars **104**. As shown in greater detail in FIGS. **9-11**, the exemplary ricochet bars **104** each include a ricochet surface **106**. The exemplary ricochet surfaces extend at a plurality of different angles. The different angles of the ricochet surfaces on the ricochet bars are configured to cause particles of material that impact the ricochet bars to bounce off of them at a plurality of different angles and in numerous directions as represented by material particles **128** shown in FIG. **16**. This helps to facilitate the breaking of the material particles by the mill in a manner that is later explained.

The interior area **44** of the housing further includes an exit opening **108**. Exit opening **108** is in connection with the interior of delivery chute **40**. In the exemplary arrangement a screen **110** extends between the ricochet bars and the exit opening **108**. The exemplary screen **110** includes a plurality of screen openings. The screen openings have a uniform screen opening size that corresponds to the maximum size of the material particles that the mill is configured to produce. Thus in the exemplary arrangement, material particles that have been broken and are below the size of the screen openings are enabled to pass out of the interior area **44** through the screen **110**, as represented by material particles **136** as shown in FIG. **16**, and into the delivery chute **40** from which they are delivered through the outlet opening **42**.

In the exemplary embodiment a ramp surface **112** extends in cross section inwardly and downward into the area **100** below the screen **110**. Ramp surface **112** is configured to direct material particles that are collected on the screen because they are too large to pass therethrough, to fall downwardly into the interior area **100** below the housing **102** which includes the ricochet bars.

As represented in FIG. **6**, in operation of an exemplary embodiment, the impeller **58** rotates in a counterclockwise direction as shown represented by arrow R within the interior area **44** of the housing **12**. The internal configuration of the housing including the concave surface **84** of the lower pan portion **82** is operative to cause at least one air jet labeled J in FIG. **6** to be produced within the area **100** shown on the right side of the impeller. Material pieces that enter the interior area through the entrance opening **46** and which move past the valve plate **50** in the open position engage the upper convex surface of the guide plate **74** as represented by material pieces **126** in engagement with guide plate **24** in FIG. **16**. The material pieces **126** move downwardly in engagement with the guide plate. Upon reaching the inward end **76** of the guide plate the material pieces **126** are impacted and propelled by engagement with the impeller heads **68** to the left as shown in FIGS. **6** and **16**. The impact of the material with the heads fractures the material into smaller pieces. Material pieces **126** are propelled by the impeller heads to impact against the fracture plates **80**, **94** which extend on the side **78** of the impeller, as shown in FIG. **16**. The engagement of the material pieces with the impeller heads and the fracture plates operates to fracture the incoming material pieces into smaller particles.

In an exemplary arrangement, the particles **130** that have been reduced in size by engagement with the fracture plates, are moved with the air flow generated by the impeller to the area **100** on the lateral side of the interior area opposite side **78**. Particles of material in the vicinity of the at least one air jet are suspended by the jet as represented by material particles **122** as shown in FIG. **17**. The Coanda Effect is operative to cause the moving air of the jet to follow the convex surfaces of the particles **122** which causes such particles to be suspended by the one or more air jets as they extend away from the concave surface **84**. In the exemplary embodiments, the particles **122** are suspended by the Coanda Effect in the area above the one or more air jets. However, in other embodiments, material particles may be suspended on a lower side of the air jet or on both sides of one or more air jets.

In exemplary arrangements, particles that are not suspended by the Coanda Effect are carried by the air jets toward the exit opening **108** from the housing. The material particles that are moved by the air jets are propelled into the ricochet bars **104** and fracture and/or bounce off the ricochet surfaces **106** at the various angles of the plurality of ricochet bars.

In the exemplary embodiment the particles that bounce off the ricochet surfaces (as represented by ricochet particles **128** in FIG. **17**) ricochet into engagement with the particles **122** that have been suspended by the one or more air jets in area **100** of the housing. The impacts, represented schematically by mark **134** between the ricochet particles **124** and the suspended particles **122** are operative to cause the particles to be broken and to produce particles that are reduced in size from the previous particles. This action of repeated impacts between ricochet particles and suspended particles are operative to repeatedly reduce the size of the particles within the housing.

In operation of the exemplary embodiment, at least a portion of the particles in the area **100** on a second side of the housing are moved by the air flow within the housing interior area and the **15** impeller back to side **78** of the interior area. Such particles may impact with additional incoming material pieces and the fracture plates **80**, **94** so as to be further reduced in size as well. Such particles may be again carried by the air flow jets along the concave surface **84** and into area **100** of the interior area.

Particles **136** that have been sufficiently reduced in size below the size of the screen openings in screen **110** may flow between the ricochet bars and pass through the screen. Such particles exit the mill through the delivery chute **40**, Material particles that are too large to pass through the screen **110** fall downwardly on the screen and are directed by ramp surface **112** back into area **100** on the second side of the interior area where they may be suspended or otherwise moved so as to undergo further impacts which reduce the particle size until such particles can be passed out of the housing through the screen **110**.

Further in exemplary embodiments, other or additional fluidic pressure devices may be utilized that facilitate the processing operation of the mill **10**. For example in some exemplary embodiments, a positive pressure port **114** as shown in FIG. **6** may be positioned above the convex upper surface of guide plate **74**. Positive pressure port **114** may be in operative connection with a source of positive air pressure. Such positive air pressure may be applied into the interior area so as to urge the movement of material pieces along the convex surface of the guide plate **74** toward the inward end **76**. Such positive pressure applied to the port **114** in exemplary embodiments may further reduce the amount of dust or other particulate material that may move through the entrance opening **46** and out of the screen covering the loading chute. This will reduce the amount of dust that is in the area where the mill **10** is operated.

Further in exemplary embodiments a negative pressure port **116** may be positioned to draw air out of the interior area **44**. In exemplary embodiments the negative pressure port **116** may be in operative connection with a negative pressure device such as a vacuum system and/or dust collector. The vacuum system and negative pressure port **116** may operate to draw air out of the interior area **44** of the housing. In exemplary arrangements, the negative pressure port may further facilitate the flow of air from the interior area through the exit opening **108** and the screen **110**. This negative pressure port may further facilitate the rate at which material particles that have been sufficiently reduced in size are drawn out of the interior area **44** and through the delivery chute. This increases the processing speed of the mill.

Further in exemplary arrangements one or more vibrators **118** such as for example pneumatically actuated vibrators, may be in operative connection with the screen **110** to facilitate the shedding of particles which cannot pass through the screen such that they drop off the screen and are directed by the ramp surface **112** back into the interior area of the housing. However, it should be appreciated that in some arrangements the turbulence in the air flow generated within the housing or the normal vibration of the mill during its operation are sufficient to cause the surface of the screen **110** that faces the interior area to shed particles that are too large to pass therethrough.

Further it should be understood that the arrangement of positive and negative pressure ports and other features described herein are exemplary. Other or additional pressure ports, devices or arrangements may be included in exemplary embodiments to facilitate the operation of milling apparatus that include the principles described herein. Numerous exemplary arrangements may include fluidic elements that facilitate the desired air flow which accomplishes the desirable suspension of friable material particles and impacts which in exemplary embodiments achieve the reduction in particle sizes. Numerous different fluidic elements may be implemented in components utilized in example arrangements which enable the control of vacuum and pressure without moving parts. Examples of capability to control vacuum and pressure through fluidic elements are demonstrated in patents that are owned by the applicant hereof, such as for example, U.S. Pat. Nos. 3,574,460; 3,628,601; 4,407,134; 4,435,719; and 4,570,597, the disclosures of which are incorporated herein by reference in their entirety.

In other exemplary embodiments other components and features may be utilized to facilitate operation of the mill. For example, in some exemplary arrangements electrostatic charge may be applied to facilitate the suspension of particles and to assure effective flow of material from the exit opening of the housing. In some exemplary arrangements the exit screen **110** may tend to collect particles even in the presence of mechanical devices that help to separate particles from the screen. As represented in FIGS. **15** and **18**, in such arrangements circuitry **119** may operate to cause the screen to be charged with an electrical charge that reverses on a periodic basis. In this manner particles that cling to the screen may take on a charge opposite to that of the screen. Such particles may be repelled from the screen and be returned to the interior area of the housing when the circuitry operates to reverse the charge on the screen as represented by material particles **152** as shown in FIG. **18**.

In other arrangements electrostatic charge may be used to help suspend particles in the area of the housing where such particles are most likely to be subject to being impacted by particles moving after impact with the ricochet bars. For example, in some arrangements as represented in FIGS. **15** and **18** the fracture plates may include electrodes **120** connected to circuitry **122** which causes the particles that impact against the fracture plates to have a common charge. Such charge may serve to help to keep the particles dis-bursed from each other as they are suspended by the Coanda Effect in the area where they sustain impacts with other particles. Further in other exemplary arrangements, as shown in FIG. **18**, charged electrodes **124** may be positioned in the housing to maintain such particles **154** in suspension away from the walls of the housing. Such electrodes **124** may be charged to repel the particles **154** so that such particles have a longer residence time within the region in which the particles are most likely to be subject to impacts with particles travelling away from the ricochet bars as represented in FIG. **18**. Of course the ability to utilize electrostatic effects to control the suspension of particles will vary with the properties of the material to be processed through operation of the mill.

Although arrangements have been described based on certain exemplary embodiments, a wide array of modifications, variations and alternative constructions are also within the spirit and scope of the principles described herein. Example arrangements for an autogenous impact mill and related systems have been described herein with reference to particular components, features, properties, attributes, relationships and methods. However, it should be understood that in other embodiments other arrangements may include other components, features, properties, attributes, relationships and/or methods which provide similar capabilities and functionalities.

It will be readily understood that the features of exemplary embodiments as generally described and illustrated in the Figures can be arranged and designed in a wide array of different configurations. That is, features, structures and/or characteristics of embodiments or arrangements described herein may be combined in any suitable manner in one or more other embodiments or arrangements. Thus the detailed description of the exemplary embodiments of apparatus, methods and articles as represented in the Figures is not intended to limit the scope of the embodiments as claimed but is merely representative of selected exemplary embodiments that implement the principles as described herein.

In the foregoing description, certain terms have been used to describe example embodiments for brevity, clarity and understanding. However, certain terms such as "upward," "downward," "higher," "lower," "left," "right," "outer," "inner," "front," "rear," "top," and "bottom" have been used. However, no unnecessary limitations are to be implied therefrom because such terms have been used for descriptive purposes and are intended to be broadly construed, and such terms shall not be construed as limitations on the scope of the claims herein. Moreover the descriptions and illustrations herein are by way of examples and the inventive teachings are not limited to the specific details that have been shown and described.

The exemplary structures and arrangements along with the methods for configuring and using such structures and arrangements achieve desirable objectives, eliminate difficulties encountered in the use of prior devices and systems, solve problems and attain the desirable results described herein.

In the following claims any feature described as a means for performing a function shall be construed as encompassing any means known to those skilled in the art as being capable of performing the recited function, and shall not be deemed to be limited to the particular means used for performing the recited function and the foregoing description or mere equivalents thereof.

Having described the features, discoveries and principles of the exemplary embodiments, the manner in which they are constructed and operated, and the advantages and useful results obtained, the new and useful structures, devices, elements, arrangements, parts, combinations, systems, equipment, operations, methods, processes and relationships are set forth in the appended claims.

I claim:

1. A method comprising:

a) receiving pieces of material to be size reduced into an interior area of a housing of an autogenous impact mill,

b) producing an air flow jet within the interior area,

c) holding particles of the received pieces of material suspended in air adjacent to the air flow jet in the interior area via a Coanda Effect,

d) concurrently while the particles are held suspended in air during step (c), propelling other particles of the received pieces of material that are not currently held suspended in air via the Coanda Effect, into ricochet bars in the interior area, wherein at least some particles ricochet from the ricochet bars into impacting engagement with the particles that are currently being held suspended in air via the Coanda Effect, wherein the impacting engagement of the particles breaks at least some particles causing them to be sized reduced,

e) passing the size reduced particles out of the interior area through an exit opening.

2. The method according to claim **1**

wherein step (d) includes propelling at least some of the other particles not currently held suspended via the Coanda Effect by engagement with a rotating impeller in the interior area into the ricochet bars in the interior area, wherein at least some particles propelled by impeller engagement ricochet from the ricochet bars into impacting engagement with the particles currently held suspended via the Coanda Effect.

3. The method according to claim **1**

wherein step (d) includes propelling with the air flow jet at least some of the other particles not currently held suspended via the Coanda Effect, into the ricochet bars in the interior area, wherein at least some particles propelled by the air flow jet ricochet from the ricochet bars into impacting engagement with the particles currently held suspended via the Coanda Effect.

4. The method according to claim **1** and further comprising:

subsequent to step (a) breaking at least some further received pieces of material into further particles by engagement with at least one moving impact head in the interior area.

5. The method according to claim **1** and further comprising:

subsequent to step (a) breaking at least some further received pieces of material into further particles by engagement with at least one moving impact head in the interior area and propelling the further particles engaged by the impact head into fracture bars in the interior area.

6. The method according to claim **1**

wherein step (b) includes rotationally moving at least one fan blade in the interior area.

7. The method according to claim **1**

wherein step (b) includes rotationally moving at least one fan blade in the interior area and introducing air from outside the housing through a manifold into the housing within an arc of rotation of the at least one fan blade.

8. The method according to claim **1**

wherein step (b) includes rotating an impeller including a plurality of radially extending arms in the interior area.

9. The method according to claim **1**

wherein step (b) includes rotating at least one contoured fan blade surface in operative connection with a rotating impeller in the interior area.

10. The method according to claim
and further comprising:
concurrently with at least a portion of step (c), electrostatically repelling at least some particles not currently held suspended via the Coanda Effect, away from a surface bounding the interior area of the housing.

11. The method according to claim **1**
and further comprising:
concurrently with at least a portion of step (c), directing air into the interior area through a positive pressure port, wherein the air directed into the interior area through the positive pressure port is operative to move pieces of material in the interior area.

12. The method according to claim **1**
and further comprising:
concurrently with at least a portion of step (c), drawing air out of the interior area through a negative pressure port, wherein drawing the air out of the interior area through the negative pressure port causes particles to move toward the exit opening.

13. The method according to claim **1**
wherein step (e) includes passing particles out of the housing through a screen, wherein the screen includes uniformly sized screen openings, whereby only particles smaller in size than the screen openings pass out of the housing.

14. The method according to claim **1**
wherein step (e) includes passing particles out of the housing through a screen and electrostatically repelling particles from the screen.

15. The method according to claim **1**
and further comprising:
suspending particles in the interior area away from at least one wall bounding the interior of the housing via at least one electrostatic charge.

16. The method according to claim **1**
and further comprising:
imparting electrostatic charge to the particles suspended in air adjacent to the air flow jet in the interior area, wherein in step (c) particles suspended via the Coanda Effect are kept separated by having a common charge.

17. A method comprising:
a) producing an air flow jet within an interior area of a housing of an autogenous impact mill containing pieces of friable material,
b) holding particles of the material suspended in air adjacent to the air flow jet in the interior area via a Coanda Effect,
c) concurrently while the particles are held suspended in air during step (b), propelling other particles of the material that are not currently held suspended in air via the Coanda Effect, into at least one ricochet surface within the interior area, wherein at least some particles ricochet from the at least one ricochet surface into impacting engagement with the particles that are currently being held suspended in air via the Coanda Effect, wherein the impacting engagement of the particles breaks at least some of the particles into smaller particles,
d) passing particles that have been reduced to below a certain size out of the interior area.

18. The method according to claim **17**
and further comprising:
during at least a portion of step (b), striking pieces of material in the interior area with at least one impact head and propelling the struck pieces into bars in the interior area to size reduce the pieces.

19. The method according to claim **17**
and further comprising:
during at least a portion of step (b), receiving the pieces of material into the interior area through an entrance opening disposed on the housing away from an exit opening through which particles pass to leave the interior area,
during at least a portion of step (b), applying at least one electrostatic charge to particles in the interior area that maintains particles separated from at least one of
at least one wall bounding the interior area, and
a screen through which particles pass to leave the interior area through the exit opening.

20. The method according to claim **1**
wherein in step (d) each of the plurality of ricochet bars includes a ricochet surface that has a different angle relative to ricochet surfaces of other ricochet bars.

21. The method according to claim **17**
wherein step (c) includes propelling the at least some of the other particles not currently held suspended via the Coanda Effect into a plurality of ricochet bars in the interior area, wherein each of the plurality of ricochet bars includes a respective ricochet surface that has a different angle relative to the respective ricochet surfaces of other ricochet bars.

22. The method according to claim **17**
wherein in step (a) the air flow jet is produced by
rotating an impeller in operative connection with a shaft in a rotational direction, wherein the impeller includes in operative connection therewith
a plurality of separate angularly disposed radially extending rotating arms, wherein each arm
extends radially outward beyond the shaft a distance greater than the shaft diameter, and
terminates radially outwardly in a respective outer peripheral impact head,
at least one contoured rotating fan blade surface,
and introducing air from outside the housing into the interior area through an air inlet through the housing during impeller rotation,
wherein the air flow jet produced is directed in the rotational direction and is radially outward of the impact heads.

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