March 12, 1963 F. D. COOPER 3,081,009

SOLIDS FLOW SYSTEM

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Fig. 4.

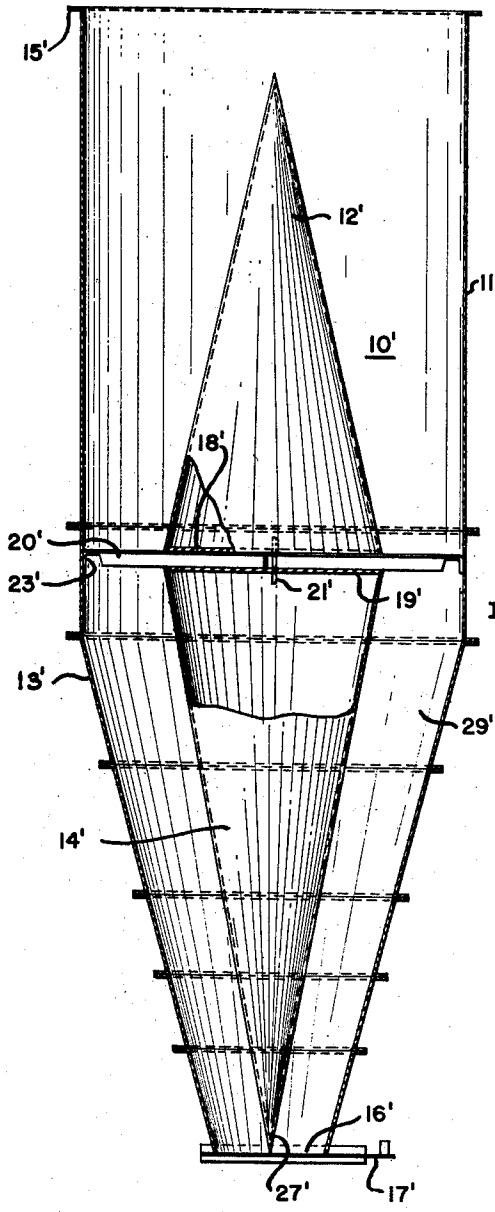
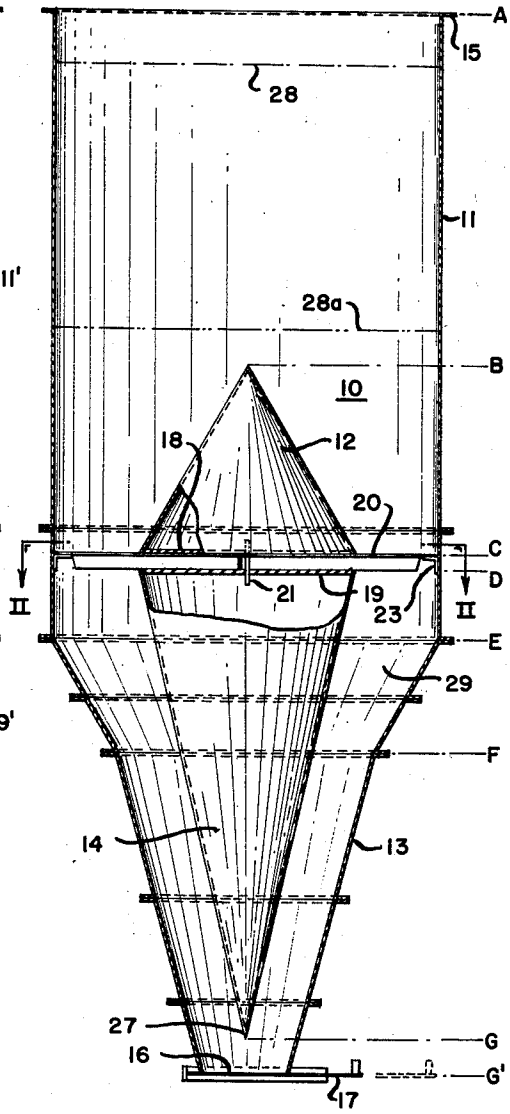


Fig. 1.



INVENTOR

Franklin D. Cooper

By Hopgood, Leonard & Buell
his attorneys

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SOLIDS FLOW SYSTEM

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Fig. 2.

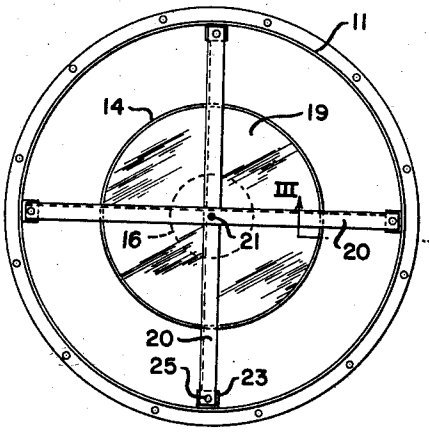


Fig. 3.

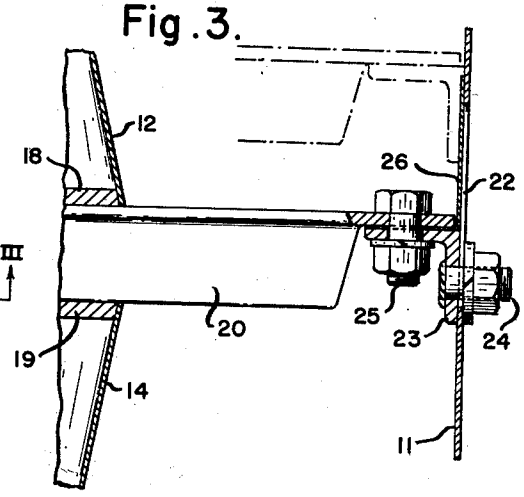
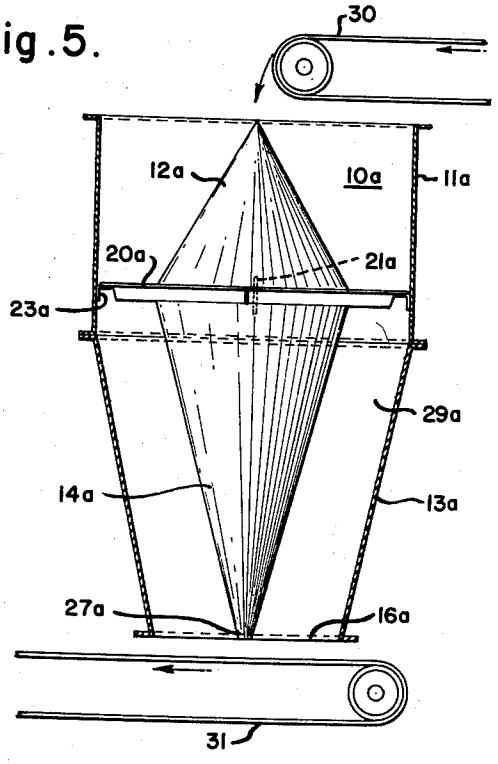


Fig. 5.



INVENTOR

Franklin D. Cooper

By Hoopes, Leonard & Buell

his attorneys

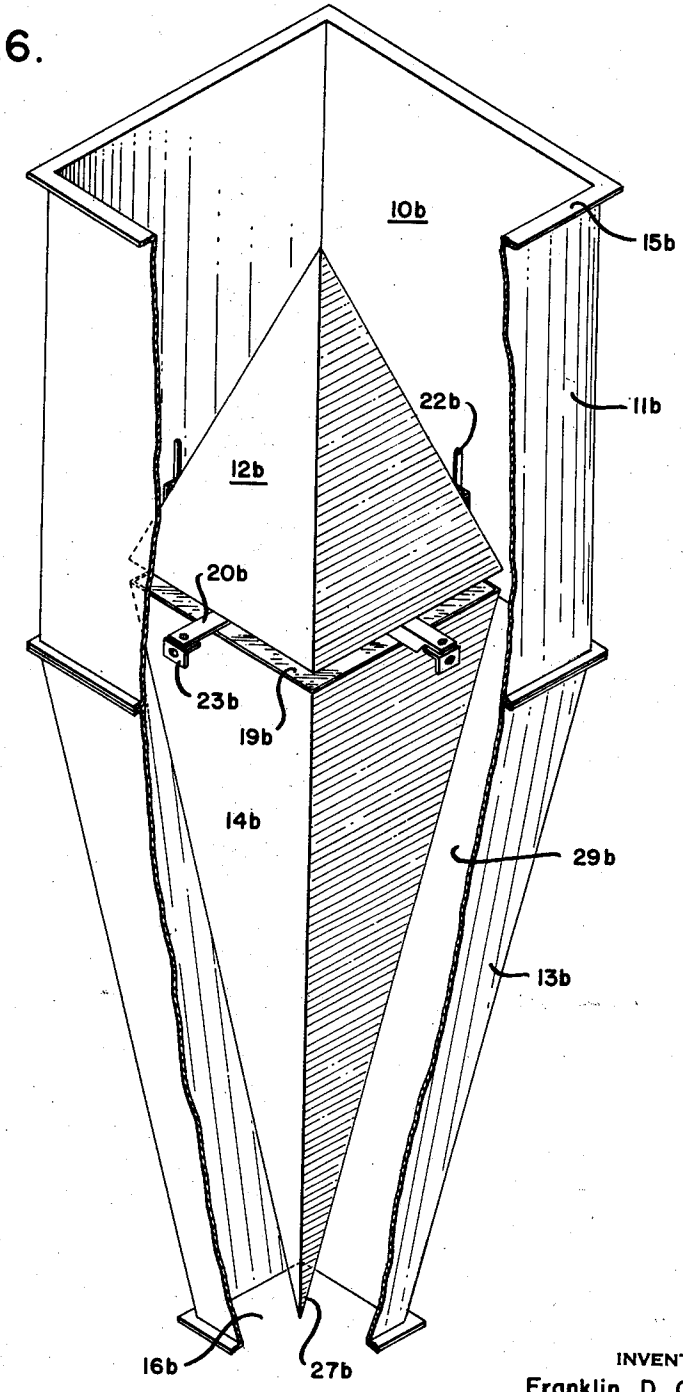
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Fig. 6.



INVENTOR
Franklin D. Cooper
By Hoppes, Leonard & Buell
his attorneys

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SOLIDS FLOW SYSTEM

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Fig. 8.

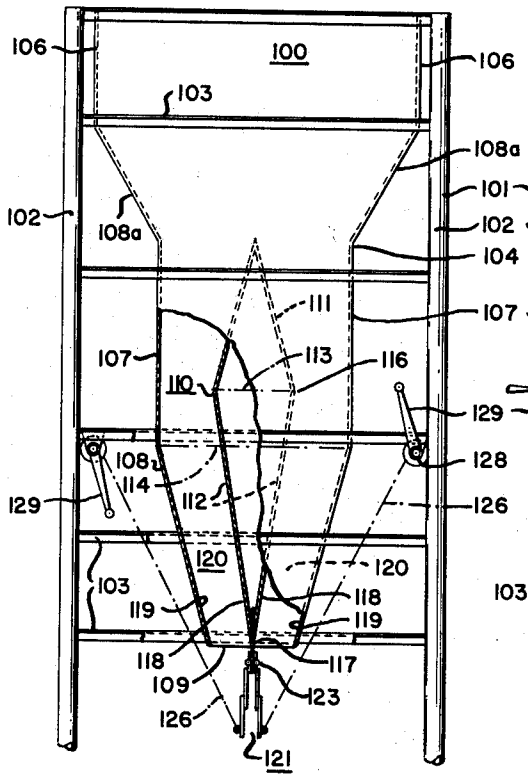


Fig. 7.

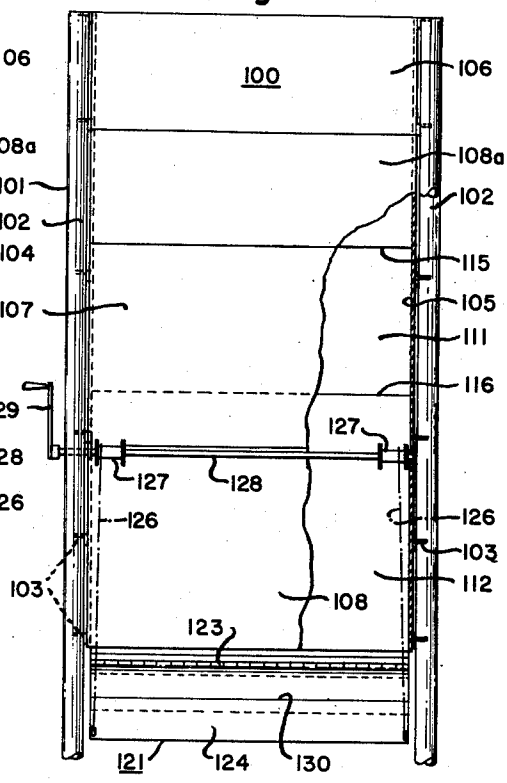


Fig. 10.

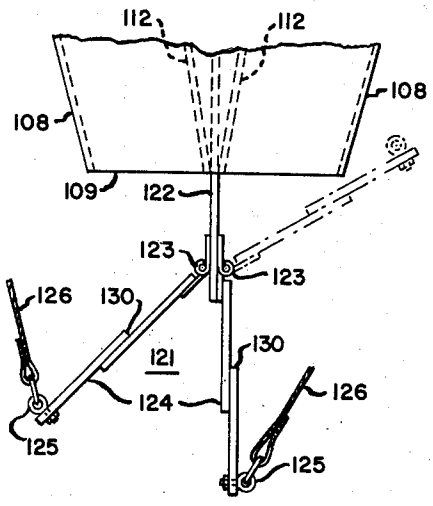
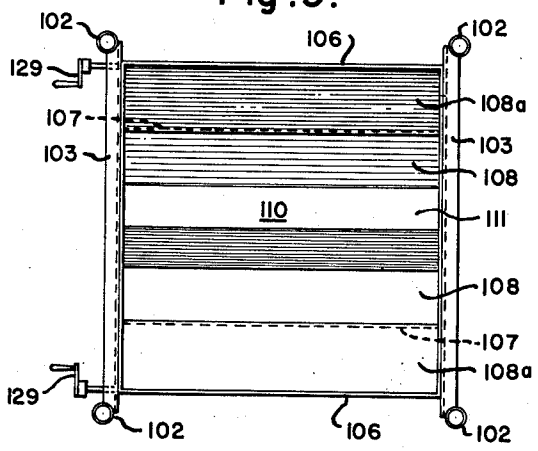


Fig. 9.



INVENTOR
Franklin D. Cooper

By Hoopes, Leonard & Buell
his Attorneys

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Fig. 11.

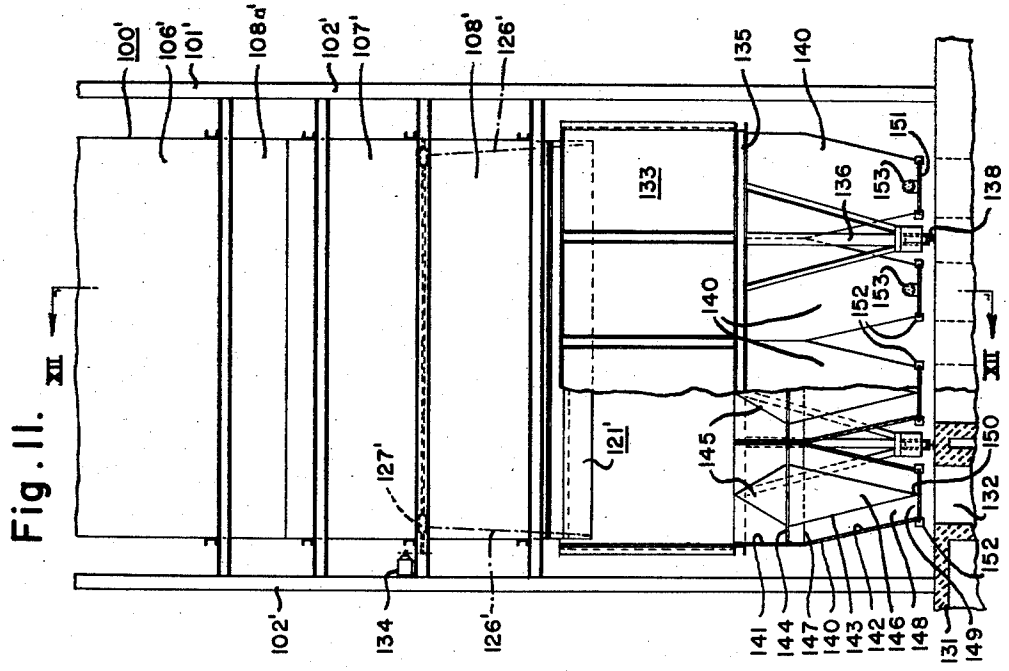
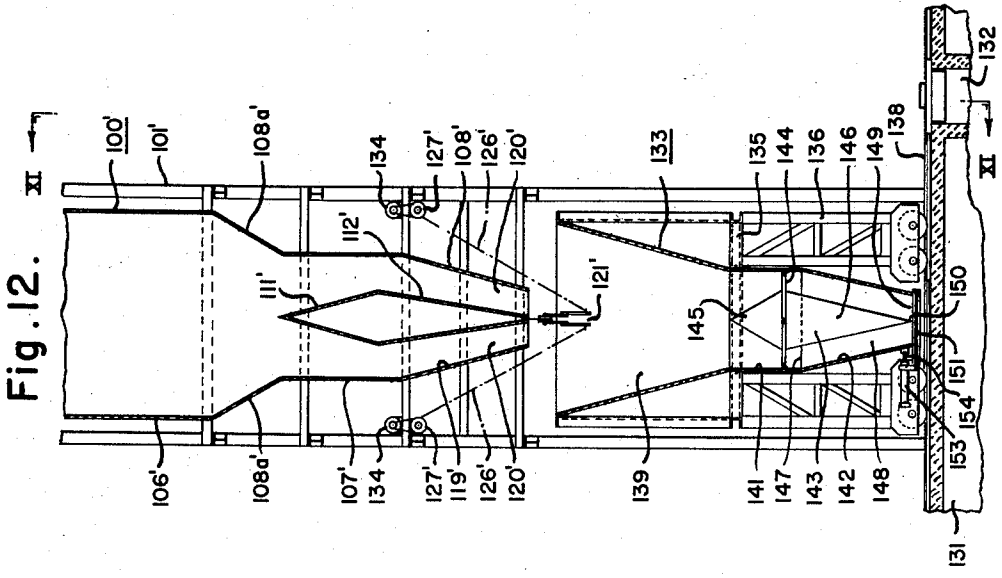


Fig. 12.



INVENTOR
Franklin D. Cooper

By Hoopes, Leonard & Buell
his attorneys

United States Patent Office 3,081,009 Patented Mar. 12, 1963

3,081,009

SOLIDS FLOW SYSTEM

Franklin D. Cooper, Worthington, Ohio, assignor to Bituminous Coal Research, Inc., Pittsburgh, Pa., a corporation of Delaware

Filed Feb. 27, 1959, Ser. No. 795,994
5 Claims. (Cl. 222—459)

This invention relates to new bin, hopper and/or conduit means from which particulate solid materials, of varying or uniform size, may be caused to flow as desired, even though in a condition that might heretofore have been considered as in either a non-flowable condition or a poor flowable condition, without packing, jamming, arching and/or channeling. More particularly, this invention pertains to new hopper-type devices for, and novel flow therethrough of, such solid materials, such devices having an inverted conical or tapered passage terminating in an outlet of practical size opening or openable into a relatively open spatial discontinuity.

Simply by way of illustration, a reference may be made to bituminous coal which is made available in a variety of sizes and in a variety of conditions of surface moisture. It long has been known that when the separate particles and lumps of such a substance have too much surface moisture for particular storage or movement conditions or service, packing or jamming of such coal would result. Indeed, in many industries using coal and other substances in which difficulty with free flow is often encountered, workmen are employed with routine duties to punch or rod or poke or hammer on bins, hoppers and conduits heretofore used in an effort to start or maintain flow of such substances. Other means to avoid the anticipated difficulties include in some prior practices equipment for drying such substances before they are stored or put into the flow passages of the system in which they are to be treated or used; in other cases, various electrical means have been used or various vibration or structural means have been attached to the equipment, or various additives have been added to the solids, to try to improve storage and/or flow characteristics of such solids. Further, when such a substance did flow as from a bin or in a hopper of prior kinds, the flow that would occur would often tend to funnel or channel with, in some cases, arching or ratholing or segragation of different sizes or uneven rates of flow, or several of these difficulties might occur at the same time. And, almost invariably relatively large quantities of material would stick or remain in such a prior bin or hopper.

In the new solids flow system of my invention disclosed herein, those problems which might normally be anticipated with coal and other substances having separate particles including pieces, lumps, granules and nodules, of varying or uniform size, are inhibited and within the capacity of the particular equipment used, are avoided. I have discovered that by providing my mechanism having an annular inverted conical passage with a terminal outlet communicating with a relatively open spatial discontinuity, particulate substances which, because of wetness, moisture content or inherent characteristics, would normally be expected in the storing and/or gravity flow movement thereof to give difficulty even up to the point of refusal to start flowing from storage or of the cessation of flow in the course of movement, such substances handled under my invention will store well in static condition and upon any opening of the outlet at the bottom of such annular inverted conical passage will flow relatively freely including flow under conditions where it would be impractical or impossible to use prior equipment. Moreover, the flow of such solids pursuant to my new system will operate with lower lateral hopper pressures upon the equipment in the course of flow, with uniform lowering

of the level of the surface of such material as flow occurs, with rapid attainment of maximum flow consonant with the opening provided at the apex of the annular inverted conical passage, with relatively uniform and full flow discharge from the new system even though fresh material may be being fed to one side of the entry portion of the passage, with self-cleaning by the complete emptying of the interior of the equipment in my new system when flow to that extent is desired, with the ability to interrupt flow as desired without detriment to resumption and to resume flow again by the mere reopening of the outlet at the bottom of the annular inverted conical passage, with trouble-free storage if desired above such annular inverted conical passage surrounding a conical recess in general registry with the base of the inverted conical center in the interior of said annular inverted conical passage, and, without need for vibrators, or other flow aids commonly employed heretofore.

Other objects, features and advantages of my new solids flow system will be apparent from the following description and the accompanying drawings, which are illustrative only, in which:

FIGURE 1 is a view in elevation and section, with parts of the cap cone and an inverted cone in the inside thereof partly broken away, to illustrate a cooperating bin and hopper embodiment of my invention.

FIGURE 2 is a plan view taken generally along line II—II of FIGURE 1, with the cap cone shown in FIGURE 1 removed;

FIGURE 3 is a detailed view in elevation taken generally along line III—III of FIGURE 2;

FIGURE 4 is a view like that shown in FIGURE 1 of a somewhat modified embodiment of my invention;

FIGURE 5 is a view in elevation and section of a further modification of my invention showing a conduit hopper embodiment at a junction between two conveyor belts for the solids being conveyed;

FIGURE 6 is a perspective view, partly broken away, of another cooperating bin and hopper modification of my invention with the cap and inverted cones and the conical hopper shell in pyramidal form;

FIGURE 7 is a front view, with a portion of the exterior thereof broken away, of a rectangular modification of my invention;

FIGURE 8 is an end view, with a portion of the exterior thereof broken away, of the modification shown in FIGURE 7;

FIGURE 9 is a plan view of the modification shown in FIGURES 7 and 8;

FIGURE 10 is a somewhat more detailed view of the bottom of the bin discharge device modification shown in FIGURE 8 to illustrate a novel closure means therefor;

FIGURE 11 is a front view of a rectangular modification of the tylpe shown in FIGURES 7 to 10 utilized as a bin and discharge device for a coke oven in cooperation with a larry car embodiment of my invention, an external portion of which has been broken away, said figure having been taken generally along line XI—XI of FIGURE 12 with the covers removed from the ports shown in FIGURE 12; and

FIGURE 12 is a view in section taken along line XII—XII of FIGURE 11.

Referring to FIGURES 1 to 3 of the drawings, a new solids flow device **10** may comprise a cylindrical bin shell portion **11** having a cap cone **12** positioned coaxially therein, a tapered hopper shell **13** and an inverted hopper cone **14** positioned coaxially therein. As shown, shell **11** is provided with an upper flange **15** for attachment, if desired, to the bottom or side of a bunker or silo to keep bin shell **11** filled with a material to be dis-

pensed or distributed as and when desired by the flow discharge thereof out of an outlet **16** adjacent the bottom of hopper **13—14**, by gravity flow, whenever, a slide gate **17** is partially or fully opened dependent upon the rate of flow desired. Or, device **10** may receive solid particles from a conveyor or a receptacle emptying into the top of shell **11** normally from a height consonant with the avoidance of undesired and known compacting to which the material may otherwise be inherently subject. Still further, my new solids flow device **10** may be made in the form of a mobile unit by being mounted on a wheeled vehicle or frame either alone or in assemblage with other such units **10** for use, as an example of a mobile form, as a larry car for coke ovens.

The shells **11** and **13** and the cones **12** and **14** may be made of any suitable material such as sheet metal or carbon steel of sufficient thickness for its capacity. As shown, portions of the bin and hopper shells **11** and **13** may be made in flanged ringlike sections joined together, if such sectional construction is preferred, as may be the case with larger capacity devices. Cap cone **12** is preferably provided with a filler plate **18** in its base and the inverted cone **14** is provided with a filler plate **19** closing its base. Both cones may be supported in operative adjoining base to base position by a spider **20** having radially extending angle arms joined at the crossover center as shown in FIGURE 2 and having a central hole in which an upwardly and downwardly coaxially extending pin **21** may be fixed for centering purposes, a central hole being provided in each of the filler plates **18** and **19** for such centering purpose. The cones **12** and **14** may be fastened in unit **10** by tack welding of the cones to the spider **20**.

In device **10**, the elevation of spider **20** and therefore of the respective bin and hopper cones **12** and **14** may be adjusted in a variety of ways one of which is shown in detail in FIGURE 3. Thus, at cardinal points around the device **10** above the junction between the bin shell and hopper shell portions thereof, vertical slots **22** may be provided so that internal brackets **23** may be affixed at the selected height to the outer shell of device **10** by a stud, lock washer and nut assembly **24**. The outer ends of the spider **20** are supported on the horizontal flange of the respective brackets **23** and rigidly connected thereto by bolt and nut assemblies **25** in the illustrated embodiment. Any portion of the respective slots **22** above the brackets **23** may be closed by a slidable shield **26** affixed to such bracket. In this way, an adjustment may be made in the height of the central cones for optimum positioning principally of the inverted hopper cone **14** in hopper shell **13** with the apex **27** of the inverted cone adjacent the restricted outlet **16** at the bottom of hopper **13—14**.

In operation, a batch of wet coal of small size including slack may, for example, originally be at a level **28** when gate **17** is opened by moving the gate to its dotted line position shown in FIGURE 1 until the level in bin **11—12** falls to the level **28***a*. In the course of such flow, the top surface of the coal remains relatively level and undisturbed. Moreover, the flow of coal from the outlet **16** is a solid fluid-like flow which quickly attains a maximum consonant with the opening provided by the extent that gate **17** is moved and which, moreover, remains approximately at that maximum despite the change in the height of the coal above outlet **16** during the course of the movement of the top surface thereof, e.g., from a higher level **28** to a lower level **28***a*. During such flow, the coal moves through the annular inverted conical passage **29** between the exterior surface of cone **14** and the interior surface of hopper shell **13** with faster movement in the portions of coal bordering the surface of cone **14** relative to the portions of the flowing coal bordering the interior surface of the shell **13**. And, those unique flow characteristics described remain even though the coal may be fed into the top of bin shell **11** from one side thereof rather than evenly across the entire area of the same. Such interior surface of shell **13** is at a relatively steep angle to the horizontal greater than the respective angle of repose in a relatively dry condition of the particular solids particles being handled. While flow is going on, the lateral pressure outwardly from the vertical axis of device **10** decreases against the upper part of shell **13** and increases slightly against the lower part of shell **13** relative to static non-flow pressure conditions. The lateral pressure against the interior of shell **11** opposite the sides of cap cone **12** under flow conditions appears to increase somewhat. The new flow results also obtain even though gate **17** is opened but a slight amount so that the opened portion of outlet **16** is somewhat offset from the vertical central axis of the device **10**. Still further, if, for example, when the level of the coal in device **10** reaches level **28***a*, the gate **17** is quickly shut closing outlet **16**, the coal remaining in device **10** will not compact or wedge or arch but will be retained in flowable condition and resume the new flow characteristics upon the reopening thereafter of gate **17**.

As an example, by way of illustration only and not by way of limitation, a test demonstration of a device like device **10'** provided a discharge flow at a maximum rate of 2500 pounds of wet coal per minute of ¼ x 0-inch bituminous coal having about 13% of surface moisture based on the combined weight of dry coal and water. Moreover, the rate of flow has been throttled to as low a rate as 9 pounds per minute by the use of a moving horizontal conveyor placed below and near to open outlet **16** to remove such coal at that rate. Further, even when gate **17** was closed very rapidly shutting off the coal, flow rapidly began again upon reopening of the gate, showing that in my new device such closure of the hopper opening does not cause wedging or jamming of the coal in the device despite the high surface water content thereof. In another test with the device, ¼ x 0-inch coal in admixture with 1/16 x 0-inch coal in the volumetric ratio of 80% and 20% respectively and having 9 weight percent surface moisture provided the same new flow characteristics which have been described in the preceding test. Indeed, small size coals, including slack, having surface moisture quantities up to 16% by weight based on the combined weight of coal and water flowed whenever the hopper outlet **16** was opened without arching, compacting, wedging, jamming, ratholing or interrupting itself. In feeding larger sized particles such as egg coal to a device such as that illustrated in FIGURE 1, which egg coal may have a general size about 2 x 3-inches with pieces as long as 5 inches, it was also noticed that there is a tendency in the use of such devices of this invention for such larger pieces to become oriented so that the longest axis thereof is in the general direction of flow, thereby further promoting the flow of such materials.

In such illustrative tests, the device used was in substantial conformance with device **10** with the interior apex angle and base angles of cap cone **12** each equal to 60°; the interior base angles between filler plate **19** and the sides of inverted cone **14** were 77°; and the interior apex angle of the inverted cone **14** was 26°; the beginning taper of the two uppermost tapered ring sections of hopper shell **13** made an angle of 60° with the horizontal while the three lowermost tapered ring sections thereof were at an angle of 75° from the horizontal. The apex point **27** of hopper cone **14** was positioned 2 inches above the plane of outlet **16**, which outlet had an internal diameter of 8½ inches. The internal diameter of shell **11** was 36 inches and the diameter of the bases of the respective cones was 20 inches. The foregoing figures and the following tabulated dimensions and areas of that test device are provided herein by way of illustration only and not by way of limitation, the heights in

the table being taken between horizontal planes at the respective levels marked by the letters A to G', inclusive:

Table I

Reference planes:	Height in inches
B to C	17¾
C to D	1½
D to E	6⅜
E to F	10⅝
F to G	28
G to G'	2
A to G'	99

Table II

Reference plane:	Area of annular hopper passage 29 in square feet
D	4.89
E	5.47
F	2.30
G	0.51
G' (16 fully open)	0.39

The somewhat modified form of my device illustrated in FIGURE 4 has its parts in substantial correspondence with the respective parts shown in device **10** in FIGURE 1, such corresponding parts in the FIGURE 4 form being provided with the same reference numerals respectively with the addition of a prime accent thereto. Device **10'** is particularly useful in the case of solid substances of a more difficult flow condition character in terms of the normal difficulty which might be encountered in trying to cause such substances to flow or to retain a flowable condition when stored, such as would be found in a slack coal having surface moisture contents in the neighborhood of 13% and above by weight based on the combined weight of coal and water. In such a situation, device **10'** facilitates the flow pursuant to this invention of such more "difficult" solid materials. It will be noted that there is a more sharply peaked cap cone **12'** which tends to reduce the lateral pressure against the interiors of shell **11'** during the course of such flow and that all of the tapered portion of hopper shell **13'** is at a uniform angle of about 75° relative to the horizontal. In the case of the modified form of device like that shown in FIGURE 3, with a 12-inch diameter outlet, a maximum outflow rate per minute would be about 7000 pounds for wet ¼ x 0-inch coal having a 12.6 weight percent moisture content, which is equal to about 6100 pounds per minute of moisture-free coal in the outflow material. It is also to be noted that devices of this invention are fully self-cleaning when a cap cone is used with a hopper cone in that they will clear themselves entirely of all of the solids therein if the outlet is left open until emptying takes place, which self-cleaning feature is an advantageous feature with many materials such as coal and grains concerning which the phenomenon of spontaneous combustion is often a problem.

In the further embodiment illustrated in FIGURE 5, parts therein corresponding generally in construction and functioning to parts of the structure shown in FIGURE 1 are provided with the same reference numerals respectively with the addition of the suffix letter "*a*" thereto. In that embodiment of FIGURE 5, it will be noticed that device **10*a*** is used substantially as a flow conduit at a junction between two conveyor belts **30** and **31**, one or both of which may be of intermittent operation relative to the other. It will be realized that the solids fed by conveyor **30** and carried away by conveyor **31** will cease flowing through device **10*a*** whenever conveyor **31** is stopped and the level of the solids thereon rises to block outlet **16*a*** thus serving as an automatic shutoff for device **10*a*** even though conveyor **30** may still be bringing material and feeding it into the top of device **10*a***. It will also be noticed that the portion **27*a*** of inverted cone **14*a*** is truncated although the theoretical apex point is still adjacent the plane of outlet **16*a***. It may still further be noted that the annular inverted conical passage **29*a*** diverges somewhat in a downward direction in terms of the elements of conical shell **13*a*** and inverted cone **14*a*** lying in a plane through the vertical axis of device **10*a***. By means of the new conduit device **10*a***, my new solids flow principle is achieved and jamming and packing, which commonly occurred at junctions between conveyors, are eliminated.

While solids flow devices of this invention having curved or round horizontal cross sections are preferred, the principle of the invention nevertheless is obtainable in respect of hopper devices or cooperating bin and hopper devices in which the inverted cone is in the form of a pyramid. As used herein, the terms "cone" and "conical" shall be deemed to include the terms "pyramid" and "pyramidal" respectively, whether square or rectangular, hexagonal, octagonal, etc. inasmuch as a cone can be considered as a pyramidal figure having an infinitude of sides around which a circle or other closed figure (e.g., an ellipse) can be circumscribed. Accordingly, another modification of my invention having a pyramidal form in the respective cones and in the hopper shell is illustrated in FIGURE 6, the parts thereof otherwise corresponding generally in construction and functioning to parts shown in the FIGURE 1 form of the device being provided with the same reference numerals respectively with the addition of the suffix letter "*b*" thereto. As shown, a plane through the vertical central axis of the device **10*b*** and the diagonal corners of the respective pyramidal cones **12*b*** and **14*b*** will also pass through the corresponding diagonal corners of shell portions **11*b*** and **13*b***, although if desired the diagonal corners of the respective pyramidal cones may rotate about the axis of the device so as to be out of registry with the respective planes passing through such diagonal corners of the shell portions of device **10*b***.

FIGURES 7 to 10, inclusive, illustrate a rectangular modification **100** of my invention employing a novel closure means. Such rectangular modification may be itself a combined bin and bin discharge device embodying the principle of my invention, or a bin discharge alone to be used in conjunction with a larger silo, bunker, or other equipment. It is rigidly connected to and supported by a girding frame **101** having vertical members **102** and binding cross members **103** rigidly connected to device **100**. As shown, device **100** has a laterally enclosing outer shell **104** which may be of welded plate construction. The ends **105** thereof are vertical while the front and back thereof may utilize vertical plates **106** and **107** in the upper and intermediate portions thereof connected by inclined plates **108*a*** which make an angle to the horizontal above the normal angle of repose of the loose material or materials to be handled by device **100**. Plates **107** are joined in flush relation to plates **108** respectively which taper to a terminal outlet **109**. Outlet **109** communicates with a relatively open spatial discontinuity, as do the outlets in the earlier described embodiments. Plates **108** form a frustum of an inverted cone in end view cross section. An elongated double cone-shaped in cross section member **110** with an upper or cap portion **111** and a lower or hopper portion **112** is welded of plates in coinciding base to base relation at a common plane **113** which is above a plane **114** passing through the joints or bends where the respective plates **107** and **108** meet. From end to end, the double cone-shaped member **110** is also somewhat like a diamond-shape in cross section and has its respective ends terminating at the plates **105** to which it may be rigidly fastened by welding. As shown in FIGURE 8, the double cone **110** flares downwardly from its upper apex **115** to corner projections **116** at the front and back where the bases of the respective cone sections meet and then the double cone **110** tapers downwardly on each side to a lower apex **117** in juxtaposition

to outlet 109. Thus, outlet 109 is divided into front and back portions either or both of which may be left open, or opened, as desired, in connection with the particular service to which device 100 is applied, whether stationary, or mobile. Device 100 and its supporting frame may be made mobile by supporting the same from a crane, or on a vehicle or other carrier and placement means.

The various plates of device 100 also instead of being welded at the joints are capable of being made by bending at those locations, or otherwise shaped as desired and various fastenings other than welding may be used in constructing the device as and when so desired. Preferably, the inner surface 118 presented by the double cones 110 and outer surface 119 presented by the shells 107–108 generally facing the inner surface, inclusive of the end portions 105 thereof, are relatively smooth and flush respectively. Those surfaces define a collective conical passage 120 in end view section below plane 114 comprising front and back inwardly and downwardly inclined portions terminating at outlet 109. The horizontal area of the opening bounded by plates 105 and 107 and of the distance between plates 107 should be selected at no less area and/or minor dimension respectively than one of the order at which particulate solids having more or less difficult flow characteristics will normally flow as a general rule. An opening of such an area inclusive of any such lesser dimension will, however, be impractical in general for the storage and/or feeding of such material into a boiler, furnace, heater, vehicle, or other customary receivers thereof. Consequently, my invention provides a means for effecting flow and feeding through a practical size outlet at controllable rates irrespective of whether or not the material has relatively difficult flow characteristics as is the case with wet coals especially in the smaller sizes. Flow through one or both sides of device 100 appears to follow the principle and achieve the novel flow character of my earlier described embodiments; and even when outlet 109 has been closed for a relatively long period of time, the opening thereof will immediately restart such flow. Further, it would appear that if a distributor or conveyor were utilized below an outlet of an embodiment of my invention and is extensive enough to carry away all flow from said outlet, there also exists a relatively open spatial discontinuity which would also exist in such a case as it does in the case of such outlet opening into a greater and relatively unconfined space.

A closure gate assembly 121 is provided for the front and back portions of outlet 109 in the illustrated embodiment which enables such flow to be relatively easily regulated between the included extremes of no-flow and full-flow. Closure assembly 121 may comprise a vertical hinge plate 122 which passes between the plates 112 at the apex 117 where it is secured thereto; such plate 122 extending horizontally to the end plates 105 where it may also be welded. Piano-type hinges 123 are fastened in horizontal fashion to each side of plate 121 below the bottom of shell 108 defining the edges of outlet 109. A gate 124 in turn is fastened to movable leaves of the respective hinges 123 and each may be provided with eyes 125 along the outer edge thereof near its ends. Eyes 125 are engaged by cables 126 the upper ends of which are adapted to be wound on drums 127 fixed to a windlass shaft 128 when a handle 129 is turned in a winding direction. Shaft 128 is fastened by suitable brackets to frame 101 and the windlass on each side of device 100 is provided with a ratcheting wheel and releasable pawl (not shown) to hold the respective gate 124 connected thereto in whichever angular position to which it may be moved by a person turning handle 129. Thus in FIGURE 10, the right-hand gate is shown fully open while the left-hand gate is shown held in a partially opened position. The right-hand gate is shown in chain outline also to indicate a fully closed position.

Each gate 124 may be provided with a step 130 to assist in the control of flow through the portion of outlet 109 thereabove, such step appearing to have an impeding effect helpful in such regulation which is a function of the angle to which a gate is adjusted by handle 129 for flow control between its fully open and fully closed positions, respectively. Further, whenever a gate 124 is moved to full closure position, no detrimental jamming of material occurs in the vicinity of the hinge and as and when that gate is lowered to a selected flow position, flow from the outlet portion thereabove will recommence immediately in the manner of a free-flowing material.

Such a type of rectangular modification is shown in FIGURES 11 and 12 as a storage and free-flow feeding device for the larry car or cars of a coke oven or ovens and parts thereof corresponding generally in construction and functioning to parts shown in FIGURES 7 to 10 are provided with the same reference numerals respectively with the addition of a prime accent thereto. Thus, device 100′ is fixed to a frame 101′ mounted on the binding of a by-product coke oven 131 with transverse retorts to a selected one of which coal for coking is fed periodically through its ports 132 by a larry car. Ports 132 normally are covered by covers 132*a* which have been removed in FIGURE 11 for the purpose of showing how a larry car 133 embodying this invention would be utilizable to refill such a retort with coking coal in a more rapid and troublefree manner after device 100′ had been shut off and car 133 moved into position directly above such ports in the selected retort oven. Remotely controllable motor operators 134 provided with magnetic brakes or other holding mechanism are shown for the powered operation of windlass drums 127′ in the operation of device 100′.

Larry car embodiment 133 is provided with a rigid vehicle frame 135 having downwardly extending legs 136 which terminate in flanged wheels which travel on rails 138 fastened to the top of the coke producing battery so that the larry car can be replenished from bin device 100′ as needed to feed the respective retorts in the furnace. A coking coal receiver body 139 is rigidly connected to frame 135 and the inside thereof is integrally connected in a relatively flush manner to a plurality of spout feeders 140 extending across the whole bottom thereof. Each such feeder spout is circular in plan and comprises a shell having a vertical upper portion 141 and a tapered lower portion 142 with a right circular double cone member 143 positioned therein and rigidly held in place by a spider 144 defining a common base plane for the upper cone shaped portion 145 and the lower inverted cone shaped portion 146. Such common base plane is above a horizontal plane 147 passing through the joint or corner where the upper and lower shell portions of feeder 140 meet. The downwardly tapered passage 148 between the inner and outer surfaces in each feeder 140 extends to an outlet 149 in juxtaposition to the apex 150 of the lower cone shaped member. The outlet is normally closed by a slide 151 remotely operable in guides 152. A cylinder 153 may be connected to each slide gate 151 with the piston rod 154 thereof pivotally fastened to the outside of feeder 140 so that upon suitable opening or closing actuation of the slide operator 153—154 by suitable valve and flexible fluid flow connections (not shown), the door of one or more of the feeders 140 can be operated individually or groupwise as desired when car 133 is directly above a set of open ports 132 to charge such retort with coking coal. It will be understood that other uses and forms of material-handling car and vehicle constructions may be made within the contemplation and teaching of my invention.

From the foregoing, it will be evident that a major new principle has been discovered to obtain flows of particulate solids as an when desired. Moreover, it will be apparent that the new constructions hereunder may be made of a variety of substances including common materials and that such constructions will be of relatively low cost. Still further, it will be apparent that while the

embodiments illustrated include both cap and inverted cones or cone-shaped sections, the principle of this invention is utilizable if material is fed into a tapered hopper of my invention around the top of or in the annular inverted conical or downwardly and inwardly inclined space between the exterior of the inverted cone or cone shaped section and the interior of the hopper shell in which event no cap cone or bin shell would be used. It will be apparent, again, that while the new devices of this invention have been illustratively described in connection with the flow of coal which heretofore has been regarded as posing a problem to place or retain in flowable condition as moisture content thereof increased, my new principle is applicable also to other solids which, because of surface moisture, whether water or other liquid, or internal moisture, or frictional characteristics, or deformability under pressure, might normally be expected to cause difficulty in flowing or to have their flowable condition depreciate when stored, may be handled by devices of this invention with improvement of flowable quality because of the forces operative upon such solids when in or flowing through devices of this invention. Such solids in addition to coal might include for example but without limitation thereto, various grains, chemicals, elastic and plastic materials, ore, fly ash, slag, cement, coke and coke breeze, crushed stone, clay, sand, gravel, sawdust, asbestos dust, starchy-content and like materials, mica and other substances, whether inherently discrete particles or otherwise placed in particle, lump, granule, nodule, pellet or other separate subdivided or agglomerated particulate form which it may be desired to subject substantially to gravity flow in the course of the handling, transporting and/or treating thereof. While devices made in accordance with my invention appear to work best when the parts thereof are in vertical coaxial or symmetrical relation with the conical or cone shaped members thereof being in the nature of a "right-angled" cone, nevertheless advantages are obtainable pursuant to my new principle if the axis of such a device is positioned somewhat out of a vertical position, or when some eccentricity may exist in the axial positioning of the cone or cones as the case may be relative to their respective shell or shells, or when any such cone has the vertex thereof offset from a vertical axis normal to the base and passing through the center thereof of said base. And conoids and conoidal members may be utilized also in practicing my invention, the terms "cone" and "conical" herein to be deemed further to include the term "conoid" and "conoidal" respectively.

This application is a continuation-in-part of my copending application, Serial No. 639,355, filed February 11, 1957, now abandoned.

It will also be apparent that various modifications may be made in embodiments of this invention without departure from the spirit thereof or the scope of the appended claims.

I claim:

1. In a solids flow system device for particulate materials such as moist coal or the like, apparatus comprising, in combination, an upright circular bin shell having an opening at the top substantially equal to the internal diameter of said shell, an inverted substantially right circular conical hopper shell, the bottom of said bin shell having an internal diameter equal to the internal diameter of the top of said hopper shell, the bottom of said bin shell being joined to the top of said hopper shell in respective coaxial relation, said hopper shell having a steep slope and a central outlet substantially at the bottom thereof in a plane normal to the axis of said shells, said axis further intersecting said plane at the center of said outlet, a right circular cap cone positioned in said bin shell in substantially coaxial relation thereto, an inverted right circular hopper cone positioned in said hopper shell in substantially coaxial relation thereto, said cones having bases substantially contiguous and positioned above the joint between said shells, said joint between said shells being positioned considerably closer to said bases of said cones than it is to said outlet, the base diameters of said respective cones being substantially equal and less than the internal diameter of said bin shell, means for holding said cones rigidly in substantially coaxial relation to said shells, the perimeter of the bases of said cones being horizontally and radially inwardly spaced from the inside of the lower end of said upper shell to provide an annular passage of somewhat increasing area in a downward direction between the base of said hopper cone and said joint between said shells, the lower end of said hopper cone being about at the level of said outlet, said hopper cone and said hopper shell having substantially coincident axes and together extending substantially directly to said outlet, the base interior angle of said hopper cone being steep and substantially at least as great as the base interior angle of said cap cone, the interior surfaces of said shells and the surfaces of said cones being smooth and the annular space therein relatively unimpeded.

2. In a solids flow system device for particulate materials such as moist coal or the like, apparatus comprising, in combination, an upright cylindrical bin shell open at the top and bottom, an inverted conical hopper shell, the lower end of said bin shell having an internal diameter substantially equal to the internal diameter of the upper end of said hopper shell, the lower end of said bin shell being joined to the upper end of said hopper shell in respective coaxial relation, said hopper shell having a steep slope and an outlet substantially at the bottom thereof extending at an angle to the axis of said hopper shell, said device substantially terminating at said outlet, an upright cap cone positioned with its base adjacent the lower end of said bin shell in rigid coaxial relation thereto, and an inverted hopper cone positioned in said hopper shell in rigid coaxial relation thereto with its base in substantially adjoining base to base relation with the base of said cap cone and the lower end of said hopper cone being adjacent said outlet, the bases of said respective cones being positioned above the junction of said shells, said junction being nearer said bases and farther from said outlet, the diameters of said bases being approximately equal and less than the internal diameter of said bin shell, the base interior angle of said hopper cone being substantially as steep as the slope of said hopper shell, said hopper cone and hopper shell defining a passage around said hopper cone which is relatively unimpeded to said outlet, said bases of said cones being horizontally and radially inwardly spaced from the inside of the lower end of said bin shell to provide an annular passage of somewhat increasing area downwardly at least between the base of said hopper cone and said junction of said bin and hopper shells.

3. In a solids flow system device for particulate materials, such as coal or other moisture-retaining substance, apparatus comprising, in combination, an upper shell with substantially vertical walls forming a lateral boundary, said upper shell being open at top and bottom and having a cone positioned generally uprightly adjacent at least the lower end thereof, said cone being spaced inwardly from the inside of said upper shell in fixed relation thereto, a lower shell forming a lateral boundary, said lower shell tapering steeply in a downward direction to an outlet for discharge therethrough, said outlet being at an angle to the axis of said lower shell adjacent the lower end thereof, said apparatus substantially terminating at said outlet, said lower shell at its upper end being at least as large as the lower end of said upper shell and joined thereto, an inverted cone positioned in said lower shell with the base of said inverted cone adjacent the base of said first-named cone and positioned above the joint between said shells, said joint between said shells being positioned considerably closer to said bases of said cones than it is to said outlet, the

lower end of said inverted cone being adjacent said outlet, said inverted cone being spaced inwardly from the inside of said lower shell in substantially immovable relation thereto, said bases of said cones being horizontally and radially inwardly spaced from the inside of the lower end of said upper shell to provide at least one passage of somewhat increasing area downwardly between said bases and the joint between said upper and lower shells, said inverted cone and the inside of said lower shell generally defining a steeply sloping inverted unimpeded conical passage, whereby when such a material is introduced into said upper shell it will flow downwardly by gravity for discharge through said outlet in a relatively solid flow having a cross section approximating that of said outlet.

4. In a solids flow device for particulate materials which relatively readily pack or arch, apparatus comprising, in combination, a laterally enclosing shell having a substantially vertical upper portion and a downwardly tapered lower portion, the angle of said taper to the horizontal being steeply sloped and at least equal to the angle of repose for said materials in loose condition relative to the substance of said shell, said shell having a substantially horizontal outlet at the lower end thereof for discharge therefrom, said apparatus substantially terminating at said lower end, a double conical member positioned in the middle of said shell, said member having the upper and lower portions thereof cone shaped in cross section with the lower such cone shaped portion being inverted and the respective bases of said portions substantially coinciding, said bases being positioned above the meeting line between said upper and lower portions of said shell, said meeting line between said shell portions being positioned considerably closer to said bases of said cone shaped portions than it is to said outlet, said inverted cone shaped portion forming an annular funnel-shaped unimpeded discharge passage with said lower portion of said shell and having its lower end in juxtaposition to said outlet, said bases being horizontally and radially spaced inwardly from said substantially vertical upper portion to define an annular passage portion of increasing area in a downward direction between the level of said bases and of said meeting line, and a selectively operable shut-off member for said outlet positioned in juxtaposition thereto.

5. In a solids flow system device for coal and other particulate materials, apparatus comprising, in combination, a shell forming a lateral boundary, said shell having at least an upper generally upright portion and a lower portion tapering in a substantially steep downward slope in the neighborhood of at least about 60° directly to an outlet extending across said shell at the lower end thereof for discharge therefrom, said device substantially terminating at said outlet, an upright cone member and an inverted cone member positioned in said shell substantially in base-to-base relation with the base of said inverted cone member positioned above the top of said tapering portion, said top of said tapering portion being positioned considerably closer to said cone bases than it is to said outlet, said inverted cone member extending downwardly in said shell to said outlet with a substantially steep slope, the exterior of said inverted cone member being substantially in inwardly spaced relation to the inside of the lower portion of said shell to define a passage around said inverted cone substantially unimpeded to said outlet, said passage decreasing in horizontal cross sectional area at a rate of approximately one square foot per unit of linear axial distance, said unit being chosen between the limits of about seven inches and about sixteen inches, extending toward said outlet within said lower tapering portion of said shell, said inverted cone member above said lower tapering portion of said shell further defining with the lower end of said upper upright portion of said shell a passage of increasing horizontal cross sectional area in a downward direction between the base of said inverted cone member and the top of said lower tapering portion, said base being inwardly spaced from the inside of said shell above said lower tapering portion.

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