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(54) **ENGINEERED TOP INFEED HOPPER SYSTEM**

(75) Inventors: **Christopher J. Lanning**, Federal Way, WA (US); **David N. Lanning**, Federal Way, WA (US)

(73) Assignee: **Forest Concepts, LLC**, Auburn, WA (US)

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Related U.S. Application Data

(63) Continuation-in-part of application No. 12/386,964, filed on Apr. 24, 2009, now abandoned.

(60) Provisional application No. 61/125,545, filed on Apr. 25, 2008.

(51) **Int. Cl.**
B30B 15/30 (2006.01)

(52) **U.S. Cl.** ..... **100/215**; 100/188 R; 100/245

(58) **Field of Classification Search** ..... 100/7, 178, 100/179, 188 R, 214, 215, 240, 245
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,827,353	A	8/1974	Isberg	
3,911,519	A	10/1975	Anlas et al.	
4,377,362	A	3/1983	Meinke	
4,463,667	A	8/1984	Jones	
4,467,712	A	8/1984	Fincham	
4,487,120	A *	12/1984	Barstow	100/40
4,572,064	A	2/1986	Burton	
4,594,942	A *	6/1986	Denneboom	100/137
4,771,540	A *	9/1988	LaBounty	30/134
4,991,498	A	2/1991	McCurdy	
5,193,454	A *	3/1993	Bollegraaf	100/142
5,243,901	A	9/1993	Green	
6,189,443	B1	2/2001	Hilford	
6,427,585	B1	8/2002	Brown et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

WO	89/10836 A1	11/1989

(Continued)

OTHER PUBLICATIONS

Beach, J. E., et al., The design and analysis of an infeed system for forest residue baler. Transactions of the ASAE, 28 (5)-1354-1357, 1985.

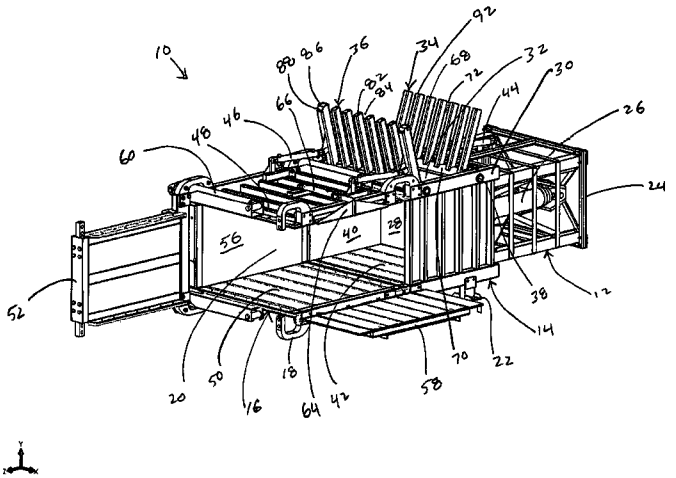
(Continued)

Primary Examiner — Jimmy T Nguyen
(74) *Attorney, Agent, or Firm* — Thomas F. Broderick

(57) **ABSTRACT**

A baler for making compacted bales of a cellulosic and preferably woody biomass material, the baler comprising: a housing defining a compaction chamber therein, wherein the housing comprises a top wall, an infeed opening defined in the top wall for introducing the material into the compaction chamber, and a hopper system comprising: first and second doors pivotably attached to the housing in opposing array over the infeed opening, wherein each door comprises a pivot having a plurality of fingers extending in planar array therefrom and defining a plurality of recesses disposed therebetween, and wherein the fingers of the first and second doors are staggered such that the fingers of each door are positioned opposite to and receivable by the recesses of the other door, and actuator means for pivoting the doors upwardly to form a chute for directing the material toward the infeed opening, and downwardly to intermesh and preferably interlock the fingers and substantially cover the infeed opening.

6 Claims, 8 Drawing Sheets



U.S. PATENT DOCUMENTS

6,779,570	B2	8/2004	Tardif
6,820,542	B1	11/2004	Truitt
7,752,960	B2	7/2010	Toor et al.
2005/0132667	A1	6/2005	McLeod et al.
2005/0145115	A1	7/2005	Garcia
2006/0086419	A1	4/2006	Aikins et al.
2007/0157825	A1	7/2007	Miller
2009/0007537	A1	1/2009	Savoie et al.

FOREIGN PATENT DOCUMENTS

WO	99/37474	A1	7/1999
WO	03/031167	A1	4/2003
WO	2007138165	A1	12/2007

OTHER PUBLICATIONS

Stuart, W.B. and T.A. Walbridge, A new approach to harvesting, transporting, and storing logging residues, in: Hardwood Symposium Proceedings, 6th Annual Proceedings, The Business of Growing and Aging Hardwoods, Madison, WI. Forest Products Society, pp. 74-83, 1978.

Stuart, W.B, et al., Economics of modifying harvesting systems to recover energy wood, Forest Products Journal 31 (8):37-42, 1981.

Walbridge, T.A., and W.B. Stuart. 1981. An alternative to whole tree chipping for the recovery of logging residues. In Proceedings of the International Conference "Harvesting and Utilization of Wood for Energy Purposes" at Elmia, Jonkoping, Sweden. Sep. 20-30, 1980. Garpenberg, Sweden: Swedish University of Agricultural Sciences.

Schiess, P., and K. Yonaka; Baling—a new concept in residue handling; Proceedings, First Technical conference on Timber Harvesting in Central Rockies, Ft. Collins, 29 pages, Jan. 4-6, 1983; pp. i-iii and 1-26.

Schiess, P., and W.E. Stuart; Baling of whole trees and/or residue as an alternative to in-woods chipping and/or residue treatment; Final Report submitted to Pacific Northwest Forest and Range Experimental Station, Seattle, WA, Jun. 1, 1983; pp. i-iii and 1-87.

Schiess, P., and K. Yonaka; Evaluation of industrial baling techniques for forest residue; Final Report to Department of Natural Resources, Olympia, WA, Jun. 30, 1983; pp. i-iv and 1-67.

Guimier, D.Y. 1985. Evaluation of forest biomass compaction systems. Special Report No. SR-30. ENFOR Project P-313. Pointe Claire, Canada: Forest Engineering Research Institute of Canada; pp. i-vii and 1-62, Aug. 1985.

Pottie, M.A., and D.L. Guimier, Harvesting and transport of logging residuals and residues, FERIC Special Report No. SR-33, IEA Cooperative Project No. CPC6, pp. i-vii and 1-62, May 1986.

Fridley, J.L., and T.H. Burkhardt, Densifying forest biomass into large round bales, Transactions of the ASAE 27(5):1277-1281, 1984.

John Deere 1490D Energy Wood Harvester, or "Bundler" www.deere.com/en_US/cfd/forestry/deere_forestry/harvesters/wheel/1490d_general.html Accessed Feb. 23, 2009.

Supertrak WB55 Biobaler https://www.timberbuysell.com/Community/DisplayAd.asp?id=2686 Accessed Nov. 7, 2008.

Dooley, J.H., M.S. DeTray, and D.N. Lanning. Mar. 2006. Technology to enable utilization of biomass from wildland-urban interface fuels reduction projects. Phase II: Field evaluation of baling vs. chipping. Auburn, WA: Forest Concepts, LLC.

Dooley, J.H., M.S. DeTray, D.N. Lanning, J.L. Fridley; Utilization of biomass from WUI fuels reduction: Biomass cpllection and handling from wildland-urban intermix projects on residential and suburban properties; Poster presented at SmallWood 2006, Richmond, VA, May 16, 2006.

Dooley, J.H., J.L. Fridley, D.N. Lanning. M.S. DeTray; Large rectangular bales for woody biomass; Paper No. 068054, presented at the 2007 ASABE Annual International Meeting, Portland, OR, Jul. 9-12, 2006.

Dooley, J.H., D.N. Lanning, C. Lanning, and M.S. DeTray; Transportation of biomass from wildland urban intermix (WUI): Biomass preprocessing and handling to reduce cost of transportation and add value; poster presented at Intermountain Roundwood Association Annual Meeting, Missoula, MT, 2007.

Lanning, D.N., J.H. Dooley, M.C. DeTray, and C.N. Lanning; Engineering factors for biomass baler design; ASABE Paper No. 078047, presented at the 2007 ASABE Annual International Meeting, Minneapolis, MI, Jun. 17-20, 2007.

Lanning, D., C. Lanning, J. Dooley, M. DeTray, T. Aristidou; Baling to improve transport of biomass from urban areas; poster presented at the Forest Innovation Conference, Missoula, MT, Apr. 25, 2008.

Dooley, J.H., D. Lanning, C. Lanning, J. Fridley; Biomass baling into large square bales for efficient transport, storage, and handling; paper presented at the Council on Forest Engineering 2008: 31st Annual Meeting, Charleston, SC, Jun. 22-25, 2008.

Van Pelt et al., Maize, soybean, and alfalfa biomass densification, Agricultural Engineering International: the CIGR Journal of Scientific Research and Development, Manuscript EE 03 002, May 2003.

* cited by examiner

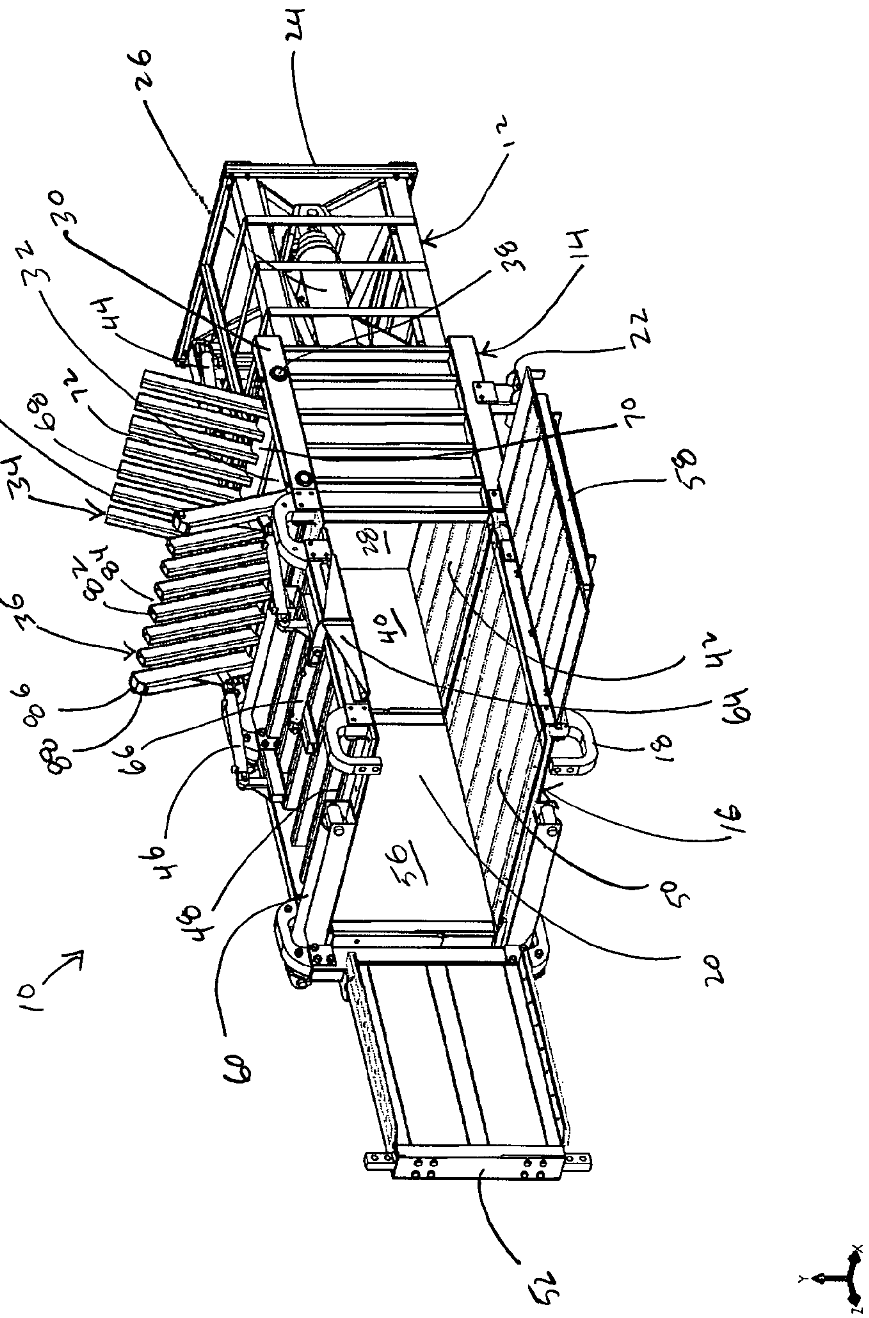


Figure 1

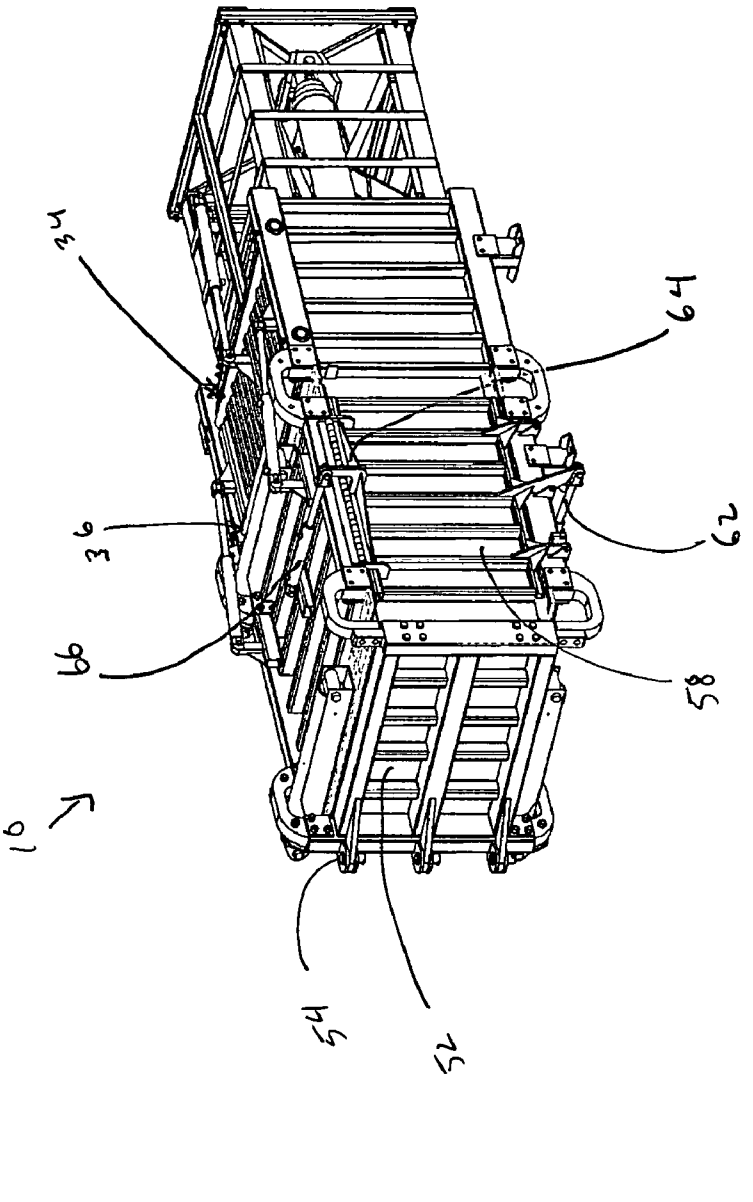


Figure 2

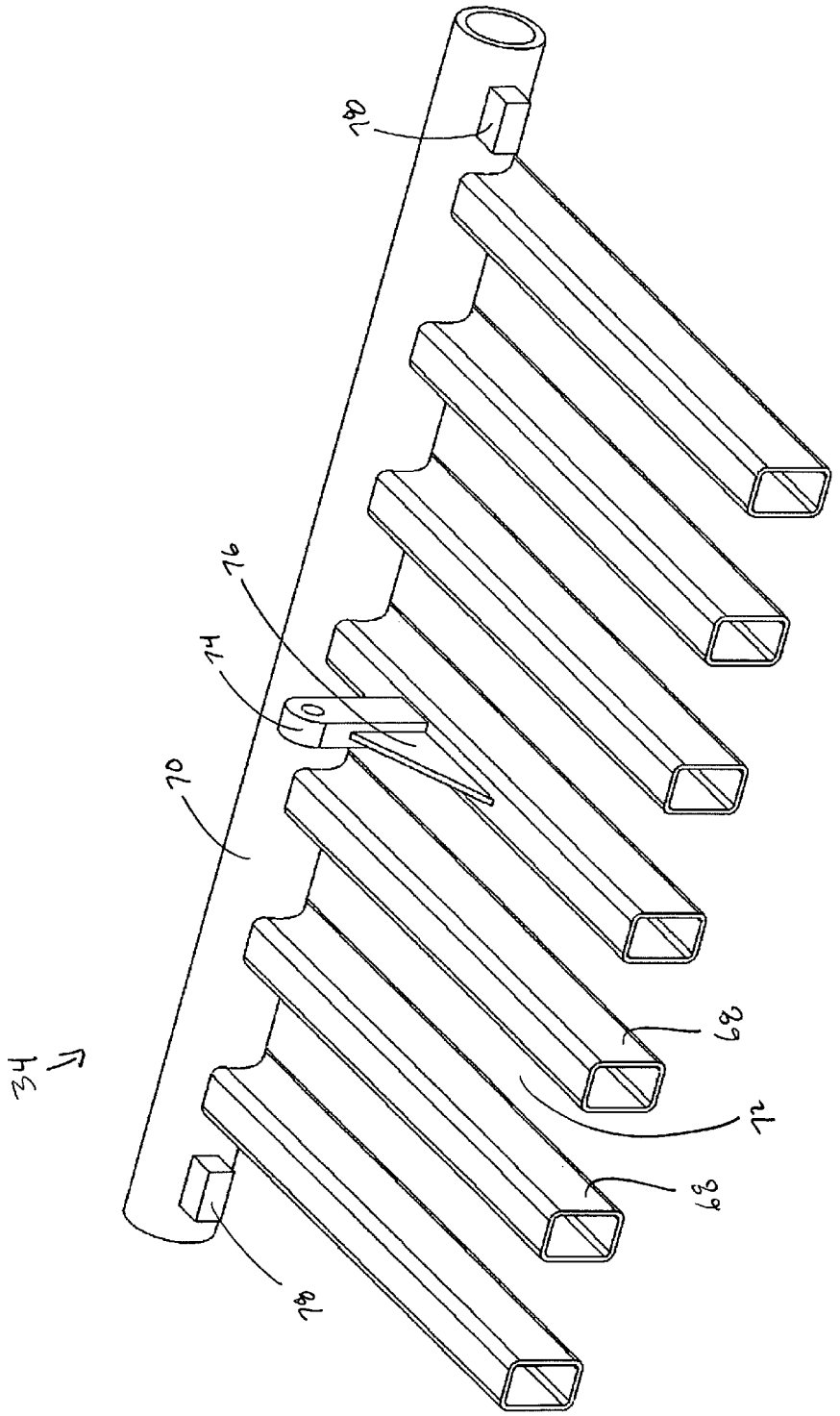


FIGURE 3

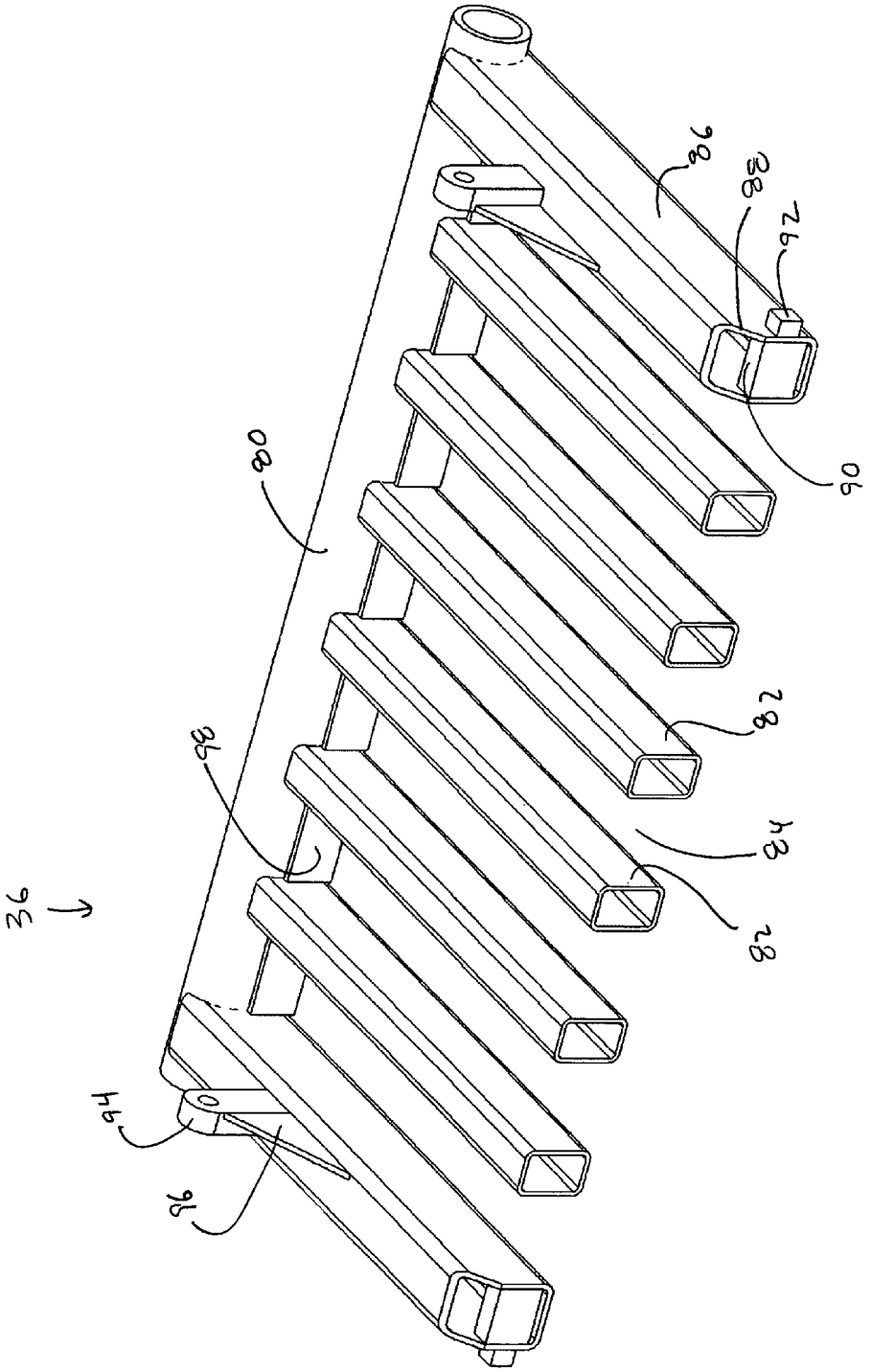


FIGURE 4

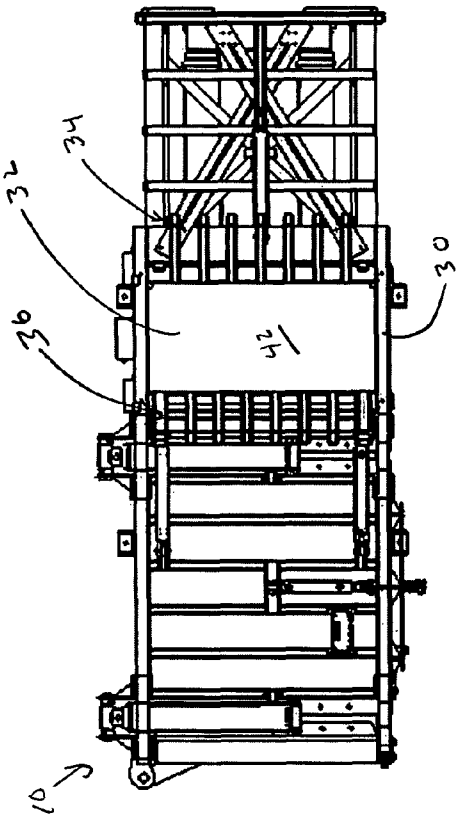


Figure 5

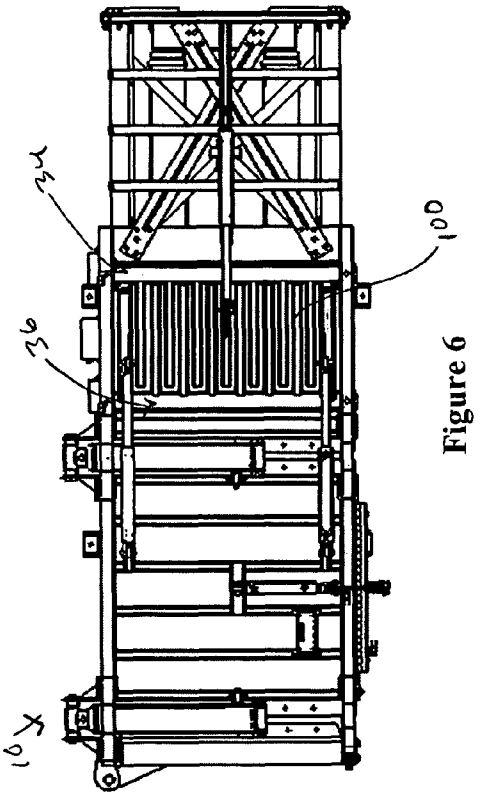


Figure 6

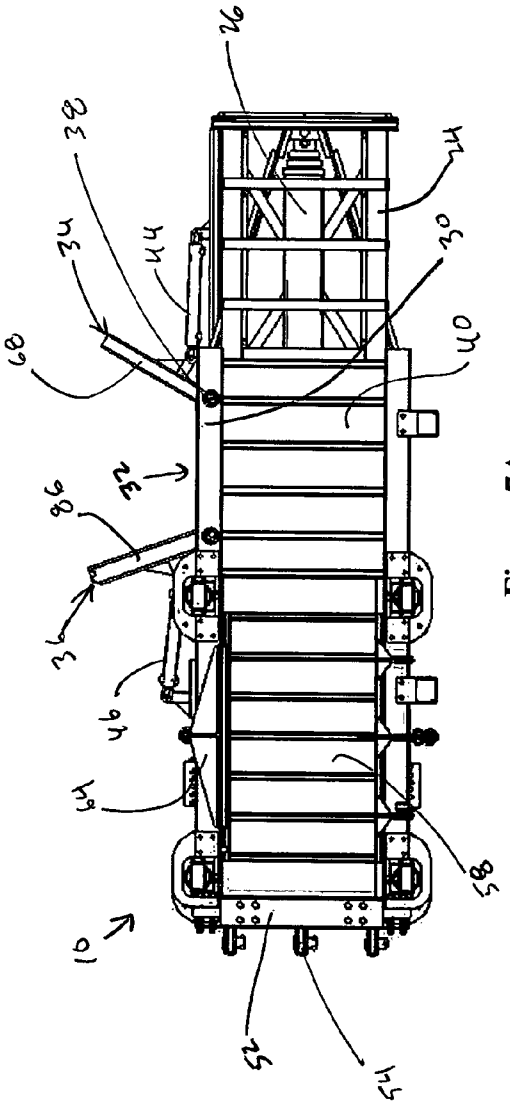


Figure 7A

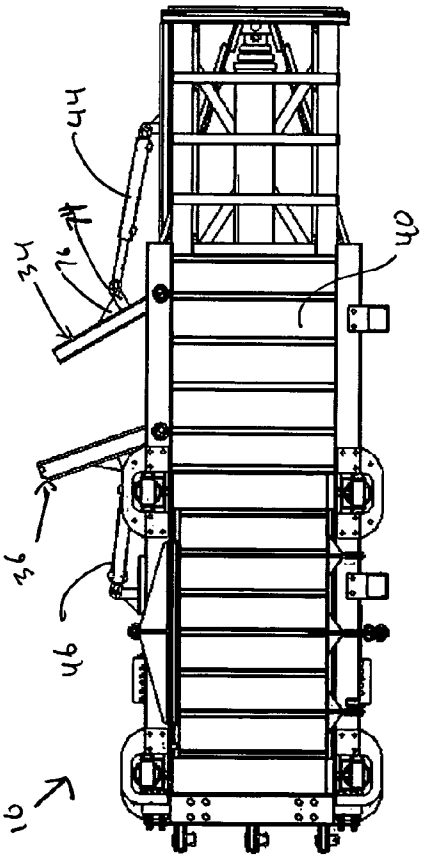


Figure 7B

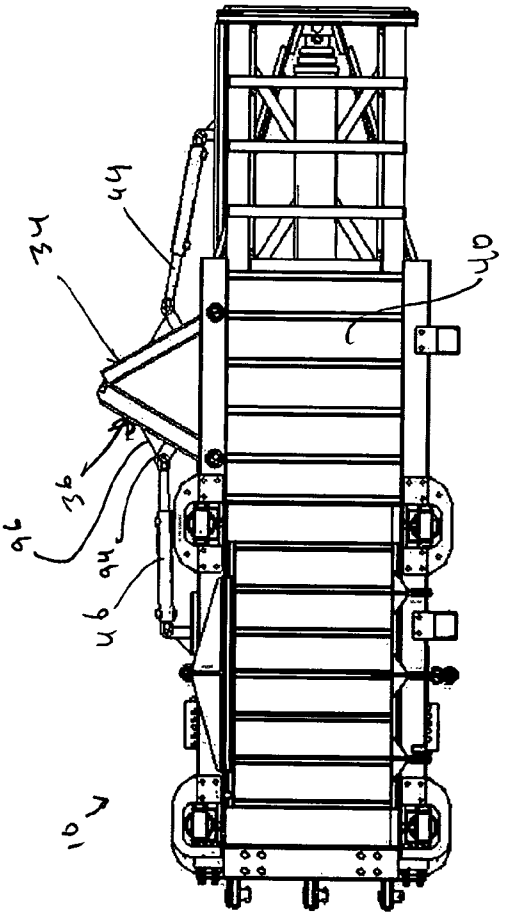


Figure 7C

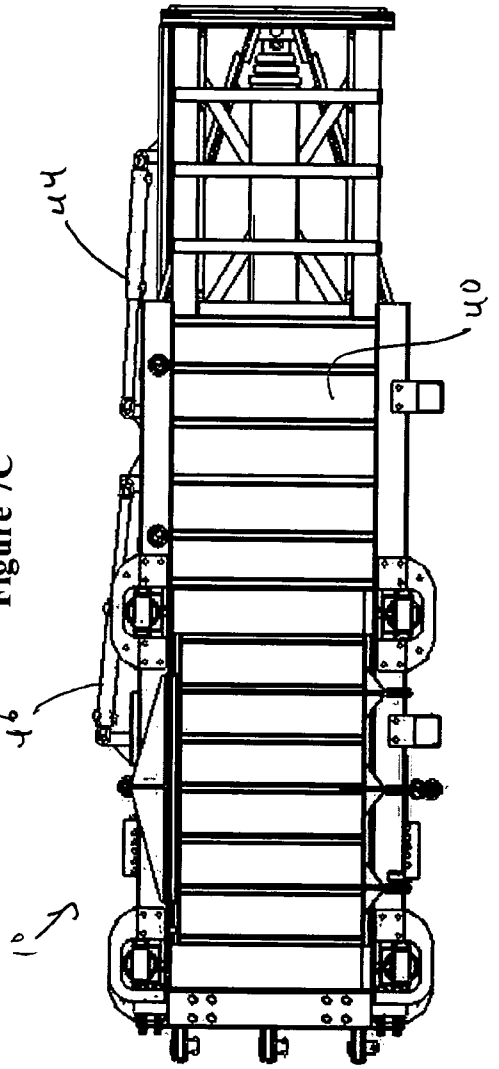


Figure 7D

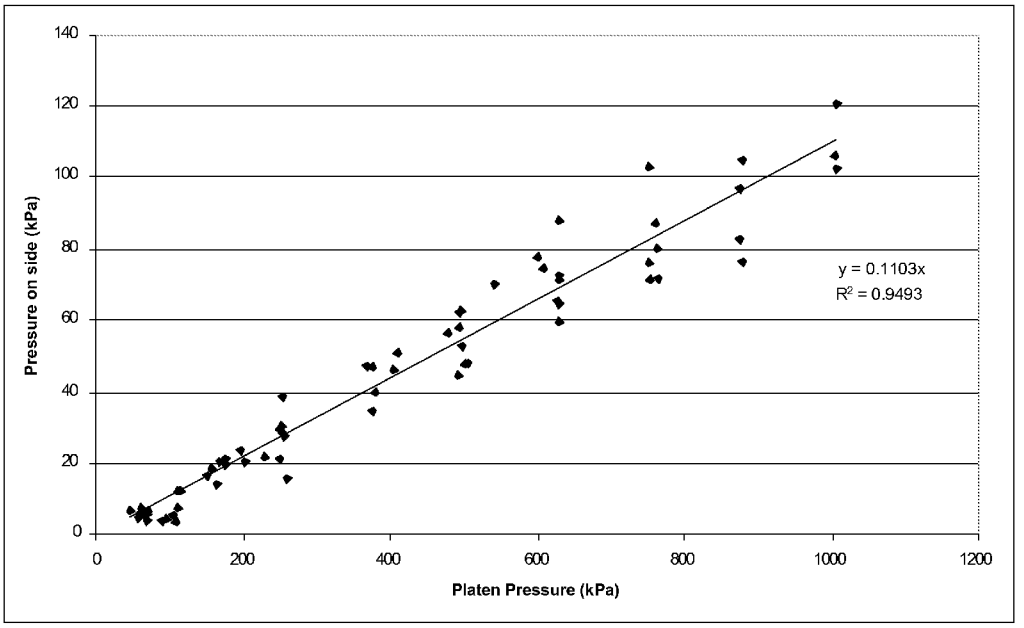

140
120
100
80
60
40
20
0
Pressure on side (kPa)
0
200
400
600
800
1000
1200
Platen Pressure (kPa)
y = 0.1103x
R2 = 0.9493

Figure 8

ENGINEERED TOP INFEED HOPPER SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part and claims priority from both patent application Ser. No. 12/386,964 filed Apr. 24, 2009 now abandoned, and provisional application No. 61/125,545 filed Apr. 25, 2008. This application also relates to patent application Ser. No. 12/386,807 filed Apr. 23, 2009, patent application Ser. No. 12/456,620 filed Jun. 19, 2009, patent application Ser. No. 12/887,916 filed Sep. 22, 2010, patent application Ser. No. 12/946,650 filed Nov. 15, 2010, patent application Ser. No. 12/969,125 filed Dec. 15, 2010, patent application Serial No. 13/013,929 filed Jan. 26, 2011, and patent application Serial No. 13/041,546 filed Mar. 7, 2011. The contents of each of these prior and related applications are hereby incorporated in their entireties by reference herein.

STATEMENT OF GOVERNMENT LICENSE RIGHTS

This invention was made with government support by the NIFA Small Business Innovation Research program of the U.S. Department of Agriculture, grant numbers 2005-33610-15483 and 2006-33610-17595. The government has certain rights in the invention.

FIELD OF THE INVENTION

Our invention relates to harvesters, particularly balers, and provides a top infeed hopper system engineered to receive and direct cellulosic and particularly woody biomass materials into a baling chamber.

BACKGROUND OF THE INVENTION

In 1978 forestry researchers at Virginia Polytechnic Institute (VPI) conducted field tests using a hay baler powered by the hydraulics of a knuckle-boom loader and concluded that baling offers considerable cost and operational advantages as a method of recovering forest residues for either fiber or fuel (1; see the appended Citations).

The VPI researchers then built and tested a prototype in-woods logging residue baler (2-7). Following testing of the VPI prototype baler in the North Western U.S.A. in the early 1980's, several design modifications were suggested for a "second generation" baler (8-9), including the need for a top infeed to allow processing of small size material (See (8) at pp. 29-30).

Various biomass bundlers and balers have been proposed in the patent literature (10). Presently the only commercial systems are a bundler, the John Deere 1490D Energy Wood Harvester (11), and a round baler, the SuperTrak WB55 Biobaler™ (12).

Particularly relevant to the present invention are the open top finger baler disclosures of Risoda Pty. Limited (13).

The present inventors have reported their progress under a federal contract from the USDA CSREES SBIR program to develop better methods to collect and transport woody biomass (14-20). Our goal has been to engineer more efficient recovery and transport of woody biomass to second-generation bioenergy and biofuel plants.

SUMMARY OF THE INVENTION

Here we describe an infeed hopper system suitable for receiving and directing cellulosic biomass materials into a baling chamber situated below the hopper. Our invention provides a baler for making compacted bales of a cellulosic and preferably woody biomass material, the baler comprising: a housing defining a compaction chamber therein, wherein the housing comprises a top wall, an infeed opening defined in the top wall for introducing the material into the compaction chamber, and a hopper system comprising: first and second doors pivotably attached to the housing in opposing array over the infeed opening, wherein each door comprises a pivot having a plurality of fingers extending in planar array therefrom and defining a plurality of recesses disposed therebetween, and wherein the fingers of the first and second doors are staggered such that the fingers of each door are positioned opposite to and receivable by the recesses of the other door, and actuator means for pivoting the doors upwardly to form a chute for directing the material toward the infeed opening, and downwardly to intermesh and preferably interlock the fingers and substantially cover the infeed opening.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevated view of a representative biomass baler with open hopper doors;

FIG. **2** shows the baler of FIG. **1** with closed hopper doors;

FIG. **3** is an isolated view of the front hopper door;

FIG. **4** is an isolated view of the rear hopper door;

FIG. **5** is a top view of the baler of FIG. **1** with open hopper doors;

FIG. **6** shows the baler of FIG. **5** with closed hopper doors;

FIGS. **7**A-**7**D depict a representative sequence for closing the hopper doors; and

FIG. **8** is a pressure ratio graph.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

We have applied engineering design principles to the long-felt need of providing a top infeed system for cellulosic and particularly woody biomass balers.

The term "cellulosic biomass" as used herein refers generally to encompass all plant materials harvested by baling for use as industrial feedstocks, including woody biomass, energy crops like switchgrass, miscanthus, and hemp, and agricultural crop residues including corn stover.

The term "woody biomass" as used herein refers to all parts of trees, shrubs and woody plants useable as industrial feedstocks for fiber, bioenergy, and biofuels, including timber harvest residues and land clearing debris, small-diameter trees, shrubs and brush, dedicated energy crops like willow and poplar, tree service prunings, and residential green waste.

The following Table lists the reference numerals used in the description of the currently preferred embodiment that is shown in the FIGURES.

10	baler
12	platen assembly
14	infeed chamber assembly
16	compaction chamber assembly
18	connector
20	baling chamber
22	foot
24	framework, platen assembly
26	hydraulic cylinder, compression
28	platen, compression
30	framework, upper infeed

-continued

	chamber assembly
32	infeed opening
34	hopper door, front
36	hopper door, rear
38	hinge pin
40	side wall, infeed chamber assembly
42	floor plate, infeed chamber assembly
44	cylinder, front hopper door
46	cylinder, rear hopper door
48	upper wall, compression chamber assembly
50	lower wall, compression chamber assembly
52	door, contingency
54	hinge
56	platen, ejection
58	door, discharge
60	hydraulic cylinder, ejection
62	hydraulic cylinder, discharge
64	door latch
66	hydraulic cylinder, door latch
68	finger, front door
70	pivot, front door
72	recess, front door
74	bracket, front door
76	gusset, front door
78	latch bar, front door
80	pivot, rear door
82	finger, rear door
84	recess, rear door
86	latch finger, rear door
88	notch
90	internal stop
92	external stop
94	bracket, rear door
96	gusset, rear door
98	shear bar
100	gap

FIG. **1** shows a representative biomass baler **10** that we designed and constructed under the aforementioned Department of Agriculture grant. The baler **10** receives woody and other cellulosic biomass materials, compacts the biomass materials into parallelepiped bales, and discharges the bales. The baler **10** is preferably constructed of three separate modules, a platen assembly **12**, an infeed chamber assembly **14**, and a compaction chamber assembly **16**, that are bolted together by metal connectors **18**. The infeed chamber assembly **14** is in open communication with the compaction chamber assembly **16** and together house a baling chamber **20**. Modular construction makes it convenient to repair or replace failed components, or replace the compaction chamber assembly **16** with alternative modules configured to produce shorter or longer bales. Also shown is one of four steel feet **22** by which the baler **10** can be bolted to, e.g., a trailer bed (not shown) or framework for stationary use.

Nomenclature with respect to the baler **10** shown in the FIGURES: toward the platen assembly **12** is referred to herein for illustrative purposes as "front", and toward the compaction chamber assembly **16** as "rear".

The platen assembly **12** has a welded steel framework **24** that anchors and supports two telescoping hydraulic cylinders **26** (three-stage: 6, 5, and 4 inches) that attach to and move a compression platen **28** reciprocally through the baling chamber **20**.

When fully retracted (as shown in this view) the compression platen **28** forms the front wall of the infeed chamber assembly **14**. The infeed chamber assembly **14** has an upper framework **30** that demarcates a large rectangular infeed opening **32**. A pair of closeable hopper doors **34**, **36** is mounted in opposing array over the infeed opening **32**. Each of the doors **34**, **36** is pivotally connected to the framework **30** by a hinge pin **38**. When raised (as shown here), the hopper doors **34**, **36** create an open chute through which a grapple loader (not shown) can drop and push biomass materials through the infeed opening **32** into the baling chamber **20**. When closed (see FIGS. **2** and **6**), the hopper doors **34**, **36** intermesh and preferably interlock together in horizontal planar array so as to substantially close the infeed opening **32** and thereby form an upper wall of the infeed chamber assembly **14** without obstructing transit of the compression platen **28**.

The infeed chamber assembly **14** also has two side walls **40** and a floor plate **42** that, together with the retracted compression platen **28** and the upper framework **30** with closed hopper doors **34**, **36** define the front end or infeed compartment of the baling chamber **20**. Construction and operation of the hopper doors **34**, **36** is discussed in detail below. Shown here is a single 2" hydraulic cylinder **44** that moves the front hopper door **34**, and two 2" hydraulic cylinders **46** that move the rear hopper door **36**.

The compaction chamber assembly **16** houses the rear end or compression compartment of the baling chamber **20**. The compaction chamber assembly **16** has fixed upper and lower walls **48**, **50**. The rear wall or end cap is configured as a contingency door **52** (shown open) that is mounted on lateral hinges **54**. The contingency door **52** is bolted shut during the baling process but can be manually opened, if need be, to remove defective bales from the baling chamber **20**; and for this purpose the compression hydraulic cylinders **26** are configured to push the compression platen **28** at least the entire length of the compaction chamber assembly **16**.

An ejection platen **56** and a discharge door **58** form the sidewalls of the compaction chamber assembly **16**. When bale formation is completed, the discharge door **58** is cantilevered downward into a horizontal platform (as shown in this view). Two pairs of telescopic hydraulic cylinders **60** (two stage: 4 and 3 inches) then move the ejection platen **56** to push the bale across the compaction chamber assembly **16** and onto the opened discharge door **58**.

FIG. **2** shows the baler **10** with the hopper doors **34**, **36**, contingency door **52**, and side discharge door **58** in the closed positions. Shown also is a 2" hydraulic cylinder **62** that lowers and raises the discharge door **58**, which is secured closed by a hinged upper door latch **64** that is controlled by a 2" hydraulic cylinder **66**.

FIG. **3** is an isolated view of the front hopper door **34**. In this illustrative embodiment, seven fingers **68** of rectangular steel tube are welded in parallel array to a pivot **70** of rounded steel tube, which houses one of the hinge pins **38**. The fingers **68** are positioned along the pivot **70** to create a plurality of recesses **72** therebetween. A bracket **74** with supporting gusset **76** on the upper surface of one of the fingers **68** provides an attachment point for the hydraulic cylinder **44**. A pair of latch bars **78** is welded to the pivot **70** in the same plane as the fingers **68** and near the outermost ends of the pivot **70**.

FIG. **4** shows the corresponding rear hopper door **36**, which also has a pivot **80** with in this embodiment six tubular fingers **82** forming a planar array of interposed recesses **84**. Notably, these fingers **82** are staggered in position with respect to the fingers **68** of the opposing front hopper door **34** such that the fingers of each door are positioned opposite to and receivable by the recesses of the other door (as shown in FIG. **5**). Preferably the pivot **80** is provided with an outermost pair of latch fingers **86** that are sized and positioned to receive and contain the latch bars **78** on the opposing front hopper door **34**, in order to interlock the doors **34**, **36** in a horizontal closed position over the infeed opening **32**. For that purpose the latch

fingers **86** are provided with a notch **88** and an internal stop **90**. The notch **88** receives the pivoting latch bar **78** against the internal stop **90** as the doors **34**, **36** approach and reach the fully closed position. The outer sides of the latch fingers **86** are provided with external stop bars **92** that help position the rear hopper door **36** (and the closed, intermeshed doors **34**, **36**) within the framework **30** surrounding the infeed opening **32**. The rear hopper door **36** also has a pair of brackets **94**, with supporting gussets **96**, which serve as attachment sites for the hydraulic cylinders **46**. Preferably the rear hopper door **36** is also provided with shear bars **98** that are mounted on the pivot **80** within the recesses **84** between the fingers **68**, **86**.

FIG. **5** is a top view of the baler **10** showing the hopper doors **34**, **36** in the raised and chute-forming positions to guide biomass materials through the uncovered infeed opening **32** into the baling chamber **20**. The hopper door pivots **70**, **80** are preferably aligned parallel to the compression platen **28**.

FIG. **6** is a top view of the baler **10** showing the hopper doors **34**, **36** in the closed and locked position.

FIGS. **7**A-**7**D are side views of the baler **10** showing a representative sequence for closing the hopper doors **34**, **36**. FIG. **7**A shows the hopper doors **34**, **36** in the raised positions. We have found that for loading woody biomass or switchgrass the front and rear hopper doors **34**, **36** are preferably pivoted to positions about 120° and 105°, respectively, above the framework **30**. When the infeed chamber assembly **14** has been loaded with biomass materials, the front hopper door **34** is partially closed to a position about 55° above the framework **30**, as shown in FIG. **7**B. This pivoting movement of the front hopper door **34** sweeps any overflowing biomass material toward the rear hopper door **36**. The rear hopper door **36** is pivoted to a position about 45° closed, which sweeps the material against the front hopper door **34** and entraps the material under the arched hopper doors **34**, **36**, as shown FIG. **7**C. These pivoting movements may be coordinated to be concurrent, at appropriate cylinder velocities, or sequenced stepwise.

The hopper doors **34**, **36** are then pivoted concurrently into full horizontal closure (FIG. **7**D). These closing movements are coordinated so that the rear hopper door **36** reaches horizontal first, thereby presenting its notched latch fingers **86** for engagement by the door latches **64** on the first hopper door **34**.

As the overlapping hopper doors **34**, **36** press the overflowing biomass material downward through the infeed opening **32**, there is an opportunity for some of the material to become entrapped between the fingers **68**, **82**, **86** and within the closing recesses **72**, **84**. We have found that configuring the hopper doors **34**, **36** so that about a one inch gap **100** of recess space **72**, **84** remains between the fully intermeshed fingers **68**, **82**, **86** is suitable for woody biomass materials like arborist tree trimmings. Any such materials that become entrapped between the framework **30** and the outer latch bars **78** or the rear pivot **80** tend to be pulled into the baling chamber **20** as the compression platen **28** advances, and any materials entrapped between the front pivot **70** and the frame **30** are pushed and broken off against the rear shear bars **98**. For forestry applications the latch fingers **86** can additionally be provided with edged shear bars, knives, or slashing saws (not shown), as can any of the fingers **68**, **82**.

EXAMPLE

Following bill of materials is for the hopper door assembly shown in the FIGURES, sized for an infeed opening **32** measuring 48" wide×30" long.

REF #	PART NAME	DESCRIPTION
34	Front hopper door	
70	Pivot	3.25" × 0.375" × 48" tube
68	Fingers (7)	2" × 3" × 3/16" × 24" tube
74	Bracket (1)	1" × 2" × 5.125" bar, 1" radius
76	Gusset (1)	1/4" × 3" × 5.2" plate
78	Latch bars (2)	1" × 1.25" × 2" bar
44	Hydraulic (1)	2" dual acting cylinder = 16"; 3000 psi
36	Rear hopper door	
80	Pivot (1)	3.25" × 0.375" × 48" tube
82	Fingers (6)	2" × 3" × 3/16" × 25" tube
86	Latch fingers (2)	3" × 4" × 1/4" × 25" tube
94	Brackets (2)	1" × 2.5" × 4.25" bar
96	Gussets (2)	1/4" × 3" × 5.2" plate
98	Shear bars (6)	2" × 2" × 1/4" × 4" angle
90	Internal stops (2)	1" × 1.625" × 2.5" bar
92	External stops (2)	3/4" × 1" × 1" bar
46	Hydraulics (2)	2" dual acting cylinder × 16"; 3000 psi
38	Hinge pins (2)	2" schedule 80 steel pipe x 55"

FIG. **8** is a pressure ratio graph. Each data point represents a peak pressure reached while making a single flake of a bale of WoodStraw™ in a bench top baler. This is a compellation of 13 bales made at different compression pressures. From the axial pressure to side pressure ratio trend observed in those experiments we estimate ν=0.11 (the pressure ratio coefficient analogous to Poisson's ratio for homogeneous solids).

CITATIONS

The contents of each of the following publications are incorporated in their entireties by reference herein.

(1) Stuart, W. B. and T. A. Walbridge, A new approach to harvesting, transporting, and storing logging residues, in: Hardwood Symposium Proceedings, 6th Annual Proceedings, The Business of Growing and Aging Hardwoods, Madison, Wis. Forest Products Society, pp. 74-83, 1978.

(2) Stuart, W. B, et al., Economics of modifying harvesting systems to recover energy wood, Forest Products Journal 31(8):37-42, 1981.

(3) Walbridge, T. A., and W. B. Stuart. 1981. An alternative to whole tree chipping for the recovery of logging residues. In Proceedings of the International Conference "Harvesting and Utilization of Wood for Energy Purposes" at Elmia, Jonkoping, Sweden. Sep. 20-30, 1980. Garpenberg, Sweden: Swedish University of Agricultural Sciences.

(4) Schiess, P., and K. Yonaka. 1982. Evaluation of new concepts in biomass fiber transport. In Progress in Biomass Conversion, Vol. III., edited by K. V. Sarkanen, D. A. Tillman and E. C. Jahn. New York: Academic Press.

(5) Schiess, P., and K. Yonaka; Baling—a new concept in residue handling; Proceedings, First Technical conference on Timber Harvesting in Central Rockies, Ft. Collins, 29 pages, Jan. 4-6, 1983; pp. i-iii and 1-26.

(6) Schiess, P., and W. E. Stuart; Baling of whole trees and/or residue as an alternative to in-woods chipping and/or residue treatment; Final Report submitted to Pacific Northwest Forest and Range Experimental Station, Seattle, Wash., Jun. 1, 1983; pp. i-iii and 1-87.

(7) Schiess, P., and K. Yonaka; Evaluation of industrial baling techniques for forest residue; Final Report to Department of Natural Resources, Olympia, Wash., Jun. 30, 1983; pp. i-iv and 1-67.

(8) Guimier, D. Y. 1985. Evaluation of forest biomass compaction systems. Special Report No. SR-30. ENFOR Project P-313. Pointe Claire, Canada: Forest Engineering Research Institute of Canada.

(9) Pottie, M. A., and D. L. Guimier, Harvesting and transport of logging residuals and residues, FERIC Special Report No. SR-33, IEA Cooperative Project No. CPC6, pp. i-vii and 1-62, May 1986.

(10) U.S. Pat. No. 3,827,353 entitled CHRISTMAS TREE BALING MACHINE; U.S. Pat. No. 3,911,519 entitled LEAF COLLECTOR AND BALER; U.S. Pat. No. 4,377,362 entitled DEVICE FOR BUNDLING FIREWOOD; U.S. Pat. No. 4,463,667 entitled LOG BUNDLING APPARATUS; U.S. Pat. No. 4,467,712 entitled WOOD BALER; U.S. Pat. No. 4,572,064 entitled BRUSH BUNDLING SYSTEM; U.S. Pat. No. 4,991,498 entitled LEAF BALER; U.S. Pat. No. 5,243,901 entitled FIREWOOD BANDING MACHINE; U.S. Pat. No. 6,189,443 B1 entitled PRUNING BALER; U.S. Pat. No. 6,427,585 B1 entitled METHOD AND APPARATUS FOR MEASURING THE LENGTH OF A WASTE LOG AND/OR WEIGHT OF WASTE LOG WHILE COMPACTING AND TRANSFERRING THE WASTE LOG FOR TRANSPORT; U.S. Pat. No. 6,779,570 B2 entitled WOOD GATHERING AND COMPACTION VEHICLE; U.S. Pat. No. 6,820,542 B1 entitled LEAF COMPACTOR AND BALER; US 2005/0132667 A1 entitled COLLECTION AND STACKING OF LUMBER PIECES FROM THE GROUND; US 2006/0086419 A1 entitled MOBILE HIGH-SPEED BIOMASS PROCESSOR FOR CHUNKWOOD WITH INTEGRAL CHUNKWOOD BALER; US 2007/0157825 A1 entitled FOLIAGE COMPACTOR; WO 2007/138165 A1 entitled METHOD AND ARRANGEMENT FOR HARVESTING; and particularly US 2005/0145115 A1 entitled MACHINE FOR THE RECOVERY OF FOREST, AGRICULTURAL AND/OR URBAN WASTE.

(11) www.deere.com/en_US/cfd/forestry/deere_forestry/harvesters/whee1/1490d_general.html Accessed 23 Feb. 2009.

(12) https://www.timberbuysell.com/Community/DisplayAd.asp?id=2686
Accessed 7 Nov. 2008; see also US 2009/0007537 entitled DEVICE AND METHOD FOR HARVESTING WOODY CROPS.

(13) WO 03/031167 A1 entitled OPEN TOP FINGER BALER; WO 99/37474 entitled IMPROVED BALING PRESS; and WO 89/10836 entitled BALING PRESS.

(14) Dooley, J. H., M. S. DeTray, and D. N. Lanning. March 2006. Technology to enable utilization of biomass from wildland-urban interface fuels reduction projects. Phase II: Field evaluation of baling vs. chipping. Auburn, Wash.: Forest Concepts, LLC.

(15) Dooley, J. H., M. S. DeTray, D. N. Lanning, J. L. Fridley; Utilization of biomass from WUI fuels reduction: Biomass collection and handling from wildland-urban intermix projects on residential and suburban properties; Poster presented at SmallWood 2006, Richmond, Va., May 16, 2006.

(16) Dooley, J. H., J. L. Fridley, D. N. Lanning. M. S. DeTray; Large rectangular bales for woody biomass; Paper No. 068054, presented at the 2007 ASABE Annual International Meeting, Portland, Oreg., Jul. 9-12, 2006.

(17) Dooley, J. H., D. N. Lanning, C. Lanning, and M. S. DeTray; Transportation of biomass from wildland urban intermix (WUI): Biomass preprocessing and handling to reduce cost of transportation and add value; poster presented at Intermountain Roundwood Association Annual Meeting, Missoula, Mont., 2007.

(18) Lanning, D. N., J. H. Dooley, M. C. DeTray, and C. J. Lanning; Engineering factors for biomass baler design; ASABE Paper No. 078047, presented at the 2007 ASABE Annual International Meeting, Minneapolis, Mich., Jun. 17-20, 2007.

(19) Lanning, D., C. Lanning, J. Dooley, M. DeTray, T. Aristidou; Baling to improve transport of biomass from urban areas; poster presented at the Forest Innovation Conference, Missoula, Mont., Apr. 25, 2008.

(20) Dooley, J. H., D. Lanning, C. Lanning, J. Fridley; Biomass baling into large square bales for efficient transport, storage, and handling; paper presented at the Council on Forest Engineering 2008: 31st Annual Meeting, Charleston, S.C., Jun. 22-25, 2008.

While the preferred embodiment of the invention has been illustrated and described, it will be appreciated that various changes can be made therein without departing from the spirit and scope of the invention.

We claim:

1. A baler for making compacted bales of a cellulosic biomass material, the baler comprising:
- a housing defining a compaction chamber therein, wherein the housing comprises a top wall,
- an infeed opening defined in the top wall for introducing the material into the compaction chamber, and
- a hopper system comprising:
  - first and second doors pivotably attached to the housing in opposing array over the infeed opening,
    - wherein each door comprises a pivot having a plurality of fingers extending in planar array therefrom and defining a plurality of recesses disposed therebetween,
    - wherein the fingers of the first and second doors are staggered such that the fingers of each door are positioned opposite to and receivable by the recesses of the other door, and
    - wherein at least one of the doors is provided with a shear bar, knife, or saw, and
  - actuator means for pivoting the doors upwardly to form a chute for directing the material toward the infeed opening, and downwardly to intermesh the fingers and substantially cover the infeed opening.

2. The baler of claim **1**, wherein the doors interlock as the fingers intermesh.

3. The baler of claim **1**, wherein the actuator means can pivot the first and second doors independently of one another.

4. A baler for making compacted bales of a woody biomass material, the baler comprising:
- a housing defining a compaction chamber therein, wherein the housing comprises a top wall,
- an infeed opening defined in the top wall for introducing the material into the compaction chamber, and
- a hopper system comprising:
  - first and second doors pivotably attached to the housing in opposing array over the infeed opening,
    - wherein each door comprises a pivot having a plurality of fingers extending in planar array therefrom and defining a plurality of recesses disposed therebetween,
    - wherein the fingers of the first and second doors are staggered such that the fingers of each door are positioned opposite to and receivable by the recesses of the other door, and
    - wherein at least one of the doors is provided with a shear bar, knife, or saw, and
  - actuator means for pivoting the doors upwardly to form a chute for directing the material toward the infeed opening, and downwardly to intermesh the fingers and substantially cover the infeed opening.

5. The baler of claim **4**, wherein the doors interlock as the fingers intermesh.

6. The baler of claim **4**, wherein the actuator means can pivot the first and second doors independently of one another.

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