IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF PENNSYLVANIA

OPEX CORPORATION, Plaintiff, v. INVATA, LLC and HC ROBOTICS, Defendants.	Civil Action No. ____________ **JURY TRIAL DEMANDED**

COMPLAINT

Plaintiff OPEX Corporation ("OPEX"), for its Complaint against Defendants Invata, LLC (*d/b/a*, Invata Intralogistics) ("Invata") and HC Robotics (*a.k.a.*, Huicang Information Technology Co., Ltd.) ("HC Robotics") (individually or collectively, "Defendant(s)") hereby alleges as follows:

The Parties

1. Plaintiff OPEX is a New Jersey corporation with its principal place of business at 305 Commerce Drive, Moorestown, NJ 08057.

2. On information and belief, Defendant Invata LLC is a Pennsylvania limited liability company with its principal place of business at 1010 Spring Mill Avenue, Suite 300, Conshohocken, PA 19428.

3. On information and belief, Defendant HC Robotics is a company organized and existing under the laws of the People's Republic of China, with its principal place of business located at 3rd Floor, Haiwei Building, No. 101 Binkang Road, Binjiang District, Hangzhou City, Zheijang Province, China.

Related Litigation

4. OPEX has concurrently filed an action in the U.S. International Trade Commission captioned *In the Matter of Certain Automated Put Walls and Automated Storage and Retrieval Systems, Associated Vehicles, Associated Control Software, and Components Thereof*. That ITC action involves accusations of infringement against the same parties (*i.e.,* Invata and HC Robotics) and the same products (*i.e.,* Defendants' Omnisort system) under five of the same seven patents asserted here.

Nature of the Action

5. This is a civil action for infringement of seven United States patents, arising under the Patent Laws of the United States, 35 U.S.C. § 1 *et seq*.

Jurisdiction and Venue

6. This Court has jurisdiction over the subject matter of this action pursuant to 28 U.S.C. §§ 1331 and 1338(a).

7. Venue is proper in this district pursuant to 28 U.S.C. §§ 1391(b) and (c), and 1400(b), because Defendant Invata resides in this district, is subject to personal jurisdiction in this district, and has committed acts of infringement in this district.

8. Venue is proper in this district pursuant to 28 U.S.C. §§ 1391(b) and (c), and 1400(b), because Defendant HC Robotics is not a resident of the United States, is subject to personal jurisdiction in this district, and has committed acts of infringement in this district.

The Patents-In-Suit

9. United States Patent No. 7,861,844 ("the '844 patent"), entitled "Method and apparatus for sorting items," was duly and legally issued by the United States Patent and Trademark Office on January 4, 2011. A copy of the '844 patent is attached hereto as Exhibit A.

10. United States Patent No. 8,104,601 (“the ’601 patent”), entitled “Method and apparatus for delivering items to destination areas,” was duly and legally issued by the United States Patent and Trademark Office on January 31, 2012. A copy of the ’601 patent is attached hereto as Exhibit B.

11. United States Patent No. 8,276,740 (“the ’740 patent”), entitled “Material handling apparatus for sorting or retrieving items,” was duly and legally issued by the United States Patent and Trademark Office on October 2, 2012. A copy of the ’740 patent is attached hereto as Exhibit C.

12. United States Patent No. 8,622,194 (“the ’194 patent”), entitled “Material handling apparatus for delivering or retrieving items,” was duly and legally issued by the United States Patent and Trademark Office on January 7, 2014. A copy of the ’194 patent is attached hereto as Exhibit D.

13. United States Patent No. 9,687,883 (“the ’883 patent”), entitled “Material handling apparatus for delivering or retrieving items,” was duly and legally issued by the United States Patent and Trademark Office on June 27, 2017. A copy of the ’883 patent is attached hereto as Exhibit E.

14. United States Patent No. 10,576,505 (“the ’505 patent”), entitled “Material handling apparatus for delivering or retrieving items,” was duly and legally issued by the United States Patent and Trademark Office on March 3, 2020. A copy of the ’505 patent is attached hereto as Exhibit F.

15. United States Patent No. 11,192,144 (“the ’144 patent”), entitled “Material handling apparatus for delivering or retrieving items,” was duly and legally issued by the United

States Patent and Trademark Office on December 7, 2021. A copy of the ’144 patent is attached hereto as Exhibit G.

16. The ’844 patent, ’601 patent, ’740 patent, ’194 patent, ’883 patent, ’505 patent, and ’144 patent are collectively referred to herein as the “patents-in-suit” or “Asserted Patents.”

17. OPEX is the exclusive owner of all right, title, and interest in each of the patents-in-suit, and has the right to bring this suit for injunctive relief and to recover damages for any current or past infringement of each of the patents-in-suit.

Defendants’ Infringing Activities

18. On information and belief, Defendants are engaged in making, using, offering to sell, and/or selling within the United States, and/or importation into the United States, of automated put walls and automated storage and retrieval systems, and their associated vehicles, associated control software, and component parts, including, without limitation, the Omnisort system and its associated vehicles, associated control software, and component parts (individually or collectively, the “Accused Products”), that infringe at least one valid, enforceable claim of each of the Asserted Patents.

19. Defendant HC Robotics offers the Omnisort system on its website, copies of which are attached as Exhibits H and I.

20. Defendant Invata offers automated put walls for sale on its website, a copy of which is attached as Exhibit J.[1]

21. Defendants imported an Omnisort product into the United States, originating from a port in Shanghai, China and arriving at a port in Long Beach, California on July 4, 2021. Exhibit

[1] On information and belief, Invata’s automated put walls are HC Robotics’s Omnisort Product. (*See, e.g.*, Ex. K, Ex. L.)

K is a copy of an importation record confirming this importation. Further, on information and belief, Invata subsequently sold and installed this Omnisort system in San Francisco, California. Exhibit L is the Declaration of Staci Dresher, a licensed private investigator, confirming this sale. As further confirmed by Ms. Dresher's attached declaration, Defendants have already imported and sold, or intend to import and sell, an additional "four to six" Omnisort products for installation during the first half of 2022.

COUNT I

Infringement of the '844 Patent

22. Paragraphs 1 through 21 are incorporated by reference as if fully stated herein.

23. The '844 patent is valid and enforceable.

24. Defendants Invata and HC Robotics have infringed, and continue to infringe, one or more claims of the '844 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, products and/or methods encompassed by those claims, including for example, by making, using, selling, offering for sale, and/or importing the Accused Products.

25. Third parties, including Defendants Invata and HC Robotics's customers, have infringed, and continue to infringe, one or more claims of the '844 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, the Accused Products supplied by Defendants Invata and HC Robotics.

26. Defendants Invata and HC Robotics have had knowledge of and notice of the '844 patent and its infringement since at least March 12, 2020, through attendance of demonstrations

by OPEX of its Sure Sort and Perfect Pick products at the 2020 Modex trade show. Defendants Invata and HC Robotics have had knowledge of and notice of the ’844 patent and its infringement since at least April 28, 2020, through OPEX’s virtual patent marking website. (*See* https://www.opex.com/patents/.) Defendants obtained actual knowledge of the ‘844 patent no later than the filing of this Complaint.

27. Defendants Invata and HC Robotics have induced infringement, and continue to induce infringement, of one or more claims of the ’844 patent under 35 U.S.C. § 271(b). Defendants Invata and HC Robotics actively, knowingly, and intentionally induced, and continue to actively, knowingly, and intentionally induce, infringement of the ’844 patent by selling or otherwise supplying the Accused Products; with the knowledge and intent that third parties will use, sell, and/or offer for sale in the United States, and/or import into the United States, the Accused Products to infringe the ’844 patent; and with the knowledge and intent to encourage and facilitate the infringement through the dissemination of the Accused Products and/or the creation and dissemination of promotional and marketing materials, supporting materials, instructions, product manuals, and/or technical information related to the Accused Products.

28. Defendants Invata and HC Robotics have contributed to the infringement by third parties, including Defendants Invata and HC Robotics’s customers, and continue to contribute to infringement by third parties, of one or more claims of the ’844 patent under 35 U.S.C. § 271(c), by selling and/or offering for sale in the United States, and/or importing into the United States, the Accused Products, knowing that those products constitute a material part of the inventions of the ’844 patent, knowing that those products are especially made or adapted to infringe the ’844 patent, and knowing that those products are not staple articles of commerce suitable for substantial noninfringing use.

29. Attached hereto as Exhibit M is an exemplary claim chart detailing how an Accused Product infringes at least independent claim 5 of the ’844 patent.

30. OPEX has been and continues to be damaged by Defendants Invata and HC Robotics’s infringement of the ’844 patent, and will suffer irreparable injury unless the infringement is enjoined by this Court.

31. Defendants Invata and HC Robotics’s infringement of the ’844 patent was, and continues to be, willful.

32. Defendants Invata and HC Robotics’s conduct in infringing the ’844 patent renders this case exceptional within the meaning of 35 U.S.C. § 285.

COUNT II

Infringement of the ’601 Patent

33. Paragraphs 1 through 32 are incorporated by reference as if fully stated herein.

34. The ’601 patent is valid and enforceable.

35. Defendants Invata and HC Robotics have infringed, and continue to infringe, one or more claims of the ’601 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, products and/or methods encompassed by those claims, including for example, by making, using, selling, offering for sale, and/or importing the Accused Products.

36. Third parties, including Defendants Invata and HC Robotics’s customers, have infringed, and continue to infringe, one or more claims of the ’601 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering

for sale in the United States, and/or importing into the United States, the Accused Products supplied by Defendants Invata and HC Robotics.

37. Defendants Invata and HC Robotics have had knowledge of and notice of the ’601 patent and its infringement since at least March 12, 2020, through attendance of demonstrations by OPEX of its Sure Sort and Perfect Pick products at the 2020 Modex trade show. Defendants Invata and HC Robotics have had knowledge of and notice of the ’601 patent and its infringement since at least April 28, 2020, through OPEX’s virtual patent marking website. (*See* https://www.opex.com/patents/.) Defendants obtained actual knowledge of the ‘601 patent no later than the filing of this Complaint.

38. Defendants Invata and HC Robotics have induced infringement, and continue to induce infringement, of one or more claims of the ’601 patent under 35 U.S.C. § 271(b). Defendants Invata and HC Robotics actively, knowingly, and intentionally induced, and continue to actively, knowingly, and intentionally induce, infringement of the ’601 patent by selling or otherwise supplying the Accused Products; with the knowledge and intent that third parties will use, sell, and/or offer for sale in the United States, and/or import into the United States, the Accused Products to infringe the ’601 patent; and with the knowledge and intent to encourage and facilitate the infringement through the dissemination of the Accused Products and/or the creation and dissemination of promotional and marketing materials, supporting materials, instructions, product manuals, and/or technical information related to the Accused Products.

39. Defendants Invata and HC Robotics have contributed to the infringement by third parties, including Defendants Invata and HC Robotics’s customers, and continue to contribute to infringement by third parties, of one or more claims of the ’601 patent under 35 U.S.C. § 271(c), by selling and/or offering for sale in the United States, and/or importing into the United States, the

Accused Products, knowing that those products constitute a material part of the inventions of the ’601 patent, knowing that those products are especially made or adapted to infringe the ’601 patent, and knowing that those products are not staple articles of commerce suitable for substantial noninfringing use.

40. Attached hereto as Exhibit N is an exemplary claim chart detailing how an Accused Product infringes at least independent claims 1, 11, and 21 of the ’601 patent.

41. OPEX has been and continues to be damaged by Defendants Invata and HC Robotics’s infringement of the ’601 patent, and will suffer irreparable injury unless the infringement is enjoined by this Court.

42. Defendants Invata and HC Robotics’s infringement of the ’601 patent was, and continues to be, willful.

43. Defendants Invata and HC Robotics’s conduct in infringing the ’601 patent renders this case exceptional within the meaning of 35 U.S.C. § 285.

COUNT III

Infringement of the ’740 Patent

44. Paragraphs 1 through 43 are incorporated by reference as if fully stated herein.

45. The ’740 patent is valid and enforceable.

46. Defendants Invata and HC Robotics have infringed, and continue to infringe, one or more claims of the ’740 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, products and/or methods encompassed by those claims, including for example, by making, using, selling, offering for sale, and/or importing the Accused Products.

47. Third parties, including Defendants Invata and HC Robotics's customers, have infringed, and continue to infringe, one or more claims of the '740 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, the Accused Products supplied by Defendants Invata and HC Robotics.

48. Defendants Invata and HC Robotics have had knowledge of and notice of the '740 patent and its infringement since at least March 12, 2020, through attendance of demonstrations by OPEX of its Sure Sort and Perfect Pick products at the 2020 Modex trade show. Defendants Invata and HC Robotics have had knowledge of and notice of the '740 patent and its infringement since at least April 28, 2020, through OPEX's virtual patent marking website. (*See* https://www.opex.com/patents/.) Defendants obtained actual knowledge of the '740 patent no later than the filing of this Complaint.

49. Defendants Invata and HC Robotics have induced infringement, and continue to induce infringement, of one or more claims of the '740 patent under 35 U.S.C. § 271(b). Defendants Invata and HC Robotics actively, knowingly, and intentionally induced, and continue to actively, knowingly, and intentionally induce, infringement of the '740 patent by selling or otherwise supplying the Accused Products; with the knowledge and intent that third parties will use, sell, and/or offer for sale in the United States, and/or import into the United States, the Accused Products to infringe the '740 patent; and with the knowledge and intent to encourage and facilitate the infringement through the dissemination of the Accused Products and/or the creation and dissemination of promotional and marketing materials, supporting materials, instructions, product manuals, and/or technical information related to the Accused Products.

50. Defendants Invata and HC Robotics have contributed to the infringement by third parties, including Defendants Invata and HC Robotics's customers, and continue to contribute to infringement by third parties, of one or more claims of the '740 patent under 35 U.S.C. § 271(c), by selling and/or offering for sale in the United States, and/or importing into the United States, the Accused Products, knowing that those products constitute a material part of the inventions of the '740 patent, knowing that those products are especially made or adapted to infringe the '740 patent, and knowing that those products are not staple articles of commerce suitable for substantial noninfringing use.

51. Attached hereto as Exhibit O is an exemplary claim chart detailing how an Accused Product infringes at least independent claims 1, 10, and 18 of the '740 patent.

52. OPEX has been and continues to be damaged by Defendants Invata and HC Robotics's infringement of the '740 patent, and will suffer irreparable injury unless the infringement is enjoined by this Court.

53. Defendants Invata and HC Robotics's infringement of the '740 patent was, and continues to be, willful.

54. Defendants Invata and HC Robotics's conduct in infringing the '740 patent renders this case exceptional within the meaning of 35 U.S.C. § 285.

COUNT IV

Infringement of the '194 Patent

55. Paragraphs 1 through 54 are incorporated by reference as if fully stated herein.

56. The '194 patent is valid and enforceable.

57. Defendants Invata and HC Robotics have infringed, and continue to infringe, one or more claims of the '194 patent under 35 U.S.C. § 271(a), either literally and/or under the

doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, products and/or methods encompassed by those claims, including for example, by making, using, selling, offering for sale, and/or importing the Accused Products.

58. Third parties, including Defendants Invata and HC Robotics's customers, have infringed, and continue to infringe, one or more claims of the '194 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, the Accused Products supplied by Defendants Invata and HC Robotics.

59. Defendants Invata and HC Robotics have had knowledge of and notice of the '194 patent and its infringement since at least March 12, 2020, through attendance of demonstrations by OPEX of its Sure Sort and Perfect Pick products at the 2020 Modex trade show. Defendants Invata and HC Robotics have had knowledge of and notice of the '194 patent and its infringement since at least April 28, 2020, through OPEX's virtual patent marking website. (*See* https://www.opex.com/patents/.) Defendants obtained actual knowledge of the '194 patent no later than the filing of this Complaint.

60. Defendants Invata and HC Robotics have induced infringement, and continue to induce infringement, of one or more claims of the '194 patent under 35 U.S.C. § 271(b). Defendants Invata and HC Robotics actively, knowingly, and intentionally induced, and continue to actively, knowingly, and intentionally induce, infringement of the '194 patent by selling or otherwise supplying the Accused Products; with the knowledge and intent that third parties will use, sell, and/or offer for sale in the United States, and/or import into the United States, the Accused Products to infringe the '194 patent; and with the knowledge and intent to encourage and

facilitate the infringement through the dissemination of the Accused Products and/or the creation and dissemination of promotional and marketing materials, supporting materials, instructions, product manuals, and/or technical information related to the Accused Products.

61. Defendants Invata and HC Robotics have contributed to the infringement by third parties, including Defendants Invata and HC Robotics's customers, and continue to contribute to infringement by third parties, of one or more claims of the '194 patent under 35 U.S.C. § 271(c), by selling and/or offering for sale in the United States, and/or importing into the United States, the Accused Products, knowing that those products constitute a material part of the inventions of the '194 patent, knowing that those products are especially made or adapted to infringe the '194 patent, and knowing that those products are not staple articles of commerce suitable for substantial noninfringing use.

62. Attached hereto as Exhibit P is an exemplary claim chart detailing how an Accused Product infringes at least independent claims 1, 7, and 10 of the '194 patent.

63. OPEX has been and continues to be damaged by Defendants Invata and HC Robotics's infringement of the '194 patent, and will suffer irreparable injury unless the infringement is enjoined by this Court.

64. Defendants Invata and HC Robotics's infringement of the '194 patent was, and continues to be, willful.

65. Defendants Invata and HC Robotics's conduct in infringing the '194 patent renders this case exceptional within the meaning of 35 U.S.C. § 285.

COUNT V

Infringement of the '883 Patent

66. Paragraphs 1 through 65 are incorporated by reference as if fully stated herein.

67. The ’883 patent is valid and enforceable.

68. Defendants Invata and HC Robotics have infringed, and continue to infringe, one or more claims of the ’883 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, products and/or methods encompassed by those claims, including for example, by making, using, selling, offering for sale, and/or importing the Accused Products.

69. Third parties, including Defendants Invata and HC Robotics’s customers, have infringed, and continue to infringe, one or more claims of the ’883 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, the Accused Products supplied by Defendants Invata and HC Robotics.

70. Defendants Invata and HC Robotics have had knowledge of and notice of the ’883 patent and its infringement since at least March 12, 2020, through attendance of demonstrations by OPEX of its Sure Sort and Perfect Pick products at the 2020 Modex trade show. Defendants Invata and HC Robotics have had knowledge of and notice of the ’883 patent and its infringement since at least April 28, 2020, through OPEX’s virtual patent marking website. (*See* https://www.opex.com/patents/.) Defendants obtained actual knowledge of the ‘883 patent no later than the filing of this Complaint.

71. Defendants Invata and HC Robotics have induced infringement, and continue to induce infringement, of one or more claims of the ’883 patent under 35 U.S.C. § 271(b). Defendants Invata and HC Robotics actively, knowingly, and intentionally induced, and continue to actively, knowingly, and intentionally induce, infringement of the ’883 patent by selling or

otherwise supplying the Accused Products; with the knowledge and intent that third parties will use, sell, and/or offer for sale in the United States, and/or import into the United States, the Accused Products to infringe the ’883 patent; and with the knowledge and intent to encourage and facilitate the infringement through the dissemination of the Accused Products and/or the creation and dissemination of promotional and marketing materials, supporting materials, instructions, product manuals, and/or technical information related to the Accused Products.

72. Defendants Invata and HC Robotics have contributed to the infringement by third parties, including Defendants Invata and HC Robotics’s customers, and continue to contribute to infringement by third parties, of one or more claims of the ’883 patent under 35 U.S.C. § 271(c), by selling and/or offering for sale in the United States, and/or importing into the United States, the Accused Products, knowing that those products constitute a material part of the inventions of the ’883 patent, knowing that those products are especially made or adapted to infringe the ’883 patent, and knowing that those products are not staple articles of commerce suitable for substantial noninfringing use.

73. Attached hereto as Exhibit Q is an exemplary claim chart detailing how an Accused Product infringes at least independent claim 1 of the ’883 patent.

74. OPEX has been and continues to be damaged by Defendants Invata and HC Robotics’s infringement of the ’883 patent, and will suffer irreparable injury unless the infringement is enjoined by this Court.

75. Defendants Invata and HC Robotics’s infringement of the ’883 patent was, and continues to be, willful.

76. Defendants Invata and HC Robotics’s conduct in infringing the ’883 patent renders this case exceptional within the meaning of 35 U.S.C. § 285.

COUNT VI

Infringement of the ’505 Patent

77. Paragraphs 1 through 76 are incorporated by reference as if fully stated herein.

78. The ’505 patent is valid and enforceable.

79. Defendants Invata and HC Robotics have infringed, and continue to infringe, one or more claims of the ’505 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, products and/or methods encompassed by those claims, including for example, by making, using, selling, offering for sale, and/or importing the Accused Products.

80. Third parties, including Defendants Invata and HC Robotics’s customers, have infringed, and continue to infringe, one or more claims of the ’505 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, the Accused Products supplied by Defendants Invata and HC Robotics.

81. Defendants Invata and HC Robotics have had knowledge of and notice of the ’505 patent and its infringement since at least March 12, 2020, through attendance of demonstrations by OPEX of its Sure Sort and Perfect Pick products at the 2020 Modex trade show. Defendants obtained actual knowledge of the ‘505 patent no later than the filing of this Complaint.

82. Defendants Invata and HC Robotics have induced infringement, and continues to induce infringement, of one or more claims of the ’505 patent under 35 U.S.C. § 271(b). Defendants Invata and HC Robotics actively, knowingly, and intentionally induced, and continues to actively, knowingly, and intentionally induce, infringement of the ’505 patent by selling or

otherwise supplying the Accused Products; with the knowledge and intent that third parties will use, sell, and/or offer for sale in the United States, and/or import into the United States, the Accused Products to infringe the ’505 patent; and with the knowledge and intent to encourage and facilitate the infringement through the dissemination of the Accused Products and/or the creation and dissemination of promotional and marketing materials, supporting materials, instructions, product manuals, and/or technical information related to the Accused Products.

83. Defendants Invata and HC Robotics have contributed to the infringement by third parties, including Defendants Invata and HC Robotics’s customers, and continue to contribute to infringement by third parties, of one or more claims of the ’505 patent under 35 U.S.C. § 271(c), by selling and/or offering for sale in the United States, and/or importing into the United States, the Accused Products, knowing that those products constitute a material part of the inventions of the ’505 patent, knowing that those products are especially made or adapted to infringe the ’505 patent, and knowing that those products are not staple articles of commerce suitable for substantial noninfringing use.

84. Attached hereto as Exhibit R is an exemplary claim chart detailing how an Accused Product infringes at least independent claims 1 and 18 of the ’505 patent.

85. OPEX has been and continues to be damaged by Defendants Invata and HC Robotics’s infringement of the ’505 patent, and will suffer irreparable injury unless the infringement is enjoined by this Court.

86. Defendants Invata and HC Robotics’s infringement of the ’505 patent was, and continues to be, willful.

87. Defendants Invata and HC Robotics’s conduct in infringing the ’505 patent renders this case exceptional within the meaning of 35 U.S.C. § 285.

COUNT VII

Infringement of the ’144 Patent

88. Paragraphs 1 through 87 are incorporated by reference as if fully stated herein.

89. The ’144 patent is valid and enforceable.

90. Defendants Invata and HC Robotics have infringed, and continue to infringe, one or more claims of the ’144 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, products and/or methods encompassed by those claims, including for example, by making, using, selling, offering for sale, and/or importing the Accused Products.

91. Third parties, including Defendants Invata and HC Robotics’s customers, have infringed, and continue to infringe, one or more claims of the ’144 patent under 35 U.S.C. § 271(a), either literally and/or under the doctrine of equivalents, by making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, the Accused Products supplied by Defendants Invata and HC Robotics.

92. Defendants Invata and HC Robotics have had knowledge of and notice of the ’144 patent and its infringement since at least December 20, 2021, through OPEX’s virtual patent marking website. (*See* https://www.opex.com/patents/.) Defendants obtained actual knowledge of the ‘144 patent no later than the filing of this Complaint.

93. Defendants Invata and HC Robotics have induced infringement, and continue to induce infringement, of one or more claims of the ’144 patent under 35 U.S.C. § 271(b). Defendants Invata and HC Robotics actively, knowingly, and intentionally induced, and continue to actively, knowingly, and intentionally induce, infringement of the ’144 patent by selling or

otherwise supplying the Accused Products; with the knowledge and intent that third parties will use, sell, and/or offer for sale in the United States, and/or import into the United States, the Accused Products to infringe the ’144 patent; and with the knowledge and intent to encourage and facilitate the infringement through the dissemination of the Accused Products and/or the creation and dissemination of promotional and marketing materials, supporting materials, instructions, product manuals, and/or technical information related to the Accused Products.

94. Defendants Invata and HC Robotics have contributed to the infringement by third parties, including Defendants Invata and HC Robotics’s customers, and continue to contribute to infringement by third parties, of one or more claims of the ’144 patent under 35 U.S.C. § 271(c), by selling and/or offering for sale in the United States, and/or importing into the United States, the Accused Products, knowing that those products constitute a material part of the inventions of the ’144 patent, knowing that those products are especially made or adapted to infringe the ’144 patent, and knowing that those products are not staple articles of commerce suitable for substantial noninfringing use.

95. Attached hereto as Exhibit S is an exemplary claim chart detailing how an Accused Product infringes at least independent claims 1, 10, and 15 of the ’144 patent.

96. OPEX has been and continues to be damaged by Defendants Invata and HC Robotics’s infringement of the ’144 patent, and will suffer irreparable injury unless the infringement is enjoined by this Court.

97. Defendants Invata and HC Robotics’s infringement of the ’144 patent was, and continues to be, willful.

98. Defendants Invata and HC Robotics’s conduct in infringing the ’144 patent renders this case exceptional within the meaning of 35 U.S.C. § 285.

Prayer for Relief

WHEREFORE, OPEX prays for judgment as follows:

A. That Defendants Invata and HC Robotics have infringed each of the patents-in-suit;

B. That Defendants Invata and HC Robotics's infringement of each of the patents-in-suit has been willful;

C. That Defendants Invata and HC Robotics, their officers, agents, and employees, and those persons in active concert or participation with any of them, and their successors and assigns, be permanently enjoined from infringement, inducing infringement, and contributory infringement of the patents-in-suit, including but not limited to the making, using, selling, and/or offering for sale in the United States, and/or importing into the United States, any devices, products, software, or methods that infringe the patents-in-suit before their respective expiration dates;

D. That OPEX be awarded all damages adequate to compensate it for Defendants Invata and HC Robotics's infringement of the patents-in-suit, such damages to be determined by a jury and, if necessary to adequately compensate OPEX for the infringement, an accounting, and that such damages be trebled and awarded to OPEX with pre-judgment and post-judgment interest;

E. That this case by declared an exceptional case within the meaning of 35 U.S.C. § 285 and that OPEX be awarded the attorney fees, costs, and expenses incurred in connection with this action; and

F. That OPEX be awarded such other and further relief as this Court deems just and proper.

Demand for Jury Trial

Plaintiff OPEX hereby demands a trial by jury on all issues so triable.

Dated: December 21, 2021

By:

/s/ Robert L. Hickok

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Hayduchok et al.

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(45) **Date of Patent: Jan. 4, 2011**

(54) **METHOD AND APPARATUS FOR SORTING ITEMS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 35 days.

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(22) Filed: **Jan. 14, 2008**

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Related U.S. Application Data

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(51) **Int. Cl.**
B65G 47/46 (2006.01)

(52) **U.S. Cl.** **198/370.1**; 198/371.2; 198/468.01

(58) **Field of Classification Search** 198/371.1, 198/358, 349, 349.6, 468.6, 468.01, 370.1, 198/371.2; 414/268, 272, 273, 279
See application file for complete search history.

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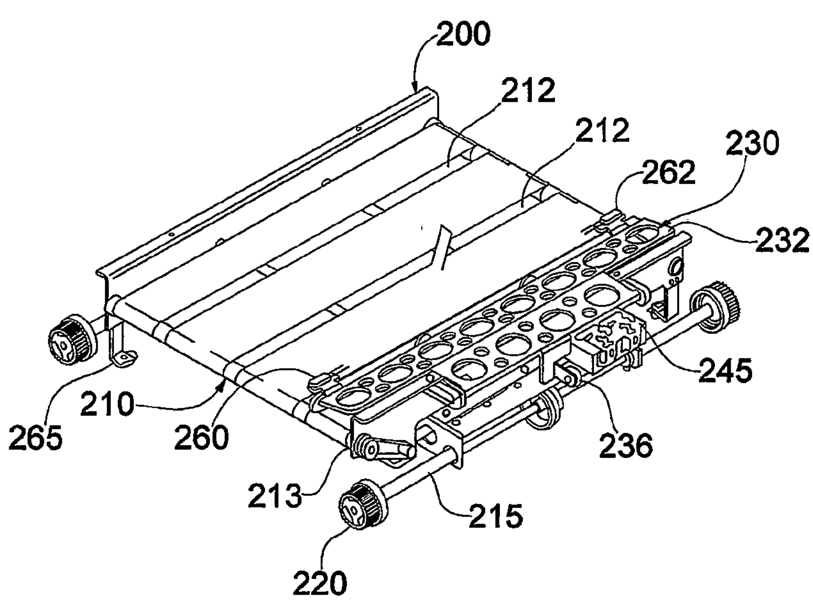
(57) **ABSTRACT**

A method and apparatus are provided for sorting items to a plurality of sort destinations. The items are loaded onto one of a plurality of independently controlled delivery vehicles. The delivery vehicles follow a track that guides the delivery vehicles to the sort destinations, which are positioned along the track. Once at the appropriate sort destination, the delivery vehicle ejects the item to the sort destination and returns to receive another item to be delivered.

30 Claims, 13 Drawing Sheets



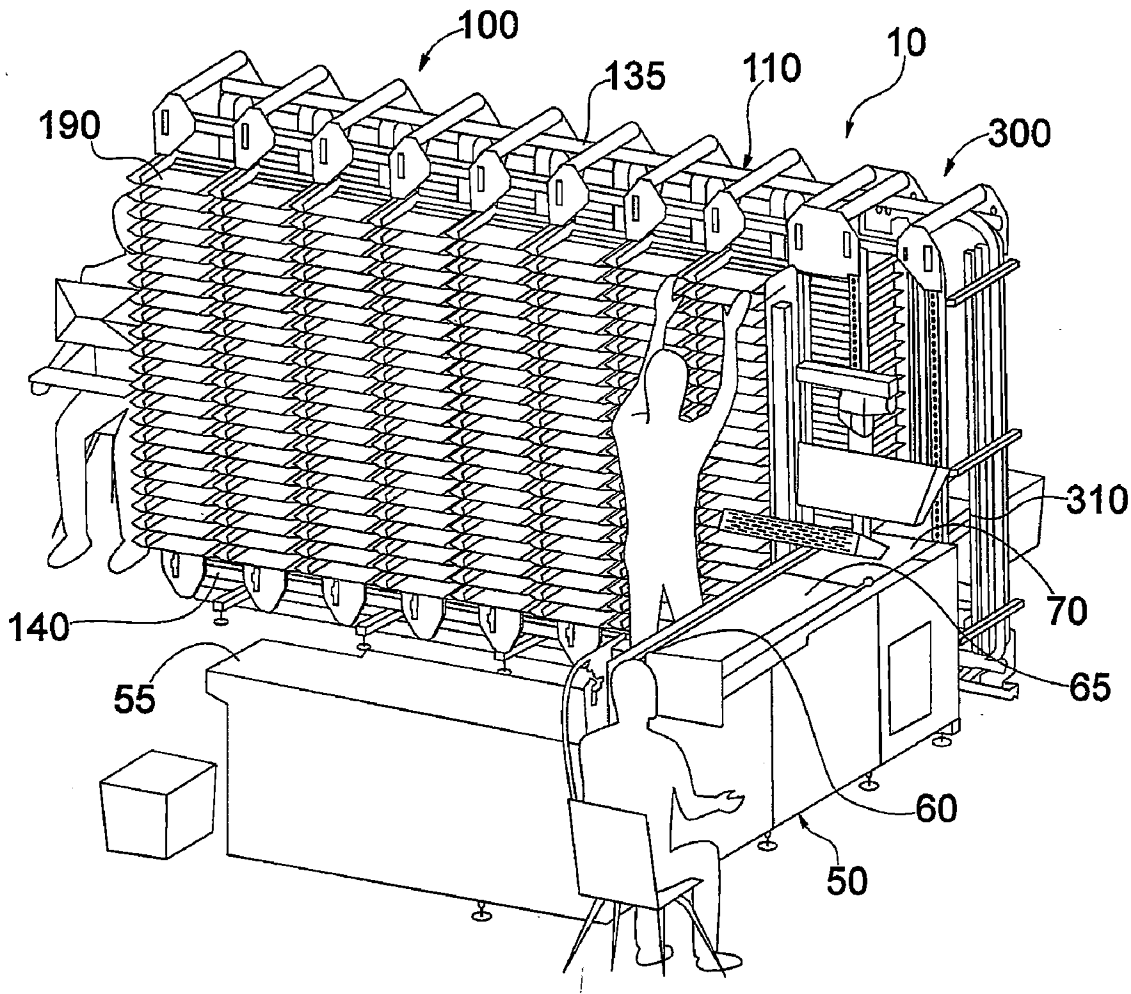


Fig. 1

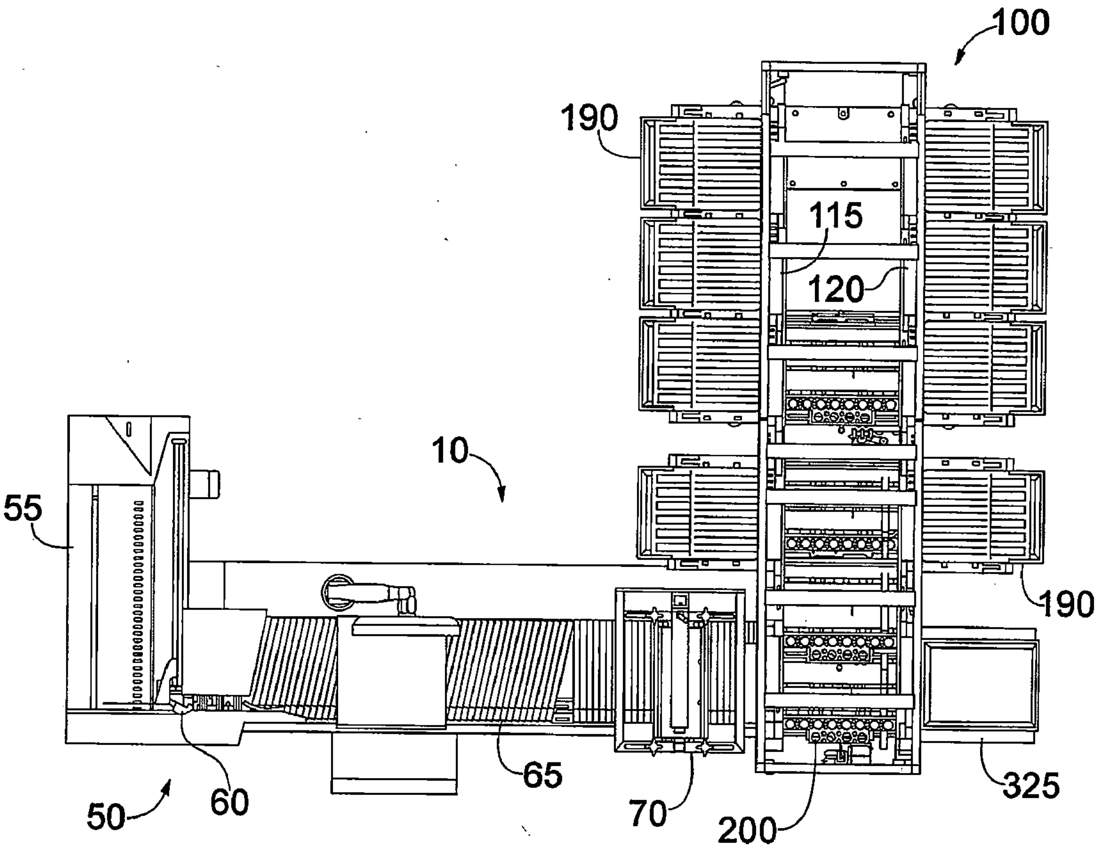


Fig. 2

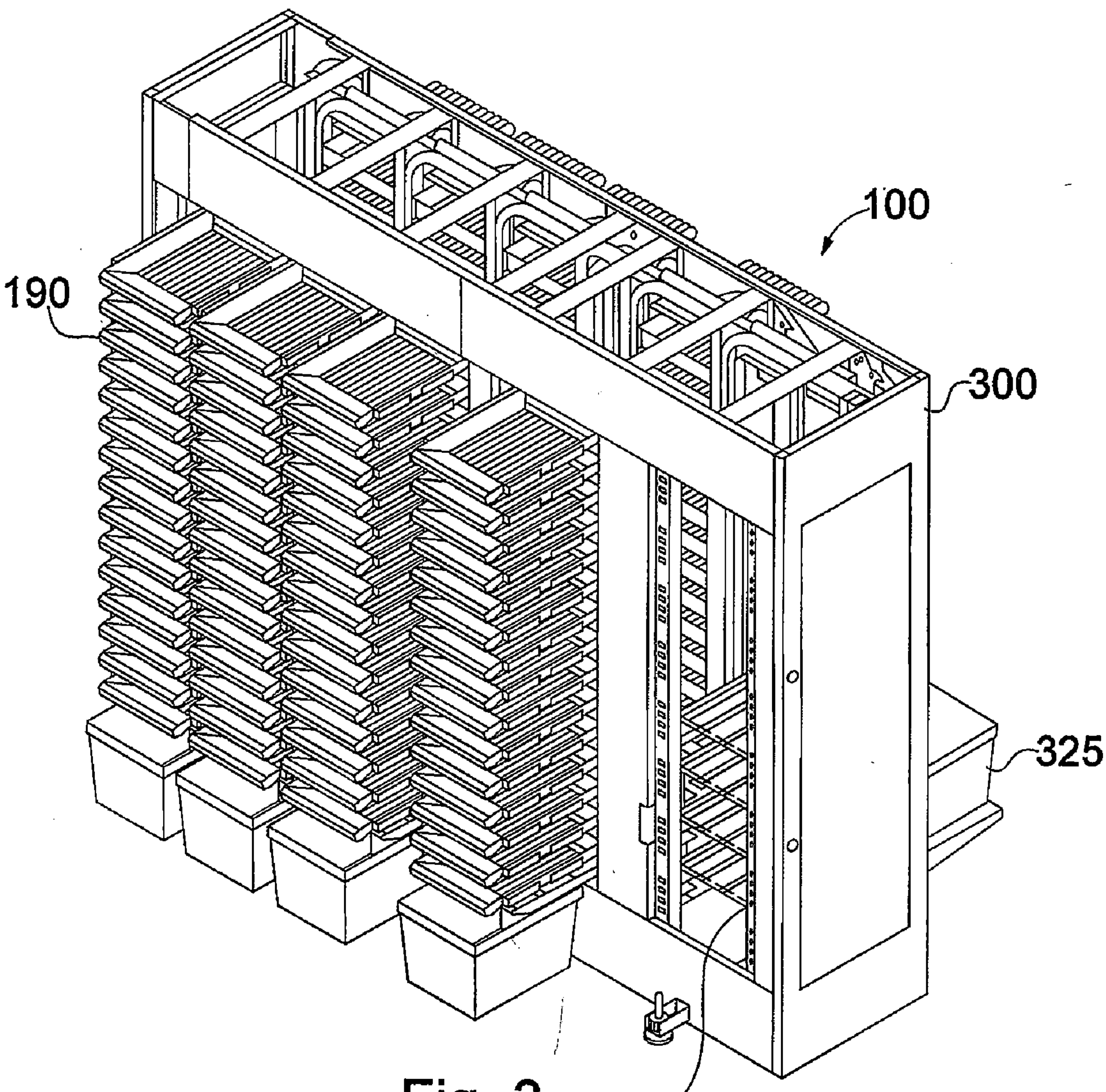


Fig. 3

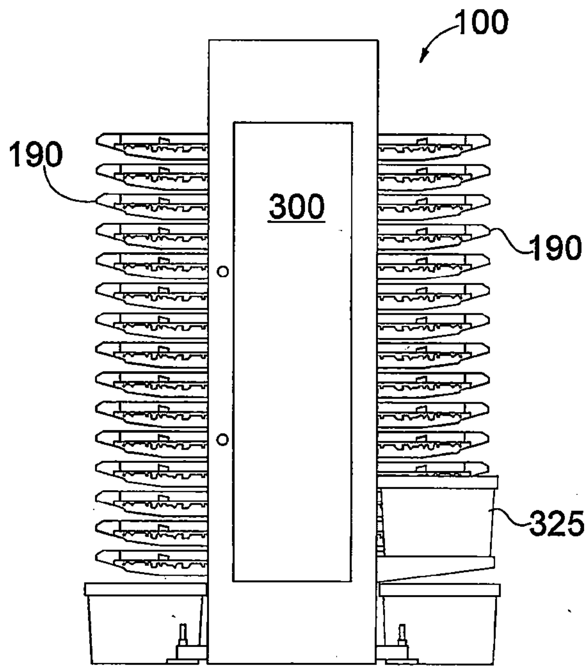


Fig. 4

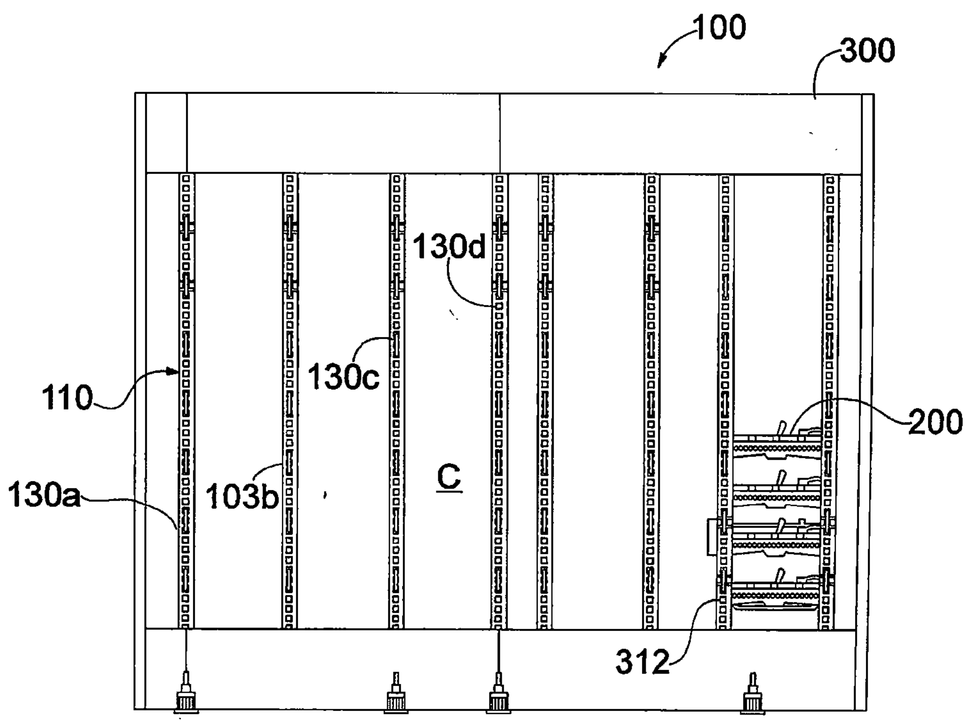


Fig. 5

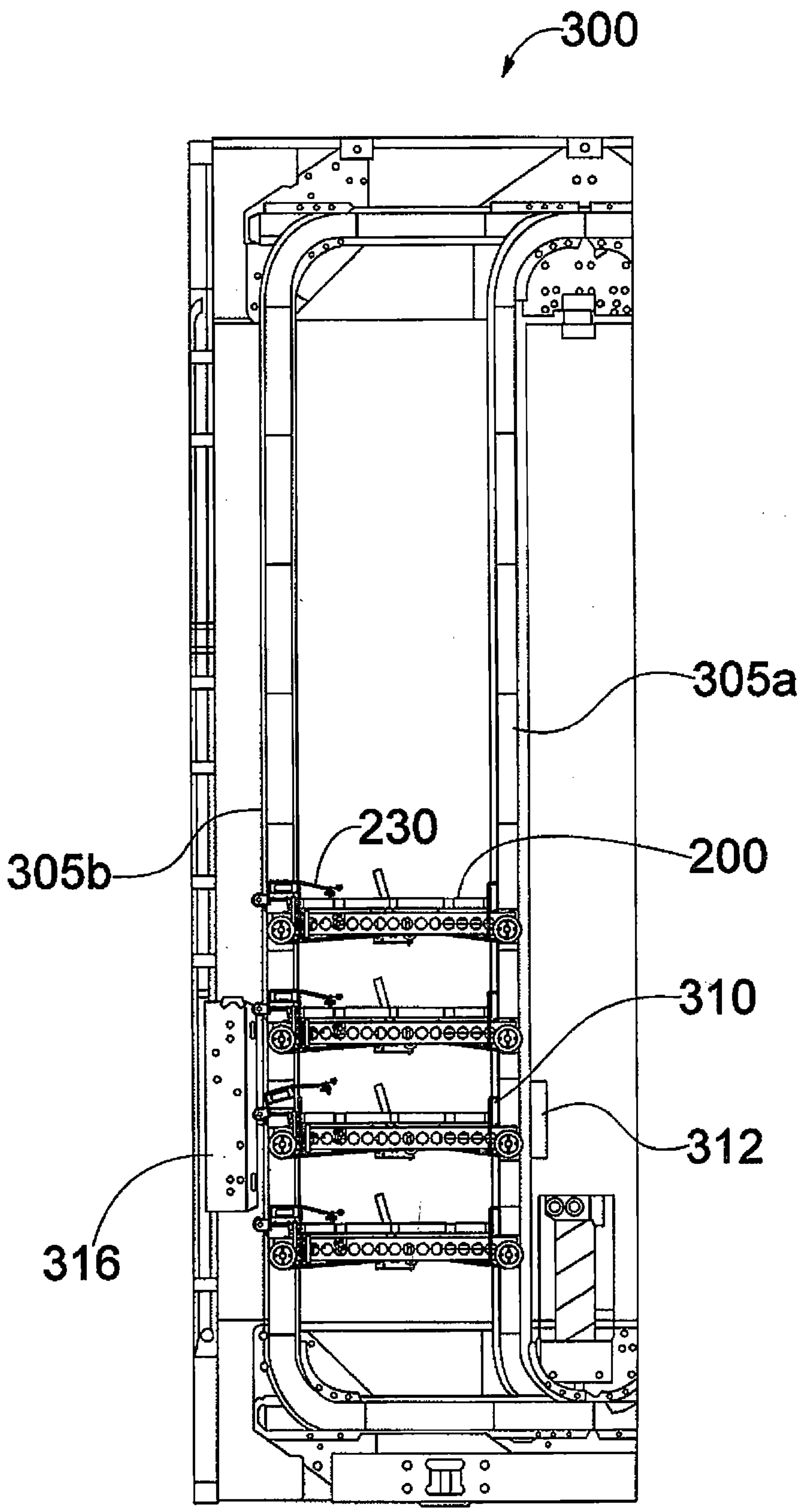


Fig. 6

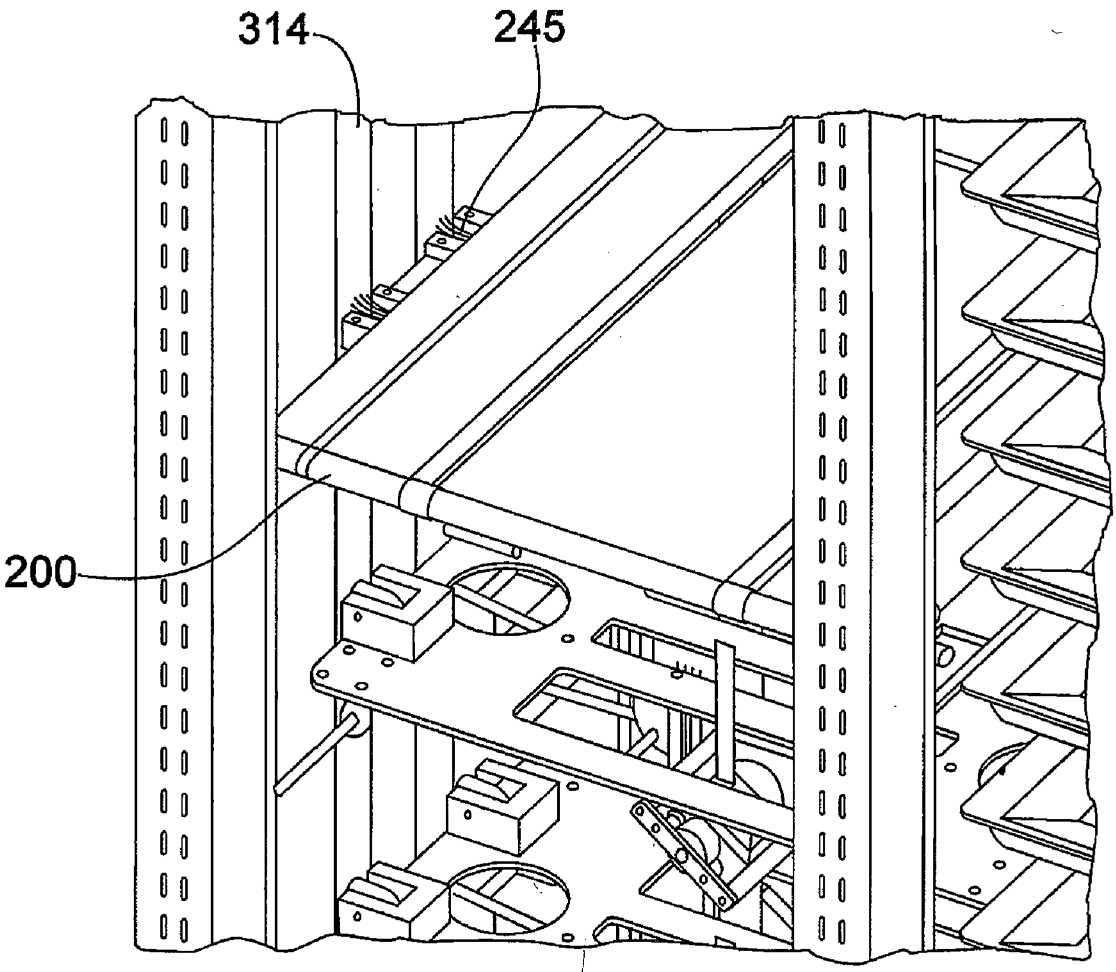


Fig. 7

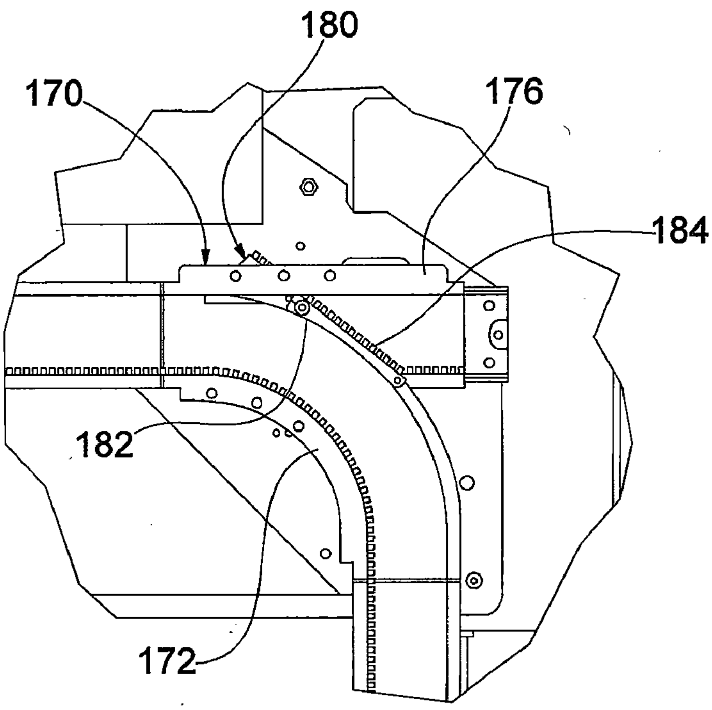


Fig. 8

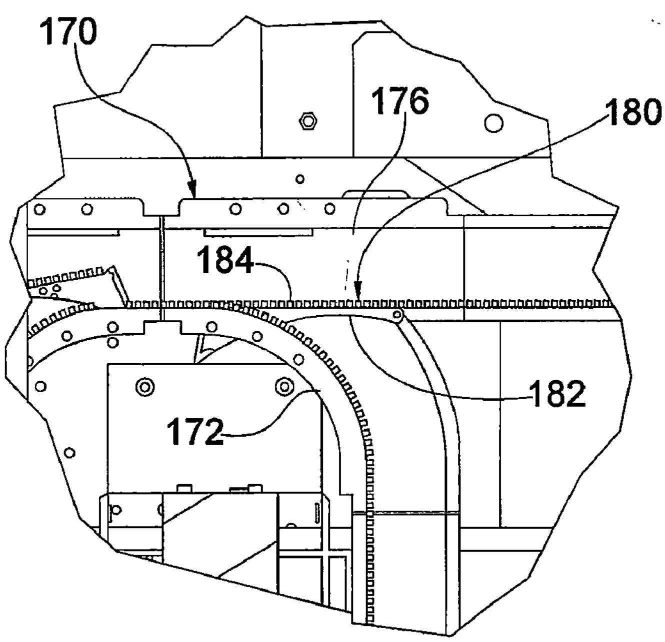


Fig. 9

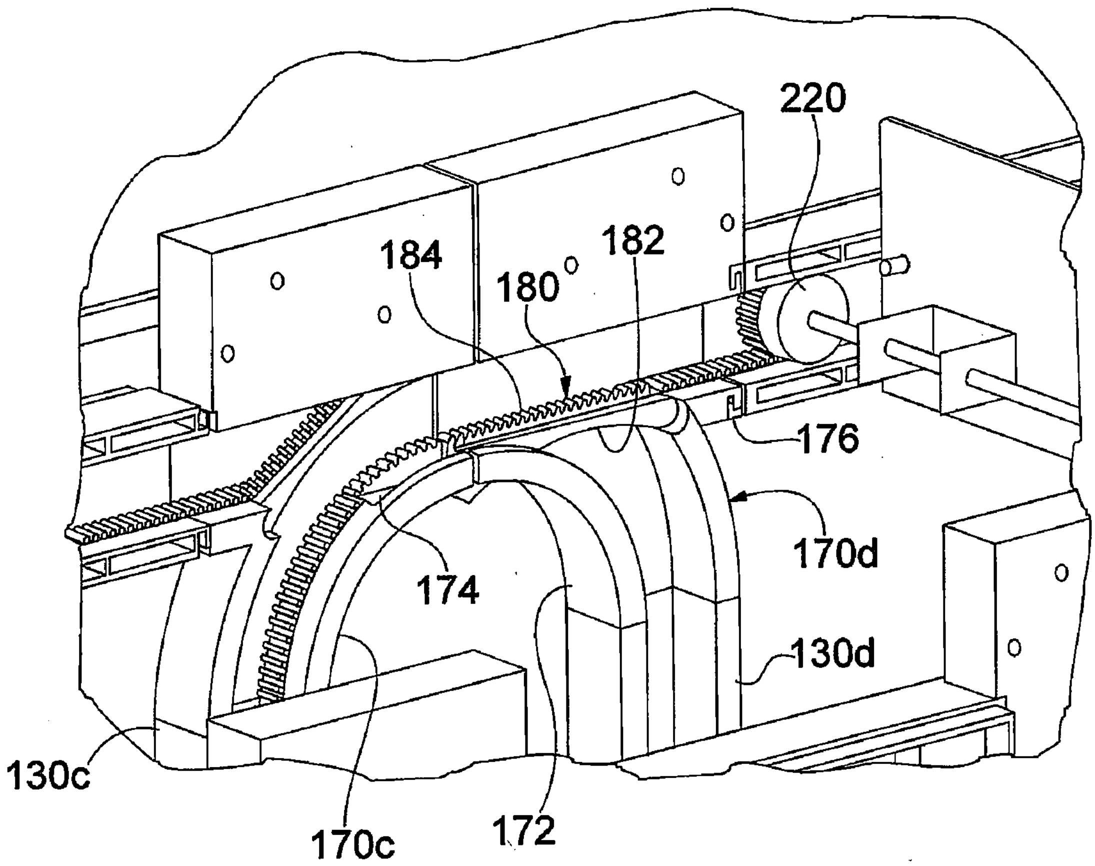


Fig. 10

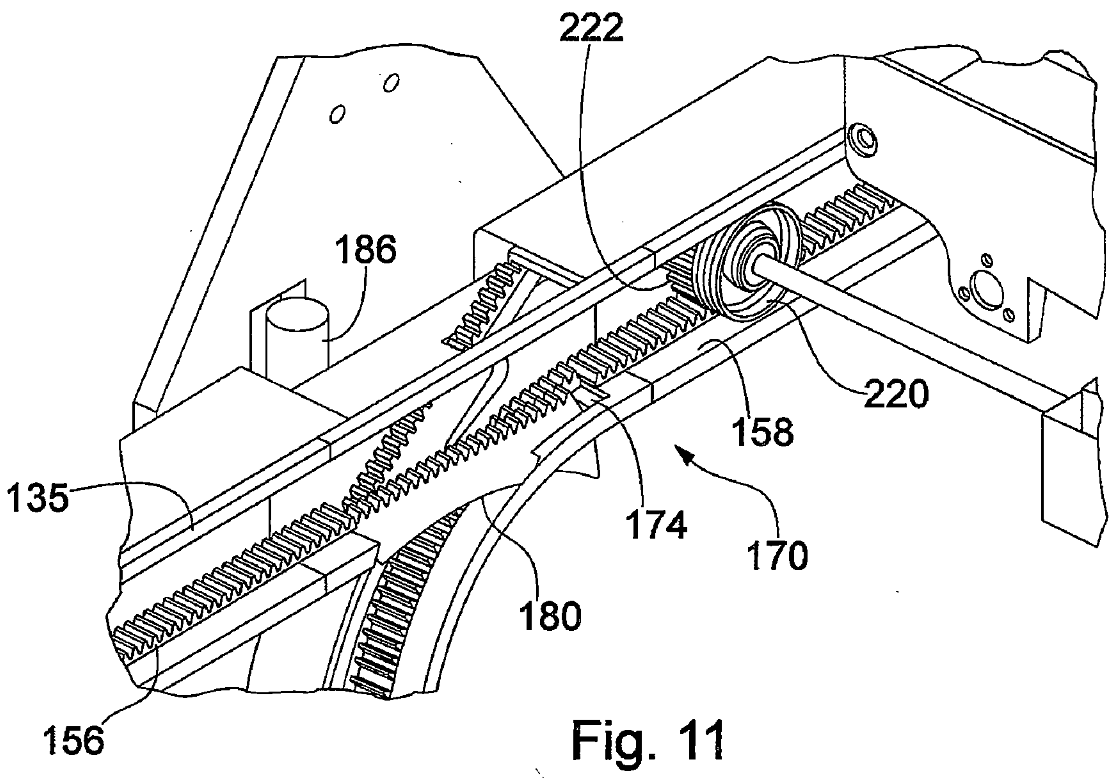


Fig. 11

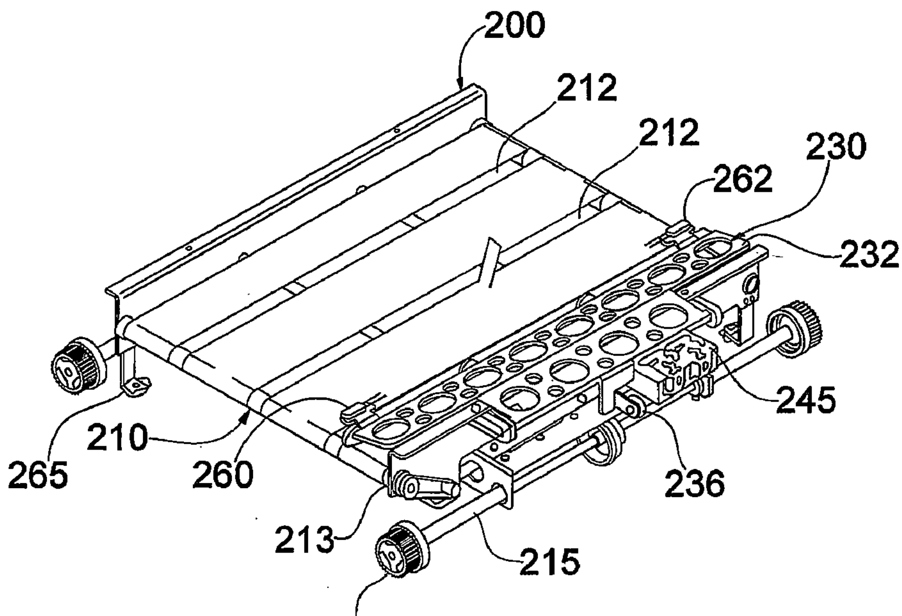


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Fig. 12

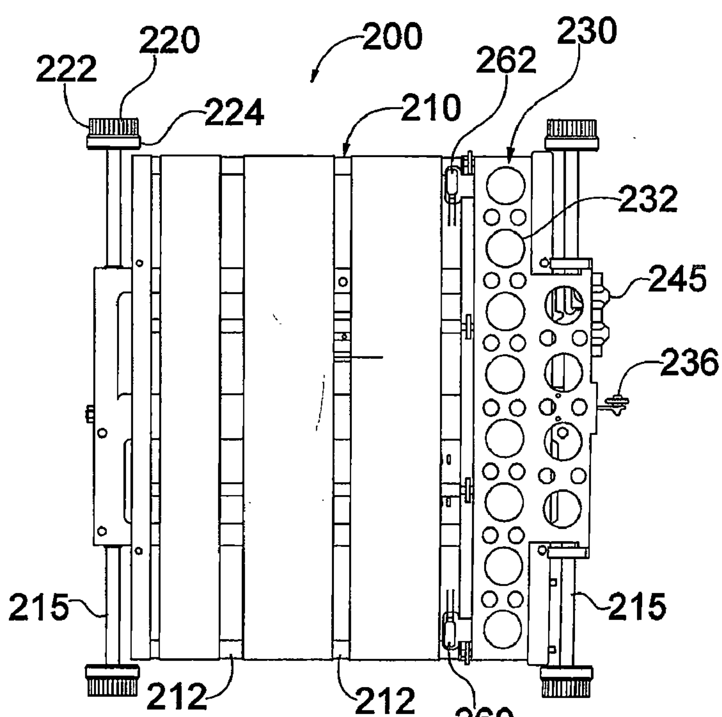

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Fig. 13

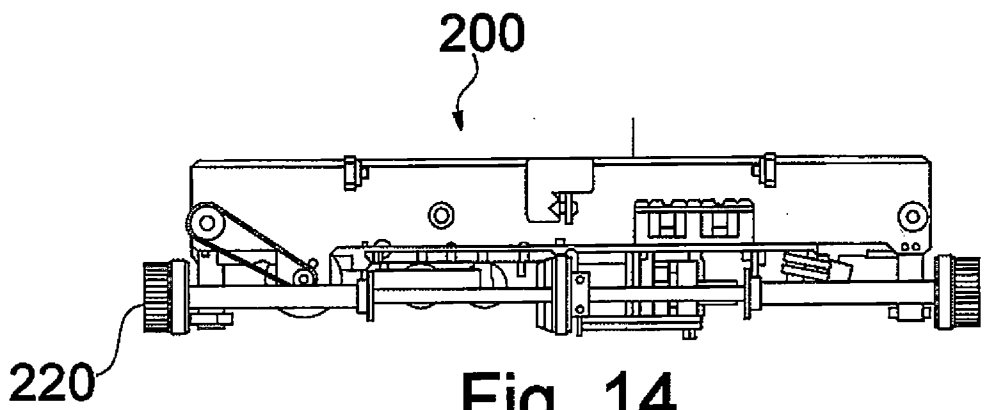

Fig. 14

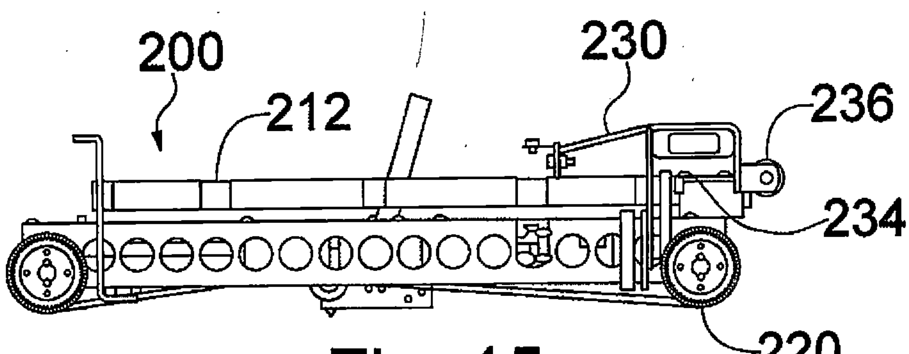

Fig. 15

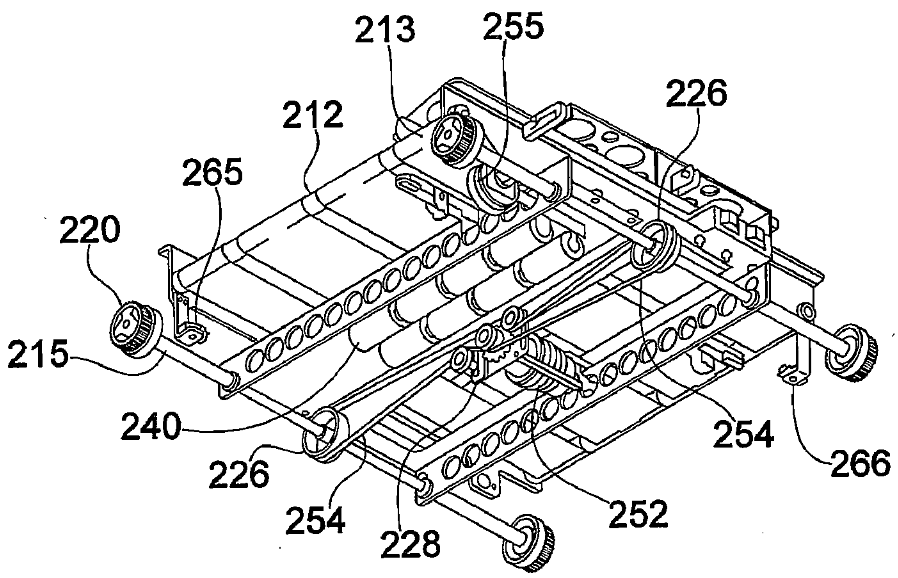
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Fig. 16

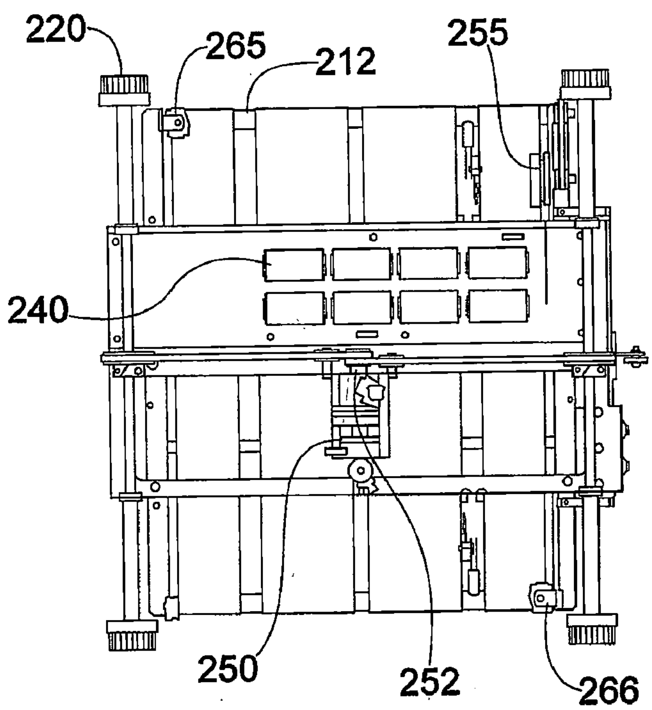
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Fig. 17

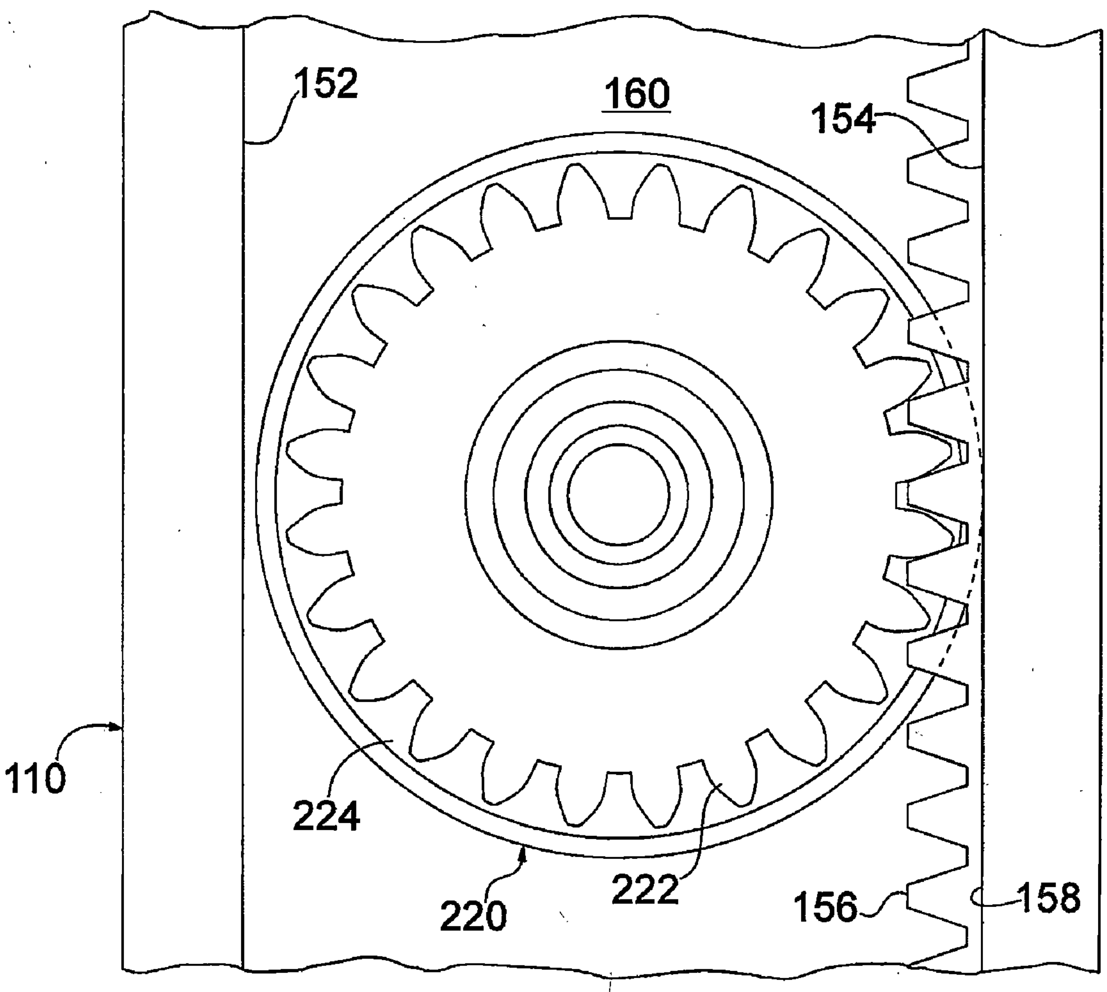

Fig. 18

METHOD AND APPARATUS FOR SORTING ITEMS

PRIORITY CLAIMS

The present application claims priority to U.S. Provisional Patent Application No. 60/884,766 filed on Jan. 12, 2007, which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a system for automating sorting of items, such as mail pieces, documents or other items.

BACKGROUND OF THE INVENTION

Sorting documents and mail pieces manually is laborious and time consuming. For example, thousands of large organizations employ numerous people full-time to manually sort and deliver incoming and interoffice mail and documents. For instance, a large company may receive 5,000 mail pieces that need to be sorted and delivered each day to different departments and/or individuals. Such volumes require a significant number of employees dedicated to sorting and delivering the mail. Nonetheless, such volume is not typically sufficient to justify the expense of traditional automated sorting equipment, which is quite expensive. Additionally, the mail for such organizations is typically quite diverse, which makes it more difficult, and therefore more expensive, to automate the sorting procedures.

Various systems for sorting have been developed to address the needs of mail rooms for large organizations. However, the known systems suffer from several problems; the most significant are cost and size. Accordingly, there is a need for a compact and affordable automated sorting system that is able to meet the needs of mid- to large-sized organization that handle several thousand mail pieces each day.

Similarly, may large organizations have extensive storage areas in which numerous items are stored. Sorting and retrieving items from the hundreds or thousands of storage areas requires significant labor to perform manually, and the known systems of automatically handling the materials are either very expensive or have limitations that hamper their effectiveness. Accordingly, there is a need in a variety of material handling applications for automatically storing and/or retrieving items.

SUMMARY OF THE INVENTION

In light of the foregoing, a system provides a method and apparatus for sorting items. The system includes a plurality of storage locations, such as bins, and a plurality of delivery vehicles for delivering items to the storage locations. A track guides the delivery vehicles to the storage locations.

In one embodiment, a controller controls the operation of the delivery vehicles based on information determined for each item to be sorted. Additionally, the track may include a plurality of interconnected vertical and horizontal sections so that the vehicles may travel along a continuous path changing from a horizontal direction to a vertical direction. Further, the vehicles may be driven such that the orientation of an item on the vehicle stays constant as the vehicles changes from a horizontal direction of travel to a vertical direction of travel.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary and the following detailed description of the preferred embodiments of the present invention will be best understood when read in conjunction with the appended drawings, in which:

FIG. **1** is a perspective view of a sorting apparatus;

FIG. **2** is a plan view of the sorting apparatus illustrated in FIG. **1**;

FIG. **3** is a fragmentary perspective view of the sorting apparatus illustrated in FIG. **1**, shown without an input station;

FIG. **4** is a right side view of the sorting apparatus illustrated in FIG. **3**;

FIG. **5** is a front elevational view of the sorting apparatus illustrated in FIG. **3**, shown without discharge bins;

FIG. **6** is a fragmentary sectional view of a loading station of the sorting apparatus illustrated in FIG. **1**;

FIG. **7** is an enlarged fragmentary perspective view of a portion of the loading station of the apparatus illustrated in FIG. **3**;

FIG. **8** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in an open position;

FIG. **9** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in a closed position;

FIG. **10** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate;

FIG. **11** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate, with the gate shown in an open position in phantom;

FIG. **12** is a top perspective view of a delivery vehicle of the apparatus illustrated in FIG. **1**;

FIG. **13** is a plan view of the delivery vehicle illustrated in FIG. **12**;

FIG. **14** is a right side view of the delivery vehicle illustrated in FIG. **12**;

FIG. **15** is a front elevational view of the delivery vehicle illustrated in FIG. **12**;

FIG. **16** is a bottom perspective view of the delivery vehicle illustrated in FIG. **12**;

FIG. **17** is a bottom view of the delivery vehicle illustrated in FIG. **12**; and

FIG. **18** is an enlarged view of a wheel of the delivery vehicle illustrated in FIG. **12**, shown in relation to the track of the sorting apparatus illustrated in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1**-**18**, an apparatus for sorting items such as documents or mail pieces is designated generally **10**. The apparatus **10** includes a plurality of delivery vehicles or cars **200** to deliver items to a plurality of sort locations, such as output bins **190**. At a loading station **310**, each car **200** receives an item from an input station **50** and delivers it to the appropriate bin.

The cars **200** travel along a track **110** to the sort locations. The track has a horizontal upper rail **135** and a horizontal lower rail **140**, which operates as a return leg. A number of parallel vertical track legs **130** extend between the upper rail and the lower return leg. In the present instance, the bins **190** are arranged in columns between the vertical track legs **130**.

After a piece is loaded onto a car, the car travels upwardly along two pairs of vertical tracks legs and then horizontally along two upper tracks **135**. The car **200** travels along the upper rail until it reaches the appropriate column containing the bin for the piece that the car is carrying. The track **110** includes gates **180** that fire to direct the car **200** down the vertical legs and the car stops at the appropriate bin. The car **200** then discharges the piece into the bin.

After discharging the piece, the car **200** continues down the vertical legs **130** of the column until it reaches the lower rail **140**. Gates fire to direct the car along the lower rail, and the car follows the lower rail to return to the loading station **310** to receive another piece.

The cars **200** are semi-autonomous vehicles that each have an onboard power source and an onboard motor to drive the cars along the track **110**. The cars also include a loading/unloading mechanism **210**, such as a conveyor, for loading pieces onto the cars and discharging the pieces from the cars.

Since the system **10** includes a number of cars **200**, the positioning of the cars is controlled to ensure that the different cars do not crash into each other. In one embodiment, the system **10** uses a central controller **350** that tracks the position of each car **200** and provides control signals to each car to control the progress of the cars along the track. The central controller **350** may also control operation of the various elements along the track, such as the gates **180**.

Input Station

At the input station **50**, the mail pieces are separated from one another so that the pieces can be conveyed serially to the loading station **310** to be loaded onto the cars **200**. Additionally, at the input station information is determined for each piece so that the piece can be sorted to the appropriate bin.

A variety of configurations may be used for the input station, including manual or automatic configurations or a combination of manual and automated features. In a manual system, the operator enters information for each piece and the system sorts the mail piece accordingly. In an automatic system, the input system includes elements that scan each mail piece and detect information regarding each piece. The system then sorts the mail piece according to the scanned information.

In an exemplary manual configuration, the input system includes a work station having a conveyor, an input device, such as a keyboard, and a monitor. The operator reads information from a mail piece and then drops in onto a conveyor that conveys the piece to the loading station **310**. Sensors positioned along the conveyor track the piece as the conveyor transports the mail piece toward the loading station. An example of a work station having a conveyor for receiving dropped pieces and tracking the pieces is provided in pending U.S. application Ser. No. 10/862,021, filed Jun. 4, 2004, which was published Jan. 27, 2005 under Publication No. US 2005-0018214 A1 and which is incorporated herein by reference. The conveyor receives mail pieces dropped by an operator and tracks the mail pieces as they are transported along the conveyor.

In an exemplary automatic configuration, the system includes an imaging station, having an imaging device such as a high speed line scanning camera. The imaging station scans each mail piece to detect information regarding the destination for each piece. The system analyzes the image data to determine the destination information and then electronically tags the mail piece with the destination and sorts the piece accordingly. An example of a system having an automated imaging station for scanning pieces as they are conveyed is described in U.S. patent application Ser. No. 09/904,471, filed Jul. 13, 2001, which was published Jan. 16, 2003 under Publication No. US 2003-0014376 A1, and which is incorporated herein by reference.

FIGS. **1** and **2** illustrate such an automated system. The input station includes an input bin **55** for receiving a stack of mail. A feeder **60** in the input bin serially feeds mail pieces from the input bin to a conveyor **65**. An imaging station **70** positioned along the conveyor scans the mails pieces as the pieces are conveyed to the loading station **310**. The system **10** analyzes the image data to read information for the mail piece, such as the recipient's address.

The conveyor **65** conveys the mail piece to the loading station **310**. At the loading station the conveyor **65** conveys the mail piece onto a car **200**. As discussed further below, after the mail piece is loaded onto the car, the car moves away from the loading station and another car moves into position at the loading station to receive the next piece of mail.

In certain instances, the system may not be able to automatically identify the relevant information for a mail piece. To process such pieces, the system may include an operator to input the relevant information so that the mail piece can be sorted. For instance, the system may include an operator station having an input device and a display, such as a monitor. If the system cannot automatically determine the address within a pre-determined time period, the system displays the scanned images for the mail piece to the monitor so that the operator at the work station can view the images and manually enter the information using the input device.

In addition to the automated and manual systems described above, the system may be configured in a hybrid or semi-automated configuration having some operations performed manually and others automated. For instance, the system may include a manual input station that also has an imaging station. Since the system can handle a wide variety of items, it may be desirable to have an operator input the pieces manually so that the pieces are properly oriented and separated. The imaging station then scans the items and processes the imaging data to determine the address information for the pieces. Additionally, the operator station may include an input device and a display for inputting information if the address for a piece cannot be automatically determined, as discussed above. The operator can input the information as soon as the system indicates to the operator that it cannot determine the information for a piece. Alternatively, as discussed below, the car may be directed to a buffer if the information for a piece cannot be determined. In such an instance, the cars having such pieces will remain in the buffer while the system continues to process pieces for which the system can determine the relevant information. The operator can continue to manually drop pieces and wait until a number of pieces need manual keying of information. The operator can then switch from the operation of dropping pieces to the operation of manually keying the pieces, sometimes referred to as local video encoding (LVE). The operator can continue keying until some or all of the pieces in the buffer have been successfully coded, and then the operator can go back to the operation of manually dropping pieces. As yet another alternative, it may be desirable to incorporate a separate operator station having the input device and display so that one operator can input the mail at the input station and a separate operator can input the information for pieces having addresses that cannot be automatically determined.

As can be seen from the foregoing, the input station **50** may be configured in a wide range of options. The options are not limited to those configurations described above, and may include additional features, such as an automated scale for weighing each piece, a labeler for selectively applying labels to the mail pieces and a printer for printing information on the mail pieces or on the labels.

Additionally, in the foregoing description, the system is described as having a single input station **50**. However, it may be desirable to incorporate a plurality of input stations positioned along the system **10**. By using a plurality of input stations, the feed rate of pieces may be increased. In addition, the input stations may be configured to process different types of items. In this way, each input station could be configured to efficiently process a particular category of items. For instance, if the system is configured to process documents, such as mail, one input station may be configured to process standard envelopes, while another input station may be configured to process larger mails, such as flats. Similarly, one input station may be configured to automatically process mail by scanning it and automatically determining the recipient. The second input station may be configured to process rejects, such as by manually keying in information regarding the recipient.

Sorting Station

Referring to FIGS. **1-6**, the system includes a sorting station **100**, such as an array of bins **190** for receiving the pieces. In the present instance, the sorting station includes a number of bins arranged in columns. Additionally, the sorting station **100** includes a track **110** for guiding the cars **200** to the bins **190**.

The track **110** includes a horizontal upper rail **135** and a horizontal lower rail **140**. A plurality of vertical legs **130** extend between the upper horizontal leg and the lower horizontal leg **140**. During transport, the cars travel up a pair of vertical legs from the loading station **310** to the upper rail **135** (as described below, the cars actually travel up two pairs of rails because the track includes a forward track and a parallel opposing track). The car then travels along the upper rail until reaching the column having the appropriate bin. The car then travels downwardly along two front vertical posts and two parallel rear posts until reaching the appropriate bin, and then discharges the mail piece into the bin. The car then continues down the vertical legs until reaching the lower horizontal leg **140**. The car then follows the lower rail back toward the loading station.

As can be seen in FIG. **2**, the track **110** includes a front track **115** and a rear track **120**. The front and rear tracks **115**, **120** are parallel tracks that cooperate to guide the cars around the track. As shown in FIG. **13**, each of the cars includes four wheels **220**: two forward wheel and two rearward wheels. The forward wheels **220** ride in the front track, while the rearward wheel ride in the rear track. It should be understood that in the discussion of the track the front and rear tracks **115**, **120** are similarly configured opposing tracks that support the forward and rearward wheels **220** of the cars. Accordingly, a description of a portion of either the front or rear track also applies to the opposing front or rear track.

Referring to FIG. **18** the details of the track will be described in greater detail. The track **110** includes an outer wall **152** and an inner wall **154** that is spaced apart from the outer wall and parallel to the outer wall. The track also has a back wall **160** extending between the inner and outer walls. As can be seen in FIG. **18**, the outer and inner walls **152**, **154** and the back wall form a channel. The wheels **220** of the car ride in this channel.

Referring to FIG. **11**, the track includes both a drive surface **156** and a guide surface **158**. The drive surface positively engages the cars to enable the car to travel along the track. The guide surface **158** guides the car, maintaining the car in operative engagement with the drive surface **156**. In the present instance, the drive surface is formed of a series of teeth, forming a rack that engages the wheels of the cars as described further below. The guide surface **158** is a generally flat surface adjacent the rack **156**. The rack **156** extends approximately halfway across the track and the guide surface **158** extends across the other half of the track. As shown in FIGS. **11** and **18**, the rack **156** is formed on the inner wall **154** of the track. The opposing outer wall **152** is a generally flat surface parallel to the guide surface **158** of the inner wall.

As described above, the track includes a plurality of vertical legs extending between the horizontal upper and lower rails **135**, **140**. An intersection **170** is formed at each section of the track at which one of the vertical legs intersects one of the horizontal legs. Each intersection includes an inner branch **172** that is curved and an outer branch **176** that is generally straight. FIG. **10** illustrates both a right-hand intersection **170***c* and a left-hand intersection **170**, which are mirrors of one another. In FIG. **10**, the intersections **170***c*, **170***d* illustrate the portion of the track in which two vertical legs **130** intersect the upper horizontal leg **135**. The intersections of the vertical legs with the lower rail incorporate similar intersections, except the intersections are reversed. Specifically, the point at which vertical leg **130***c* intersects the lower rail incorporates an intersection configured similar to intersection **170***d*, and the point at which vertical leg **130***d* intersects the lower rail incorporates an intersection configured similar to intersection **170***c*.

Each intersection **170** includes a pivotable gate **180** that has a smooth curved inner race and a flat outer race that has teeth that correspond to the teeth of the drive surface **156** for the track. The gate **180** pivots between a first position and a second position. In the first position, the gate **180** is closed so that the straight outer race **184** of the gate is aligned with the straight outer branch **176** of the intersection. In the second position, the gate is open so that the curved inner race **182** of the gate is aligned with the curved branch **172** of the intersection.

Accordingly, in the closed position, the gate is pivoted downwardly so that the outer race **184** of the gate aligns with the drive surface **156**. In this position, the gate blocks the car from turning down the curved portion, so that the car continues straight through the intersection. In contrast, as illustrated n FIG. **10**, when the gate is pivoted into the open position, the gate blocks the car from going straight through the intersection. Instead, the curved inner race **182** of the gate aligns with the curved surface of the inner branch **172** and the car turns through the intersection. In other words, when the gate is closed, a car goes straight through the intersection along either the upper rail **130** or the lower rail, depending on the location of the intersection. When the gate is opened, the gate directs the car from either a vertical rail to a horizontal rail or from a horizontal rail to a vertical rail, depending on the location of the intersection.

As can be seen in FIG. **11**, the end of the gate remote from the pivot point of the gate flares outwardly so that the curved inner race matches the curved profile of the inner branch when the gate is open. As a result, the gate has a generally L-shaped configuration. To accommodate the flared end of the gate **180**, the drive surface **156** of the inner branch has a notch or recessed portion. When the gate is closed, the notch provides clearance so that the outer race **184** of the gate lies flat, parallel with the drive surface of the outer branch **176**. Further, in the example shown in FIG. **11**, the gate is positioned along the upper rail **135** of the track **110**. When the gate is closed, the recess in the inner branch of the intersection **170** allows the gate to lie flat so that it is aligned with the drive surface of the upper rail.

In the foregoing description, the gates allow one of the cars to either continue in the same direction (e.g. horizontally) or turn in one direction (e.g. vertically). However, in some applications, the system may include more than two horizontal rails that intersect the vertical columns. In such a configuration, it may be desirable to include a different rail that allows the cars to turn in more than one direction. For instance, if a car is traveling down a column, the gate may allow the car to turn either left or right down a horizontal rail, or travel straight through along the vertical column. Additionally, in some applications it may be desirable to allow the cars to travel upwardly, whereas in the system described above, the cars only travel downwardly through the sorting station. If the cars also travel upwardly in the sorting station, then the gates should be configured to accommodate and guide the cars when the cars travel upwardly through an intersection.

The gates **180** are controlled by signals received from the central controller **350**. Specifically, each gate is connected with an actuator **186** that displaces the gate from the opened position to the closed position and back. There may be any of a variety of controllable elements operable to displace the gate. In the present instance, the actuator **186** is a solenoid having a linearly displaceable piston.

In the foregoing description, the sorting station **100** is described as a plurality of output bins **190**. However, it should be understood that the system may include a variety of types of destinations, not simply output bins. For instance, in certain applications it may be desirable to sort items to a storage area, such as an area on a storage shelf. Alternatively, the destination may be an output device that conveys items to other locations. According to one example of an output device, the system may include one or more output conveyors that convey pieces away from the sorting system toward a different material handling or processing system. For instance, an output conveyor designated A may convey pieces to a processing center designated A. Therefore, if a piece is to be delivered to processing center A, the car will travel along the track to output conveyor A. Once the car reaches output conveyor A, the car will stop and transfer the piece onto output conveyor A. Output conveyor A will then convey the piece to processing center A. Further, it should be understood that the system may be configured to include a plurality of output devices, such as output conveyors.

In some embodiments, the system may include a plurality of output conveyors in addition to the output bins. In other embodiments, the system may only include a plurality of output devices, such as conveyors, and the system is configured to sort the pieces to the various output devices. Further still, the system may be configured to retrieve pieces from storage locations. In such embodiments, the cars may sort pieces to a storage location, such as a bin. Subsequently, one of the cars may travel to the storage location and retrieve the item from the storage location and transport it to one of the output devices.

One manner that the cars may retrieve items from the storage locations is by including a conveyor at the storage locations. In this way, an item at a storage location can be conveyed by the conveyor toward the track. When a car arrives at the storage location, the conveyor at the storage location conveys the item onto the car, similar to the manner in which a piece is loaded onto the car at the loading column. Accordingly, the system can sort pieces to a plurality of output devices, in addition to sorting pieces to a plurality of storage locations before subsequently retrieving the pieces and conveying the pieces to the output devices.

As discussed above, the system is operable to sort a variety of items to a plurality of destinations. One type of destination is a bin; a second type is a shelf or other location on which the item is to be stored; and a third type of destination is an output device that may be used to convey the item to a different location. The system may include one or more of each of these types or other types of destinations.

Delivery Vehicles

Referring now to FIGS. **12-17**, the details of the delivery vehicles **200** will be described in greater detail. Each delivery vehicle is a semi-autonomous car having an onboard drive system, including an onboard power supply. Each car includes a mechanism for loading and unloading items for delivery.

The car **200** may incorporate any of a variety of mechanisms for loading an item onto the car and discharging the item from the car into one of the bins. Additionally, the loading/unloading mechanism **210** may be specifically tailored for a particular application. However, in the present instance, the loading/unloading mechanism **210** is a conveyor belt. Specifically, referring to FIG. **12**, the loading/unloading mechanism includes a plurality of narrow belts **212** that extend along the top surface of the car. The conveyor belts are reversible. Driving the belts in a first direction displaces the item toward the rearward end of the car; driving the belt in a second direction displaces the item toward the forward end of the car.

A conveyor motor **255** mounted on the underside of the car drives the conveyor belts **212**. Specifically, the conveyor belts **212** are entrained around a forward roller **213** at the forward edge of the car, and a rearward roller at the rearward edge of the car. The conveyor motor **255** is connected with the forward roller **213** to drive the forward roller, thereby operating the conveyor belts.

The car includes four wheels **220** that are used to transport the car along the track **110**. The wheels **220** are mounted onto two parallel spaced apart axles **215**, so that two or the wheels are disposed along the forward edge of the car and two of the wheels are disposed along the rearward edge of the car.

Referring to FIG. **18**, each wheel comprises an inner idler roller **224** and an outer gear **222** that cooperates with the drive surface **156** of the track. The idler roller **224** rotates freely relative to the axles, while the outer gear is fixed relative to the axle onto which it is mounted. In this way, rotating the axle operates to rotate the gear **222**. Additionally, the idler roller is sized to have a diameter slightly smaller than the distance between the upper wall **152** and the lower wall **154** of the track. In this way, the idler roller may rotate freely within the track, while ensuring that the gear **222** of each wheel remains in operative engagement with the drive surface (i.e. the teeth) **156** of the track. Accordingly, when the vehicle is moving horizontally, the rollers carry the weight of the cart, while the gears **222** cooperate with the drive surface **156** of the track to drive the vehicle along the track.

The car includes an onboard motor **250** for driving the wheels **220**. More specifically, the drive motor **250** is operatively connected with the axles to rotate the axles **215**, which in turn rotates the gears **222** of the wheels. As shown in FIG. **16**, the drive motor **250** is interconnected to the axles **215** via a pair of drive belts **254** that are driven by the drive motor.

The drive system for the car may be configured to synchronously drive the car along the track. In the present instance, the drive system is configured so that each gear is driven in a synchronous manner. Specifically, each gear **222** is connected to an end of one of the axles in a manner that substantially impedes rotation of the gear relative to the axle. In this way each axle drives the attached two gears in a synchronous manner. Additionally, in the present instance, both axles are driven in a synchronous manner so that all four gears are driven in a synchronous manner. There are various mechanisms that can be used to synchronously drive the axles. For instance, a pair of drive motors can be used to drive the axles, and the drive motors can be synchronized. However, in the present instance, a single drive motor **250** is used to drive both axles. Each axle includes a timing pulley **226** that is rigidly connected to the axle to prevent rotation of the pulley relative to the axle. Similarly, a timing pulley **228** is connected to the motor shaft. The drive belt **254** connecting the timing pulley **226** on the axle with the motor is a timing belt so that the rotation of the drive motor is precisely linked to the rotation of the axle. Although a single timing belt can be used to drive both axles synchronously, in the present instance, a pair of timing pulleys is connected to the motor shaft, and each timing pulley is connected to a corresponding timing pulley on one of the axles, as shown in FIG. **16**.

The drive motor **250** includes a sensor that is operable to detect the rotation of the motor to thereby determine the distance the car has traveled. Since the gears **222** are rigidly connected with the axles, which are in turn synchronously connected with the drive motor, the forward distance that the car moves corresponds can be exactly controlled to correlate to the distance that the drive motor is displaced. Accordingly, the distance that a car has traveled along the determined path depends on the distance through which the car motor is rotated.

To detect the rotation of the drive motor **250**, the motor includes a sensor **252** for detecting the amount of rotation of the drive motor. In the present instance the sensor **252** is a hall sensor. A portion of rotation of the motor corresponds to what is referred to as a tick. The sensor detects the number of ticks and sends a signal to the central processor **350**, which determines how far along the designate path the car has traveled based on the known information regarding the path and the number of ticks that the sensor detects for the motor.

As the car travels along the track, an item on top of the car may tend to fall off the car, especially as the car accelerates and decelerates. Therefore, in the present instance, the car includes a retainer **230** to retain the element on the car during delivery. As illustrated in FIGS. **12-17**, the retainer **230** is a hold down that clamps the item against the top surface of the car.

The retainer includes an elongated pivotable arm **232**. A biasing element, such as a spring, biases the arm downwardly against the top surface of the retainer **230**. The retainer **230** further includes an operator **234** in the form of a tab. Pushing downwardly on the tab raises the clamp from the top surface of the conveyor to allow a piece to be loaded onto the car or discharged from the car.

The car **200** may be powered by an external power supply, such as a contact along the rail that provides the electric power needed to drive the car. However, in the present instance, the car includes an onboard power source **240** that provides the requisite power for both the drive motor **250** and the conveyor motor **255**. Additionally, in the present instance, the power supply is rechargeable. Although the power supply may include a known power source, such as a rechargeable battery, in the present instance, the power supply **240** is made up of one or more ultracapacitors. Ultracapacitors are extremely high energy density capacitors. Capacitors store electrical energy by physically separating positive and negative charges, in contrast to the chemical means a battery uses. Ultracapacitors rely on an electrostatic effect, which is physical rather than chemical, and highly reversible. The ultracapacitors can accept very high amperage to recharge the ultracapacitors. By using a high current, the ultracapacitors can be recharged in a very short time, such as a few seconds or less.

The car includes one or more contacts for recharging the power source **240**. In the present instance, the car includes a plurality of brushes **245**, such as copper brushes that are spring-loaded so that the brushes are biased outwardly. The brushes **245** cooperate with a charging rail in the loading station to recharge the power source, as described further below.

Each car includes at least one and preferably two load sensors for detecting the items as it is loaded onto the car. The sensor(s) ensure that the mail piece is properly positioned on the car. In the present instance, the car includes a forward loading sensor **260** and a rearward loading sensor **262**. The forward loading sensor detects the leading edge of the item as it is loaded onto the car. The forward loading sensor **260** also detects the trailing edge of the item to ensure that the entire length of the item is loaded onto the car. Similarly, the rearward sensor **262** detects the leading edge and in certain instances, may detect the trailing edge of the mail piece. The loading sensors **260**, **262** may be simple I/R sensors that detect the presence or absence of a document or mail piece.

Although the car operates in response to signals received from the central controller **350**, which tracks the location of each car, the car may also include a reader **265** for reading indicia along the track to confirm the position of the car. For instance, each bin may be assigned a unique bar code, and the forward reader may scan the track or other area around the bin **190** at which an item is to be delivered. The data that the central processor has regarding the path that the car is to follow and the data regarding the distance the car has traveled based on the data regarding the rotation of the drive motor **250** should be sufficient to determine whether the car **200** is positioned at the appropriate bin. Nonetheless, it may be desirable to double check the location of the car before the item is discharged into the appropriate bin. Therefore, the scanner may operate to scan and read information regarding the bin at which the car is stopped. If the scanned data indicates that the bin is the appropriate bin, then the car discharges its item into the bin. Similarly, the car may have a second reader **266** for reading indicia adjacent the rearward edge of the car. The second reader **266** may be used in applications in which the system is set up to utilize a first series of bins **190** along the forward side and a second series of bins along the rearward side of the track **110**.

In foregoing description, the cars have drive gears that interact with teeth in the track to guide the cars around the track. Additionally, as described further below in the operation section, the location of the car may be controlled based on information regarding how far the car has traveled. In such applications it is desirable to synchronize the drive wheels of the car. However, in some applications alternative control systems may be used. For instance, the location of the cars can be controlled based on signals from sensors positioned along the track or indicators positioned along the track. In such instances, the cars may be configured to use a drive mechanism that is not synchronous as described above.

As discussed further below, the car further includes a processor for controlling the operation of the car in response to signals received from the central processor. Additionally, the car includes a wireless transceiver so that the car can continuously communicate with the central processor as it travels along the track. Alternatively, in some applications, it may be desirable to incorporate a plurality of sensors or indicators positioned along the track. The car may include a reader for sensing the sensor signals and/or the indicators, as well as a central processor for controlling the operation of the vehicle in response to the sensors or indicators.

Loading Column

Referring now to FIGS. **6-7** the details of the loading column **300** will be described in greater detail. The loading column **300** is formed adjacent the output end of the input station **50**. The loading column **300** is formed of a front pair of vertical rails **305***a*, **305***b* and a corresponding rearward set of vertical rails. The loading station **310** is positioned along the loading column. The loading station **310** is the position along the track in which the car **200** is aligned with the discharge end of the conveyor of the input station **50**. In this way, a mail piece from the input station may be loaded onto the car as it is conveyed toward the car from the input station.

Although the central processor **350** tracks the position of the car, a home sensor **312** is positioned adjacent the loading station **310**. When the home sensor detects the car, the position for the car is known relative to a fixed point along the track, and the central processor resets the position of the car to the home or zero position.

Referring to FIG. **7**, a pair of charging rails are disposed along the vertical rails **305***a*, **305***b*. The charging rails are conductive strips connected with an electrical supply. The charging contacts **245** of the car **200** engage the conductive strips to recharge the ultracapacitors **240**. Specifically, the biasing element of the brushes **245** biases the brushes outwardly toward the charging contacts. The electricity flowing through the charging contact **245** is a high amperage, low voltage source that allows the ultracapacitors to recharge in a few seconds or less. In addition, since the power supply provided by the ultracapacitors last for only a few minutes, the car recharges each time it travels through the loading column.

Additionally, it may be desirable to incorporate a startup charging rail similar to the charging rails described above, but disposed along either the return rail or the rails in the column adjacent to the loading column, depending on where the cars are stored when the cars are shut down. Since the cars use ultracapacitors, it is possible that the ultracapacitors will discharge while the system is shut down. Therefore, upon startup the cars will not have any charge and will not be able to move to the loading column to charge the ultracapacitors. Accordingly, the system may include a startup charging rail disposed along a rail that the cars contact when the cars are stored during shutdown. If the cars are stored in the loading column and the adjacent column during shutdown, then the startup rail is disposed in the column adjacent the loading column. Alternatively, if the cars are stored on the return rail and the loading column during shutdown, then the startup rail is disposed along the return rail. In this way, when the system is started, a charging current is supplied to the cars through the startup charging rail and the charging rail in the loading column.

As discussed previously, each car **200** includes a retainer **230** to hold down items on the car during transport. The retainer should be opened at the loading station to allow an item to be loaded onto the car. Accordingly, as shown in FIG. **6**, an actuator **316** is positioned along the column. The actuator **316** projects inwardly toward the cars as the cars are conveyed up the loading column. As a car is conveyed upwardly in the loading column **300**, the hold down actuator **316** contacts the hold down operator or tab **236**. The interaction between the actuator **316** and the tab **236** causes the retainer to open, so that items can be loaded onto the car. As the car moves upwardly past the actuator **316**, the tab **236** on the car disengages the actuator, thereby releasing the retainer, thereby holding down or clamping the mail piece against the top surface of the vehicle.

In the foregoing description, the loading station has been described as a column in which an item is loaded onto the car and the car then travels upwardly to the horizontal upper rail **135**. However, in some applications in may be desirable to configure the loading station so that the items are loaded onto the cars at or near the top of the vertical column. In such an application, the load on the cars would be reduced since the car will not have to lift the item loaded on the car. In order to load the items on the cars at the top of the conveyor, a vertical conveyor may be added to the system. For instance, a conveyor angled upwardly may convey the items upwardly to the top of the column to load the items onto the cars. Alternatively, one or more of a variety of conveyor configurations can be used to transport to items toward the top of the loading column to load the items onto the cars.

Operation

The system **10** operates as follows. An item is processed at the input station **50** to identify a characteristic of the piece that is indicative of where the piece should be sorted. For instance, the item may be a mail piece that is to be sorted according to department, box number or recipient. If the mail pieces are sorted by department, the piece may be processed to identify either an indicator of the department (such as box number) or the piece may be processed to identify the recipient. The central controller maintains a database that correlates various data to identify the destination bin. For instance, the database may correlate the recipient names with the appropriate department if the mail is being sorted according to department. In other embodiments, the piece may be a part that has a product code and the database may correlate the product code with the sort location.

As discussed previously, the input station may process the items automatically or manually. In a manual mode, the operator manually enters information regarding a piece and then drops the piece on a conveyor. The system electronically tags the piece with the sort information and the conveyor conveys the piece toward the loading station. Alternatively, if the input system is an automated system, the piece is automatically scanned to identify the relevant sort characteristic. For instance, the input station may use a scanner, such as a bar code scanner to read the postnet code on a piece, or the input station may include an imaging device, such as a high speed line scan camera in combination with an OCR engine to read information on the piece.

To prepare to receive an item, a car **200** moves along the track toward the loading station **310** in the loading column **300**. As the car approaches the loading station, the operator **236** for the hold down **230** engages the actuator **316**, which pivots the hold down upwardly to prepare the car to receive an item, as illustrated in FIG. **6**. When the car **200** moves into position at the loading station **310** the home sensor detects the presence of the car and sends a signal to the central processor **350** indicating that the car is positioned at the loading station. In the following description, the item being sorted is described as being a mail piece. It should be understood that such an item is an exemplary application of the system. As described above, the system can be configured to sort a variety of items in a variety of material handling applications.

Once the car is positioned at the loading station, the input station conveys a mail piece onto the car. As the mail piece is being conveyed onto the car **200**, the loading mechanism **210** on the car loads the mail piece onto the car. Specifically, the input station conveys the mail piece into contact with the conveyor belts **212** on the car. The conveyor belts **212** rotate toward the rearward side of the car, thereby driving the mail piece rearwardly on the car.

The operation of the conveyor belts is controlled by the loading sensors **260**, **262**. The forward loading sensor detects the leading edge of the mail piece as the mail piece is loaded onto the car. Once the forward loading sensor **260** detects the trailing edge of the mail piece, a controller onboard the car determines that the mail piece is loaded on the car and stops the conveyor motor. Additionally, the onboard controller may control the operation of the conveyor in response to signals received from the rearward sensor **262**. Specifically, if the rearward sensor **262** detects the leading edge of the mail piece, then the leading edge of the mail piece is adjacent the rearward edge of the car. To ensure that the mail piece does not overhang from the rearward edge of the car, the controller may stop the conveyor once the rearward sensor detects the leading edge of the mail piece. However, if the rearward sensor detects the leading edge of the mail piece before the forward sensor detects the trailing edge of the mail piece, the controller may determine that there is a problem with the mail piece (i.e. it is too long or two overlapping mail pieces were fed onto the car. In such an instance, the car may communicate an error message with the central controller, which may declare an error and provide an indicator to the operator that the car at the loading station requires attention. Alternatively, a reject bin **325** may be positioned behind the loading station so that mail pieces on the car at the loading station can be ejected into the reject bin **325**. In this way, if there is an error loading a mail piece onto a car, the mail piece can simply be ejected into the reject bin, and a subsequent mail piece can be loaded onto the car.

After a mail piece is loaded onto the car, the car moves away from the loading station. Specifically, once the onboard controller detects that a mail piece is properly loaded onto the car, the onboard controller sends a signal to start the drive motor **250**. The drive motor **250** rotates the axles, which in turn rotates the gears **222** on the wheels **220**. The gears **222** mesh with the drive surface **156** of the vertical rails **305** in the loading column to drive the car upwardly. Specifically, the gears and the drive surfaces mesh and operate as a rack and pinion mechanism, translating the rotational motion of the wheels into linear motion along the track **110**.

Since the cars move up the loading column from the loading station, the destination for the car does not need to be determined until after the car reaches the first gate along the upper rail **135**. For instance, if an automated system is used at the input station to scan and determine the characteristic used to sort the mail pieces, it may take some processing time to determine the relevant characteristic. The time that it takes to convey the mail piece onto the car and then convey the car up the loading column will typically be sufficient time to determine the relevant characteristic for the mail piece. However, if the characteristic is not determined by the time the car reaches the upper rail, the car may be directed down the second column, which is the column next to the loading column. The car travels down the second column to the lower rail **140**, and then back to the loading column. The car may stop in the second column to provide additional time to determine the characteristic. However, after waiting for a predetermined period the system may declare that the address cannot be determined and the car may be advanced from the second column and the piece may be discharged to a reject bin. Alternatively, rather than declare an error the car may continue to travel around the loop from the loading column to the second column until the characteristic is determined or until a predetermined time at which the central controller declares an error. Additionally, rather than using the reject bin when the system is unable to determine the characteristic for a mail piece, one of the bins in the second column can also be used as a reject bin. In this way, the cars are ready to receive a mail piece as soon as the car reaches the loading station, without having to eject the problem mail piece into the reject bin **325** at the loading station.

As described above, the system includes a loop that can be utilized as a buffer track to provide additional processing time to analyze the characteristic for the mail piece if necessary. Although the first and second columns can be used as the buffer loop, other columns can be used as a buffer loop if desired.

The foregoing discussion described the process for buffering a car if the system is unable to determine the characteristic for the mail piece by the time the car reaches the top rail. However, for most mail pieces, the system should be able to identify the characteristic without having to buffer the car. The following discussion describes the operation of the system assuming that the characteristic for the mail piece is determined before the car reaches the upper rail **135**.

Once the characteristic for the mail piece is determined, the central controller **350** determines the appropriate bin **190** for the mail piece. Based on the location of the bin for the mail piece, the route for the car is determined. Specifically, the central controller determines the route for the car and communicates information to the car regarding the bin into which the mail piece is to be delivered. The central controller then controls the gates along the track to direct the car to the appropriate column. Once the car reaches the appropriate column the car moves down the column to the appropriate bin. The car stops at the appropriate bin **190** and the onboard controller sends an appropriate signal to the conveyor motor **255** to drive the conveyor belts **212**, which drives the mail piece forwardly to discharge the mail piece into the bin. Specifically, the top of the car aligns with the gap between the appropriate bin **190** and the bottom edge of the bin that is immediately above the appropriate bin.

As discussed above, the central controller **350** controls the operation of the gates **180** in response to the location of the car **200** and the route that the car is to follow to deliver the mail piece. Additionally, as discussed below, the central controller controls the gates in response to the position of other cars on the track.

As the car **200** travels along the upper rail **135** and approaches a column, the gates for the vertical rails **130** are controlled as follows. If the car is to pass over the column on the way to the next column, the gates are displaced into the closed position, as shown in FIG. **9**. Specifically, both gates at the top of the column are closed so that the outer race **184** of the gate aligns with the straight track, with the outer race aligning with the drive surface **156** of the track **110**. In this way, the gates provide a straight drive surface that cooperates with the drive surface **156** to allow the car to travel over the column.

When the car comes to a column that it is to turn down, the gates are controlled as follows. Referring to FIG. **5**, the columns can be seen without the bins attached. The view in FIG. **5** is from the front of the apparatus **10**, so the car will be traveling along the upper rail from the right to the left in the perspective of FIG. **5**. In the following discussion, the car is to be conveyed to a bin in the column designated C in FIG. **5**. Column C includes two pairs of vertical legs. The first pair is front and back vertical legs **130***c* on the left side of column C; the second pair is front and back vertical legs **130***d* on the right side of column C.

In order for the car to travel down column C, the wheels on the left side of the car must travel down legs **130***c* and the right side wheels must travel down legs **130***d*. Therefore, as the car approaches column C, the gates at the top of **130***d* are displaced to the closed position so that the left side wheels remain on the upper rail and pass over the right side legs **130***d*. After the left side wheels of the car pass over the right legs **130***c*, the gates **180** at the top of the right legs **130***d* are displaced into the open position so that the right side wheels can turn down legs **130***d*. Specifically, after the left side wheels pass right legs **130***d*, the central controller operates the solenoids **186** of the gates **180** at the top of legs **130** to displace the gates into the open position, as shown in FIG. **8** (note that the view in FIG. **8** is taken from the rear side of the apparatus so that the perspective of the gates is reversed relative to the front side). The gates **180** block the straight path through the intersection **170** and the curved inner race **182** of the gates direct the right side wheels down vertical legs **130***d*. Similarly, the gates **180** at the top of the left side legs **130***c* are displaced into the open position to direct the left side wheels down vertical legs **130***c*.

As the car approaches the intersections at the bottom of legs **130***c* and **130***d*, the gates are operated similarly to the above description, but in reverse. Specifically, as the car approaches the intersections **170** at the bottom of legs **130***c* and **130***d*, the gates **180** in the intersections are displaced into the opened position so that the gates direct the forward and leading wheels to turn down the lower rail. From the perspective of FIG. **5**, the car travels from left to right after the car reaches the lower rail. After the car passes though the intersections at the bottom of the rails **130***c*, **130***d*, the gates at the bottom of right side legs **130***d* are displaced into the closed position before the left side wheels of the car reach the intersection at the bottom of the right side legs **130***d*. In this way, the left side wheels of the car pass straight through the intersection at the bottom of legs **130***d* along the bottom rail **140**.

As discussed above, the central controller **350** controls the operation of the gates in response to the position of the car and more specifically in response to the position of the left hand and right hand wheels of the car. The gates are fired sequentially to ensure that the different pairs of wheels are directed down the proper vertical legs. Alternatively, the operation of the gates may be controlled by signals received from the cars. Specifically, the cars may include a transmitter that transmits a signal to the central controller indicating that it is in proximity to a gate that is to be fired. Further still, the car may include an indicator that may be scanned as the car approaches the gate. Based on the indicator and the know destination for the car, the gate may fire. Still further, the car may include an mechanical actuator that selectively triggers or actuates a gate to appropriately direct the car.

One of the advantages of the system as described above is that the orientation of the cars does not substantially change as the cars move from travelling horizontally (along the upper or lower rails) to vertically (down one of the columns). Specifically, when a car is travelling horizontally, the two front geared wheels **220** cooperate with the upper or lower horizontal rail **135** or **140** of the front track **115**, and the two rear geared wheels **220** cooperate with the corresponding upper or lower rail **135** or **140** of the rear track **120**. As the car passes through a gate and then into a column, the two front geared wheels engage a pair of vertical legs **130** in the front track **115**, and the two rear geared wheels engage the corresponding vertical legs in the rear track **120**.

As the car travels from the horizontal rails to the vertical columns or from vertical to horizontal, the tracks allow all four geared wheels to be positioned at the same height. In this way, as the car travels along the track it does not skew or tilt as it changes between moving horizontally and vertically. Additionally, it may be desirable to configure the cars with a single axle. In such a configuration, the car would be oriented generally vertically as opposed to the generally horizontal orientation of the cars described above. In the single axle configuration, the weight of the cars would maintain the orientation of the cars. However, when using a single axle car, the orientation of the sort locations would be re-configured to accommodate the vertical orientation of the cars. Similarly, the loading station would also be re-configured to load the pieces onto the cars in the vertical orientation.

Traffic Control

Since the system includes a number of cars **200**, the system controls the operation of the different cars to ensure the cars do not collide into one another. In the following discussion, this is referred to as traffic control.

A variety of methodologies can be used for traffic control. For instance, the traffic control can be a distributed system in which each car monitors its position relative to adjacent cars and the onboard controller controls the car accordingly. One example of such as system utilizes proximity sensors on each car. If the proximity sensor for a car detects a car within a predefined distance ahead of the car, the onboard controller for the trailing car may control the car by slowing down or stopping the trailing car. Similarly, if a car detects a car within a predefined distance behind the car, the lead car may speed up unless the lead car detects a car ahead of it within the predefined distance. In this way, the cars may control the speed of the cars independently based on the feedback from the proximity sensors.

Although the system may use a distributed system for traffic control, in the present instance, the system uses a centralized system for traffic control. Specifically, the central controller **350** tracks the position of each car **200** and provides traffic control signals to each car based on the position of each car relative to adjacent cars and based on the route for each car.

In the present instance, the central controller **350** operates as the traffic controller, continuously communicating with the cars as the cars travel along the track **110**. For each car, the central controller determines the distance that each car can travel, and communicates this information with the cars. For instance, if car B is following car A along the track, and car A is at point A, car B can safely travel to a point just before point A without crashing into car A. As car A advances to a subsequent point B along the track, car B can travel safely to a point just before point B without crashing into car A.

The cars continuously communicate with the central controller to provide information indicative of their positions, so that the central controller can continuously update the safe distances for each car as the cars advance around the track.

Although the foregoing discussion is limited to determining safe zones based on the positions of the various cars on the track, the determination of safe zones is based on other factors that affect the traffic. For instance, when calculating the safe distance for a car, the central controller considers the distance between the car and the next gate, as well as the distance to the destination bin for the car.

As can be seen from the foregoing, increasing the frequency of communication between the cars and the central controller increases the efficiency of the traffic flow along the track. Accordingly, in the present instance, the traffic control is designed to communicate with a car once for every inch the car travels along the track. Therefore, if a car travels at 25 inches per second, the central controller communicates with the car every 40 msec. Further, it is desirable to have the cars travel at up to 50 inch/sec. Therefore, it is desirable to configure the communications to allow the cars to communicate with the central controller every 20 msec.

In addition, to the foregoing variables used to calculate safe distances, information regarding the track profile ahead of each car is used to calculate safe distances. For instance, the central controller determines whether the path ahead of a car is sideways movement, uphill movement (i.e. movement vertically upwardly) or downhill movement (i.e. movement vertically downwardly).

One of the issues in traffic control relates to merging at intersections **170**. The problem arises when a car needs to merge onto the return rail **140**. If two cars will arrive at the intersection close enough to collide, one of the cars needs to have priority and the other car needs to wait or slow down to allow the first car to go through.

A first method for controlling merging traffic is based on determining the next gap large enough for a car to have time to pass through an intersection without colliding with another car. In other words, if a first car approaches an intersection and it is determined that the gap between the first car and a second car is not sufficient for the first car to pass through, the first car waits at the intersection until there is a gap large enough to allow the first car to pass through.

A second method for controlling merging traffic is based on determining which car is closest to the homing sensor at the loading station **310**. The car with the shortest distance to the homing sensor gets priority at the intersection.

Another factor that the traffic controller considers when calculating safe distances relates to the position of cars in adjacent columns. In the present instance, most of the adjacent columns share a common vertical rail. For instance, in FIG. **5**, the leftmost column uses vertical rails **130***a* and **130***b*. The column next to the leftmost column uses vertical rails **130***b* and **130***c*.

However, in the present instance, some of the columns may have two vertical rails **130** that are independent from the adjacent columns. For instance, the loading column **300** has two independent rails that are not shared with the adjacent column. Therefore, cars can travel up the loading column without regard to the position of cars in the column next to the loading column. Furthermore, as shown in FIG. **5**, it may be desirable to configure the column next to the loading column so that it also has two independent vertical rails. In this way, cars can more freely travel up the loading column and down the adjacent column to provide a buffer loop as described previously.

Accordingly, when calculating safe distances, the traffic controller evaluates the position of cars in adjacent columns if the cars share a common vertical rail to ensure that the two cars do not collide as the car travel down the adjacent columns.

In the foregoing discussion, the sorting of items was described in relation to an array of bins disposed on the front of the sorting station **100**. However, as illustrated in FIGS. **2** & **4**, the number of bins in the system can be doubled by attaching a rear array of bins on the back side of the sorting station. In this way, the cars can deliver items to bins on the front side of the sorting station by traveling to the bin and then rotating the conveyor on the car forwardly to eject the piece into the front bin. Alternatively, the cars can deliver items to bins on the rear side of the sorting station by traveling to the bin and then rotating the conveyor on the car rearwardly to eject the piece into the rear bin.

Additionally, the sorting station **100** is modular and can be readily expanded as necessary simply by attaching an additional section to the left end of the sorting station. Further, although the foregoing describes the array of bins as being essentially a two dimensional array in which the cars simply travel in X and Y directions, the sorting station can be expanded to add additional "runs" of track. Specifically, a separate sorting station parallel to or perpendicular to the sorting station illustrated in FIG. **2** may be connected to the sorting station. In this way, the car would travel in a third dimension relative to the X and Y directions of the sorting station illustrated in FIG. **2**. For instance, additional sections of track may be connected to the sorting station illustrated in FIG. **2** perpendicular to the illustrated sorting station, so that the additional track forms an L-shape intersecting the loading column. In such a configuration, gates selectively direct the cars either down the upper rail **135** or rearwardly toward the additional track. Similarly, a plurality of parallel rows of sorting stations can be interconnected so that the cars selectively travel along a crossover rail until the car reaches the appropriate row. The car then travels down the row until it reaches the appropriate column as described above.

It will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the broad inventive concepts of the invention. For instance, in the foregoing description, the operation of the sorting station is described as being centralized with the central controller. However, it may be desirable to have the cars control the operation of the gates. According to one alternative, the cars incorporate one or more mechanical actuators that cooperate with an operator on the gate. The actuators on the cars are operable between first and second positions. In a first position, the actuator engages the gate operator to displace the gate into the closed position. In a second position, the actuator engages the gate to displace the gate into the open position. Alternatively, the gate may be biased toward the opened position, so that when the car actuator is in the second position it does not engage the gate operator. In another alternative, each car includes a mechanism for communicating with each gate. If the gate needs to be pivoted to direct an approaching car along a particular path, the car sends a signal to the gate indicating whether the gate should be opened or closed. In response to the signal from the car, the gate pivots to the appropriate position.

Further, in the above description, the system uses a wireless communication between the cars and the central controller. In an alternative embodiment, a communication line may be installed on the track and the cars may communicate with the central controller over a hard wired communication link. Still further, the system has been described as being useful in sorting incoming mail. However, the system may also be utilized to sort and prepare outgoing mail. For instance, after determining a characteristic for a mail piece, the system may print a marking onto the mail piece. For instance, after determining the recipient's address for a mail piece, the system determines which bin the mail piece is to be sorted to. As the mail piece is conveyed to the bin, a printer prints the appropriate postnet bar code on the piece before sorting the piece. To provide the printing functionality, the system may include a printer disposed along the track. When the car approaches the printer the car stops and at least partially discharges the mail piece to extend the mail piece toward the printer. The printer then prints the appropriate postnet code. The car then reverses the conveyors to load the piece back onto the car all the way, and then travels to the appropriate bin. Similarly, the system may include a device for selectively applying labels to the pieces. Similar to the above example of printing markings onto the pieces, the labeler may be positioned along the track. The cars selectively stop at the labeler on route to the appropriate bin and at least partially discharge the mail piece toward the labeler. The labeler then applies a label onto the mail piece and the conveyor on the car then reverses to load the piece back onto the car.

In addition to outgoing mail applications, it may be desirable to incorporate a printer and/or a labeler in systems configured to process incoming mail. For instance, when sorting incoming mail pieces, it may be desirable to print certain information, such as sort codes, a time stamp or audit trail information onto some or all of the pieces being processed. In some instances such information may be printed directly onto the mail pieces. In other instances, a label may be applied to the mail pieces and the information may be printed on the label.

In addition to a printer and a labeler, the system may include a scale for weighing the mail pieces. The scale may be positioned along the track **110**, such as along the loading column. To weigh a piece, the car stops adjacent the scale, and ejects the piece from the car onto the scale by driving the conveyor belts **212**. Preferably, the scale includes a conveyor or transfer mechanism for discharging the piece from the scale and back onto the car or onto a subsequent car. When the piece is loaded onto the car from the scale, the car drives the conveyors to load the piece as discussed above in connection with the loading station.

It should therefore be understood that this invention is not limited to the particular embodiments described herein, but is intended to include all changes and modifications that are within the scope and spirit of the invention as set forth in the claims.

What is claimed is:

1. A delivery vehicle operable with a material handling system having a plurality of sort locations and a guide system, wherein the delivery vehicle comprises:

a platform for receiving an item to be conveyed to one of the sort locations;

a motor for driving the vehicle to one of the sort locations;

a drive system cooperable with the guide system to guide the vehicle to one of the sort locations, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a first direction of travel to a second direction of travel, wherein the first direction is at an angle to the second direction;

a releasable retainer for positively engaging the item to be delivered by the vehicle, wherein the retainer includes a release for releasing the retainer when the vehicle is adjacent the one sort location; and

an ejector for ejecting the item from the vehicle toward the one sort location after the retainer releases the item to be delivered to the one sort location;

wherein the drive system for the vehicle is operable to move the vehicle in a first direction and a second direction transverse the first direction, and wherein the ejector is operable to eject the item along a third direction that is transverse both the first and second directions.

2. The delivery vehicle of claim **1** wherein the drive system comprises a plurality of driven gears that interact with the guide system to control the position of the vehicle along the guide system.

3. The delivery vehicle of claim **2** comprising a pair of synchronously drive axles, wherein the gears are fixed to the axles so that the gears are synchronously driven to drive the vehicle along the guide system.

4. The delivery vehicle of claim **1** wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon when the vehicle changes between a first direction and a second direction transverse the first direction and transverse horizontal.

5. A system for sorting or retrieving a plurality of items, comprising:

a plurality of destination areas for receiving items, wherein the destination areas are arranged in a first array of columns or rows;

a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and

a track system for guiding the delivery vehicles to the destinations, wherein the track system forms a loop having a forward leg leading away from a loading station along the track where materials are loaded onto the delivery vehicles and a return leg leading back to the station, wherein the track system comprises:

an upper generally horizontal track section

a lower generally horizontal track section vertically spaced apart from the upper track section;

a first generally vertical track section intersecting the upper track section to form a first intersection, and intersecting the lower horizontal track section to form a second intersection;

a second generally vertical track section intersecting the upper track section to form a third intersection, and intersecting the lower track section to form a fourth intersection;

wherein the intersections provide paths between a generally horizontal path of travel along one of the horizontal track sections, and a generally vertical path of travel along one of the vertical track sections;

wherein the array of destination areas are positioned along the track system so that the flow of material between a delivery vehicle and a destination area is in a third direction that is transverse both the horizontal direction of the upper and lower track and the vertical direction of the first and second vertical track section;

wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between a vertical track and a horizontal track.

6. The system of claim **5** wherein the loop of the track system is configured so that each delivery vehicle is directed along the return leg to the loading station to complete a loop.

7. The system of claim **5** wherein each delivery vehicle comprises an ejector for ejecting material from the delivery vehicle in the third direction that is transverse both the upper and lower horizontal track sections and the first and second vertical track sections.

8. The system of claim **5** wherein the track system comprises a first gate at the first intersection, wherein in a first position, the gate provides a first path through the first intersection along one the upper horizontal track while impeding travel along the first vertical track section, and wherein in a second position, the first gate provides a path through the intersection toward the first vertical track section to allow one of the delivery vehicles to change path direction.

9. The system of claim **8** wherein the track system comprises a second gate at the second intersection, wherein in a first position, the second gate provides a path along the lower track, and in a second position, the second gate closes the path along the lower track and provides a continuous path from the first vertical track to the lower track to allow the delivery vehicle to change directions from a vertical path to a horizontal path.

10. The system of claim **5** wherein the track comprises a row of teeth and the vehicles comprise drive wheels having teeth that mesh with the row of teeth in the track to provide positive drive surfaces for controlling the position of the vehicles as the delivery vehicles are driven along the track.

11. The system of claim **10** wherein each vehicle comprises a pair of synchronously driven axles, wherein drive wheels having teeth are fixed to the axles that mesh with corresponding teeth formed in the track, wherein the drive wheels having teeth are fixed to the axles so that the vehicle is synchronously driven along the track system.

12. The system of claim 10 comprising a second array of sort locations positioned along the track system so that the flow of material between a delivery vehicle and a destination area is in the third direction on a side of the track system opposite of the first array of sort destinations.

13. The system of claim 12 wherein the vehicles are configured to transfer items between the vehicles and both the first and second arrays of destinations.

14. The system of claim 5 comprising:

a destination module operable to identify the destination area to which an item is to be delivered by one of the delivery vehicles, wherein the destination module identifies the destination area based on a marking on the item; and

a controller for controlling the operation of the one vehicle as the vehicle delivers the item to the identified destination area.

15. The system of claim 5 comprising a scanning station for scanning the items to identify information on the item, wherein the system determines the destination area for an item based on the scanned information.

16. The system of claim 15 wherein the scanning station comprises an optical imager for obtaining image data for the item.

17. The system of claim 15 comprising a controller communicating with a vehicle controller on the vehicle transporting the item, wherein the vehicle controller controls the movement of the vehicle as it travels to the determined destination area.

18. A system for sorting or retrieving a plurality of items, comprising:

a plurality of destination areas for receiving items, wherein the destination areas are arranged in a first array of columns or rows;

a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and

a track system for guiding the delivery vehicles to the destinations, wherein the track system forms a loop having a forward leg leading away from a loading station along the track where materials are loaded onto the delivery vehicles and a return leg leading back to the station, wherein the track system comprises:

a first track section extending in a first direction;

a second track section spaced apart from the first track section extending generally in the first direction;

a third track section extending in a second direction transverse the first direction, intersecting the first track section to form a first intersection, and intersecting the second track section to form a second intersection;

a fourth track section extending generally in the second direction, intersecting the first track section to form a third intersection, and intersecting the second track section to form a fourth intersection;

wherein the intersections provide paths between a path of travel along the first direction and a path of travel along the second direction;

wherein the array of destination areas are positioned along the track system so that the flow of material between a delivery vehicle and a destination area is along a third axis that is transverse both the first direction and the second direction;

wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between the first track section and the third track section.

19. The system of claim 18 wherein the loop of the track system is configured so that each delivery vehicle is directed along the return leg to the loading station to complete a loop.

20. The system of claim 18 wherein each delivery vehicle comprises an ejector for ejecting material from the delivery vehicle along the third axis.

21. The system of claim 5 wherein the track system comprises a first gate at the first intersection, wherein in a first position, the gate provides a first path through the first intersection along the first section while impeding travel along the third track section, and wherein in a second position, the first gate provides a path through the intersection toward the third track section to allow one of the delivery vehicles to change path direction.

22. The system of claim 21 wherein the track system comprises a second gate at the second intersection, wherein in a first position, the second gate provides a path along the second track, and in a second position, the second gate closes the path along the second track and provides a continuous path from the third track section to the second track section to allow the delivery vehicle to change directions from a path along the second direction to a path along the first direction.

23. The system of claim 18 wherein the track comprises a row of teeth and the vehicles comprise drive wheels having teeth that mesh with the row of teeth in the track to provide positive drive surfaces for controlling the position of the vehicles as the delivery vehicles are driven along the track.

24. The system of claim 23 wherein each vehicle comprises a pair of synchronously driven axles, wherein drive wheels having teeth are fixed to the axles that mesh with corresponding teeth formed in the track, wherein the drive wheels having teeth are fixed to the axles so that the vehicle is synchronously driven along the track system.

25. The system of claim 23 comprising a second array of sort locations positioned along the track system so that the flow of material between a delivery vehicle and a destination area generally parallel to the third axis on a side of the track system opposite of the first array of sort destinations.

26. The system of claim 25 wherein the vehicles are configured to transfer items between the vehicles and both the first and second arrays of destinations.

27. The system of claim 18 comprising:

a destination module operable to identify the destination area to which an item is to be delivered by one of the delivery vehicles, wherein the destination module identifies the destination area based on a marking on the item; and

a controller for controlling the operation of the one vehicle as the vehicle delivers the item to the identified destination area.

28. The system of claim 18 comprising a scanning station for scanning the items to identify information on the item, wherein the system determines the destination area for an item based on the scanned information.

29. The system of claim 18 wherein the scanning station comprises an optical imager for obtaining image data for the item.

30. The system of claim 28 comprising a controller communicating with a vehicle controller on the vehicle transporting the item, wherein the vehicle controller controls the movement of the vehicle as it travels to the determined destination area.

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EXHIBIT B

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U.S. PATENT: *8,104,601*

ISSUE DATE: *January 31, 2012*

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DEPARTMENT OF COMMERCE

US008104601B2

(12) **United States Patent**
Hayduchok et al.

(10) **Patent No.: US 8,104,601 B2**
(45) **Date of Patent: Jan. 31, 2012**

(54) **METHOD AND APPARATUS FOR DELIVERING ITEMS TO DESTINATION AREAS**

(75) Inventors: **George Hayduchok**, Mount Holly, NJ (US); **Robert R. DeWitt**, Marlton, NJ (US)

(73) Assignee: **Opex Corporation**, Moorestown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **Jan. 3, 2011**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(60) Provisional application No. 60/884,766, filed on Jan. 12, 2007.

(51) **Int. Cl.**
B65G 1/00 (2006.01)

(52) **U.S. Cl.** **198/347.1**; 198/468.6

(58) **Field of Classification Search** 198/347.1, 198/358, 349, 349.6, 468.6, 468.1; 413/273
See application file for complete search history.

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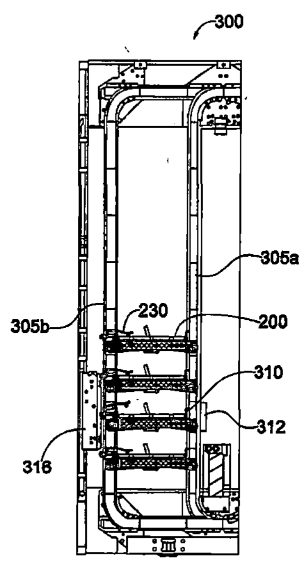
Primary Examiner — James R Bidwell

(74) *Attorney, Agent, or Firm* — Stephen H. Eland; Dann, Dorfman, Herrell & Skillman

(57) **ABSTRACT**

A method and apparatus are provided for sorting items to a plurality of sort destinations. The items are loaded onto one of a plurality of independently controlled delivery vehicles. The delivery vehicles follow a track that guides the delivery vehicles to the sort destinations, which are positioned along the track. Once at the appropriate sort destination, the delivery vehicle ejects the item to the sort destination and returns to receive another item to be delivered.

28 Claims, 13 Drawing Sheets



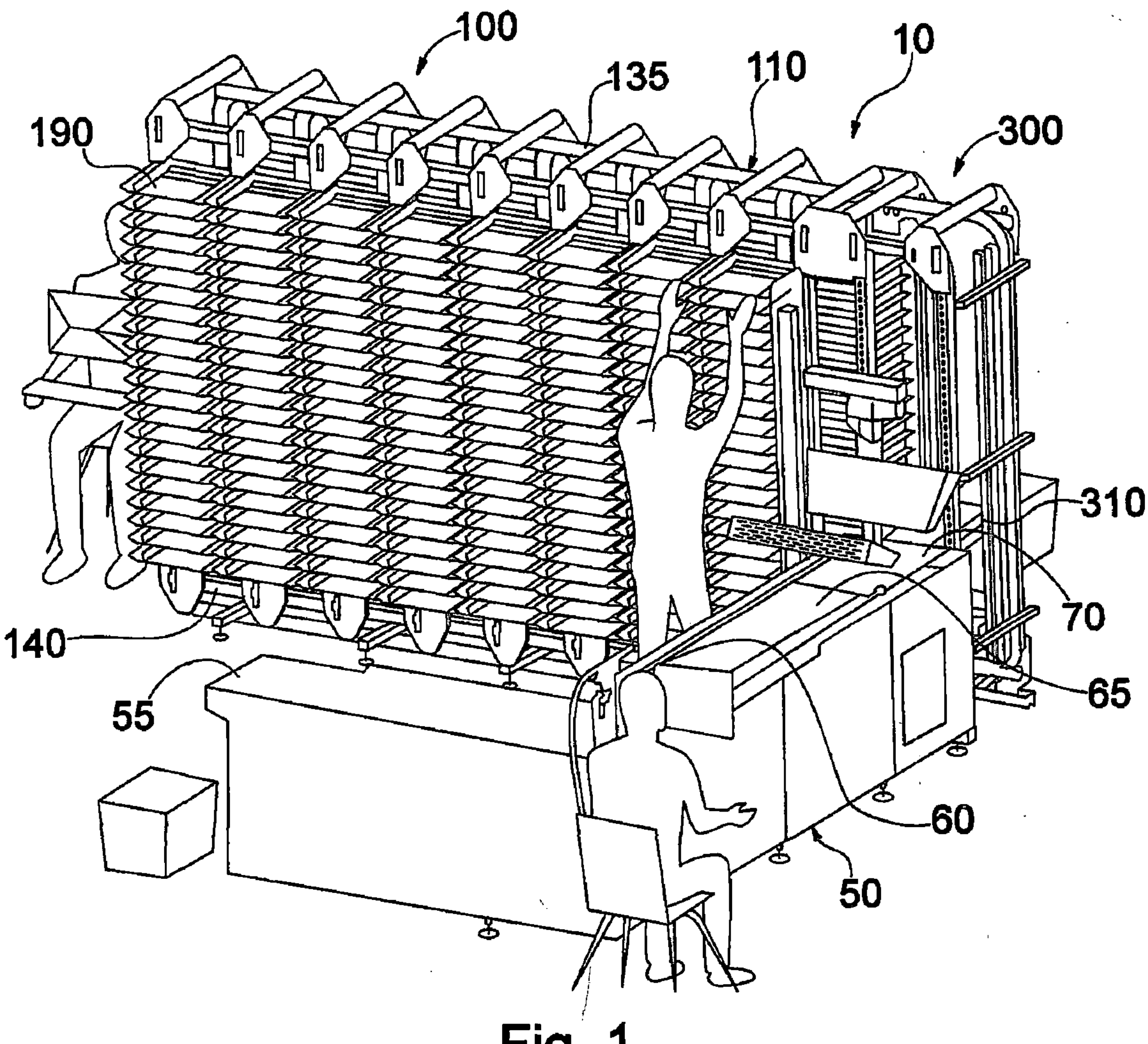


Fig. 1

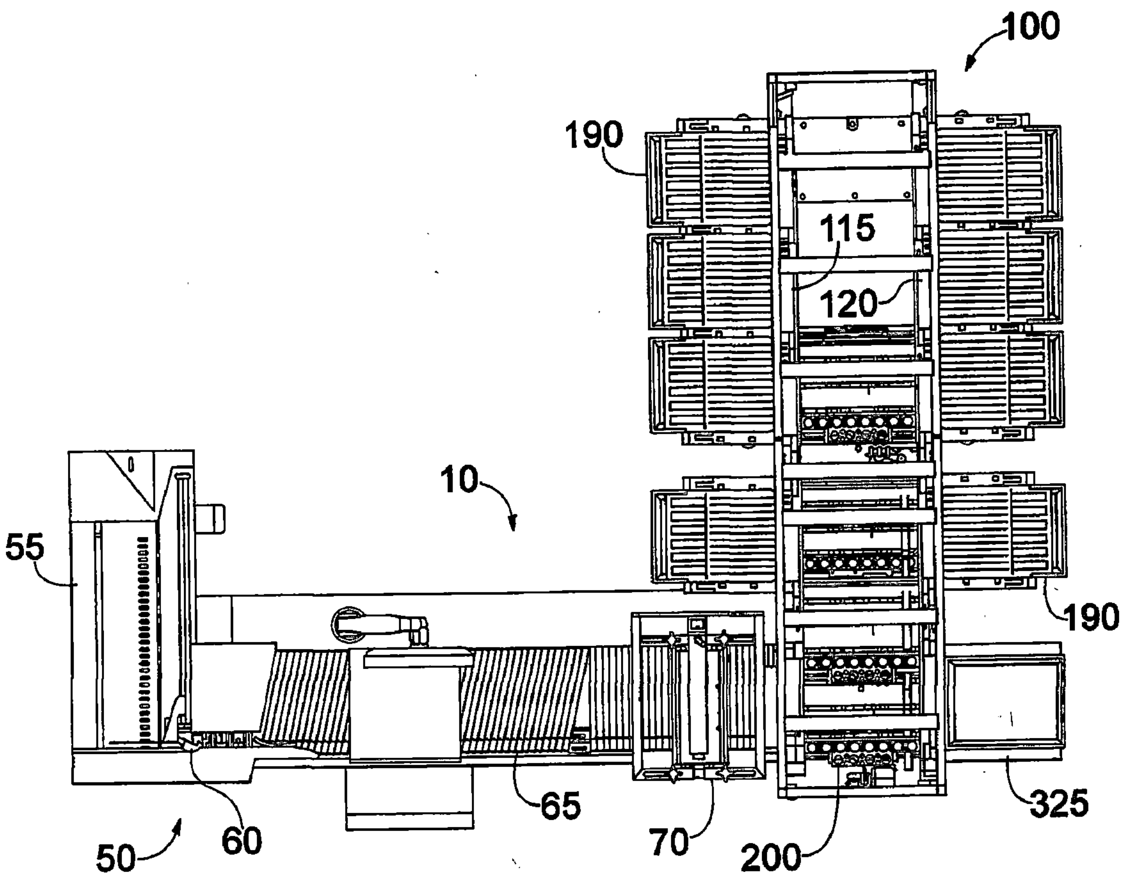


Fig. 2

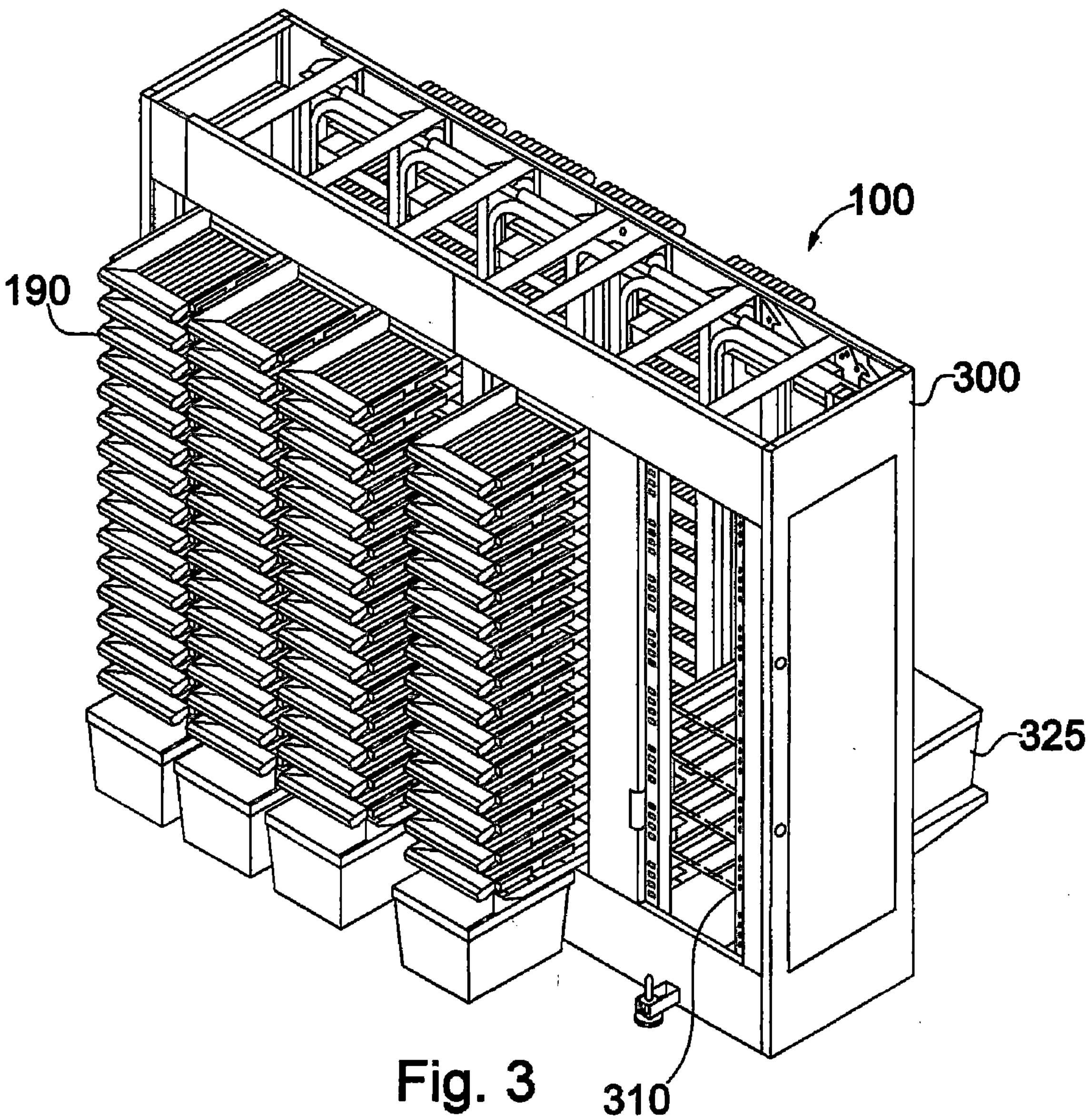


Fig. 3

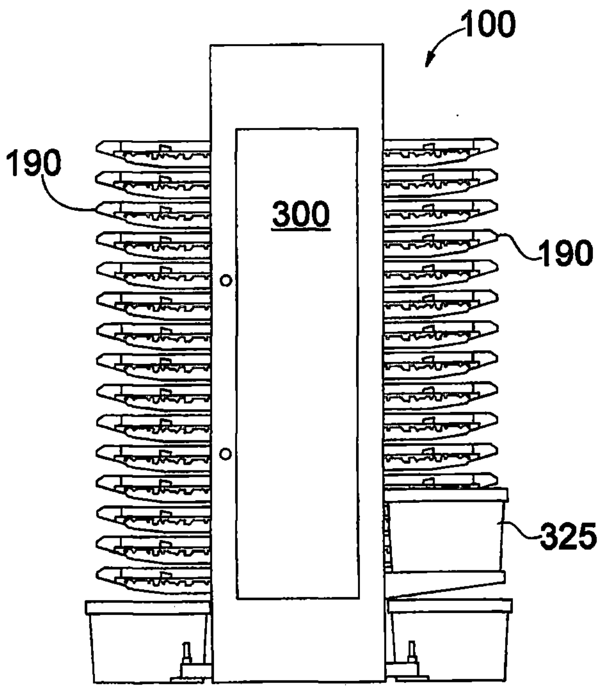


Fig. 4

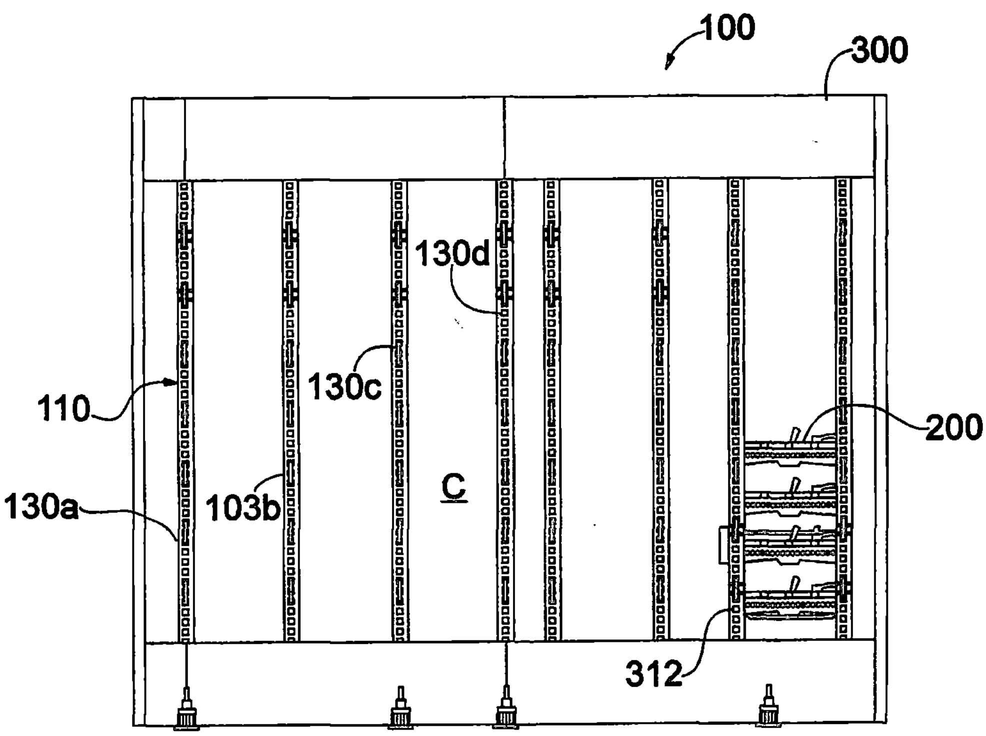


Fig. 5

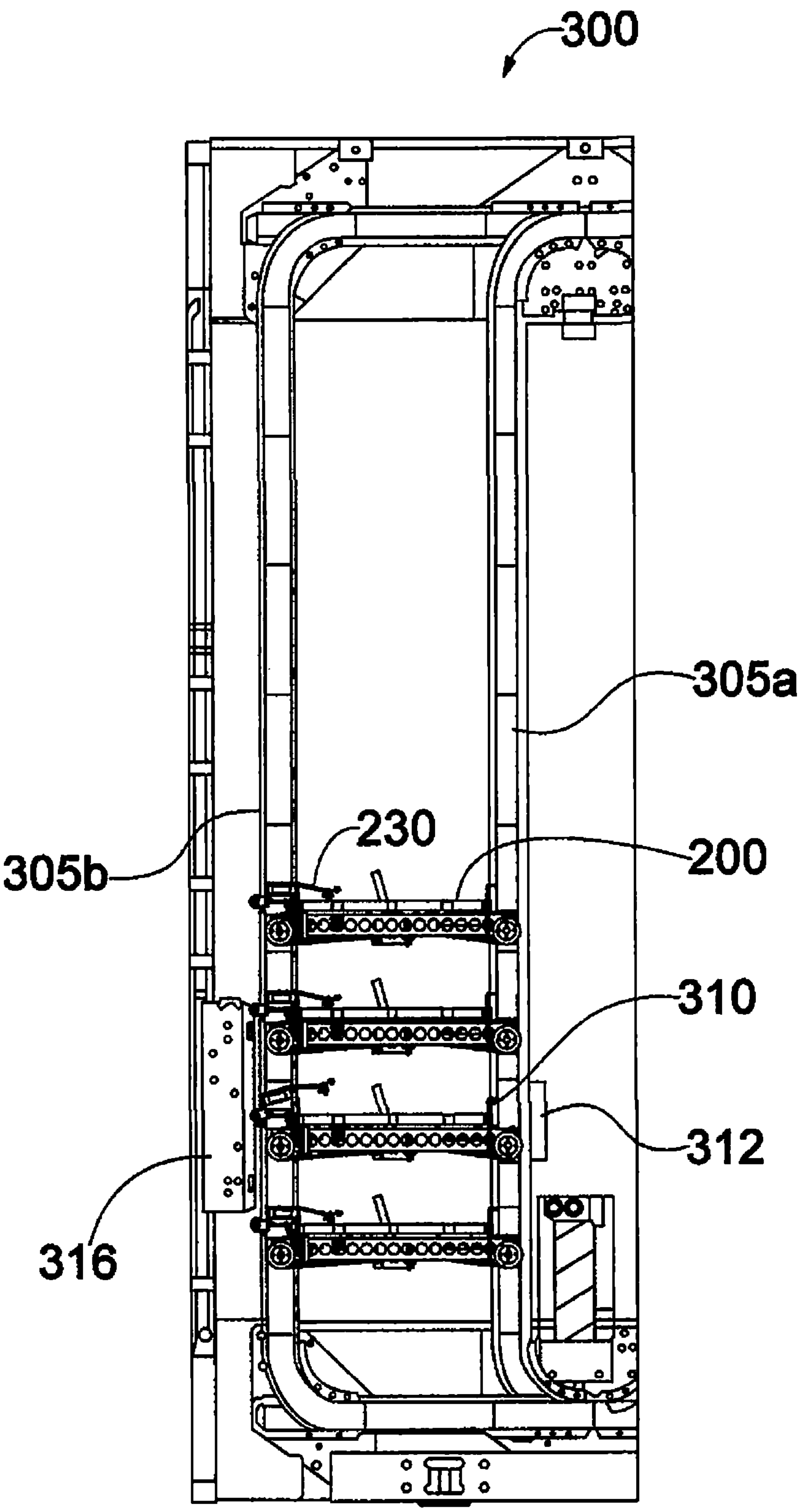


Fig. 6

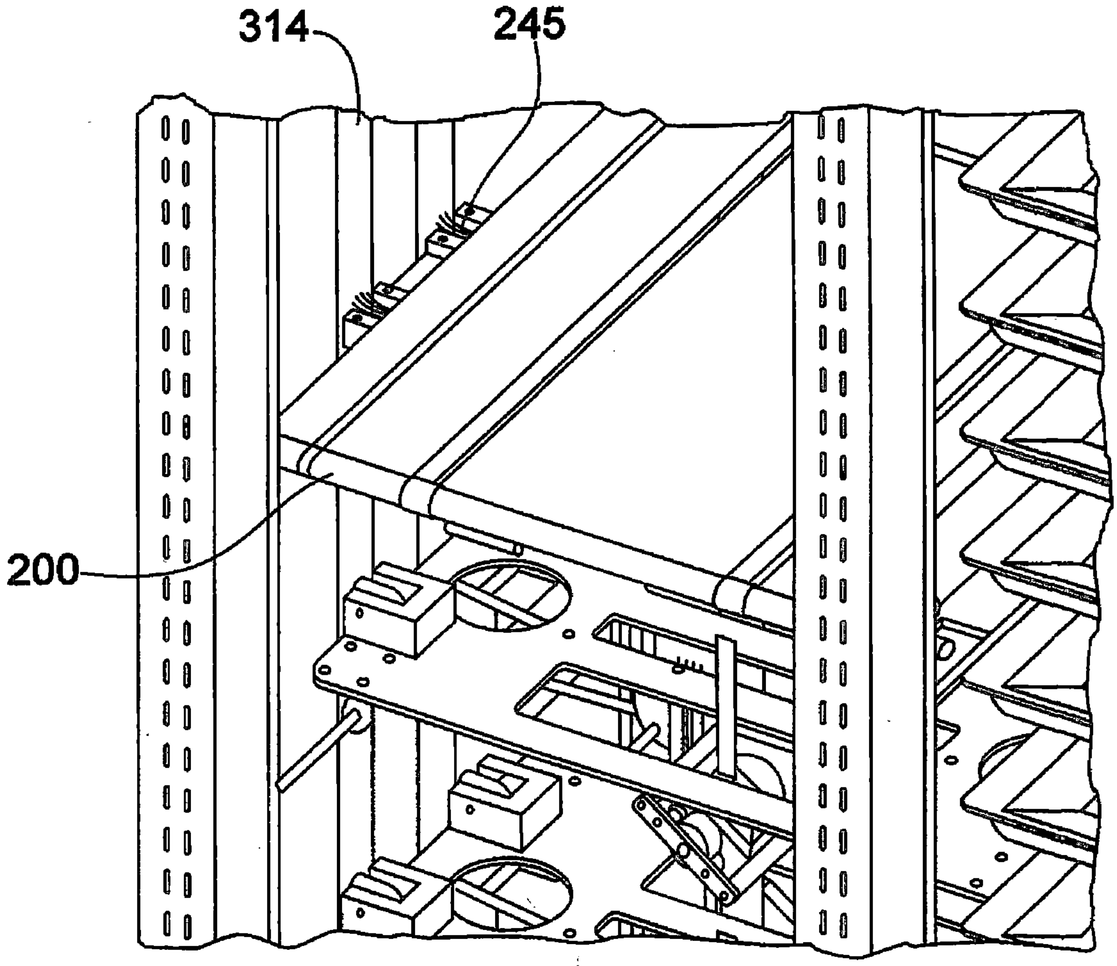


Fig. 7

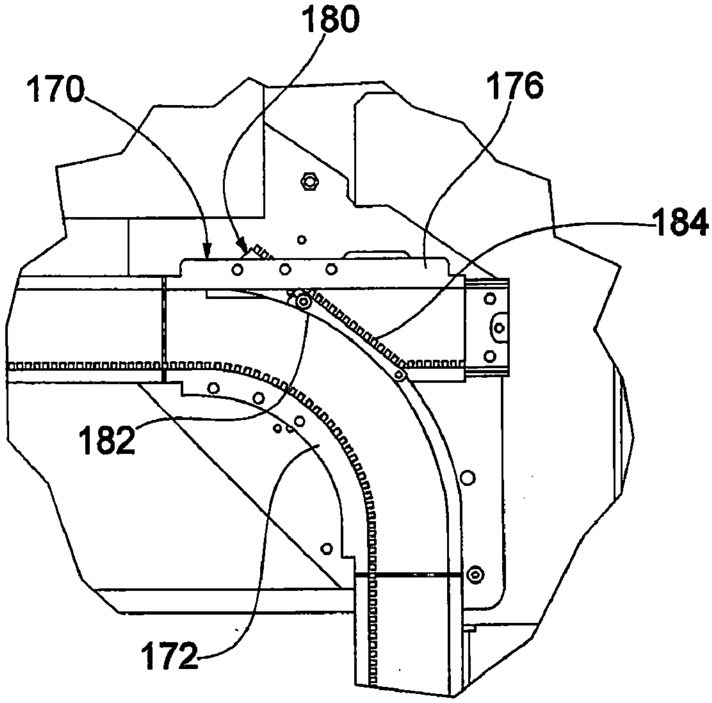


Fig. 8

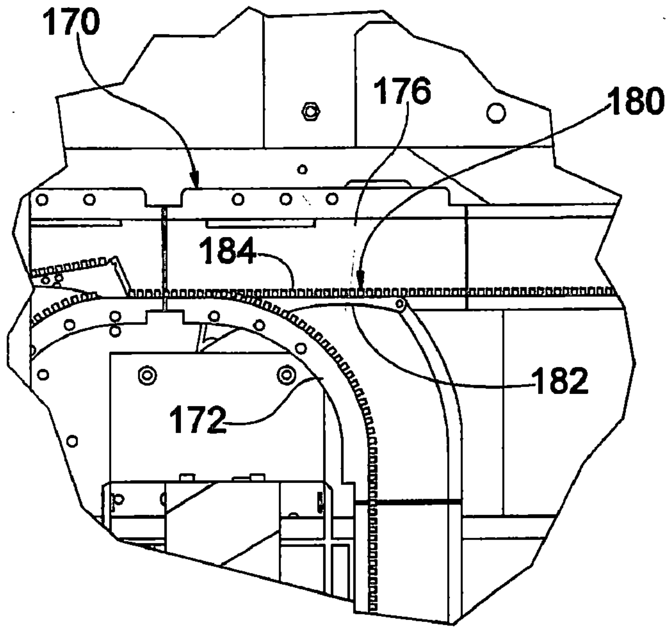


Fig. 9

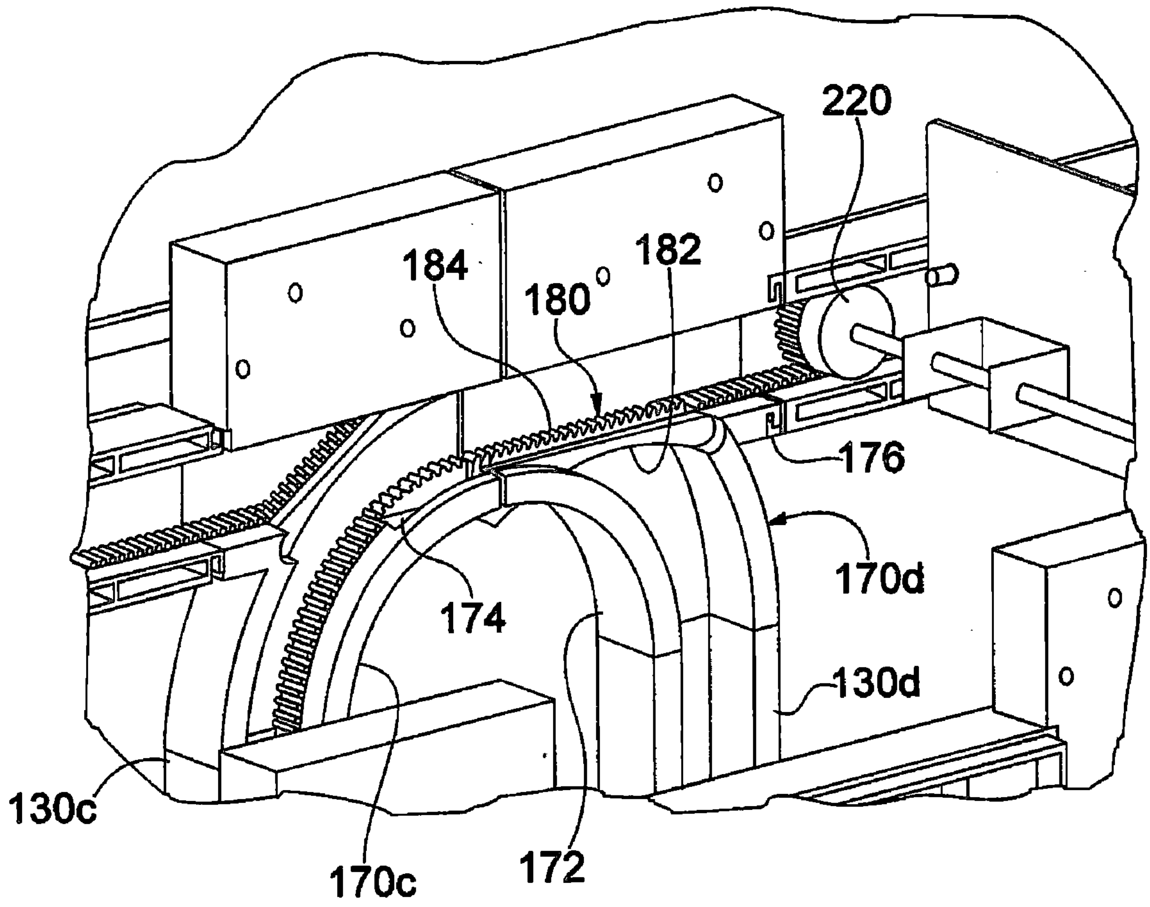
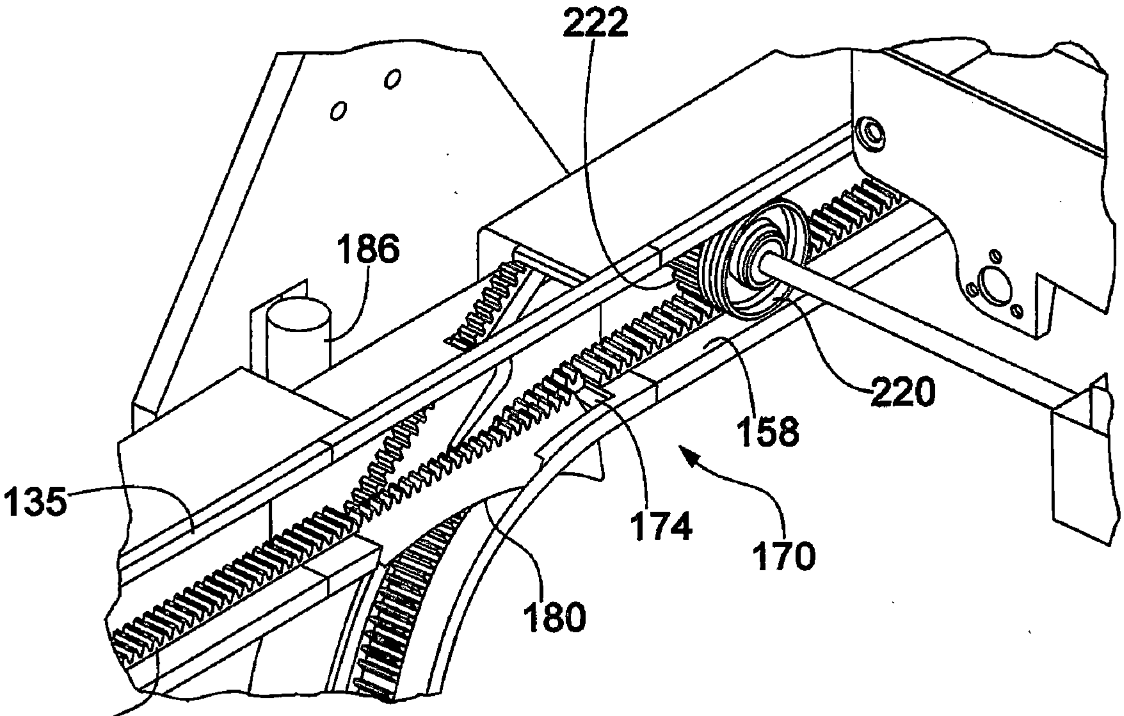


Fig. 10



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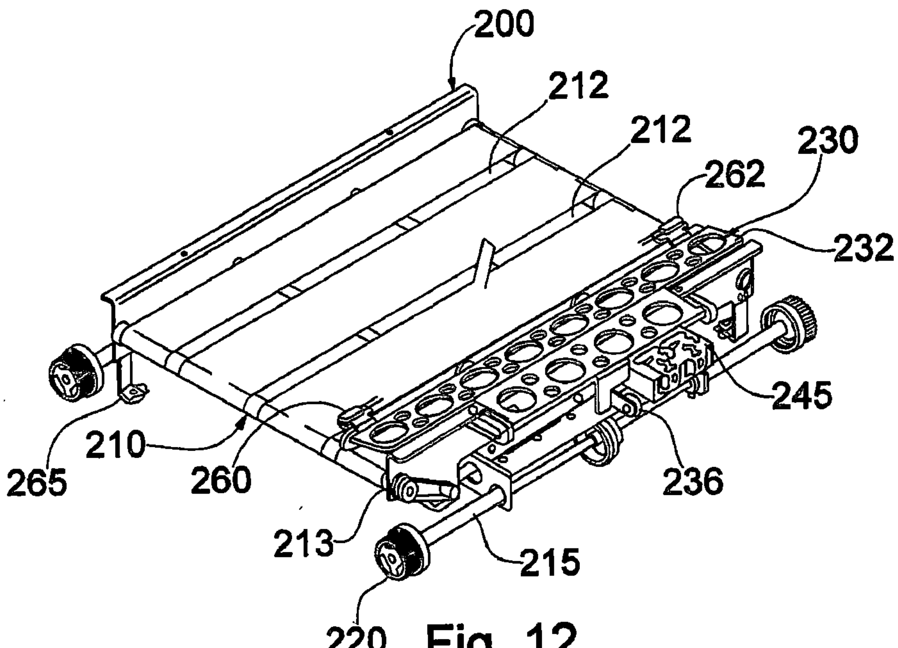
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Fig. 12

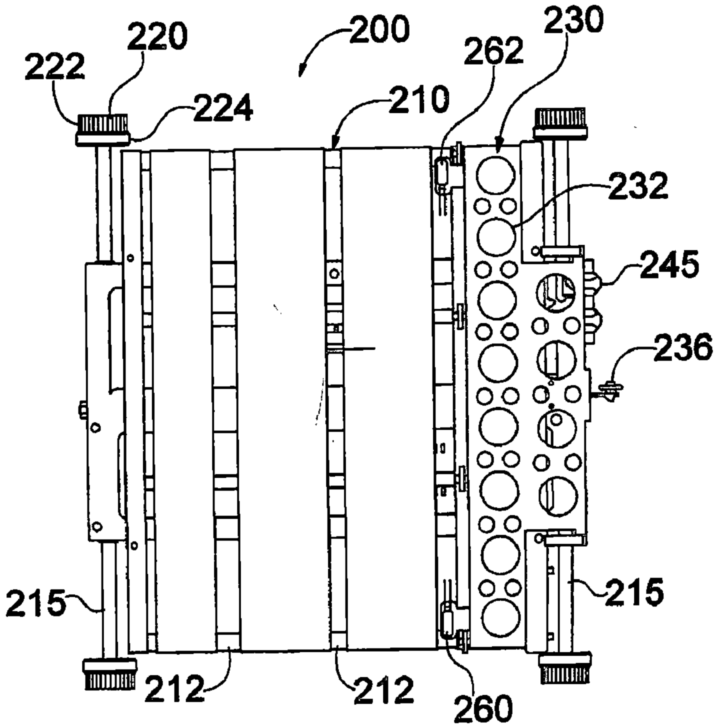
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Fig. 13

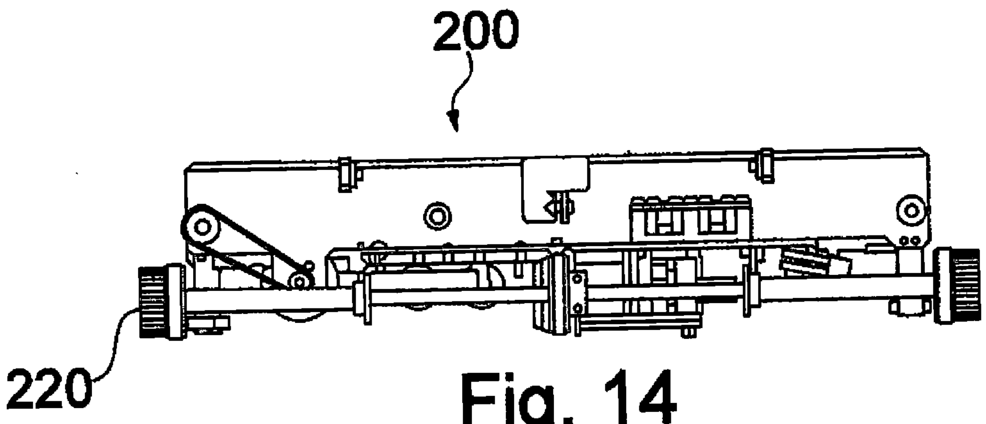


Fig. 14

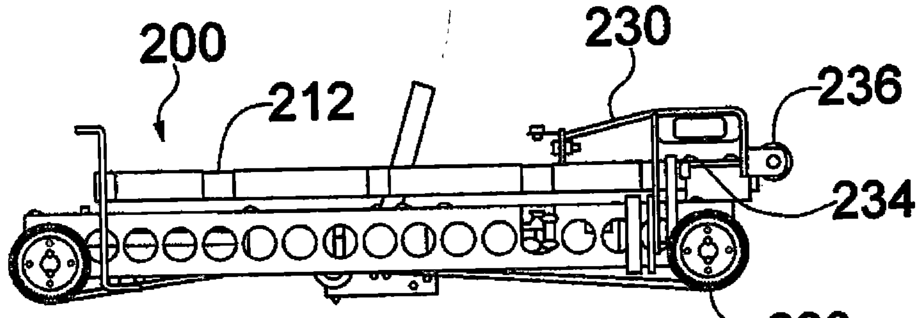
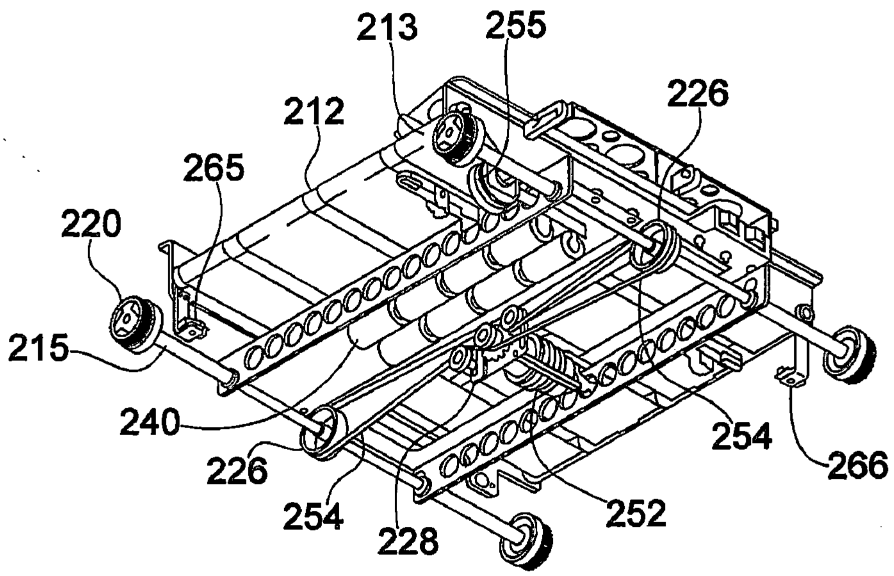


Fig. 15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212
226
265
220
215
240
226
254
228
254
252
266

Fig. 16

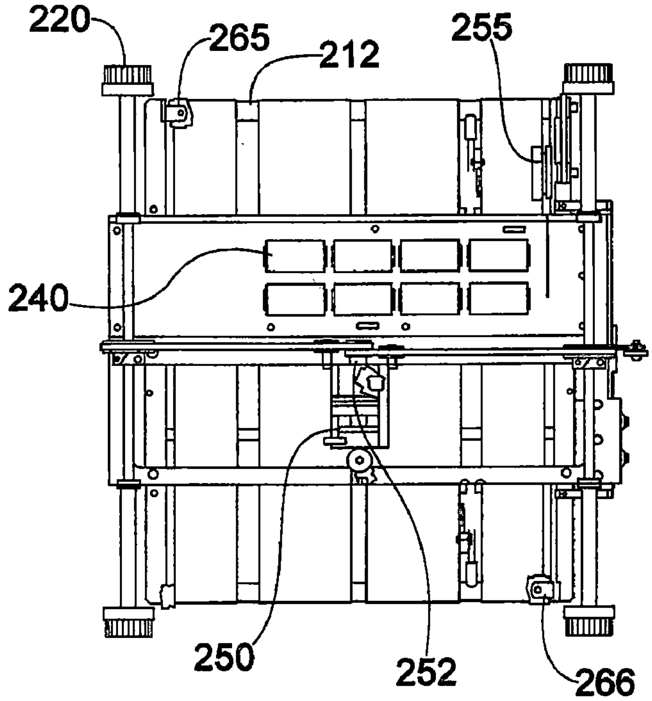
220
265
212
255
240
250
252
266

Fig. 17

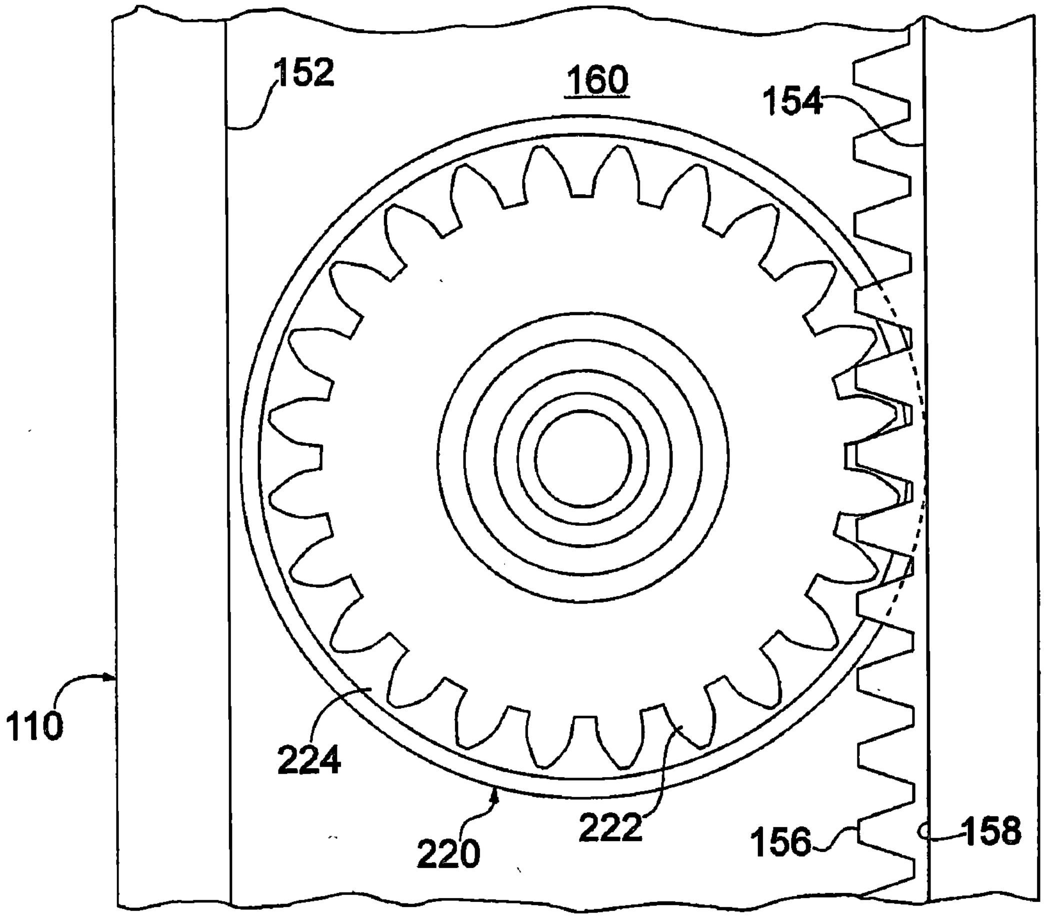

Fig. 18

METHOD AND APPARATUS FOR DELIVERING ITEMS TO DESTINATION AREAS

PRIORITY CLAIMS

The present application is a continuation of U.S. patent application Ser. No. 12/014,011, filed Jan. 14, 2008 now U.S. Pat. No. 7,861,844 which also claims priority to U.S. Provisional Patent Application No. 60/884,766 filed on Jan. 12, 2007. Each of the forgoing applications are hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a system for automating sorting of items, such as mail pieces, documents or other items.

BACKGROUND OF THE INVENTION

Sorting documents and mail pieces manually is laborious and time consuming. For example, thousands of large organizations employ numerous people full-time to manually sort and deliver incoming and interoffice mail and documents. For instance, a large company may receive 5,000 mail pieces that need to be sorted and delivered each day to different departments and/or individuals. Such volumes require a significant number of employees dedicated to sorting and delivering the mail. Nonetheless, such volume is not typically sufficient to justify the expense of traditional automated sorting equipment, which is quite expensive. Additionally, the mail for such organizations is typically quite diverse, which makes it more difficult, and therefore more expensive, to automate the sorting procedures.

Various systems for sorting have been developed to address the needs of mail rooms for large organizations. However, the known systems suffer from several problems; the most significant are cost and size. Accordingly, there is a need for a compact and affordable automated sorting system that is able to meet the needs of mid- to large-sized organization that handle several thousand mail pieces each day.

Similarly, may large organizations have extensive storage areas in which numerous items are stored. Sorting and retrieving items from the hundreds or thousands of storage areas requires significant labor to perform manually, and the known systems of automatically handling the materials are either very expensive or have limitations that hamper their effectiveness. Accordingly, there is a need in a variety of material handling applications for automatically storing and/or retrieving items.

SUMMARY OF THE INVENTION

In light of the foregoing, a system provides a method and apparatus for delivering items. The system includes a plurality of destination areas, such as bins, and a plurality of delivery vehicles for delivering items to the destination areas. A track guides the delivery vehicles to the destination areas.

In one embodiment, a controller controls the operation of the delivery vehicles based on information determined for each item to be delivered. Additionally, the track may include a plurality of interconnected sections so that the vehicles may travel along a continuous path changing from one direction to a second direction. Further, the vehicles may be driven such that the orientation of an item on the vehicle stays constant as the vehicles changes from a first direction of travel to a second direction of travel.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary and the following detailed description of the preferred embodiments of the present invention will be best understood when read in conjunction with the appended drawings, in which:

FIG. **1** is a perspective view of a sorting apparatus;

FIG. **2** is a plan view of the sorting apparatus illustrated in FIG. **1**;

FIG. **3** is a fragmentary perspective view of the sorting apparatus illustrated in FIG. **1**, shown without an input station;

FIG. **4** is a right side view of the sorting apparatus illustrated in FIG. **3**;

FIG. **5** is a front elevational view of the sorting apparatus illustrated in FIG. **3**, shown without discharge bins;

FIG. **6** is a fragmentary sectional view of a loading station of the sorting apparatus illustrated in FIG. **1**;

FIG. **7** is an enlarged fragmentary perspective view of a portion of the loading station of the apparatus illustrated in FIG. **3**;

FIG. **8** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in an open position;

FIG. **9** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in a closed position;

FIG. **10** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate;

FIG. **11** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate, with the gate shown in an open position in phantom;

FIG. **12** is a top perspective view of a delivery vehicle of the apparatus illustrated in FIG. **1**;

FIG. **13** is a plan view of the delivery vehicle illustrated in FIG. **12**;

FIG. **14** is a right side view of the delivery vehicle illustrated in FIG. **12**;

FIG. **15** is a front elevational view of the delivery vehicle illustrated in FIG. **12**;

FIG. **16** is a bottom perspective view of the delivery vehicle illustrated in FIG. **12**;

FIG. **17** is a bottom view of the delivery vehicle illustrated in FIG. **12**; and

FIG. **18** is an enlarged view of a wheel of the delivery vehicle illustrated in FIG. **12**, shown in relation to the track of the sorting apparatus illustrated in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1-18**, an apparatus for sorting items such as documents or mail pieces is designated generally **10**. The apparatus **10** includes a plurality of delivery vehicles or cars **200** to deliver items to a plurality of sort locations, such as output bins **190**. At a loading station **310**, each car **200** receives an item from an input station **50** and delivers it to the appropriate bin.

The cars **200** travel along a track **110** to the sort locations. The track has a horizontal upper rail **135** and a horizontal lower rail **140**, which operates as a return leg. A number of parallel vertical track legs **130** extend between the upper rail and the lower return leg. In the present instance, the bins **190** are arranged in columns between the vertical track legs **130**.

After a piece is loaded onto a car, the car travels upwardly along two pairs of vertical tracks legs and then horizontally along two upper tracks **135**. The car **200** travels along the upper rail until it reaches the appropriate column containing the bin for the piece that the car is carrying. The track **110** includes gates **180** that fire to direct the car **200** down the vertical legs and the car stops at the appropriate bin. The car **200** then discharges the piece into the bin.

After discharging the piece, the car **200** continues down the vertical legs **130** of the column until it reaches the lower rail **140**. Gates fire to direct the car along the lower rail, and the car follows the lower rail to return to the loading station **310** to receive another piece.

The cars **200** are semi-autonomous vehicles that each have an onboard power source and an onboard motor to drive the cars along the track **110**. The cars also include a loading/unloading mechanism **210**, such as a conveyor, for loading pieces onto the cars and discharging the pieces from the cars.

Since the system **10** includes a number of cars **200**, the positioning of the cars is controlled to ensure that the different cars do not crash into each other. In one embodiment, the system **10** uses a central controller **350** that tracks the position of each car **200** and provides control signals to each car to control the progress of the cars along the track. The central controller **350** may also control operation of the various elements along the track, such as the gates **180**.

Input Station

At the input station **50**, the mail pieces are separated from one another so that the pieces can be conveyed serially to the loading station **310** to be loaded onto the cars **200**. Additionally, at the input station information is determined for each piece so that the piece can be sorted to the appropriate bin.

A variety of configurations may be used for the input station, including manual or automatic configurations or a combination of manual and automated features. In a manual system, the operator enters information for each piece and the system sorts the mail piece accordingly. In an automatic system, the input system includes elements that scan each mail piece and detect information regarding each piece. The system then sorts the mail piece according to the scanned information.

In an exemplary manual configuration, the input system includes a work station having a conveyor, an input device, such as a keyboard, and a monitor. The operator reads information from a mail piece and then drops in onto a conveyor that conveys the piece to the loading station **310**. Sensors positioned along the conveyor track the piece as the conveyor transports the mail piece toward the loading station. An example of a work station having a conveyor for receiving dropped pieces and tracking the pieces is provided in pending U.S. application Ser. No. 10/862,021, filed Jun. 4, 2004, which was published Jan. 27, 2005 under Publication No. US 2005-0018214 A1 and which is incorporated herein by reference. The conveyor receives mail pieces dropped by an operator and tracks the mail pieces as they are transported along the conveyor.

In an exemplary automatic configuration, the system includes an imaging station, having an imaging device such as a high speed line scanning camera. The imaging station scans each mail piece to detect information regarding the destination for each piece. The system analyzes the image data to determine the destination information and then electronically tags the mail piece with the destination and sorts the piece accordingly. An example of a system having an automated imaging station for scanning pieces as they are conveyed is described in U.S. patent application Ser. No. 09/904,471, filed Jul. 13, 2001, which was published Jan. 16, 2003 under Publication No. US 2003-0014376 A1, and which is incorporated herein by reference.

FIGS. **1** and **2** illustrate such an automated system. The input station includes an input bin **55** for receiving a stack of mail. A feeder **60** in the input bin serially feeds mail pieces from the input bin to a conveyor **65**. An imaging station **70** positioned along the conveyor scans the mails pieces as the pieces are conveyed to the loading station **310**. The system **10** analyzes the image data to read information for the mail piece, such as the recipient's address.

The conveyor **65** conveys the mail piece to the loading station **310**. At the loading station the conveyor **65** conveys the mail piece onto a car **200**. As discussed further below, after the mail piece is loaded onto the car, the car moves away from the loading station and another car moves into position at the loading station to receive the next piece of mail.

In certain instances, the system may not be able to automatically identify the relevant information for a mail piece. To process such pieces, the system may include an operator to input the relevant information so that the mail piece can be sorted. For instance, the system may include an operator station having an input device and a display, such as a monitor. If the system cannot automatically determine the address within a pre-determined time period, the system displays the scanned images for the mail piece to the monitor so that the operator at the work station can view the images and manually enter the information using the input device.

In addition to the automated and manual systems described above, the system may be configured in a hybrid or semi-automated configuration having some operations performed manually and others automated. For instance, the system may include a manual input station that also has an imaging station. Since the system can handle a wide variety of items, it may be desirable to have an operator input the pieces manually so that the pieces are properly oriented and separated. The imaging station then scans the items and processes the imaging data to determine the address information for the pieces. Additionally, the operator station may include an input device and a display for inputting information if the address for a piece cannot be automatically determined, as discussed above. The operator can input the information as soon as the system indicates to the operator that it cannot determine the information for a piece. Alternatively, as discussed below, the car may be directed to a buffer if the information for a piece cannot be determined. In such an instance, the cars having such pieces will remain in the buffer while the system continues to process pieces for which the system can determine the relevant information. The operator can continue to manually drop pieces and wait until a number of pieces need manual keying of information. The operator can then switch from the operation of dropping pieces to the operation of manually keying the pieces, sometimes referred to as local video encoding (LVE). The operator can continue keying until some or all of the pieces in the buffer have been successfully coded, and then the operator can go back to the operation of manually dropping pieces. As yet another alternative, it may be desirable to incorporate a separate operator station having the input device and display so that one operator can input the mail at the input station and a separate operator can input the information for pieces having addresses that cannot be automatically determined.

As can be seen from the foregoing, the input station **50** may be configured in a wide range of options. The options are not limited to those configurations described above, and may include additional features, such as an automated scale for weighing each piece, a labeler for selectively applying labels to the mail pieces and a printer for printing information on the mail pieces or on the labels.

Additionally, in the foregoing description, the system is described as having a single input station **50**. However, it may be desirable to incorporate a plurality of input stations positioned along the system **10**. By using a plurality of input stations, the feed rate of pieces may be increased. In addition, the input stations may be configured to process different types of items. In this way, each input station could be configured to efficiently process a particular category of items. For instance, if the system is configured to process documents, such as mail, one input station may be configured to process standard envelopes, while another input station may be configured to process larger mails, such as flats. Similarly, one input station may be configured to automatically process mail by scanning it and automatically determining the recipient. The second input station may be configured to process rejects, such as by manually keying in information regarding the recipient.

Sorting Station

Referring to FIGS. **1-6**, the system includes a sorting station **100**, such as an array of bins **190** for receiving the pieces. In the present instance, the sorting station includes a number of bins arranged in columns. Additionally, the sorting station **100** includes a track **110** for guiding the cars **200** to the bins **190**.

The track **110** includes a horizontal upper rail **135** and a horizontal lower rail **140**. A plurality of vertical legs **130** extend between the upper horizontal leg and the lower horizontal leg **140**. During transport, the cars travel up a pair of vertical legs from the loading station **310** to the upper rail **135** (as described below, the cars actually travel up two pairs of rails because the track includes a forward track and a parallel opposing track). The car then travels along the upper rail until reaching the column having the appropriate bin. The car then travels downwardly along two front vertical posts and two parallel rear posts until reaching the appropriate bin, and then discharges the mail piece into the bin. The car then continues down the vertical legs until reaching the lower horizontal leg **140**. The car then follows the lower rail back toward the loading station.

As can be seen in FIG. **2**, the track **110** includes a front track **115** and a rear track **120**. The front and rear tracks **115**, **120** are parallel tracks that cooperate to guide the cars around the track. As shown in FIG. **13**, each of the cars includes four wheels **220**: two forward wheel and two rearward wheels. The forward wheels **220** ride in the front track, while the rearward wheel ride in the rear track. It should be understood that in the discussion of the track the front and rear tracks **115**, **120** are similarly configured opposing tracks that support the forward and rearward wheels **220** of the cars. Accordingly, a description of a portion of either the front or rear track also applies to the opposing front or rear track.

Referring to FIG. **18** the details of the track will be described in greater detail. The track **110** includes an outer wall **152** and an inner wall **154** that is spaced apart from the outer wall and parallel to the outer wall. The track also has a back wall **160** extending between the inner and outer walls. As can be seen in FIG. **18**, the outer and inner walls **152**, **154** and the back wall form a channel. The wheels **220** of the car ride in this channel.

Referring to FIG. **11**, the track includes both a drive surface **156** and a guide surface **158**. The drive surface positively engages the cars to enable the car to travel along the track. The guide surface **158** guides the car, maintaining the car in operative engagement with the drive surface **156**. In the present instance, the drive surface is formed of a series of teeth, forming a rack that engages the wheels of the cars as described further below. The guide surface **158** is a generally flat surface adjacent the rack **156**. The rack **156** extends approximately halfway across the track and the guide surface **158** extends across the other half of the track. As shown in FIGS. **11** and **18**, the rack **156** is formed on the inner wall **154** of the track. The opposing outer wall **152** is a generally flat surface parallel to the guide surface **158** of the inner wall.

As described above, the track includes a plurality of vertical legs extending between the horizontal upper and lower rails **135**, **140**. An intersection **170** is formed at each section of the track at which one of the vertical legs intersects one of the horizontal legs. Each intersection includes an inner branch **172** that is curved and an outer branch **176** that is generally straight. FIG. **10** illustrates both a right-hand intersection **170***c* and a left-hand intersection **170**, which are mirrors of one another. In FIG. **10**, the intersections **170***c*, **170***d* illustrate the portion of the track in which two vertical legs **130** intersect the upper horizontal leg **135**. The intersections of the vertical legs with the lower rail incorporate similar intersections, except the intersections are reversed. Specifically, the point at which vertical leg **130***c* intersects the lower rail incorporates an intersection configured similar to intersection **170***d*, and the point at which vertical leg **130***d* intersects the lower rail incorporates an intersection configured similar to intersection **170***c*.

Each intersection **170** includes a pivotable gate **180** that has a smooth curved inner race and a flat outer race that has teeth that correspond to the teeth of the drive surface **156** for the track. The gate **180** pivots between a first position and a second position. In the first position, the gate **180** is closed so that the straight outer race **184** of the gate is aligned with the straight outer branch **176** of the intersection. In the second position, the gate is open so that the curved inner race **182** of the gate is aligned with the curved branch **172** of the intersection.

Accordingly, in the closed position, the gate is pivoted downwardly so that the outer race **184** of the gate aligns with the drive surface **156**. In this position, the gate blocks the car from turning down the curved portion, so that the car continues straight through the intersection. In contrast, as illustrated in FIG. **10**, when the gate is pivoted into the open position, the gate blocks the car from going straight through the intersection. Instead, the curved inner race **182** of the gate aligns with the curved surface of the inner branch **172** and the car turns through the intersection. In other words, when the gate is closed, a car goes straight through the intersection along either the upper rail **130** or the lower rail, depending on the location of the intersection. When the gate is opened, the gate directs the car from either a vertical rail to a horizontal rail or from a horizontal rail to a vertical rail, depending on the location of the intersection.

As can be seen in FIG. **11**, the end of the gate remote from the pivot point of the gate flares outwardly so that the curved inner race matches the curved profile of the inner branch when the gate is open. As a result, the gate has a generally L-shaped configuration. To accommodate the flared end of the gate **180**, the drive surface **156** of the inner branch has a notch or recessed portion. When the gate is closed, the notch provides clearance so that the outer race **184** of the gate lies flat, parallel with the drive surface of the outer branch **176**. Further, in the example shown in FIG. **11**, the gate is positioned along the upper rail **135** of the track **110**. When the gate is closed, the recess in the inner branch of the intersection **170** allows the gate to lie flat so that it is aligned with the drive surface of the upper rail.

In the foregoing description, the gates allow one of the cars to either continue in the same direction (e.g. horizontally) or turn in one direction (e.g. vertically). However, in some applications, the system may include more than two horizontal rails that intersect the vertical columns. In such a configuration, it may be desirable to include a different rail that allows the cars to turn in more than one direction. For instance, if a car is traveling down a column, the gate may allow the car to turn either left or right down a horizontal rail, or travel straight through along the vertical column. Additionally, in some applications it may be desirable to allow the cars to travel upwardly, whereas in the system described above, the cars only travel downwardly through the sorting station. If the cars also travel upwardly in the sorting station, then the gates should be configured to accommodate and guide the cars when the cars travel upwardly through an intersection.

The gates **180** are controlled by signals received from the central controller **350**. Specifically, each gate is connected with an actuator **186** that displaces the gate from the opened position to the closed position and back. There may be any of a variety of controllable elements operable to displace the gate. In the present instance, the actuator **186** is a solenoid having a linearly displaceable piston.

In the foregoing description, the sorting station **100** is described as a plurality of output bins **190**. However, it should be understood that the system may include a variety of types of destinations, not simply output bins. For instance, in certain applications it may be desirable to sort items to a storage area, such as an area on a storage shelf. Alternatively, the destination may be an output device that conveys items to other locations. According to one example of an output device, the system may include one or more output conveyors that convey pieces away from the sorting system toward a different material handling or processing system. For instance, an output conveyor designated A may convey pieces to a processing center designated A. Therefore, if a piece is to be delivered to processing center A, the car will travel along the track to output conveyor A. Once the car reaches output conveyor A, the car will stop and transfer the piece onto output conveyor A. Output conveyor A will then convey the piece to processing center A. Further, it should be understood that the system may be configured to include a plurality of output devices, such as output conveyors.

In some embodiments, the system may include a plurality of output conveyors in addition to the output bins. In other embodiments, the system may only include a plurality of output devices, such as conveyors, and the system is configured to sort the pieces to the various output devices. Further still, the system may be configured to retrieve pieces from storage locations. In such embodiments, the cars may sort pieces to a storage location, such as a bin. Subsequently, one of the cars may travel to the storage location and retrieve the item from the storage location and transport it to one of the output devices.

One manner that the cars may retrieve items from the storage locations is by including a conveyor at the storage locations. In this way, an item at a storage location can be conveyed by the conveyor toward the track. When a car arrives at the storage location, the conveyor at the storage location conveys the item onto the car, similar to the manner in which a piece is loaded onto the car at the loading column. Accordingly, the system can sort pieces to a plurality of output devices, in addition to sorting pieces to a plurality of storage locations before subsequently retrieving the pieces and conveying the pieces to the output devices.

As discussed above, the system is operable to sort a variety of items to a plurality of destinations. One type of destination is a bin; a second type is a shelf or other location on which the item is to be stored; and a third type of destination is an output device that may be used to convey the item to a different location. The system may include one or more of each of these types or other types of destinations.

Delivery Vehicles

Referring now to FIGS. **12**-**17**, the details of the delivery vehicles **200** will be described in greater detail. Each delivery vehicle is a semi-autonomous car having an onboard drive system, including an onboard power supply. Each car includes a mechanism for loading and unloading items for delivery.

The car **200** may incorporate any of a variety of mechanisms for loading an item onto the car and discharging the item from the car into one of the bins. Additionally, the loading/unloading mechanism **210** may be specifically tailored for a particular application. However, in the present instance, the loading/unloading mechanism **210** is a conveyor belt. Specifically, referring to FIG. **12**, the loading/unloading mechanism includes a plurality of narrow belts **212** that extend along the top surface of the car. The conveyor belts are reversible. Driving the belts in a first direction displaces the item toward the rearward end of the car; driving the belt in a second direction displaces the item toward the forward end of the car.

A conveyor motor **255** mounted on the underside of the car drives the conveyor belts **212**. Specifically, the conveyor belts **212** are entrained around a forward roller **213** at the forward edge of the car, and a rearward roller at the rearward edge of the car. The conveyor motor **255** is connected with the forward roller **213** to drive the forward roller, thereby operating the conveyor belts.

The car includes four wheels **220** that are used to transport the car along the track **110**. The wheels **220** are mounted onto two parallel spaced apart axles **215**, so that two or the wheels are disposed along the forward edge of the car and two of the wheels are disposed along the rearward edge of the car.

Referring to FIG. **18**, each wheel comprises an inner idler roller **224** and an outer gear **222** that cooperates with the drive surface **156** of the track. The idler roller **224** rotates freely relative to the axles, while the outer gear is fixed relative to the axle onto which it is mounted. In this way, rotating the axle operates to rotate the gear **222**. Additionally, the idler roller is sized to have a diameter slightly smaller than the distance between the upper wall **152** and the lower wall **154** of the track. In this way, the idler roller may rotate freely within the track, while ensuring that the gear **222** of each wheel remains in operative engagement with the drive surface (i.e. the teeth) **156** of the track. Accordingly, when the vehicle is moving horizontally, the rollers carry the weight of the cart, while the gears **222** cooperate with the drive surface **156** of the track to drive the vehicle along the track.

The car includes an onboard motor **250** for driving the wheels **220**. More specifically, the drive motor **250** is operatively connected with the axles to rotate the axles **215**, which in turn rotates the gears **222** of the wheels. As shown in FIG. **16**, the drive motor **250** is interconnected to the axles **215** via a pair of drive belts **254** that are driven by the drive motor.

The drive system for the car may be configured to synchronously drive the car along the track. In the present instance, the drive system is configured so that each gear is driven in a synchronous manner. Specifically, each gear **222** is connected to an end of one of the axles in a manner that substantially impedes rotation of the gear relative to the axle. In this way each axle drives the attached two gears in a synchronous manner. Additionally, in the present instance, both axles are driven in a synchronous manner so that all four gears are driven in a synchronous manner. There are various mechanisms that can be used to synchronously drive the axles. For instance, a pair of drive motors can be used to drive the axles, and the drive motors can be synchronized. However, in the present instance, a single drive motor **250** is used to drive both axles. Each axle includes a timing pulley **226** that is rigidly connected to the axle to prevent rotation of the pulley relative to the axle. Similarly, a timing pulley **228** is connected to the motor shaft. The drive belt **254** connecting the timing pulley **226** on the axle with the motor is a timing belt so that the rotation of the drive motor is precisely linked to the rotation of the axle. Although a single timing belt can be used to drive both axles synchronously, in the present instance, a pair of timing pulleys is connected to the motor shaft, and each timing pulley is connected to a corresponding timing pulley on one of the axles, as shown in FIG. **16**.

The drive motor **250** includes a sensor that is operable to detect the rotation of the motor to thereby determine the distance the car has traveled. Since the gears **222** are rigidly connected with the axles, which are in turn synchronously connected with the drive motor, the forward distance that the car moves corresponds can be exactly controlled to correlate to the distance that the drive motor is displaced. Accordingly, the distance that a car has traveled along the determined path depends on the distance through which the car motor is rotated.

To detect the rotation of the drive motor **250**, the motor includes a sensor **252** for detecting the amount of rotation of the drive motor. In the present instance the sensor **252** is a hall sensor. A portion of rotation of the motor corresponds to what is referred to as a tick. The sensor detects the number of ticks and sends a signal to the central processor **350**, which determines how far along the designate path the car has traveled based on the known information regarding the path and the number of ticks that the sensor detects for the motor.

As the car travels along the track, an item on top of the car may tend to fall off the car, especially as the car accelerates and decelerates. Therefore, in the present instance, the car includes a retainer **230** to retain the element on the car during delivery. As illustrated in FIGS. **12-17**, the retainer **230** is a hold down that clamps the item against the top surface of the car.

The retainer includes an elongated pivotable arm **232**. A biasing element, such as a spring, biases the arm downwardly against the top surface of the retainer **230**. The retainer **230** further includes an operator **234** in the form of a tab. Pushing downwardly on the tab raises the clamp from the top surface of the conveyor to allow a piece to be loaded onto the car or discharged from the car.

The car **200** may be powered by an external power supply, such as a contact along the rail that provides the electric power needed to drive the car. However, in the present instance, the car includes an onboard power source **240** that provides the requisite power for both the drive motor **250** and the conveyor motor **255**. Additionally, in the present instance, the power supply is rechargeable. Although the power supply may include a known power source, such as a rechargeable battery, in the present instance, the power supply **240** is made up of one or more ultracapacitors. Ultracapacitors are extremely high energy density capacitors. Capacitors store electrical energy by physically separating positive and negative charges, in contrast to the chemical means a battery uses. Ultracapacitors rely on an electrostatic effect, which is physical rather than chemical, and highly reversible. The ultracapacitors can accept very high amperage to recharge the ultracapacitors. By using a high current, the ultracapacitors can be recharged in a very short time, such as a few seconds or less.

The car includes one or more contacts for recharging the power source **240**. In the present instance, the car includes a plurality of brushes **245**, such as copper brushes that are spring-loaded so that the brushes are biased outwardly. The brushes **245** cooperate with a charging rail in the loading station to recharge the power source, as described further below.

Each car includes at least one and preferably two load sensors for detecting the items as it is loaded onto the car. The sensor(s) ensure that the mail piece is properly positioned on the car. In the present instance, the car includes a forward loading sensor **260** and a rearward loading sensor **262**. The forward loading sensor detects the leading edge of the item as it is loaded onto the car. The forward loading sensor **260** also detects the trailing edge of the item to ensure that the entire length of the item is loaded onto the car. Similarly, the rearward sensor **262** detects the leading edge and in certain instances, may detect the trailing edge of the mail piece. The loading sensors **260, 262** may be simple I/R sensors that detect the presence or absence of a document or mail piece.

Although the car operates in response to signals received from the central controller **350**, which tracks the location of each car, the car may also include a reader **265** for reading indicia along the track to confirm the position of the car. For instance, each bin may be assigned a unique bar code, and the forward reader may scan the track or other area around the bin **190** at which an item is to be delivered. The data that the central processor has regarding the path that the car is to follow and the data regarding the distance the car has traveled based on the data regarding the rotation of the drive motor **250** should be sufficient to determine whether the car **200** is positioned at the appropriate bin. Nonetheless, it may be desirable to double check the location of the car before the item is discharged into the appropriate bin. Therefore, the scanner may operate to scan and read information regarding the bin at which the car is stopped. If the scanned data indicates that the bin is the appropriate bin, then the car discharges its item into the bin. Similarly, the car may have a second reader **266** for reading indicia adjacent the rearward edge of the car. The second reader **266** may be used in applications in which the system is set up to utilize a first series of bins **190** along the forward side and a second series of bins along the rearward side of the track **110**.

In foregoing description, the cars have drive gears that interact with teeth in the track to guide the cars around the track. Additionally, as described further below in the operation section, the location of the car may be controlled based on information regarding how far the car has traveled. In such applications it is desirable to synchronize the drive wheels of the car. However, in some applications alternative control systems may be used. For instance, the location of the cars can be controlled based on signals from sensors positioned along the track or indicators positioned along the track. In such instances, the cars may be configured to use a drive mechanism that is not synchronous as described above.

As discussed further below, the car further includes a processor for controlling the operation of the car in response to signals received from the central processor. Additionally, the car includes a wireless transceiver so that the car can continuously communicate with the central processor as it travels along the track. Alternatively, in some applications, it may be desirable to incorporate a plurality of sensors or indicators positioned along the track. The car may include a reader for sensing the sensor signals and/or the indicators, as well as a central processor for controlling the operation of the vehicle in response to the sensors or indicators.

Loading Column

Referring now to FIGS. **6-7** the details of the loading column **300** will be described in greater detail. The loading column **300** is formed adjacent the output end of the input station **50**. The loading column **300** is formed of a front pair of vertical rails **305***a*, **305***b* and a corresponding rearward set of vertical rails. The loading station **310** is positioned along the loading column. The loading station **310** is the position along the track in which the car **200** is aligned with the discharge end of the conveyor of the input station **50**. In this way, a mail piece from the input station may be loaded onto the car as it is conveyed toward the car from the input station.

Although the central processor **350** tracks the position of the car, a home sensor **312** is positioned adjacent the loading station **310**. When the home sensor detects the car, the position for the car is known relative to a fixed point along the track, and the central processor resets the position of the car to the home or zero position.

Referring to FIG. **7**, a pair of charging rails are disposed along the vertical rails **305***a*, **305***b*. The charging rails are conductive strips connected with an electrical supply. The charging contacts **245** of the car **200** engage the conductive strips to recharge the ultracapacitors **240**. Specifically, the biasing element of the brushes **245** biases the brushes outwardly toward the charging contacts. The electricity flowing through the charging contact **245** is a high amperage, low voltage source that allows the ultracapacitors to recharge in a few seconds or less. In addition, since the power supply provided by the ultracapacitors last for only a few minutes, the car recharges each time it travels through the loading column.

Additionally, it may be desirable to incorporate a startup charging rail similar to the charging rails described above, but disposed along either the return rail or the rails in the column adjacent to the loading column, depending on where the cars are stored when the cars are shut down. Since the cars use ultracapacitors, it is possible that the ultracapacitors will discharge while the system is shut down. Therefore, upon startup the cars will not have any charge and will not be able to move to the loading column to charge the ultracapacitors. Accordingly, the system may include a startup charging rail disposed along a rail that the cars contact when the cars are stored during shutdown. If the cars are stored in the loading column and the adjacent column during shutdown, then the startup rail is disposed in the column adjacent the loading column. Alternatively, if the cars are stored on the return rail and the loading column during shutdown, then the startup rail is disposed along the return rail. In this way, when the system is started, a charging current is supplied to the cars through the startup charging rail and the charging rail in the loading column.

As discussed previously, each car **200** includes a retainer **230** to hold down items on the car during transport. The retainer should be opened at the loading station to allow an item to be loaded onto the car. Accordingly, as shown in FIG. **6**, an actuator **316** is positioned along the column. The actuator **316** projects inwardly toward the cars as the cars are conveyed up the loading column. As a car is conveyed upwardly in the loading column **300**, the hold down actuator **316** contacts the hold down operator or tab **236**. The interaction between the actuator **316** and the tab **236** causes the retainer to open, so that items can be loaded onto the car. As the car moves upwardly past the actuator **316**, the tab **236** on the car disengages the actuator, thereby releasing the retainer, thereby holding down or clamping the mail piece against the top surface of the vehicle.

In the foregoing description, the loading station has been described as a column in which an item is loaded onto the car and the car then travels upwardly to the horizontal upper rail **135**. However, in some applications in may be desirable to configure the loading station so that the items are loaded onto the cars at or near the top of the vertical column. In such an application, the load on the cars would be reduced since the car will not have to lift the item loaded on the car. In order to load the items on the cars at the top of the conveyor, a vertical conveyor may be added to the system. For instance, a conveyor angled upwardly may convey the items upwardly to the top of the column to load the items onto the cars. Alternatively, one or more of a variety of conveyor configurations can be used to transport to items toward the top of the loading column to load the items onto the cars.

Operation

The system **10** operates as follows. An item is processed at the input station **50** to identify a characteristic of the piece that is indicative of where the piece should be sorted. For instance, the item may be a mail piece that is to be sorted according to department, box number or recipient. If the mail pieces are sorted by department, the piece may be processed to identify either an indicator of the department (such as box number) or the piece may be processed to identify the recipient. The central controller maintains a database that correlates various data to identify the destination bin. For instance, the database may correlate the recipient names with the appropriate department if the mail is being sorted according to department. In other embodiments, the piece may be a part that has a product code and the database may correlate the product code with the sort location.

As discussed previously, the input station may process the items automatically or manually. In a manual mode, the operator manually enters information regarding a piece and then drops the piece on a conveyor. The system electronically tags the piece with the sort information and the conveyor conveys the piece toward the loading station. Alternatively, if the input system is an automated system, the piece is automatically scanned to identify the relevant sort characteristic. For instance, the input station may use a scanner, such as a bar code scanner to read the postnet code on a piece, or the input station may include an imaging device, such as a high speed line scan camera in combination with an OCR engine to read information on the piece.

To prepare to receive an item, a car **200** moves along the track toward the loading station **310** in the loading column **300**. As the car approaches the loading station, the operator **236** for the hold down **230** engages the actuator **316**, which pivots the hold down upwardly to prepare the car to receive an item, as illustrated in FIG. **6**. When the car **200** moves into position at the loading station **310** the home sensor detects the presence of the car and sends a signal to the central processor **350** indicating that the car is positioned at the loading station. In the following description, the item being sorted is described as being a mail piece. It should be understood that such an item is an exemplary application of the system. As described above, the system can be configured to sort a variety of items in a variety of material handling applications.

Once the car is positioned at the loading station, the input station conveys a mail piece onto the car. As the mail piece is being conveyed onto the car **200**, the loading mechanism **210** on the car loads the mail piece onto the car. Specifically, the input station conveys the mail piece into contact with the conveyor belts **212** on the car. The conveyor belts **212** rotate toward the rearward side of the car, thereby driving the mail piece rearwardly on the car.

The operation of the conveyor belts is controlled by the loading sensors **260**, **262**. The forward loading sensor detects the leading edge of the mail piece as the mail piece is loaded onto the car. Once the forward loading sensor **260** detects the trailing edge of the mail piece, a controller onboard the car determines that the mail piece is loaded on the car and stops the conveyor motor. Additionally, the onboard controller may control the operation of the conveyor in response to signals received from the rearward sensor **262**. Specifically, if the rearward sensor **262** detects the leading edge of the mail piece, then the leading edge of the mail piece is adjacent the rearward edge of the car. To ensure that the mail piece does not overhang from the rearward edge of the car, the controller may stop the conveyor once the rearward sensor detects the leading edge of the mail piece. However, if the rearward sensor detects the leading edge of the mail piece before the forward sensor detects the trailing edge of the mail piece, the controller may determine that there is a problem with the mail piece (i.e. it is too long or two overlapping mail pieces were fed onto the car. In such an instance, the car may communicate an error message with the central controller, which may declare an error and provide an indicator to the operator that the car at the loading station requires attention. Alternatively, a reject bin **325** may be positioned behind the loading station so that mail pieces on the car at the loading station can be ejected into the reject bin **325**. In this way, if there is an error loading a mail piece onto a car, the mail piece can simply be ejected into the reject bin, and a subsequent mail piece can be loaded onto the car.

After a mail piece is loaded onto the car, the car moves away from the loading station. Specifically, once the onboard controller detects that a mail piece is properly loaded onto the car, the onboard controller sends a signal to start the drive motor **250**. The drive motor **250** rotates the axles, which in turn rotates the gears **222** on the wheels **220**. The gears **222** mesh with the drive surface **156** of the vertical rails **305** in the loading column to drive the car upwardly. Specifically, the gears and the drive surfaces mesh and operate as a rack and pinion mechanism, translating the rotational motion of the wheels into linear motion along the track **110**.

Since the cars move up the loading column from the loading station, the destination for the car does not need to be determined until after the car reaches the first gate along the upper rail **135**. For instance, if an automated system is used at the input station to scan and determine the characteristic used to sort the mail pieces, it may take some processing time to determine the relevant characteristic. The time that it takes to convey the mail piece onto the car and then convey the car up the loading column will typically be sufficient time to determine the relevant characteristic for the mail piece. However, if the characteristic is not determined by the time the car reaches the upper rail, the car may be directed down the second column, which is the column next to the loading column. The car travels down the second column to the lower rail **140**, and then back to the loading column. The car may stop in the second column to provide additional time to determine the characteristic. However, after waiting for a predetermined period the system may declare that the address cannot be determined and the car may be advanced from the second column and the piece may be discharged to a reject bin. Alternatively, rather than declare an error the car may continue to travel around the loop from the loading column to the second column until the characteristic is determined or until a predetermined time at which the central controller declares an error. Additionally, rather than using the reject bin when the system is unable to determine the characteristic for a mail piece, one of the bins in the second column can also be

used as a reject bin. In this way, the cars are ready to receive a mail piece as soon as the car reaches the loading station, without having to eject the problem mail piece into the reject bin **325** at the loading station.

As described above, the system includes a loop that can be utilized as a buffer track to provide additional processing time to analyze the characteristic for the mail piece if necessary. Although the first and second columns can be used as the buffer loop, other columns can be used as a buffer loop if desired.

The foregoing discussion described the process for buffering a car if the system is unable to determine the characteristic for the mail piece by the time the car reaches the top rail. However, for most mail pieces, the system should be able to identify the characteristic without having to buffer the car. The following discussion describes the operation of the system assuming that the characteristic for the mail piece is determined before the car reaches the upper rail **135**.

Once the characteristic for the mail piece is determined, the central controller **350** determines the appropriate bin **190** for the mail piece. Based on the location of the bin for the mail piece, the route for the car is determined. Specifically, the central controller determines the route for the car and communicates information to the car regarding the bin into which the mail piece is to be delivered. The central controller then controls the gates along the track to direct the car to the appropriate column. Once the car reaches the appropriate column the car moves down the column to the appropriate bin. The car stops at the appropriate bin **190** and the onboard controller sends an appropriate signal to the conveyor motor **255** to drive the conveyor belts **212**, which drives the mail piece forwardly to discharge the mail piece into the bin. Specifically, the top of the car aligns with the gap between the appropriate bin **190** and the bottom edge of the bin that is immediately above the appropriate bin.

As discussed above, the central controller **350** controls the operation of the gates **180** in response to the location of the car **200** and the route that the car is to follow to deliver the mail piece. Additionally, as discussed below, the central controller controls the gates in response to the position of other cars on the track.

As the car **200** travels along the upper rail **135** and approaches a column, the gates for the vertical rails **130** are controlled as follows. If the car is to pass over the column on the way to the next column, the gates are displaced into the closed position, as shown in FIG. **9**. Specifically, both gates at the top of the column are closed so that the outer race **184** of the gate aligns with the straight track, with the outer race aligning with the drive surface **156** of the track **110**. In this way, the gates provide a straight drive surface that cooperates with the drive surface **156** to allow the car to travel over the column.

When the car comes to a column that it is to turn down, the gates are controlled as follows. Referring to FIG. **5**, the columns can be seen without the bins attached. The view in FIG. **5** is from the front of the apparatus **10**, so the car will be traveling along the upper rail from the right to the left in the perspective of FIG. **5**. In the following discussion, the car is to be conveyed to a bin in the column designated C in FIG. **5**. Column C includes two pairs of vertical legs. The first pair is front and back vertical legs **130***c* on the left side of column C; the second pair is front and back vertical legs **130***d* on the right side of column C.

In order for the car to travel down column C, the wheels on the left side of the car travel down legs **130***c* and the right side wheels travel down legs **130***d*. Therefore, as the car approaches column C, the gates at the top of **130***d* are displaced to the closed position so that the left side wheels remain on the upper rail and pass over the right side legs **130**_d_. After the left side wheels of the car pass over the right legs **130**_c_, the gates **180** at the top of the right legs **130**_d_ are displaced into the open position so that the right side wheels can turn down legs **130**_d_. Specifically, after the left side wheels pass right legs **130**_d_, the central controller operates the solenoids **186** of the gates **180** at the top of legs **130** to displace the gates into the open position, as shown in FIG. **8** (note that the view in FIG. **8** is taken from the rear side of the apparatus so that the perspective of the gates is reversed relative to the front side). The gates **180** block the straight path through the intersection **170** and the curved inner race **182** of the gates direct the right side wheels down vertical legs **130**_d_. Similarly, the gates **180** at the top of the left side legs **130**_c_ are displaced into the open position to direct the left side wheels down vertical legs **130**_c_.

As the car approaches the intersections at the bottom of legs **130**_c_ and **130**_d_, the gates are operated similarly to the above description, but in reverse. Specifically, as the car approaches the intersections **170** at the bottom of legs **130**_c_ and **130**_d_, the gates **180** in the intersections are displaced into the opened position so that the gates direct the forward and leading wheels to turn down the lower rail. From the perspective of FIG. **5**, the car travels from left to right after the car reaches the lower rail. After the car passes though the intersections at the bottom of the rails **130**_c_, **130**_d_, the gates at the bottom of right side legs **130**_d_ are displaced into the closed position before the left side wheels of the car reach the intersection at the bottom of the right side legs **130**_d_. In this way, the left side wheels of the car pass straight through the intersection at the bottom of legs **130**_d_ along the bottom rail **140**.

As discussed above, the central controller **350** controls the operation of the gates in response to the position of the car and more specifically in response to the position of the left hand and right hand wheels of the car. The gates are fired sequentially to ensure that the different pairs of wheels are directed down the proper vertical legs. Alternatively, the operation of the gates may be controlled by signals received from the cars. Specifically, the cars may include a transmitter that transmits a signal to the central controller indicating that it is in proximity to a gate that is to be fired. Further still, the car may include an indicator that may be scanned as the car approaches the gate. Based on the indicator and the know destination for the car, the gate may fire. Still further, the car may include an mechanical actuator that selectively triggers or actuates a gate to appropriately direct the car.

One of the advantages of the system as described above is that the orientation of the cars does not substantially change as the cars move from travelling horizontally (along the upper or lower rails) to vertically (down one of the columns). Specifically, when a car is travelling horizontally, the two front geared wheels **220** cooperate with the upper or lower horizontal rail **135** or **140** of the front track **115**, and the two rear geared wheels **220** cooperate with the corresponding upper or lower rail **135** or **140** of the rear track **120**. As the car passes through a gate and then into a column, the two front geared wheels engage a pair of vertical legs **130** in the front track **115**, and the two rear geared wheels engage the corresponding vertical legs in the rear track **120**.

As the car travels from the horizontal rails to the vertical columns or from vertical to horizontal, the tracks allow all four geared wheels to be positioned at the same height. In this way, as the car travels along the track it does not skew or tilt as it changes between moving horizontally and vertically. Additionally, it may be desirable to configure the cars with a single axle. In such a configuration, the car would be oriented generally vertically as opposed to the generally horizontal orientation of the cars described above. In the single axle configuration, the weight of the cars would maintain the orientation of the cars. However, when using a single axle car, the orientation of the sort locations would be re-configured to accommodate the vertical orientation of the cars. Similarly, the loading station would also be re-configured to load the pieces onto the cars in the vertical orientation.

Traffic Control

Since the system includes a number of cars **200**, the system controls the operation of the different cars to ensure the cars do not collide into one another. In the following discussion, this is referred to as traffic control.

A variety of methodologies can be used for traffic control. For instance, the traffic control can be a distributed system in which each car monitors its position relative to adjacent cars and the onboard controller controls the car accordingly. One example of such as system utilizes proximity sensors on each car. If the proximity sensor for a car detects a car within a predefined distance ahead of the car, the onboard controller for the trailing car may control the car by slowing down or stopping the trailing car. Similarly, if a car detects a car within a predefined distance behind the car, the lead car may speed up unless the lead car detects a car ahead of it within the predefined distance. In this way, the cars may control the speed of the cars independently based on the feedback from the proximity sensors.

Although the system may use a distributed system for traffic control, in the present instance, the system uses a centralized system for traffic control. Specifically, the central controller **350** tracks the position of each car **200** and provides traffic control signals to each car based on the position of each car relative to adjacent cars and based on the route for each car.

In the present instance, the central controller **350** operates as the traffic controller, continuously communicating with the cars as the cars travel along the track **110**. For each car, the central controller determines the distance that each car can travel, and communicates this information with the cars. For instance, if car B is following car A along the track, and car A is at point A, car B can safely travel to a point just before point A without crashing into car A. As car A advances to a subsequent point B along the track, car B can travel safely to a point just before point B without crashing into car A.

The cars continuously communicate with the central controller to provide information indicative of their positions, so that the central controller can continuously update the safe distances for each car as the cars advance around the track.

Although the foregoing discussion is limited to determining safe zones based on the positions of the various cars on the track, the determination of safe zones is based on other factors that affect the traffic. For instance, when calculating the safe distance for a car, the central controller considers the distance between the car and the next gate, as well as the distance to the destination bin for the car.

As can be seen from the foregoing, increasing the frequency of communication between the cars and the central controller increases the efficiency of the traffic flow along the track. Accordingly, in the present instance, the traffic control is designed to communicate with a car once for every inch the car travels along the track. Therefore, if a car travels at 25 inches per second, the central controller communicates with the car every 40 msec. Further, it is desirable to have the cars travel at up to 50 inch/sec. Therefore, it is desirable to configure the communications to allow the cars to communicate with the central controller every 20 msec.

In addition, to the foregoing variables used to calculate safe distances, information regarding the track profile ahead of each car is used to calculate safe distances. For instance, the central controller determines whether the path ahead of a car is sideways movement, uphill movement (i.e. movement vertically upwardly) or downhill movement (i.e. movement vertically downwardly).

One of the issues in traffic control relates to merging at intersections **170**. The problem arises when a car needs to merge onto the return rail **140**. If two cars will arrive at the intersection close enough to collide, one of the cars needs to have priority and the other car needs to wait or slow down to allow the first car to go through.

A first method for controlling merging traffic is based on determining the next gap large enough for a car to have time to pass through an intersection without colliding with another car. In other words, if a first car approaches an intersection and it is determined that the gap between the first car and a second car is not sufficient for the first car to pass through, the first car waits at the intersection until there is a gap large enough to allow the first car to pass through.

A second method for controlling merging traffic is based on determining which car is closest to the homing sensor at the loading station **310**. The car with the shortest distance to the homing sensor gets priority at the intersection.

Another factor that the traffic controller considers when calculating safe distances relates to the position of cars in adjacent columns. In the present instance, most of the adjacent columns share a common vertical rail. For instance, in FIG. **5**, the leftmost column uses vertical rails **130***a* and **130***b*. The column next to the leftmost column uses vertical rails **130***b* and **130***c*.

However, in the present instance, some of the columns may have two vertical rails **130** that are independent from the adjacent columns. For instance, the loading column **300** has two independent rails that are not shared with the adjacent column. Therefore, cars can travel up the loading column without regard to the position of cars in the column next to the loading column. Furthermore, as shown in FIG. **5**, it may be desirable to configure the column next to the loading column so that it also has two independent vertical rails. In this way, cars can more freely travel up the loading column and down the adjacent column to provide a buffer loop as described previously.

Accordingly, when calculating safe distances, the traffic controller evaluates the position of cars in adjacent columns if the cars share a common vertical rail to ensure that the two cars do not collide as the car travel down the adjacent columns.

In the foregoing discussion, the sorting of items was described in relation to an array of bins disposed on the front of the sorting station **100**. However, as illustrated in FIGS. **2** & **4**, the number of bins in the system can be doubled by attaching a rear array of bins on the back side of the sorting station. In this way, the cars can deliver items to bins on the front side of the sorting station by traveling to the bin and then rotating the conveyor on the car forwardly to eject the piece into the front bin. Alternatively, the cars can deliver items to bins on the rear side of the sorting station by traveling to the bin and then rotating the conveyor on the car rearwardly to eject the piece into the rear bin.

Additionally, the sorting station **100** is modular and can be readily expanded as necessary simply by attaching an additional section to the left end of the sorting station. Further, although the foregoing describes the array of bins as being essentially a two dimensional array in which the cars simply travel in X and Y directions, the sorting station can be expanded to add additional "runs" of track. Specifically, a separate sorting station parallel to or perpendicular to the sorting station illustrated in FIG. **2** may be connected to the sorting station. In this way, the car would travel in a third dimension relative to the X and Y directions of the sorting station illustrated in FIG. **2**. For instance, additional sections of track may be connected to the sorting station illustrated in FIG. **2** perpendicular to the illustrated sorting station, so that the additional track forms an L-shape intersecting the loading column. In such a configuration, gates selectively direct the cars either down the upper rail **135** or rearwardly toward the additional track. Similarly, a plurality of parallel rows of sorting stations can be interconnected so that the cars selectively travel along a crossover rail until the car reaches the appropriate row. The car then travels down the row until it reaches the appropriate column as described above.

It will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the broad inventive concepts of the invention. For instance, in the foregoing description, the operation of the sorting station is described as being centralized with the central controller. However, it may be desirable to have the cars control the operation of the gates. According to one alternative, the cars incorporate one or more mechanical actuators that cooperate with an operator on the gate. The actuators on the cars are operable between first and second positions. In a first position, the actuator engages the gate operator to displace the gate into the closed position. In a second position, the actuator engages the gate to displace the gate into the open position. Alternatively, the gate may be biased toward the opened position, so that when the car actuator is in the second position it does not engage the gate operator. In another alternative, each car includes a mechanism for communicating with each gate. If the gate needs to be pivoted to direct an approaching car along a particular path, the car sends a signal to the gate indicating whether the gate should be opened or closed. In response to the signal from the car, the gate pivots to the appropriate position.

Further, in the above description, the system uses a wireless communication between the cars and the central controller. In an alternative embodiment, a communication line may be installed on the track and the cars may communicate with the central controller over a hard wired communication link. Still further, the system has been described as being useful in sorting incoming mail. However, the system may also be utilized to sort and prepare outgoing mail. For instance, after determining a characteristic for a mail piece, the system may print a marking onto the mail piece. For instance, after determining the recipient's address for a mail piece, the system determines which bin the mail piece is to be sorted to. As the mail piece is conveyed to the bin, a printer prints the appropriate postnet bar code on the piece before sorting the piece. To provide the printing functionality, the system may include a printer disposed along the track. When the car approaches the printer the car stops and at least partially discharges the mail piece to extend the mail piece toward the printer. The printer then prints the appropriate postnet code. The car then reverses the conveyors to load the piece back onto the car all the way, and then travels to the appropriate bin. Similarly, the system may include a device for selectively applying labels to the pieces. Similar to the above example of printing markings onto the pieces, the labeler may be positioned along the track. The cars selectively stop at the labeler on route to the appropriate bin and at least partially discharge the mail piece toward the labeler. The labeler then applies a label onto the mail piece and the conveyor on the car then reverses to load the piece back onto the car.

In addition to outgoing mail applications, it may be desirable to incorporate a printer and/or a labeler in systems configured to process incoming mail. For instance, when sorting incoming mail pieces, it may be desirable to print certain information, such as sort codes, a time stamp or audit trail information onto some or all of the pieces being processed. In some instances such information may be printed directly onto the mail pieces. In other instances, a label may be applied to the mail pieces and the information may be printed on the label.

In addition to a printer and a labeler, the system may include a scale for weighing the mail pieces. The scale may be positioned along the track **110**, such as along the loading column. To weigh a piece, the car stops adjacent the scale, and ejects the piece from the car onto the scale by driving the conveyor belts **212**. Preferably, the scale includes a conveyor or transfer mechanism for discharging the piece from the scale and back onto the car or onto a subsequent car. When the piece is loaded onto the car from the scale, the car drives the conveyors to load the piece as discussed above in connection with the loading station.

It should therefore be understood that this invention is not limited to the particular embodiments described herein, but is intended to include all changes and modifications that are within the scope and spirit of the invention as set forth in the claims.

What is claimed is:

1. A system for sorting or retrieving a plurality of items, comprising:

a plurality of destination areas for receiving the items, wherein the destination areas are arranged in a first array of columns or rows;

a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and

a track system for guiding the delivery vehicles to the destinations, wherein the track system forms a loop that the vehicles can circulate around, and the track system comprises:

a generally horizontal upper track section;

a generally horizontal lower track section positioned at a lower height than the upper track;

a plurality of generally vertical track sections intersecting the upper track and the lower track; and

a plurality of intersections where the horizontal sections intersect the vertical sections, wherein the intersections provide paths between a generally horizontal path of travel along one of the upper or lower track, and a generally vertical path of travel along one of the vertical track sections;

a first gate at an intersection of the upper track and a first one of the vertical track sections, wherein in a first position, the gate provides a first path through the intersection along one of either the upper track or the first vertical track while impeding travel along the other of the upper track and the first vertical track, and wherein in a second position, the gate provides a second path through the intersection substantially orthogonal to the first path to allow one of the delivery vehicles to change path direction;

wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between a vertical track and a horizontal track.

2. The system of claim **1** wherein the upper track is positioned higher than a plurality of the destination areas.

3. The system of claim **1** wherein each vehicle comprises an ejection mechanism for ejecting the item conveyed by the vehicle to the destination area after the vehicle arrives at the destination area.

4. The system of claim **1** comprising a loading station wherein one or more items are loaded onto one of the vehicles, wherein the loading station has an entry and an exit and the exit is along a path to one of the upper track section or the lower track section, and wherein the entry is along a path from one of the upper track section or the lower track section.

5. The system of claim **4** wherein the loading station exit is along a path to the upper track section.

6. The system of claim **5** wherein the loading station entry is along a path from the lower track section.

7. The system of claim **1** comprising a loading station wherein one or more items are loaded onto one of the vehicles, wherein the track system provides a continuous loop allowing the vehicles to circulate between the loading station and the destination areas.

8. The system of claim **1** wherein the array of destination areas are adjacent a front side of the track system, and a plurality of the destination areas arranged as a second array of rows or columns of destinations are adjacent a rearward side of the track system.

9. The system of claim **8** wherein the vehicles travel along the track system between the array of destination areas adjacent the front side and the array of destination areas adjacent the rearward side.

10. The system of claim **9** wherein the vehicles are configured to transfer items from the vehicles to both the first and second arrays of destination areas.

11. A system for sorting or retrieving a plurality of items, comprising:

a plurality of destination areas for receiving the items, wherein the destination areas are arranged in a first array of columns or rows;

a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and

a track system for guiding the delivery vehicles to the destinations, wherein the track system forms a loop that the vehicles can circulate around, and the track system comprises:

a first track section;

a second track section;

a plurality of transverse track sections intersecting the first and second track sections; and

a plurality of intersections where one of the transverse track sections intersects the first track section or the second track section, wherein the intersections provide paths between a path of travel in a first direction along the first or second track, and a path of travel in a second direction along one of the transverse tracks;

a first gate at an intersection of the first track section and a first one of the transverse track sections, wherein in a first position, the gate provides a first path through the intersection along one of either the first track or one of the transverse track sections while impeding travel along the other of the first track and the one transverse track sections, and wherein in a second position, the gate provides a second path through the intersection transverse the first path to allow one of the delivery vehicles to change path direction;

wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between the first or second track section and one of the transverse tracks.

12. The system of claim 11 wherein the first track is positioned higher than a plurality of the destination areas.

13. The system of claim 11 wherein each vehicle comprises an ejection mechanism for ejecting the item conveyed by the vehicle to the destination area after the vehicle arrives at the destination area.

14. The system of claim 11 comprising a loading station wherein one or more items are loaded onto one of the vehicles, wherein the loading station has an entry and an exit, and the exit is along a path to one of the first track section or the second track section, and wherein the entry is along a path from one of the first track section or the second track section.

15. The system of claim 14 wherein the loading station exit is along a path to the first track section.

16. The system of claim 15 wherein the loading station entry is along a path from the second track section.

17. The system of claim 11 comprising a loading station wherein one or more items are loaded onto one of the vehicles, wherein the track system provides a continuous loop allowing the vehicles to circulate between the loading station and the destination areas.

18. The system of claim 11 wherein the array of destination areas are adjacent a front side of the track system, and a plurality of the destination areas arranged as a second array of rows or columns of destinations are adjacent a rearward side of the track system.

19. The system of claim 18 wherein the vehicles travel along the track system between the array of destination areas adjacent the front side and the array of destination areas adjacent the rearward side.

20. The system of claim 19 wherein the vehicles are configured to transfer items from the vehicles to both the first and second arrays of destination areas.

21. A system for sorting or retrieving a plurality of items, comprising:

- a plurality of destination areas for receiving the items, wherein the destination areas are arranged in columns or rows;
- a plurality of vehicles for delivering the items to or from the destination areas, and
- a track system for guiding the delivery vehicles to the destinations, wherein the track system comprises:
  - a first track section;
  - a second track section;
  - a plurality of transverse track sections intersecting the first and second track sections; and
  - a plurality of intersections where one of the transverse track sections intersects the first track section or the second track section, wherein the intersections provide paths between a path of travel in a first direction along the first or second track, and a path of travel in a second direction along one of the transverse tracks;
  - a first gate at an intersection of the first track section and a first one of the transverse track sections, wherein in a first position, the gate provides a first path through the intersection along one of either the first track or one of the transverse track sections while impeding travel along the other of the first track and the one transverse track sections, and wherein in a second position, the gate provides a second path through the intersection transverse the first path to allow one of the delivery vehicles to change path direction;
- wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between the first or second track section and one of the transverse tracks.

22. The system of claim 21 wherein each vehicle comprises an ejection mechanism for ejecting the item conveyed by the vehicle to the destination area after the vehicle arrives at the destination area.

23. The system of claim 21 comprising a loading station wherein one or more items are loaded onto one of the vehicles, wherein the loading station has an entry and an exit, and the exit is along a path to one of the first track section or the second track section, and wherein the entry is along a path from one of the first track section or the second track section.

24. The system of claim 23 wherein the loading station exit is along a path to the first track section.

25. The system of claim 24 wherein the loading station entry is along a path from the second track section.

26. The system of claim 21 comprising a loading station wherein one or more items are loaded onto one of the vehicles, wherein the track system provides a continuous loop allowing the vehicles to circulate between the loading station and the destination areas.

27. The system of claim 21 wherein the destination areas are arranged as an array adjacent a front side of the track system, and a plurality of the destination areas arranged as a second array of rows or columns of destinations are adjacent a rearward side of the track system.

28. The system of claim 27 wherein the vehicles travel along the track system between the array of destination areas adjacent the front side and the array of destination areas adjacent the rearward side.

* * * * *

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THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THIS OFFICE OF:

U.S. PATENT: *8,276,740*
ISSUE DATE: *October 02, 2012*

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Under Secretary of Commerce for Intellectual Property
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US008276740B2

(12) **United States Patent**
Hayduchok et al.

(10) **Patent No.: US 8,276,740 B2**
(45) **Date of Patent: Oct. 2, 2012**

(54) **MATERIAL HANDLING APPARATUS FOR SORTING OR RETRIEVING ITEMS**

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(73) Assignee: **Opex Corporation**, Moorestown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/361,490**

(22) Filed: **Jan. 30, 2012**

(65) **Prior Publication Data**

US 2012/0128454 A1 May 24, 2012

Related U.S. Application Data

(63) Continuation of application No. 12/983,726, filed on Jan. 3, 2011, now Pat. No. 8,104,601, which is a continuation of application No. 12/014,011, filed on Jan. 14, 2008, now Pat. No. 7,861,844.

(60) Provisional application No. 60/884,766, filed on Jan. 12, 2007.

(51) **Int. Cl.**
B65G 1/00 (2006.01)

(52) **U.S. Cl.** **198/347.1**; 198/468.6

(58) **Field of Classification Search** 198/347.1, 198/358, 349, 349.6, 468.6, 468.1; 414/273
See application file for complete search history.

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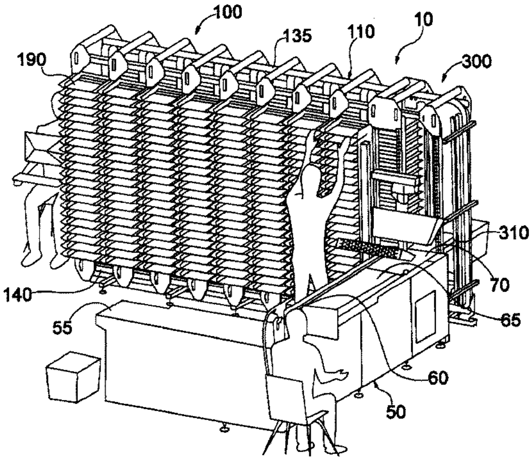
Primary Examiner — James R Bidwell

(74) *Attorney, Agent, or Firm* — Stephen H. Eland; Dann, Dorfman, Herrell & Skillman

(57) **ABSTRACT**

A method and apparatus are provided for sorting or retrieving items to/from a plurality of destinations areas. The items are loaded onto one of a plurality of independently controlled delivery vehicles. The delivery vehicles follow a track that guides the delivery vehicles to/from the destination areas, which are positioned along the track. Once at the appropriate destination area, an item is transferred between the delivery vehicle and the destination area.

25 Claims, 13 Drawing Sheets



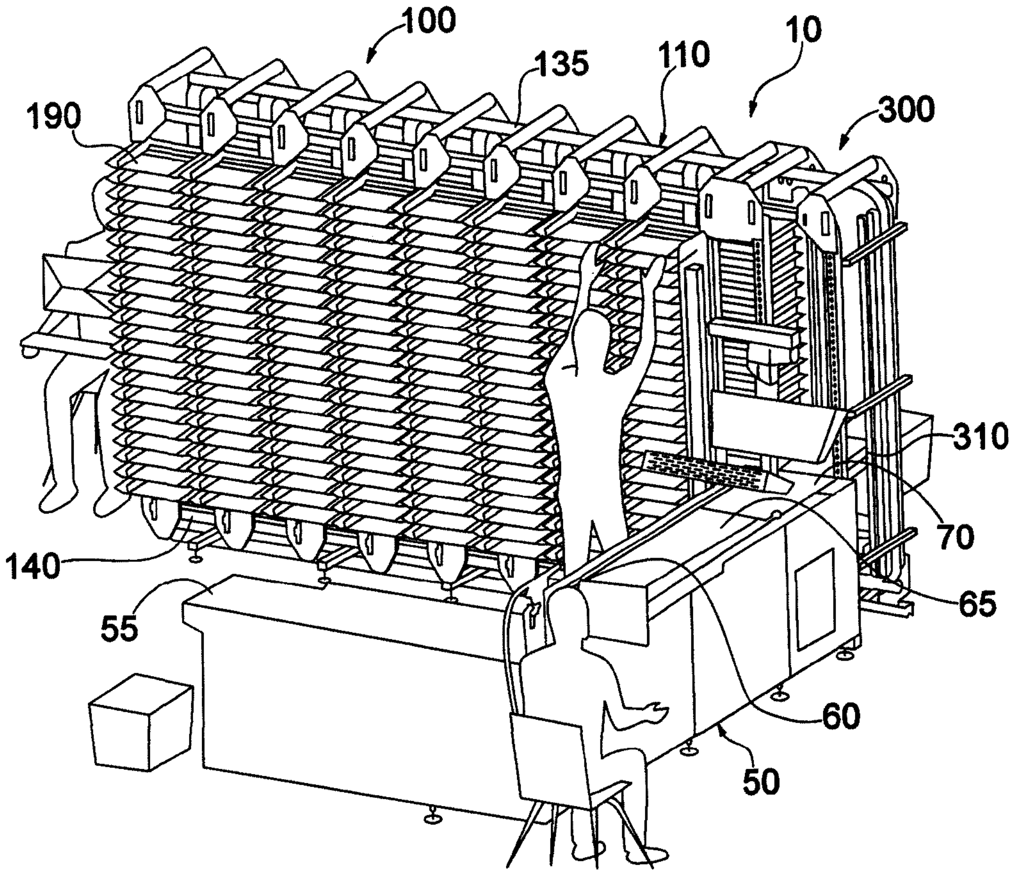


Fig. 1

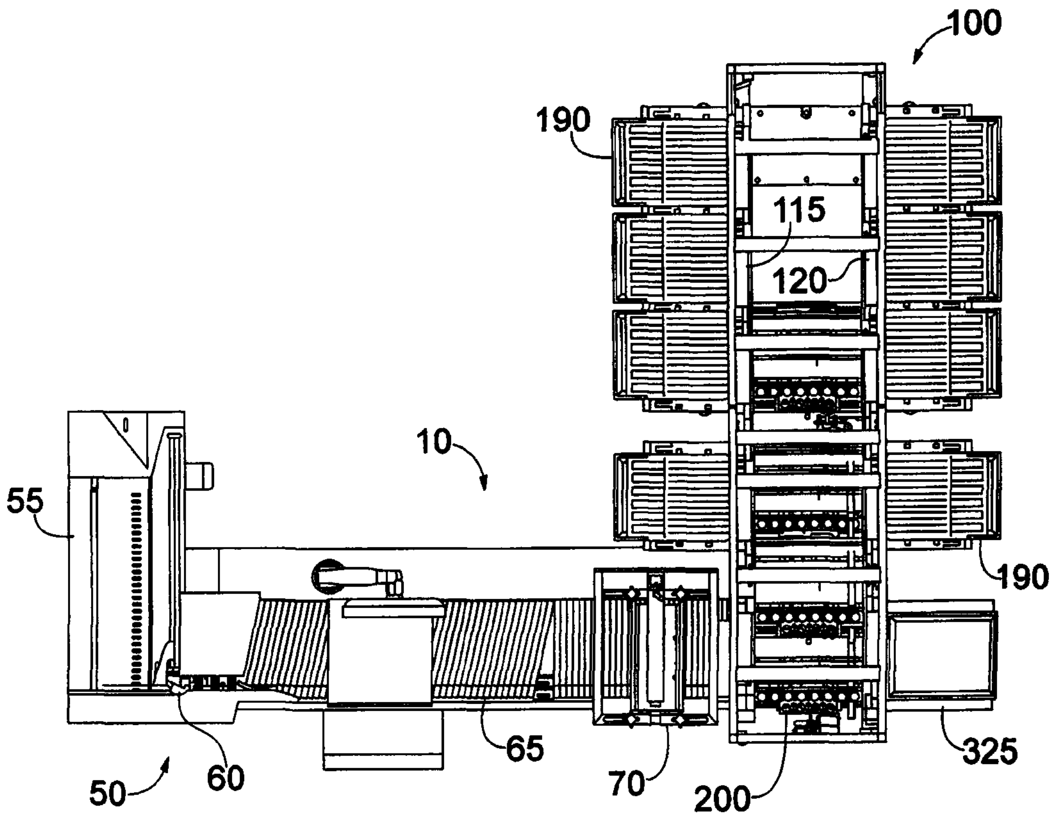


Fig. 2

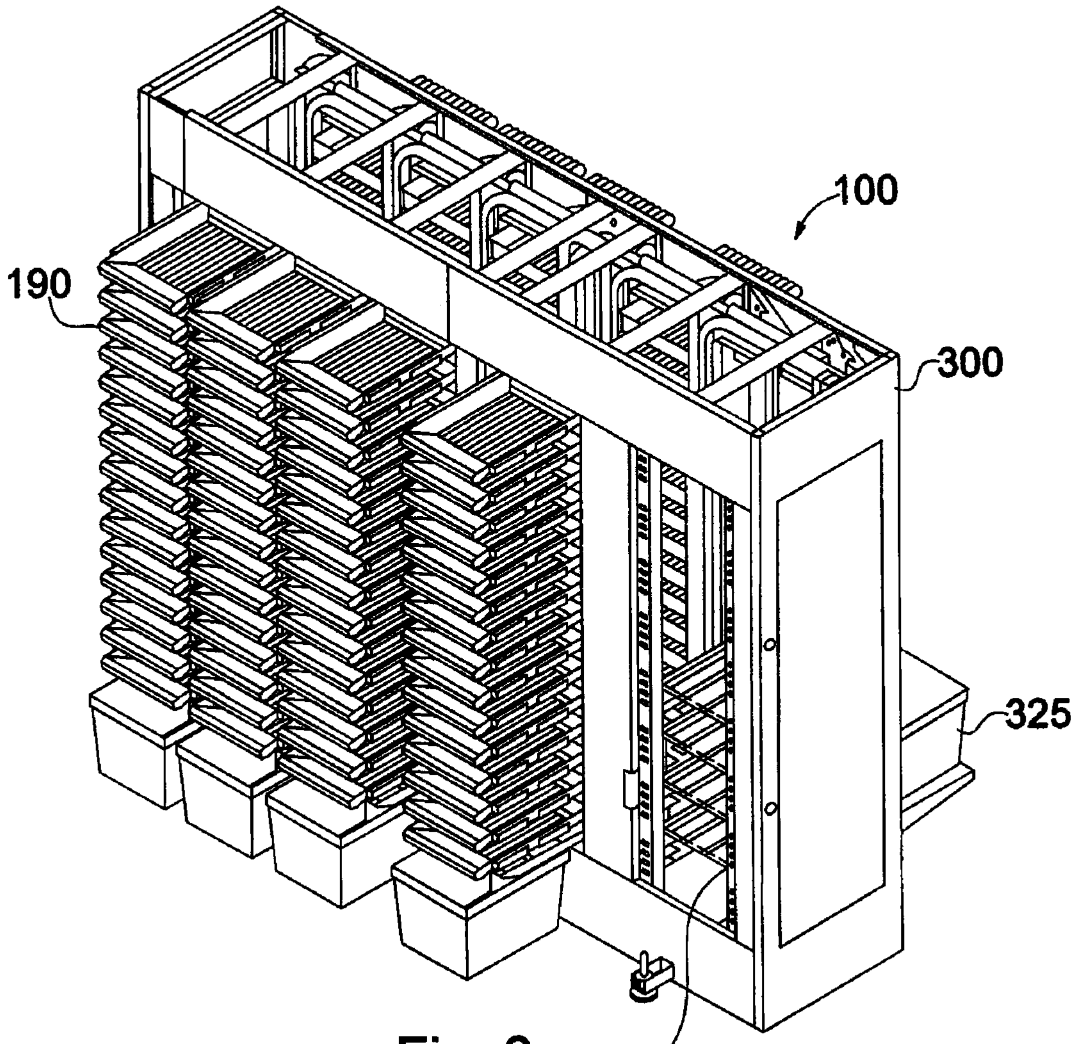
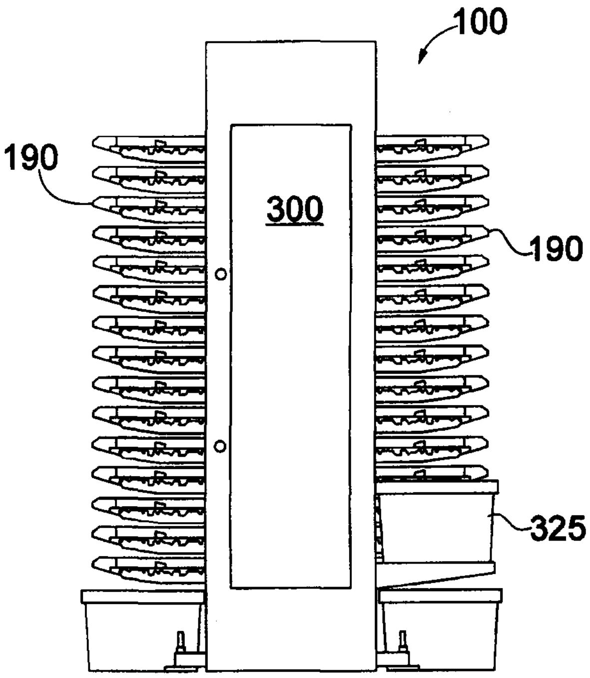


Fig. 3



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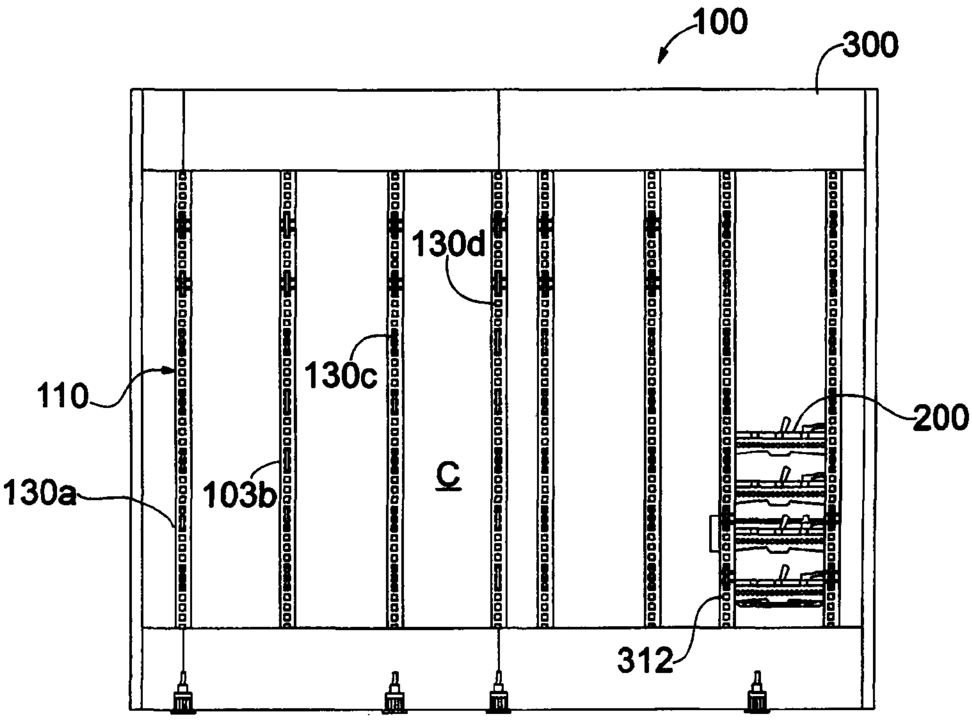

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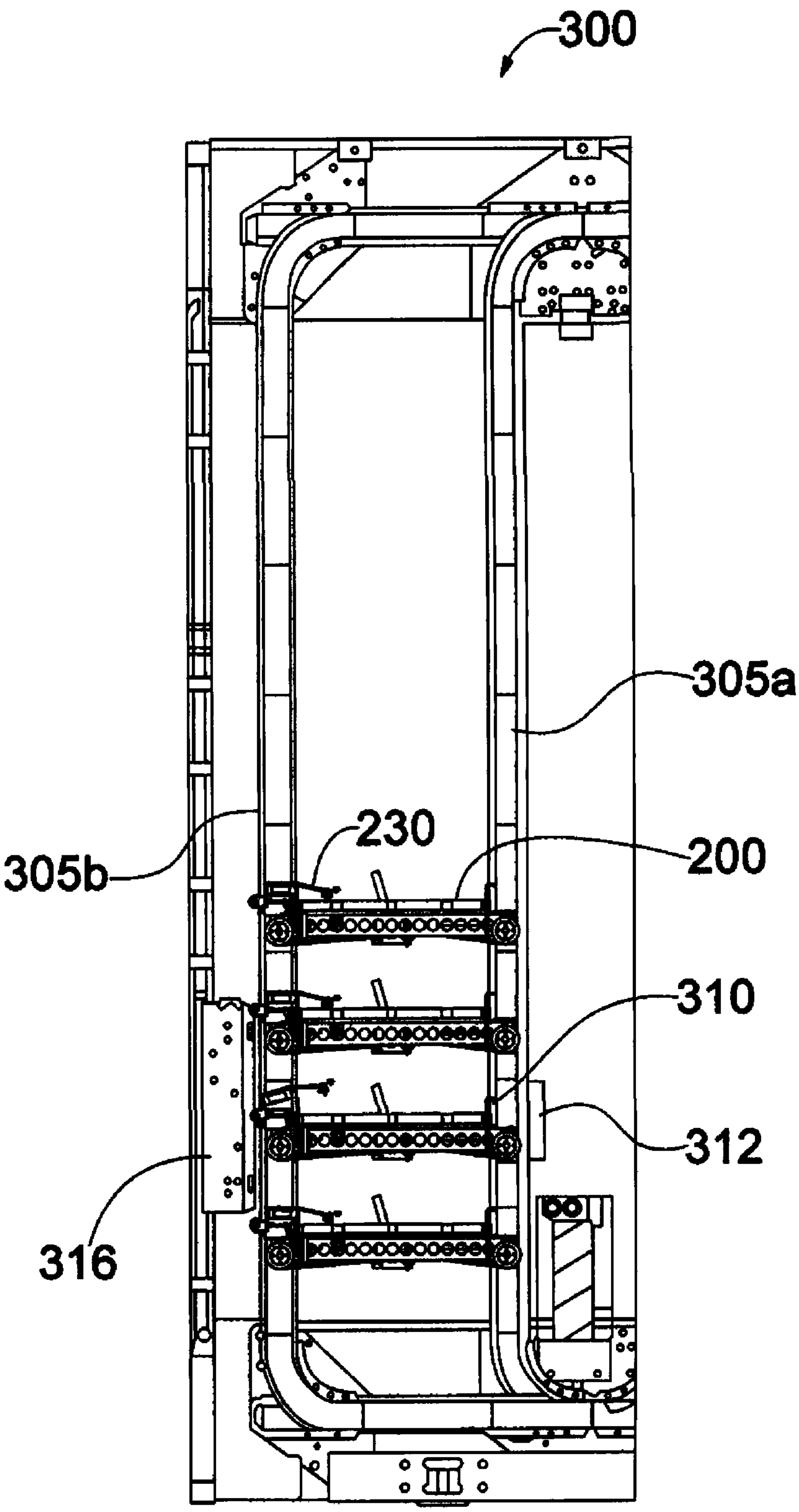


Fig. 6

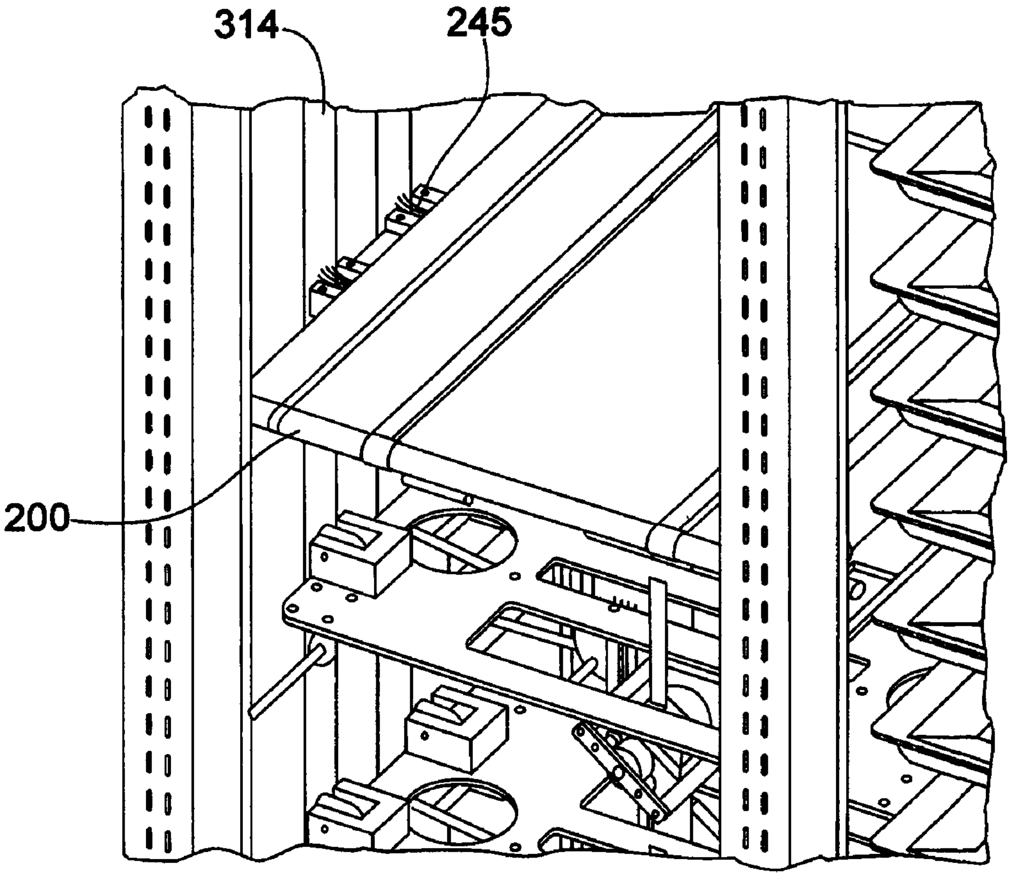


Fig. 7

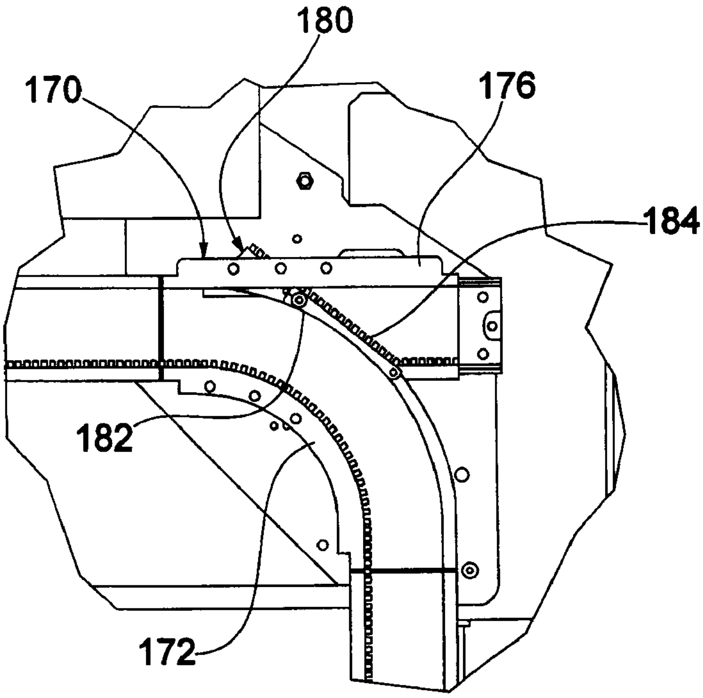


Fig. 8

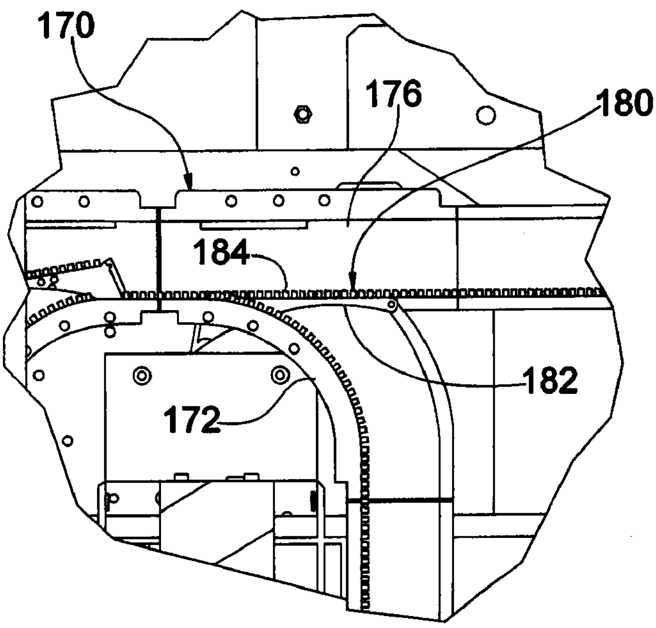


Fig. 9

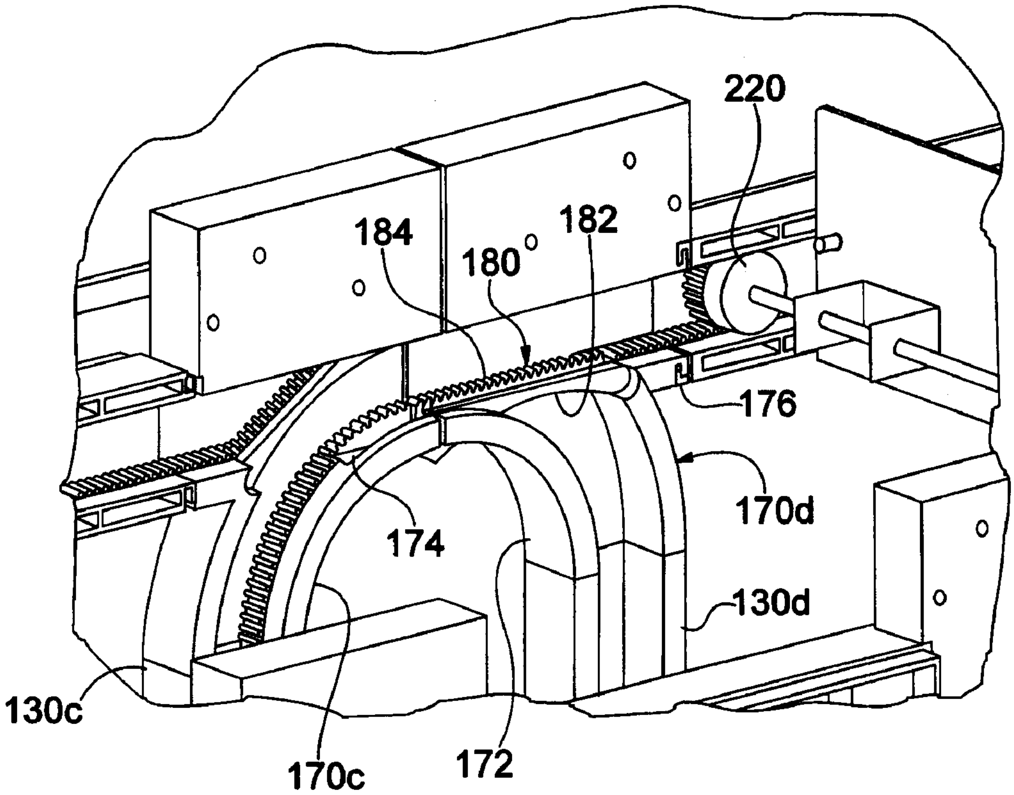
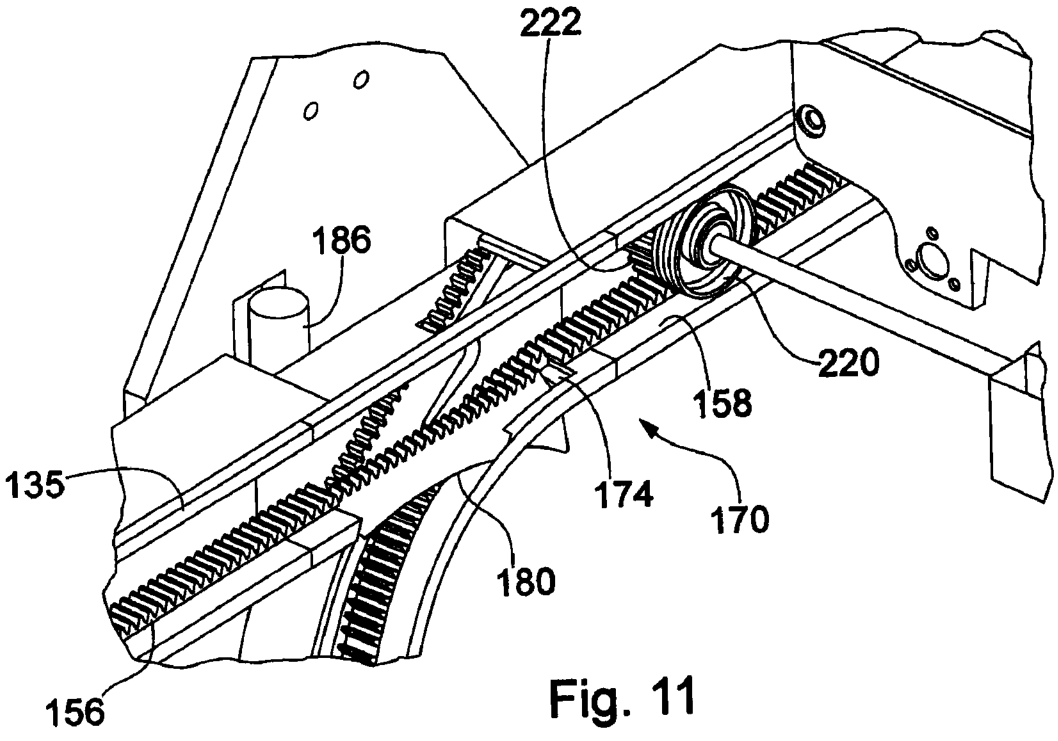


Fig. 10



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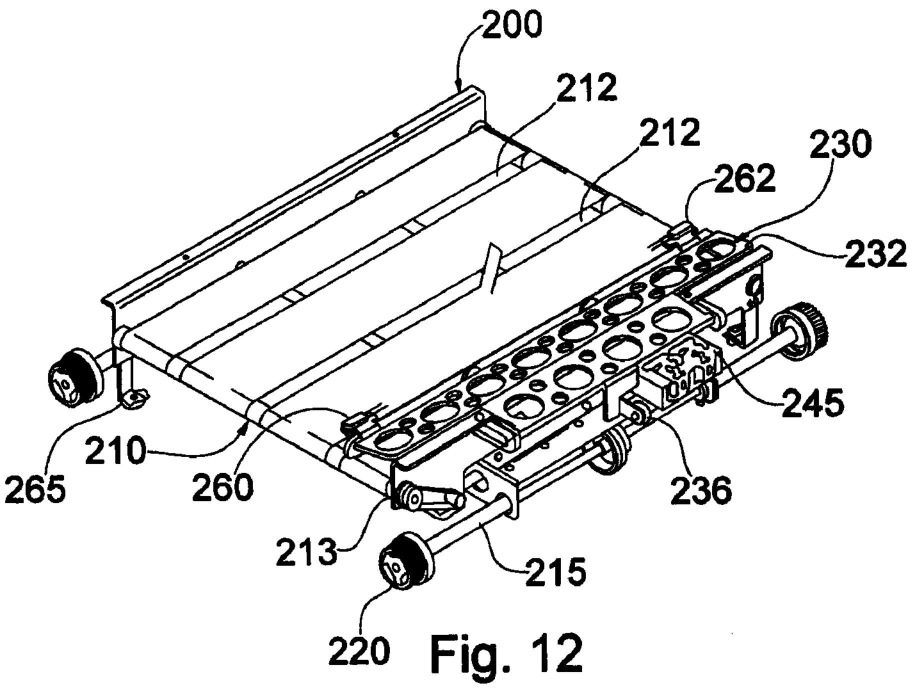
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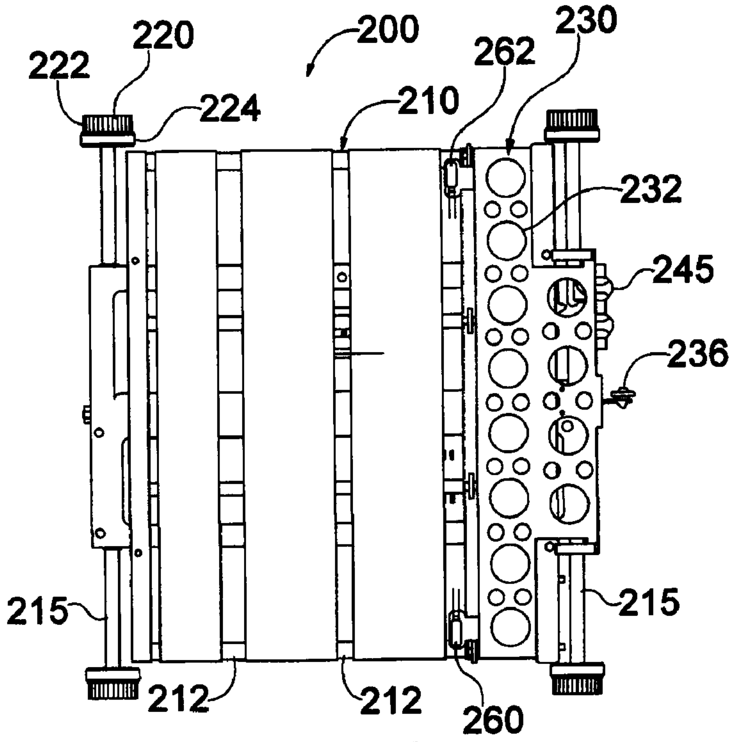
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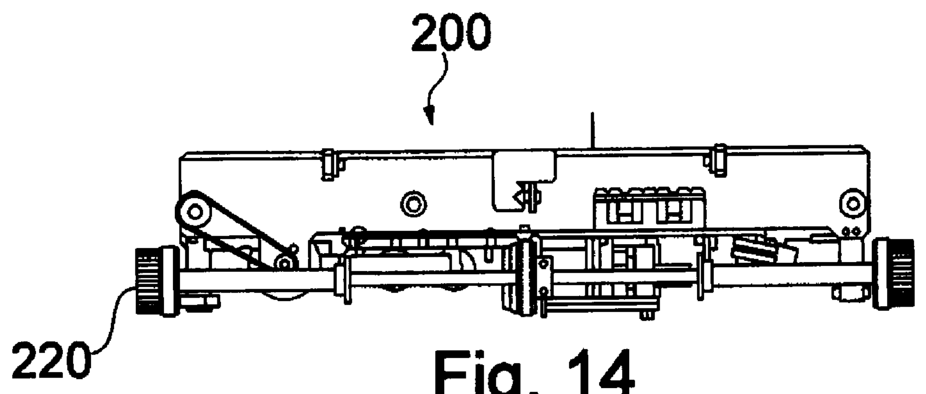
Fig. 13



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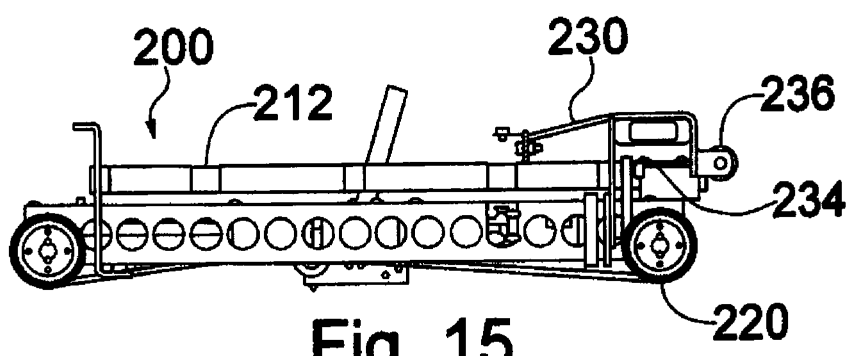

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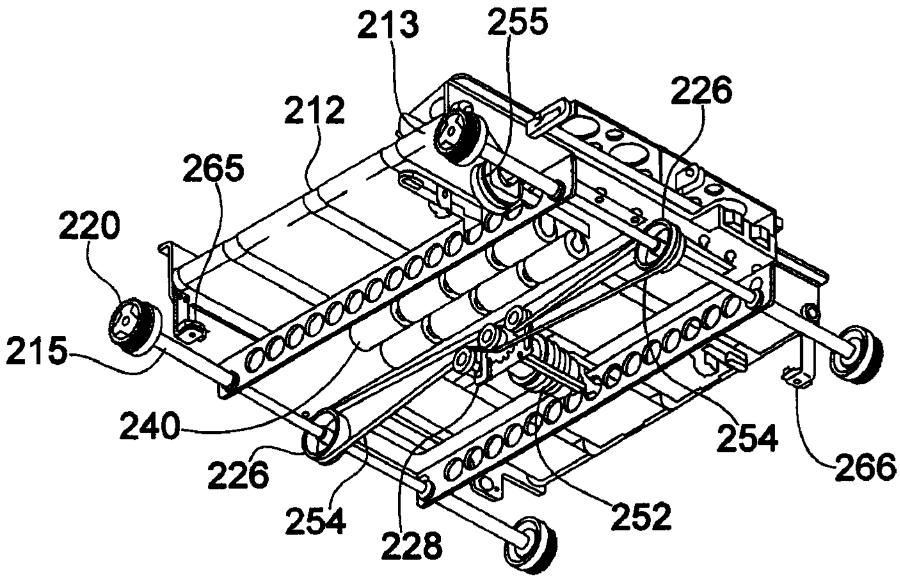
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Fig. 16

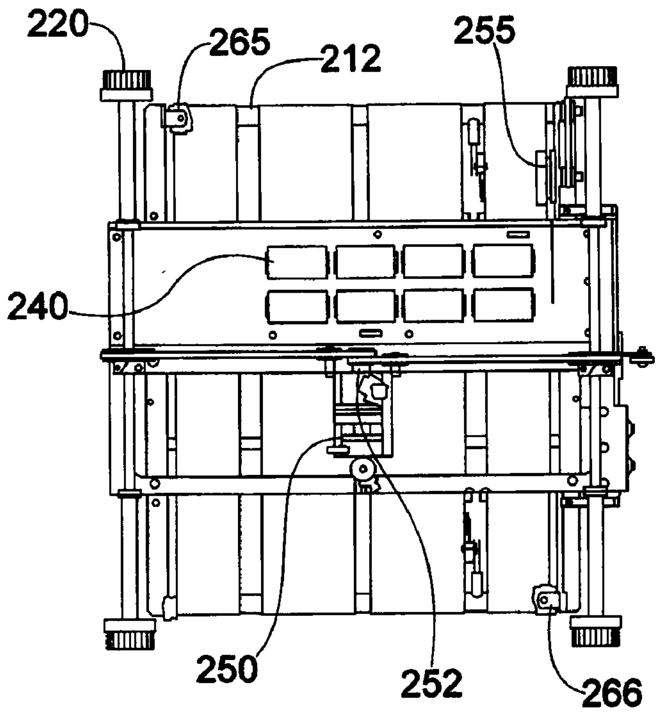
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Fig. 17

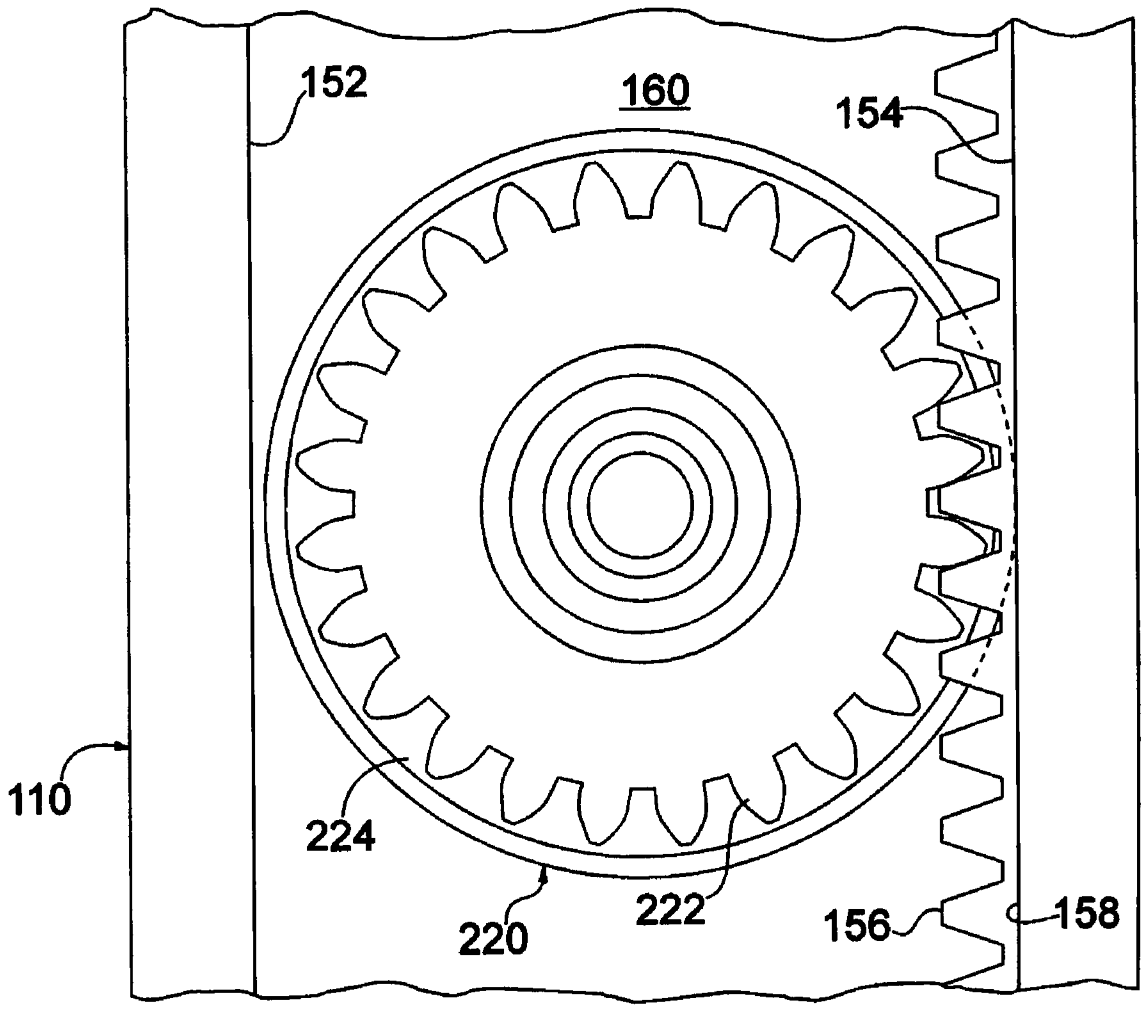

Fig. 18

MATERIAL HANDLING APPARATUS FOR SORTING OR RETRIEVING ITEMS

PRIORITY CLAIMS

The present application is a continuation application of U.S. patent application Ser. No. 12/983,726 filed Jan. 3, 2011 set to issue as U.S. Pat. No. 8,104,601, which is a continuation of U.S. patent application Ser. No. 12/014,011 filed Jan. 14, 2008 issued as U.S. Pat. No. 7,861,844. The present application also claims priority to U.S. Provisional Patent Application No. 60/884,766 filed on Jan. 12, 2007. The entire disclosure of each of the foregoing applications is hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to a material handling system for sorting or retrieving items. More specifically, the present invention relates to a material handling system incorporating a plurality of destination areas arranged along a track for guiding a plurality of vehicles for carrying items to and/or from the destination areas.

BACKGROUND OF THE INVENTION

Sorting documents and mail pieces manually is laborious and time consuming. For example, thousands of large organizations employ numerous people full-time to manually sort and deliver incoming and interoffice mail and documents. For instance, a large company may receive 5,000 mail pieces that need to be sorted and delivered each day to different departments and/or individuals. Such volumes require a significant number of employees dedicated to sorting and delivering the mail. Nonetheless, such volume is not typically sufficient to justify the expense of traditional automated sorting equipment, which is quite expensive. Additionally, the mail for such organizations is typically quite diverse, which makes it more difficult, and therefore more expensive, to automate the sorting procedures.

Various systems for sorting have been developed to address the needs of mail rooms for large organizations. However, the known systems suffer from several problems; the most significant are cost and size. Accordingly, there is a need for a compact and affordable automated sorting system that is able to meet the needs of mid- to large-sized organization that handle several thousand mail pieces each day.

Similarly, may large organizations have extensive storage areas in which numerous items are stored. Sorting and retrieving items from the hundreds or thousands of storage areas requires significant labor to perform manually, and the known systems of automatically handling the materials are either very expensive or have limitations that hamper their effectiveness. Accordingly, there is a need in a variety of material handling applications for automatically storing and/or retrieving items.

SUMMARY OF THE INVENTION

In light of the foregoing, a system provides a method and apparatus for sorting items. The system includes a plurality of storage locations, such as bins, and a plurality of delivery vehicles for delivering items to the storage locations. A track guides the delivery vehicles to the storage locations.

In one embodiment, a controller controls the operation of the delivery vehicles based on information determined for each item to be sorted. Additionally, the track may include a plurality of interconnected vertical and horizontal sections so that the vehicles may travel along a continuous path changing from a horizontal direction to a vertical direction. Further, the vehicles may be driven such that the orientation of an item on the vehicle stays constant as the vehicles changes from a horizontal direction of travel to a vertical direction of travel.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary and the following detailed description of the preferred embodiments of the present invention will be best understood when read in conjunction with the appended drawings, in which:

FIG. **1** is a perspective view of a sorting apparatus;

FIG. **2** is a plan view of the sorting apparatus illustrated in FIG. **1**;

FIG. **3** is a fragmentary perspective view of the sorting apparatus illustrated in FIG. **1**, shown without an input station;

FIG. **4** is a right side view of the sorting apparatus illustrated in FIG. **3**;

FIG. **5** is a front elevational view of the sorting apparatus illustrated in FIG. **3**, shown without discharge bins;

FIG. **6** is a fragmentary sectional view of a loading station of the sorting apparatus illustrated in FIG. **1**;

FIG. **7** is an enlarged fragmentary perspective view of a portion of the loading station of the apparatus illustrated in FIG. **3**;

FIG. **8** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in an open position;

FIG. **9** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in a closed position;

FIG. **10** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate;

FIG. **11** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate, with the gate shown in an open position in phantom;

FIG. **12** is a top perspective view of a delivery vehicle of the apparatus illustrated in FIG. **1**;

FIG. **13** is a plan view of the delivery vehicle illustrated in FIG. **12**;

FIG. **14** is a right side view of the delivery vehicle illustrated in FIG. **12**;

FIG. **15** is a front elevational view of the delivery vehicle illustrated in FIG. **12**;

FIG. **16** is a bottom perspective view of the delivery vehicle illustrated in FIG. **12**;

FIG. **17** is a bottom view of the delivery vehicle illustrated in

FIG. **12**; and

FIG. **18** is an enlarged view of a wheel of the delivery vehicle illustrated in FIG. **12**, shown in relation to the track of the sorting apparatus illustrated in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1-18**, an apparatus for sorting items such as documents or mail pieces is designated generally **10**. The apparatus **10** includes a plurality of delivery vehicles or cars **200** to deliver items to a plurality of sort locations, such as output bins **190**. At a loading station **310**, each car **200** receives an item from an input station **50** and delivers it to the appropriate bin.

The cars **200** travel along a track **110** to the sort locations. The track has a horizontal upper rail **135** and a horizontal lower rail **140**, which operates as a return leg. A number of parallel vertical track legs **130** extend between the upper rail and the lower return leg. In the present instance, the bins **190** are arranged in columns between the vertical track legs **130**.

After a piece is loaded onto a car, the car travels upwardly along two pairs of vertical tracks legs and then horizontally along two upper tracks **135**. The car **200** travels along the upper rail until it reaches the appropriate column containing the bin for the piece that the car is carrying. The track **110** includes gates **180** that fire to direct the car **200** down the vertical legs and the car stops at the appropriate bin. The car **200** then discharges the piece into the bin.

After discharging the piece, the car **200** continues down the vertical legs **130** of the column until it reaches the lower rail **140**. Gates fire to direct the car along the lower rail, and the car follows the lower rail to return to the loading station **310** to receive another piece.

The cars **200** are semi-autonomous vehicles that each have an onboard power source and an onboard motor to drive the cars along the track **110**. The cars also include a loading/unloading mechanism **210**, such as a conveyor, for loading pieces onto the cars and discharging the pieces from the cars.

Since the system **10** includes a number of cars **200**, the positioning of the cars is controlled to ensure that the different cars do not crash into each other. In one embodiment, the system **10** uses a central controller **350** that tracks the position of each car **200** and provides control signals to each car to control the progress of the cars along the track. The central controller **350** may also control operation of the various elements along the track, such as the gates **180**.

Input Station

At the input station **50**, the mail pieces are separated from one another so that the pieces can be conveyed serially to the loading station **310** to be loaded onto the cars **200**. Additionally, at the input station information is determined for each piece so that the piece can be sorted to the appropriate bin.

A variety of configurations may be used for the input station, including manual or automatic configurations or a combination of manual and automated features. In a manual system, the operator enters information for each piece and the system sorts the mail piece accordingly. In an automatic system, the input system includes elements that scan each mail piece and detect information regarding each piece. The system then sorts the mail piece according to the scanned information.

In an exemplary manual configuration, the input system includes a work station having a conveyor, an input device, such as a keyboard, and a monitor. The operator reads information from a mail piece and then drops in onto a conveyor that conveys the piece to the loading station **310**. Sensors positioned along the conveyor track the piece as the conveyor transports the mail piece toward the loading station. An example of a work station having a conveyor for receiving dropped pieces and tracking the pieces is provided in pending U.S. application Ser. No. 10/862,021, filed Jun. 4, 2004, which was published Jan. 27, 2005 under Publication No. US 2005-0018214 A1 and which is incorporated herein by reference. The conveyor receives mail pieces dropped by an operator and tracks the mail pieces as they are transported along the conveyor.

In an exemplary automatic configuration, the system includes an imaging station, having an imaging device such as a high speed line scanning camera. The imaging station scans each mail piece to detect information regarding the destination for each piece. The system analyzes the image data to

determine the destination information and then electronically tags the mail piece with the destination and sorts the piece accordingly. An example of a system having an automated imaging station for scanning pieces as they are conveyed is described in U.S. patent application Ser. No. 09/904,471, filed Jul. 13, 2001, which was published Jan. 16, 2003 under Publication No. US 2003-0014376 A1, and which is incorporated herein by reference.

FIGS. **1** and **2** illustrate such an automated system. The input station includes an input bin **55** for receiving a stack of mail. A feeder **60** in the input bin serially feeds mail pieces from the input bin to a conveyor **65**. An imaging station **70** positioned along the conveyor scans the mails pieces as the pieces are conveyed to the loading station **310**. The system **10** analyzes the image data to read information for the mail piece, such as the recipient's address.

The conveyor **65** conveys the mail piece to the loading station **310**. At the loading station the conveyor **65** conveys the mail piece onto a car **200**. As discussed further below, after the mail piece is loaded onto the car, the car moves away from the loading station and another car moves into position at the loading station to receive the next piece of mail.

In certain instances, the system may not be able to automatically identify the relevant information for a mail piece. To process such pieces, the system may include an operator to input the relevant information so that the mail piece can be sorted. For instance, the system may include an operator station having an input device and a display, such as a monitor. If the system cannot automatically determine the address within a pre-determined time period, the system displays the scanned images for the mail piece to the monitor so that the operator at the work station can view the images and manually enter the information using the input device.

In addition to the automated and manual systems described above, the system may be configured in a hybrid or semi-automated configuration having some operations performed manually and others automated. For instance, the system may include a manual input station that also has an imaging station. Since the system can handle a wide variety of items, it may be desirable to have an operator input the pieces manually so that the pieces are properly oriented and separated. The imaging station then scans the items and processes the imaging data to determine the address information for the pieces. Additionally, the operator station may include an input device and a display for inputting information if the address for a piece cannot be automatically determined, as discussed above. The operator can input the information as soon as the system indicates to the operator that it cannot determine the information for a piece. Alternatively, as discussed below, the car may be directed to a buffer if the information for a piece cannot be determined. In such an instance, the cars having such pieces will remain in the buffer while the system continues to process pieces for which the system can determine the relevant information. The operator can continue to manually drop pieces and wait until a number of pieces need manual keying of information. The operator can then switch from the operation of dropping pieces to the operation of manually keying the pieces, sometimes referred to as local video encoding (LVE). The operator can continue keying until some or all of the pieces in the buffer have been successfully coded, and then the operator can go back to the operation of manually dropping pieces. As yet another alternative, it may be desirable to incorporate a separate operator station having the input device and display so that one operator can input the mail at the input station and a separate operator can input the information for pieces having addresses that cannot be automatically determined.

As can be seen from the foregoing, the input station **50** may be configured in a wide range of options. The options are not limited to those configurations described above, and may include additional features, such as an automated scale for weighing each piece, a labeler for selectively applying labels to the mail pieces and a printer for printing information on the mail pieces or on the labels.

Additionally, in the foregoing description, the system is described as having a single input station **50**. However, it may be desirable to incorporate a plurality of input stations positioned along the system **10**. By using a plurality of input stations, the feed rate of pieces may be increased. In addition, the input stations may be configured to process different types of items. In this way, each input station could be configured to efficiently process a particular category of items. For instance, if the system is configured to process documents, such as mail, one input station may be configured to process standard envelopes, while another input station may be configured to process larger mails, such as flats. Similarly, one input station may be configured to automatically process mail by scanning it and automatically determining the recipient. The second input station may be configured to process rejects, such as by manually keying in information regarding the recipient.

Sorting Station

Referring to FIGS. **1-6**, the system includes a sorting station **100**, such as an array of bins **190** for receiving the pieces. In the present instance, the sorting station includes a number of bins arranged in columns. Additionally, the sorting station **100** includes a track **110** for guiding the cars **200** to the bins **190**.

The track **110** includes a horizontal upper rail **135** and a horizontal lower rail **140**. A plurality of vertical legs **130** extend between the upper horizontal leg and the lower horizontal leg **140**. During transport, the cars travel up a pair of vertical legs from the loading station **310** to the upper rail **135** (as described below, the cars actually travel up two pairs of rails because the track includes a forward track and a parallel opposing track). The car then travels along the upper rail until reaching the column having the appropriate bin. The car then travels downwardly along two front vertical posts and two parallel rear posts until reaching the appropriate bin, and then discharges the mail piece into the bin. The car then continues down the vertical legs until reaching the lower horizontal leg **140**. The car then follows the lower rail back toward the loading station.

As can be seen in FIG. **2**, the track **110** includes a front track **115** and a rear track **120**. The front and rear tracks **115, 120** are parallel tracks that cooperate to guide the cars around the track. As shown in FIG. **13**, each of the cars includes four wheels **220**: two forward wheel and two rearward wheels. The forward wheels **220** ride in the front track, while the rearward wheel ride in the rear track. It should be understood that in the discussion of the track the front and rear tracks **115, 120** are similarly configured opposing tracks that support the forward and rearward wheels **220** of the cars. Accordingly, a description of a portion of either the front or rear track also applies to the opposing front or rear track.

Referring to FIG. **18** the details of the track will be described in greater detail. The track **110** includes an outer wall **152** and an inner wall **154** that is spaced apart from the outer wall and parallel to the outer wall. The track also has a back wall **160** extending between the inner and outer walls. As can be seen in FIG. **18**, the outer and inner walls **152, 154** and the back wall form a channel. The wheels **220** of the car ride in this channel.

Referring to FIG. **11**, the track includes both a drive surface **156** and a guide surface **158**. The drive surface positively engages the cars to enable the car to travel along the track. The guide surface **158** guides the car, maintaining the car in operative engagement with the drive surface **156**. In the present instance, the drive surface is formed of a series of teeth, forming a rack that engages the wheels of the cars as described further below. The guide surface **158** is a generally flat surface adjacent the rack **156**. The rack **156** extends approximately halfway across the track and the guide surface **158** extends across the other half of the track. As shown in FIGS. **11** and **18**, the rack **156** is formed on the inner wall **154** of the track. The opposing outer wall **152** is a generally flat surface parallel to the guide surface **158** of the inner wall.

As described above, the track includes a plurality of vertical legs extending between the horizontal upper and lower rails **135, 140**. An intersection **170** is formed at each section of the track at which one of the vertical legs intersects one of the horizontal legs. Each intersection includes an inner branch **172** that is curved and an outer branch **176** that is generally straight. FIG. **10** illustrates both a right-hand intersection **170***c* and a left-hand intersection **170**, which are mirrors of one another. In FIG. **10**, the intersections **170***c*, **170***d* illustrate the portion of the track in which two vertical legs **130** intersect the upper horizontal leg **135**. The intersections of the vertical legs with the lower rail incorporate similar intersections, except the intersections are reversed. Specifically, the point at which vertical leg **130***c* intersects the lower rail incorporates an intersection configured similar to intersection **170***d*, and the point at which vertical leg **130***d* intersects the lower rail incorporates an intersection configured similar to intersection **170***c*.

Each intersection **170** includes a pivotable gate **180** that has a smooth curved inner race and a flat outer race that has teeth that correspond to the teeth of the drive surface **156** for the track. The gate **180** pivots between a first position and a second position. In the first position, the gate **180** is closed so that the straight outer race **184** of the gate is aligned with the straight outer branch **176** of the intersection. In the second position, the gate is open so that the curved inner race **182** of the gate is aligned with the curved branch **172** of the intersection.

Accordingly, in the closed position, the gate is pivoted downwardly so that the outer race **184** of the gate aligns with the drive surface **156**. In this position, the gate blocks the car from turning down the curved portion, so that the car continues straight through the intersection. In contrast, as illustrated n FIG. **10**, when the gate is pivoted into the open position, the gate blocks the car from going straight through the intersection. Instead, the curved inner race **182** of the gate aligns with the curved surface of the inner branch **172** and the car turns through the intersection. In other words, when the gate is closed, a car goes straight through the intersection along either the upper rail **130** or the lower rail, depending on the location of the intersection. When the gate is opened, the gate directs the car from either a vertical rail to a horizontal rail or from a horizontal rail to a vertical rail, depending on the location of the intersection.

As can be seen in FIG. **11**, the end of the gate remote from the pivot point of the gate flares outwardly so that the curved inner race matches the curved profile of the inner branch when the gate is open. As a result, the gate has a generally L-shaped configuration. To accommodate the flared end of the gate **180**, the drive surface **156** of the inner branch has a notch or recessed portion. When the gate is closed, the notch provides clearance so that the outer race **184** of the gate lies flat, parallel with the drive surface of the outer branch **176**.

Further, in the example shown in FIG. **11**, the gate is positioned along the upper rail **135** of the track **110**. When the gate is closed, the recess in the inner branch of the intersection **170** allows the gate to lie flat so that it is aligned with the drive surface of the upper rail.

In the foregoing description, the gates allow one of the cars to either continue in the same direction (e.g. horizontally) or turn in one direction (e.g. vertically). However, in some applications, the system may include more than two horizontal rails that intersect the vertical columns. In such a configuration, it may be desirable to include a different rail that allows the cars to turn in more than one direction. For instance, if a car is traveling down a column, the gate may allow the car to turn either left or right down a horizontal rail, or travel straight through along the vertical column. Additionally, in some applications it may be desirable to allow the cars to travel upwardly, whereas in the system described above, the cars only travel downwardly through the sorting station. If the cars also travel upwardly in the sorting station, then the gates should be configured to accommodate and guide the cars when the cars travel upwardly through an intersection.

The gates **180** are controlled by signals received from the central controller **350**. Specifically, each gate is connected with an actuator **186** that displaces the gate from the opened position to the closed position and back. There may be any of a variety of controllable elements operable to displace the gate. In the present instance, the actuator **186** is a solenoid having a linearly displaceable piston.

In the foregoing description, the sorting station **100** is described as a plurality of output bins **190**. However, it should be understood that the system may include a variety of types of destinations, not simply output bins. For instance, in certain applications it may be desirable to sort items to a storage area, such as an area on a storage shelf. Alternatively, the destination may be an output device that conveys items to other locations. According to one example of an output device, the system may include one or more output conveyors that convey pieces away from the sorting system toward a different material handling or processing system. For instance, an output conveyor designated A may convey pieces to a processing center designated A. Therefore, if a piece is to be delivered to processing center A, the car will travel along the track to output conveyor A. Once the car reaches output conveyor A, the car will stop and transfer the piece onto output conveyor A. Output conveyor A will then convey the piece to processing center A. Further, it should be understood that the system may be configured to include a plurality of output devices, such as output conveyors.

In some embodiments, the system may include a plurality of output conveyors in addition to the output bins. In other embodiments, the system may only include a plurality of output devices, such as conveyors, and the system is configured to sort the pieces to the various output devices. Further still, the system may be configured to retrieve pieces from storage locations. In such embodiments, the cars may sort pieces to a storage location, such as a bin. Subsequently, one of the cars may travel to the storage location and retrieve the item from the storage location and transport it to one of the output devices.

One manner that the cars may retrieve items from the storage locations is by including a conveyor at the storage locations. In this way, an item at a storage location can be conveyed by the conveyor toward the track. When a car arrives at the storage location, the conveyor at the storage location conveys the item onto the car, similar to the manner in which a piece is loaded onto the car at the loading column. Accordingly, the system can sort pieces to a plurality of output devices, in addition to sorting pieces to a plurality of storage locations before subsequently retrieving the pieces and conveying the pieces to the output devices.

As discussed above, the system is operable to sort a variety of items to a plurality of destinations. One type of destination is a bin; a second type is a shelf or other location on which the item is to be stored; and a third type of destination is an output device that may be used to convey the item to a different location. The system may include one or more of each of these types or other types of destinations.

Delivery Vehicles

Referring now to FIGS. **12-17**, the details of the delivery vehicles **200** will be described in greater detail. Each delivery vehicle is a semi-autonomous car having an onboard drive system, including an onboard power supply. Each car includes a mechanism for loading and unloading items for delivery.

The car **200** may incorporate any of a variety of mechanisms for loading an item onto the car and discharging the item from the car into one of the bins. Additionally, the loading/unloading mechanism **210** may be specifically tailored for a particular application. However, in the present instance, the loading/unloading mechanism **210** is a conveyor belt. Specifically, referring to FIG. **12**, the loading/unloading mechanism includes a plurality of narrow belts **212** that extend along the top surface of the car. The conveyor belts are reversible. Driving the belts in a first direction displaces the item toward the rearward end of the car; driving the belt in a second direction displaces the item toward the forward end of the car.

A conveyor motor **255** mounted on the underside of the car drives the conveyor belts **212**. Specifically, the conveyor belts **212** are entrained around a forward roller **213** at the forward edge of the car, and a rearward roller at the rearward edge of the car. The conveyor motor **255** is connected with the forward roller **213** to drive the forward roller, thereby operating the conveyor belts.

The car includes four wheels **220** that are used to transport the car along the track **110**. The wheels **220** are mounted onto two parallel spaced apart axles **215**, so that two or the wheels are disposed along the forward edge of the car and two of the wheels are disposed along the rearward edge of the car.

Referring to FIG. **18**, each wheel comprises an inner idler roller **224** and an outer gear **222** that cooperates with the drive surface **156** of the track. The idler roller **224** rotates freely relative to the axles, while the outer gear is fixed relative to the axle onto which it is mounted. In this way, rotating the axle operates to rotate the gear **222**. Additionally, the idler roller is sized to have a diameter slightly smaller than the distance between the upper wall **152** and the lower wall **154** of the track. In this way, the idler roller may rotate freely within the track, while ensuring that the gear **222** of each wheel remains in operative engagement with the drive surface (i.e. the teeth) **156** of the track. Accordingly, when the vehicle is moving horizontally, the rollers carry the weight of the cart, while the gears **222** cooperate with the drive surface **156** of the track to drive the vehicle along the track.

The car includes an onboard motor **250** for driving the wheels **220**. More specifically, the drive motor **250** is operatively connected with the axles to rotate the axles **215**, which in turn rotates the gears **222** of the wheels. As shown in FIG. **16**, the drive motor **250** is interconnected to the axles **215** via a pair of drive belts **254** that are driven by the drive motor.

The drive system for the car may be configured to synchronously drive the car along the track. In the present instance, the drive system is configured so that each gear is driven in a synchronous manner. Specifically, each gear **222** is connected to an end of one of the axles in a manner that substantially impedes rotation of the gear relative to the axle. In this way each axle drives the attached two gears in a synchronous manner. Additionally, in the present instance, both axles are driven in a synchronous manner so that all four gears are driven in a synchronous manner. There are various mechanisms that can be used to synchronously drive the axles. For instance, a pair of drive motors can be used to drive the axles, and the drive motors can be synchronized. However, in the present instance, a single drive motor **250** is used to drive both axles. Each axle includes a timing pulley **226** that is rigidly connected to the axle to prevent rotation of the pulley relative to the axle. Similarly, a timing pulley **228** is connected to the motor shaft. The drive belt **254** connecting the timing pulley **226** on the axle with the motor is a timing belt so that the rotation of the drive motor is precisely linked to the rotation of the axle. Although a single timing belt can be used to drive both axles synchronously, in the present instance, a pair of timing pulleys is connected to the motor shaft, and each timing pulley is connected to a corresponding timing pulley on one of the axles, as shown in FIG. **16**.

The drive motor **250** includes a sensor that is operable to detect the rotation of the motor to thereby determine the distance the car has traveled. Since the gears **222** are rigidly connected with the axles, which are in turn synchronously connected with the drive motor, the forward distance that the car moves corresponds can be exactly controlled to correlate to the distance that the drive motor is displaced. Accordingly, the distance that a car has traveled along the determined path depends on the distance through which the car motor is rotated.

To detect the rotation of the drive motor **250**, the motor includes a sensor **252** for detecting the amount of rotation of the drive motor. In the present instance the sensor **252** is a hall sensor. A portion of rotation of the motor corresponds to what is referred to as a tick. The sensor detects the number of ticks and sends a signal to the central processor **350**, which determines how far along the designate path the car has traveled based on the known information regarding the path and the number of ticks that the sensor detects for the motor.

As the car travels along the track, an item on top of the car may tend to fall off the car, especially as the car accelerates and decelerates. Therefore, in the present instance, the car includes a retainer **230** to retain the element on the car during delivery. As illustrated in FIGS. **12-17**, the retainer **230** is a hold down that clamps the item against the top surface of the car.

The retainer includes an elongated pivotable arm **232**. A biasing element, such as a spring, biases the arm downwardly against the top surface of the retainer **230**. The retainer **230** further includes an operator **234** in the form of a tab. Pushing downwardly on the tab raises the clamp from the top surface of the conveyor to allow a piece to be loaded onto the car or discharged from the car.

The car **200** may be powered by an external power supply, such as a contact along the rail that provides the electric power needed to drive the car. However, in the present instance, the car includes an onboard power source **240** that provides the requisite power for both the drive motor **250** and the conveyor motor **255**. Additionally, in the present instance, the power supply is rechargeable. Although the power supply may include a known power source, such as a rechargeable battery, in the present instance, the power supply **240** is made up of one or more ultracapacitors. Ultracapacitors are extremely high energy density capacitors. Capacitors store electrical energy by physically separating positive and negative charges, in contrast to the chemical means a battery uses. Ultracapacitors rely on an electrostatic effect, which is physical rather than chemical, and highly reversible. The ultracapacitors can accept very high amperage to recharge the ultracapacitors. By using a high current, the ultracapacitors can be recharged in a very short time, such as a few seconds or less.

The car includes one or more contacts for recharging the power source **240**. In the present instance, the car includes a plurality of brushes **245**, such as copper brushes that are spring-loaded so that the brushes are biased outwardly. The brushes **245** cooperate with a charging rail in the loading station to recharge the power source, as described further below.

Each car includes at least one and preferably two load sensors for detecting the items as it is loaded onto the car. The sensor(s) ensure that the mail piece is properly positioned on the car. In the present instance, the car includes a forward loading sensor **260** and a rearward loading sensor **262**. The forward loading sensor detects the leading edge of the item as it is loaded onto the car. The forward loading sensor **260** also detects the trailing edge of the item to ensure that the entire length of the item is loaded onto the car. Similarly, the rearward sensor **262** detects the leading edge and in certain instances, may detect the trailing edge of the mail piece. The loading sensors **260**, **262** may be simple I/R sensors that detect the presence or absence of a document or mail piece.

Although the car operates in response to signals received from the central controller **350**, which tracks the location of each car, the car may also include a reader **265** for reading indicia along the track to confirm the position of the car. For instance, each bin may be assigned a unique bar code, and the forward reader may scan the track or other area around the bin **190** at which an item is to be delivered. The data that the central processor has regarding the path that the car is to follow and the data regarding the distance the car has traveled based on the data regarding the rotation of the drive motor **250** should be sufficient to determine whether the car **200** is positioned at the appropriate bin. Nonetheless, it may be desirable to double check the location of the car before the item is discharged into the appropriate bin. Therefore, the scanner may operate to scan and read information regarding the bin at which the car is stopped. If the scanned data indicates that the bin is the appropriate bin, then the car discharges its item into the bin. Similarly, the car may have a second reader **266** for reading indicia adjacent the rearward edge of the car. The second reader **266** may be used in applications in which the system is set up to utilize a first series of bins **190** along the forward side and a second series of bins along the rearward side of the track **110**.

In foregoing description, the cars have drive gears that interact with teeth in the track to guide the cars around the track. Additionally, as described further below in the operation section, the location of the car may be controlled based on information regarding how far the car has traveled. In such applications it is desirable to synchronize the drive wheels of the car. However, in some applications alternative control systems may be used. For instance, the location of the cars can be controlled based on signals from sensors positioned along the track or indicators positioned along the track. In such instances, the cars may be configured to use a drive mechanism that is not synchronous as described above.

As discussed further below, the car further includes a processor for controlling the operation of the car in response to signals received from the central processor. Additionally, the car includes a wireless transceiver so that the car can continuously communicate with the central processor as it travels along the track. Alternatively, in some applications, it may be desirable to incorporate a plurality of sensors or indicators positioned along the track. The car may include a reader for sensing the sensor signals and/or the indicators, as well as a central processor for controlling the operation of the vehicle in response to the sensors or indicators.

Loading Column

Referring now to FIGS. **6**-**7** the details of the loading column **300** will be described in greater detail. The loading column **300** is formed adjacent the output end of the input station **50**. The loading column **300** is formed of a front pair of vertical rails **305***a*, **305***b* and a corresponding rearward set of vertical rails. The loading station **310** is positioned along the loading column. The loading station **310** is the position along the track in which the car **200** is aligned with the discharge end of the conveyor of the input station **50**. In this way, a mail piece from the input station may be loaded onto the car as it is conveyed toward the car from the input station.

Although the central processor **350** tracks the position of the car, a home sensor **312** is positioned adjacent the loading station **310**. When the home sensor detects the car, the position for the car is known relative to a fixed point along the track, and the central processor resets the position of the car to the home or zero position.

Referring to FIG. **7**, a pair of charging rails are disposed along the vertical rails **305***a*, **305***b*. The charging rails are conductive strips connected with an electrical supply. The charging contacts **245** of the car **200** engage the conductive strips to recharge the ultracapacitors **240**. Specifically, the biasing element of the brushes **245** biases the brushes outwardly toward the charging contacts. The electricity flowing through the charging contact **245** is a high amperage, low voltage source that allows the ultracapacitors to recharge in a few seconds or less. In addition, since the power supply provided by the ultracapacitors last for only a few minutes, the car recharges each time it travels through the loading column.

Additionally, it may be desirable to incorporate a startup charging rail similar to the charging rails described above, but disposed along either the return rail or the rails in the column adjacent to the loading column, depending on where the cars are stored when the cars are shut down. Since the cars use ultracapacitors, it is possible that the ultracapacitors will discharge while the system is shut down. Therefore, upon startup the cars will not have any charge and will not be able to move to the loading column to charge the ultracapacitors. Accordingly, the system may include a startup charging rail disposed along a rail that the cars contact when the cars are stored during shutdown. If the cars are stored in the loading column and the adjacent column during shutdown, then the startup rail is disposed in the column adjacent the loading column. Alternatively, if the cars are stored on the return rail and the loading column during shutdown, then the startup rail is disposed along the return rail. In this way, when the system is started, a charging current is supplied to the cars through the startup charging rail and the charging rail in the loading column.

As discussed previously, each car **200** includes a retainer **230** to hold down items on the car during transport. The retainer should be opened at the loading station to allow an item to be loaded onto the car. Accordingly, as shown in FIG. **6**, an actuator **316** is positioned along the column. The actuator **316** projects inwardly toward the cars as the cars are conveyed up the loading column. As a car is conveyed upwardly in the loading column **300**, the hold down actuator **316** contacts the hold down operator or tab **236**. The interaction between the actuator **316** and the tab **236** causes the retainer to open, so that items can be loaded onto the car. As the car moves upwardly past the actuator **316**, the tab **236** on the car disengages the actuator, thereby releasing the retainer, thereby holding down or clamping the mail piece against the top surface of the vehicle.

In the foregoing description, the loading station has been described as a column in which an item is loaded onto the car and the car then travels upwardly to the horizontal upper rail **135**. However, in some applications in may be desirable to configure the loading station so that the items are loaded onto the cars at or near the top of the vertical column. In such an application, the load on the cars would be reduced since the car will not have to lift the item loaded on the car. In order to load the items on the cars at the top of the conveyor, a vertical conveyor may be added to the system. For instance, a conveyor angled upwardly may convey the items upwardly to the top of the column to load the items onto the cars. Alternatively, one or more of a variety of conveyor configurations can be used to transport to items toward the top of the loading column to load the items onto the cars.

Operation

The system **10** operates as follows. An item is processed at the input station **50** to identify a characteristic of the piece that is indicative of where the piece should be sorted. For instance, the item may be a mail piece that is to be sorted according to department, box number or recipient. If the mail pieces are sorted by department, the piece may be processed to identify either an indicator of the department (such as box number) or the piece may be processed to identify the recipient. The central controller maintains a database that correlates various data to identify the destination bin. For instance, the database may correlate the recipient names with the appropriate department if the mail is being sorted according to department. In other embodiments, the piece may be a part that has a product code and the database may correlate the product code with the sort location.

As discussed previously, the input station may process the items automatically or manually. In a manual mode, the operator manually enters information regarding a piece and then drops the piece on a conveyor. The system electronically tags the piece with the sort information and the conveyor conveys the piece toward the loading station. Alternatively, if the input system is an automated system, the piece is automatically scanned to identify the relevant sort characteristic. For instance, the input station may use a scanner, such as a bar code scanner to read the postnet code on a piece, or the input station may include an imaging device, such as a high speed line scan camera in combination with an OCR engine to read information on the piece.

To prepare to receive an item, a car **200** moves along the track toward the loading station **310** in the loading column **300**. As the car approaches the loading station, the operator **236** for the hold down **230** engages the actuator **316**, which pivots the hold down upwardly to prepare the car to receive an item, as illustrated in FIG. **6**. When the car **200** moves into position at the loading station **310** the home sensor detects the presence of the car and sends a signal to the central processor **350** indicating that the car is positioned at the loading station. In the following description, the item being sorted is described as being a mail piece. It should be understood that such an item is an exemplary application of the system. As described above, the system can be configured to sort a variety of items in a variety of material handling applications.

Once the car is positioned at the loading station, the input station conveys a mail piece onto the car. As the mail piece is being conveyed onto the car **200**, the loading mechanism **210** on the car loads the mail piece onto the car. Specifically, the input station conveys the mail piece into contact with the conveyor belts **212** on the car. The conveyor belts **212** rotate toward the rearward side of the car, thereby driving the mail piece rearwardly on the car.

The operation of the conveyor belts is controlled by the loading sensors **260**, **262**. The forward loading sensor detects the leading edge of the mail piece as the mail piece is loaded onto the car. Once the forward loading sensor **260** detects the trailing edge of the mail piece, a controller onboard the car determines that the mail piece is loaded on the car and stops the conveyor motor. Additionally, the onboard controller may control the operation of the conveyor in response to signals received from the rearward sensor **262**. Specifically, if the rearward sensor **262** detects the leading edge of the mail piece, then the leading edge of the mail piece is adjacent the rearward edge of the car. To ensure that the mail piece does not overhang from the rearward edge of the car, the controller may stop the conveyor once the rearward sensor detects the leading edge of the mail piece. However, if the rearward sensor detects the leading edge of the mail piece before the forward sensor detects the trailing edge of the mail piece, the controller may determine that there is a problem with the mail piece (i.e. it is too long or two overlapping mail pieces were fed onto the car. In such an instance, the car may communicate an error message with the central controller, which may declare an error and provide an indicator to the operator that the car at the loading station requires attention. Alternatively, a reject bin **325** may be positioned behind the loading station so that mail pieces on the car at the loading station can be ejected into the reject bin **325**. In this way, if there is an error loading a mail piece onto a car, the mail piece can simply be ejected into the reject bin, and a subsequent mail piece can be loaded onto the car.

After a mail piece is loaded onto the car, the car moves away from the loading station. Specifically, once the onboard controller detects that a mail piece is properly loaded onto the car, the onboard controller sends a signal to start the drive motor **250**. The drive motor **250** rotates the axles, which in turn rotates the gears **222** on the wheels **220**. The gears **222** mesh with the drive surface **156** of the vertical rails **305** in the loading column to drive the car upwardly. Specifically, the gears and the drive surfaces mesh and operate as a rack and pinion mechanism, translating the rotational motion of the wheels into linear motion along the track **110**.

Since the cars move up the loading column from the loading station, the destination for the car does not need to be determined until after the car reaches the first gate along the upper rail **135**. For instance, if an automated system is used at the input station to scan and determine the characteristic used to sort the mail pieces, it may take some processing time to determine the relevant characteristic. The time that it takes to convey the mail piece onto the car and then convey the car up the loading column will typically be sufficient time to determine the relevant characteristic for the mail piece. However, if the characteristic is not determined by the time the car reaches the upper rail, the car may be directed down the second column, which is the column next to the loading column. The car travels down the second column to the lower rail **140**, and then back to the loading column. The car may stop in the second column to provide additional time to determine the characteristic. However, after waiting for a predetermined period the system may declare that the address cannot be determined and the car may be advanced from the second column and the piece may be discharged to a reject bin. Alternatively, rather than declare an error the car may continue to travel around the loop from the loading column to the second column until the characteristic is determined or until a predetermined time at which the central controller declares an error. Additionally, rather than using the reject bin when the system is unable to determine the characteristic for a mail piece, one of the bins in the second column can also be used as a reject bin. In this way, the cars are ready to receive a mail piece as soon as the car reaches the loading station, without having to eject the problem mail piece into the reject bin **325** at the loading station.

As described above, the system includes a loop that can be utilized as a buffer track to provide additional processing time to analyze the characteristic for the mail piece if necessary. Although the first and second columns can be used as the buffer loop, other columns can be used as a buffer loop if desired.

The foregoing discussion described the process for buffering a car if the system is unable to determine the characteristic for the mail piece by the time the car reaches the top rail. However, for most mail pieces, the system should be able to identify the characteristic without having to buffer the car. The following discussion describes the operation of the system assuming that the characteristic for the mail piece is determined before the car reaches the upper rail **135**.

Once the characteristic for the mail piece is determined, the central controller **350** determines the appropriate bin **190** for the mail piece. Based on the location of the bin for the mail piece, the route for the car is determined. Specifically, the central controller determines the route for the car and communicates information to the car regarding the bin into which the mail piece is to be delivered. The central controller then controls the gates along the track to direct the car to the appropriate column. Once the car reaches the appropriate column the car moves down the column to the appropriate bin. The car stops at the appropriate bin **190** and the onboard controller sends an appropriate signal to the conveyor motor **255** to drive the conveyor belts **212**, which drives the mail piece forwardly to discharge the mail piece into the bin. Specifically, the top of the car aligns with the gap between the appropriate bin **190** and the bottom edge of the bin that is immediately above the appropriate bin.

As discussed above, the central controller **350** controls the operation of the gates **180** in response to the location of the car **200** and the route that the car is to follow to deliver the mail piece. Additionally, as discussed below, the central controller controls the gates in response to the position of other cars on the track.

As the car **200** travels along the upper rail **135** and approaches a column, the gates for the vertical rails **130** are controlled as follows. If the car is to pass over the column on the way to the next column, the gates are displaced into the closed position, as shown in FIG. **9**. Specifically, both gates at the top of the column are closed so that the outer race **184** of the gate aligns with the straight track, with the outer race aligning with the drive surface **156** of the track **110**. In this way, the gates provide a straight drive surface that cooperates with the drive surface **156** to allow the car to travel over the column.

When the car comes to a column that it is to turn down, the gates are controlled as follows. Referring to FIG. **5**, the columns can be seen without the bins attached. The view in FIG. **5** is from the front of the apparatus **10**, so the car will be traveling along the upper rail from the right to the left in the perspective of FIG. **5**. In the following discussion, the car is to be conveyed to a bin in the column designated C in FIG. **5**. Column C includes two pairs of vertical legs. The first pair is front and back vertical legs **130**c on the left side of column C; the second pair is front and back vertical legs **130**d on the right side of column C.

In order for the car to travel down column C, the wheels on the left side of the car travel down legs **130***c* and the right side wheels travel down legs **130***d*. Therefore, as the car approaches column C, the gates at the top of **130***d* are displaced to the closed position so that the left side wheels remain on the upper rail and pass over the right side legs **130***d*. After the left side wheels of the car pass over the right legs **130***c*, the gates **180** at the top of the right legs **130***d* are displaced into the open position so that the right side wheels can turn down legs **130***d*. Specifically, after the left side wheels pass right legs **130***d*, the central controller operates the solenoids **186** of the gates **180** at the top of legs **130** to displace the gates into the open position, as shown in FIG. **8** (note that the view in FIG. **8** is taken from the rear side of the apparatus so that the perspective of the gates is reversed relative to the front side). The gates **180** block the straight path through the intersection **170** and the curved inner race **182** of the gates direct the right side wheels down vertical legs **130***d*. Similarly, the gates **180** at the top of the left side legs **130***c* are displaced into the open position to direct the left side wheels down vertical legs **130***c*.

As the car approaches the intersections at the bottom of legs **130***c* and **130***d*, the gates are operated similarly to the above description, but in reverse. Specifically, as the car approaches the intersections **170** at the bottom of legs **130***c* and **130***d*, the gates **180** in the intersections are displaced into the opened position so that the gates direct the forward and leading wheels to turn down the lower rail. From the perspective of FIG. **5**, the car travels from left to right after the car reaches the lower rail. After the car passes though the intersections at the bottom of the rails **130***c*, **130***d*, the gates at the bottom of right side legs **130***d* are displaced into the closed position before the left side wheels of the car reach the intersection at the bottom of the right side legs **130***d*. In this way, the left side wheels of the car pass straight through the intersection at the bottom of legs **130***d* along the bottom rail **140**.

As discussed above, the central controller **350** controls the operation of the gates in response to the position of the car and more specifically in response to the position of the left hand and right hand wheels of the car. The gates are fired sequentially to ensure that the different pairs of wheels are directed down the proper vertical legs. Alternatively, the operation of the gates may be controlled by signals received from the cars. Specifically, the cars may include a transmitter that transmits a signal to the central controller indicating that it is in proximity to a gate that is to be fired. Further still, the car may include an indicator that may be scanned as the car approaches the gate. Based on the indicator and the know destination for the car, the gate may fire. Still further, the car may include an mechanical actuator that selectively triggers or actuates a gate to appropriately direct the car.

One of the advantages of the system as described above is that the orientation of the cars does not substantially change as the cars move from travelling horizontally (along the upper or lower rails) to vertically (down one of the columns). Specifically, when a car is travelling horizontally, the two front geared wheels **220** cooperate with the upper or lower horizontal rail **135** or **140** of the front track **115**, and the two rear geared wheels **220** cooperate with the corresponding upper or lower rail **135** or **140** of the rear track **120**. As the car passes through a gate and then into a column, the two front geared wheels engage a pair of vertical legs **130** in the front track **115**, and the two rear geared wheels engage the corresponding vertical legs in the rear track **120**.

As the car travels from the horizontal rails to the vertical columns or from vertical to horizontal, the tracks allow all four geared wheels to be positioned at the same height. In this way, as the car travels along the track it does not skew or tilt as it changes between moving horizontally and vertically. Additionally, it may be desirable to configure the cars with a single axle. In such a configuration, the car would be oriented generally vertically as opposed to the generally horizontal orientation of the cars described above. In the single axle configuration, the weight of the cars would maintain the orientation of the cars. However, when using a single axle car, the orientation of the sort locations would be re-configured to accommodate the vertical orientation of the cars. Similarly, the loading station would also be re-configured to load the pieces onto the cars in the vertical orientation.

Traffic Control

Since the system includes a number of cars **200**, the system controls the operation of the different cars to ensure the cars do not collide into one another. In the following discussion, this is referred to as traffic control.

A variety of methodologies can be used for traffic control. For instance, the traffic control can be a distributed system in which each car monitors its position relative to adjacent cars and the onboard controller controls the car accordingly. One example of such as system utilizes proximity sensors on each car. If the proximity sensor for a car detects a car within a predefined distance ahead of the car, the onboard controller for the trailing car may control the car by slowing down or stopping the trailing car. Similarly, if a car detects a car within a predefined distance behind the car, the lead car may speed up unless the lead car detects a car ahead of it within the predefined distance. In this way, the cars may control the speed of the cars independently based on the feedback from the proximity sensors.

Although the system may use a distributed system for traffic control, in the present instance, the system uses a centralized system for traffic control. Specifically, the central controller **350** tracks the position of each car **200** and provides traffic control signals to each car based on the position of each car relative to adjacent cars and based on the route for each car.

In the present instance, the central controller **350** operates as the traffic controller, continuously communicating with the cars as the cars travel along the track **110**. For each car, the central controller determines the distance that each car can travel, and communicates this information with the cars. For instance, if car B is following car A along the track, and car A is at point A, car B can safely travel to a point just before point A without crashing into car A. As car A advances to a subsequent point B along the track, car B can travel safely to a point just before point B without crashing into car A.

The cars continuously communicate with the central controller to provide information indicative of their positions, so that the central controller can continuously update the safe distances for each car as the cars advance around the track.

Although the foregoing discussion is limited to determining safe zones based on the positions of the various cars on the track, the determination of safe zones is based on other factors that affect the traffic. For instance, when calculating the safe distance for a car, the central controller considers the distance between the car and the next gate, as well as the distance to the destination bin for the car.

As can be seen from the foregoing, increasing the frequency of communication between the cars and the central controller increases the efficiency of the traffic flow along the track. Accordingly, in the present instance, the traffic control is designed to communicate with a car once for every inch the car travels along the track. Therefore, if a car travels at 25 inches per second, the central controller communicates with the car every 40 msec. Further, it is desirable to have the cars travel at up to 50 inch/sec. Therefore, it is desirable to configure the communications to allow the cars to communicate with the central controller every 20 msec.

In addition, to the foregoing variables used to calculate safe distances, information regarding the track profile ahead of each car is used to calculate safe distances. For instance, the central controller determines whether the path ahead of a car is sideways movement, uphill movement (i.e. movement vertically upwardly) or downhill movement (i.e. movement vertically downwardly).

One of the issues in traffic control relates to merging at intersections **170**. The problem arises when a car needs to merge onto the return rail **140**. If two cars will arrive at the intersection close enough to collide, one of the cars needs to have priority and the other car needs to wait or slow down to allow the first car to go through.

A first method for controlling merging traffic is based on determining the next gap large enough for a car to have time to pass through an intersection without colliding with another car. In other words, if a first car approaches an intersection and it is determined that the gap between the first car and a second car is not sufficient for the first car to pass through, the first car waits at the intersection until there is a gap large enough to allow the first car to pass through.

A second method for controlling merging traffic is based on determining which car is closest to the homing sensor at the loading station **310**. The car with the shortest distance to the homing sensor gets priority at the intersection.

Another factor that the traffic controller considers when calculating safe distances relates to the position of cars in adjacent columns. In the present instance, most of the adjacent columns share a common vertical rail. For instance, in FIG. **5**, the leftmost column uses vertical rails **130***a* and **130***b*. The column next to the leftmost column uses vertical rails **130***b* and **130***c*.

However, in the present instance, some of the columns may have two vertical rails **130** that are independent from the adjacent columns. For instance, the loading column **300** has two independent rails that are not shared with the adjacent column. Therefore, cars can travel up the loading column without regard to the position of cars in the column next to the loading column. Furthermore, as shown in FIG. **5**, it may be desirable to configure the column next to the loading column so that it also has two independent vertical rails. In this way, cars can more freely travel up the loading column and down the adjacent column to provide a buffer loop as described previously.

Accordingly, when calculating safe distances, the traffic controller evaluates the position of cars in adjacent columns if the cars share a common vertical rail to ensure that the two cars do not collide as the car travel down the adjacent columns.

In the foregoing discussion, the sorting of items was described in relation to an array of bins disposed on the front of the sorting station **100**. However, as illustrated in FIGS. **2** & **4**, the number of bins in the system can be doubled by attaching a rear array of bins on the back side of the sorting station. In this way, the cars can deliver items to bins on the front side of the sorting station by traveling to the bin and then rotating the conveyor on the car forwardly to eject the piece into the front bin. Alternatively, the cars can deliver items to bins on the rear side of the sorting station by traveling to the bin and then rotating the conveyor on the car rearwardly to eject the piece into the rear bin.

Additionally, the sorting station **100** is modular and can be readily expanded as necessary simply by attaching an additional section to the left end of the sorting station. Further, although the foregoing describes the array of bins as being essentially a two dimensional array in which the cars simply travel in X and Y directions, the sorting station can be expanded to add additional "runs" of track. Specifically, a separate sorting station parallel to or perpendicular to the sorting station illustrated in FIG. **2** may be connected to the sorting station. In this way, the car would travel in a third dimension relative to the X and Y directions of the sorting station illustrated in FIG. **2**. For instance, additional sections of track may be connected to the sorting station illustrated in FIG. **2** perpendicular to the illustrated sorting station, so that the additional track forms an L-shape intersecting the loading column. In such a configuration, gates selectively direct the cars either down the upper rail **135** or rearwardly toward the additional track. Similarly, a plurality of parallel rows of sorting stations can be interconnected so that the cars selectively travel along a crossover rail until the car reaches the appropriate row. The car then travels down the row until it reaches the appropriate column as described above.

It will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the broad inventive concepts of the invention. For instance, in the foregoing description, the operation of the sorting station is described as being centralized with the central controller. However, it may be desirable to have the cars control the operation of the gates. According to one alternative, the cars incorporate one or more mechanical actuators that cooperate with an operator on the gate. The actuators on the cars are operable between first and second positions. In a first position, the actuator engages the gate operator to displace the gate into the closed position. In a second position, the actuator engages the gate to displace the gate into the open position. Alternatively, the gate may be biased toward the opened position, so that when the car actuator is in the second position it does not engage the gate operator. In another alternative, each car includes a mechanism for communicating with each gate. If the gate needs to be pivoted to direct an approaching car along a particular path, the car sends a signal to the gate indicating whether the gate should be opened or closed. In response to the signal from the car, the gate pivots to the appropriate position.

Further, in the above description, the system uses a wireless communication between the cars and the central controller. In an alternative embodiment, a communication line may be installed on the track and the cars may communicate with the central controller over a hard wired communication link. Still further, the system has been described as being useful in sorting incoming mail. However, the system may also be utilized to sort and prepare outgoing mail. For instance, after determining a characteristic for a mail piece, the system may print a marking onto the mail piece. For instance, after determining the recipient's address for a mail piece, the system determines which bin the mail piece is to be sorted to. As the mail piece is conveyed to the bin, a printer prints the appropriate postnet bar code on the piece before sorting the piece. To provide the printing functionality, the system may include a printer disposed along the track. When the car approaches the printer the car stops and at least partially discharges the mail piece to extend the mail piece toward the printer. The printer then prints the appropriate postnet code. The car then reverses the conveyors to load the piece back onto the car all the way, and then travels to the appropriate bin. Similarly, the system may include a device for selectively applying labels to the pieces. Similar to the above example of printing markings onto the pieces, the labeler may be positioned along the track. The cars selectively stop at the labeler on route to the appropriate bin and at least partially discharge the mail piece toward the labeler. The labeler then applies a label onto the mail piece and the conveyor on the car then reverses to load the piece back onto the car.

In addition to outgoing mail applications, it may be desirable to incorporate a printer and/or a labeler in systems configured to process incoming mail. For instance, when sorting incoming mail pieces, it may be desirable to print certain information, such as sort codes, a time stamp or audit trail information onto some or all of the pieces being processed. In some instances such information may be printed directly onto the mail pieces. In other instances, a label may be applied to the mail pieces and the information may be printed on the label.

In addition to a printer and a labeler, the system may include a scale for weighing the mail pieces. The scale may be positioned along the track **110**, such as along the loading column. To weigh a piece, the car stops adjacent the scale, and ejects the piece from the car onto the scale by driving the conveyor belts **212**. Preferably, the scale includes a conveyor or transfer mechanism for discharging the piece from the scale and back onto the car or onto a subsequent car. When the piece is loaded onto the car from the scale, the car drives the conveyors to load the piece as discussed above in connection with the loading station.

It should therefore be understood that this invention is not limited to the particular embodiments described herein, but is intended to include all changes and modifications that are within the scope and spirit of the invention as set forth in the claims.

What is claimed is:

1. A material handling system for sorting or retrieving a plurality of items, comprising:

- a plurality of destination areas for items, wherein the destination areas are arranged in a plurality of columns or rows;
- a plurality of vehicles for transporting items to or from the destination areas; and
- a track for guiding the delivery vehicles to the destination areas, wherein the track comprises a plurality of columns or rows adjacent the plurality of destination areas, wherein the track comprises engagement elements;
- wherein at least one of the vehicles comprises:
  - a motor for driving the vehicle to one of the destination areas;
  - a drive system cooperable with the track to guide the vehicle to one of the destination areas, wherein the drive system comprises a plurality of teeth that mesh with the engagement elements on the track, and wherein the drive system is operable to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a first direction of travel to a second direction of travel, wherein the first direction is at an angle to the second direction; and
  - a transfer mechanism for transferring an item between the vehicle and one of the destination areas, wherein the transfer mechanism is operable to transfer the item along a third direction that is transverse both the first and second directions.

2. The system of claim **1** wherein the track comprises:

- a loop having an upper leg and a lower leg spaced apart from the lower leg; and
- a plurality of generally vertical track segments connecting the upper leg with the lower leg so that the vehicles can travel along the upper leg, then down one of the vertical track segments to the lower leg.

3. The system of claim **2** wherein the track comprises a plurality of gates at intersections of the upper leg and the

vertical legs, wherein in a first position the gates allow the vehicle to travel through the intersection and remain on the upper leg and wherein in a second position the gates allow the vehicle to travel through the intersection and onto the vertical leg.

4. The system of claim **1** comprising a controller for controlling the movement of the vehicles to direct each vehicle to a particular destination area, wherein the controller is operable to determine the appropriate route for each vehicle to take to the destination to which the vehicle is directed.

5. The system of claim **4** wherein the controller receives data relating to the position of each vehicle to control the movement of the vehicles to ensure that vehicles do not collide.

6. The system of claim **1** wherein the transfer mechanism comprises a retainer operable to positively engage the item.

7. The system of claim **1** wherein the track comprises three generally vertical segments forming first and second columns of the track, wherein when a vehicle travels along the first column, the drive system of the vehicle engages the first and second vertical segments and when the vehicle travels along the second column the drive system of the vehicle engages the second and third vertical segments.

8. The system of claim **1** wherein the plurality of destination areas are positioned adjacent a forward side of the track, wherein the system comprises a second group of destination areas arranged in a plurality of columns or rows, wherein the second group of destination areas are positioned adjacent a rearward side of the track.

9. The system of claim **8** wherein a gap is formed between the plurality of destination areas and the second group of destination area and the vehicles travel in the gap.

10. A material handling system for sorting or retrieving a plurality of items, comprising:

- a plurality of destination areas for items, wherein the destination areas are arranged in a plurality of columns or rows;
- a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and
  - a plurality of horizontal track sections spaced apart from one another and extending in a generally horizontal direction;
  - a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the horizontal track sections intersect vertical track sections; and
  - a plurality of intersections where the horizontal track sections intersect the vertical track sections, wherein the intersections provide a first path along the generally horizontal direction, and a second path along the generally vertical direction;
  - wherein at least one of the vehicles comprises a transfer mechanism for transferring an item between the vehicle and one of the destination areas, wherein the transfer mechanism is operable to transfer the item along a third direction that is transverse both the vertical track sections and the horizontal track sections.

11. The system of claim **10** wherein the plurality of track sections comprise an upper leg and a lower leg spaced apart from the lower leg and the vertical track segments connect the upper leg with the lower leg to form a loop so that the vehicles can travel along the upper leg, then down one of the vertical track segments to the lower leg.

12. The system of claim **11** wherein the track comprises a plurality of gates at intersections of the upper leg and the vertical legs, wherein in a first position the gates allow the vehicle to travel through the intersection and remain on the upper leg and wherein in a second position the gates allow the vehicle to travel through the intersection and onto the vertical leg.

13. The system of claim **10** wherein the track comprises a gate at an intersection of one of the horizontal tracks and one of the vertical tracks, wherein in a first position the gate allows the vehicle to travel through the intersection and remain on one of the horizontal track and the vertical track and wherein in a second position the gate allows the vehicle to change direction and travel on the other of the horizontal track and the vertical track.

14. The system of claim **10** comprising a controller for controlling the movement of the vehicles to direct each vehicle to a particular destination area, wherein the controller is operable to determine the appropriate route for each vehicle to take to the destination to which the vehicle is directed.

15. The system of claim **14** wherein the controller receives data relating to the position of each vehicle to control the movement of the vehicles to ensure that vehicles do not collide.

16. The system of claim **10** wherein the drive system comprises a plurality of engagement elements that mesh with engagement elements on the track.

17. The system of claim **16** wherein the engagement elements of the drive system comprise a plurality of teeth.

18. A material handling system for sorting or retrieving a plurality of items, comprising:

- a plurality of destination areas for items, wherein the destination areas are arranged in a plurality of columns or rows;
- a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and
  - a plurality of horizontal track sections spaced apart from one another and extending in a generally horizontal direction;
  - a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein first track sections intersect second track sections; and
  - a plurality of intersections where the horizontal track sections intersect the vertical track sections, wherein the intersections provide a first path along the horizontal direction, and a second path along the vertical direction;
- wherein at least one of the vehicles comprises a drive element that interacts with the track system to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between a horizontal track section and a vertical track section.

19. The system of claim **18** wherein the plurality of track sections comprise an upper leg and a lower leg spaced apart from the lower leg and the vertical track segments connect the upper leg with the lower leg to form a loop so that the vehicles can travel along the upper leg, then down one of the vertical track segments to the lower leg.

20. The system of claim **19** wherein the track comprises a plurality of gates at intersections of the upper leg and the vertical legs, wherein in a first position the gates allow the vehicle to travel through the intersection and remain on the upper leg and wherein in a second position the gates allow the vehicle to travel through the intersection and onto the vertical leg.

21. The system of claim **18** wherein the track comprises a gate at an intersection of one of the horizontal tracks and one of the vertical tracks, wherein in a first position the gate allows the vehicle to travel through the intersection and remain on one of the horizontal track and the vertical track and wherein in a second position the gate allows the vehicle to change direction and travel on the other of the horizontal track and the vertical track.

22. The system of claim **18** comprising a controller for controlling the movement of the vehicles to direct each vehicle to a particular destination area, wherein the controller is operable to determine the appropriate route for each vehicle to take to the destination to which the vehicle is directed.

23. The system of claim **22** wherein the controller receives data relating to the position of each vehicle to control the movement of the vehicles to ensure that vehicles do not collide.

24. The system of claim **18** wherein the drive system comprises a plurality of engagement elements that mesh with engagement elements on the track.

25. The system of claim **24** wherein the engagement elements of the drive system comprise a plurality of teeth.

* * * * *

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CERTIFICATE OF CORRECTION

PATENT NO. : 8,276,740 B2
APPLICATION NO. : 13/361490
DATED : October 2, 2012
INVENTOR(S) : Hayduchok et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

	Reads	Should Read
Column 20, Line 59-60	"the plurality of track sections"	--the plurality of horizontal track sections--
Column 20, Line 61	"from the lower leg"	--from the upper leg--
Column 20, Line 61	"vertical track segments"	--vertical track sections--
Column 20, Line 63-64	"vertical track segments"	--vertical track sections--
Column 21, Line 41-42	"first track sections intersect track sections"	--the horizontal track sections second intersect the vertical track sections--
Column 22, Line 9-10	"the plurality of track sections"	--the plurality of horizontal track sections--
Column 22, Line 11	"from the lower leg"	--from the upper leg--
Column 22, Line 11	"vertical track segments"	--vertical track sections--
Column 22, Line 13-14	"vertical track segments"	--vertical track sections--

Signed and Sealed this
Sixteenth Day of November, 2021

Drew Hirshfeld
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office

EXHIBIT D

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October 21, 2021

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THIS OFFICE OF:

U.S. PATENT: *8,622,194*

ISSUE DATE: *January 07, 2014*

By Authority of the

Under Secretary of Commerce for Intellectual Property

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Certifying Officer

US008622194B2

(12) **United States Patent**
DeWitt et al.

(10) **Patent No.: US 8,622,194 B2**
(45) **Date of Patent: Jan. 7, 2014**

(54) **MATERIAL HANDLING APPARATUS FOR DELIVERING OR RETRIEVING ITEMS**

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(72) Inventors: **Robert R DeWitt**, Marlton, NJ (US); **George L Hayduchok**, Mount Holly, NJ (US)

(73) Assignee: **Opex Corporation**, Moorestown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/631,817**

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(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 13/361,490, filed on Jan. 30, 2012, now Pat. No. 8,276,740, which is a continuation of application No. 12/983,726, filed on Jan. 3, 2011, now Pat. No. 8,104,601, which is a continuation of application No. 12/014,011, filed on Jan. 14, 2008, now Pat. No. 7,861,844.

(60) Provisional application No. 60/884,766, filed on Jan. 12, 2007.

(51) **Int. Cl.**
B65G 1/00 (2006.01)

(52) **U.S. Cl.**
USPC **198/347.1**; 198/358

(58) **Field of Classification Search**
USPC 198/347.1, 468.6, 358, 349, 349.6, 198/468.1; 414/273
See application file for complete search history.

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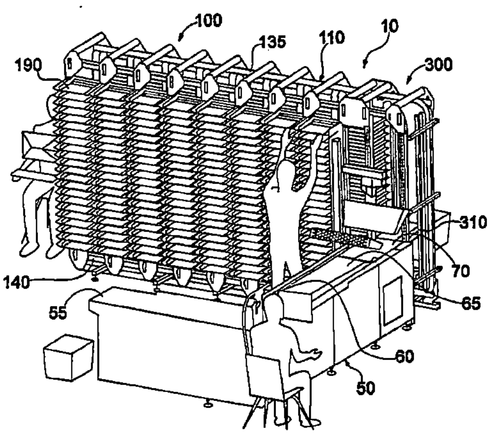
(57) **ABSTRACT**

A method and apparatus are provided for sorting or retrieving items to/from a plurality of destinations areas. The items are loaded onto one of a plurality of independently controlled delivery vehicles. The delivery vehicles follow a track that guides the delivery vehicles to/from the destination areas, which are positioned along the track. Once at the appropriate destination area, an item is transferred between the delivery vehicle and the destination area.

31 Claims, 13 Drawing Sheets



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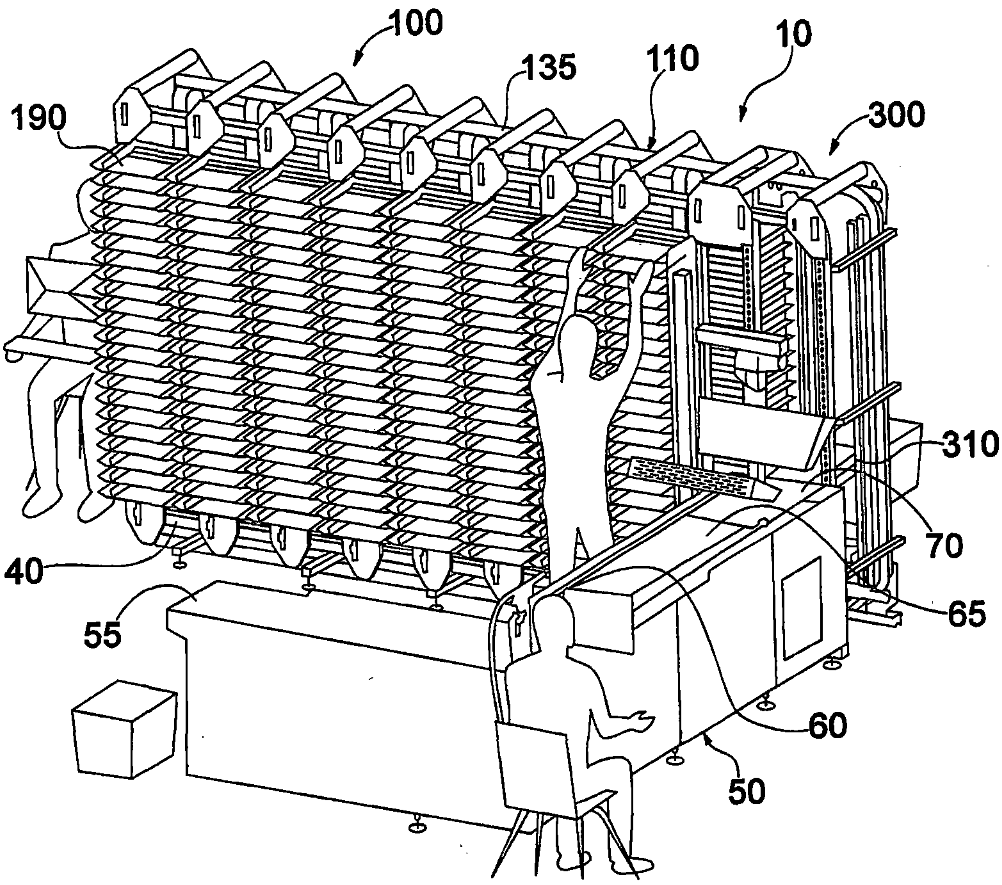


Fig. 1

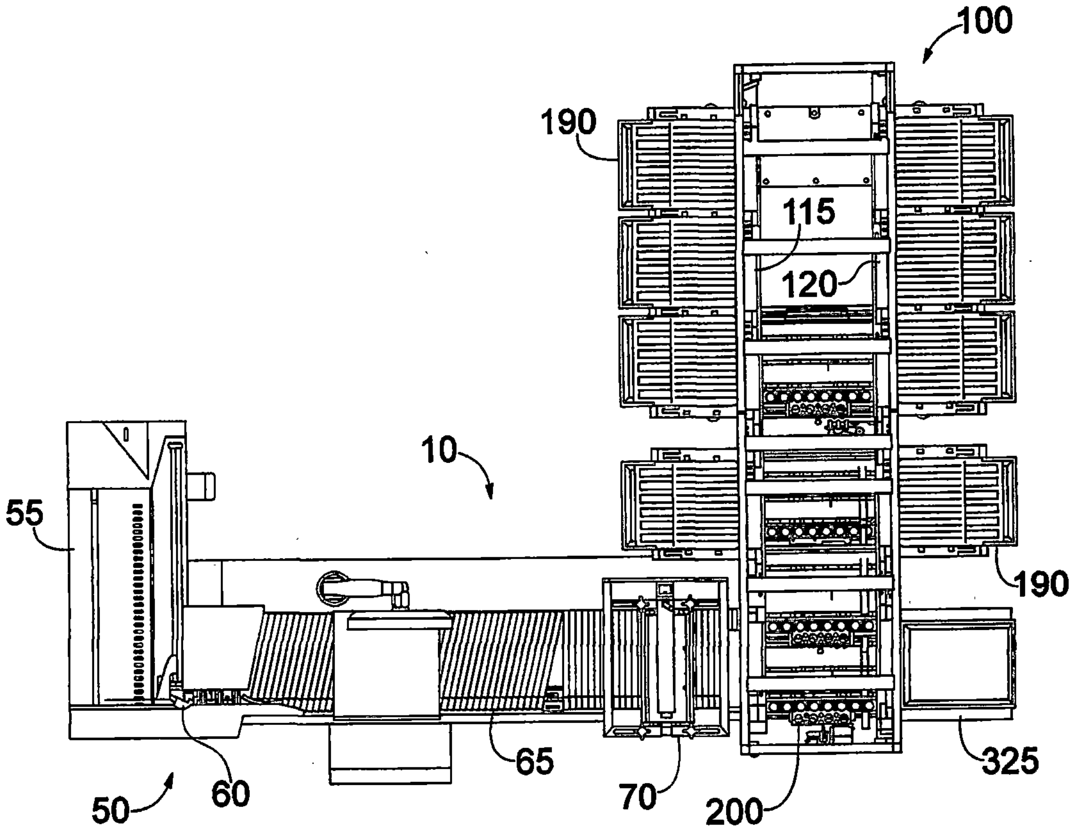


Fig. 2

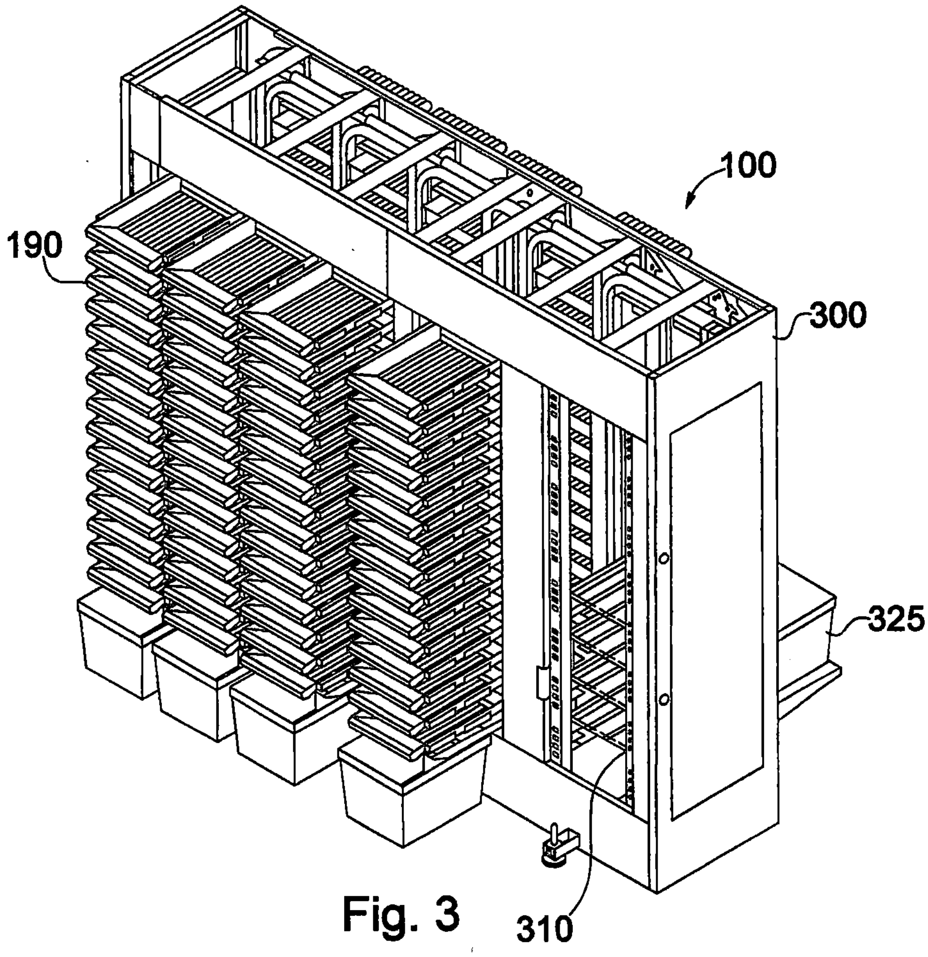


Fig. 3

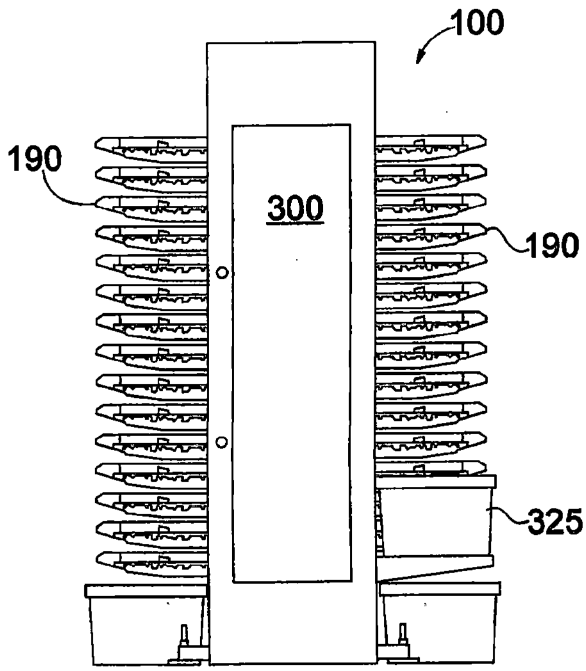


Fig. 4

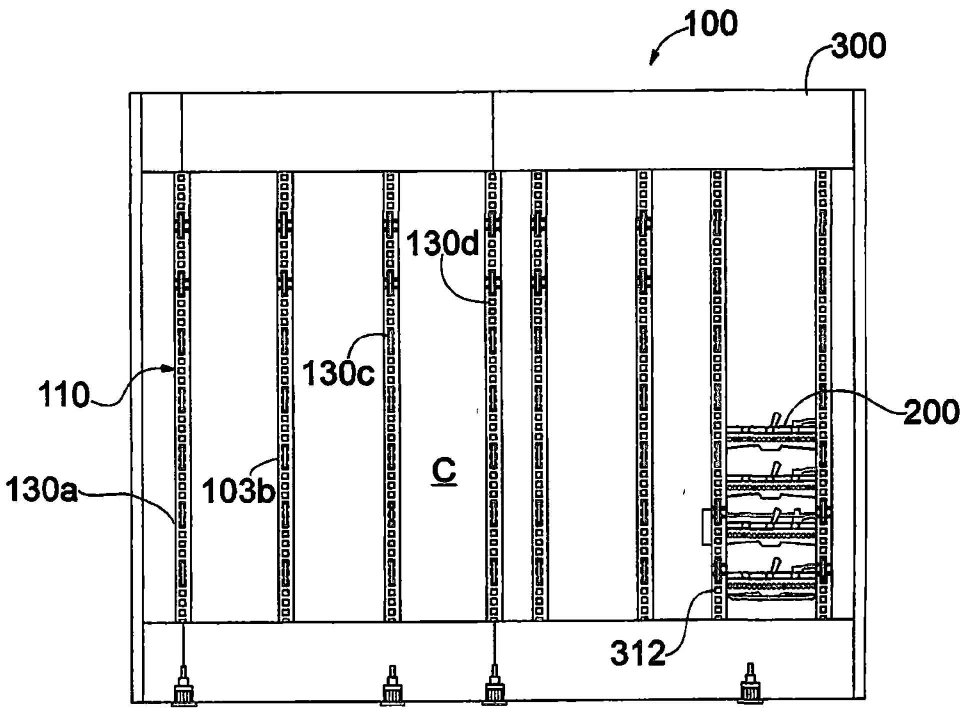


Fig. 5

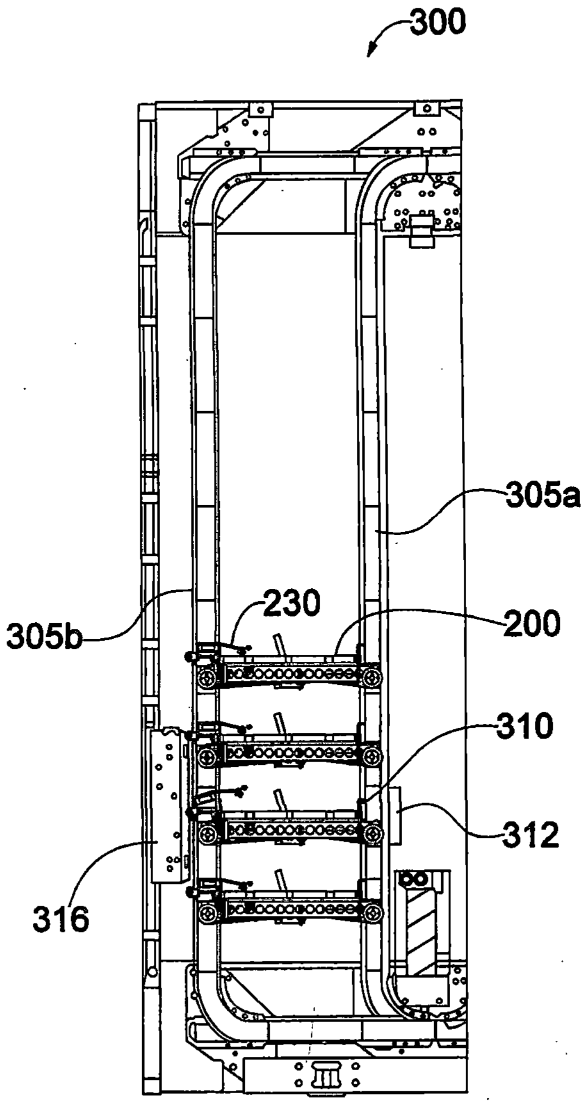


Fig. 6

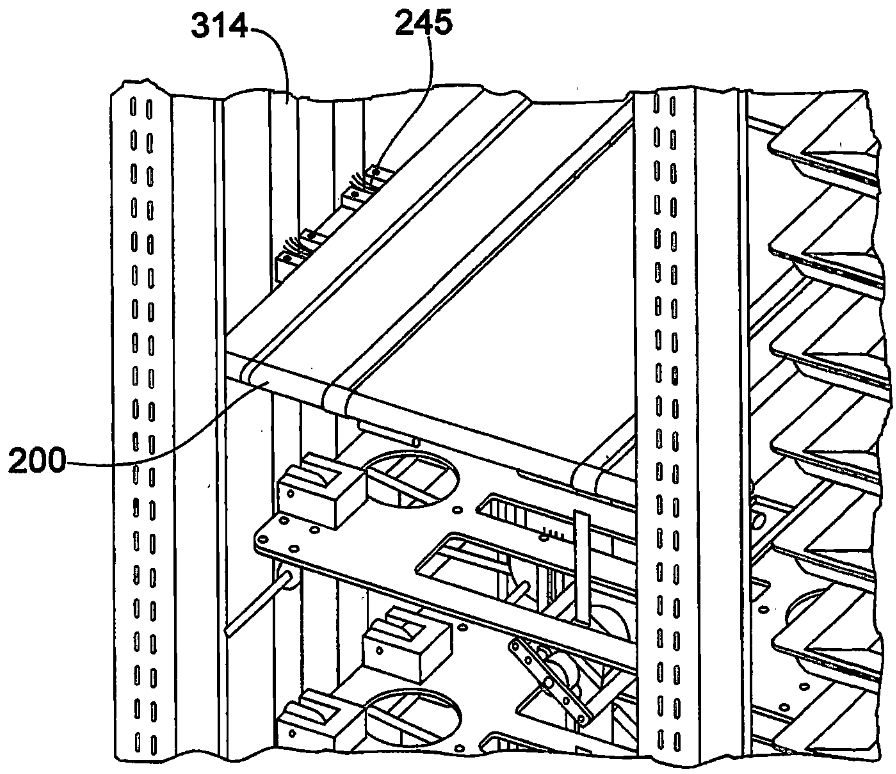


Fig. 7

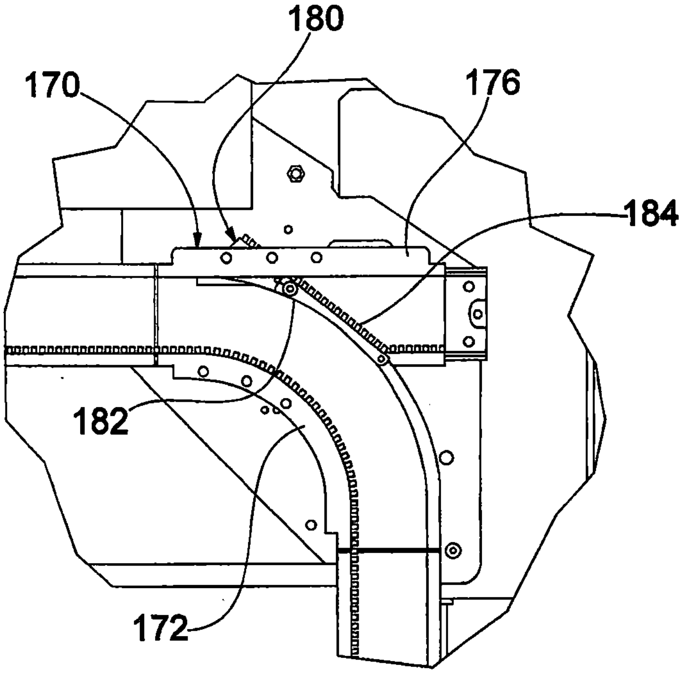


Fig. 8

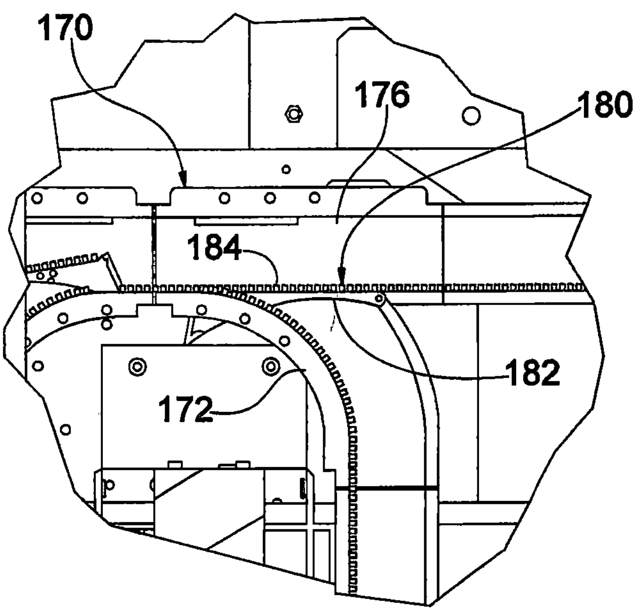


Fig. 9

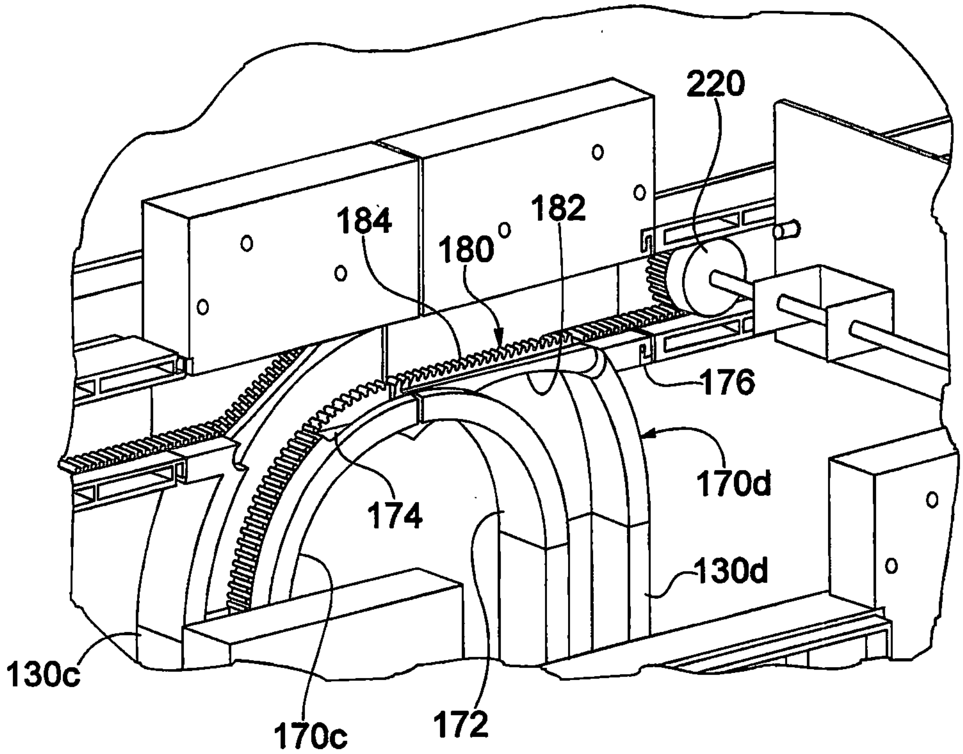


Fig. 10

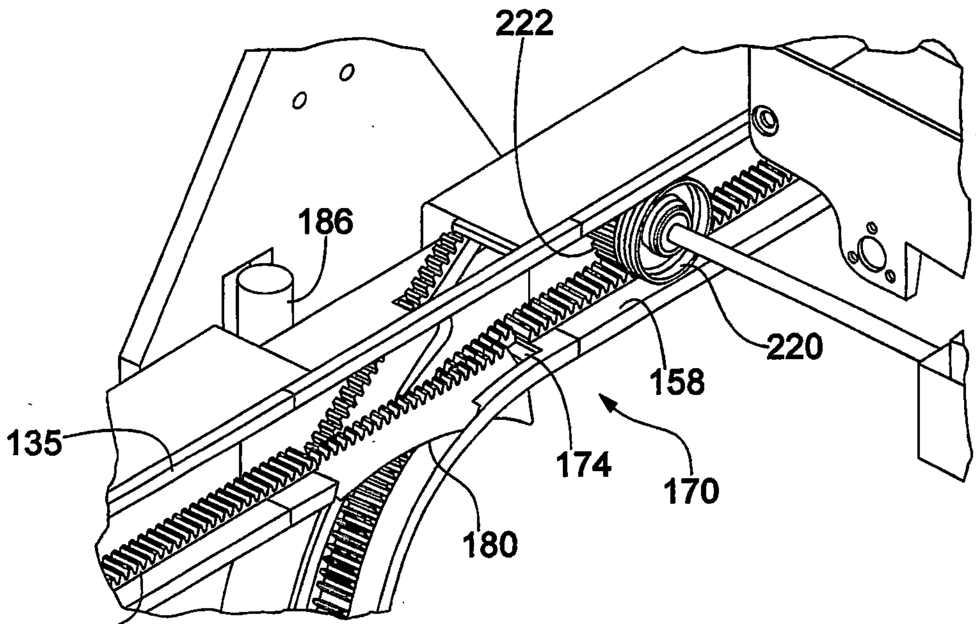


Fig. 11

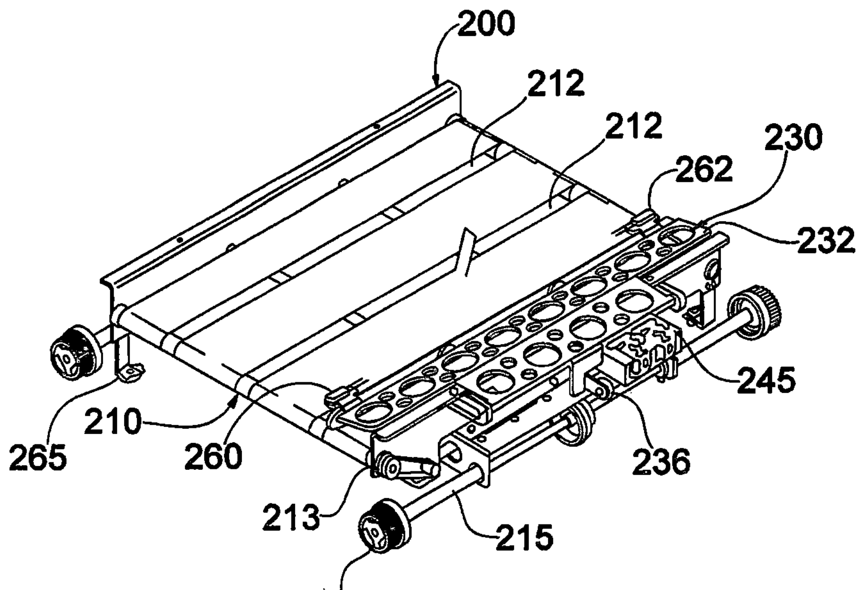
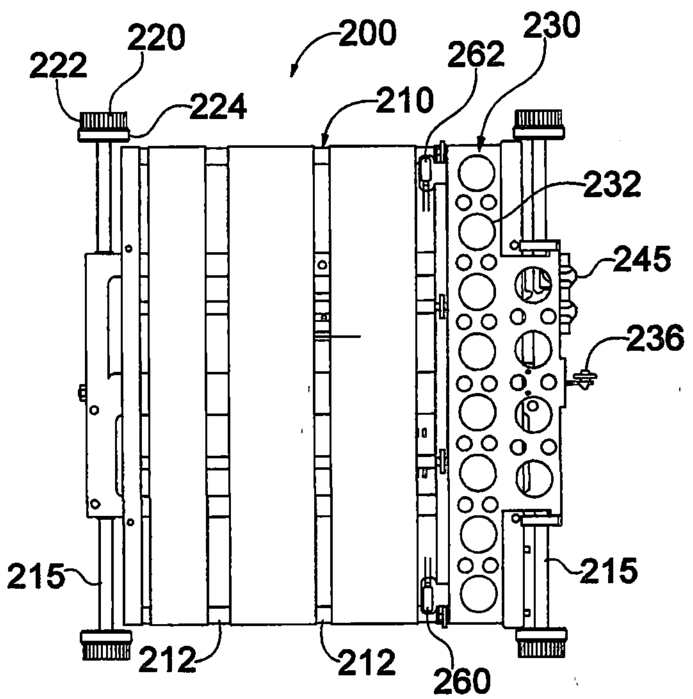

200
212
212
230
262
232
245
236
215
213
210
265
260
220

Fig. 12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210
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230
232
245
236
215
215
212
212
260

Fig. 13

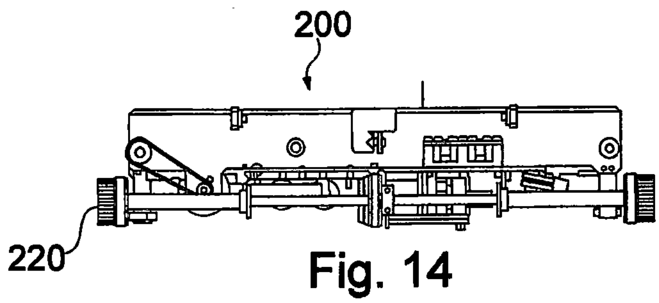


Fig. 14

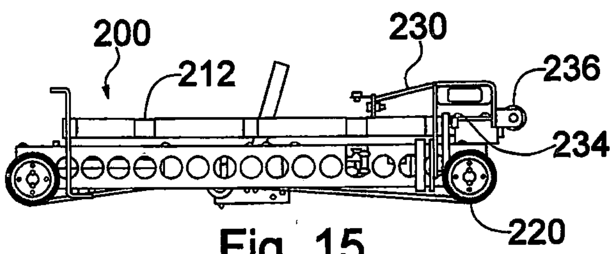
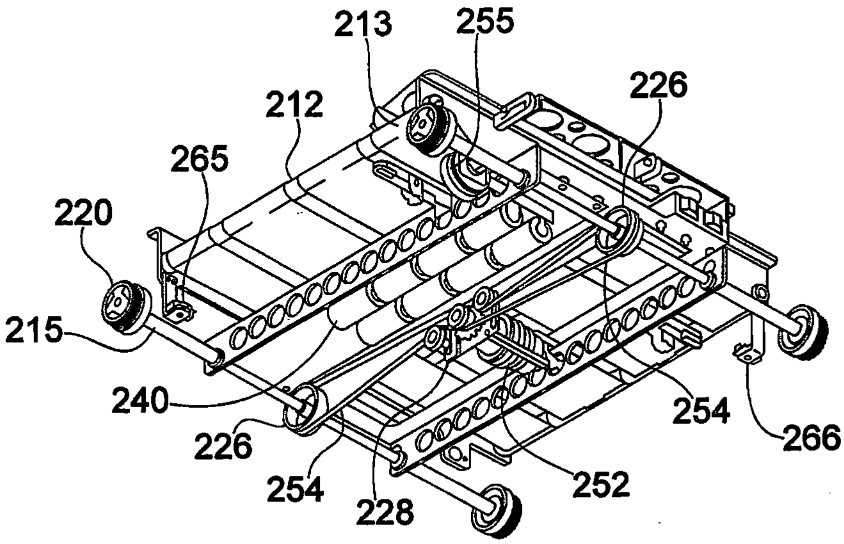


Fig. 15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254
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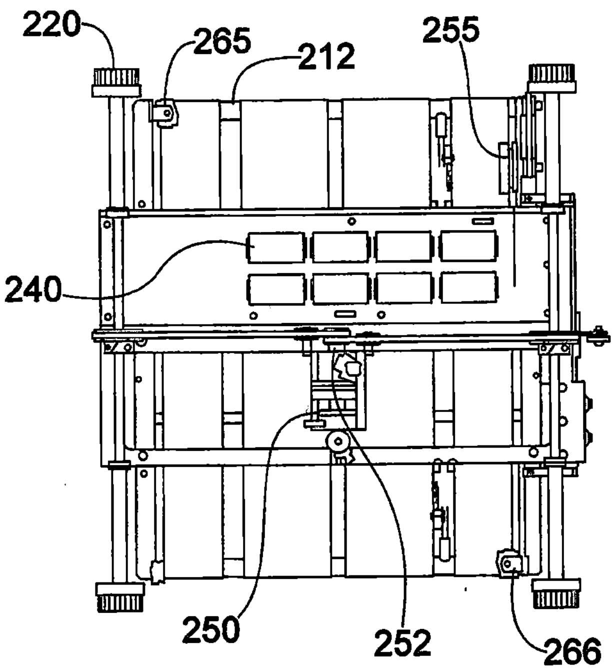
226
254
252
228

Fig. 16


220
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212
255
240
250
252
266

Fig. 17

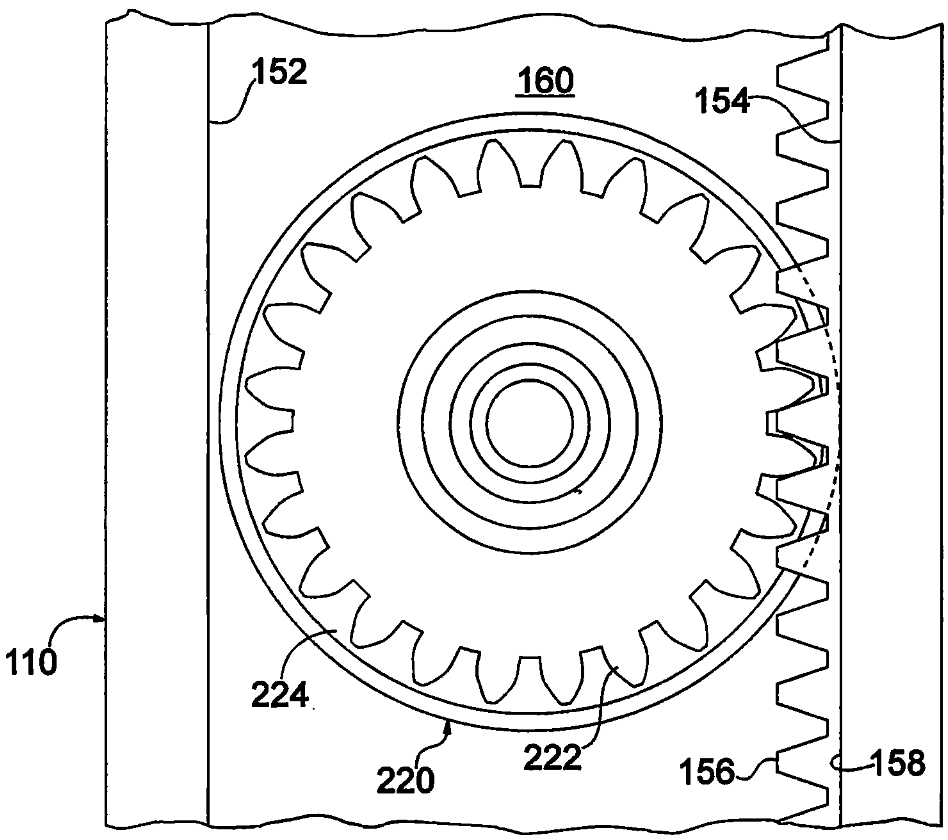

Fig. 18

MATERIAL HANDLING APPARATUS FOR DELIVERING OR RETRIEVING ITEMS

PRIORITY CLAIMS

The present application is a continuation application of U.S. patent application Ser. No. 13/361,490 filed Jan. 30, 2012 set to issue as U.S. Pat. No. 8,276,740 on Oct. 2, 2012, which is a continuation of U.S. patent application Ser. No. 12/983,726 filed Jan. 3, 2011 issued as U.S. Pat. No. 8,104, 601, which is a continuation of U.S. patent application Ser. No. 12/014,011 filed Jan. 14, 2008 issued as U.S. Pat. No. 7,861,844, which claims priority to U.S. Provisional Patent Application No. 60/884,766 filed on Jan. 12, 2007. The present application claims priority to each of the foregoing applications and the entire disclosure of each of the foregoing applications is hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to a material handling system for sorting or retrieving items. More specifically, the present invention relates to a material handling system incorporating a plurality of destination areas arranged along a track for guiding a plurality of vehicles for carrying items to and/or from the destination areas.

BACKGROUND OF THE INVENTION

Sorting documents and mail pieces manually is laborious and time consuming. For example, thousands of large organizations employ numerous people full-time to manually sort and deliver incoming and interoffice mail and documents. For instance, a large company may receive 5,000 mail pieces that need to be sorted and delivered each day to different departments and/or individuals. Such volumes require a significant number of employees dedicated to sorting and delivering the mail. Nonetheless, such volume is not typically sufficient to justify the expense of traditional automated sorting equipment, which is quite expensive. Additionally, the mail for such organizations is typically quite diverse, which makes it more difficult, and therefore more expensive, to automate the sorting procedures.

Various systems for sorting have been developed to address the needs of mail rooms for large organizations. However, the known systems suffer from several problems; the most significant are cost and size. Accordingly, there is a need for a compact and affordable automated sorting system that is able to meet the needs of mid- to large-sized organization that handle several thousand mail pieces each day.

Similarly, may large organizations have extensive storage areas in which numerous items are stored. Sorting and retrieving items from the hundreds or thousands of storage areas requires significant labor to perform manually, and the known systems of automatically handling the materials are either very expensive or have limitations that hamper their effectiveness. Accordingly, there is a need in a variety of material handling applications for automatically storing and/or retrieving items.

SUMMARY OF THE INVENTION

In light of the foregoing, a system provides a method and apparatus for delivering items to storage locations. The system includes a plurality of storage locations, such as bins, and a plurality of delivery vehicles for delivering items to the

storage locations or retrieving items from the storage locations. A track guides the delivery vehicles to the storage locations.

In one embodiment, a controller controls the operation of the delivery vehicles based on information determined for each item to be sorted. Additionally, the track may include a plurality of interconnected vertical and horizontal sections so that the vehicles may travel along a continuous path changing from a horizontal direction to a vertical direction. Further, the vehicles may be driven such that the orientation of an item on the vehicle stays constant as the vehicles changes from a horizontal direction of travel to a vertical direction of travel.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary and the following detailed description of the preferred embodiments of the present invention will be best understood when read in conjunction with the appended drawings, in which:

FIG. **1** is a perspective view of a sorting apparatus;

FIG. **2** is a plan view of the sorting apparatus illustrated in FIG. **1**;

FIG. **3** is a fragmentary perspective view of the sorting apparatus illustrated in FIG. **1**, shown without an input station;

FIG. **4** is a right side view of the sorting apparatus illustrated in FIG. **3**;

FIG. **5** is a front elevational view of the sorting apparatus illustrated in FIG. **3**, shown without discharge bins;

FIG. **6** is a fragmentary sectional view of a loading station of the sorting apparatus illustrated in FIG. **1**;

FIG. **7** is an enlarged fragmentary perspective view of a portion of the loading station of the apparatus illustrated in FIG. **3**;

FIG. **8** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in an open position;

FIG. **9** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in a closed position;

FIG. **10** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate;

FIG. **11** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate, with the gate shown in an open position in phantom;

FIG. **12** is a top perspective view of a delivery vehicle of the apparatus illustrated in FIG. **1**;

FIG. **13** is a plan view of the delivery vehicle illustrated in FIG. **12**;

FIG. **14** is a right side view of the delivery vehicle illustrated in FIG. **12**;

FIG. **15** is a front elevational view of the delivery vehicle illustrated in FIG. **12**;

FIG. **16** is a bottom perspective view of the delivery vehicle illustrated in FIG. **12**;

FIG. **17** is a bottom view of the delivery vehicle illustrated in FIG. **12**; and

FIG. **18** is an enlarged view of a wheel of the delivery vehicle illustrated in FIG. **12**, shown in relation to the track of the sorting apparatus illustrated in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1-18**, an apparatus for sorting items such as documents or mail pieces is designated generally **10**. The apparatus **10** includes a plurality of delivery vehicles or cars **200** to deliver items to a plurality of sort locations, such as output bins **190**. At a loading station **310**, each car **200** receives an item from an input station **50** and delivers it to the appropriate bin.

The cars **200** travel along a track **110** to the sort locations. The track has a horizontal upper rail **135** and a horizontal lower rail **140**, which operates as a return leg. A number of parallel vertical track legs **130** extend between the upper rail and the lower return leg. In the present instance, the bins **190** are arranged in columns between the vertical track legs **130**.

After a piece is loaded onto a car, the car travels upwardly along two pairs of vertical tracks legs and then horizontally along two upper tracks **135**. The car **200** travels along the upper rail until it reaches the appropriate column containing the bin for the piece that the car is carrying. The track **110** includes gates **180** that fire to direct the car **200** down the vertical legs and the car stops at the appropriate bin. The car **200** then discharges the piece into the bin.

After discharging the piece, the car **200** continues down the vertical legs **130** of the column until it reaches the lower rail **140**. Gates fire to direct the car along the lower rail, and the car follows the lower rail to return to the loading station **310** to receive another piece.

The cars **200** are semi-autonomous vehicles that each have an onboard power source and an onboard motor to drive the cars along the track **110**. The cars also include a loading/unloading mechanism **210**, such as a conveyor, for loading pieces onto the cars and discharging the pieces from the cars.

Since the system **10** includes a number of cars **200**, the positioning of the cars is controlled to ensure that the different cars do not crash into each other. In one embodiment, the system **10** uses a central controller **350** that tracks the position of each car **200** and provides control signals to each car to control the progress of the cars along the track. The central controller **350** may also control operation of the various elements along the track, such as the gates **180**.

Input Station

At the input station **50**, the mail pieces are separated from one another so that the pieces can be conveyed serially to the loading station **310** to be loaded onto the cars **200**. Additionally, at the input station information is determined for each piece so that the piece can be sorted to the appropriate bin.

A variety of configurations may be used for the input station, including manual or automatic configurations or a combination of manual and automated features. In a manual system, the operator enters information for each piece and the system sorts the mail piece accordingly. In an automatic system, the input system includes elements that scan each mail piece and detect information regarding each piece. The system then sorts the mail piece according to the scanned information.

In an exemplary manual configuration, the input system includes a work station having a conveyor, an input device, such as a keyboard, and a monitor. The operator reads information from a mail piece and then drops in onto a conveyor that conveys the piece to the loading station **310**. Sensors positioned along the conveyor track the piece as the conveyor transports the mail piece toward the loading station. An example of a work station having a conveyor for receiving dropped pieces and tracking the pieces is provided in pending U.S. application Ser. No. 10/862,021, filed Jun. 4, 2004, which was published Jan. 27, 2005 under Publication No. U.S. 2005-0018214 A2 and which is incorporated herein by reference. The conveyor receives mail pieces dropped by an operator and tracks the mail pieces as they are transported along the conveyor.

In an exemplary automatic configuration, the system includes an imaging station, having an imaging device such as a high speed line scanning camera. The imaging station scans each mail piece to detect information regarding the destination for each piece. The system analyzes the image data to determine the destination information and then electronically tags the mail piece with the destination and sorts the piece accordingly. An example of a system having an automated imaging station for scanning pieces as they are conveyed is described in U.S. patent application Ser. No. 09/904,471, filed Jul. 13, 2001, which was published Jan. 16, 2003 under Publication No. U.S. 2003-0014376 A1, and which is incorporated herein by reference.

FIGS. **1** and **2** illustrate such an automated system. The input station includes an input bin **55** for receiving a stack of mail. A feeder **60** in the input bin serially feeds mail pieces from the input bin to a conveyor **65**. An imaging station **70** positioned along the conveyor scans the mails pieces as the pieces are conveyed to the loading station **310**. The system **10** analyzes the image data to read information for the mail piece, such as the recipient's address.

The conveyor **65** conveys the mail piece to the loading station **310**. At the loading station the conveyor **65** conveys the mail piece onto a car **200**. As discussed further below, after the mail piece is loaded onto the car, the car moves away from the loading station and another car moves into position at the loading station to receive the next piece of mail.

In certain instances, the system may not be able to automatically identify the relevant information for a mail piece. To process such pieces, the system may include an operator to input the relevant information so that the mail piece can be sorted. For instance, the system may include an operator station having an input device and a display, such as a monitor. If the system cannot automatically determine the address within a pre-determined time period, the system displays the scanned images for the mail piece to the monitor so that the operator at the work station can view the images and manually enter the information using the input device.

In addition to the automated and manual systems described above, the system may be configured in a hybrid or semi-automated configuration having some operations performed manually and others automated. For instance, the system may include a manual input station that also has an imaging station. Since the system can handle a wide variety of items, it may be desirable to have an operator input the pieces manually so that the pieces are properly oriented and separated. The imaging station then scans the items and processes the imaging data to determine the address information for the pieces. Additionally, the operator station may include an input device and a display for inputting information if the address for a piece cannot be automatically determined, as discussed above. The operator can input the information as soon as the system indicates to the operator that it cannot determine the information for a piece. Alternatively, as discussed below, the car may be directed to a buffer if the information for a piece cannot be determined. In such an instance, the cars having such pieces will remain in the buffer while the system continues to process pieces for which the system can determine the relevant information. The operator can continue to manually drop pieces and wait until a number of pieces need manual keying of information. The operator can then switch from the operation of dropping pieces to the operation of manually keying the pieces, sometimes referred to as local video encoding (LVE). The operator can continue keying until some or all of the pieces in the buffer have been successfully coded, and then the operator can go back to the operation of manually dropping pieces. As yet another alternative, it may be desirable to incorporate a separate operator station having the input device and display so that one operator can input the mail at the input station and a separate operator can input the information for pieces having addresses that cannot be automatically determined.

As can be seen from the foregoing, the input station 50 may be configured in a wide range of options. The options are not limited to those configurations described above, and may include additional features, such as an automated scale for weighing each piece, a labeler for selectively applying labels to the mail pieces and a printer for printing information on the mail pieces or on the labels.

Additionally, in the foregoing description, the system is described as having a single input station 50. However, it may be desirable to incorporate a plurality of input stations positioned along the system 10. By using a plurality of input stations, the feed rate of pieces may be increased. In addition, the input stations may be configured to process different types of items. In this way, each input station could be configured to efficiently process a particular category of items. For instance, if the system is configured to process documents, such as mail, one input station may be configured to process standard envelopes, while another input station may be configured to process larger mails, such as flats. Similarly, one input station may be configured to automatically process mail by scanning it and automatically determining the recipient. The second input station may be configured to process rejects, such as by manually keying in information regarding the recipient.

Sorting Station

Referring to FIGS. **1**-**6**, the system includes a sorting station **100**, such as an array of bins **190** for receiving the pieces. In the present instance, the sorting station includes a number of bins arranged in columns. Additionally, the sorting station **100** includes a track **110** for guiding the cars **200** to the bins **190**.

The track **110** includes a horizontal upper rail **135** and a horizontal lower rail **140**. A plurality of vertical legs **130** extend between the upper horizontal leg and the lower horizontal leg **140**. During transport, the cars travel up a pair of vertical legs from the loading station **310** to the upper rail **135** (as described below, the cars actually travel up two pairs of rails because the track includes a forward track and a parallel opposing track). The car then travels along the upper rail until reaching the column having the appropriate bin. The car then travels downwardly along two front vertical posts and two parallel rear posts until reaching the appropriate bin, and then discharges the mail piece into the bin. The car then continues down the vertical legs until reaching the lower horizontal leg **140**. The car then follows the lower rail back toward the loading station.

As can be seen in FIG. **2**, the track **110** includes a front track **115** and a rear track **120**. The front and rear tracks **115**, **120** are parallel tracks that cooperate to guide the cars around the track. As shown in FIG. **13**, each of the cars includes four wheels **220**: two forward wheel and two rearward wheels. The forward wheels **220** ride in the front track, while the rearward wheel ride in the rear track. It should be understood that in the discussion of the track the front and rear tracks **115**, **120** are similarly configured opposing tracks that support the forward and rearward wheels **220** of the cars. Accordingly, a description of a portion of either the front or rear track also applies to the opposing front or rear track.

Referring to FIG. **18** the details of the track will be described in greater detail. The track **110** includes an outer wall **152** and an inner wall **154** that is spaced apart from the outer wall and parallel to the outer wall. The track also has a back wall **160** extending between the inner and outer walls. As can be seen in FIG. **18**, the outer and inner walls **152**, **154** and the back wall form a channel. The wheels **220** of the car ride in this channel.

Referring to FIG. **11**, the track includes both a drive surface **156** and a guide surface **158**. The drive surface positively engages the cars to enable the car to travel along the track. The guide surface **158** guides the car, maintaining the car in operative engagement with the drive surface **156**. In the present instance, the drive surface is formed of a series of teeth, forming a rack that engages the wheels of the cars as described further below. The guide surface **158** is a generally flat surface adjacent the rack **156**. The rack **156** extends approximately halfway across the track and the guide surface **158** extends across the other half of the track. As shown in FIGS. **11** and **18**, the rack **156** is formed on the inner wall **154** of the track. The opposing outer wall **152** is a generally flat surface parallel to the guide surface **158** of the inner wall.

As described above, the track includes a plurality of vertical legs extending between the horizontal upper and lower rails **135**, **140**. An intersection **170** is formed at each section of the track at which one of the vertical legs intersects one of the horizontal legs. Each intersection includes an inner branch **172** that is curved and an outer branch **176** that is generally straight. FIG. **10** illustrates both a right-hand intersection **170***c* and a left-hand intersection **170**, which are mirrors of one another. In FIG. **10**, the intersections **170***c*, **170***d* illustrate the portion of the track in which two vertical legs **130** intersect the upper horizontal leg **135**. The intersections of the vertical legs with the lower rail incorporate similar intersections, except the intersections are reversed. Specifically, the point at which vertical leg **130***c* intersects the lower rail incorporates an intersection configured similar to intersection **170***d*, and the point at which vertical leg **130***d* intersects the lower rail incorporates an intersection configured similar to intersection **170***c*.

Each intersection **170** includes a pivotable gate **180** that has a smooth curved inner race and a flat outer race that has teeth that correspond to the teeth of the drive surface **156** for the track. The gate **180** pivots between a first position and a second position. In the first position, the gate **180** is closed so that the straight outer race **184** of the gate is aligned with the straight outer branch **176** of the intersection. In the second position, the gate is open so that the curved inner race **182** of the gate is aligned with the curved branch **172** of the intersection.

Accordingly, in the closed position, the gate is pivoted downwardly so that the outer race **184** of the gate aligns with the drive surface **156**. In this position, the gate blocks the car from turning down the curved portion, so that the car continues straight through the intersection. In contrast, as illustrated n FIG. **10**, when the gate is pivoted into the open position, the gate blocks the car from going straight through the intersection. Instead, the curved inner race **182** of the gate aligns with the curved surface of the inner branch **172** and the car turns through the intersection. In other words, when the gate is closed, a car goes straight through the intersection along either the upper rail **130** or the lower rail, depending on the location of the intersection. When the gate is opened, the gate directs the car from either a vertical rail to a horizontal rail or from a horizontal rail to a vertical rail, depending on the location of the intersection.

As can be seen in FIG. **11**, the end of the gate remote from the pivot point of the gate flares outwardly so that the curved inner race matches the curved profile of the inner branch when the gate is open. As a result, the gate has a generally L-shaped configuration. To accommodate the flared end of the gate 180, the drive surface 156 of the inner branch has a notch or recessed portion. When the gate is closed, the notch provides clearance so that the outer race 184 of the gate lies flat, parallel with the drive surface of the outer branch 176. Further, in the example shown in FIG. 11, the gate is positioned along the upper rail 135 of the track 110. When the gate is closed, the recess in the inner branch of the intersection 170 allows the gate to lie flat so that it is aligned with the drive surface of the upper rail.

In the foregoing description, the gates allow one of the cars to either continue in the same direction (e.g. horizontally) or turn in one direction (e.g. vertically). However, in some applications, the system may include more than two horizontal rails that intersect the vertical columns. In such a configuration, it may be desirable to include a different rail that allows the cars to turn in more than one direction. For instance, if a car is traveling down a column, the gate may allow the car to turn either left or right down a horizontal rail, or travel straight through along the vertical column. Additionally, in some applications it may be desirable to allow the cars to travel upwardly, whereas in the system described above, the cars only travel downwardly through the sorting station. If the cars also travel upwardly in the sorting station, then the gates should be configured to accommodate and guide the cars when the cars travel upwardly through an intersection.

The gates 180 are controlled by signals received from the central controller 350. Specifically, each gate is connected with an actuator 186 that displaces the gate from the opened position to the closed position and back. There may be any of a variety of controllable elements operable to displace the gate. In the present instance, the actuator 186 is a solenoid having a linearly displaceable piston.

In the foregoing description, the sorting station 100 is described as a plurality of output bins 190. However, it should be understood that the system may include a variety of types of destinations, not simply output bins. For instance, in certain applications it may be desirable to sort items to a storage area, such as an area on a storage shelf. Alternatively, the destination may be an output device that conveys items to other locations. According to one example of an output device, the system may include one or more output conveyors that convey pieces away from the sorting system toward a different material handling or processing system. For instance, an output conveyor designated A may convey pieces to a processing center designated A. Therefore, if a piece is to be delivered to processing center A, the car will travel along the track to output conveyor A. Once the car reaches output conveyor A, the car will stop and transfer the piece onto output conveyor A. Output conveyor A will then convey the piece to processing center A. Further, it should be understood that the system may be configured to include a plurality of output devices, such as output conveyors.

In some embodiments, the system may include a plurality of output conveyors in addition to the output bins. In other embodiments, the system may only include a plurality of output devices, such as conveyors, and the system is configured to sort the pieces to the various output devices. Further still, the system may be configured to retrieve pieces from storage locations. In such embodiments, the cars may sort pieces to a storage location, such as a bin. Subsequently, one of the cars may travel to the storage location and retrieve the item from the storage location and transport it to one of the output devices.

One manner that the cars may retrieve items from the storage locations is by including a conveyor at the storage locations. In this way, an item at a storage location can be conveyed by the conveyor toward the track. When a car arrives at the storage location, the conveyor at the storage location conveys the item onto the car, similar to the manner in which a piece is loaded onto the car at the loading column. Accordingly, the system can sort pieces to a plurality of output devices, in addition to sorting pieces to a plurality of storage locations before subsequently retrieving the pieces and conveying the pieces to the output devices.

As discussed above, the system is operable to sort a variety of items to a plurality of destinations. One type of destination is a bin; a second type is a shelf or other location on which the item is to be stored; and a third type of destination is an output device that may be used to convey the item to a different location. The system may include one or more of each of these types or other types of destinations.

Delivery Vehicles

Referring now to FIGS. 12-17, the details of the delivery vehicles 200 will be described in greater detail. Each delivery vehicle is a semi-autonomous car having an onboard drive system, including an onboard power supply. Each car includes a mechanism for loading and unloading items for delivery.

The car 200 may incorporate any of a variety of mechanisms for loading an item onto the car and discharging the item from the car into one of the bins. Additionally, the loading/unloading mechanism 210 may be specifically tailored for a particular application. However, in the present instance, the loading/unloading mechanism 210 is a conveyor belt. Specifically, referring to FIG. 12, the loading/unloading mechanism includes a plurality of narrow belts 212 that extend along the top surface of the car. The conveyor belts are reversible. Driving the belts in a first direction displaces the item toward the rearward end of the car; driving the belt in a second direction displaces the item toward the forward end of the car.

A conveyor motor 255 mounted on the underside of the car drives the conveyor belts 212. Specifically, the conveyor belts 212 are entrained around a forward roller 213 at the forward edge of the car, and a rearward roller at the rearward edge of the car. The conveyor motor 255 is connected with the forward roller 213 to drive the forward roller, thereby operating the conveyor belts.

The car includes four wheels 220 that are used to transport the car along the track 110. The wheels 220 are mounted onto two parallel spaced apart axles 215, so that two or the wheels are disposed along the forward edge of the car and two of the wheels are disposed along the rearward edge of the car.

Referring to FIG. 18, each wheel comprises an inner idler roller 224 and an outer gear 222 that cooperates with the drive surface 156 of the track. The idler roller 224 rotates freely relative to the axles, while the outer gear is fixed relative to the axle onto which it is mounted. In this way, rotating the axle operates to rotate the gear 222. Additionally, the idler roller is sized to have a diameter slightly smaller than the distance between the upper wall 152 and the lower wall 154 of the track. In this way, the idler roller may rotate freely within the track, while ensuring that the gear 222 of each wheel remains in operative engagement with the drive surface (i.e. the teeth) 156 of the track. Accordingly, when the vehicle is moving horizontally, the rollers carry the weight of the cart, while the gears 222 cooperate with the drive surface 156 of the track to drive the vehicle along the track.

The car includes an onboard motor 250 for driving the wheels 220. More specifically, the drive motor 250 is operatively connected with the axles to rotate the axles 215, which in turn rotates the gears 222 of the wheels. As shown in FIG. 16, the drive motor 250 is interconnected to the axles 215 via a pair of drive belts 254 that are driven by the drive motor.

The drive system for the car may be configured to synchronously drive the car along the track. In the present instance, the drive system is configured so that each gear is driven in a synchronous manner. Specifically, each gear **222** is connected to an end of one of the axles in a manner that substantially impedes rotation of the gear relative to the axle. In this way each axle drives the attached two gears in a synchronous manner. Additionally, in the present instance, both axles are driven in a synchronous manner so that all four gears are driven in a synchronous manner. There are various mechanisms that can be used to synchronously drive the axles. For instance, a pair of drive motors can be used to drive the axles, and the drive motors can be synchronized. However, in the present instance, a single drive motor **250** is used to drive both axles. Each axle includes a timing pulley **226** that is rigidly connected to the axle to prevent rotation of the pulley relative to the axle. Similarly, a timing pulley **228** is connected to the motor shaft. The drive belt **254** connecting the timing pulley **226** on the axle with the motor is a timing belt so that the rotation of the drive motor is precisely linked to the rotation of the axle. Although a single timing belt can be used to drive both axles synchronously, in the present instance, a pair of timing pulleys is connected to the motor shaft, and each timing pulley is connected to a corresponding timing pulley on one of the axles, as shown in FIG. **16**.

The drive motor **250** includes a sensor that is operable to detect the rotation of the motor to thereby determine the distance the car has traveled. Since the gears **222** are rigidly connected with the axles, which are in turn synchronously connected with the drive motor, the forward distance that the car moves corresponds can be exactly controlled to correlate to the distance that the drive motor is displaced. Accordingly, the distance that a car has traveled along the determined path depends on the distance through which the car motor is rotated.

To detect the rotation of the drive motor **250**, the motor includes a sensor **252** for detecting the amount of rotation of the drive motor. In the present instance the sensor **252** is a hall sensor. A portion of rotation of the motor corresponds to what is referred to as a tick. The sensor detects the number of ticks and sends a signal to the central processor **350**, which determines how far along the designate path the car has traveled based on the known information regarding the path and the number of ticks that the sensor detects for the motor.

As the car travels along the track, an item on top of the car may tend to fall off the car, especially as the car accelerates and decelerates. Therefore, in the present instance, the car includes a retainer **230** to retain the element on the car during delivery. As illustrated in FIGS. **12-17**, the retainer **230** is a hold down that clamps the item against the top surface of the car.

The retainer includes an elongated pivotable arm **232**. A biasing element, such as a spring, biases the arm downwardly against the top surface of the retainer **230**. The retainer **230** further includes an operator **234** in the form of a tab. Pushing downwardly on the tab raises the clamp from the top surface of the conveyor to allow a piece to be loaded onto the car or discharged from the car.

The car **200** may be powered by an external power supply, such as a contact along the rail that provides the electric power needed to drive the car. However, in the present instance, the car includes an onboard power source **240** that provides the requisite power for both the drive motor **250** and the conveyor motor **255**. Additionally, in the present instance, the power supply is rechargeable. Although the power supply may include a known power source, such as a rechargeable battery, in the present instance, the power supply **240** is made up of one or more ultracapacitors. Ultracapacitors are extremely high energy density capacitors. Capacitors store electrical energy by physically separating positive and negative charges, in contrast to the chemical means a battery uses. Ultracapacitors rely on an electrostatic effect, which is physical rather than chemical, and highly reversible. The ultracapacitors can accept very high amperage to recharge the ultracapacitors. By using a high current, the ultracapacitors can be recharged in a very short time, such as a few seconds or less.

The car includes one or more contacts for recharging the power source **240**. In the present instance, the car includes a plurality of brushes **245**, such as copper brushes that are spring-loaded so that the brushes are biased outwardly. The brushes **245** cooperate with a charging rail in the loading station to recharge the power source, as described further below.

Each car includes at least one and preferably two load sensors for detecting the items as it is loaded onto the car. The sensor(s) ensure that the mail piece is properly positioned on the car. In the present instance, the car includes a forward loading sensor **260** and a rearward loading sensor **262**. The forward loading sensor detects the leading edge of the item as it is loaded onto the car. The forward loading sensor **260** also detects the trailing edge of the item to ensure that the entire length of the item is loaded onto the car. Similarly, the rearward sensor **262** detects the leading edge and in certain instances, may detect the trailing edge of the mail piece. The loading sensors **260**, **262** may be simple I/R sensors that detect the presence or absence of a document or mail piece.

Although the car operates in response to signals received from the central controller **350**, which tracks the location of each car, the car may also include a reader **265** for reading indicia along the track to confirm the position of the car. For instance, each bin may be assigned a unique bar code, and the forward reader may scan the track or other area around the bin **190** at which an item is to be delivered. The data that the central processor has regarding the path that the car is to follow and the data regarding the distance the car has traveled based on the data regarding the rotation of the drive motor **250** should be sufficient to determine whether the car **200** is positioned at the appropriate bin. Nonetheless, it may be desirable to double check the location of the car before the item is discharged into the appropriate bin. Therefore, the scanner may operate to scan and read information regarding the bin at which the car is stopped. If the scanned data indicates that the bin is the appropriate bin, then the car discharges its item into the bin. Similarly, the car may have a second reader **266** for reading indicia adjacent the rearward edge of the car. The second reader **266** may be used in applications in which the system is set up to utilize a first series of bins **190** along the forward side and a second series of bins along the rearward side of the track **110**.

In foregoing description, the cars have drive gears that interact with teeth in the track to guide the cars around the track. Additionally, as described further below in the operation section, the location of the car may be controlled based on information regarding how far the car has traveled. In such applications it is desirable to synchronize the drive wheels of the car. However, in some applications alternative control systems may be used. For instance, the location of the cars can be controlled based on signals from sensors positioned along the track or indicators positioned along the track. In such instances, the cars may be configured to use a drive mechanism that is not synchronous as described above.

As discussed further below, the car further includes a processor for controlling the operation of the car in response to signals received from the central processor. Additionally, the car includes a wireless transceiver so that the car can continuously communicate with the central processor as it travels along the track. Alternatively, in some applications, it may be desirable to incorporate a plurality of sensors or indicators positioned along the track. The car may include a reader for sensing the sensor signals and/or the indicators, as well as a central processor for controlling the operation of the vehicle in response to the sensors or indicators.

Loading Column

Referring now to FIGS. **6-7** the details of the loading column **300** will be described in greater detail. The loading column **300** is formed adjacent the output end of the input station **50**. The loading column **300** is formed of a front pair of vertical rails **305***a*, **305***b* and a corresponding rearward set of vertical rails. The loading station **310** is positioned along the loading column. The loading station **310** is the position along the track in which the car **200** is aligned with the discharge end of the conveyor of the input station **50**. In this way, a mail piece from the input station may be loaded onto the car as it is conveyed toward the car from the input station.

Although the central processor **350** tracks the position of the car, a home sensor **312** is positioned adjacent the loading station **310**. When the home sensor detects the car, the position for the car is known relative to a fixed point along the track, and the central processor resets the position of the car to the home or zero position.

Referring to FIG. **7**, a pair of charging rails are disposed along the vertical rails **305***a*, **305***b*. The charging rails are conductive strips connected with an electrical supply. The charging contacts **245** of the car **200** engage the conductive strips to recharge the ultracapacitors **240**. Specifically, the biasing element of the brushes **245** biases the brushes outwardly toward the charging contacts. The electricity flowing through the charging contact **245** is a high amperage, low voltage source that allows the ultracapacitors to recharge in a few seconds or less. In addition, since the power supply provided by the ultracapacitors last for only a few minutes, the car recharges each time it travels through the loading column.

Additionally, it may be desirable to incorporate a startup charging rail similar to the charging rails described above, but disposed along either the return rail or the rails in the column adjacent to the loading column, depending on where the cars are stored when the cars are shut down. Since the cars use ultracapacitors, it is possible that the ultracapacitors will discharge while the system is shut down. Therefore, upon startup the cars will not have any charge and will not be able to move to the loading column to charge the ultracapacitors. Accordingly, the system may include a startup charging rail disposed along a rail that the cars contact when the cars are stored during shutdown. If the cars are stored in the loading column and the adjacent column during shutdown, then the startup rail is disposed in the column adjacent the loading column. Alternatively, if the cars are stored on the return rail and the loading column during shutdown, then the startup rail is disposed along the return rail. In this way, when the system is started, a charging current is supplied to the cars through the startup charging rail and the charging rail in the loading column.

As discussed previously, each car **200** includes a retainer **230** to hold down items on the car during transport. The retainer should be opened at the loading station to allow an item to be loaded onto the car. Accordingly, as shown in FIG. **6**, an actuator **316** is positioned along the column. The actuator **316** projects inwardly toward the cars as the cars are conveyed up the loading column. As a car is conveyed upwardly in the loading column **300**, the hold down actuator **316** contacts the hold down operator or tab **236**. The interaction between the actuator **316** and the tab **236** causes the retainer to open, so that items can be loaded onto the car. As the car moves upwardly past the actuator **316**, the tab **236** on the car disengages the actuator, thereby releasing the retainer, thereby holding down or clamping the mail piece against the top surface of the vehicle.

In the foregoing description, the loading station has been described as a column in which an item is loaded onto the car and the car then travels upwardly to the horizontal upper rail **135**. However, in some applications in may be desirable to configure the loading station so that the items are loaded onto the cars at or near the top of the vertical column. In such an application, the load on the cars would be reduced since the car will not have to lift the item loaded on the car. In order to load the items on the cars at the top of the conveyor, a vertical conveyor may be added to the system. For instance, a conveyor angled upwardly may convey the items upwardly to the top of the column to load the items onto the cars. Alternatively, one or more of a variety of conveyor configurations can be used to transport to items toward the top of the loading column to load the items onto the cars.

Operation

The system **10** operates as follows. An item is processed at the input station **50** to identify a characteristic of the piece that is indicative of where the piece should be sorted. For instance, the item may be a mail piece that is to be sorted according to department, box number or recipient. If the mail pieces are sorted by department, the piece may be processed to identify either an indicator of the department (such as box number) or the piece may be processed to identify the recipient. The central controller maintains a database that correlates various data to identify the destination bin. For instance, the database may correlate the recipient names with the appropriate department if the mail is being sorted according to department. In other embodiments, the piece may be a part that has a product code and the database may correlate the product code with the sort location.

As discussed previously, the input station may process the items automatically or manually. In a manual mode, the operator manually enters information regarding a piece and then drops the piece on a conveyor. The system electronically tags the piece with the sort information and the conveyor conveys the piece toward the loading station. Alternatively, if the input system is an automated system, the piece is automatically scanned to identify the relevant sort characteristic. For instance, the input station may use a scanner, such as a bar code scanner to read the postnet code on a piece, or the input station may include an imaging device, such as a high speed line scan camera in combination with an OCR engine to read information on the piece.

To prepare to receive an item, a car **200** moves along the track toward the loading station **310** in the loading column **300**. As the car approaches the loading station, the operator **236** for the hold down **230** engages the actuator **316**, which pivots the hold down upwardly to prepare the car to receive an item, as illustrated in FIG. **6**. When the car **200** moves into position at the loading station **310** the home sensor detects the presence of the car and sends a signal to the central processor **350** indicating that the car is positioned at the loading station. In the following description, the item being sorted is described as being a mail piece. It should be understood that such an item is an exemplary application of the system. As described above, the system can be configured to sort a variety of items in a variety of material handling applications.

Once the car is positioned at the loading station, the input station conveys a mail piece onto the car. As the mail piece is being conveyed onto the car **200**, the loading mechanism **210** on the car loads the mail piece onto the car. Specifically, the input station conveys the mail piece into contact with the conveyor belts **212** on the car. The conveyor belts **212** rotate toward the rearward side of the car, thereby driving the mail piece rearwardly on the car.

The operation of the conveyor belts is controlled by the loading sensors **260**, **262**. The forward loading sensor detects the leading edge of the mail piece as the mail piece is loaded onto the car. Once the forward loading sensor **260** detects the trailing edge of the mail piece, a controller onboard the car determines that the mail piece is loaded on the car and stops the conveyor motor. Additionally, the onboard controller may control the operation of the conveyor in response to signals received from the rearward sensor **262**. Specifically, if the rearward sensor **262** detects the leading edge of the mail piece, then the leading edge of the mail piece is adjacent the rearward edge of the car. To ensure that the mail piece does not overhang from the rearward edge of the car, the controller may stop the conveyor once the rearward sensor detects the leading edge of the mail piece. However, if the rearward sensor detects the leading edge of the mail piece before the forward sensor detects the trailing edge of the mail piece, the controller may determine that there is a problem with the mail piece (i.e. it is too long or two overlapping mail pieces were fed onto the car. In such an instance, the car may communicate an error message with the central controller, which may declare an error and provide an indicator to the operator that the car at the loading station requires attention. Alternatively, a reject bin **325** may be positioned behind the loading station so that mail pieces on the car at the loading station can be ejected into the reject bin **325**. In this way, if there is an error loading a mail piece onto a car, the mail piece can simply be ejected into the reject bin, and a subsequent mail piece can be loaded onto the car.

After a mail piece is loaded onto the car, the car moves away from the loading station. Specifically, once the onboard controller detects that a mail piece is properly loaded onto the car, the onboard controller sends a signal to start the drive motor **250**. The drive motor **250** rotates the axles, which in turn rotates the gears **222** on the wheels **220**. The gears **222** mesh with the drive surface **156** of the vertical rails **305** in the loading column to drive the car upwardly. Specifically, the gears and the drive surfaces mesh and operate as a rack and pinion mechanism, translating the rotational motion of the wheels into linear motion along the track **110**.

Since the cars move up the loading column from the loading station, the destination for the car does not need to be determined until after the car reaches the first gate along the upper rail **135**. For instance, if an automated system is used at the input station to scan and determine the characteristic used to sort the mail pieces, it may take some processing time to determine the relevant characteristic. The time that it takes to convey the mail piece onto the car and then convey the car up the loading column will typically be sufficient time to determine the relevant characteristic for the mail piece. However, if the characteristic is not determined by the time the car reaches the upper rail, the car may be directed down the second column, which is the column next to the loading column. The car travels down the second column to the lower rail **140**, and then back to the loading column. The car may stop in the second column to provide additional time to determine the characteristic. However, after waiting for a predetermined period the system may declare that the address cannot be determined and the car may be advanced from the second column and the piece may be discharged to a reject bin. Alternatively, rather than declare an error the car may

continue to travel around the loop from the loading column to the second column until the characteristic is determined or until a predetermined time at which the central controller declares an error. Additionally, rather than using the reject bin when the system is unable to determine the characteristic for a mail piece, one of the bins in the second column can also be used as a reject bin. In this way, the cars are ready to receive a mail piece as soon as the car reaches the loading station, without having to eject the problem mail piece into the reject bin **325** at the loading station.

As described above, the system includes a loop that can be utilized as a buffer track to provide additional processing time to analyze the characteristic for the mail piece if necessary. Although the first and second columns can be used as the buffer loop, other columns can be used as a buffer loop if desired.

The foregoing discussion described the process for buffering a car if the system is unable to determine the characteristic for the mail piece by the time the car reaches the top rail. However, for most mail pieces, the system should be able to identify the characteristic without having to buffer the car. The following discussion describes the operation of the system assuming that the characteristic for the mail piece is determined before the car reaches the upper rail **135**.

Once the characteristic for the mail piece is determined, the central controller **350** determines the appropriate bin **190** for the mail piece. Based on the location of the bin for the mail piece, the route for the car is determined. Specifically, the central controller determines the route for the car and communicates information to the car regarding the bin into which the mail piece is to be delivered. The central controller then controls the gates along the track to direct the car to the appropriate column. Once the car reaches the appropriate column the car moves down the column to the appropriate bin. The car stops at the appropriate bin **190** and the onboard controller sends an appropriate signal to the conveyor motor **255** to drive the conveyor belts **212**, which drives the mail piece forwardly to discharge the mail piece into the bin. Specifically, the top of the car aligns with the gap between the appropriate bin **190** and the bottom edge of the bin that is immediately above the appropriate bin.

As discussed above, the central controller **350** controls the operation of the gates **180** in response to the location of the car **200** and the route that the car is to follow to deliver the mail piece. Additionally, as discussed below, the central controller controls the gates in response to the position of other cars on the track.

As the car **200** travels along the upper rail **135** and approaches a column, the gates for the vertical rails **130** are controlled as follows. If the car is to pass over the column on the way to the next column, the gates are displaced into the closed position, as shown in FIG. **9**. Specifically, both gates at the top of the column are closed so that the outer race **184** of the gate aligns with the straight track, with the outer race aligning with the drive surface **156** of the track **110**. In this way, the gates provide a straight drive surface that cooperates with the drive surface **156** to allow the car to travel over the column.

When the car comes to a column that it is to turn down, the gates are controlled as follows. Referring to FIG. **5**, the columns can be seen without the bins attached. The view in FIG. **5** is from the front of the apparatus **10**, so the car will be traveling along the upper rail from the right to the left in the perspective of FIG. **5**. In the following discussion, the car is to be conveyed to a bin in the column designated C in FIG. **5**. Column C includes two pairs of vertical legs. The first pair is front and back vertical legs **130***c* on the left side of column C; the second pair is front and back vertical legs **130***d* on the right side of column C.

In order for the car to travel down column C, the wheels on the left side of the car travel down legs **130***c* and the right side wheels travel down legs **130***d*. Therefore, as the car approaches column C, the gates at the top of **130***d* are displaced to the closed position so that the left side wheels remain on the upper rail and pass over the right side legs **130***d*. After the left side wheels of the car pass over the right legs **130***c*, the gates **180** at the top of the right legs **130***d* are displaced into the open position so that the right side wheels can turn down legs **130***d*. Specifically, after the left side wheels pass right legs **130***d*, the central controller operates the solenoids **186** of the gates **180** at the top of legs **130** to displace the gates into the open position, as shown in FIG. **8** (note that the view in FIG. **8** is taken from the rear side of the apparatus so that the perspective of the gates is reversed relative to the front side). The gates **180** block the straight path through the intersection **170** and the curved inner race **182** of the gates direct the right side wheels down vertical legs **130***d*. Similarly, the gates **180** at the top of the left side legs **130***c* are displaced into the open position to direct the left side wheels down vertical legs **130***c*.

As the car approaches the intersections at the bottom of legs **130***c* and **130***d*, the gates are operated similarly to the above description, but in reverse. Specifically, as the car approaches the intersections **170** at the bottom of legs **130***c* and **130***d*, the gates **180** in the intersections are displaced into the opened position so that the gates direct the forward and leading wheels to turn down the lower rail. From the perspective of FIG. **5**, the car travels from left to right after the car reaches the lower rail. After the car passes though the intersections at the bottom of the rails **130***c*, **130***d*, the gates at the bottom of right side legs **130***d* are displaced into the closed position before the left side wheels of the car reach the intersection at the bottom of the right side legs **130***d*. In this way, the left side wheels of the car pass straight through the intersection at the bottom of legs **130***d* along the bottom rail **140**.

As discussed above, the central controller **350** controls the operation of the gates in response to the position of the car and more specifically in response to the position of the left hand and right hand wheels of the car. The gates are fired sequentially to ensure that the different pairs of wheels are directed down the proper vertical legs. Alternatively, the operation of the gates may be controlled by signals received from the cars. Specifically, the cars may include a transmitter that transmits a signal to the central controller indicating that it is in proximity to a gate that is to be fired. Further still, the car may include an indicator that may be scanned as the car approaches the gate. Based on the indicator and the know destination for the car, the gate may fire. Still further, the car may include an mechanical actuator that selectively triggers or actuates a gate to appropriately direct the car.

One of the advantages of the system as described above is that the orientation of the cars does not substantially change as the cars move from travelling horizontally (along the upper or lower rails) to vertically (down one of the columns). Specifically, when a car is travelling horizontally, the two front geared wheels **220** cooperate with the upper or lower horizontal rail **135** or **140** of the front track **115**, and the two rear geared wheels **220** cooperate with the corresponding upper or lower rail **135** or **140** of the rear track **120**. As the car passes through a gate and then into a column, the two front geared wheels engage a pair of vertical legs **130** in the front track **115**, and the two rear geared wheels engage the corresponding vertical legs in the rear track **120**.

As the car travels from the horizontal rails to the vertical columns or from vertical to horizontal, the tracks allow all four geared wheels to be positioned at the same height. In this way, as the car travels along the track it does not skew or tilt as it changes between moving horizontally and vertically. Additionally, it may be desirable to configure the cars with a single axle. In such a configuration, the car would be oriented generally vertically as opposed to the generally horizontal orientation of the cars described above. In the single axle configuration, the weight of the cars would maintain the orientation of the cars. However, when using a single axle car, the orientation of the sort locations would be re-configured to accommodate the vertical orientation of the cars. Similarly, the loading station would also be re-configured to load the pieces onto the cars in the vertical orientation.

Traffic Control

Since the system includes a number of cars **200**, the system controls the operation of the different cars to ensure the cars do not collide into one another. In the following discussion, this is referred to as traffic control.

A variety of methodologies can be used for traffic control. For instance, the traffic control can be a distributed system in which each car monitors its position relative to adjacent cars and the onboard controller controls the car accordingly. One example of such as system utilizes proximity sensors on each car. If the proximity sensor for a car detects a car within a predefined distance ahead of the car, the onboard controller for the trailing car may control the car by slowing down or stopping the trailing car. Similarly, if a car detects a car within a predefined distance behind the car, the lead car may speed up unless the lead car detects a car ahead of it within the predefined distance. In this way, the cars may control the speed of the cars independently based on the feedback from the proximity sensors.

Although the system may use a distributed system for traffic control, in the present instance, the system uses a centralized system for traffic control. Specifically, the central controller **350** tracks the position of each car **200** and provides traffic control signals to each car based on the position of each car relative to adjacent cars and based on the route for each car.

In the present instance, the central controller **350** operates as the traffic controller, continuously communicating with the cars as the cars travel along the track **110**. For each car, the central controller determines the distance that each car can travel, and communicates this information with the cars. For instance, if car B is following car A along the track, and car A is at point A, car B can safely travel to a point just before point A without crashing into car A. As car A advances to a subsequent point B along the track, car B can travel safely to a point just before point B without crashing into car A.

The cars continuously communicate with the central controller to provide information indicative of their positions, so that the central controller can continuously update the safe distances for each car as the cars advance around the track.

Although the foregoing discussion is limited to determining safe zones based on the positions of the various cars on the track, the determination of safe zones is based on other factors that affect the traffic. For instance, when calculating the safe distance for a car, the central controller considers the distance between the car and the next gate, as well as the distance to the destination bin for the car.

As can be seen from the foregoing, increasing the frequency of communication between the cars and the central controller increases the efficiency of the traffic flow along the track. Accordingly, in the present instance, the traffic control is designed to communicate with a car once for every inch the car travels along the track. Therefore, if a car travels at 25 inches per second, the central controller communicates with the car every 40 msec. Further, it is desirable to have the cars travel at up to 50 inch/sec. Therefore, it is desirable to configure the communications to allow the cars to communicate with the central controller every 20 msec.

In addition, to the foregoing variables used to calculate safe distances, information regarding the track profile ahead of each car is used to calculate safe distances. For instance, the central controller determines whether the path ahead of a car is sideways movement, uphill movement (i.e. movement vertically upwardly) or downhill movement (i.e. movement vertically downwardly).

One of the issues in traffic control relates to merging at intersections **170**. The problem arises when a car needs to merge onto the return rail **140**. If two cars will arrive at the intersection close enough to collide, one of the cars needs to have priority and the other car needs to wait or slow down to allow the first car to go through.

A first method for controlling merging traffic is based on determining the next gap large enough for a car to have time to pass through an intersection without colliding with another car. In other words, if a first car approaches an intersection and it is determined that the gap between the first car and a second car is not sufficient for the first car to pass through, the first car waits at the intersection until there is a gap large enough to allow the first car to pass through.

A second method for controlling merging traffic is based on determining which car is closest to the homing sensor at the loading station **310**. The car with the shortest distance to the homing sensor gets priority at the intersection.

Another factor that the traffic controller considers when calculating safe distances relates to the position of cars in adjacent columns. In the present instance, most of the adjacent columns share a common vertical rail. For instance, in FIG. **5**, the leftmost column uses vertical rails **130***a* and **130***b*. The column next to the leftmost column uses vertical rails **130***b* and **130***c*.

However, in the present instance, some of the columns may have two vertical rails **130** that are independent from the adjacent columns. For instance, the loading column **300** has two independent rails that are not shared with the adjacent column. Therefore, cars can travel up the loading column without regard to the position of cars in the column next to the loading column. Furthermore, as shown in FIG. **5**, it may be desirable to configure the column next to the loading column so that it also has two independent vertical rails. In this way, cars can more freely travel up the loading column and down the adjacent column to provide a buffer loop as described previously.

Accordingly, when calculating safe distances, the traffic controller evaluates the position of cars in adjacent columns if the cars share a common vertical rail to ensure that the two cars do not collide as the car travel down the adjacent columns.

In the foregoing discussion, the sorting of items was described in relation to an array of bins disposed on the front of the sorting station **100**. However, as illustrated in FIGS. **2** & **4**, the number of bins in the system can be doubled by attaching a rear array of bins on the back side of the sorting station. In this way, the cars can deliver items to bins on the front side of the sorting station by traveling to the bin and then rotating the conveyor on the car forwardly to eject the piece into the front bin. Alternatively, the cars can deliver items to bins on the rear side of the sorting station by traveling to the bin and then rotating the conveyor on the car rearwardly to eject the piece into the rear bin.

Additionally, the sorting station **100** is modular and can be readily expanded as necessary simply by attaching an additional section to the left end of the sorting station. Further, although the foregoing describes the array of bins as being essentially a two dimensional array in which the cars simply travel in X and Y directions, the sorting station can be expanded to add additional "runs" of track. Specifically, a separate sorting station parallel to or perpendicular to the sorting station illustrated in FIG. **2** may be connected to the sorting station. In this way, the car would travel in a third dimension relative to the X and Y directions of the sorting station illustrated in FIG. **2**. For instance, additional sections of track may be connected to the sorting station illustrated in FIG. **2** perpendicular to the illustrated sorting station, so that the additional track forms an L-shape intersecting the loading column. In such a configuration, gates selectively direct the cars either down the upper rail **135** or rearwardly toward the additional track. Similarly, a plurality of parallel rows of sorting stations can be interconnected so that the cars selectively travel along a crossover rail until the car reaches the appropriate row. The car then travels down the row until it reaches the appropriate column as described above.

It will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the broad inventive concepts of the invention. For instance, in the foregoing description, the operation of the sorting station is described as being centralized with the central controller. However, it may be desirable to have the cars control the operation of the gates. According to one alternative, the cars incorporate one or more mechanical actuators that cooperate with an operator on the gate. The actuators on the cars are operable between first and second positions. In a first position, the actuator engages the gate operator to displace the gate into the closed position. In a second position, the actuator engages the gate to displace the gate into the open position. Alternatively, the gate may be biased toward the opened position, so that when the car actuator is in the second position it does not engage the gate operator. In another alternative, each car includes a mechanism for communicating with each gate. If the gate needs to be pivoted to direct an approaching car along a particular path, the car sends a signal to the gate indicating whether the gate should be opened or closed. In response to the signal from the car, the gate pivots to the appropriate position.

Further, in the above description, the system uses a wireless communication between the cars and the central controller. In an alternative embodiment, a communication line may be installed on the track and the cars may communicate with the central controller over a hard wired communication link. Still further, the system has been described as being useful in sorting incoming mail. However, the system may also be utilized to sort and prepare outgoing mail. For instance, after determining a characteristic for a mail piece, the system may print a marking onto the mail piece. For instance, after determining the recipient's address for a mail piece, the system determines which bin the mail piece is to be sorted to. As the mail piece is conveyed to the bin, a printer prints the appropriate postnet bar code on the piece before sorting the piece. To provide the printing functionality, the system may include a printer disposed along the track. When the car approaches the printer the car stops and at least partially discharges the mail piece to extend the mail piece toward the printer. The printer then prints the appropriate postnet code. The car then reverses the conveyors to load the piece back onto the car all the way, and then travels to the appropriate bin. Similarly, the system may include a device for selectively applying labels to the pieces. Similar to the above example of printing markings onto the pieces, the labeler may be positioned along the track. The cars selectively stop at the labeler on route to the appropriate bin and at least partially discharge the mail piece toward the labeler. The labeler then applies a label onto the mail piece and the conveyor on the car then reverses to load the piece back onto the car.

In addition to outgoing mail applications, it may be desirable to incorporate a printer and/or a labeler in systems configured to process incoming mail. For instance, when sorting incoming mail pieces, it may be desirable to print certain information, such as sort codes, a time stamp or audit trail information onto some or all of the pieces being processed. In some instances such information may be printed directly onto the mail pieces. In other instances, a label may be applied to the mail pieces and the information may be printed on the label.

In addition to a printer and a labeler, the system may include a scale for weighing the mail pieces. The scale may be positioned along the track **110**, such as along the loading column. To weigh a piece, the car stops adjacent the scale, and ejects the piece from the car onto the scale by driving the conveyor belts **212**. Preferably, the scale includes a conveyor or transfer mechanism for discharging the piece from the scale and back onto the car or onto a subsequent car. When the piece is loaded onto the car from the scale, the car drives the conveyors to load the piece as discussed above in connection with the loading station.

It should therefore be understood that this invention is not limited to the particular embodiments described herein, but is intended to include all changes and modifications that are within the scope and spirit of the invention as set forth in the claims.

What is claimed is:

1. A material handling system for delivering a plurality of items to or from a plurality of destination areas, comprising:

a plurality of delivery vehicles for delivering item to the destination areas, wherein the destination areas are arranged into a first series of columns extending generally vertically and a second series of columns extending generally vertically, wherein each vehicle comprises:

a power source for driving the vehicle; and

a transfer mechanism for transferring an item forwardly or rearwardly to transfer an item between the delivery vehicle and one of the destination areas;

a track for guiding the delivery vehicles to the destination areas, wherein the track is positioned between the first series of columns and the second series of columns so that a delivery vehicle can move vertically between the first series of columns and the second series of columns, and wherein when a delivery vehicle is stopped at a point along the track, the transfer mechanism can transfer an item forwardly between the vehicle and a destination area in the first series of columns and the transfer mechanism can transfer an item rearwardly between the vehicle and a destination in the second series of columns;

a destination module operable to identify the destination area to which one item is to be delivered to or retrieved by one of the delivery vehicles, wherein the destination module identifies the destination area based on a marking on the item; and

a controller for controlling the operation of the one vehicle as the vehicle delivers the item to the identified destination area.

2. The method of claim **1** wherein the track comprises a plurality of horizontal sections intersecting a plurality of vertical sections to provide a plurality of interconnected vertical and horizontal paths.

3. The method of claim **1** wherein the track comprises a substantially vertical section and the delivery vehicle move along the substantially vertical section to move between destination areas.

4. The method of claim **1** wherein the track comprises a pair of substantially parallel spaced apart horizontal track sections and a pair of substantially parallel spaced apart vertical sections intersecting the horizontal track sections, wherein the delivery vehicles move from one of the horizontal track sections to one of the vertical track sections to retrieve an item from one of the destination areas.

5. The system of claim **1** wherein a gap is formed between the first series of columns and the second series of columns and the track is disposed in the gap between the first and second series of columns so that the vehicles can move horizontally within the gap.

6. The system of claim **5** wherein the track is positioned so that the vehicles can move horizontally within the gap.

7. A material handling system for delivering a plurality of items to or from a plurality of destination areas, wherein the system comprises:

a plurality of destination areas for receiving the items;

a plurality of delivery vehicles for delivering the items, wherein each vehicle comprises an on-board motor for driving the vehicle and a rechargeable power source for powering the motor; and

track for guiding the delivery vehicles, wherein the track comprises a substantially vertical portion and a horizontal portion providing a continuous path from horizontal to vertical direction, wherein the track comprises a charging strip along a track section and the charging strip terminates along the track section, wherein the charging strip is operable to recharge the rechargeable power source as the vehicle travels along the charging strip.

8. The material handling system of claim **7** wherein the charging strip extends for less than one quarter of the length of the track.

9. The material handling system of claim **7** wherein the charging strip provides a charging current of sufficient amperage to recharge the rechargeable power source within several seconds as the vehicle travels along the charging strip.

10. A delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system, wherein the delivery vehicle comprises:

a platform for receiving an item to be conveyed to one of the destination areas;

a motor for driving the vehicle to one of the destination areas;

a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel, wherein the drive system comprises a plurality of driven gears that interact with the guide system to control the position of the vehicle along the guide system.

11. The delivery vehicle of claim **10** comprising a pair of synchronous drive axles, wherein the gears are fixed to the axles so that the gears are synchronously driven to drive the vehicle along the guide system.

12. The delivery vehicle of claim **10** comprising a transfer mechanism operable to transfer an item forwardly toward a first destination area or in an opposite direction toward a second destination area.

13. The delivery vehicle of claim **12** wherein the transfer mechanism is operable to transfer an item onto the vehicle.

14. The delivery vehicle of claim **10** wherein the delivery vehicle comprises a rechargeable power source for powering the motor and an electrical contact for contacting a charging rail along the guide system to recharge the rechargeable power source as the vehicle travels along the guide system to deliver an item.

15. The delivery vehicle of claim **10** comprising a transfer mechanism for transferring an item between the vehicle and a destination area.

16. The delivery vehicle of claim **15** wherein the delivery vehicle is configured to move in a first horizontal direction and a vertical direction substantially orthogonal to the first horizontal direction.

17. The delivery vehicle of claim **16** wherein the transfer mechanism is configured to transfer the item in a third direction that is transverse the horizontal direction and the vertical direction.

18. The delivery vehicle of claim **15** wherein the transfer mechanism comprises a retainer operable to positively engage the item.

19. The delivery vehicle of claim **10** wherein the drive system is operable to engage a first track on a first side of the vehicle and a second track on a second side of the vehicle.

20. The delivery vehicle of claim **10** wherein the vehicle comprises a controller configured to wirelessly receive signals regarding the direction of travel for the vehicle.

21. A delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system, wherein the delivery vehicle comprises:

a platform for receiving an item to be conveyed to one of the destination areas;

a motor for driving the vehicle to one of the destination areas;

a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel, wherein the delivery vehicle comprises a rechargeable power source for powering the motor and an electrical contact for contacting a charging rail along the guide system to recharge the rechargeable power source as the vehicle travels along the guide system to deliver an item.

22. The material handling system of claim **21** wherein the electrical contact is configured so that when the vehicle contacts the charging strip a charging current flows to the vehicle having sufficient amperage to recharge the rechargeable power source within several seconds as the vehicle travels along the charging strip.

23. The delivery vehicle of claim **21** comprising a pair of synchronously drive axles, wherein the gears are fixed to the axles so that the gears are synchronously driven to drive the vehicle along the guide system.

24. The delivery vehicle of claim **21** comprising a transfer mechanism operable to transfer an item forwardly toward a first destination area or in an opposite direction toward a second destination area.

25. The delivery vehicle of claim **24** wherein the transfer mechanism is operable to transfer an item onto the vehicle.

26. The delivery vehicle of claim **21** comprising a transfer mechanism for transferring an item between the vehicle and a destination area.

27. The delivery vehicle of claim **26** wherein the delivery vehicle is configured to move in a first horizontal direction and a vertical direction substantially orthogonal to the first horizontal direction.

28. The delivery vehicle of claim **27** wherein the transfer mechanism is configured to transfer the item in a third direction that is transverse the horizontal direction and the vertical direction.

29. The delivery vehicle of claim **26** wherein the transfer mechanism comprises a retainer operable to positively engage the item.

30. The delivery vehicle of claim **21** wherein the drive system is operable to engage a first track on a first side of the vehicle and a second track on a second side of the vehicle.

31. The delivery vehicle of claim **21** wherein the vehicle comprises a controller configured to wirelessly receive signals regarding the direction of travel for the vehicle.

* * * * *

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EXHIBIT E

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October 21, 2021

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U.S. PATENT: ***9,687,883***

ISSUE DATE: ***June 27, 2017***

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Certifying Officer

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DEPARTMENT OF COMMERCE

US009687883B2

(12) **United States Patent**
Hayduchok et al.

(10) **Patent No.: US 9,687,883 B2**
(45) **Date of Patent: Jun. 27, 2017**

(54) **MATERIAL HANDLING APPARATUS FOR DELIVERING OR RETRIEVING ITEMS**

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(72) Inventors: **George Hayduchok**, Mount Holly, NJ (US); **Robert R. DeWitt**, Marlton, NJ (US)

(73) Assignee: **Opex Corporation**, Moorestown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/690,541**

(22) Filed: **Apr. 20, 2015**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 14/149,282, filed on Jan. 7, 2014, now Pat. No. 9,010,517, which is a continuation of application No. 13/631,817, filed on Sep. 28, 2012, now Pat. No. 8,622,194, which is a continuation of application No. 13/361,490, filed on

(Continued)

(51) **Int. Cl.**

B65G 1/00	(2006.01)
B65G 35/06	(2006.01)
B07C 3/08	(2006.01)
B07C 7/00	(2006.01)
B07C 7/02	(2006.01)
B61B 13/02	(2006.01)
B61C 11/04	(2006.01)
B65G 1/04	(2006.01)
B65G 1/06	(2006.01)

(52) **U.S. Cl.**
CPC ***B07C 3/087*** (2013.01); ***B07C 7/005*** (2013.01); ***B07C 7/02*** (2013.01); ***B61B 13/02*** (2013.01); ***B61C 11/04*** (2013.01); ***B65G 1/04*** (2013.01); ***B65G 1/065*** (2013.01); *Y02T 30/10* (2013.01); *Y02T 30/30* (2013.01)

(58) **Field of Classification Search**
CPC B65G 1/00; B65G 2203/00; B65G 35/06
USPC 198/347.1–347.4, 468.6, 358, 349, 349.6, 198/468.1; 414/273, 279
See application file for complete search history.

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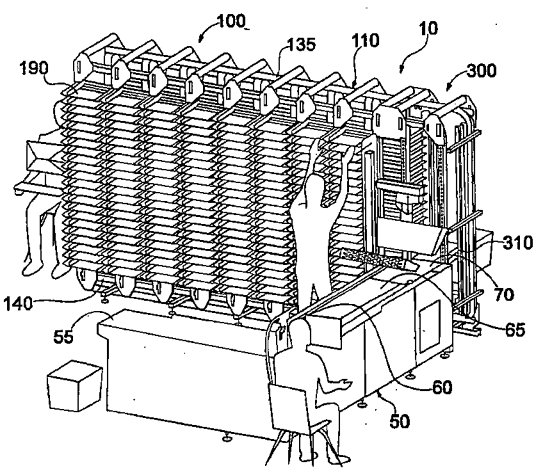
(74) *Attorney, Agent, or Firm* — Stephen H. Eland; Dann, Dorfman, Herrell & Skillman

(57) **ABSTRACT**

A method and apparatus are provided for sorting or retrieving items to/from a plurality of destinations areas. The items are loaded onto one of a plurality of independently controlled delivery vehicles. The delivery vehicles follow a track that guides the delivery vehicles to/from the destination areas, which are positioned along the track. Once at the appropriate destination area, an item is transferred between the delivery vehicle and the destination area.

35 Claims, 13 Drawing Sheets



Related U.S. Application Data

Jan. 30, 2012, now Pat. No. 8,276,740, which is a continuation of application No. 12/983,726, filed on Jan. 3, 2011, now Pat. No. 8,104,601, which is a continuation of application No. 12/014,011, filed on Jan. 14, 2008, now Pat. No. 7,861,844.

(60) Provisional application No. 60/884,766, filed on Jan. 12, 2007.

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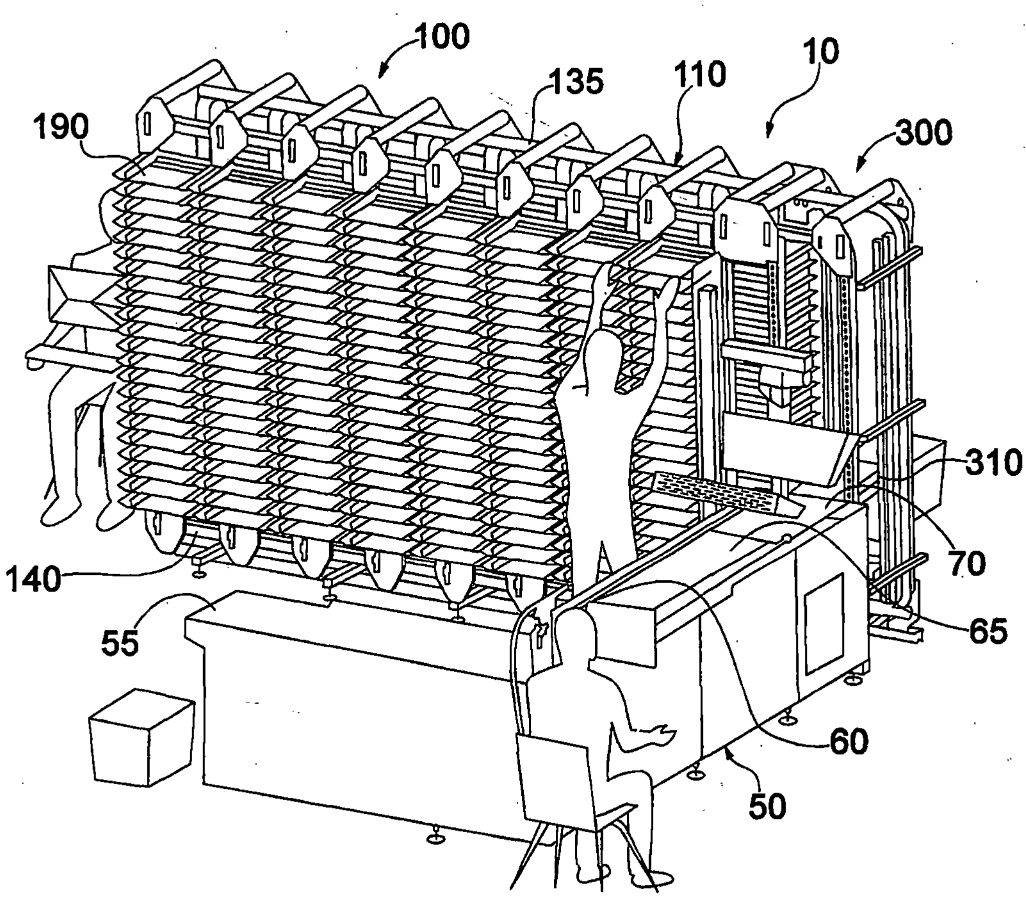


Fig. 1

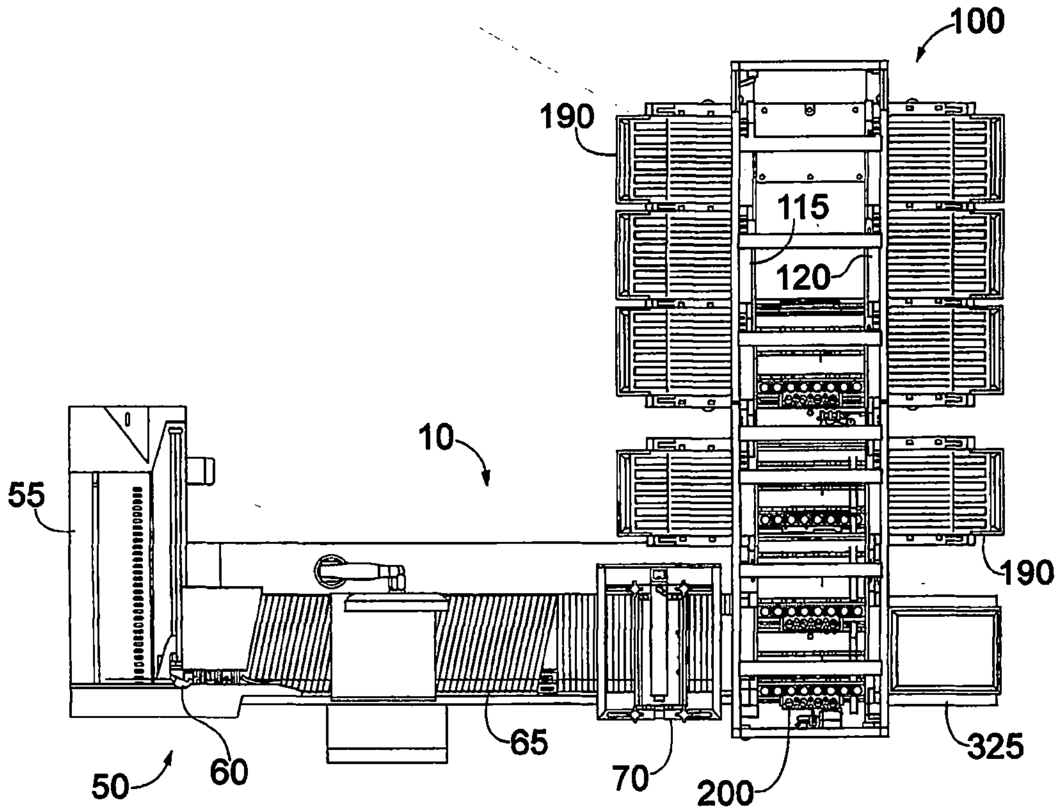


Fig. 2

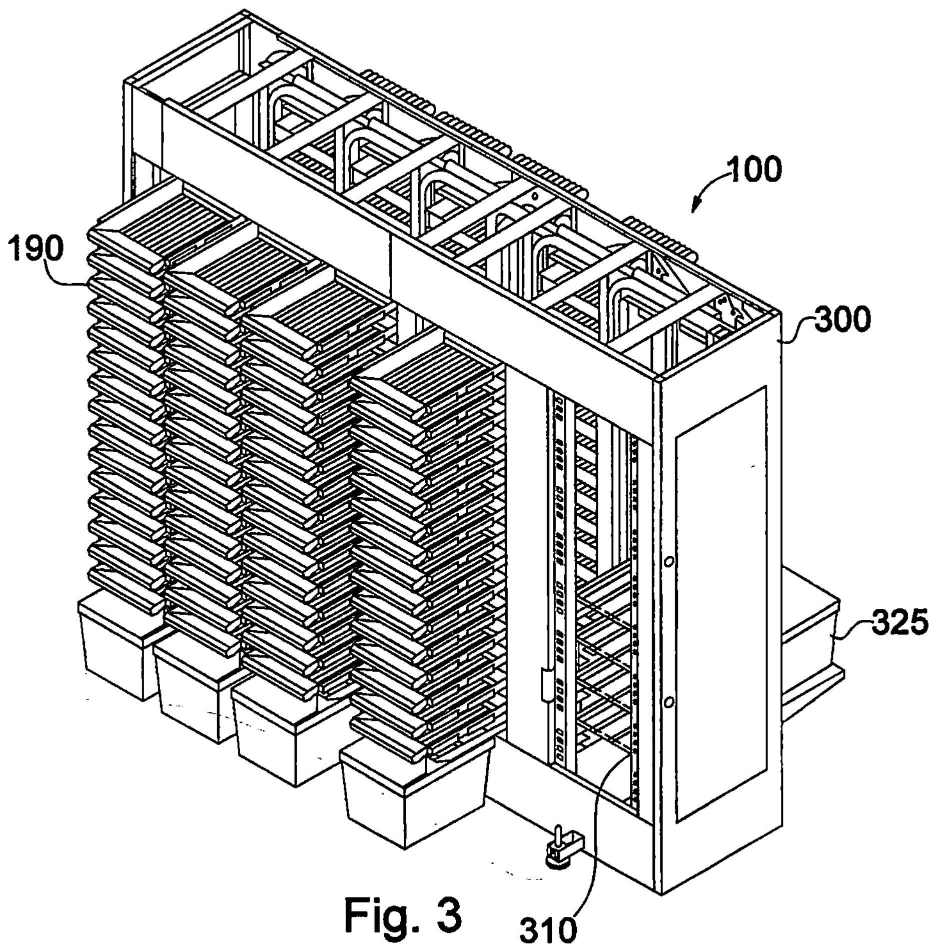


Fig. 3

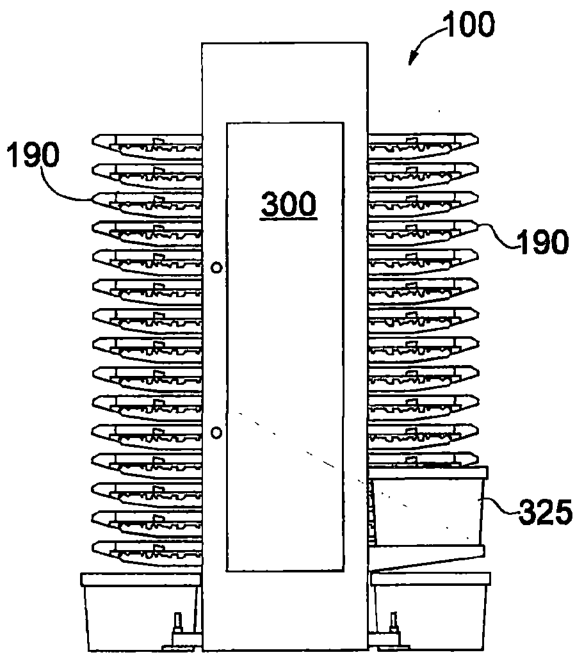


Fig. 4

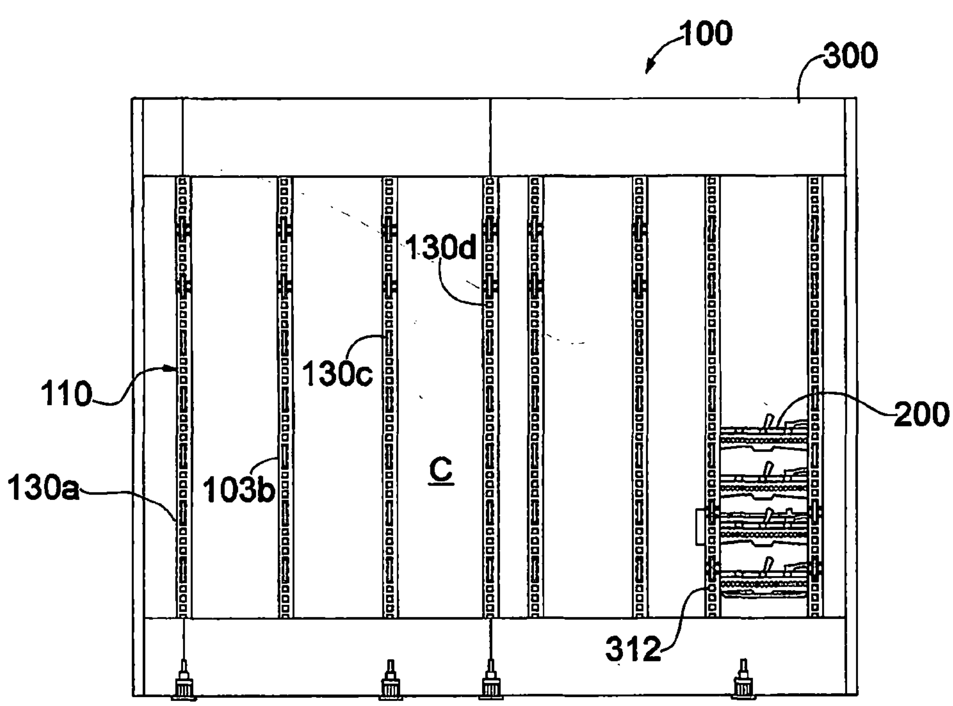


Fig. 5

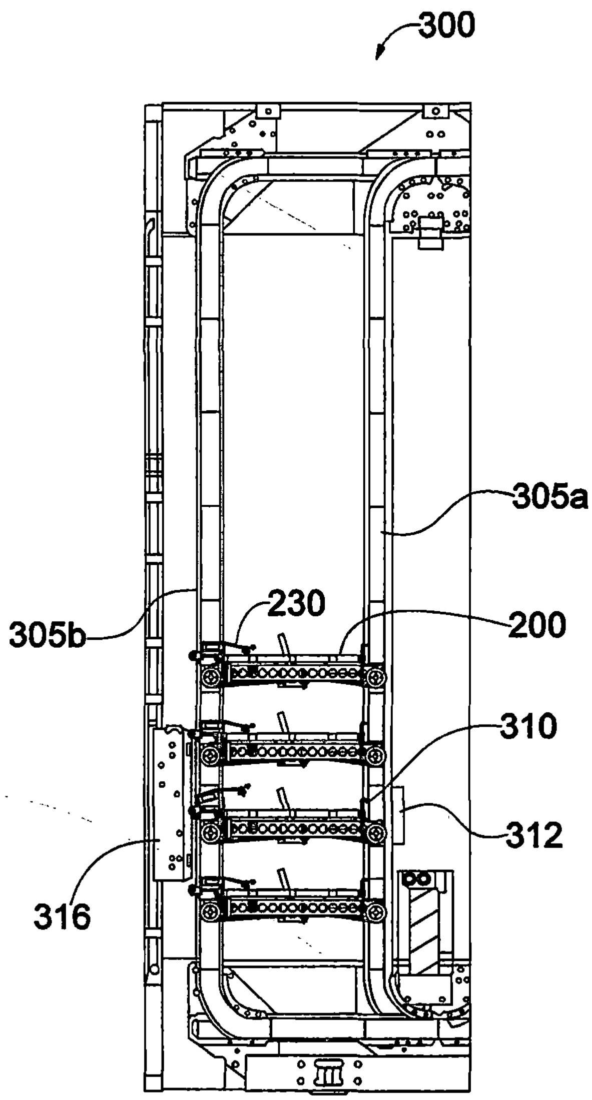


Fig. 6

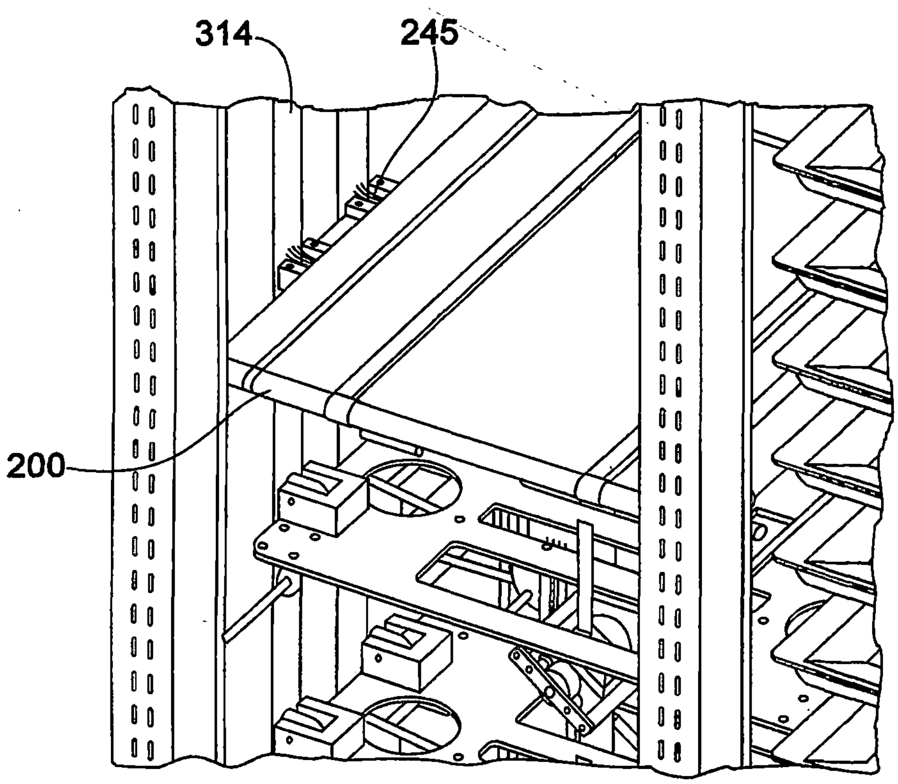


Fig. 7

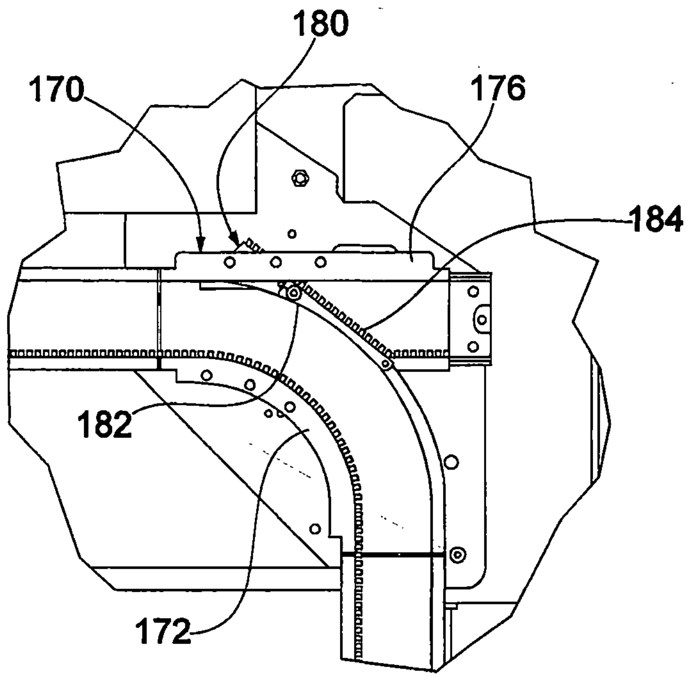


Fig. 8

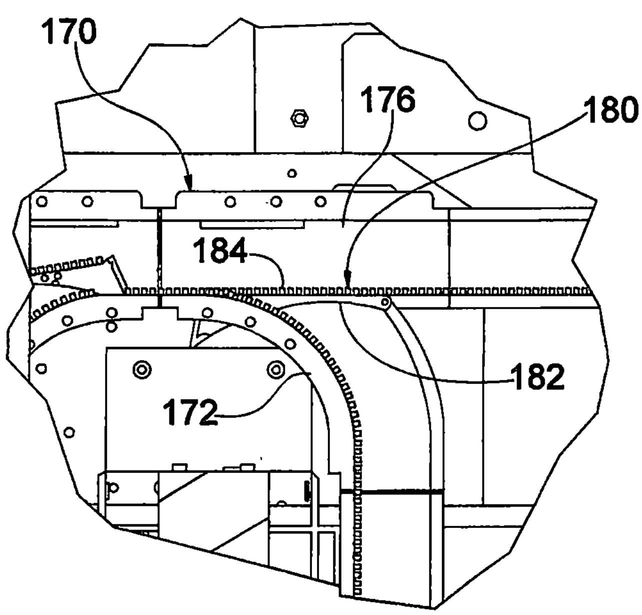


Fig. 9

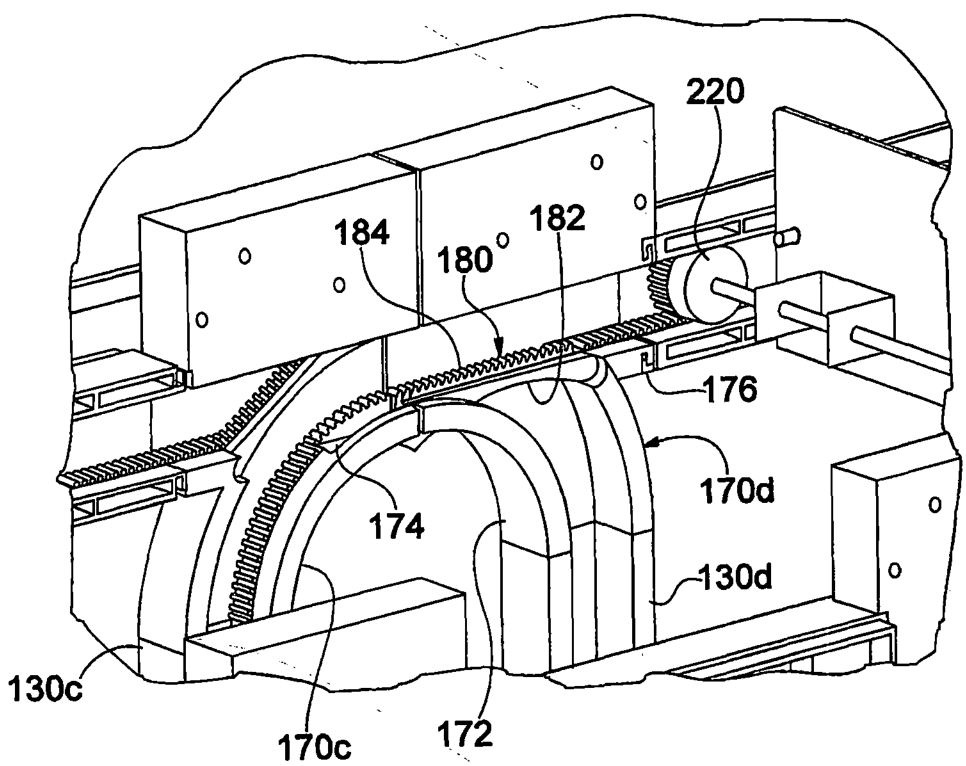
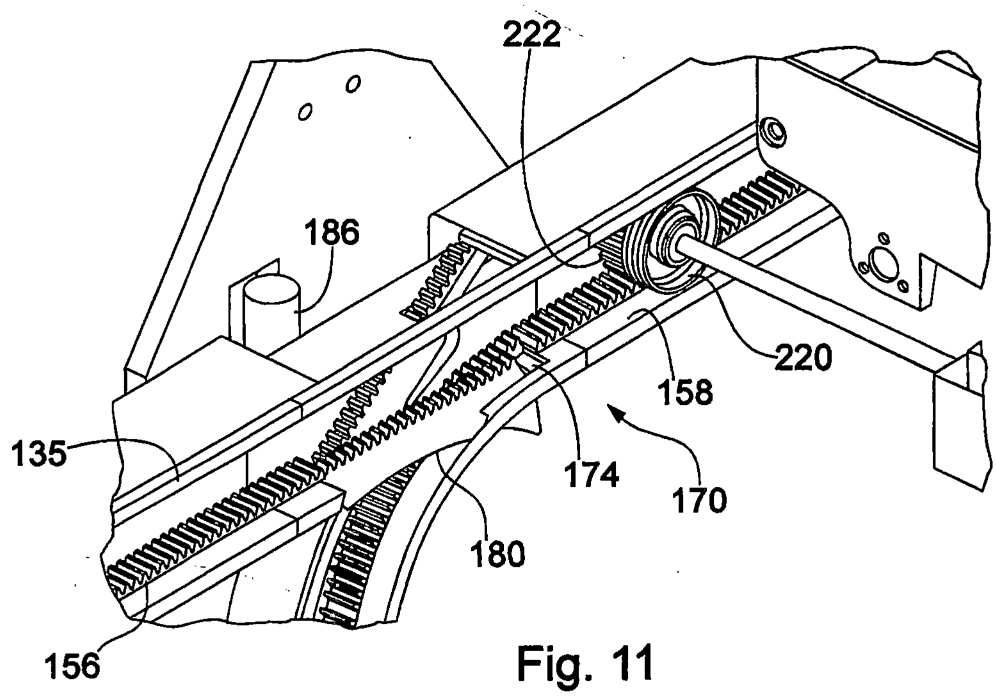


Fig. 10



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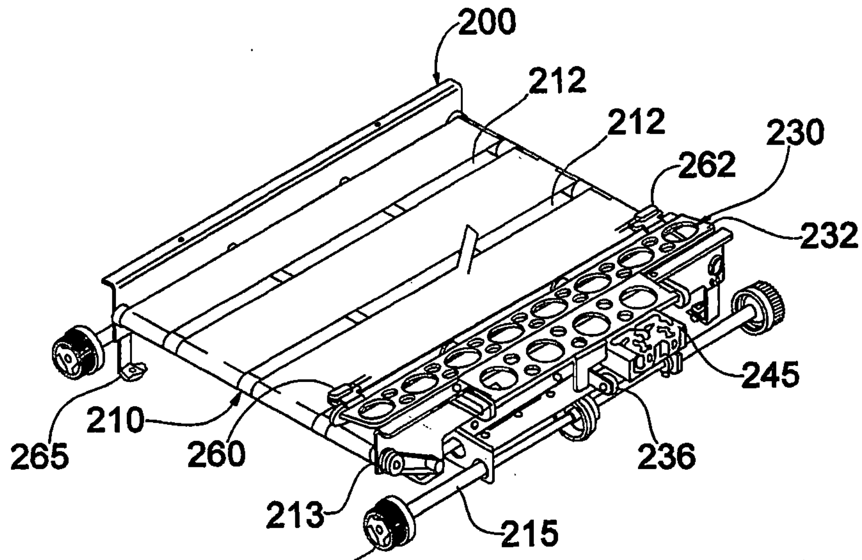

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Fig. 12

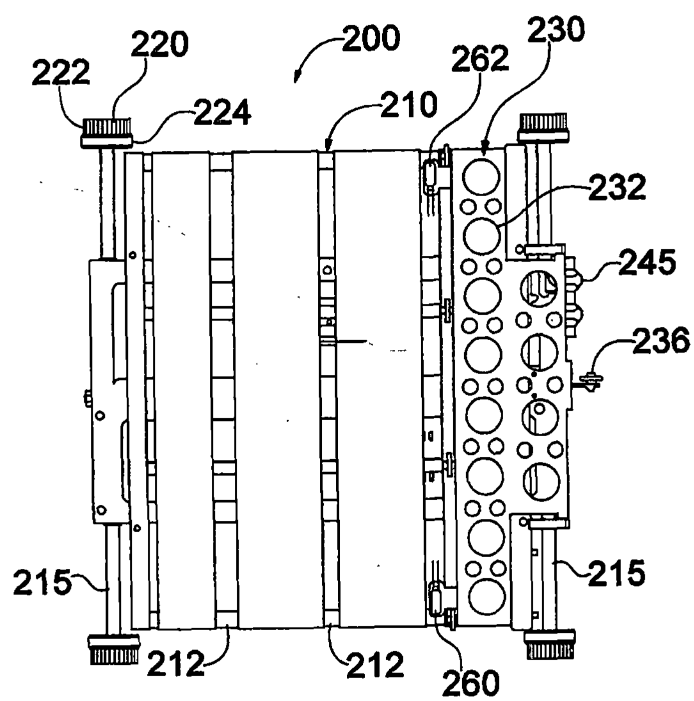

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Fig. 13

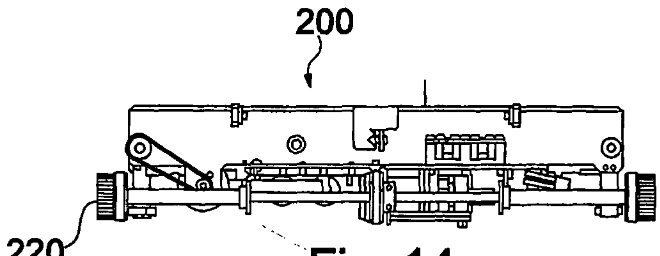

Fig. 14

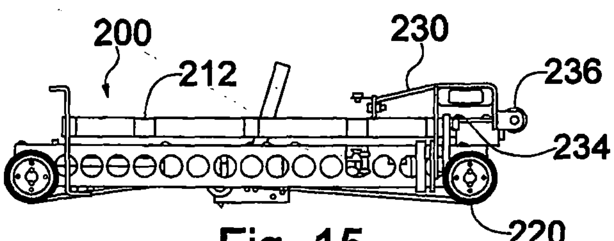

Fig. 15

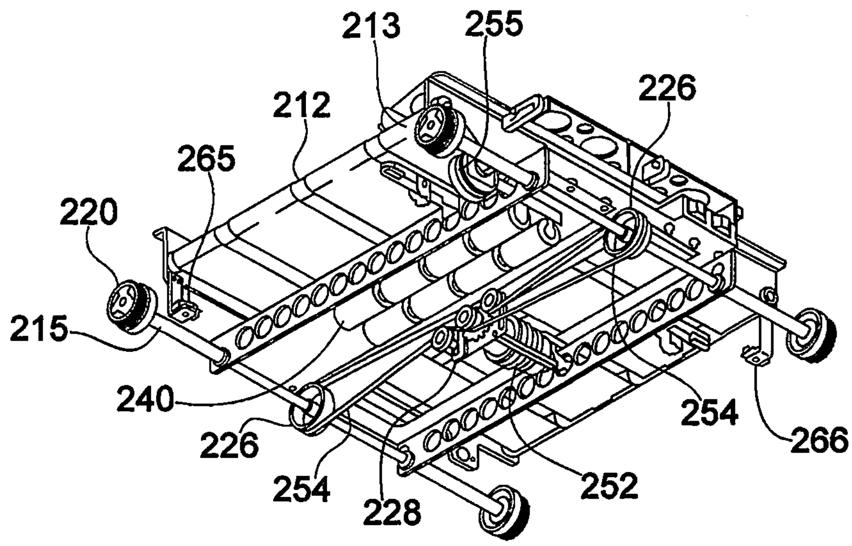
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Fig. 16

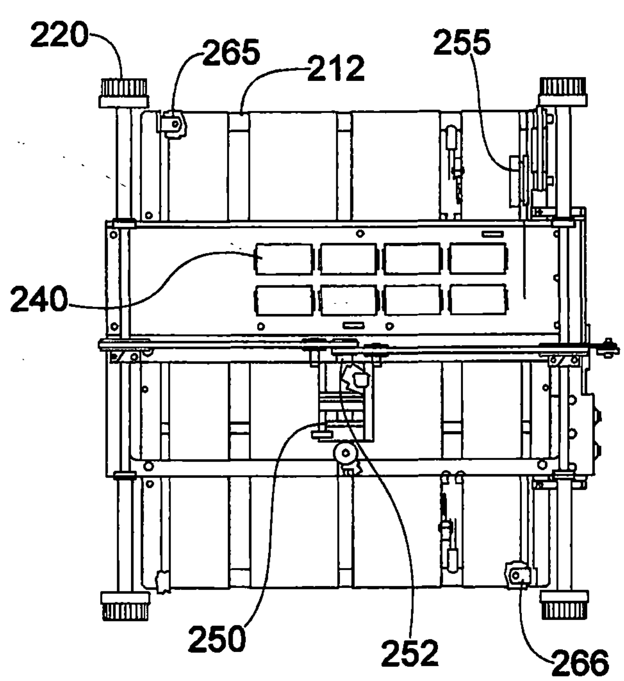
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Fig. 17

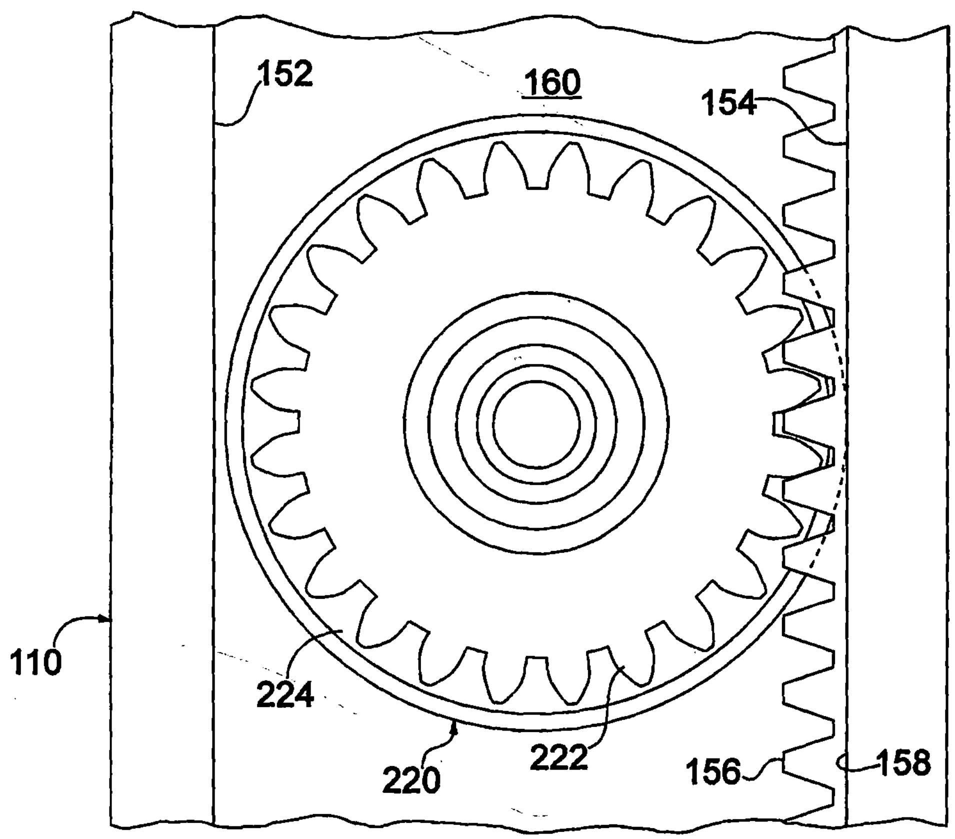

Fig. 18

MATERIAL HANDLING APPARATUS FOR DELIVERING OR RETRIEVING ITEMS

PRIORITY CLAIMS

The present application is a continuation of co-pending application U.S. patent application Ser. No. 14/149,282, filed Jan. 7, 2014 which is set to issue as U.S. Pat. No. 9,010,517 on Apr. 21, 2015, which is a continuation of U.S. patent application Ser. No. 13/631,817, filed Sep. 28, 2012 issued as U.S. Pat. No. 8,622,194 on Jan. 7, 2014, which is a continuation of U.S. patent application Ser. No. 13/361,490 filed Jan. 30, 2012 issued as U.S. Pat. No. 8,276,740 on Oct. 2, 2012, which is a continuation of U.S. patent application Ser. No. 12/983,726 filed Jan. 3, 2011 issued as U.S. Pat. No. 8,104,601, which is a continuation of U.S. patent application Ser. No. 12/014,011 filed Jan. 14, 2008 issued as U.S. Pat. No. 7,861,844, which claims priority to U.S. Provisional Patent Application No. 60/884,766 filed on Jan. 12, 2007. The present application claims priority to each of the foregoing applications and the entire disclosure of each of the foregoing applications is hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to a material handling system for sorting or retrieving items. More specifically, the present invention relates to a material handling system incorporating a plurality of destination areas arranged along a track for guiding a plurality of vehicles for carrying items to and/or from the destination areas.

BACKGROUND OF THE INVENTION

Sorting documents and mail pieces manually is laborious and time consuming. For example, thousands of large organizations employ numerous people full-time to manually sort and deliver incoming and interoffice mail and documents. For instance, a large company may receive 5,000 mail pieces that need to be sorted and delivered each day to different departments and/or individuals. Such volumes require a significant number of employees dedicated to sorting and delivering the mail. Nonetheless, such volume is not typically sufficient to justify the expense of traditional automated sorting equipment, which is quite expensive. Additionally, the mail for such organizations is typically quite diverse, which makes it more difficult, and therefore more expensive, to automate the sorting procedures.

Various systems for sorting have been developed to address the needs of mail rooms for large organizations. However, the known systems suffer from several problems; the most significant are cost and size. Accordingly, there is a need for a compact and affordable automated sorting system that is able to meet the needs of mid- to large-sized organization that handle several thousand mail pieces each day.

Similarly, may large organizations have extensive storage areas in which numerous items are stored. Sorting and retrieving items from the hundreds or thousands of storage areas requires significant labor to perform manually, and the known systems of automatically handling the materials are either very expensive or have limitations that hamper their effectiveness. Accordingly, there is a need in a variety of material handling applications for automatically storing and/or retrieving items.

SUMMARY OF THE INVENTION

In light of the foregoing, a system provides a method and apparatus for delivering items to storage locations. The system includes a plurality of storage locations, such as bins, and a plurality of delivery vehicles for delivering items to the storage locations or retrieving items from the storage locations. A track guides the delivery vehicles to the storage locations.

In one embodiment, a controller controls the operation of the delivery vehicles based on information determined for each item to be sorted. Additionally, the track may include a plurality of interconnected vertical and horizontal sections so that the vehicles may travel along a continuous path changing from a horizontal direction to a vertical direction. Further, the vehicles may be driven such that the orientation of an item on the vehicle stays constant as the vehicles changes from a horizontal direction of travel to a vertical direction of travel.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary and the following detailed description of the preferred embodiments of the present invention will be best understood when read in conjunction with the appended drawings, in which:

FIG. **1** is a perspective view of a sorting apparatus;

FIG. **2** is a plan view of the sorting apparatus illustrated in FIG. **1**;

FIG. **3** is a fragmentary perspective view of the sorting apparatus illustrated in FIG. **1**, shown without an input station;

FIG. **4** is a right side view of the sorting apparatus illustrated in FIG. **3**;

FIG. **5** is a front elevational view of the sorting apparatus illustrated in FIG. **3**, shown without discharge bins;

FIG. **6** is a fragmentary sectional view of a loading station of the sorting apparatus illustrated in FIG. **1**;

FIG. **7** is an enlarged fragmentary perspective view of a portion of the loading station of the apparatus illustrated in FIG. **3**;

FIG. **8** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in an open position;

FIG. **9** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in a closed position;

FIG. **10** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate;

FIG. **11** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate, with the gate shown in an open position in phantom;

FIG. **12** is a top perspective view of a delivery vehicle of the apparatus illustrated in FIG. **1**;

FIG. **13** is a plan view of the delivery vehicle illustrated in FIG. **12**;

FIG. **14** is a right side view of the delivery vehicle illustrated in FIG. **12**;

FIG. **15** is a front elevational view of the delivery vehicle illustrated in FIG. **12**;

FIG. **16** is a bottom perspective view of the delivery vehicle illustrated in FIG. **12**;

FIG. **17** is a bottom view of the delivery vehicle illustrated in FIG. **12**; and

FIG. **18** is an enlarged view of a wheel of the delivery vehicle illustrated in FIG. **12**, shown in relation to the track of the sorting apparatus illustrated in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1-18**, an apparatus for sorting items such as documents or mail pieces is designated generally **10**. The apparatus **10** includes a plurality of delivery vehicles or cars **200** to deliver items to a plurality of sort locations, such as output bins **190**. At a loading station **310**, each car **200** receives an item from an input station **50** and delivers it to the appropriate bin.

The cars **200** travel along a track **110** to the sort locations. The track has a horizontal upper rail **135** and a horizontal lower rail **140**, which operates as a return leg. A number of parallel vertical track legs **130** extend between the upper rail and the lower return leg. In the present instance, the bins **190** are arranged in columns between the vertical track legs **130**.

After a piece is loaded onto a car, the car travels upwardly along two pairs of vertical tracks legs and then horizontally along two upper tracks **135**. The car **200** travels along the upper rail until it reaches the appropriate column containing the bin for the piece that the car is carrying. The track **110** includes gates **180** that fire to direct the car **200** down the vertical legs and the car stops at the appropriate bin. The car **200** then discharges the piece into the bin.

After discharging the piece, the car **200** continues down the vertical legs **130** of the column until it reaches the lower rail **140**. Gates fire to direct the car along the lower rail, and the car follows the lower rail to return to the loading station **310** to receive another piece.

The cars **200** are semi-autonomous vehicles that each have an onboard power source and an onboard motor to drive the cars along the track **110**. The cars also include a loading/unloading mechanism **210**, such as a conveyor, for loading pieces onto the cars and discharging the pieces from the cars.

Since the system **10** includes a number of cars **200**, the positioning of the cars is controlled to ensure that the different cars do not crash into each other. In one embodiment, the system **10** uses a central controller **350** that tracks the position of each car **200** and provides control signals to each car to control the progress of the cars along the track. The central controller **350** may also control operation of the various elements along the track, such as the gates **180**.

Input Station

At the input station **50**, the mail pieces are separated from one another so that the pieces can be conveyed serially to the loading station **310** to be loaded onto the cars **200**. Additionally, at the input station information is determined for each piece so that the piece can be sorted to the appropriate bin.

A variety of configurations may be used for the input station, including manual or automatic configurations or a combination of manual and automated features. In a manual system, the operator enters information for each piece and the system sorts the mail piece accordingly. In an automatic system, the input system includes elements that scan each mail piece and detect information regarding each piece. The system then sorts the mail piece according to the scanned information.

In an exemplary manual configuration, the input system includes a work station having a conveyor, an input device, such as a keyboard, and a monitor. The operator reads information from a mail piece and then drops in onto a conveyor that conveys the piece to the loading station **310**. Sensors positioned along the conveyor track the piece as the conveyor transports the mail piece toward the loading station. An example of a work station having a conveyor for receiving dropped pieces and tracking the pieces is provided in pending U.S. application Ser. No. 10/862,021, filed Jun. 4, 2004, which was published Jan. 27, 2005 under Publication No. US 2005-0018214 A1 and which is incorporated herein by reference. The conveyor receives mail pieces dropped by an operator and tracks the mail pieces as they are transported along the conveyor.

In an exemplary automatic configuration, the system includes an imaging station, having an imaging device such as a high speed line scanning camera. The imaging station scans each mail piece to detect information regarding the destination for each piece. The system analyzes the image data to determine the destination information and then electronically tags the mail piece with the destination and sorts the piece accordingly. An example of a system having an automated imaging station for scanning pieces as they are conveyed is described in U.S. patent application Ser. No. 09/904,471, filed Jul. 13, 2001, which was published Jan. 16, 2003 under Publication No. US 2003-0014376 A1, and which is incorporated herein by reference.

FIGS. **1** and **2** illustrate such an automated system. The input station includes an input bin **55** for receiving a stack of mail. A feeder **60** in the input bin serially feeds mail pieces from the input bin to a conveyor **65**. An imaging station **70** positioned along the conveyor scans the mails pieces as the pieces are conveyed to the loading station **310**. The system **10** analyzes the image data to read information for the mail piece, such as the recipient's address.

The conveyor **65** conveys the mail piece to the loading station **310**. At the loading station the conveyor **65** conveys the mail piece onto a car **200**. As discussed further below, after the mail piece is loaded onto the car, the car moves away from the loading station and another car moves into position at the loading station to receive the next piece of mail.

In certain instances, the system may not be able to automatically identify the relevant information for a mail piece. To process such pieces, the system may include an operator to input the relevant information so that the mail piece can be sorted. For instance, the system may include an operator station having an input device and a display, such as a monitor. If the system cannot automatically determine the address within a pre-determined time period, the system displays the scanned images for the mail piece to the monitor so that the operator at the work station can view the images and manually enter the information using the input device.

In addition to the automated and manual systems described above, the system may be configured in a hybrid or semi-automated configuration having some operations performed manually and others automated. For instance, the system may include a manual input station that also has an imaging station. Since the system can handle a wide variety of items, it may be desirable to have an operator input the pieces manually so that the pieces are properly oriented and separated. The imaging station then scans the items and processes the imaging data to determine the address information for the pieces. Additionally, the operator station may include an input device and a display for inputting information if the address for a piece cannot be automatically determined, as discussed above. The operator can input the information as soon as the system indicates to the operator that it cannot determine the information for a piece. Alternatively, as discussed below, the car may be directed to a buffer if the information for a piece cannot be determined. In such an instance, the cars having such pieces will remain in the buffer while the system continues to process pieces for which the system can determine the relevant information. The operator can continue to manually drop pieces and wait until a number of pieces need manual keying of information. The operator can then switch from the operation of dropping pieces to the operation of manually keying the pieces, sometimes referred to as local video encoding (LVE). The operator can continue keying until some or all of the pieces in the buffer have been successfully coded, and then the operator can go back to the operation of manually dropping pieces. As yet another alternative, it may be desirable to incorporate a separate operator station having the input device and display so that one operator can input the mail at the input station and a separate operator can input the information for pieces having addresses that cannot be automatically determined.

As can be seen from the foregoing, the input station **50** may be configured in a wide range of options. The options are not limited to those configurations described above, and may include additional features, such as an automated scale for weighing each piece, a labeler for selectively applying labels to the mail pieces and a printer for printing information on the mail pieces or on the labels.

Additionally, in the foregoing description, the system is described as having a single input station **50**. However, it may be desirable to incorporate a plurality of input stations positioned along the system **10**. By using a plurality of input stations, the feed rate of pieces may be increased. In addition, the input stations may be configured to process different types of items. In this way, each input station could be configured to efficiently process a particular category of items. For instance, if the system is configured to process documents, such as mail, one input station may be configured to process standard envelopes, while another input station may be configured to process larger mails, such as flats. Similarly, one input station may be configured to automatically process mail by scanning it and automatically determining the recipient. The second input station may be configured to process rejects, such as by manually keying in information regarding the recipient.

Sorting Station

Referring to FIGS. **1-6**, the system includes a sorting station **100**, such as an array of bins **190** for receiving the pieces. In the present instance, the sorting station includes a number of bins arranged in columns. Additionally, the sorting station **100** includes a track **110** for guiding the cars **200** to the bins **190**.

The track **110** includes a horizontal upper rail **135** and a horizontal lower rail **140**. A plurality of vertical legs **130** extend between the upper horizontal leg and the lower horizontal leg **140**. During transport, the cars travel up a pair of vertical legs from the loading station **310** to the upper rail **135** (as described below, the cars actually travel up two pairs of rails because the track includes a forward track and a parallel opposing track). The car then travels along the upper rail until reaching the column having the appropriate bin. The car then travels downwardly along two front vertical posts and two parallel rear posts until reaching the appropriate bin, and then discharges the mail piece into the bin. The car then continues down the vertical legs until reaching the lower horizontal leg **140**. The car then follows the lower rail back toward the loading station.

As can be seen in FIG. **2**, the track **110** includes a front track **115** and a rear track **120**. The front and rear tracks **115**, **120** are parallel tracks that cooperate to guide the cars around the track. As shown in FIG. **13**, each of the cars includes four wheels **220**: two forward wheel and two rearward wheels. The forward wheels **220** ride in the front track, while the rearward wheel ride in the rear track. It should be understood that in the discussion of the track the front and rear tracks **115**, **120** are similarly configured opposing tracks that support the forward and rearward wheels **220** of the cars. Accordingly, a description of a portion of either the front or rear track also applies to the opposing front or rear track.

Referring to FIG. **18** the details of the track will be described in greater detail. The track **110** includes an outer wall **152** and an inner wall **154** that is spaced apart from the outer wall and parallel to the outer wall. The track also has a back wall **160** extending between the inner and outer walls. As can be seen in FIG. **18**, the outer and inner walls **152**, **154** and the back wall form a channel. The wheels **220** of the car ride in this channel.

Referring to FIG. **11**, the track includes both a drive surface **156** and a guide surface **158**. The drive surface positively engages the cars to enable the car to travel along the track. The guide surface **158** guides the car, maintaining the car in operative engagement with the drive surface **156**. In the present instance, the drive surface is formed of a series of teeth, forming a rack that engages the wheels of the cars as described further below. The guide surface **158** is a generally flat surface adjacent the rack **156**. The rack **156** extends approximately halfway across the track and the guide surface **158** extends across the other half of the track. As shown in FIGS. **11** and **18**, the rack **156** is formed on the inner wall **154** of the track. The opposing outer wall **152** is a generally flat surface parallel to the guide surface **158** of the inner wall.

As described above, the track includes a plurality of vertical legs extending between the horizontal upper and lower rails **135**, **140**. An intersection **170** is formed at each section of the track at which one of the vertical legs intersects one of the horizontal legs. Each intersection includes an inner branch **172** that is curved and an outer branch **176** that is generally straight. FIG. **10** illustrates both a right-hand intersection **170***c* and a left-hand intersection **170**, which are mirrors of one another. In FIG. **10**, the intersections **170***c*, **170***d* illustrate the portion of the track in which two vertical legs **130** intersect the upper horizontal leg **135**. The intersections of the vertical legs with the lower rail incorporate similar intersections, except the intersections are reversed. Specifically, the point at which vertical leg **130***c* intersects the lower rail incorporates an intersection configured similar to intersection **170***d*, and the point at which vertical leg **130***d* intersects the lower rail incorporates an intersection configured similar to intersection **170***c*.

Each intersection **170** includes a pivotable gate **180** that has a smooth curved inner race and a flat outer race that has teeth that correspond to the teeth of the drive surface **156** for the track. The gate **180** pivots between a first position and a second position. In the first position, the gate **180** is closed so that the straight outer race **184** of the gate is aligned with the straight outer branch **176** of the intersection. In the second position, the gate is open so that the curved inner race **182** of the gate is aligned with the curved branch **172** of the intersection.

Accordingly, in the closed position, the gate is pivoted downwardly so that the outer race **184** of the gate aligns with the drive surface **156**. In this position, the gate blocks the car from turning down the curved portion, so that the car continues straight through the intersection. In contrast, as illustrated in FIG. **10**, when the gate is pivoted into the open position, the gate blocks the car from going straight through the intersection. Instead, the curved inner race **182** of the gate aligns with the curved surface of the inner branch **172** and the car turns through the intersection. In other words, when the gate is closed, a car goes straight through the intersection along either the upper rail **130** or the lower rail, depending on the location of the intersection. When the gate is opened, the gate directs the car from either a vertical rail to a horizontal rail or from a horizontal rail to a vertical rail, depending on the location of the intersection.

As can be seen in FIG. **11**, the end of the gate remote from the pivot point of the gate flares outwardly so that the curved inner race matches the curved profile of the inner branch when the gate is open. As a result, the gate has a generally L-shaped configuration. To accommodate the flared end of the gate **180**, the drive surface **156** of the inner branch has a notch or recessed portion. When the gate is closed, the notch provides clearance so that the outer race **184** of the gate lies flat, parallel with the drive surface of the outer branch **176**. Further, in the example shown in FIG. **11**, the gate is positioned along the upper rail **135** of the track **110**. When the gate is closed, the recess in the inner branch of the intersection **170** allows the gate to lie flat so that it is aligned with the drive surface of the upper rail.

In the foregoing description, the gates allow one of the cars to either continue in the same direction (e.g. horizontally) or turn in one direction (e.g. vertically). However, in some applications, the system may include more than two horizontal rails that intersect the vertical columns. In such a configuration, it may be desirable to include a different rail that allows the cars to turn in more than one direction. For instance, if a car is traveling down a column, the gate may allow the car to turn either left or right down a horizontal rail, or travel straight through along the vertical column. Additionally, in some applications it may be desirable to allow the cars to travel upwardly, whereas in the system described above, the cars only travel downwardly through the sorting station. If the cars also travel upwardly in the sorting station, then the gates should be configured to accommodate and guide the cars when the cars travel upwardly through an intersection.

The gates **180** are controlled by signals received from the central controller **350**. Specifically, each gate is connected with an actuator **186** that displaces the gate from the opened position to the closed position and back. There may be any of a variety of controllable elements operable to displace the gate. In the present instance, the actuator **186** is a solenoid having a linearly displaceable piston.

In the foregoing description, the sorting station **100** is described as a plurality of output bins **190**. However, it should be understood that the system may include a variety of types of destinations, not simply output bins. For instance, in certain applications it may be desirable to sort items to a storage area, such as an area on a storage shelf. Alternatively, the destination may be an output device that conveys items to other locations. According to one example of an output device, the system may include one or more output conveyors that convey pieces away from the sorting system toward a different material handling or processing system. For instance, an output conveyor designated A may convey pieces to a processing center designated A. Therefore, if a piece is to be delivered to processing center A, the car will travel along the track to output conveyor A. Once the car reaches output conveyor A, the car will stop and transfer the piece onto output conveyor A. Output conveyor A will then convey the piece to processing center A. Further, it should be understood that the system may be configured to include a plurality of output devices, such as output conveyors.

In some embodiments, the system may include a plurality of output conveyors in addition to the output bins. In other embodiments, the system may only include a plurality of output devices, such as conveyors, and the system is configured to sort the pieces to the various output devices. Further still, the system may be configured to retrieve pieces from storage locations. In such embodiments, the cars may sort pieces to a storage location, such as a bin. Subsequently, one of the cars may travel to the storage location and retrieve the item from the storage location and transport it to one of the output devices.

One manner that the cars may retrieve items from the storage locations is by including a conveyor at the storage locations. In this way, an item at a storage location can be conveyed by the conveyor toward the track. When a car arrives at the storage location, the conveyor at the storage location conveys the item onto the car, similar to the manner in which a piece is loaded onto the car at the loading column. Accordingly, the system can sort pieces to a plurality of output devices, in addition to sorting pieces to a plurality of storage locations before subsequently retrieving the pieces and conveying the pieces to the output devices.

As discussed above, the system is operable to sort a variety of items to a plurality of destinations. One type of destination is a bin; a second type is a shelf or other location on which the item is to be stored; and a third type of destination is an output device that may be used to convey the item to a different location. The system may include one or more of each of these types or other types of destinations.

Delivery Vehicles

Referring now to FIGS. **12-17**, the details of the delivery vehicles **200** will be described in greater detail. Each delivery vehicle is a semi-autonomous car having an onboard drive system, including an onboard power supply. Each car includes a mechanism for loading and unloading items for delivery.

The car **200** may incorporate any of a variety of mechanisms for loading an item onto the car and discharging the item from the car into one of the bins. Additionally, the loading/unloading mechanism **210** may be specifically tailored for a particular application. However, in the present instance, the loading/unloading mechanism **210** is a conveyor belt. Specifically, referring to FIG. **12**, the loading/unloading mechanism includes a plurality of narrow belts **212** that extend along the top surface of the car. The conveyor belts are reversible. Driving the belts in a first direction displaces the item toward the rearward end of the car; driving the belt in a second direction displaces the item toward the forward end of the car.

A conveyor motor **255** mounted on the underside of the car drives the conveyor belts **212**. Specifically, the conveyor belts **212** are entrained around a forward roller **213** at the forward edge of the car, and a rearward roller at the rearward edge of the car. The conveyor motor **255** is connected with the forward roller **213** to drive the forward roller, thereby operating the conveyor belts.

The car includes four wheels **220** that are used to transport the car along the track **110**. The wheels **220** are mounted onto two parallel spaced apart axles **215**, so that two or the wheels are disposed along the forward edge of the car and two of the wheels are disposed along the rearward edge of the car.

Referring to FIG. **18**, each wheel comprises an inner idler roller **224** and an outer gear **222** that cooperates with the drive surface **156** of the track. The idler roller **224** rotates freely relative to the axles, while the outer gear is fixed relative to the axle onto which it is mounted. In this way, rotating the axle operates to rotate the gear **222**. Additionally, the idler roller is sized to have a diameter slightly smaller than the distance between the upper wall **152** and the lower wall **154** of the track. In this way, the idler roller may rotate freely within the track, while ensuring that the gear **222** of each wheel remains in operative engagement with the drive surface (i.e. the teeth) **156** of the track. Accordingly, when the vehicle is moving horizontally, the rollers carry the weight of the cart, while the gears **222** cooperate with the drive surface **156** of the track to drive the vehicle along the track.

The car includes an onboard motor **250** for driving the wheels **220**. More specifically, the drive motor **250** is operatively connected with the axles to rotate the axles **215**, which in turn rotates the gears **222** of the wheels. As shown in FIG. **16**, the drive motor **250** is interconnected to the axles **215** via a pair of drive belts **254** that are driven by the drive motor.

The drive system for the car may be configured to synchronously drive the car along the track. In the present instance, the drive system is configured so that each gear is driven in a synchronous manner. Specifically, each gear **222** is connected to an end of one of the axles in a manner that substantially impedes rotation of the gear relative to the axle. In this way each axle drives the attached two gears in a synchronous manner. Additionally, in the present instance, both axles are driven in a synchronous manner so that all four gears are driven in a synchronous manner. There are various mechanisms that can be used to synchronously drive the axles. For instance, a pair of drive motors can be used to drive the axles, and the drive motors can be synchronized. However, in the present instance, a single drive motor **250** is used to drive both axles. Each axle includes a timing pulley **226** that is rigidly connected to the axle to prevent rotation of the pulley relative to the axle. Similarly, a timing pulley **228** is connected to the motor shaft. The drive belt **254** connecting the timing pulley **226** on the axle with the motor is a timing belt so that the rotation of the drive motor is precisely linked to the rotation of the axle. Although a single timing belt can be used to drive both axles synchronously, in the present instance, a pair of timing pulleys is connected to the motor shaft, and each timing pulley is connected to a corresponding timing pulley on one of the axles, as shown in FIG. **16**.

The drive motor **250** includes a sensor that is operable to detect the rotation of the motor to thereby determine the distance the car has traveled. Since the gears **222** are rigidly connected with the axles, which are in turn synchronously connected with the drive motor, the forward distance that the car moves corresponds can be exactly controlled to correlate to the distance that the drive motor is displaced. Accordingly, the distance that a car has traveled along the determined path depends on the distance through which the car motor is rotated.

To detect the rotation of the drive motor **250**, the motor includes a sensor **252** for detecting the amount of rotation of the drive motor. In the present instance the sensor **252** is a hall sensor. A portion of rotation of the motor corresponds to what is referred to as a tick. The sensor detects the number of ticks and sends a signal to the central processor **350**, which determines how far along the designate path the car has traveled based on the known information regarding the path and the number of ticks that the sensor detects for the motor.

As the car travels along the track, an item on top of the car may tend to fall off the car, especially as the car accelerates and decelerates. Therefore, in the present instance, the car includes a retainer **230** to retain the element on the car during delivery. As illustrated in FIGS. **12-17**, the retainer **230** is a hold down that clamps the item against the top surface of the car.

The retainer includes an elongated pivotable arm **232**. A biasing element, such as a spring, biases the arm downwardly against the top surface of the retainer **230**. The retainer **230** further includes an operator **234** in the form of a tab. Pushing downwardly on the tab raises the clamp from the top surface of the conveyor to allow a piece to be loaded onto the car or discharged from the car.

The car **200** may be powered by an external power supply, such as a contact along the rail that provides the electric power needed to drive the car. However, in the present instance, the car includes an onboard power source **240** that provides the requisite power for both the drive motor **250** and the conveyor motor **255**. Additionally, in the present instance, the power supply is rechargeable. Although the power supply may include a known power source, such as a rechargeable battery, in the present instance, the power supply **240** is made up of one or more ultracapacitors. Ultracapacitors are extremely high energy density capacitors. Capacitors store electrical energy by physically separating positive and negative charges, in contrast to the chemical means a battery uses. Ultracapacitors rely on an electrostatic effect, which is physical rather than chemical, and highly reversible. The ultracapacitors can accept very high amperage to recharge the ultracapacitors. By using a high current, the ultracapacitors can be recharged in a very short time, such as a few seconds or less.

The car includes one or more contacts for recharging the power source **240**. In the present instance, the car includes a plurality of brushes **245**, such as copper brushes that are spring-loaded so that the brushes are biased outwardly. The brushes **245** cooperate with a charging rail in the loading station to recharge the power source, as described further below.

Each car includes at least one and preferably two load sensors for detecting the items as it is loaded onto the car. The sensor(s) ensure that the mail piece is properly positioned on the car. In the present instance, the car includes a forward loading sensor **260** and a rearward loading sensor **262**. The forward loading sensor detects the leading edge of the item as it is loaded onto the car. The forward loading sensor **260** also detects the trailing edge of the item to ensure that the entire length of the item is loaded onto the car. Similarly, the rearward sensor **262** detects the leading edge and in certain instances, may detect the trailing edge of the mail piece. The loading sensors **260**, **262** may be simple I/R sensors that detect the presence or absence of a document or mail piece.

Although the car operates in response to signals received from the central controller **350**, which tracks the location of each car, the car may also include a reader **265** for reading indicia along the track to confirm the position of the car. For instance, each bin may be assigned a unique bar code, and the forward reader may scan the track or other area around the bin **190** at which an item is to be delivered. The data that the central processor has regarding the path that the car is to follow and the data regarding the distance the car has traveled based on the data regarding the rotation of the drive motor **250** should be sufficient to determine whether the car **200** is positioned at the appropriate bin. Nonetheless, it may be desirable to double check the location of the car before the item is discharged into the appropriate bin. Therefore, the scanner may operate to scan and read information regarding the bin at which the car is stopped. If the scanned data indicates that the bin is the appropriate bin, then the car discharges its item into the bin. Similarly, the car may have a second reader **266** for reading indicia adjacent the rearward edge of the car. The second reader **266** may be used in applications in which the system is set up to utilize a first series of bins **190** along the forward side and a second series of bins along the rearward side of the track **110**.

In foregoing description, the cars have drive gears that interact with teeth in the track to guide the cars around the track. Additionally, as described further below in the operation section, the location of the car may be controlled based on information regarding how far the car has traveled. In such applications it is desirable to synchronize the drive wheels of the car. However, in some applications alternative control systems may be used. For instance, the location of the cars can be controlled based on signals from sensors positioned along the track or indicators positioned along the track. In such instances, the cars may be configured to use a drive mechanism that is not synchronous as described above.

As discussed further below, the car further includes a processor for controlling the operation of the car in response to signals received from the central processor. Additionally, the car includes a wireless transceiver so that the car can continuously communicate with the central processor as it travels along the track. Alternatively, in some applications, it may be desirable to incorporate a plurality of sensors or indicators positioned along the track. The car may include a reader for sensing the sensor signals and/or the indicators, as well as a central processor for controlling the operation of the vehicle in response to the sensors or indicators.

Loading Column

Referring now to FIGS. **6-7** the details of the loading column **300** will be described in greater detail. The loading column **300** is formed adjacent the output end of the input station **50**. The loading column **300** is formed of a front pair of vertical rails **305***a*, **305***b* and a corresponding rearward set of vertical rails. The loading station **310** is positioned along the loading column. The loading station **310** is the position along the track in which the car **200** is aligned with the discharge end of the conveyor of the input station **50**. In this way, a mail piece from the input station may be loaded onto the car as it is conveyed toward the car from the input station.

Although the central processor **350** tracks the position of the car, a home sensor **312** is positioned adjacent the loading station **310**. When the home sensor detects the car, the position for the car is known relative to a fixed point along the track, and the central processor resets the position of the car to the home or zero position.

Referring to FIG. **7**, a pair of charging rails are disposed along the vertical rails **305***a*, **305***b*. The charging rails are conductive strips connected with an electrical supply. The charging contacts **245** of the car **200** engage the conductive strips to recharge the ultracapacitors **240**. Specifically, the biasing element of the brushes **245** biases the brushes outwardly toward the charging contacts. The electricity flowing through the charging contact **245** is a high amperage, low voltage source that allows the ultracapacitors to recharge in a few seconds or less. In addition, since the power supply provided by the ultracapacitors last for only a few minutes, the car recharges each time it travels through the loading column.

Additionally, it may be desirable to incorporate a startup charging rail similar to the charging rails described above, but disposed along either the return rail or the rails in the column adjacent to the loading column, depending on where the cars are stored when the cars are shut down. Since the cars use ultracapacitors, it is possible that the ultracapacitors will discharge while the system is shut down. Therefore, upon startup the cars will not have any charge and will not be able to move to the loading column to charge the ultracapacitors. Accordingly, the system may include a startup charging rail disposed along a rail that the cars contact when the cars are stored during shutdown. If the cars are stored in the loading column and the adjacent column during shutdown, then the startup rail is disposed in the column adjacent the loading column. Alternatively, if the cars are stored on the return rail and the loading column during shutdown, then the startup rail is disposed along the return rail. In this way, when the system is started, a charging current is supplied to the cars through the startup charging rail and the charging rail in the loading column.

As discussed previously, each car **200** includes a retainer **230** to hold down items on the car during transport. The retainer should be opened at the loading station to allow an item to be loaded onto the car. Accordingly, as shown in FIG. **6**, an actuator **316** is positioned along the column. The actuator **316** projects inwardly toward the cars as the cars are conveyed up the loading column. As a car is conveyed upwardly in the loading column **300**, the hold down actuator **316** contacts the hold down operator or tab **236**. The interaction between the actuator **316** and the tab **236** causes the retainer to open, so that items can be loaded onto the car. As the car moves upwardly past the actuator **316**, the tab **236** on the car disengages the actuator, thereby releasing the retainer, thereby holding down or clamping the mail piece against the top surface of the vehicle.

In the foregoing description, the loading station has been described as a column in which an item is loaded onto the car and the car then travels upwardly to the horizontal upper rail **135**. However, in some applications in may be desirable to configure the loading station so that the items are loaded onto the cars at or near the top of the vertical column. In such an application, the load on the cars would be reduced since the car will not have to lift the item loaded on the car. In order to load the items on the cars at the top of the conveyor, a vertical conveyor may be added to the system. For instance, a conveyor angled upwardly may convey the items upwardly to the top of the column to load the items onto the cars. Alternatively, one or more of a variety of conveyor configurations can be used to transport to items toward the top of the loading column to load the items onto the cars.

Operation

The system **10** operates as follows. An item is processed at the input station **50** to identify a characteristic of the piece that is indicative of where the piece should be sorted. For instance, the item may be a mail piece that is to be sorted according to department, box number or recipient. If the mail pieces are sorted by department, the piece may be processed to identify either an indicator of the department (such as box number) or the piece may be processed to identify the recipient. The central controller maintains a database that correlates various data to identify the destination bin. For instance, the database may correlate the recipient names with the appropriate department if the mail is being sorted according to department. In other embodiments, the piece may be a part that has a product code and the database may correlate the product code with the sort location.

As discussed previously, the input station may process the items automatically or manually. In a manual mode, the operator manually enters information regarding a piece and then drops the piece on a conveyor. The system electronically tags the piece with the sort information and the conveyor conveys the piece toward the loading station. Alternatively, if the input system is an automated system, the piece is automatically scanned to identify the relevant sort characteristic. For instance, the input station may use a scanner, such as a bar code scanner to read the postnet code on a piece, or the input station may include an imaging device, such as a high speed line scan camera in combination with an OCR engine to read information on the piece.

To prepare to receive an item, a car **200** moves along the track toward the loading station **310** in the loading column **300**. As the car approaches the loading station, the operator **236** for the hold down **230** engages the actuator **316**, which pivots the hold down upwardly to prepare the car to receive an item, as illustrated in FIG. **6**. When the car **200** moves into position at the loading station **310** the home sensor detects the presence of the car and sends a signal to the central processor **350** indicating that the car is positioned at the loading station. In the following description, the item being sorted is described as being a mail piece. It should be understood that such an item is an exemplary application of the system. As described above, the system can be configured to sort a variety of items in a variety of material handling applications.

Once the car is positioned at the loading station, the input station conveys a mail piece onto the car. As the mail piece is being conveyed onto the car **200**, the loading mechanism **210** on the car loads the mail piece onto the car. Specifically, the input station conveys the mail piece into contact with the conveyor belts **212** on the car. The conveyor belts **212** rotate toward the rearward side of the car, thereby driving the mail piece rearwardly on the car.

The operation of the conveyor belts is controlled by the loading sensors **260**, **262**. The forward loading sensor detects the leading edge of the mail piece as the mail piece is loaded onto the car. Once the forward loading sensor **260** detects the trailing edge of the mail piece, a controller onboard the car determines that the mail piece is loaded on the car and stops the conveyor motor. Additionally, the onboard controller may control the operation of the conveyor in response to signals received from the rearward sensor **262**. Specifically, if the rearward sensor **262** detects the leading edge of the mail piece, then the leading edge of the mail piece is adjacent the rearward edge of the car. To ensure that the mail piece does not overhang from the rearward edge of the car, the controller may stop the conveyor once the rearward sensor detects the leading edge of the mail piece. However, if the rearward sensor detects the leading edge of the mail piece before the forward sensor detects the trailing edge of the mail piece, the controller may determine that there is a problem with the mail piece (i.e. it is too long or two overlapping mail pieces were fed onto the car. In such an instance, the car may communicate an error message with the central controller, which may declare an error and provide an indicator to the operator that the car at the loading station requires attention. Alternatively, a reject bin **325** may be positioned behind the loading station so that mail pieces on the car at the loading station can be ejected into the reject bin **325**. In this way, if there is an error loading a mail piece onto a car, the mail piece can simply be ejected into the reject bin, and a subsequent mail piece can be loaded onto the car.

After a mail piece is loaded onto the car, the car moves away from the loading station. Specifically, once the onboard controller detects that a mail piece is properly loaded onto the car, the onboard controller sends a signal to start the drive motor **250**. The drive motor **250** rotates the axles, which in turn rotates the gears **222** on the wheels **220**. The gears **222** mesh with the drive surface **156** of the vertical rails **305** in the loading column to drive the car upwardly. Specifically, the gears and the drive surfaces mesh and operate as a rack and pinion mechanism, translating the rotational motion of the wheels into linear motion along the track **110**.

Since the cars move up the loading column from the loading station, the destination for the car does not need to be determined until after the car reaches the first gate along the upper rail **135**. For instance, if an automated system is used at the input station to scan and determine the characteristic used to sort the mail pieces, it may take some processing time to determine the relevant characteristic. The time that it takes to convey the mail piece onto the car and then convey the car up the loading column will typically be sufficient time to determine the relevant characteristic for the mail piece. However, if the characteristic is not determined by the time the car reaches the upper rail, the car may be directed down the second column, which is the column next to the loading column. The car travels down the second column to the lower rail **140**, and then back to the loading column. The car may stop in the second column to provide additional time to determine the characteristic. However, after waiting for a pre-determined period the system may declare that the address cannot be determined and the car may be advanced from the second column and the piece may be discharged to a reject bin. Alternatively, rather than declare an error the car may continue to travel around the loop from the loading column to the second column until the characteristic is determined or until a predetermined time at which the central controller declares an error. Additionally, rather than using the reject bin when the system is unable to determine the characteristic for a mail piece, one of the bins in the second column can also be used as a reject bin. In this way, the cars are ready to receive a mail piece as soon as the car reaches the loading station, without having to eject the problem mail piece into the reject bin **325** at the loading station.

As described above, the system includes a loop that can be utilized as a buffer track to provide additional processing time to analyze the characteristic for the mail piece if necessary. Although the first and second columns can be used as the buffer loop, other columns can be used as a buffer loop if desired.

The foregoing discussion described the process for buffering a car if the system is unable to determine the characteristic for the mail piece by the time the car reaches the top rail. However, for most mail pieces, the system should be able to identify the characteristic without having to buffer the car. The following discussion describes the operation of the system assuming that the characteristic for the mail piece is determined before the car reaches the upper rail **135**.

Once the characteristic for the mail piece is determined, the central controller **350** determines the appropriate bin **190** for the mail piece. Based on the location of the bin for the mail piece, the route for the car is determined. Specifically, the central controller determines the route for the car and communicates information to the car regarding the bin into which the mail piece is to be delivered. The central controller then controls the gates along the track to direct the car to the appropriate column. Once the car reaches the appropriate column the car moves down the column to the appropriate bin. The car stops at the appropriate bin **190** and the onboard controller sends an appropriate signal to the conveyor motor **255** to drive the conveyor belts **212**, which drives the mail piece forwardly to discharge the mail piece into the bin. Specifically, the top of the car aligns with the gap between the appropriate bin **190** and the bottom edge of the bin that is immediately above the appropriate bin.

As discussed above, the central controller **350** controls the operation of the gates **180** in response to the location of the car **200** and the route that the car is to follow to deliver the mail piece. Additionally, as discussed below, the central controller controls the gates in response to the position of other cars on the track.

As the car **200** travels along the upper rail **135** and approaches a column, the gates for the vertical rails **130** are controlled as follows. If the car is to pass over the column on the way to the next column, the gates are displaced into the closed position, as shown in FIG. **9**. Specifically, both gates at the top of the column are closed so that the outer race **184** of the gate aligns with the straight track, with the outer race aligning with the drive surface **156** of the track **110**. In this way, the gates provide a straight drive surface that cooperates with the drive surface **156** to allow the car to travel over the column.

When the car comes to a column that it is to turn down, the gates are controlled as follows. Referring to FIG. **5**, the columns can be seen without the bins attached. The view in FIG. **5** is from the front of the apparatus **10**, so the car will be traveling along the upper rail from the right to the left in the perspective of FIG. **5**. In the following discussion, the car is to be conveyed to a bin in the column designated C in FIG. **5**. Column C includes two pairs of vertical legs. The first pair is front and back vertical legs **130*c*** on the left side of column C; the second pair is front and back vertical legs **130*d*** on the right side of column C.

In order for the car to travel down column C, the wheels on the left side of the car travel down legs **130*c*** and the right side wheels travel down legs **130*d***. Therefore, as the car approaches column C, the gates at the top of **130*d*** are displaced to the closed position so that the left side wheels remain on the upper rail and pass over the right side legs **130*d***. After the left side wheels of the car pass over the right legs **130*c***, the gates **180** at the top of the right legs **130*d*** are displaced into the open position so that the right side wheels can turn down legs **130*d***. Specifically, after the left side wheels pass right legs **130*d***, the central controller operates the solenoids **186** of the gates **180** at the top of legs **130** to displace the gates into the open position, as shown in FIG. **8** (note that the view in FIG. **8** is taken from the rear side of the apparatus so that the perspective of the gates is reversed relative to the front side). The gates **180** block the straight path through the intersection **170** and the curved inner race **182** of the gates direct the right side wheels down vertical legs **130*d***. Similarly, the gates **180** at the top of the left side legs **130*c*** are displaced into the open position to direct the left side wheels down vertical legs **130*c***.

As the car approaches the intersections at the bottom of legs **130*c*** and **130*d***, the gates are operated similarly to the above description, but in reverse. Specifically, as the car approaches the intersections **170** at the bottom of legs **130*c*** and **130*d***, the gates **180** in the intersections are displaced into the opened position so that the gates direct the forward and leading wheels to turn down the lower rail. From the perspective of FIG. **5**, the car travels from left to right after the car reaches the lower rail. After the car passes though the intersections at the bottom of the rails **130*c***, **130*d***, the gates at the bottom of right side legs **130*d*** are displaced into the closed position before the left side wheels of the car reach the intersection at the bottom of the right side legs **130*d***. In this way, the left side wheels of the car pass straight through the intersection at the bottom of legs **130*d*** along the bottom rail **140**.

As discussed above, the central controller **350** controls the operation of the gates in response to the position of the car and more specifically in response to the position of the left hand and right hand wheels of the car. The gates are fired sequentially to ensure that the different pairs of wheels are directed down the proper vertical legs. Alternatively, the operation of the gates may be controlled by signals received from the cars. Specifically, the cars may include a transmitter that transmits a signal to the central controller indicating that it is in proximity to a gate that is to be fired. Further still, the car may include an indicator that may be scanned as the car approaches the gate. Based on the indicator and the know destination for the car, the gate may fire. Still further, the car may include an mechanical actuator that selectively triggers or actuates a gate to appropriately direct the car.

One of the advantages of the system as described above is that the orientation of the cars does not substantially change as the cars move from travelling horizontally (along the upper or lower rails) to vertically (down one of the columns). Specifically, when a car is travelling horizontally, the two front geared wheels **220** cooperate with the upper or lower horizontal rail **135** or **140** of the front track **115**, and the two rear geared wheels **220** cooperate with the corresponding upper or lower rail **135** or **140** of the rear track **120**. As the car passes through a gate and then into a column, the two front geared wheels engage a pair of vertical legs **130** in the front track **115**, and the two rear geared wheels engage the corresponding vertical legs in the rear track **120**.

As the car travels from the horizontal rails to the vertical columns or from vertical to horizontal, the tracks allow all four geared wheels to be positioned at the same height. In this way, as the car travels along the track it does not skew or tilt as it changes between moving horizontally and vertically. Additionally, it may be desirable to configure the cars with a single axle. In such a configuration, the car would be oriented generally vertically as opposed to the generally horizontal orientation of the cars described above. In the single axle configuration, the weight of the cars would maintain the orientation of the cars. However, when using a single axle car, the orientation of the sort locations would be re-configured to accommodate the vertical orientation of the cars. Similarly, the loading station would also be re-configured to load the pieces onto the cars in the vertical orientation.

Traffic Control

Since the system includes a number of cars **200**, the system controls the operation of the different cars to ensure the cars do not collide into one another. In the following discussion, this is referred to as traffic control.

A variety of methodologies can be used for traffic control. For instance, the traffic control can be a distributed system in which each car monitors its position relative to adjacent cars and the onboard controller controls the car accordingly. One example of such as system utilizes proximity sensors on each car. If the proximity sensor for a car detects a car within a predefined distance ahead of the car, the onboard controller for the trailing car may control the car by slowing down or stopping the trailing car. Similarly, if a car detects a car within a predefined distance behind the car, the lead car may speed up unless the lead car detects a car ahead of it within the predefined distance. In this way, the cars may control the speed of the cars independently based on the feedback from the proximity sensors.

Although the system may use a distributed system for traffic control, in the present instance, the system uses a centralized system for traffic control. Specifically, the central controller **350** tracks the position of each car **200** and provides traffic control signals to each car based on the position of each car relative to adjacent cars and based on the route for each car.

In the present instance, the central controller **350** operates as the traffic controller, continuously communicating with the cars as the cars travel along the track **110**. For each car, the central controller determines the distance that each car can travel, and communicates this information with the cars. For instance, if car B is following car A along the track, and car A is at point A, car B can safely travel to a point just before point A without crashing into car A. As car A advances to a subsequent point B along the track, car B can travel safely to a point just before point B without crashing into car A.

The cars continuously communicate with the central controller to provide information indicative of their positions, so that the central controller can continuously update the safe distances for each car as the cars advance around the track.

Although the foregoing discussion is limited to determining safe zones based on the positions of the various cars on the track, the determination of safe zones is based on other factors that affect the traffic. For instance, when calculating the safe distance for a car, the central controller considers the distance between the car and the next gate, as well as the distance to the destination bin for the car.

As can be seen from the foregoing, increasing the frequency of communication between the cars and the central controller increases the efficiency of the traffic flow along the track. Accordingly, in the present instance, the traffic control is designed to communicate with a car once for every inch the car travels along the track. Therefore, if a car travels at 25 inches per second, the central controller communicates with the car every 40 msec. Further, it is desirable to have the cars travel at up to 50 inch/sec. Therefore, it is desirable to configure the communications to allow the cars to communicate with the central controller every 20 msec.

In addition, to the foregoing variables used to calculate safe distances, information regarding the track profile ahead of each car is used to calculate safe distances. For instance, the central controller determines whether the path ahead of a car is sideways movement, uphill movement (i.e. movement vertically upwardly) or downhill movement (i.e. movement vertically downwardly).

One of the issues in traffic control relates to merging at intersections **170**. The problem arises when a car needs to merge onto the return rail **140**. If two cars will arrive at the intersection close enough to collide, one of the cars needs to have priority and the other car needs to wait or slow down to allow the first car to go through.

A first method for controlling merging traffic is based on determining the next gap large enough for a car to have time to pass through an intersection without colliding with another car. In other words, if a first car approaches an intersection and it is determined that the gap between the first car and a second car is not sufficient for the first car to pass through, the first car waits at the intersection until there is a gap large enough to allow the first car to pass through.

A second method for controlling merging traffic is based on determining which car is closest to the homing sensor at the loading station **310**. The car with the shortest distance to the homing sensor gets priority at the intersection.

Another factor that the traffic controller considers when calculating safe distances relates to the position of cars in adjacent columns. In the present instance, most of the adjacent columns share a common vertical rail. For instance, in FIG. **5**, the leftmost column uses vertical rails **130*a*** and **130*b***. The column next to the leftmost column uses vertical rails **130*b*** and **130*c***.

However, in the present instance, some of the columns may have two vertical rails **130** that are independent from the adjacent columns. For instance, the loading column **300** has two independent rails that are not shared with the adjacent column. Therefore, cars can travel up the loading column without regard to the position of cars in the column next to the loading column. Furthermore, as shown in FIG. **5**, it may be desirable to configure the column next to the loading column so that it also has two independent vertical rails. In this way, cars can more freely travel up the loading column and down the adjacent column to provide a buffer loop as described previously.

Accordingly, when calculating safe distances, the traffic controller evaluates the position of cars in adjacent columns if the cars share a common vertical rail to ensure that the two cars do not collide as the car travel down the adjacent columns.

In the foregoing discussion, the sorting of items was described in relation to an array of bins disposed on the front of the sorting station **100**. However, as illustrated in FIGS. **2** & **4**, the number of bins in the system can be doubled by attaching a rear array of bins on the back side of the sorting station. In this way, the cars can deliver items to bins on the front side of the sorting station by traveling to the bin and then rotating the conveyor on the car forwardly to eject the piece into the front bin. Alternatively, the cars can deliver items to bins on the rear side of the sorting station by traveling to the bin and then rotating the conveyor on the car rearwardly to eject the piece into the rear bin.

Additionally, the sorting station **100** is modular and can be readily expanded as necessary simply by attaching an additional section to the left end of the sorting station. Further, although the foregoing describes the array of bins as being essentially a two dimensional array in which the cars simply travel in X and Y directions, the sorting station can be expanded to add additional "runs" of track. Specifically, a separate sorting station parallel to or perpendicular to the sorting station illustrated in FIG. **2** may be connected to the sorting station. In this way, the car would travel in a third dimension relative to the X and Y directions of the sorting station illustrated in FIG. **2**. For instance, additional sections of track may be connected to the sorting station illustrated in FIG. **2** perpendicular to the illustrated sorting station, so that the additional track forms an L-shape intersecting the loading column. In such a configuration, gates selectively direct the cars either down the upper rail **135** or rearwardly toward the additional track. Similarly, a plurality of parallel rows of sorting stations can be interconnected so that the cars selectively travel along a crossover rail until the car reaches the appropriate row. The car then travels down the row until it reaches the appropriate column as described above.

It will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the broad inventive concepts of the invention. For instance, in the foregoing description, the operation of the sorting station is described as being centralized with the central controller. However, it may be desirable to have the cars control the operation of the gates. According to one alternative, the cars incorporate one or more mechanical actuators that cooperate with an operator on the gate. The actuators on the cars are operable between first and second positions. In a first position, the actuator engages the gate operator to displace the gate into the closed position. In a second position, the actuator engages the gate to displace the gate into the open position. Alternatively, the gate may be biased toward the opened position, so that when the car actuator is in the second position it does not engage the gate operator. In another alternative, each car includes a mechanism for communicating with each gate. If the gate needs to be pivoted to direct an approaching car along a particular path, the car sends a signal to the gate indicating whether the gate should be opened or closed. In response to the signal from the car, the gate pivots to the appropriate position.

Further, in the above description, the system uses a wireless communication between the cars and the central controller. In an alternative embodiment, a communication line may be installed on the track and the cars may communicate with the central controller over a hard wired communication link. Still further, the system has been described as being useful in sorting incoming mail. However, the system may also be utilized to sort and prepare outgoing mail. For instance, after determining a characteristic for a mail piece, the system may print a marking onto the mail piece. For instance, after determining the recipient's address for a mail piece, the system determines which bin the mail piece is to be sorted to. As the mail piece is conveyed to the bin, a printer prints the appropriate postnet bar code on the piece before sorting the piece. To provide the printing functionality, the system may include a printer disposed along the track. When the car approaches the printer the car stops and at least partially discharges the mail piece to extend the mail piece toward the printer. The printer then prints the appropriate postnet code. The car then reverses the conveyors to load the piece back onto the car all the way, and then travels to the appropriate bin. Similarly, the system may include a device for selectively applying labels to the pieces. Similar to the above example of printing markings onto the pieces, the labeler may be positioned along the track. The cars selectively stop at the labeler on route to the appropriate bin and at least partially discharge the mail piece toward the labeler. The labeler then applies a label onto the mail piece and the conveyor on the car then reverses to load the piece back onto the car.

In addition to outgoing mail applications, it may be desirable to incorporate a printer and/or a labeler in systems configured to process incoming mail. For instance, when sorting incoming mail pieces, it may be desirable to print certain information, such as sort codes, a time stamp or audit trail information onto some or all of the pieces being processed. In some instances such information may be printed directly onto the mail pieces. In other instances, a label may be applied to the mail pieces and the information may be printed on the label.

In addition to a printer and a labeler, the system may include a scale for weighing the mail pieces. The scale may be positioned along the track **110**, such as along the loading column. To weigh a piece, the car stops adjacent the scale, and ejects the piece from the car onto the scale by driving the conveyor belts **212**. Preferably, the scale includes a conveyor or transfer mechanism for discharging the piece from the scale and back onto the car or onto a subsequent car. When the piece is loaded onto the car from the scale, the car drives the conveyors to load the piece as discussed above in connection with the loading station.

It should therefore be understood that this invention is not limited to the particular embodiments described herein, but is intended to include all changes and modifications that are within the scope and spirit of the invention as set forth in the claims.

What is claimed is:

1. A material handling system for sorting or retrieving a plurality of items, comprising:

a plurality of vehicles for delivering and retrieving items, wherein each vehicle delivers an item to a destination and wherein each vehicle comprises an on-board motor for driving the vehicle;

a track for guiding the vehicles, wherein the track comprises:

a plurality of horizontal track sections vertically spaced apart from one another and extending in a generally horizontal direction;

a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the vertical track sections intersect the horizontal track sections to form a loop; and

an intersection where one of the horizontal track sections intersects one of the vertical track sections, wherein the intersection provides a first path in a generally horizontal direction and a second path in a generally vertical direction;

wherein at least one of the vehicles comprises a drive element that interacts with an engagement surface of one of the vertical track sections to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between one of the horizontal track sections and the one vertical track sections.

2. The system of claim **1** wherein the track comprise an upper leg and a lower leg spaced apart from the lower leg and the vertical track segments connect the upper leg with the lower leg to form a loop so that the vehicles can travel along the upper leg, then down one of the vertical track segments to the lower leg.

3. The system of claim **2** wherein the track comprises a gates at the intersection, wherein in a first position the gates allow the vehicle to travel through the intersection and remain on the upper leg and wherein in a second position the gates allow the vehicle to travel down the vertical leg.

4. The system of claim **1** wherein the track comprises a gate at an intersection of one of the horizontal tracks and one of the vertical tracks, wherein in a first position the gate allows the vehicle to travel through the intersection and remain on the horizontal track and wherein in a second position the gate allows the vehicle to change direction and travel on the vertical track.

5. The system of claim **1** comprising a controller for controlling the movement of the vehicles to direct each vehicle, wherein the controller receives data relating to the position of each vehicle to control the movement of the vehicles to ensure that vehicles do not collide.

6. The system of claim **1** wherein the each vehicle comprises a drive system comprising a plurality of engagement elements that mesh with engagement elements on the track.

7. The system of claim **6** wherein the engagement elements of the drive system comprise a plurality of teeth.

8. A material handling system, comprising:

a plurality of delivery vehicles, wherein each vehicle is operable to deliver an item to or retrieve an item from a destination area and wherein each vehicle comprises:

a generally horizontal platform for receiving an item to be stored or retrieved;

a drive mechanism comprising a pair of forward drive elements spaced apart from one another and a pair of reward drive elements spaced apart from one another;

a motor for driving the forward drive elements and the rear drive elements;

a track for guiding the delivery vehicles, wherein the track comprises:

a forward track forming a loop for guiding the forward drive elements of the vehicles; and

a rearward track forming a loop for guiding the rearward drive elements of the vehicles;

wherein each of the forward track and the rearward track comprises:

an upper leg extending generally horizontally;

a lower leg spaced apart from the upper leg and extending generally horizontally;

a first connecting leg extending generally vertically and connecting the upper leg with the lower leg; and

a second connecting leg spaced apart from the first connecting leg and connecting the upper leg with the lower leg;

wherein the drive mechanism of each vehicle interacts with the track to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between the upper or lower leg and the first or second connecting leg.

9. A material handling system, comprising:

a plurality of delivery vehicles for transporting items, wherein each vehicle has a forward end and a rearward end, and wherein each vehicle comprises:

a generally horizontal platform for receiving an item to be stored or retrieved;

a drive mechanism;

a motor for driving the drive mechanism;

a track for guiding the delivery vehicles, wherein the drive mechanism of each vehicle engages the track so that the track guides the movement of the vehicles, wherein the track comprises:

a forward track forming a loop for guiding the forward end of the vehicles; and

a rearward track forming a loop for guiding the rearward end of the vehicles;

wherein each of the forward track and the rearward track are substantially parallel loops having upper and lower horizontal portions connected by connecting tracks having substantially vertical portions;

wherein the drive mechanism of each vehicle interacts with the track to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between the upper portion and one of the substantially vertical portions.

10. The system of claim **9** wherein each vehicle comprises a transfer mechanism for transferring an item between the delivery vehicle and a destination area where an item is to be stored or retrieved by the vehicle.

11. The system of claim **9** comprising a controller configured to calculate a travel route for each vehicle and control the operation of the vehicles so that each vehicle moves along the respective route calculated for the respective vehicle.

12. The system of claim **11** wherein the controller is configured to monitor the positions of the vehicles located on the track and calculate a safe distance for each vehicle and communicate the safe distance to the vehicles, wherein the safe distance for a vehicle corresponds to the distance that the vehicle can advance without interfering with another vehicle on the track.

13. The system of claim **9** wherein the track comprises a gate at an intersection of the upper horizontal portion of the forward track and one of the vertical portions of the forward track, wherein in a first position the gates allow the vehicle to travel through the intersection and remain on the upper horizontal portion and wherein in a second position the gates allow the vehicle to travel down the vertical portion.

14. The system of claim **9** comprising a controller for controlling the movement of the vehicles to direct each vehicle, wherein the controller receives data relating to the position of each vehicle to control the movement of the vehicles to ensure that vehicles do not collide.

15. The system of claim **9** wherein the drive mechanism of each vehicle comprises a plurality of engagement elements that mesh with engagement elements on the track.

16. The system of claim **15** wherein the engagement elements of the drive mechanism comprise a plurality of teeth.

17. The delivery vehicle of claim **16** comprising a pair of synchronously drive axles, wherein the drive mechanism comprises gears fixed to the axles so that the gears are synchronously driven to drive the vehicle along the guide system.

18. The delivery vehicle of claim **15** wherein the drive system is operable to engage the forward track on a first side of the vehicle and the rearward track on a second side of the vehicle.

19. The system of claim **8** wherein each vehicle comprises a transfer mechanism for transferring an item between the delivery vehicle and one of the destination areas.

20. The system of claim **8** comprising a controller configured to calculate a travel route for each vehicle and control the operation of the vehicles so that each vehicle moves along the respective route calculated for the respective vehicle.

21. The system of claim **20** wherein the controller is configured to monitor the positions of the vehicles located on the track and calculate a safe distance for each vehicle and communicate the safe distance to the vehicles, wherein the safe distance for a vehicle corresponds to the distance that the vehicle can advance without interfering with another vehicle on the track.

22. The system of claim **8** wherein the track comprises a gates at an intersection of the upper leg of the forward track and the first connecting leg, wherein in a first position the gates allow the vehicle to travel through the intersection and remain on the upper leg and wherein in a second position the gates allow the vehicle to travel down the first connecting leg.

23. The system of claim **8** comprising a controller for controlling the movement of the vehicles to direct each vehicle, wherein the controller receives data relating to the position of each vehicle to control the movement of the vehicles to ensure that vehicles do not collide.

24. The system of claim **8** wherein the forward drive elements comprise a plurality of engagement elements that mesh with engagement elements on the track.

25. The system of claim **24** wherein the engagement elements on the track comprise a plurality of teeth.

26. The delivery vehicle of claim **24** wherein the drive mechanism comprises a pair of synchronously drive axles, wherein the engagement elements comprise gears fixed to the axles so that the gears are synchronously driven to drive the vehicle along the guide system.

27. A material handling system for sorting or retrieving a plurality of items, comprising:

a plurality of vehicles for delivering and retrieving items, wherein each vehicle delivers an item to a destination and wherein each vehicle comprises an on-board motor for driving the vehicle;

a track for guiding the vehicles, wherein the track comprises:

a plurality of horizontal track sections spaced apart from one another and extending in a generally horizontal direction, wherein the horizontal track sections include an upper leg and a lower leg spaced apart from the upper leg;

a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the vertical track sections intersect the horizontal track sections to form a loop so that the vehicles can travel along the upper leg, then down one of the vertical track segments to the lower leg; and

an intersection where one of the horizontal track sections intersects one of the vertical track sections, wherein the intersection provides a first path in a generally horizontal direction and a second path in a generally vertical direction;

wherein at least one of the vehicles comprises a drive element that interacts with the track to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between one of the horizontal track sections and the one vertical track sections.

28. The system of claim **27** wherein the track comprises a gates at the intersection, wherein in a first position the gates allow the vehicle to travel through the intersection and remain on the upper leg and wherein in a second position the gates allow the vehicle to travel down the vertical leg.

29. The system of claim **27** comprising a controller for controlling the movement of the vehicles to direct each vehicle, wherein the controller receives data relating to the position of each vehicle to control the movement of the vehicles to ensure that vehicles do not collide.

30. The system of claim **27** wherein the drive element comprises a plurality of engagement elements that mesh with engagement elements on the track.

31. The system of claim **30** wherein the engagement elements of the drive system comprise a plurality of teeth.

32. A material handling system for sorting or retrieving a plurality of items, comprising:

a plurality of vehicles for delivering and retrieving items, wherein each vehicle delivers an item to a destination and wherein each vehicle comprises an on-board motor for driving the vehicle;

a track for guiding the vehicles, wherein the track comprises:

a plurality of horizontal track sections spaced apart from one another and extending in a generally horizontal direction;

a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the vertical track sections intersect the horizontal track sections to form a loop; and

an intersection where one of the horizontal track sections intersects one of the vertical track sections, wherein the intersection provides a first path in a generally horizontal direction and a second path in a generally vertical direction;

a gate at an intersection of one of the horizontal tracks and one of the vertical tracks, wherein in a first position the gate allows the vehicle to travel through the intersection and remain on the horizontal track and wherein in a second position the gate allows the vehicle to change direction and travel on the vertical track;

wherein at least one of the vehicles comprises a drive element that interacts with the track to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between one of the horizontal track sections and one of the vertical track sections.

33. The system of claim **32** comprising a controller for controlling the movement of the vehicles to direct each vehicle, wherein the controller receives data relating to the position of each vehicle to control the movement of the vehicles to ensure that vehicles do not collide.

34. The system of claim **32** wherein the each vehicle comprises a drive system comprising a plurality of engagement elements that mesh with engagement elements on the track.

35. The system of claim **32** wherein the engagement elements of the drive system comprise a plurality of teeth.

* * * * *

U.S. DEPARTMENT OF COMMERCE • PATENT & TRADEMARK OFFICE •

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,687,883 B2
APPLICATION NO. : 14/690541
DATED : June 27, 2017
INVENTOR(S) : Hayduchok et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

	Reads	Should Read
Column 20, Line 33	"wherein the track comprise"	--wherein the horizontal track sections comprise--
Column 20, Line 34	"from the lower leg"	--from the upper leg--
Column 20, Line 35	"vertical track segments"	--vertical track sections--
Column 20, Line 37-38	"vertical track segments"	--vertical track sections--
Column 23, Line 31-32	"comprises a gates at the intersection"	--comprises a gate at the intersection--
Column 23, Line 32-33	"in a first position the gates allow"	--in a first position the gate allows--
Column 23, Line 34-35	"in a second position the gates allow"	--in a second position the gate allows--

Signed and Sealed this
Sixteenth Day of November, 2021

Drew Hirshfeld
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office

EXHIBIT F

U 8170589

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United States Patent and Trademark Office

October 21, 2021

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THIS OFFICE OF:

U.S. PATENT: *10,576,505*

ISSUE DATE: *March 03, 2020*

By Authority of the

Under Secretary of Commerce for Intellectual Property

and Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

DEPARTMENT OF COMMERCE

R GLOVER

Certifying Officer

US010576505B2

(12) **United States Patent**
Hayduchok et al.

(10) **Patent No.: US 10,576,505 B2**
(45) **Date of Patent: Mar. 3, 2020**

(54) **MATERIAL HANDLING APPARATUS FOR DELIVERING OR RETRIEVING ITEMS**

(71) Applicant: **Opex Corporation**, Moorestown, NJ (US)

(72) Inventors: **George Hayduchok**, Mount Holly, NJ (US); **Robert R. DeWitt**, Marlton, NJ (US)

(73) Assignee: **OPEX Corporation**, Moorestown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/039,713**

(22) Filed: **Jul. 19, 2018**

(65) **Prior Publication Data**

US 2018/0318881 A1 Nov. 8, 2018

Related U.S. Application Data

(63) Continuation of application No. 15/618,744, filed on Jun. 9, 2017, now Pat. No. 10,052,661, which is a continuation of application No. 14/690,541, filed on Apr. 20, 2015, now Pat. No. 9,687,883, which is a continuation of application No. 14/149,282, filed on Jan. 7, 2014, now Pat. No. 9,010,517, which is a continuation of application No. 13/631,817, filed on Sep. 28, 2012, now Pat. No. 8,622,194, which is a

(Continued)

(51) **Int. Cl.**

B07C 7/02	(2006.01)
B61B 13/02	(2006.01)
B61C 11/04	(2006.01)
B65G 1/04	(2006.01)
B65G 1/06	(2006.01)
B07C 3/08	(2006.01)
B07C 7/00	(2006.01)
B65G 67/02	(2006.01)

(52) **U.S. Cl.**

CPC ***B07C 3/087*** (2013.01); ***B07C 7/005*** (2013.01); ***B07C 7/02*** (2013.01); ***B61B 13/02*** (2013.01); ***B61C 11/04*** (2013.01); ***B65G 1/04*** (2013.01); ***B65G 1/065*** (2013.01); ***B65G 67/02*** (2013.01); *Y02T 30/10* (2013.01); *Y02T 30/30* (2013.01)

(58) **Field of Classification Search**

CPC B65G 1/0492; B65G 1/1373; B65G 1/137; B65G 67/02; B65G 1/00; B65G 35/06; B65G 1/04; B65G 1/06; B65G 1/065; Y02T 31/10; Y02T 30/30; B61B 13/02; B61C 11/04; B07C 3/087; B07C 7/005; B07C 7/02

USPC 198/347.1–347.4; 414/279, 280

See application file for complete search history.

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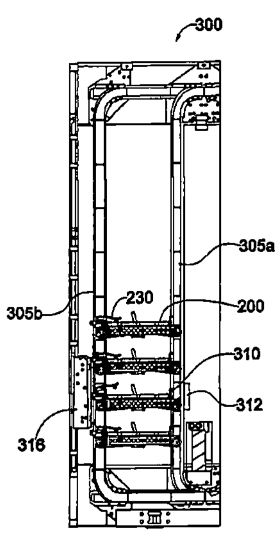
Primary Examiner — James R Bidwell

(74) *Attorney, Agent, or Firm* — Stephen H. Eland

(57) **ABSTRACT**

A method and apparatus are provided for sorting or retrieving items to/from a plurality of destinations areas. The items are loaded onto one of a plurality of independently controlled delivery vehicles. The delivery vehicles follow a track that guides the delivery vehicles to/from the destination areas, which are positioned along the track. Once at the appropriate destination area, an item is transferred between the delivery vehicle and the destination area.

21 Claims, 13 Drawing Sheets



Related U.S. Application Data

continuation of application No. 13/361,490, filed on Jan. 30, 2012, now Pat. No. 8,276,740, which is a continuation of application No. 12/983,726, filed on Jan. 3, 2011, now Pat. No. 8,104,601, which is a continuation of application No. 12/014,011, filed on Jan. 14, 2008, now Pat. No. 7,861,844.

(60) Provisional application No. 60/884,766, filed on Jan. 12, 2007.

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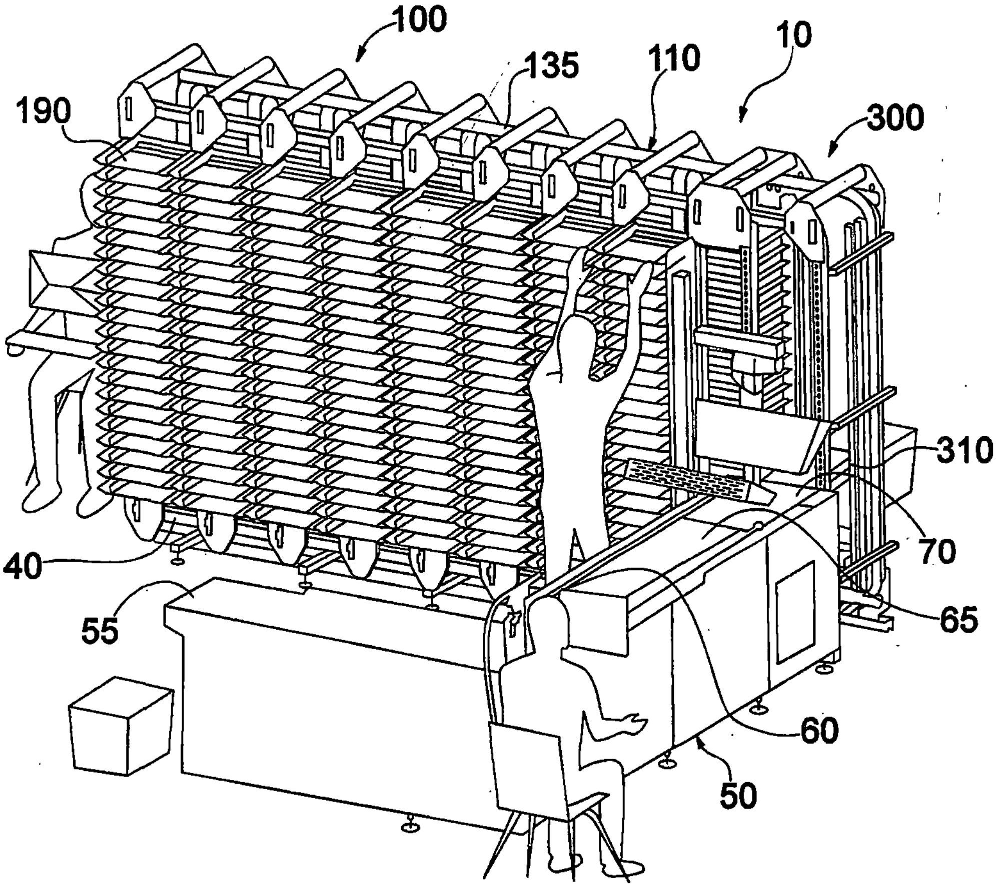

Fig. 1

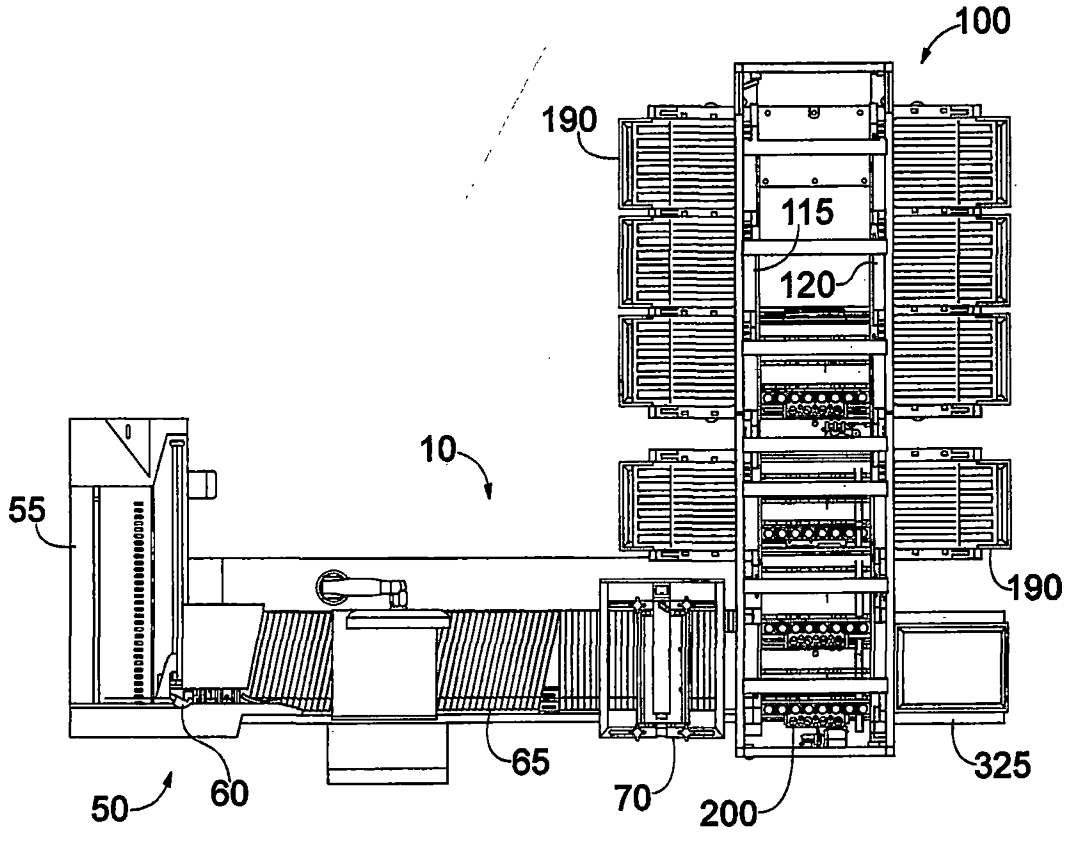

Fig. 2

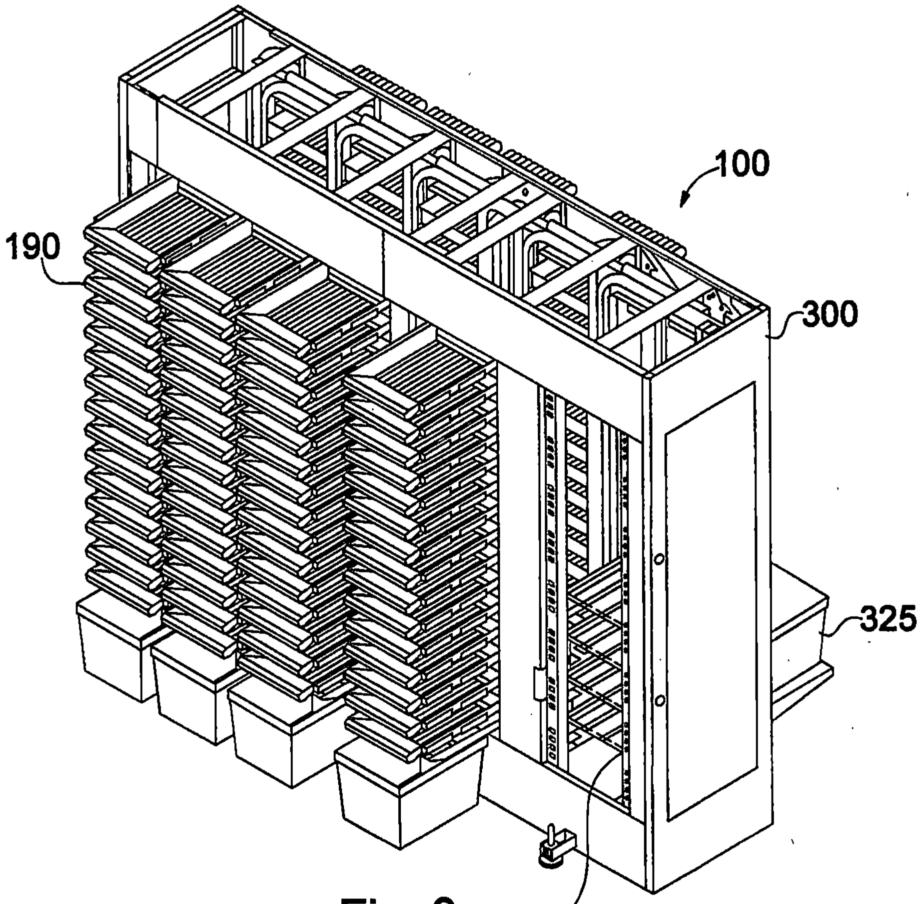

Fig. 3

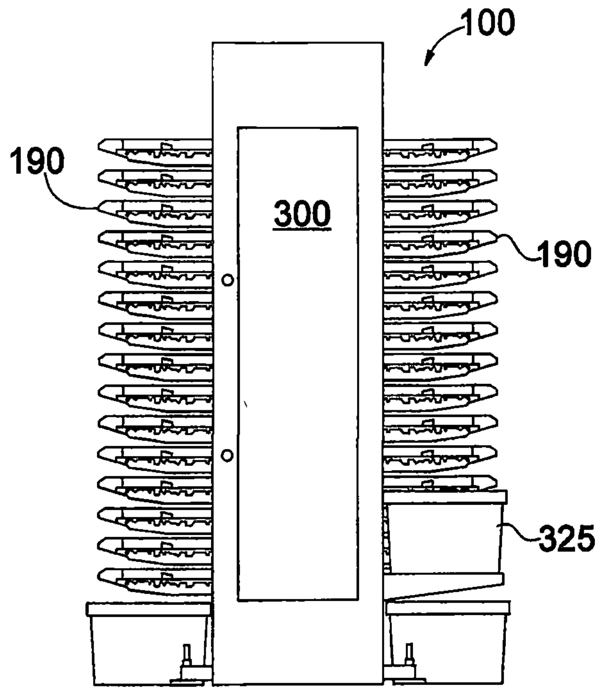

Fig. 4

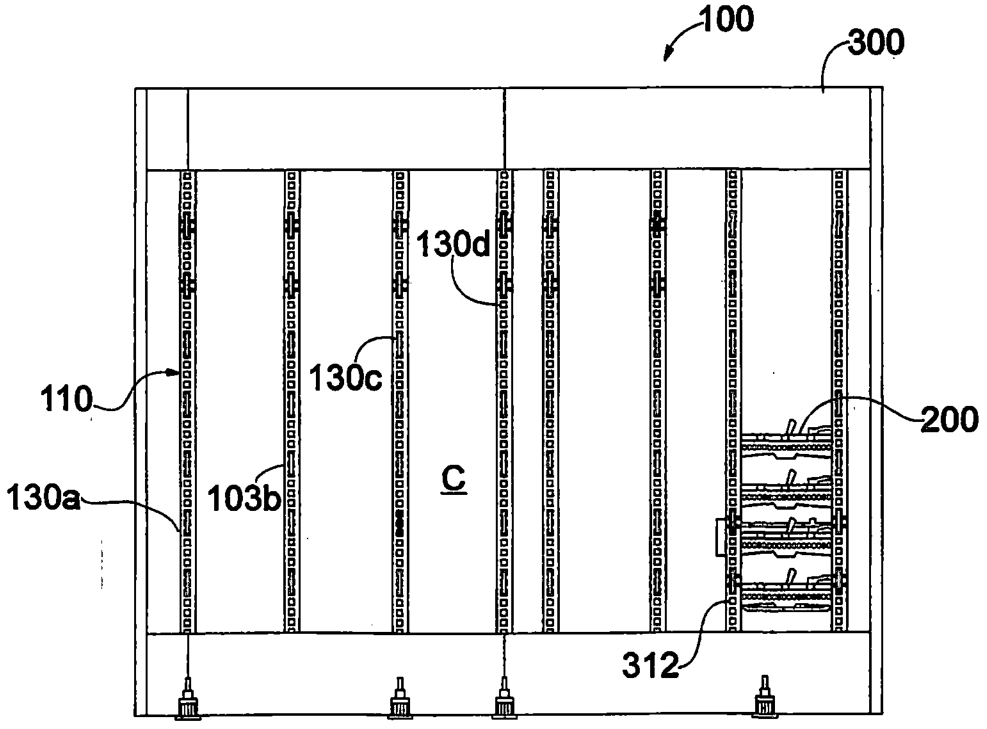

Fig. 5

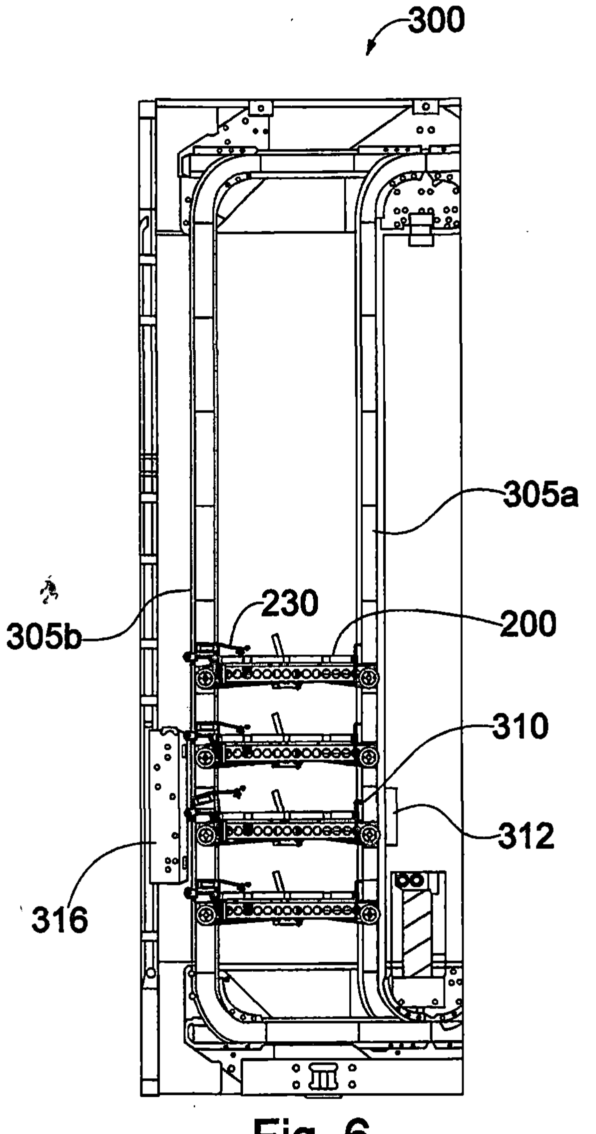

Fig. 6

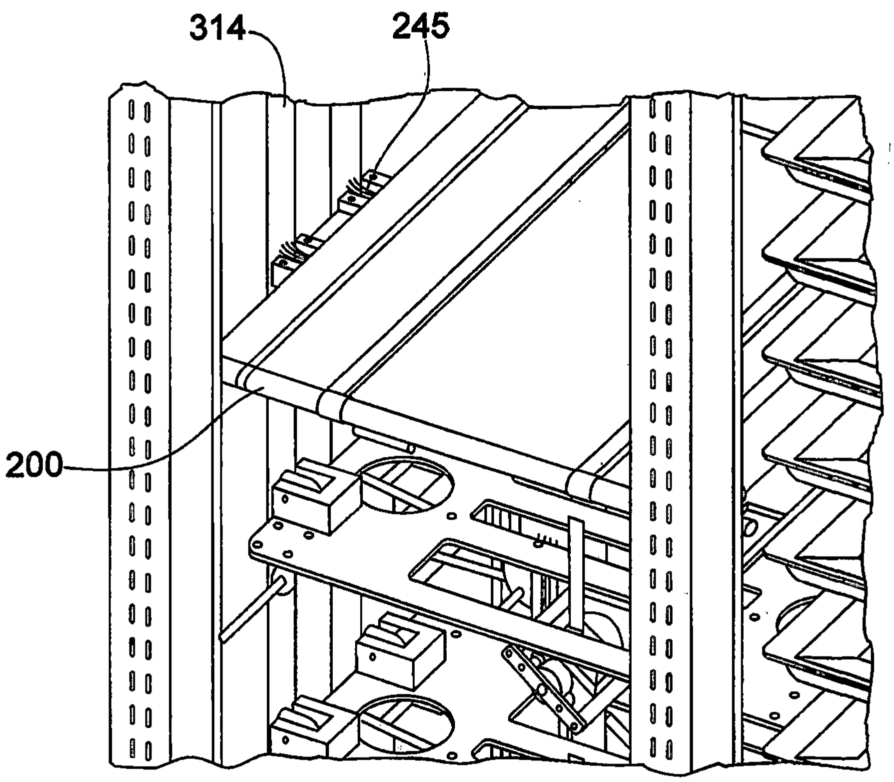

Fig. 7

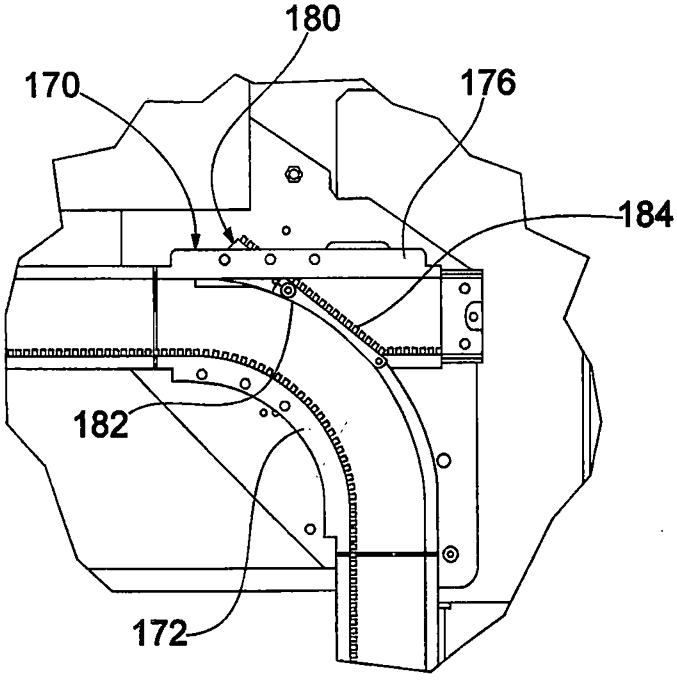

Fig. 8

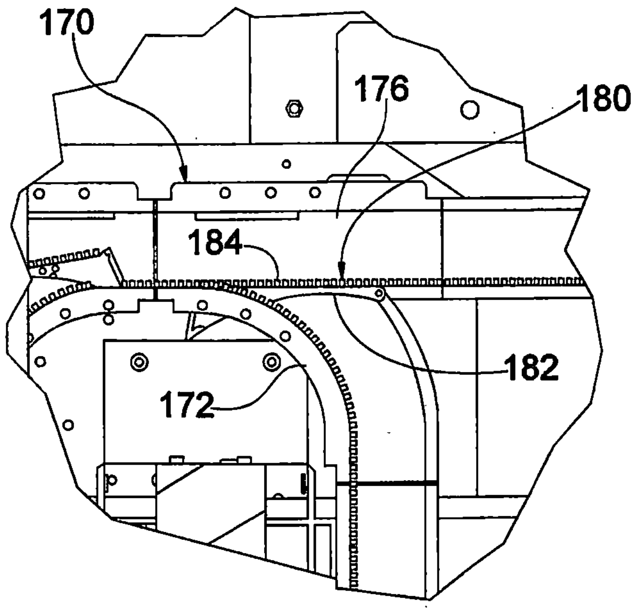

Fig. 9

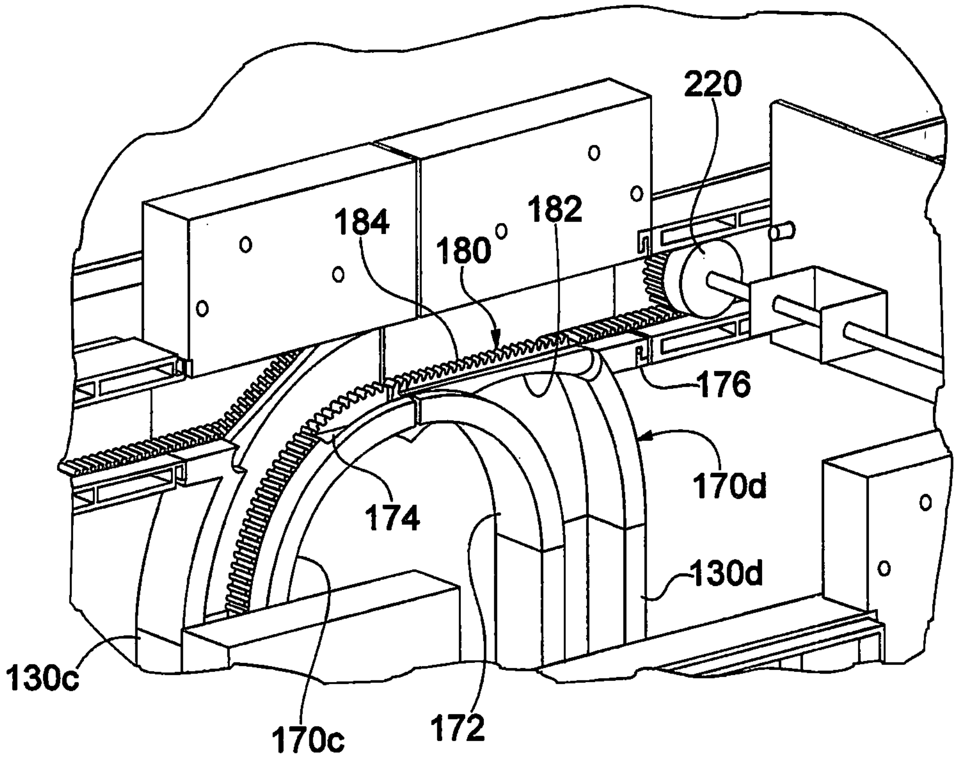

Fig. 10

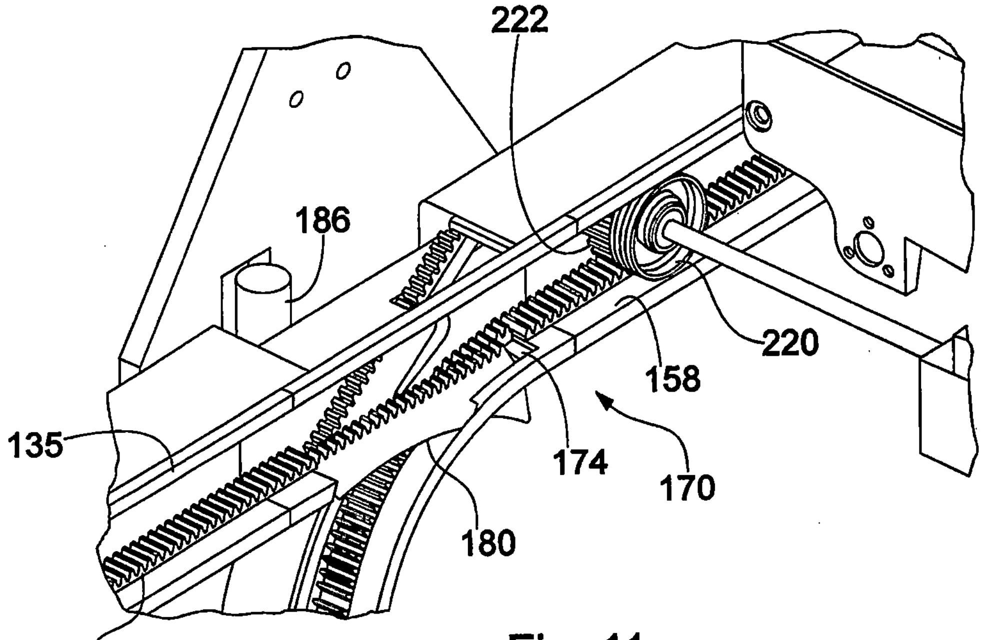

Fig. 11

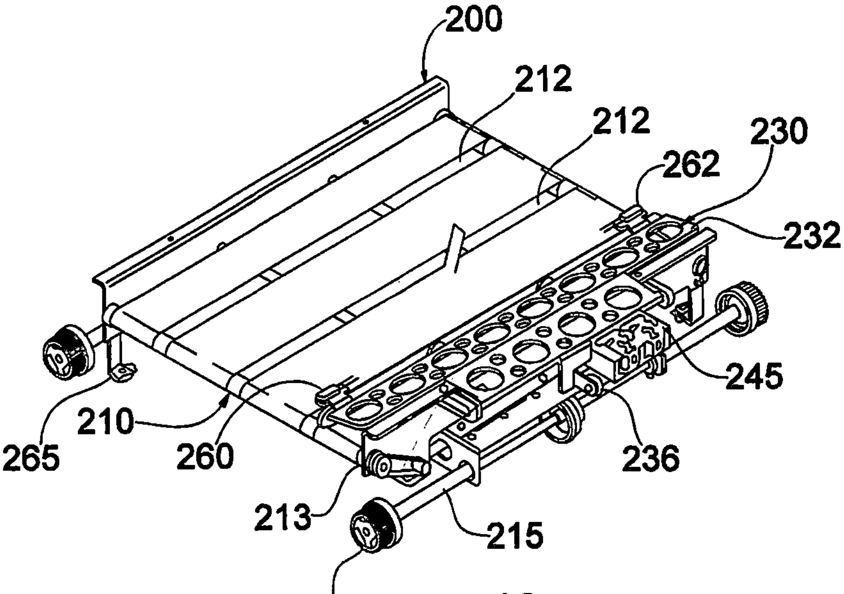
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Fig. 12

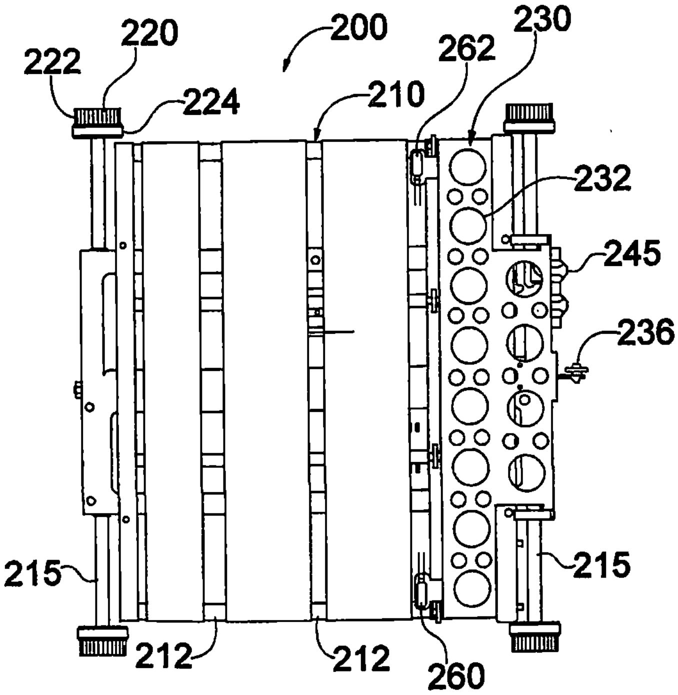
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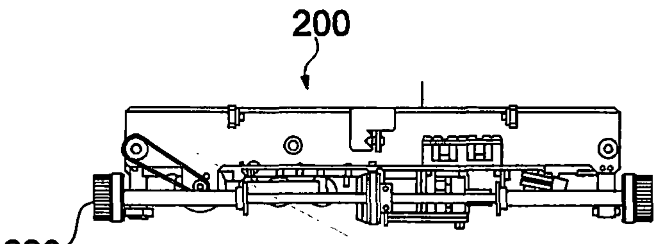
Fig. 13



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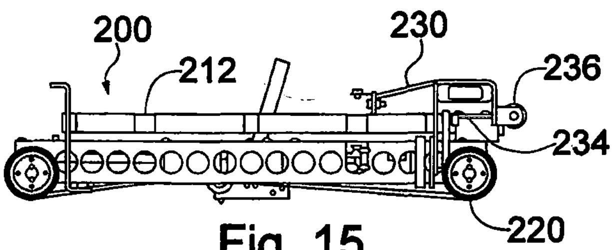

Fig. 15

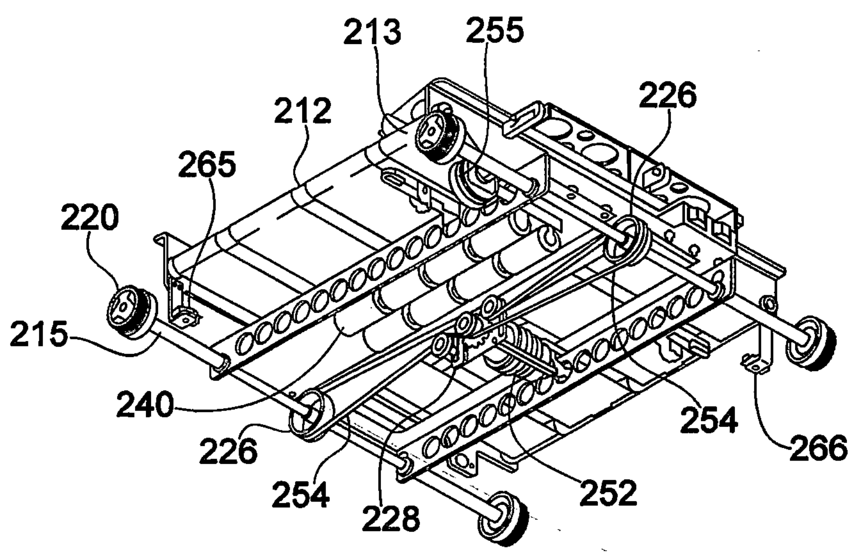
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Fig. 16

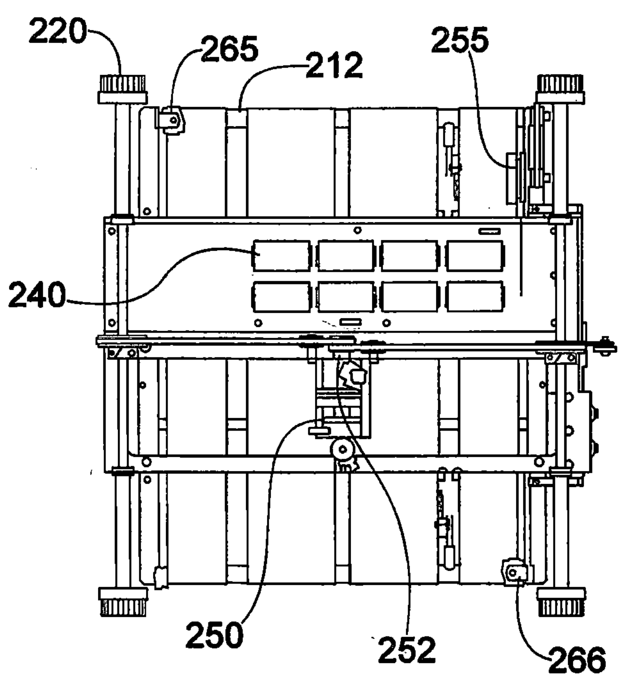
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Fig. 17

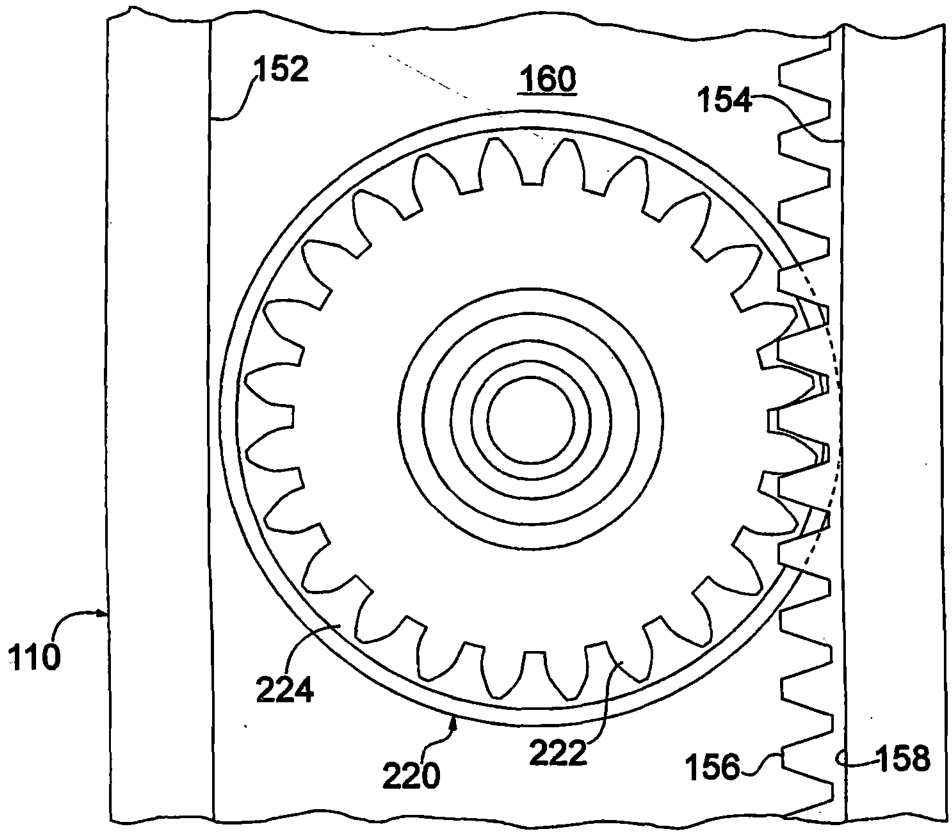

Fig. 18

MATERIAL HANDLING APPARATUS FOR DELIVERING OR RETRIEVING ITEMS

PRIORITY CLAIMS

The present application is a continuation of co-pending application U.S. patent application Ser. No. 15/618,744, filed Jun. 9, 2017, which is a continuation of U.S. patent application Ser. No. 14/690,541, filed Apr. 20, 2015 issued as U.S. Pat. No. 9,687,883, which is a continuation of U.S. patent application Ser. No. 14/149,282, filed Jan. 7, 2014 issued as U.S. Pat. No. 9,010,517, which is a continuation of U.S. patent application Ser. No. 13/631,817, filed Sep. 28, 2012 issued as U.S. Pat. No. 8,622,194, which is a continuation of U.S. patent application Ser. No. 13/361,490 filed Jan. 30, 2012 issued as U.S. Pat. No. 8,276,740, which is a continuation of U.S. patent application Ser. No. 12/983,726 filed Jan. 3, 2011 issued as U.S. Pat. No. 8,104,601, which is a continuation of U.S. patent application Ser. No. 12/014,011 filed Jan. 14, 2008 issued as U.S. Pat. No. 7,861,844, which claims priority to U.S. Provisional Patent Application No. 60/884,766 filed on Jan. 12, 2007. The present application claims priority to each of the foregoing applications and the entire disclosure of each of the foregoing applications is hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to a material handling system for sorting or retrieving items. More specifically, the present invention relates to a material handling system incorporating a plurality of destination areas arranged along a track for guiding a plurality of vehicles for carrying items to and/or from the destination areas.

BACKGROUND OF THE INVENTION

Sorting documents and mail pieces manually is laborious and time consuming. For example, thousands of large organizations employ numerous people full-time to manually sort and deliver incoming and interoffice mail and documents. For instance, a large company may receive 5,000 mail pieces that need to be sorted and delivered each day to different departments and/or individuals. Such volumes require a significant number of employees dedicated to sorting and delivering the mail. Nonetheless, such volume is not typically sufficient to justify the expense of traditional automated sorting equipment, which is quite expensive. Additionally, the mail for such organizations is typically quite diverse, which makes it more difficult, and therefore more expensive, to automate the sorting procedures.

Various systems for sorting have been developed to address the needs of mail rooms for large organizations. However, the known systems suffer from several problems; the most significant are cost and size. Accordingly, there is a need for a compact and affordable automated sorting system that is able to meet the needs of mid- to large-sized organization that handle several thousand mail pieces each day.

Similarly, may large organizations have extensive storage areas in which numerous items are stored. Sorting and retrieving items from the hundreds or thousands of storage areas requires significant labor to perform manually, and the known systems of automatically handling the materials are either very expensive or have limitations that hamper their effectiveness. Accordingly, there is a need in a variety of material handling applications for automatically storing and/or retrieving items.

SUMMARY OF THE INVENTION

In light of the foregoing, a system provides a method and apparatus for delivering items to storage locations. The system includes a plurality of storage locations, such as bins, and a plurality of delivery vehicles for delivering items to the storage locations or retrieving items from the storage locations. A track guides the delivery vehicles to the storage locations.

In one embodiment, a controller controls the operation of the delivery vehicles based on information determined for each item to be sorted. Additionally, the track may include a plurality of interconnected vertical and horizontal sections so that the vehicles may travel along a continuous path changing from a horizontal direction to a vertical direction. Further, the vehicles may be driven such that the orientation of an item on the vehicle stays constant as the vehicles changes from a horizontal direction of travel to a vertical direction of travel.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary and the following detailed description of the preferred embodiments of the present invention will be best understood when read in conjunction with the appended drawings, in which:

FIG. **1** is a perspective view of a sorting apparatus;

FIG. **2** is a plan view of the sorting apparatus illustrated in FIG. **1**;

FIG. **3** is a fragmentary perspective view of the sorting apparatus illustrated in FIG. **1**, shown without an input station;

FIG. **4** is a right side view of the sorting apparatus illustrated in FIG. **3**;

FIG. **5** is a front elevational view of the sorting apparatus illustrated in FIG. **3**, shown without discharge bins;

FIG. **6** is a fragmentary sectional view of a loading station of the sorting apparatus illustrated in FIG. **1**;

FIG. **7** is an enlarged fragmentary perspective view of a portion of the loading station of the apparatus illustrated in FIG. **3**;

FIG. **8** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in an open position;

FIG. **9** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in a closed position;

FIG. **10** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate;

FIG. **11** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate, with the gate shown in an open position in phantom;

FIG. **12** is a top perspective view of a delivery vehicle of the apparatus illustrated in FIG. **1**;

FIG. **13** is a plan view of the delivery vehicle illustrated in FIG. **12**;

FIG. **14** is a right side view of the delivery vehicle illustrated in FIG. **12**;

FIG. **15** is a front elevational view of the delivery vehicle illustrated in FIG. **12**;

FIG. **16** is a bottom perspective view of the delivery vehicle illustrated in FIG. **12**;

FIG. **17** is a bottom view of the delivery vehicle illustrated in FIG. **12**; and

FIG. **18** is an enlarged view of a wheel of the delivery vehicle illustrated in FIG. **12**, shown in relation to the track of the sorting apparatus illustrated in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1-18**, an apparatus for sorting items such as documents or mail pieces is designated generally **10**. The apparatus **10** includes a plurality of delivery vehicles or cars **200** to deliver items to a plurality of sort locations, such as output bins **190**. At a loading station **310**, each car **200** receives an item from an input station **50** and delivers it to the appropriate bin.

The cars **200** travel along a track **110** to the sort locations. The track has a horizontal upper rail **135** and a horizontal lower rail **140**, which operates as a return leg. A number of parallel vertical track legs **130** extend between the upper rail and the lower return leg. In the present instance, the bins **190** are arranged in columns between the vertical track legs **130**.

After a piece is loaded onto a car, the car travels upwardly along two pairs of vertical tracks legs and then horizontally along two upper tracks **135**. The car **200** travels along the upper rail until it reaches the appropriate column containing the bin for the piece that the car is carrying. The track **110** includes gates **180** that fire to direct the car **200** down the vertical legs and the car stops at the appropriate bin. The car **200** then discharges the piece into the bin.

After discharging the piece, the car **200** continues down the vertical legs **130** of the column until it reaches the lower rail **140**. Gates fire to direct the car along the lower rail, and the car follows the lower rail to return to the loading station **310** to receive another piece.

The cars **200** are semi-autonomous vehicles that each have an onboard power source and an onboard motor to drive the cars along the track **110**. The cars also include a loading/unloading mechanism **210**, such as a conveyor, for loading pieces onto the cars and discharging the pieces from the cars.

Since the system **10** includes a number of cars **200**, the positioning of the cars is controlled to ensure that the different cars do not crash into each other. In one embodiment, the system **10** uses a central controller **350** that tracks the position of each car **200** and provides control signals to each car to control the progress of the cars along the track. The central controller **350** may also control operation of the various elements along the track, such as the gates **180**.

Input Station

At the input station **50**, the mail pieces are separated from one another so that the pieces can be conveyed serially to the loading station **310** to be loaded onto the cars **200**. Additionally, at the input station information is determined for each piece so that the piece can be sorted to the appropriate bin.

A variety of configurations may be used for the input station, including manual or automatic configurations or a combination of manual and automated features. In a manual system, the operator enters information for each piece and the system sorts the mail piece accordingly. In an automatic system, the input system includes elements that scan each mail piece and detect information regarding each piece. The system then sorts the mail piece according to the scanned information.

In an exemplary manual configuration, the input system includes a work station having a conveyor, an input device, such as a keyboard, and a monitor. The operator reads information from a mail piece and then drops in onto a conveyor that conveys the piece to the loading station **310**. Sensors positioned along the conveyor track the piece as the conveyor transports the mail piece toward the loading station. An example of a work station having a conveyor for receiving dropped pieces and tracking the pieces is provided in pending U.S. application Ser. No. 10/862,021, filed Jun. 4, 2004, which was published Jan. 27, 2005 under Publication No. US 2005-0018214 A1 and which is incorporated herein by reference. The conveyor receives mail pieces dropped by an operator and tracks the mail pieces as they are transported along the conveyor.

In an exemplary automatic configuration, the system includes an imaging station, having an imaging device such as a high speed line scanning camera. The imaging station scans each mail piece to detect information regarding the destination for each piece. The system analyzes the image data to determine the destination information and then electronically tags the mail piece with the destination and sorts the piece accordingly. An example of a system having an automated imaging station for scanning pieces as they are conveyed is described in U.S. patent application Ser. No. 09/904,471, filed Jul. 13, 2001, which was published Jan. 16, 2003 under Publication No. US 2003-0014376 A1, and which is incorporated herein by reference.

FIGS. **1** and **2** illustrate such an automated system. The input station includes an input bin **55** for receiving a stack of mail. A feeder **60** in the input bin serially feeds mail pieces from the input bin to a conveyor **65**. An imaging station **70** positioned along the conveyor scans the mails pieces as the pieces are conveyed to the loading station **310**. The system **10** analyzes the image data to read information for the mail piece, such as the recipient's address.

The conveyor **65** conveys the mail piece to the loading station **310**. At the loading station the conveyor **65** conveys the mail piece onto a car **200**. As discussed further below, after the mail piece is loaded onto the car, the car moves away from the loading station and another car moves into position at the loading station to receive the next piece of mail.

In certain instances, the system may not be able to automatically identify the relevant information for a mail piece. To process such pieces, the system may include an operator to input the relevant information so that the mail piece can be sorted. For instance, the system may include an operator station having an input device and a display, such as a monitor. If the system cannot automatically determine the address within a pre-determined time period, the system displays the scanned images for the mail piece to the monitor so that the operator at the work station can view the images and manually enter the information using the input device.

In addition to the automated and manual systems described above, the system may be configured in a hybrid or semi-automated configuration having some operations performed manually and others automated. For instance, the system may include a manual input station that also has an imaging station. Since the system can handle a wide variety of items, it may be desirable to have an operator input the pieces manually so that the pieces are properly oriented and separated. The imaging station then scans the items and processes the imaging data to determine the address information for the pieces. Additionally, the operator station may include an input device and a display for inputting information if the address for a piece cannot be automatically determined, as discussed above. The operator can input the information as soon as the system indicates to the operator that it cannot determine the information for a piece. Alternatively, as discussed below, the car may be directed to a buffer if the information for a piece cannot be determined. In such an instance, the cars having such pieces will remain in the buffer while the system continues to process pieces for which the system can determine the relevant information. The operator can continue to manually drop pieces and wait until a number of pieces need manual keying of information. The operator can then switch from the operation of dropping pieces to the operation of manually keying the pieces, sometimes referred to as local video encoding (LVE). The operator can continue keying until some or all of the pieces in the buffer have been successfully coded, and then the operator can go back to the operation of manually dropping pieces. As yet another alternative, it may be desirable to incorporate a separate operator station having the input device and display so that one operator can input the mail at the input station and a separate operator can input the information for pieces having addresses that cannot be automatically determined.

As can be seen from the foregoing, the input station **50** may be configured in a wide range of options. The options are not limited to those configurations described above, and may include additional features, such as an automated scale for weighing each piece, a labeler for selectively applying labels to the mail pieces and a printer for printing information on the mail pieces or on the labels.

Additionally, in the foregoing description, the system is described as having a single input station **50**. However, it may be desirable to incorporate a plurality of input stations positioned along the system **10**. By using a plurality of input stations, the feed rate of pieces may be increased. In addition, the input stations may be configured to process different types of items. In this way, each input station could be configured to efficiently process a particular category of items. For instance, if the system is configured to process documents, such as mail, one input station may be configured to process standard envelopes, while another input station may be configured to process larger mails, such as flats. Similarly, one input station may be configured to automatically process mail by scanning it and automatically determining the recipient. The second input station may be configured to process rejects, such as by manually keying in information regarding the recipient.

Sorting Station

Referring to FIGS. **1-6**, the system includes a sorting station **100**, such as an array of bins **190** for receiving the pieces. In the present instance, the sorting station includes a number of bins arranged in columns. Additionally, the sorting station **100** includes a track **110** for guiding the cars **200** to the bins **190**.

The track **110** includes a horizontal upper rail **135** and a horizontal lower rail **140**. A plurality of vertical legs **130** extend between the upper horizontal leg and the lower horizontal leg **140**. During transport, the cars travel up a pair of vertical legs from the loading station **310** to the upper rail **135** (as described below, the cars actually travel up two pairs of rails because the track includes a forward track and a parallel opposing track). The car then travels along the upper rail until reaching the column having the appropriate bin. The car then travels downwardly along two front vertical posts and two parallel rear posts until reaching the appropriate bin, and then discharges the mail piece into the bin. The car then continues down the vertical legs until reaching the lower horizontal leg **140**. The car then follows the lower rail back toward the loading station.

As can be seen in FIG. **2**, the track **110** includes a front track **115** and a rear track **120**. The front and rear tracks **115**, **120** are parallel tracks that cooperate to guide the cars around the track. As shown in FIG. **13**, each of the cars includes four wheels **220**: two forward wheel and two rearward wheels. The forward wheels **220** ride in the front track, while the rearward wheel ride in the rear track. It should be understood that in the discussion of the track the front and rear tracks **115**, **120** are similarly configured opposing tracks that support the forward and rearward wheels **220** of the cars. Accordingly, a description of a portion of either the front or rear track also applies to the opposing front or rear track.

Referring to FIG. **18** the details of the track will be described in greater detail. The track **110** includes an outer wall **152** and an inner wall **154** that is spaced apart from the outer wall and parallel to the outer wall. The track also has a back wall **160** extending between the inner and outer walls. As can be seen in FIG. **18**, the outer and inner walls **152**, **154** and the back wall form a channel. The wheels **220** of the car ride in this channel.

Referring to FIG. **11**, the track includes both a drive surface **156** and a guide surface **158**. The drive surface positively engages the cars to enable the car to travel along the track. The guide surface **158** guides the car, maintaining the car in operative engagement with the drive surface **156**. In the present instance, the drive surface is formed of a series of teeth, forming a rack that engages the wheels of the cars as described further below. The guide surface **158** is a generally flat surface adjacent the rack **156**. The rack **156** extends approximately halfway across the track and the guide surface **158** extends across the other half of the track. As shown in FIGS. **11** and **18**, the rack **156** is formed on the inner wall **154** of the track. The opposing outer wall **152** is a generally flat surface parallel to the guide surface **158** of the inner wall.

As described above, the track includes a plurality of vertical legs extending between the horizontal upper and lower rails **135**, **140**. An intersection **170** is formed at each section of the track at which one of the vertical legs intersects one of the horizontal legs. Each intersection includes an inner branch **172** that is curved and an outer branch **176** that is generally straight. FIG. **10** illustrates both a right-hand intersection **170***c* and a left-hand intersection **170**, which are mirrors of one another. In FIG. **10**, the intersections **170***c*, **170***d* illustrate the portion of the track in which two vertical legs **130** intersect the upper horizontal leg **135**. The intersections of the vertical legs with the lower rail incorporate similar intersections, except the intersections are reversed. Specifically, the point at which vertical leg **130***c* intersects the lower rail incorporates an intersection configured similar to intersection **170***d*, and the point at which vertical leg **130***d* intersects the lower rail incorporates an intersection configured similar to intersection **170***c*.

Each intersection **170** includes a pivotable gate **180** that has a smooth curved inner race and a flat outer race that has teeth that correspond to the teeth of the drive surface **156** for the track. The gate **180** pivots between a first position and a second position. In the first position, the gate **180** is closed so that the straight outer race **184** of the gate is aligned with the straight outer branch **176** of the intersection. In the second position, the gate is open so that the curved inner race **182** of the gate is aligned with the curved branch **172** of the intersection.

Accordingly, in the closed position, the gate is pivoted downwardly so that the outer race **184** of the gate aligns with the drive surface **156**. In this position, the gate blocks the car from turning down the curved portion, so that the car continues straight through the intersection. In contrast, as illustrated n FIG. **10**, when the gate is pivoted into the open position, the gate blocks the car from going straight through the intersection. Instead, the curved inner race **182** of the gate aligns with the curved surface of the inner branch **172** and the car turns through the intersection. In other words, when the gate is closed, a car goes straight through the intersection along either the upper rail **130** or the lower rail, depending on the location of the intersection. When the gate is opened, the gate directs the car from either a vertical rail to a horizontal rail or from a horizontal rail to a vertical rail, depending on the location of the intersection.

As can be seen in FIG. **11**, the end of the gate remote from the pivot point of the gate flares outwardly so that the curved inner race matches the curved profile of the inner branch when the gate is open. As a result, the gate has a generally L-shaped configuration. To accommodate the flared end of the gate **180**, the drive surface **156** of the inner branch has a notch or recessed portion. When the gate is closed, the notch provides clearance so that the outer race **184** of the gate lies flat, parallel with the drive surface of the outer branch **176**. Further, in the example shown in FIG. **11**, the gate is positioned along the upper rail **135** of the track **110**. When the gate is closed, the recess in the inner branch of the intersection **170** allows the gate to lie flat so that it is aligned with the drive surface of the upper rail.

In the foregoing description, the gates allow one of the cars to either continue in the same direction (e.g. horizontally) or turn in one direction (e.g. vertically). However, in some applications, the system may include more than two horizontal rails that intersect the vertical columns. In such a configuration, it may be desirable to include a different rail that allows the cars to turn in more than one direction. For instance, if a car is traveling down a column, the gate may allow the car to turn either left or right down a horizontal rail, or travel straight through along the vertical column. Additionally, in some applications it may be desirable to allow the cars to travel upwardly, whereas in the system described above, the cars only travel downwardly through the sorting station. If the cars also travel upwardly in the sorting station, then the gates should be configured to accommodate and guide the cars when the cars travel upwardly through an intersection.

The gates **180** are controlled by signals received from the central controller **350**. Specifically, each gate is connected with an actuator **186** that displaces the gate from the opened position to the closed position and back. There may be any of a variety of controllable elements operable to displace the gate. In the present instance, the actuator **186** is a solenoid having a linearly displaceable piston.

In the foregoing description, the sorting station **100** is described as a plurality of output bins **190**. However, it should be understood that the system may include a variety of types of destinations, not simply output bins. For instance, in certain applications it may be desirable to sort items to a storage area, such as an area on a storage shelf. Alternatively, the destination may be an output device that conveys items to other locations. According to one example of an output device, the system may include one or more output conveyors that convey pieces away from the sorting system toward a different material handling or processing system. For instance, an output conveyor designated A may convey pieces to a processing center designated A. Therefore, if a piece is to be delivered to processing center A, the car will travel along the track to output conveyor A. Once the car reaches output conveyor A, the car will stop and transfer the piece onto output conveyor A. Output conveyor A will then convey the piece to processing center A. Further, it should be understood that the system may be configured to include a plurality of output devices, such as output conveyors.

In some embodiments, the system may include a plurality of output conveyors in addition to the output bins. In other embodiments, the system may only include a plurality of output devices, such as conveyors, and the system is configured to sort the pieces to the various output devices. Further still, the system may be configured to retrieve pieces from storage locations. In such embodiments, the cars may sort pieces to a storage location, such as a bin. Subsequently, one of the cars may travel to the storage location and retrieve the item from the storage location and transport it to one of the output devices.

One manner that the cars may retrieve items from the storage locations is by including a conveyor at the storage locations. In this way, an item at a storage location can be conveyed by the conveyor toward the track. When a car arrives at the storage location, the conveyor at the storage location conveys the item onto the car, similar to the manner in which a piece is loaded onto the car at the loading column. Accordingly, the system can sort pieces to a plurality of output devices, in addition to sorting pieces to a plurality of storage locations before subsequently retrieving the pieces and conveying the pieces to the output devices.

As discussed above, the system is operable to sort a variety of items to a plurality of destinations. One type of destination is a bin; a second type is a shelf or other location on which the item is to be stored; and a third type of destination is an output device that may be used to convey the item to a different location. The system may include one or more of each of these types or other types of destinations.

Delivery Vehicles

Referring now to FIGS. **12-17**, the details of the delivery vehicles **200** will be described in greater detail. Each delivery vehicle is a semi-autonomous car having an onboard drive system, including an onboard power supply. Each car includes a mechanism for loading and unloading items for delivery.

The car **200** may incorporate any of a variety of mechanisms for loading an item onto the car and discharging the item from the car into one of the bins. Additionally, the loading/unloading mechanism **210** may be specifically tailored for a particular application. However, in the present instance, the loading/unloading mechanism **210** is a conveyor belt. Specifically, referring to FIG. **12**, the loading/unloading mechanism includes a plurality of narrow belts **212** that extend along the top surface of the car. The conveyor belts are reversible. Driving the belts in a first direction displaces the item toward the rearward end of the car; driving the belt in a second direction displaces the item toward the forward end of the car.

A conveyor motor **255** mounted on the underside of the car drives the conveyor belts **212**. Specifically, the conveyor belts **212** are entrained around a forward roller **213** at the forward edge of the car, and a rearward roller at the rearward edge of the car. The conveyor motor **255** is connected with the forward roller **213** to drive the forward roller, thereby operating the conveyor belts.

The car includes four wheels **220** that are used to transport the car along the track **110**. The wheels **220** are mounted onto two parallel spaced apart axles **215**, so that two or the wheels are disposed along the forward edge of the car and two of the wheels are disposed along the rearward edge of the car.

Referring to FIG. **18**, each wheel comprises an inner idler roller **224** and an outer gear **222** that cooperates with the drive surface **156** of the track. The idler roller **224** rotates freely relative to the axles, while the outer gear is fixed relative to the axle onto which it is mounted. In this way, rotating the axle operates to rotate the gear **222**. Additionally, the idler roller is sized to have a diameter slightly smaller than the distance between the upper wall **152** and the lower wall **154** of the track. In this way, the idler roller may rotate freely within the track, while ensuring that the gear **222** of each wheel remains in operative engagement with the drive surface (i.e. the teeth) **156** of the track. Accordingly, when the vehicle is moving horizontally, the rollers carry the weight of the cart, while the gears **222** cooperate with the drive surface **156** of the track to drive the vehicle along the track.

The car includes an onboard motor **250** for driving the wheels **220**. More specifically, the drive motor **250** is operatively connected with the axles to rotate the axles **215**, which in turn rotates the gears **222** of the wheels. As shown in FIG. **16**, the drive motor **250** is interconnected to the axles **215** via a pair of drive belts **254** that are driven by the drive motor.

The drive system for the car may be configured to synchronously drive the car along the track. In the present instance, the drive system is configured so that each gear is driven in a synchronous manner. Specifically, each gear **222** is connected to an end of one of the axles in a manner that substantially impedes rotation of the gear relative to the axle. In this way each axle drives the attached two gears in a synchronous manner. Additionally, in the present instance, both axles are driven in a synchronous manner so that all four gears are driven in a synchronous manner. There are various mechanisms that can be used to synchronously drive the axles. For instance, a pair of drive motors can be used to drive the axles, and the drive motors can be synchronized. However, in the present instance, a single drive motor **250** is used to drive both axles. Each axle includes a timing pulley **226** that is rigidly connected to the axle to prevent rotation of the pulley relative to the axle. Similarly, a timing pulley **228** is connected to the motor shaft. The drive belt **254** connecting the timing pulley **226** on the axle with the motor is a timing belt so that the rotation of the drive motor is precisely linked to the rotation of the axle. Although a single timing belt can be used to drive both axles synchronously, in the present instance, a pair of timing pulleys is connected to the motor shaft, and each timing pulley is connected to a corresponding timing pulley on one of the axles, as shown in FIG. **16**.

The drive motor **250** includes a sensor that is operable to detect the rotation of the motor to thereby determine the distance the car has traveled. Since the gears **222** are rigidly connected with the axles, which are in turn synchronously connected with the drive motor, the forward distance that the car moves corresponds can be exactly controlled to correlate to the distance that the drive motor is displaced. Accordingly, the distance that a car has traveled along the determined path depends on the distance through which the car motor is rotated.

To detect the rotation of the drive motor **250**, the motor includes a sensor **252** for detecting the amount of rotation of the drive motor. In the present instance the sensor **252** is a hall sensor. A portion of rotation of the motor corresponds to what is referred to as a tick. The sensor detects the number of ticks and sends a signal to the central processor **350**, which determines how far along the designate path the car

has traveled based on the known information regarding the path and the number of ticks that the sensor detects for the motor.

As the car travels along the track, an item on top of the car may tend to fall off the car, especially as the car accelerates and decelerates. Therefore, in the present instance, the car includes a retainer **230** to retain the element on the car during delivery. As illustrated in FIGS. **12-17**, the retainer **230** is a hold down that clamps the item against the top surface of the car.

The retainer includes an elongated pivotable arm **232**. A biasing element, such as a spring, biases the arm downwardly against the top surface of the retainer **230**. The retainer **230** further includes an operator **234** in the form of a tab. Pushing downwardly on the tab raises the clamp from the top surface of the conveyor to allow a piece to be loaded onto the car or discharged from the car.

The car **200** may be powered by an external power supply, such as a contact along the rail that provides the electric power needed to drive the car. However, in the present instance, the car includes an onboard power source **240** that provides the requisite power for both the drive motor **250** and the conveyor motor **255**. Additionally, in the present instance, the power supply is rechargeable. Although the power supply may include a known power source, such as a rechargeable battery, in the present instance, the power supply **240** is made up of one or more ultracapacitors. Ultracapacitors are extremely high energy density capacitors. Capacitors store electrical energy by physically separating positive and negative charges, in contrast to the chemical means a battery uses. Ultracapacitors rely on an electrostatic effect, which is physical rather than chemical, and highly reversible. The ultracapacitors can accept very high amperage to recharge the ultracapacitors. By using a high current, the ultracapacitors can be recharged in a very short time, such as a few seconds or less.

The car includes one or more contacts for recharging the power source **240**. In the present instance, the car includes a plurality of brushes **245**, such as copper brushes that are spring-loaded so that the brushes are biased outwardly. The brushes **245** cooperate with a charging rail in the loading station to recharge the power source, as described further below.

Each car includes at least one and preferably two load sensors for detecting the items as it is loaded onto the car. The sensor(s) ensure that the mail piece is properly positioned on the car. In the present instance, the car includes a forward loading sensor **260** and a rearward loading sensor **262**. The forward loading sensor detects the leading edge of the item as it is loaded onto the car. The forward loading sensor **260** also detects the trailing edge of the item to ensure that the entire length of the item is loaded onto the car. Similarly, the rearward sensor **262** detects the leading edge and in certain instances, may detect the trailing edge of the mail piece. The loading sensors **260, 262** may be simple I/R sensors that detect the presence or absence of a document or mail piece.

Although the car operates in response to signals received from the central controller **350**, which tracks the location of each car, the car may also include a reader **265** for reading indicia along the track to confirm the position of the car. For instance, each bin may be assigned a unique bar code, and the forward reader may scan the track or other area around the bin **190** at which an item is to be delivered. The data that the central processor has regarding the path that the car is to follow and the data regarding the distance the car has traveled based on the data regarding the rotation of the drive motor **250** should be sufficient to determine whether the car **200** is positioned at the appropriate bin. Nonetheless, it may be desirable to double check the location of the car before the item is discharged into the appropriate bin. Therefore, the scanner may operate to scan and read information regarding the bin at which the car is stopped. If the scanned data indicates that the bin is the appropriate bin, then the car discharges its item into the bin. Similarly, the car may have a second reader **266** for reading indicia adjacent the rearward edge of the car. The second reader **266** may be used in applications in which the system is set up to utilize a first series of bins **190** along the forward side and a second series of bins along the rearward side of the track **110**.

In foregoing description, the cars have drive gears that interact with teeth in the track to guide the cars around the track. Additionally, as described further below in the operation section, the location of the car may be controlled based on information regarding how far the car has traveled. In such applications it is desirable to synchronize the drive wheels of the car. However, in some applications alternative control systems may be used. For instance, the location of the cars can be controlled based on signals from sensors positioned along the track or indicators positioned along the track. In such instances, the cars may be configured to use a drive mechanism that is not synchronous as described above.

As discussed further below, the car further includes a processor for controlling the operation of the car in response to signals received from the central processor. Additionally, the car includes a wireless transceiver so that the car can continuously communicate with the central processor as it travels along the track. Alternatively, in some applications, it may be desirable to incorporate a plurality of sensors or indicators positioned along the track. The car may include a reader for sensing the sensor signals and/or the indicators, as well as a central processor for controlling the operation of the vehicle in response to the sensors or indicators.

Loading Column

Referring now to FIGS. **6-7** the details of the loading column **300** will be described in greater detail. The loading column **300** is formed adjacent the output end of the input station **50**. The loading column **300** is formed of a front pair of vertical rails **305***a*, **305***b* and a corresponding rearward set of vertical rails. The loading station **310** is positioned along the loading column. The loading station **310** is the position along the track in which the car **200** is aligned with the discharge end of the conveyor of the input station **50**. In this way, a mail piece from the input station may be loaded onto the car as it is conveyed toward the car from the input station.

Although the central processor **350** tracks the position of the car, a home sensor **312** is positioned adjacent the loading station **310**. When the home sensor detects the car, the position for the car is known relative to a fixed point along the track, and the central processor resets the position of the car to the home or zero position.

Referring to FIG. **7**, a pair of charging rails are disposed along the vertical rails **305***a*, **305***b*. The charging rails are conductive strips connected with an electrical supply. The charging contacts **245** of the car **200** engage the conductive strips to recharge the ultracapacitors **240**. Specifically, the biasing element of the brushes **245** biases the brushes outwardly toward the charging contacts. The electricity flowing through the charging contact **245** is a high amperage, low voltage source that allows the ultracapacitors to recharge in a few seconds or less. In addition, since the

power supply provided by the ultracapacitors last for only a few minutes, the car recharges each time it travels through the loading column.

Additionally, it may be desirable to incorporate a startup charging rail similar to the charging rails described above, but disposed along either the return rail or the rails in the column adjacent to the loading column, depending on where the cars are stored when the cars are shut down. Since the cars use ultracapacitors, it is possible that the ultracapacitors will discharge while the system is shut down. Therefore, upon startup the cars will not have any charge and will not be able to move to the loading column to charge the ultracapacitors. Accordingly, the system may include a startup charging rail disposed along a rail that the cars contact when the cars are stored during shutdown. If the cars are stored in the loading column and the adjacent column during shutdown, then the startup rail is disposed in the column adjacent the loading column. Alternatively, if the cars are stored on the return rail and the loading column during shutdown, then the startup rail is disposed along the return rail. In this way, when the system is started, a charging current is supplied to the cars through the startup charging rail and the charging rail in the loading column.

As discussed previously, each car **200** includes a retainer **230** to hold down items on the car during transport. The retainer should be opened at the loading station to allow an item to be loaded onto the car. Accordingly, as shown in FIG. **6**, an actuator **316** is positioned along the column. The actuator **316** projects inwardly toward the cars as the cars are conveyed up the loading column. As a car is conveyed upwardly in the loading column **300**, the hold down actuator **316** contacts the hold down operator or tab **236**. The interaction between the actuator **316** and the tab **236** causes the retainer to open, so that items can be loaded onto the car. As the car moves upwardly past the actuator **316**, the tab **236** on the car disengages the actuator, thereby releasing the retainer, thereby holding down or clamping the mail piece against the top surface of the vehicle.

In the foregoing description, the loading station has been described as a column in which an item is loaded onto the car and the car then travels upwardly to the horizontal upper rail **135**. However, in some applications in may be desirable to configure the loading station so that the items are loaded onto the cars at or near the top of the vertical column. In such an application, the load on the cars would be reduced since the car will not have to lift the item loaded on the car. In order to load the items on the cars at the top of the conveyor, a vertical conveyor may be added to the system. For instance, a conveyor angled upwardly may convey the items upwardly to the top of the column to load the items onto the cars. Alternatively, one or more of a variety of conveyor configurations can be used to transport to items toward the top of the loading column to load the items onto the cars.

Operation

The system **10** operates as follows. An item is processed at the input station **50** to identify a characteristic of the piece that is indicative of where the piece should be sorted. For instance, the item may be a mail piece that is to be sorted according to department, box number or recipient. If the mail pieces are sorted by department, the piece may be processed to identify either an indicator of the department (such as box number) or the piece may be processed to identify the recipient. The central controller maintains a database that correlates various data to identify the destination bin. For instance, the database may correlate the recipient names with the appropriate department if the mail is being sorted according to department. In other embodiments, the piece may be a part that has a product code and the database may correlate the product code with the sort location.

As discussed previously, the input station may process the items automatically or manually. In a manual mode, the operator manually enters information regarding a piece and then drops the piece on a conveyor. The system electronically tags the piece with the sort information and the conveyor conveys the piece toward the loading station. Alternatively, if the input system is an automated system, the piece is automatically scanned to identify the relevant sort characteristic. For instance, the input station may use a scanner, such as a bar code scanner to read the postnet code on a piece, or the input station may include an imaging device, such as a high speed line scan camera in combination with an OCR engine to read information on the piece.

To prepare to receive an item, a car **200** moves along the track toward the loading station **310** in the loading column **300**. As the car approaches the loading station, the operator **236** for the hold down **230** engages the actuator **316**, which pivots the hold down upwardly to prepare the car to receive an item, as illustrated in FIG. **6**. When the car **200** moves into position at the loading station **310** the home sensor detects the presence of the car and sends a signal to the central processor **350** indicating that the car is positioned at the loading station. In the following description, the item being sorted is described as being a mail piece. It should be understood that such an item is an exemplary application of the system. As described above, the system can be configured to sort a variety of items in a variety of material handling applications.

Once the car is positioned at the loading station, the input station conveys a mail piece onto the car. As the mail piece is being conveyed onto the car **200**, the loading mechanism **210** on the car loads the mail piece onto the car. Specifically, the input station conveys the mail piece into contact with the conveyor belts **212** on the car. The conveyor belts **212** rotate toward the rearward side of the car, thereby driving the mail piece rearwardly on the car.

The operation of the conveyor belts is controlled by the loading sensors **260**, **262**. The forward loading sensor detects the leading edge of the mail piece as the mail piece is loaded onto the car. Once the forward loading sensor **260** detects the trailing edge of the mail piece, a controller onboard the car determines that the mail piece is loaded on the car and stops the conveyor motor. Additionally, the onboard controller may control the operation of the conveyor in response to signals received from the rearward sensor **262**. Specifically, if the rearward sensor **262** detects the leading edge of the mail piece, then the leading edge of the mail piece is adjacent the rearward edge of the car. To ensure that the mail piece does not overhang from the rearward edge of the car, the controller may stop the conveyor once the rearward sensor detects the leading edge of the mail piece. However, if the rearward sensor detects the leading edge of the mail piece before the forward sensor detects the trailing edge of the mail piece, the controller may determine that there is a problem with the mail piece (i.e. it is too long or two overlapping mail pieces were fed onto the car. In such an instance, the car may communicate an error message with the central controller, which may declare an error and provide an indicator to the operator that the car at the loading station requires attention. Alternatively, a reject bin **325** may be positioned behind the loading station so that mail pieces on the car at the loading station can be ejected into the reject bin **325**. In this way, if there is an error loading a mail piece onto a car, the mail piece can simply be ejected into the reject bin, and a subsequent mail piece can be loaded onto the car.

After a mail piece is loaded onto the car, the car moves away from the loading station. Specifically, once the onboard controller detects that a mail piece is properly loaded onto the car, the onboard controller sends a signal to start the drive motor **250**. The drive motor **250** rotates the axles, which in turn rotates the gears **222** on the wheels **220**. The gears **222** mesh with the drive surface **156** of the vertical rails **305** in the loading column to drive the car upwardly. Specifically, the gears and the drive surfaces mesh and operate as a rack and pinion mechanism, translating the rotational motion of the wheels into linear motion along the track **110**.

Since the cars move up the loading column from the loading station, the destination for the car does not need to be determined until after the car reaches the first gate along the upper rail **135**. For instance, if an automated system is used at the input station to scan and determine the characteristic used to sort the mail pieces, it may take some processing time to determine the relevant characteristic. The time that it takes to convey the mail piece onto the car and then convey the car up the loading column will typically be sufficient time to determine the relevant characteristic for the mail piece. However, if the characteristic is not determined by the time the car reaches the upper rail, the car may be directed down the second column, which is the column next to the loading column. The car travels down the second column to the lower rail **140**, and then back to the loading column. The car may stop in the second column to provide additional time to determine the characteristic. However, after waiting for a pre-determined period the system may declare that the address cannot be determined and the car may be advanced from the second column and the piece may be discharged to a reject bin. Alternatively, rather than declare an error the car may continue to travel around the loop from the loading column to the second column until the characteristic is determined or until a predetermined time at which the central controller declares an error. Additionally, rather than using the reject bin when the system is unable to determine the characteristic for a mail piece, one of the bins in the second column can also be used as a reject bin. In this way, the cars are ready to receive a mail piece as soon as the car reaches the loading station, without having to eject the problem mail piece into the reject bin **325** at the loading station.

As described above, the system includes a loop that can be utilized as a buffer track to provide additional processing time to analyze the characteristic for the mail piece if necessary. Although the first and second columns can be used as the buffer loop, other columns can be used as a buffer loop if desired.

The foregoing discussion described the process for buffering a car if the system is unable to determine the characteristic for the mail piece by the time the car reaches the top rail. However, for most mail pieces, the system should be able to identify the characteristic without having to buffer the car. The following discussion describes the operation of the system assuming that the characteristic for the mail piece is determined before the car reaches the upper rail **135**.

Once the characteristic for the mail piece is determined, the central controller **350** determines the appropriate bin **190** for the mail piece. Based on the location of the bin for the mail piece, the route for the car is determined. Specifically, the central controller determines the route for the car and communicates information to the car regarding the bin into which the mail piece is to be delivered. The central controller then controls the gates along the track to direct the car to the appropriate column. Once the car reaches the appropriate column the car moves down the column to the appropriate bin. The car stops at the appropriate bin **190** and the onboard controller sends an appropriate signal to the conveyor motor **255** to drive the conveyor belts **212**, which drives the mail piece forwardly to discharge the mail piece into the bin. Specifically, the top of the car aligns with the gap between the appropriate bin **190** and the bottom edge of the bin that is immediately above the appropriate bin.

As discussed above, the central controller **350** controls the operation of the gates **180** in response to the location of the car **200** and the route that the car is to follow to deliver the mail piece. Additionally, as discussed below, the central controller controls the gates in response to the position of other cars on the track.

As the car **200** travels along the upper rail **135** and approaches a column, the gates for the vertical rails **130** are controlled as follows. If the car is to pass over the column on the way to the next column, the gates are displaced into the closed position, as shown in FIG. **9**. Specifically, both gates at the top of the column are closed so that the outer race **184** of the gate aligns with the straight track, with the outer race aligning with the drive surface **156** of the track **110**. In this way, the gates provide a straight drive surface that cooperates with the drive surface **156** to allow the car to travel over the column.

When the car comes to a column that it is to turn down, the gates are controlled as follows. Referring to FIG. **5**, the columns can be seen without the bins attached. The view in FIG. **5** is from the front of the apparatus **10**, so the car will be traveling along the upper rail from the right to the left in the perspective of FIG. **5**. In the following discussion, the car is to be conveyed to a bin in the column designated C in FIG. **5**. Column C includes two pairs of vertical legs. The first pair is front and back vertical legs **130***c* on the left side of column C; the second pair is front and back vertical legs **130***d* on the right side of column C.

In order for the car to travel down column C, the wheels on the left side of the car travel down legs **130***c* and the right side wheels travel down legs **130***d*. Therefore, as the car approaches column C, the gates at the top of **130***d* are displaced to the closed position so that the left side wheels remain on the upper rail and pass over the right side legs **130***d*. After the left side wheels of the car pass over the right legs **130***c*, the gates **180** at the top of the right legs **130***d* are displaced into the open position so that the right side wheels can turn down legs **130***d*. Specifically, after the left side wheels pass right legs **130***d*, the central controller operates the solenoids **186** of the gates **180** at the top of legs **130** to displace the gates into the open position, as shown in FIG. **8** (note that the view in FIG. **8** is taken from the rear side of the apparatus so that the perspective of the gates is reversed relative to the front side). The gates **180** block the straight path through the intersection **170** and the curved inner race **182** of the gates direct the right side wheels down vertical legs **130***d*. Similarly, the gates **180** at the top of the left side legs **130***c* are displaced into the open position to direct the left side wheels down vertical legs **130***c*.

As the car approaches the intersections at the bottom of legs **130***c* and **130***d*, the gates are operated similarly to the above description, but in reverse. Specifically, as the car approaches the intersections **170** at the bottom of legs **130***c* and **130***d*, the gates **180** in the intersections are displaced into the opened position so that the gates direct the forward and leading wheels to turn down the lower rail. From the perspective of FIG. **5**, the car travels from left to right after the car reaches the lower rail. After the car passes though the intersections at the bottom of the rails **130***c*, **130***d*, the gates at the bottom of right side legs **130***d* are displaced into the closed position before the left side wheels of the car reach the intersection at the bottom of the right side legs **130***d*. In this way, the left side wheels of the car pass straight through the intersection at the bottom of legs **130***d* along the bottom rail **140**.

As discussed above, the central controller **350** controls the operation of the gates in response to the position of the car and more specifically in response to the position of the left hand and right hand wheels of the car. The gates are fired sequentially to ensure that the different pairs of wheels are directed down the proper vertical legs. Alternatively, the operation of the gates may be controlled by signals received from the cars. Specifically, the cars may include a transmitter that transmits a signal to the central controller indicating that it is in proximity to a gate that is to be fired. Further still, the car may include an indicator that may be scanned as the car approaches the gate. Based on the indicator and the know destination for the car, the gate may fire. Still further, the car may include an mechanical actuator that selectively triggers or actuates a gate to appropriately direct the car.

One of the advantages of the system as described above is that the orientation of the cars does not substantially change as the cars move from travelling horizontally (along the upper or lower rails) to vertically (down one of the columns). Specifically, when a car is travelling horizontally, the two front geared wheels **220** cooperate with the upper or lower horizontal rail **135** or **140** of the front track **115**, and the two rear geared wheels **220** cooperate with the corresponding upper or lower rail **135** or **140** of the rear track **120**. As the car passes through a gate and then into a column, the two front geared wheels engage a pair of vertical legs **130** in the front track **115**, and the two rear geared wheels engage the corresponding vertical legs in the rear track **120**.

As the car travels from the horizontal rails to the vertical columns or from vertical to horizontal, the tracks allow all four geared wheels to be positioned at the same height. In this way, as the car travels along the track it does not skew or tilt as it changes between moving horizontally and vertically. Additionally, it may be desirable to configure the cars with a single axle. In such a configuration, the car would be oriented generally vertically as opposed to the generally horizontal orientation of the cars described above. In the single axle configuration, the weight of the cars would maintain the orientation of the cars. However, when using a single axle car, the orientation of the sort locations would be re-configured to accommodate the vertical orientation of the cars. Similarly, the loading station would also be re-configured to load the pieces onto the cars in the vertical orientation.

Traffic Control

Since the system includes a number of cars **200**, the system controls the operation of the different cars to ensure the cars do not collide into one another. In the following discussion, this is referred to as traffic control.

A variety of methodologies can be used for traffic control. For instance, the traffic control can be a distributed system in which each car monitors its position relative to adjacent cars and the onboard controller controls the car accordingly. One example of such as system utilizes proximity sensors on each car. If the proximity sensor for a car detects a car within a predefined distance ahead of the car, the onboard controller for the trailing car may control the car by slowing down or stopping the trailing car. Similarly, if a car detects a car within a predefined distance behind the car, the lead car may speed up unless the lead car detects a car ahead of it within the predefined distance. In this way, the cars may control the speed of the cars independently based on the feedback from the proximity sensors.

Although the system may use a distributed system for traffic control, in the present instance, the system uses a centralized system for traffic control. Specifically, the central controller **350** tracks the position of each car **200** and provides traffic control signals to each car based on the position of each car relative to adjacent cars and based on the route for each car.

In the present instance, the central controller **350** operates as the traffic controller, continuously communicating with the cars as the cars travel along the track **110**. For each car, the central controller determines the distance that each car can travel, and communicates this information with the cars. For instance, if car B is following car A along the track, and car A is at point A, car B can safely travel to a point just before point A without crashing into car A. As car A advances to a subsequent point B along the track, car B can travel safely to a point just before point B without crashing into car A.

The cars continuously communicate with the central controller to provide information indicative of their positions, so that the central controller can continuously update the safe distances for each car as the cars advance around the track.

Although the foregoing discussion is limited to determining safe zones based on the positions of the various cars on the track, the determination of safe zones is based on other factors that affect the traffic. For instance, when calculating the safe distance for a car, the central controller considers the distance between the car and the next gate, as well as the distance to the destination bin for the car.

As can be seen from the foregoing, increasing the frequency of communication between the cars and the central controller increases the efficiency of the traffic flow along the track. Accordingly, in the present instance, the traffic control is designed to communicate with a car once for every inch the car travels along the track. Therefore, if a car travels at 25 inches per second, the central controller communicates with the car every 40 msec. Further, it is desirable to have the cars travel at up to 50 inch/sec. Therefore, it is desirable to configure the communications to allow the cars to communicate with the central controller every 20 msec.

In addition, to the foregoing variables used to calculate safe distances, information regarding the track profile ahead of each car is used to calculate safe distances. For instance, the central controller determines whether the path ahead of a car is sideways movement, uphill movement (i.e. movement vertically upwardly) or downhill movement (i.e. movement vertically downwardly).

One of the issues in traffic control relates to merging at intersections **170**. The problem arises when a car needs to merge onto the return rail **140**. If two cars will arrive at the intersection close enough to collide, one of the cars needs to have priority and the other car needs to wait or slow down to allow the first car to go through.

A first method for controlling merging traffic is based on determining the next gap large enough for a car to have time to pass through an intersection without colliding with another car. In other words, if a first car approaches an intersection and it is determined that the gap between the first car and a second car is not sufficient for the first car to pass through, the first car waits at the intersection until there is a gap large enough to allow the first car to pass through.

A second method for controlling merging traffic is based on determining which car is closest to the homing sensor at the loading station **310**. The car with the shortest distance to the homing sensor gets priority at the intersection.

Another factor that the traffic controller considers when calculating safe distances relates to the position of cars in adjacent columns. In the present instance, most of the adjacent columns share a common vertical rail. For instance, in FIG. **5**, the leftmost column uses vertical rails **130*a*** and **130*b***. The column next to the leftmost column uses vertical rails **130*b*** and **130*c***.

However, in the present instance, some of the columns may have two vertical rails **130** that are independent from the adjacent columns. For instance, the loading column **300** has two independent rails that are not shared with the adjacent column. Therefore, cars can travel up the loading column without regard to the position of cars in the column next to the loading column. Furthermore, as shown in FIG. **5**, it may be desirable to configure the column next to the loading column so that it also has two independent vertical rails. In this way, cars can more freely travel up the loading column and down the adjacent column to provide a buffer loop as described previously.

Accordingly, when calculating safe distances, the traffic controller evaluates the position of cars in adjacent columns if the cars share a common vertical rail to ensure that the two cars do not collide as the car travel down the adjacent columns.

In the foregoing discussion, the sorting of items was described in relation to an array of bins disposed on the front of the sorting station **100**. However, as illustrated in FIGS. **2** & **4**, the number of bins in the system can be doubled by attaching a rear array of bins on the back side of the sorting station. In this way, the cars can deliver items to bins on the front side of the sorting station by traveling to the bin and then rotating the conveyor on the car forwardly to eject the piece into the front bin. Alternatively, the cars can deliver items to bins on the rear side of the sorting station by traveling to the bin and then rotating the conveyor on the car rearwardly to eject the piece into the rear bin.

Additionally, the sorting station **100** is modular and can be readily expanded as necessary simply by attaching an additional section to the left end of the sorting station. Further, although the foregoing describes the array of bins as being essentially a two dimensional array in which the cars simply travel in X and Y directions, the sorting station can be expanded to add additional "runs" of track. Specifically, a separate sorting station parallel to or perpendicular to the sorting station illustrated in FIG. **2** may be connected to the sorting station. In this way, the car would travel in a third dimension relative to the X and Y directions of the sorting station illustrated in FIG. **2**. For instance, additional sections of track may be connected to the sorting station illustrated in FIG. **2** perpendicular to the illustrated sorting station, so that the additional track forms an L-shape intersecting the loading column. In such a configuration, gates selectively direct the cars either down the upper rail **135** or rearwardly toward the additional track. Similarly, a plurality of parallel rows of sorting stations can be interconnected so that the cars selectively travel along a crossover rail until the car reaches the appropriate row. The car then travels down the row until it reaches the appropriate column as described above.

It will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the broad inventive concepts of the invention. For instance, in the foregoing description, the operation of the sorting station is described as being centralized with the central controller. However, it may be desirable to have the cars control the operation of the gates. According to one alternative, the cars incorporate one or more mechanical actuators that cooperate with an operator on the gate. The actuators on the cars are operable between first and second positions. In a first position, the actuator engages the gate operator to displace the gate into the closed position. In a second position, the actuator engages the gate to displace the gate into the open position. Alternatively, the gate may be biased toward the opened position, so that when the car actuator is in the second position it does not engage the gate operator. In another alternative, each car includes a mechanism for communicating with each gate. If the gate needs to be pivoted to direct an approaching car along a particular path, the car sends a signal to the gate indicating whether the gate should be opened or closed. In response to the signal from the car, the gate pivots to the appropriate position.

Further, in the above description, the system uses a wireless communication between the cars and the central controller. In an alternative embodiment, a communication line may be installed on the track and the cars may communicate with the central controller over a hard wired communication link. Still further, the system has been described as being useful in sorting incoming mail. However, the system may also be utilized to sort and prepare outgoing mail. For instance, after determining a characteristic for a mail piece, the system may print a marking onto the mail piece. For instance, after determining the recipient's address for a mail piece, the system determines which bin the mail piece is to be sorted to. As the mail piece is conveyed to the bin, a printer prints the appropriate postnet bar code on the piece before sorting the piece. To provide the printing functionality, the system may include a printer disposed along the track. When the car approaches the printer the car stops and at least partially discharges the mail piece to extend the mail piece toward the printer. The printer then prints the appropriate postnet code. The car then reverses the conveyors to load the piece back onto the car all the way, and then travels to the appropriate bin. Similarly, the system may include a device for selectively applying labels to the pieces. Similar to the above example of printing markings onto the pieces, the labeler may be positioned along the track. The cars selectively stop at the labeler on route to the appropriate bin and at least partially discharge the mail piece toward the labeler. The labeler then applies a label onto the mail piece and the conveyor on the car then reverses to load the piece back onto the car.

In addition to outgoing mail applications, it may be desirable to incorporate a printer and/or a labeler in systems configured to process incoming mail. For instance, when sorting incoming mail pieces, it may be desirable to print certain information, such as sort codes, a time stamp or audit trail information onto some or all of the pieces being processed. In some instances such information may be printed directly onto the mail pieces. In other instances, a label may be applied to the mail pieces and the information may be printed on the label.

In addition to a printer and a labeler, the system may include a scale for weighing the mail pieces. The scale may be positioned along the track **110**, such as along the loading column. To weigh a piece, the car stops adjacent the scale, and ejects the piece from the car onto the scale by driving the conveyor belts **212**. Preferably, the scale includes a conveyor or transfer mechanism for discharging the piece from the scale and back onto the car or onto a subsequent car. When the piece is loaded onto the car from the scale, the car drives the conveyors to load the piece as discussed above in connection with the loading station.

It should therefore be understood that this invention is not limited to the particular embodiments described herein, but is intended to include all changes and modifications that are within the scope and spirit of the invention as set forth in the claims.

The invention claimed is:

1. A delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system, wherein the delivery vehicle comprises:

- a loading mechanism for loading an item onto the delivery vehicle, wherein the loading mechanism comprises:
  - a conveyor having a length forming a substantially horizontal surface for receiving an item to be conveyed to one of the destination areas; and
  - a load controller for controlling operation of the conveyor to control the position of the item on the vehicle;
- a motor for driving the vehicle to one of the destination areas;
- a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel.

2. The delivery vehicle of claim **1** wherein the load controller comprises a pair of detectors wherein each of the detectors is operable to detect the presence of the item at a point along the length of the conveyor.

3. The delivery vehicle of claim **2** wherein the pair of detectors comprise a first sensor operable to detect a leading edge of the item when the item is moved in a first direction and a second sensor operable to detect a trailing edge of the item.

4. The delivery vehicle of claim **2** comprising a motor controller for controlling operation of the motor for driving the vehicle, wherein the motor controller controls the motor in response to signals from one or more of the detectors.

5. The delivery vehicle of claim **4** wherein the motor controller drives the motor to advance the vehicle in response to the load controller detecting the presence of the item loaded on the conveyor.

6. The delivery vehicle of claim **1** comprising a pair of synchronously drive axles, wherein gears are fixed to the axles so that the gears are synchronously driven to drive the vehicle along the guide system.

7. The delivery vehicle of claim **1** wherein the conveyor is operable to eject the item from the delivery vehicle into one of the destination areas.

8. The delivery vehicle of claim **1** wherein the delivery vehicle is configured to move in a first horizontal direction and a vertical direction substantially orthogonal to the first horizontal direction.

9. The delivery vehicle of claim **8** wherein the conveyor is configured to transfer the item in a third direction that is transverse the first horizontal direction and the vertical direction.

10. The delivery vehicle of claim **1** comprising a retainer operable to positively engage the item.

11. The delivery vehicle of claim **1** wherein the drive system is operable to engage a first track on a first side of the vehicle and a second track on a second side of the vehicle.

12. The delivery vehicle of claim 1 wherein the vehicle comprises a vehicle controller configured to wirelessly receive signals regarding the direction of travel for the vehicle.

13. The delivery vehicle of claim 1 wherein the guide system includes a first series of columns and a second series of columns wherein a gap is formed between the first series of columns and the second series of columns and a track is disposed in the gap between the first and second series of columns, wherein the delivery vehicle is configured to move horizontally within the gap.

14. The delivery vehicle system of claim 13 wherein the delivery vehicle is configured so that the delivery vehicle is moveable horizontally within the gap.

15. The delivery vehicle of claim 1 wherein the conveyor comprises a conveyor belt having an outer surface configured to frictionally engage the item to be conveyed.

16. The delivery vehicle of claim 15 comprising a plurality of rotatable elements, wherein the conveyor belt is entrained about the rotatable elements and the conveyor controller is configured to control the rotation of the rotatable elements.

17. The delivery vehicle of claim 15 wherein the drive system is configured to convey the vehicle in a vertical direction and along a first horizontal direction, and wherein the conveyor is configured to convey the item in a second horizontal direction that is transverse the first horizontal direction.

18. A delivery vehicle operable with a material handling system having a guide system comprising a track positioned along a plurality of destination areas, wherein the delivery vehicle comprises:

a transfer mechanism configured to load an item onto the delivery vehicle or eject the item from the vehicle into one of the destination areas, wherein the transfer mechanism comprises:

a conveyor having a length forming a substantially horizontal surface for receiving an item to be conveyed to one of the destination areas; and

a conveyor controller for controlling operation of the conveyor to control the position of the item on the vehicle;

a motor for driving the vehicle to one of the destination areas;

a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel.

19. The delivery vehicle of claim 18 wherein the conveyor comprises a conveyor belt having an outer surface configured to frictionally engage the item to be conveyed.

20. The delivery vehicle of claim 19 comprising a plurality of rotatable elements, wherein the conveyor belt is entrained about the rotatable elements and the conveyor controller is configured to control the rotation of the rotatable elements.

21. The delivery vehicle of claim 19 wherein the drive system is configured to convey the vehicle in a vertical direction and along a first horizontal direction, and wherein the conveyor is configured to convey the item in a second horizontal direction that is transverse the first horizontal direction.

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EXHIBIT G

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Hayduchok et al.

(10) **Patent No.: US 11,192,144 B2**
(45) **Date of Patent: Dec. 7, 2021**

(54) **MATERIAL HANDLING APPARATUS FOR DELIVERING OR RETRIEVING ITEMS**

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B65G 67/02	(2006.01)
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B65G 1/06	(2006.01)

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CPC ***B07C 3/087*** (2013.01); ***B07C 7/005*** (2013.01); ***B07C 7/02*** (2013.01); ***B61B 13/02*** (2013.01); ***B61C 11/04*** (2013.01); ***B65G 1/04*** (2013.01); ***B65G 1/065*** (2013.01); ***B65G 67/02*** (2013.01); *Y02T 30/00* (2013.01)

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CPC B65G 1/0492; B65G 1/1373; B65G 1/137; B65G 67/02; B65G 1/00; B65G 35/06; B65G 1/04; B65G 1/06; B65G 1/065; Y02T 31/10; Y02T 30/30; B61B 13/02; B61C 11/04; B07C 3/087; B07C 7/005; B07C 7/02
USPC 198/347.1–347.4; 414/279, 280
See application file for complete search history.

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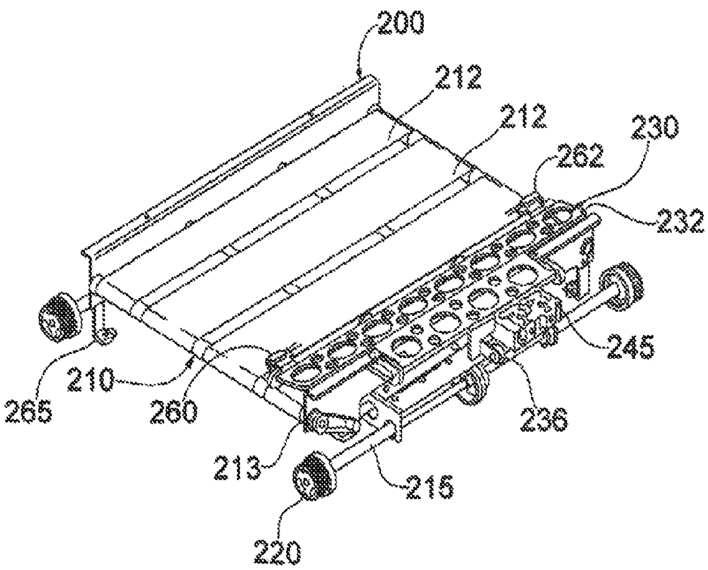
(57) **ABSTRACT**

A method and apparatus are provided for sorting or retrieving items to/from a plurality of destinations areas. The items are loaded onto one of a plurality of independently controlled delivery vehicles. The delivery vehicles follow a track that guides the delivery vehicles to/from the destination areas, which are positioned along the track. Once at the appropriate destination area, an item is transferred between the delivery vehicle and the destination area.

19 Claims, 13 Drawing Sheets



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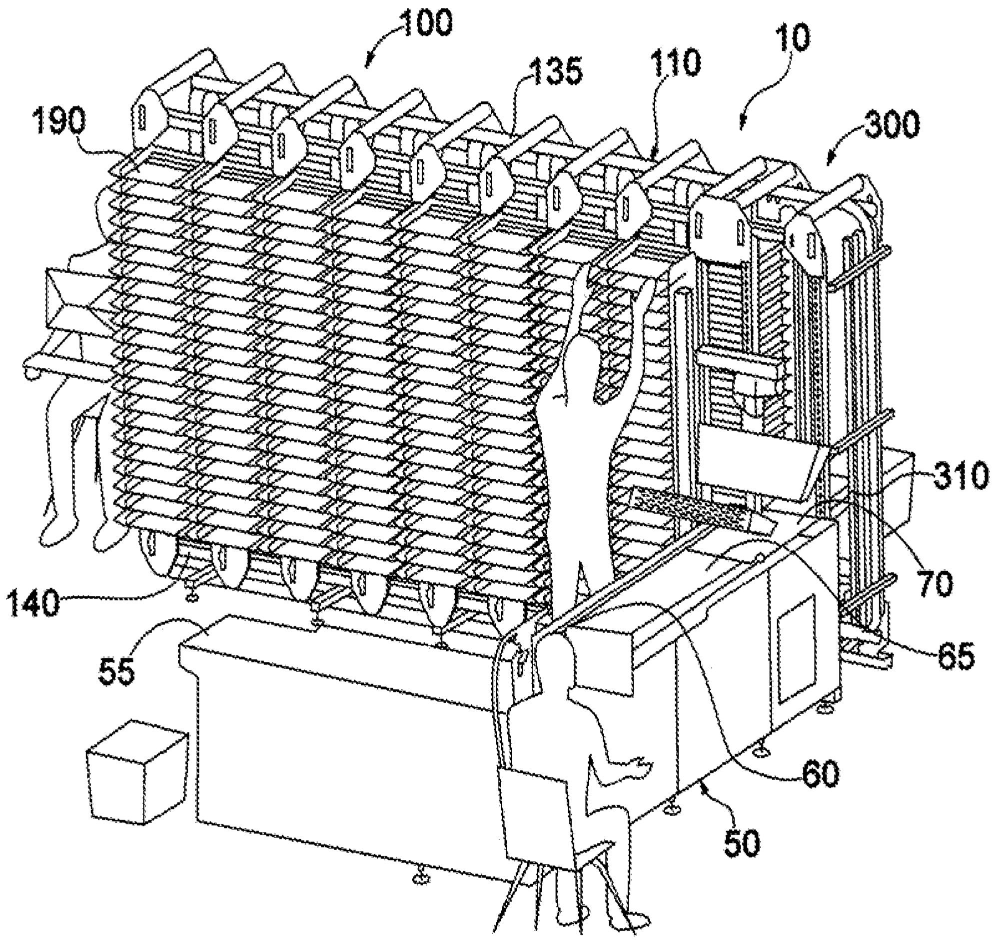


Fig. 1

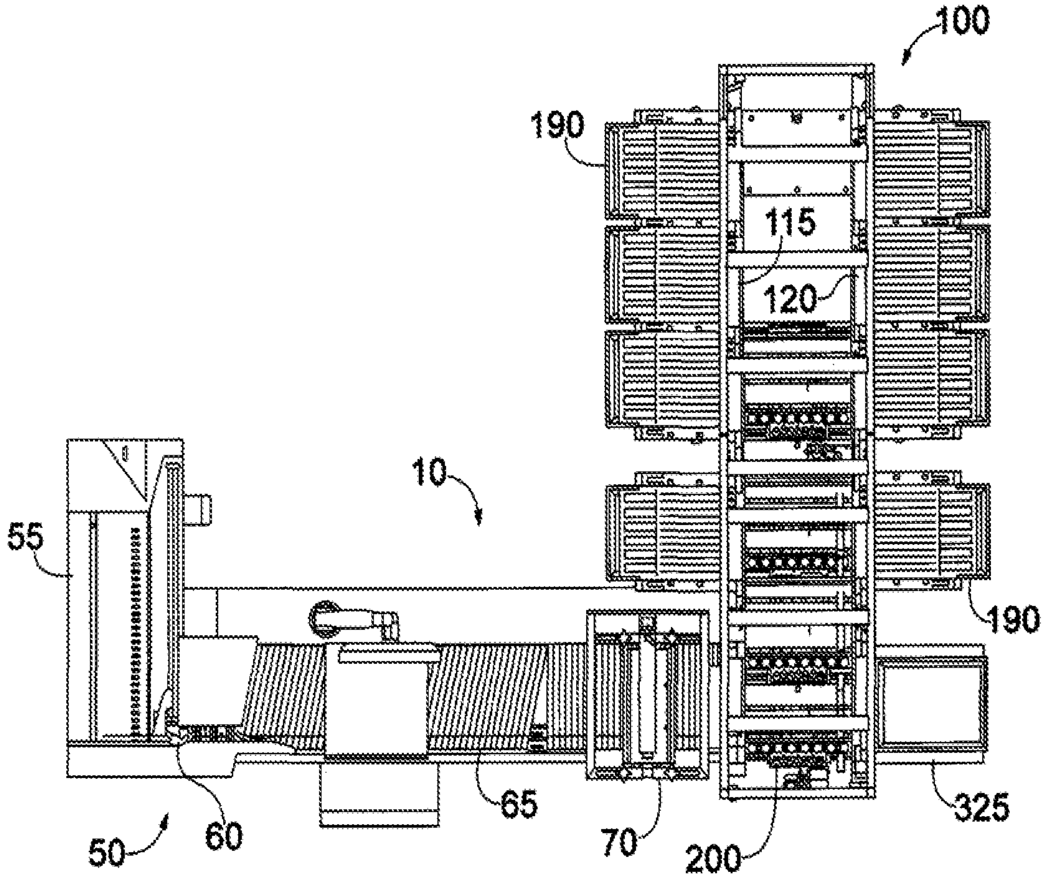
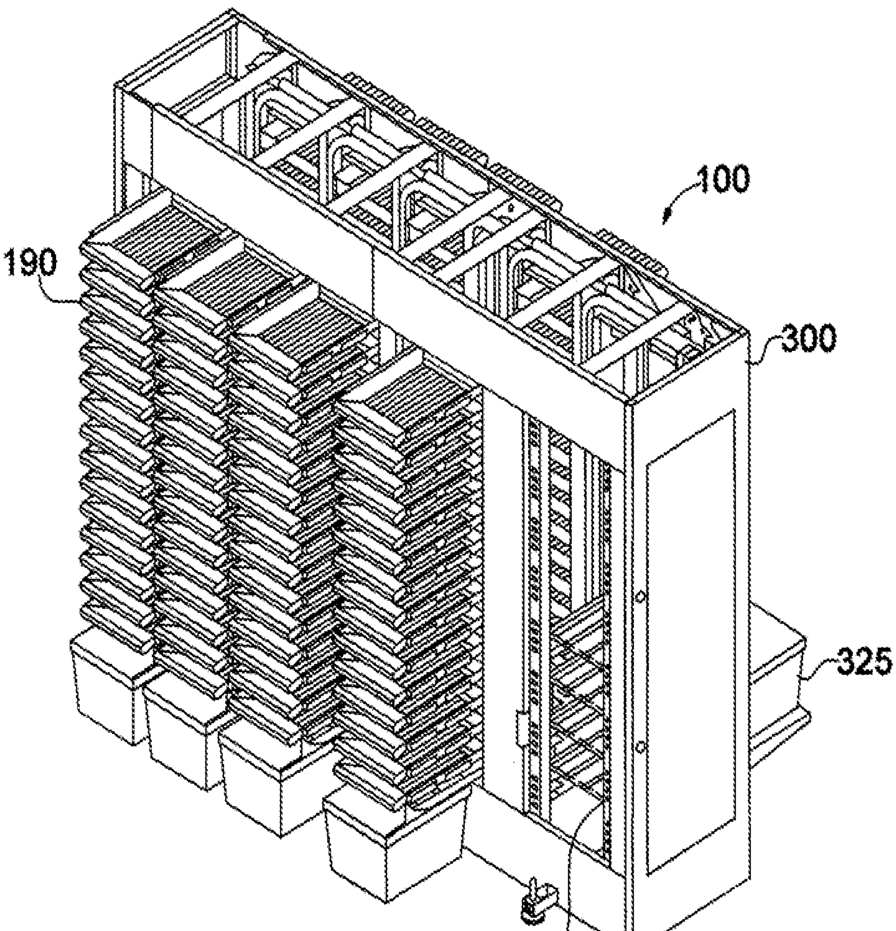


Fig. 2



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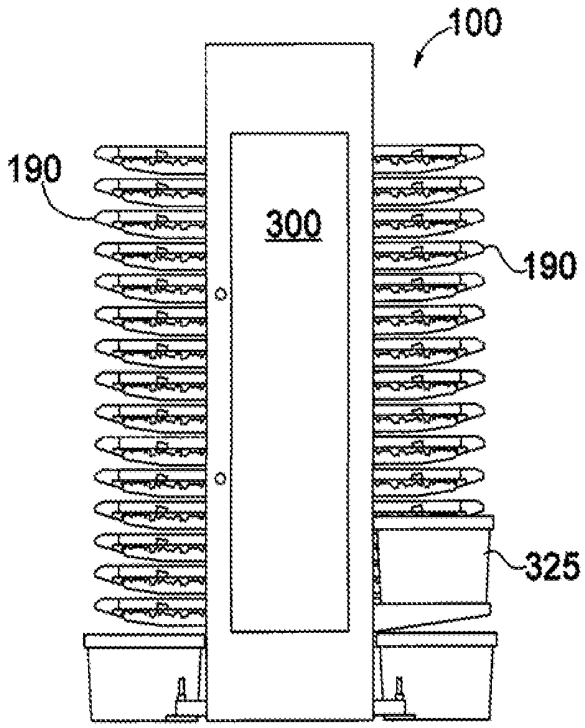

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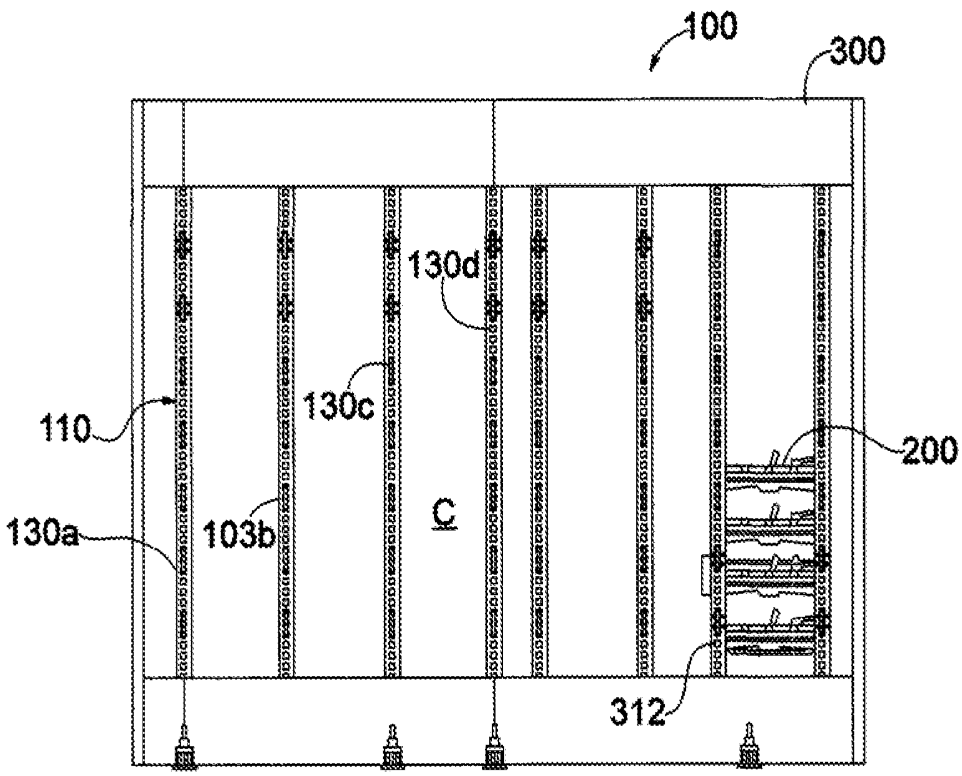

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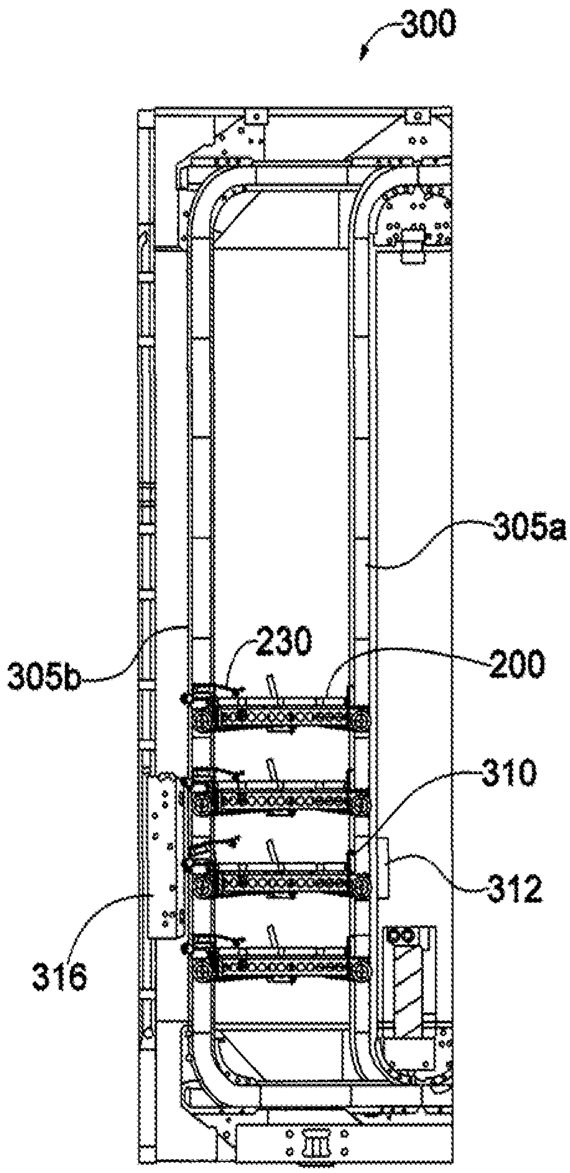

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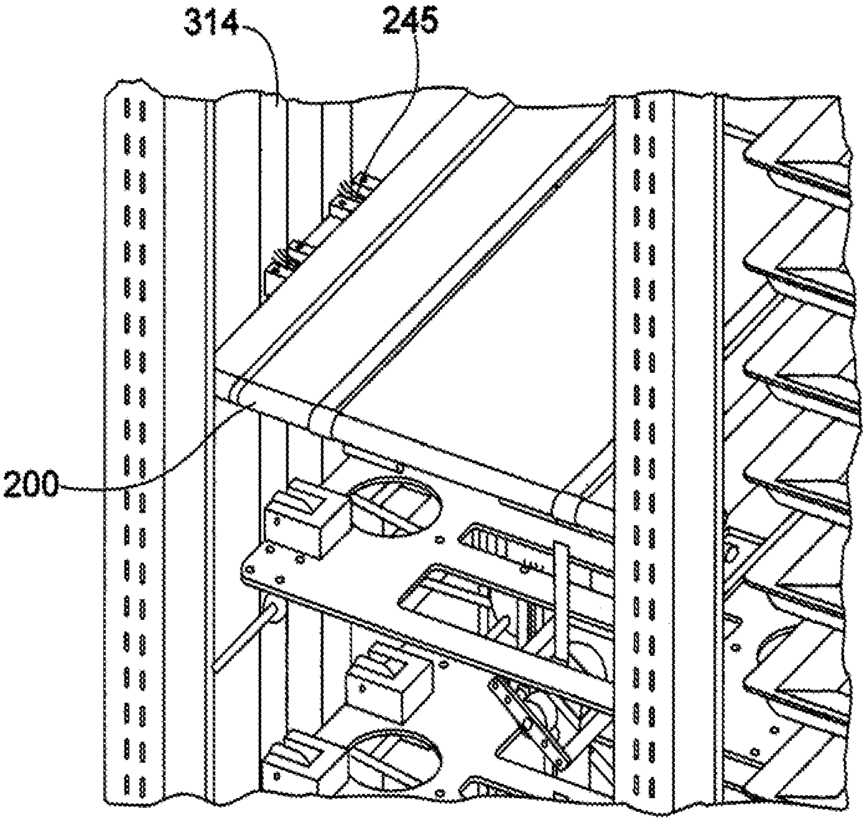

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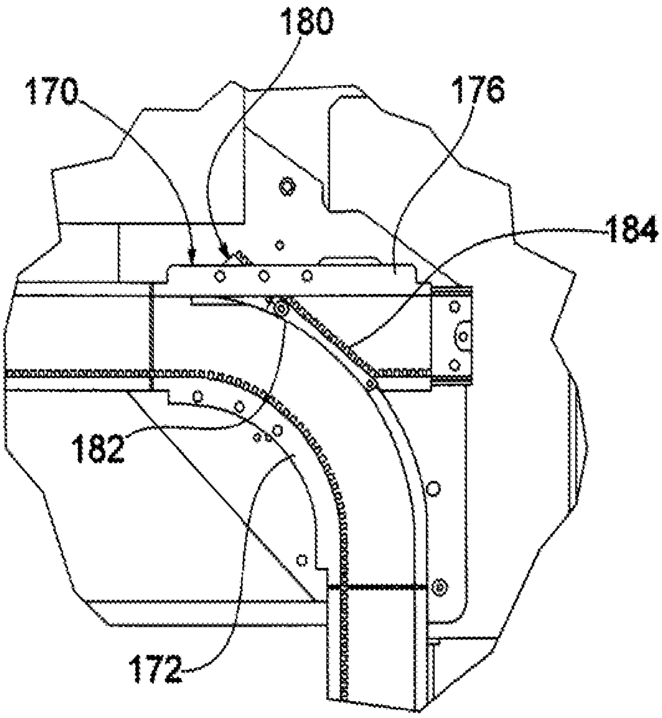

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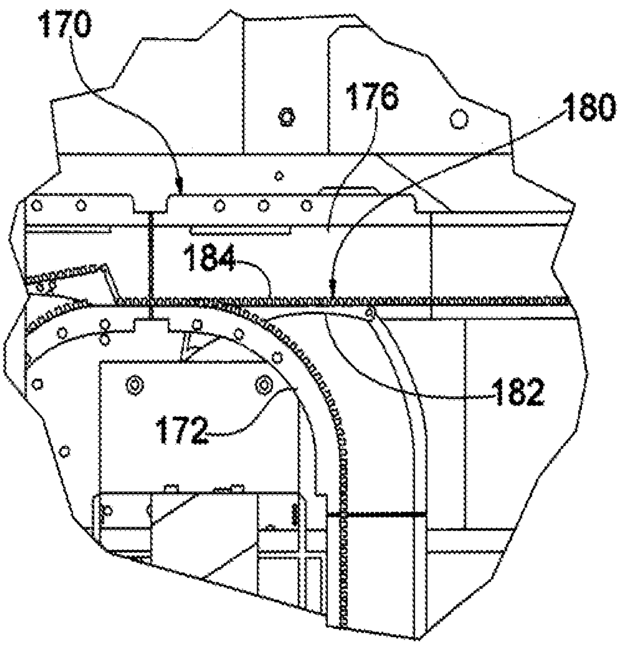

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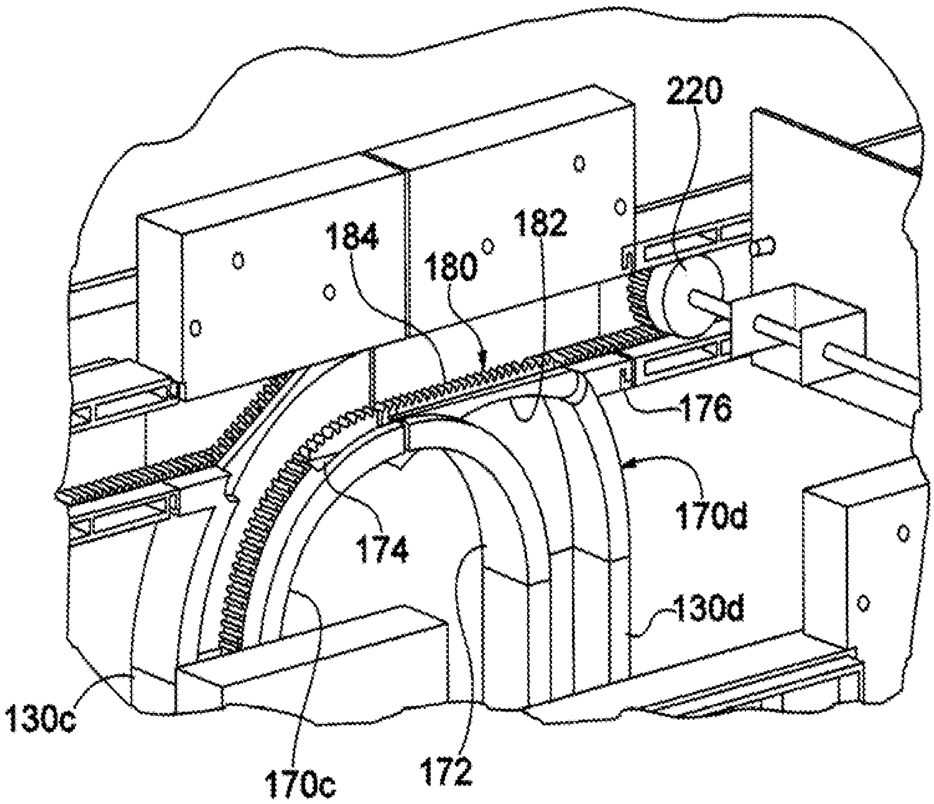

Fig. 10

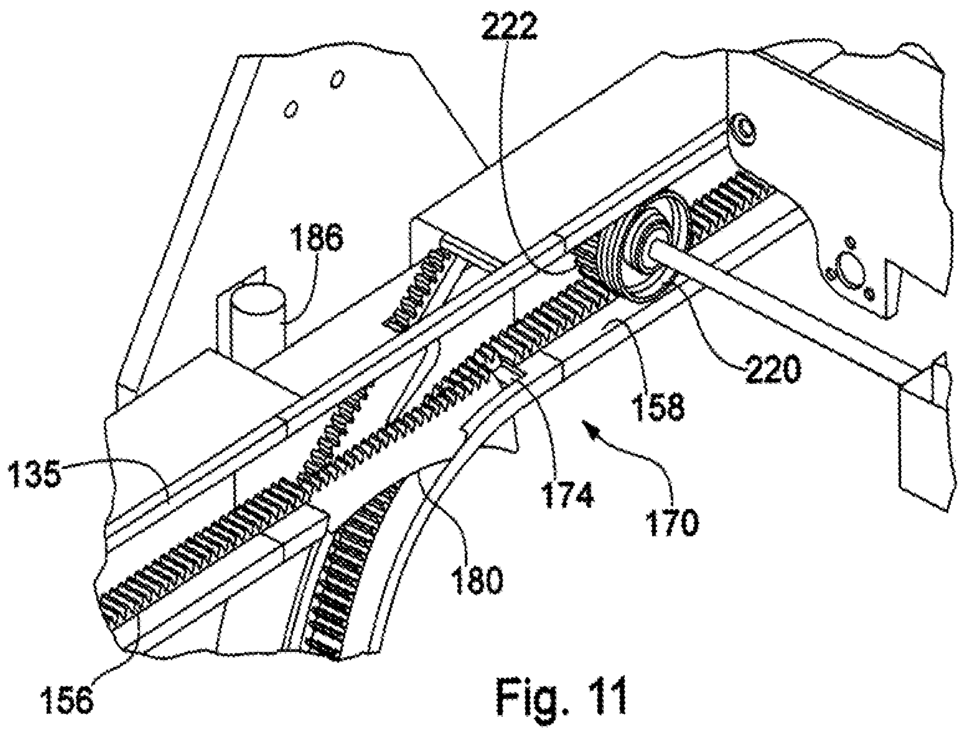

Fig. 11

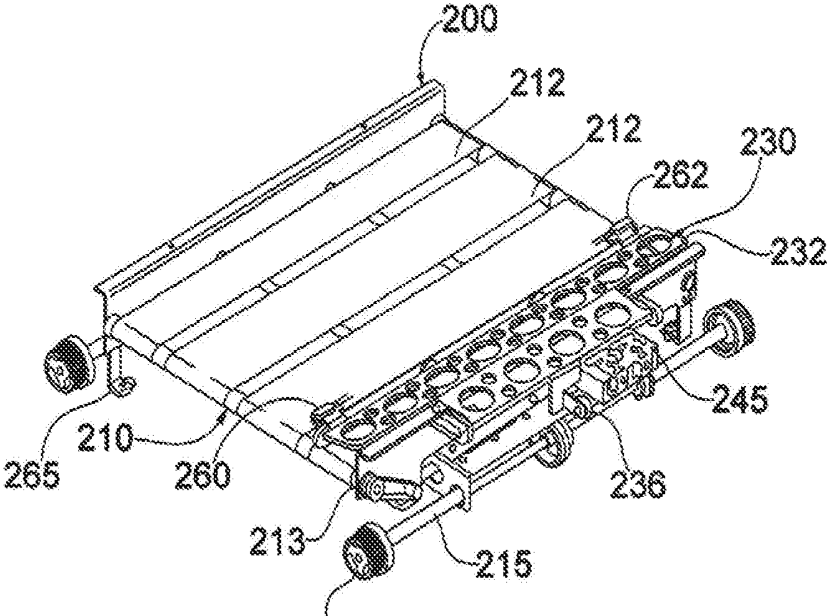
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Fig. 12

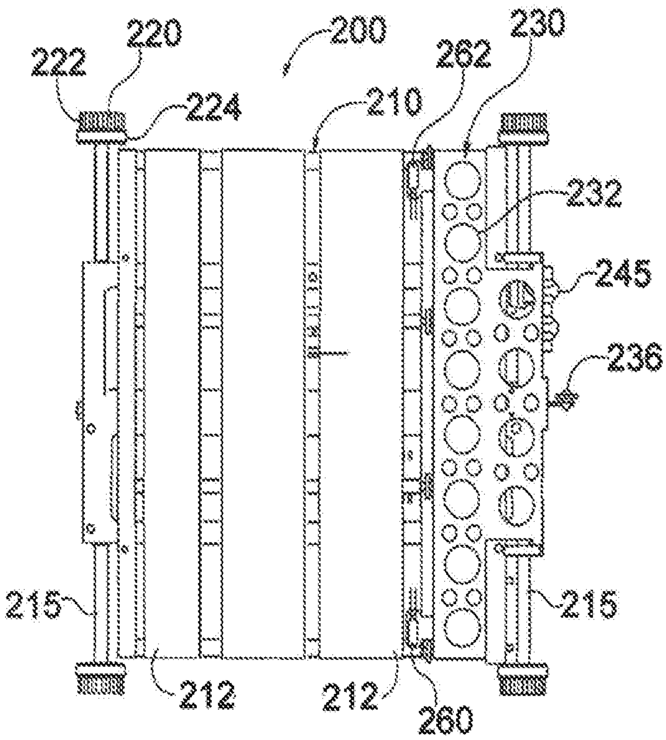
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Fig. 13

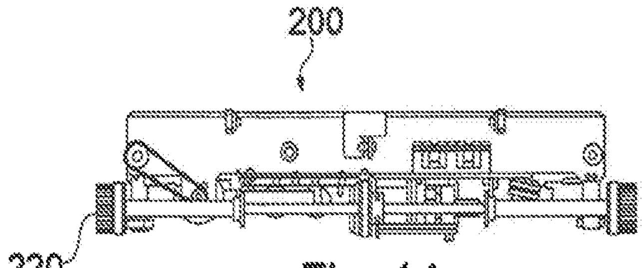

Fig. 14

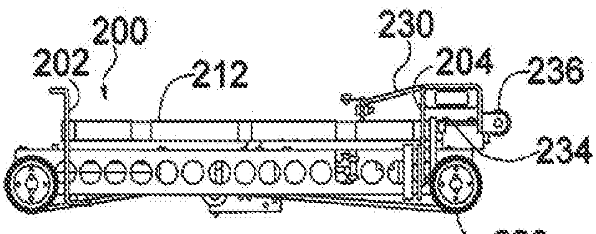

Fig. 15

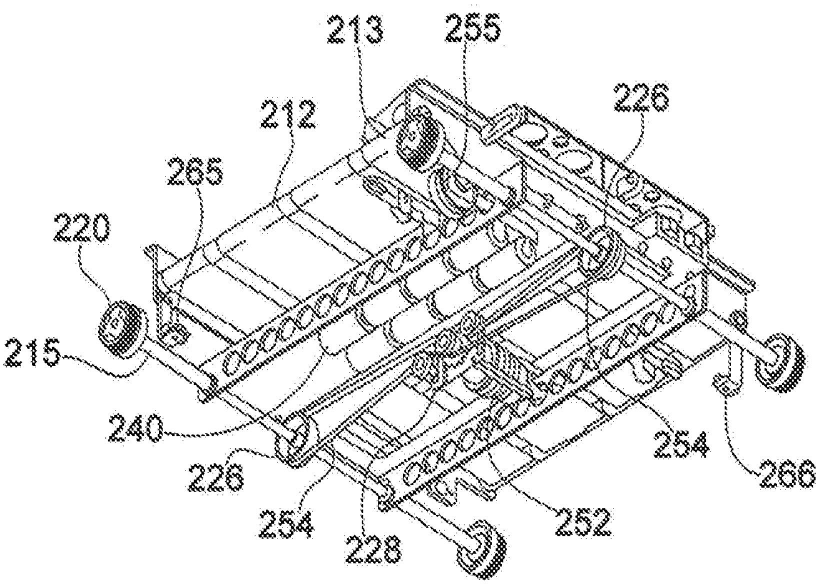
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Fig. 16

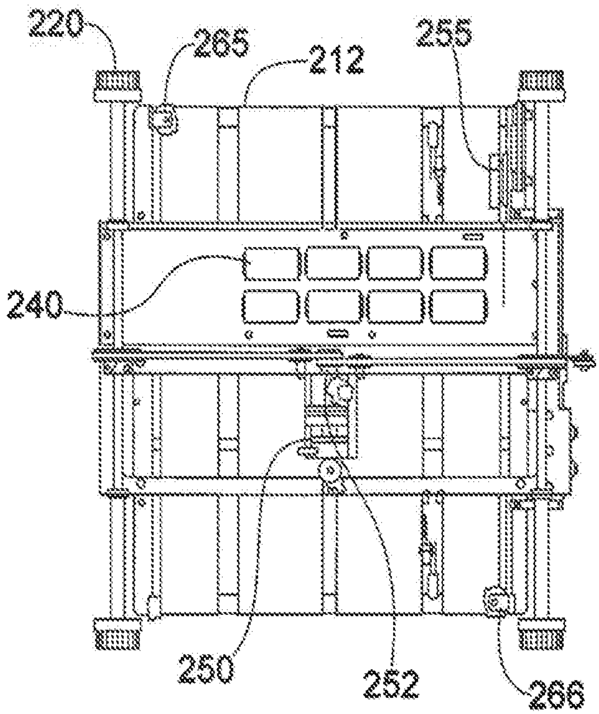
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Fig. 17

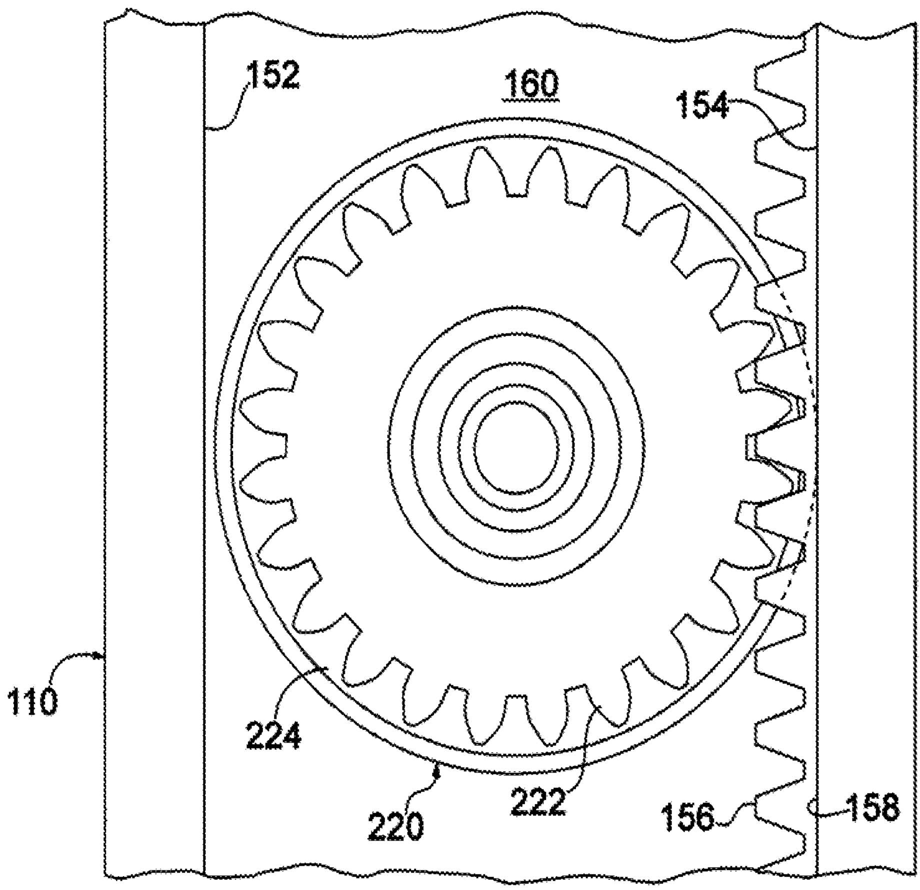


Fig. 18

MATERIAL HANDLING APPARATUS FOR DELIVERING OR RETRIEVING ITEMS

PRIORITY CLAIMS

The present application is a continuation of co-pending U.S. patent application Ser. No. 16/039,713, filed Jul. 19, 2018, which is a continuation of U.S. patent application Ser. No. 15/618,744, filed Jun. 9, 2017 issued as U.S. Pat. No. 10,052,661, which is a continuation of U.S. patent application Ser. No. 14/690,541, filed Apr. 20, 2015 issued as U.S. Pat. No. 9,687,883, which is a continuation of U.S. patent application Ser. No. 14/149,282, filed Jan. 7, 2014 issued as U.S. Pat. No. 9,010,517, which is a continuation of U.S. patent application Ser. No. 13/631,817, filed Sep. 28, 2012 issued as U.S. Pat. No. 8,622,194, which is a continuation of U.S. patent application Ser. No. 13/361,490 filed Jan. 30, 2012 issued as U.S. Pat. No. 8,276,740, which is a continuation of U.S. patent application Ser. No. 12/983,726 filed Jan. 3, 2011 issued as U.S. Pat. No. 8,104,601, which is a continuation of U.S. patent application Ser. No. 12/014,011 filed Jan. 14, 2008 issued as U.S. Pat. No. 7,861,844, which claims priority to U.S. Provisional Patent Application No. 60/884,766 filed on Jan. 12, 2007. The present application claims priority to each of the foregoing applications and the entire disclosure of each of the foregoing applications is hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to a material handling system for sorting or retrieving items. More specifically, the present invention relates to a material handling system incorporating a plurality of destination areas arranged along a track for guiding a plurality of vehicles for carrying items to and/or from the destination areas.

BACKGROUND OF THE INVENTION

Sorting documents and mail pieces manually is laborious and time consuming. For example, thousands of large organizations employ numerous people full-time to manually sort and deliver incoming and interoffice mail and documents. For instance, a large company may receive 5,000 mail pieces that need to be sorted and delivered each day to different departments and/or individuals. Such volumes require a significant number of employees dedicated to sorting and delivering the mail. Nonetheless, such volume is not typically sufficient to justify the expense of traditional automated sorting equipment, which is quite expensive. Additionally, the mail for such organizations is typically quite diverse, which makes it more difficult, and therefore more expensive, to automate the sorting procedures.

Various systems for sorting have been developed to address the needs of mail rooms for large organizations. However, the known systems suffer from several problems; the most significant are cost and size. Accordingly, there is a need for a compact and affordable automated sorting system that is able to meet the needs of mid- to large-sized organization that handle several thousand mail pieces each day.

Similarly, may large organizations have extensive storage areas in which numerous items are stored. Sorting and retrieving items from the hundreds or thousands of storage areas requires significant labor to perform manually, and the known systems of automatically handling the materials are either very expensive or have limitations that hamper their

effectiveness. Accordingly, there is a need in a variety of material handling applications for automatically storing and/or retrieving items.

SUMMARY OF THE INVENTION

In light of the foregoing, a system provides a method and apparatus for delivering items to storage locations. The system includes a plurality of storage locations, such as bins, and a plurality of delivery vehicles for delivering items to the storage locations or retrieving items from the storage locations. A track guides the delivery vehicles to the storage locations.

In one embodiment, a controller controls the operation of the delivery vehicles based on information determined for each item to be sorted. Additionally, the track may include a plurality of interconnected vertical and horizontal sections so that the vehicles may travel along a continuous path changing from a horizontal direction to a vertical direction. Further, the vehicles may be driven such that the orientation of an item on the vehicle stays constant as the vehicles changes from a horizontal direction of travel to a vertical direction of travel.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary and the following detailed description of the preferred embodiments of the present invention will be best understood when read in conjunction with the appended drawings, in which:

FIG. **1** is a perspective view of a sorting apparatus;

FIG. **2** is a plan view of the sorting apparatus illustrated in FIG. **1**;

FIG. **3** is a fragmentary perspective view of the sorting apparatus illustrated in FIG. **1**, shown without an input station;

FIG. **4** is a right side view of the sorting apparatus illustrated in FIG. **3**;

FIG. **5** is a front elevational view of the sorting apparatus illustrated in FIG. **3**, shown without discharge bins;

FIG. **6** is a fragmentary sectional view of a loading station of the sorting apparatus illustrated in FIG. **1**;

FIG. **7** is an enlarged fragmentary perspective view of a portion of the loading station of the apparatus illustrated in FIG. **3**;

FIG. **8** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in an open position;

FIG. **9** is an enlarged fragmentary view of a portion of track of the apparatus illustrated in FIG. **1**, showing details of a gate in a closed position;

FIG. **10** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate;

FIG. **11** is an enlarged fragmentary perspective view of a portion of the track illustrated in FIG. **1**, showing details of a gate, with the gate shown in an open position in phantom;

FIG. **12** is a top perspective view of a delivery vehicle of the apparatus illustrated in FIG. **1**;

FIG. **13** is a plan view of the delivery vehicle illustrated in FIG. **12**;

FIG. **14** is a right side view of the delivery vehicle illustrated in FIG. **12**;

FIG. **15** is a front elevational view of the delivery vehicle illustrated in FIG. **12**;

FIG. **16** is a bottom perspective view of the delivery vehicle illustrated in FIG. **12**;

FIG. **17** is a bottom view of the delivery vehicle illustrated in FIG. **12**; and

FIG. **18** is an enlarged view of a wheel of the delivery vehicle illustrated in FIG. **12**, shown in relation to the track of the sorting apparatus illustrated in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1-18**, an apparatus for sorting items such as documents or mail pieces is designated generally **10**. The apparatus **10** includes a plurality of delivery vehicles or cars **200** to deliver items to a plurality of sort locations, such as output bins **190**. At a loading station **310**, each car **200** receives an item from an input station **50** and delivers it to the appropriate bin.

The cars **200** travel along a track **110** to the sort locations. The track has a horizontal upper rail **135** and a horizontal lower rail **140**, which operates as a return leg. A number of parallel vertical track legs **130** extend between the upper rail and the lower return leg. In the present instance, the bins **190** are arranged in columns between the vertical track legs **130**.

After a piece is loaded onto a car, the car travels upwardly along two pairs of vertical tracks legs and then horizontally along two upper tracks **135**. The car **200** travels along the upper rail until it reaches the appropriate column containing the bin for the piece that the car is carrying. The track **110** includes gates **180** that fire to direct the car **200** down the vertical legs and the car stops at the appropriate bin. The car **200** then discharges the piece into the bin.

After discharging the piece, the car **200** continues down the vertical legs **130** of the column until it reaches the lower rail **140**. Gates fire to direct the car along the lower rail, and the car follows the lower rail to return to the loading station **310** to receive another piece.

The cars **200** are semi-autonomous vehicles that each have an onboard power source and an onboard motor to drive the cars along the track **110**. The cars also include a loading/unloading mechanism **210**, such as a conveyor, for loading pieces onto the cars and discharging the pieces from the cars.

Since the system **10** includes a number of cars **200**, the positioning of the cars is controlled to ensure that the different cars do not crash into each other. In one embodiment, the system **10** uses a central controller **350** that tracks the position of each car **200** and provides control signals to each car to control the progress of the cars along the track. The central controller **350** may also control operation of the various elements along the track, such as the gates **180**.

Input Station

At the input station **50**, the mail pieces are separated from one another so that the pieces can be conveyed serially to the loading station **310** to be loaded onto the cars **200**. Additionally, at the input station information is determined for each piece so that the piece can be sorted to the appropriate bin.

A variety of configurations may be used for the input station, including manual or automatic configurations or a combination of manual and automated features. In a manual system, the operator enters information for each piece and the system sorts the mail piece accordingly. In an automatic system, the input system includes elements that scan each mail piece and detect information regarding each piece. The system then sorts the mail piece according to the scanned information.

In an exemplary manual configuration, the input system includes a work station having a conveyor, an input device, such as a keyboard, and a monitor. The operator reads information from a mail piece and then drops in onto a conveyor that conveys the piece to the loading station **310**. Sensors positioned along the conveyor track the piece as the conveyor transports the mail piece toward the loading station. An example of a work station having a conveyor for receiving dropped pieces and tracking the pieces is provided in pending U.S. application Ser. No. 10/862,021, filed Jun. 4, 2004, which was published Jan. 27, 2005 under Publication No. US 2005-0018214 A1 and which is incorporated herein by reference. The conveyor receives mail pieces dropped by an operator and tracks the mail pieces as they are transported along the conveyor.

In an exemplary automatic configuration, the system includes an imaging station, having an imaging device such as a high speed line scanning camera. The imaging station scans each mail piece to detect information regarding the destination for each piece. The system analyzes the image data to determine the destination information and then electronically tags the mail piece with the destination and sorts the piece accordingly. An example of a system having an automated imaging station for scanning pieces as they are conveyed is described in U.S. patent application Ser. No. 09/904,471, filed Jul. 13, 2001, which was published Jan. 16, 2003 under Publication No. US 2003-0014376 A1, and which is incorporated herein by reference.

FIGS. **1** and **2** illustrate such an automated system. The input station includes an input bin **55** for receiving a stack of mail. A feeder **60** in the input bin serially feeds mail pieces from the input bin to a conveyor **65**. An imaging station **70** positioned along the conveyor scans the mails pieces as the pieces are conveyed to the loading station **310**. The system **10** analyzes the image data to read information for the mail piece, such as the recipient's address.

The conveyor **65** conveys the mail piece to the loading station **310**. At the loading station the conveyor **65** conveys the mail piece onto a car **200**. As discussed further below, after the mail piece is loaded onto the car, the car moves away from the loading station and another car moves into position at the loading station to receive the next piece of mail.

In certain instances, the system may not be able to automatically identify the relevant information for a mail piece. To process such pieces, the system may include an operator to input the relevant information so that the mail piece can be sorted. For instance, the system may include an operator station having an input device and a display, such as a monitor. If the system cannot automatically determine the address within a pre-determined time period, the system displays the scanned images for the mail piece to the monitor so that the operator at the work station can view the images and manually enter the information using the input device.

In addition to the automated and manual systems described above, the system may be configured in a hybrid or semi-automated configuration having some operations performed manually and others automated. For instance, the system may include a manual input station that also has an imaging station. Since the system can handle a wide variety of items, it may be desirable to have an operator input the pieces manually so that the pieces are properly oriented and separated. The imaging station then scans the items and processes the imaging data to determine the address information for the pieces. Additionally, the operator station may include an input device and a display for inputting information if the address for a piece cannot be automatically determined, as discussed above. The operator can input the information as soon as the system indicates to the operator that it cannot determine the information for a piece. Alternatively, as discussed below, the car may be directed to a buffer if the information for a piece cannot be determined. In such an instance, the cars having such pieces will remain in the buffer while the system continues to process pieces for which the system can determine the relevant information. The operator can continue to manually drop pieces and wait until a number of pieces need manual keying of information. The operator can then switch from the operation of dropping pieces to the operation of manually keying the pieces, sometimes referred to as local video encoding (LVE). The operator can continue keying until some or all of the pieces in the buffer have been successfully coded, and then the operator can go back to the operation of manually dropping pieces. As yet another alternative, it may be desirable to incorporate a separate operator station having the input device and display so that one operator can input the mail at the input station and a separate operator can input the information for pieces having addresses that cannot be automatically determined.

As can be seen from the foregoing, the input station **50** may be configured in a wide range of options. The options are not limited to those configurations described above, and may include additional features, such as an automated scale for weighing each piece, a labeler for selectively applying labels to the mail pieces and a printer for printing information on the mail pieces or on the labels.

Additionally, in the foregoing description, the system is described as having a single input station **50**. However, it may be desirable to incorporate a plurality of input stations positioned along the system **10**. By using a plurality of input stations, the feed rate of pieces may be increased. In addition, the input stations may be configured to process different types of items. In this way, each input station could be configured to efficiently process a particular category of items. For instance, if the system is configured to process documents, such as mail, one input station may be configured to process standard envelopes, while another input station may be configured to process larger mails, such as flats. Similarly, one input station may be configured to automatically process mail by scanning it and automatically determining the recipient. The second input station may be configured to process rejects, such as by manually keying in information regarding the recipient.

Sorting Station

Referring to FIGS. **1-6**, the system includes a sorting station **100**, such as an array of bins **190** for receiving the pieces. In the present instance, the sorting station includes a number of bins arranged in columns. Additionally, the sorting station **100** includes a track **110** for guiding the cars **200** to the bins **190**.

The track **110** includes a horizontal upper rail **135** and a horizontal lower rail **140**. A plurality of vertical legs **130** extend between the upper horizontal leg and the lower horizontal leg **140**. During transport, the cars travel up a pair of vertical legs from the loading station **310** to the upper rail **135** (as described below, the cars actually travel up two pairs of rails because the track includes a forward track and a parallel opposing track). The car then travels along the upper rail until reaching the column having the appropriate bin. The car then travels downwardly along two front vertical posts and two parallel rear posts until reaching the appropriate bin, and then discharges the mail piece into the bin. The car then continues down the vertical legs until reaching the lower horizontal leg **140**. The car then follows the lower rail back toward the loading station.

As can be seen in FIG. **2**, the track **110** includes a front track **115** and a rear track **120**. The front and rear tracks **115**, **120** are parallel tracks that cooperate to guide the cars around the track. As shown in FIG. **13**, each of the cars includes four wheels **220**: two forward wheel and two rearward wheels. The forward wheels **220** ride in the front track, while the rearward wheel ride in the rear track. It should be understood that in the discussion of the track the front and rear tracks **115**, **120** are similarly configured opposing tracks that support the forward and rearward wheels **220** of the cars. Accordingly, a description of a portion of either the front or rear track also applies to the opposing front or rear track.

Referring to FIG. **18** the details of the track will be described in greater detail. The track **110** includes an outer wall **152** and an inner wall **154** that is spaced apart from the outer wall and parallel to the outer wall. The track also has a back wall **160** extending between the inner and outer walls. As can be seen in FIG. **18**, the outer and inner walls **152**, **154** and the back wall form a channel. The wheels **220** of the car ride in this channel.

Referring to FIG. **11**, the track includes both a drive surface **156** and a guide surface **158**. The drive surface positively engages the cars to enable the car to travel along the track. The guide surface **158** guides the car, maintaining the car in operative engagement with the drive surface **156**. In the present instance, the drive surface is formed of a series of teeth, forming a rack that engages the wheels of the cars as described further below. The guide surface **158** is a generally flat surface adjacent the rack **156**. The rack **156** extends approximately halfway across the track and the guide surface **158** extends across the other half of the track. As shown in FIGS. **11** and **18**, the rack **156** is formed on the inner wall **154** of the track. The opposing outer wall **152** is a generally flat surface parallel to the guide surface **158** of the inner wall.

As described above, the track includes a plurality of vertical legs extending between the horizontal upper and lower rails **135**, **140**. An intersection **170** is formed at each section of the track at which one of the vertical legs intersects one of the horizontal legs. Each intersection includes an inner branch **172** that is curved and an outer branch **176** that is generally straight. FIG. **10** illustrates both a right-hand intersection **170***c* and a left-hand intersection **170**, which are mirrors of one another. In FIG. **10**, the intersections **170***c*, **170***d* illustrate the portion of the track in which two vertical legs **130** intersect the upper horizontal leg **135**. The intersections of the vertical legs with the lower rail incorporate similar intersections, except the intersections are reversed. Specifically, the point at which vertical leg **130***c* intersects the lower rail incorporates an intersection configured similar to intersection **170***d*, and the point at which vertical leg **130***d* intersects the lower rail incorporates an intersection configured similar to intersection **170***c*.

Each intersection **170** includes a pivotable gate **180** that has a smooth curved inner race and a flat outer race that has teeth that correspond to the teeth of the drive surface **156** for the track. The gate **180** pivots between a first position and a second position. In the first position, the gate **180** is closed so that the straight outer race **184** of the gate is aligned with the straight outer branch **176** of the intersection. In the second position, the gate is open so that the curved inner race **182** of the gate is aligned with the curved branch **172** of the intersection.

Accordingly, in the closed position, the gate is pivoted downwardly so that the outer race **184** of the gate aligns with the drive surface **156**. In this position, the gate blocks the car from turning down the curved portion, so that the car continues straight through the intersection. In contrast, as illustrated n FIG. **10**, when the gate is pivoted into the open position, the gate blocks the car from going straight through the intersection. Instead, the curved inner race **182** of the gate aligns with the curved surface of the inner branch **172** and the car turns through the intersection. In other words, when the gate is closed, a car goes straight through the intersection along either the upper rail **130** or the lower rail, depending on the location of the intersection. When the gate is opened, the gate directs the car from either a vertical rail to a horizontal rail or from a horizontal rail to a vertical rail, depending on the location of the intersection.

As can be seen in FIG. **11**, the end of the gate remote from the pivot point of the gate flares outwardly so that the curved inner race matches the curved profile of the inner branch when the gate is open. As a result, the gate has a generally L-shaped configuration. To accommodate the flared end of the gate **180**, the drive surface **156** of the inner branch has a notch or recessed portion. When the gate is closed, the notch provides clearance so that the outer race **184** of the gate lies flat, parallel with the drive surface of the outer branch **176**. Further, in the example shown in FIG. **11**, the gate is positioned along the upper rail **135** of the track **110**. When the gate is closed, the recess in the inner branch of the intersection **170** allows the gate to lie flat so that it is aligned with the drive surface of the upper rail.

In the foregoing description, the gates allow one of the cars to either continue in the same direction (e.g. horizontally) or turn in one direction (e.g. vertically). However, in some applications, the system may include more than two horizontal rails that intersect the vertical columns. In such a configuration, it may be desirable to include a different rail that allows the cars to turn in more than one direction. For instance, if a car is traveling down a column, the gate may allow the car to turn either left or right down a horizontal rail, or travel straight through along the vertical column. Additionally, in some applications it may be desirable to allow the cars to travel upwardly, whereas in the system described above, the cars only travel downwardly through the sorting station. If the cars also travel upwardly in the sorting station, then the gates should be configured to accommodate and guide the cars when the cars travel upwardly through an intersection.

The gates **180** are controlled by signals received from the central controller **350**. Specifically, each gate is connected with an actuator **186** that displaces the gate from the opened position to the closed position and back. There may be any of a variety of controllable elements operable to displace the gate. In the present instance, the actuator **186** is a solenoid having a linearly displaceable piston.

In the foregoing description, the sorting station **100** is described as a plurality of output bins **190**. However, it should be understood that the system may include a variety of types of destinations, not simply output bins. For instance, in certain applications it may be desirable to sort items to a storage area, such as an area on a storage shelf. Alternatively, the destination may be an output device that conveys items to other locations. According to one example of an output device, the system may include one or more output conveyors that convey pieces away from the sorting system toward a different material handling or processing system. For instance, an output conveyor designated A may convey pieces to a processing center designated A. Therefore, if a piece is to be delivered to processing center A, the car will travel along the track to output conveyor A. Once the car reaches output conveyor A, the car will stop and transfer the piece onto output conveyor A. Output conveyor A will then convey the piece to processing center A. Further, it should be understood that the system may be configured to include a plurality of output devices, such as output conveyors.

In some embodiments, the system may include a plurality of output conveyors in addition to the output bins. In other embodiments, the system may only include a plurality of output devices, such as conveyors, and the system is configured to sort the pieces to the various output devices. Further still, the system may be configured to retrieve pieces from storage locations. In such embodiments, the cars may sort pieces to a storage location, such as a bin. Subsequently, one of the cars may travel to the storage location and retrieve the item from the storage location and transport it to one of the output devices.

One manner that the cars may retrieve items from the storage locations is by including a conveyor at the storage locations. In this way, an item at a storage location can be conveyed by the conveyor toward the track. When a car arrives at the storage location, the conveyor at the storage location conveys the item onto the car, similar to the manner in which a piece is loaded onto the car at the loading column. Accordingly, the system can sort pieces to a plurality of output devices, in addition to sorting pieces to a plurality of storage locations before subsequently retrieving the pieces and conveying the pieces to the output devices.

As discussed above, the system is operable to sort a variety of items to a plurality of destinations. One type of destination is a bin; a second type is a shelf or other location on which the item is to be stored; and a third type of destination is an output device that may be used to convey the item to a different location. The system may include one or more of each of these types or other types of destinations.

Delivery Vehicles

Referring now to FIGS. **12-17**, the details of the delivery vehicles **200** will be described in greater detail. Each delivery vehicle is a semi-autonomous car having an onboard drive system, including an onboard power supply. Each car includes a mechanism for loading and unloading items for delivery.

The car **200** may incorporate any of a variety of mechanisms for loading an item onto the car and discharging the item from the car into one of the bins. Additionally, the loading/unloading mechanism **210** may be specifically tailored for a particular application. However, in the present instance, the loading/unloading mechanism **210** is a conveyor belt. Specifically, referring to FIGS. **12** and **15**, the loading/unloading mechanism includes a plurality of narrow belts **212** that extend along the top surface of the car between two opposing walls **202**, **204**. The conveyor belts are reversible. Driving the belts in a first direction displaces the item toward the rearward end of the car; driving the belt in a second direction displaces the item toward the forward end of the car.

A conveyor motor **255** mounted on the underside of the car drives the conveyor belts **212**. Specifically, the conveyor belts **212** are entrained around a forward roller **213** at the forward edge of the car, and a rearward roller at the rearward edge of the car. The conveyor motor **255** is connected with the forward roller **213** to drive the forward roller, thereby operating the conveyor belts.

The car includes four wheels **220** that are used to transport the car along the track **110**. The wheels **220** are mounted onto two parallel spaced apart axles **215**, so that two or the wheels are disposed along the forward edge of the car and two of the wheels are disposed along the rearward edge of the car.

Referring to FIG. **18**, each wheel comprises an inner idler roller **224** and an outer gear **222** that cooperates with the drive surface **156** of the track. The idler roller **224** rotates freely relative to the axles, while the outer gear is fixed relative to the axle onto which it is mounted. In this way, rotating the axle operates to rotate the gear **222**. Additionally, the idler roller is sized to have a diameter slightly smaller than the distance between the upper wall **152** and the lower wall **154** of the track. In this way, the idler roller may rotate freely within the track, while ensuring that the gear **222** of each wheel remains in operative engagement with the drive surface (i.e. the teeth) **156** of the track. Accordingly, when the vehicle is moving horizontally, the rollers carry the weight of the cart, while the gears **222** cooperate with the drive surface **156** of the track to drive the vehicle along the track.

The car includes an onboard motor **250** for driving the wheels **220**. More specifically, the drive motor **250** is operatively connected with the axles to rotate the axles **215**, which in turn rotates the gears **222** of the wheels. As shown in FIG. **16**, the drive motor **250** is interconnected to the axles **215** via a pair of drive belts **254** that are driven by the drive motor.

The drive system for the car may be configured to synchronously drive the car along the track. In the present instance, the drive system is configured so that each gear is driven in a synchronous manner. Specifically, each gear **222** is connected to an end of one of the axles in a manner that substantially impedes rotation of the gear relative to the axle. In this way each axle drives the attached two gears in a synchronous manner. Additionally, in the present instance, both axles are driven in a synchronous manner so that all four gears are driven in a synchronous manner. There are various mechanisms that can be used to synchronously drive the axles. For instance, a pair of drive motors can be used to drive the axles, and the drive motors can be synchronized. However, in the present instance, a single drive motor **250** is used to drive both axles. Each axle includes a timing pulley **226** that is rigidly connected to the axle to prevent rotation of the pulley relative to the axle. Similarly, a timing pulley **228** is connected to the motor shaft. The drive belt **254** connecting the timing pulley **226** on the axle with the motor is a timing belt so that the rotation of the drive motor is precisely linked to the rotation of the axle. Although a single timing belt can be used to drive both axles synchronously, in the present instance, a pair of timing pulleys is connected to the motor shaft, and each timing pulley is connected to a corresponding timing pulley on one of the axles, as shown in FIG. **16**.

The drive motor **250** includes a sensor that is operable to detect the rotation of the motor to thereby determine the distance the car has traveled. Since the gears **222** are rigidly connected with the axles, which are in turn synchronously connected with the drive motor, the forward distance that the car moves corresponds can be exactly controlled to correlate to the distance that the drive motor is displaced. Accordingly, the distance that a car has traveled along the determined path depends on the distance through which the car motor is rotated.

To detect the rotation of the drive motor **250**, the motor includes a sensor **252** for detecting the amount of rotation of the drive motor. In the present instance the sensor **252** is a hall sensor. A portion of rotation of the motor corresponds to what is referred to as a tick. The sensor detects the number of ticks and sends a signal to the central processor **350**, which determines how far along the designate path the car has traveled based on the known information regarding the path and the number of ticks that the sensor detects for the motor.

As the car travels along the track, an item on top of the car may tend to fall off the car, especially as the car accelerates and decelerates. Therefore, in the present instance, the car includes a retainer **230** to retain the element on the car during delivery. As illustrated in FIGS. **12-17**, the retainer **230** is a hold down that clamps the item against the top surface of the car.

The retainer includes an elongated pivotable arm **232**. A biasing element, such as a spring, biases the arm downwardly against the top surface of the retainer **230**. The retainer **230** further includes an operator **234** in the form of a tab. Pushing downwardly on the tab raises the clamp from the top surface of the conveyor to allow a piece to be loaded onto the car or discharged from the car.

The car **200** may be powered by an external power supply, such as a contact along the rail that provides the electric power needed to drive the car. However, in the present instance, the car includes an onboard power source **240** that provides the requisite power for both the drive motor **250** and the conveyor motor **255**. Additionally, in the present instance, the power supply is rechargeable. Although the power supply may include a known power source, such as a rechargeable battery, in the present instance, the power supply **240** is made up of one or more ultracapacitors. Ultracapacitors are extremely high energy density capacitors. Capacitors store electrical energy by physically separating positive and negative charges, in contrast to the chemical means a battery uses. Ultracapacitors rely on an electrostatic effect, which is physical rather than chemical, and highly reversible. The ultracapacitors can accept very high amperage to recharge the ultracapacitors. By using a high current, the ultracapacitors can be recharged in a very short time, such as a few seconds or less.

The car includes one or more contacts for recharging the power source **240**. In the present instance, the car includes a plurality of brushes **245**, such as copper brushes that are spring-loaded so that the brushes are biased outwardly. The brushes **245** cooperate with a charging rail in the loading station to recharge the power source, as described further below.

Each car includes at least one and preferably two load sensors for detecting the items as it is loaded onto the car. The sensor(s) ensure that the mail piece is properly positioned on the car. In the present instance, the car includes a forward loading sensor **260** and a rearward loading sensor **262**. The forward loading sensor detects the leading edge of the item as it is loaded onto the car. The forward loading sensor **260** also detects the trailing edge of the item to ensure that the entire length of the item is loaded onto the car. Similarly, the rearward sensor **262** detects the leading edge and in certain instances, may detect the trailing edge of the mail piece. The loading sensors **260**, **262** may be simple I/R sensors that detect the presence or absence of a document or mail piece.

Although the car operates in response to signals received from the central controller **350**, which tracks the location of each car, the car may also include a reader **265** for reading indicia along the track to confirm the position of the car. For instance, each bin may be assigned a unique bar code, and the forward reader may scan the track or other area around the bin **190** at which an item is to be delivered. The data that the central processor has regarding the path that the car is to follow and the data regarding the distance the car has traveled based on the data regarding the rotation of the drive motor **250** should be sufficient to determine whether the car **200** is positioned at the appropriate bin. Nonetheless, it may be desirable to double check the location of the car before the item is discharged into the appropriate bin. Therefore, the scanner may operate to scan and read information regarding the bin at which the car is stopped. If the scanned data indicates that the bin is the appropriate bin, then the car discharges its item into the bin. Similarly, the car may have a second reader **266** for reading indicia adjacent the rearward edge of the car. The second reader **266** may be used in applications in which the system is set up to utilize a first series of bins **190** along the forward side and a second series of bins along the rearward side of the track **110**.

In foregoing description, the cars have drive gears that interact with teeth in the track to guide the cars around the track. Additionally, as described further below in the operation section, the location of the car may be controlled based on information regarding how far the car has traveled. In such applications it is desirable to synchronize the drive wheels of the car. However, in some applications alternative control systems may be used. For instance, the location of the cars can be controlled based on signals from sensors positioned along the track or indicators positioned along the track. In such instances, the cars may be configured to use a drive mechanism that is not synchronous as described above.

As discussed further below, the car further includes a processor for controlling the operation of the car in response to signals received from the central processor. Additionally, the car includes a wireless transceiver so that the car can continuously communicate with the central processor as it travels along the track. Alternatively, in some applications, it may be desirable to incorporate a plurality of sensors or indicators positioned along the track. The car may include a reader for sensing the sensor signals and/or the indicators, as well as a central processor for controlling the operation of the vehicle in response to the sensors or indicators.

Loading Column

Referring now to FIGS. **6-7** the details of the loading column **300** will be described in greater detail. The loading column **300** is formed adjacent the output end of the input station **50**. The loading column **300** is formed of a front pair of vertical rails **305***a*, **305***b* and a corresponding rearward set of vertical rails. The loading station **310** is positioned along the loading column. The loading station **310** is the position along the track in which the car **200** is aligned with the discharge end of the conveyor of the input station **50**. In this way, a mail piece from the input station may be loaded onto the car as it is conveyed toward the car from the input station.

Although the central processor **350** tracks the position of the car, a home sensor **312** is positioned adjacent the loading station **310**. When the home sensor detects the car, the position for the car is known relative to a fixed point along the track, and the central processor resets the position of the car to the home or zero position.

Referring to FIG. **7**, a pair of charging rails are disposed along the vertical rails **305***a*, **305***b*. The charging rails are conductive strips connected with an electrical supply. The charging contacts **245** of the car **200** engage the conductive strips to recharge the ultracapacitors **240**. Specifically, the biasing element of the brushes **245** biases the brushes outwardly toward the charging contacts. The electricity flowing through the charging contact **245** is a high amperage, low voltage source that allows the ultracapacitors to recharge in a few seconds or less. In addition, since the power supply provided by the ultracapacitors last for only a few minutes, the car recharges each time it travels through the loading column.

Additionally, it may be desirable to incorporate a startup charging rail similar to the charging rails described above, but disposed along either the return rail or the rails in the column adjacent to the loading column, depending on where the cars are stored when the cars are shut down. Since the cars use ultracapacitors, it is possible that the ultracapacitors will discharge while the system is shut down. Therefore, upon startup the cars will not have any charge and will not be able to move to the loading column to charge the ultracapacitors. Accordingly, the system may include a startup charging rail disposed along a rail that the cars contact when the cars are stored during shutdown. If the cars are stored in the loading column and the adjacent column during shutdown, then the startup rail is disposed in the column adjacent the loading column. Alternatively, if the cars are stored on the return rail and the loading column during shutdown, then the startup rail is disposed along the return rail. In this way, when the system is started, a charging current is supplied to the cars through the startup charging rail and the charging rail in the loading column.

As discussed previously, each car **200** includes a retainer **230** to hold down items on the car during transport. The retainer should be opened at the loading station to allow an item to be loaded onto the car. Accordingly, as shown in FIG. **6**, an actuator **316** is positioned along the column. The actuator **316** projects inwardly toward the cars as the cars are conveyed up the loading column. As a car is conveyed upwardly in the loading column **300**, the hold down actuator **316** contacts the hold down operator or tab **236**. The interaction between the actuator **316** and the tab **236** causes the retainer to open, so that items can be loaded onto the car. As the car moves upwardly past the actuator **316**, the tab **236** on the car disengages the actuator, thereby releasing the retainer, thereby holding down or clamping the mail piece against the top surface of the vehicle.

In the foregoing description, the loading station has been described as a column in which an item is loaded onto the car and the car then travels upwardly to the horizontal upper rail **135**. However, in some applications in may be desirable to configure the loading station so that the items are loaded onto the cars at or near the top of the vertical column. In such an application, the load on the cars would be reduced since the car will not have to lift the item loaded on the car. In order to load the items on the cars at the top of the conveyor, a vertical conveyor may be added to the system. For instance, a conveyor angled upwardly may convey the items upwardly to the top of the column to load the items onto the cars. Alternatively, one or more of a variety of conveyor configurations can be used to transport to items toward the top of the loading column to load the items onto the cars.

Operation

The system **10** operates as follows. An item is processed at the input station **50** to identify a characteristic of the piece that is indicative of where the piece should be sorted. For instance, the item may be a mail piece that is to be sorted according to department, box number or recipient. If the mail pieces are sorted by department, the piece may be processed to identify either an indicator of the department (such as box number) or the piece may be processed to identify the recipient. The central controller maintains a database that correlates various data to identify the destination bin. For instance, the database may correlate the recipient names with the appropriate department if the mail is being sorted according to department. In other embodiments, the piece may be a part that has a product code and the database may correlate the product code with the sort location.

As discussed previously, the input station may process the items automatically or manually. In a manual mode, the operator manually enters information regarding a piece and then drops the piece on a conveyor. The system electronically tags the piece with the sort information and the conveyor conveys the piece toward the loading station. Alternatively, if the input system is an automated system, the piece is automatically scanned to identify the relevant sort characteristic. For instance, the input station may use a scanner, such as a bar code scanner to read the postnet code on a piece, or the input station may include an imaging device, such as a high speed line scan camera in combination with an OCR engine to read information on the piece.

To prepare to receive an item, a car **200** moves along the track toward the loading station **310** in the loading column **300**. As the car approaches the loading station, the operator **236** for the hold down **230** engages the actuator **316**, which pivots the hold down upwardly to prepare the car to receive an item, as illustrated in FIG. **6**. When the car **200** moves into position at the loading station **310** the home sensor detects the presence of the car and sends a signal to the central processor **350** indicating that the car is positioned at the loading station. In the following description, the item being sorted is described as being a mail piece. It should be understood that such an item is an exemplary application of the system. As described above, the system can be configured to sort a variety of items in a variety of material handling applications.

Once the car is positioned at the loading station, the input station conveys a mail piece onto the car. As the mail piece is being conveyed onto the car **200**, the loading mechanism **210** on the car loads the mail piece onto the car. Specifically, the input station conveys the mail piece into contact with the conveyor belts **212** on the car. The conveyor belts **212** rotate toward the rearward side of the car, thereby driving the mail piece rearwardly on the car.

The operation of the conveyor belts is controlled by the loading sensors **260**, **262**. The forward loading sensor detects the leading edge of the mail piece as the mail piece is loaded onto the car. Once the forward loading sensor **260** detects the trailing edge of the mail piece, a controller onboard the car determines that the mail piece is loaded on the car and stops the conveyor motor. Additionally, the onboard controller may control the operation of the conveyor in response to signals received from the rearward sensor **262**. Specifically, if the rearward sensor **262** detects the leading edge of the mail piece, then the leading edge of the mail piece is adjacent the rearward edge of the car. To ensure that the mail piece does not overhang from the rearward edge of the car, the controller may stop the conveyor once the rearward sensor detects the leading edge of the mail piece. However, if the rearward sensor detects the leading edge of the mail piece before the forward sensor detects the trailing edge of the mail piece, the controller may determine that there is a problem with the mail piece (i.e. it is too long or two overlapping mail pieces were fed onto the car. In such an instance, the car may communicate an error message with the central controller, which may declare an error and provide an indicator to the operator that the car at the loading station requires attention. Alternatively, a reject bin **325** may be positioned behind the loading station so that mail pieces on the car at the loading station can be ejected into the reject bin **325**. In this way, if there is an error loading

a mail piece onto a car, the mail piece can simply be ejected into the reject bin, and a subsequent mail piece can be loaded onto the car.

After a mail piece is loaded onto the car, the car moves away from the loading station. Specifically, once the onboard controller detects that a mail piece is properly loaded onto the car, the onboard controller sends a signal to start the drive motor **250**. The drive motor **250** rotates the axles, which in turn rotates the gears **222** on the wheels **220**. The gears **222** mesh with the drive surface **156** of the vertical rails **305** in the loading column to drive the car upwardly. Specifically, the gears and the drive surfaces mesh and operate as a rack and pinion mechanism, translating the rotational motion of the wheels into linear motion along the track **110**.

Since the cars move up the loading column from the loading station, the destination for the car does not need to be determined until after the car reaches the first gate along the upper rail **135**. For instance, if an automated system is used at the input station to scan and determine the characteristic used to sort the mail pieces, it may take some processing time to determine the relevant characteristic. The time that it takes to convey the mail piece onto the car and then convey the car up the loading column will typically be sufficient time to determine the relevant characteristic for the mail piece. However, if the characteristic is not determined by the time the car reaches the upper rail, the car may be directed down the second column, which is the column next to the loading column. The car travels down the second column to the lower rail **140**, and then back to the loading column. The car may stop in the second column to provide additional time to determine the characteristic. However, after waiting for a pre-determined period the system may declare that the address cannot be determined and the car may be advanced from the second column and the piece may be discharged to a reject bin. Alternatively, rather than declare an error the car may continue to travel around the loop from the loading column to the second column until the characteristic is determined or until a predetermined time at which the central controller declares an error. Additionally, rather than using the reject bin when the system is unable to determine the characteristic for a mail piece, one of the bins in the second column can also be used as a reject bin. In this way, the cars are ready to receive a mail piece as soon as the car reaches the loading station, without having to eject the problem mail piece into the reject bin **325** at the loading station.

As described above, the system includes a loop that can be utilized as a buffer track to provide additional processing time to analyze the characteristic for the mail piece if necessary. Although the first and second columns can be used as the buffer loop, other columns can be used as a buffer loop if desired.

The foregoing discussion described the process for buffering a car if the system is unable to determine the characteristic for the mail piece by the time the car reaches the top rail. However, for most mail pieces, the system should be able to identify the characteristic without having to buffer the car. The following discussion describes the operation of the system assuming that the characteristic for the mail piece is determined before the car reaches the upper rail **135**.

Once the characteristic for the mail piece is determined, the central controller **350** determines the appropriate bin **190** for the mail piece. Based on the location of the bin for the mail piece, the route for the car is determined. Specifically, the central controller determines the route for the car and communicates information to the car regarding the bin into which the mail piece is to be delivered. The central controller then controls the gates along the track to direct the car to the appropriate column. Once the car reaches the appropriate column the car moves down the column to the appropriate bin. The car stops at the appropriate bin **190** and the onboard controller sends an appropriate signal to the conveyor motor **255** to drive the conveyor belts **212**, which drives the mail piece forwardly to discharge the mail piece into the bin. Specifically, the top of the car aligns with the gap between the appropriate bin **190** and the bottom edge of the bin that is immediately above the appropriate bin.

As discussed above, the central controller **350** controls the operation of the gates **180** in response to the location of the car **200** and the route that the car is to follow to deliver the mail piece. Additionally, as discussed below, the central controller controls the gates in response to the position of other cars on the track.

As the car **200** travels along the upper rail **135** and approaches a column, the gates for the vertical rails **130** are controlled as follows. If the car is to pass over the column on the way to the next column, the gates are displaced into the closed position, as shown in FIG. **9**. Specifically, both gates at the top of the column are closed so that the outer race **184** of the gate aligns with the straight track, with the outer race aligning with the drive surface **156** of the track **110**. In this way, the gates provide a straight drive surface that cooperates with the drive surface **156** to allow the car to travel over the column.

When the car comes to a column that it is to turn down, the gates are controlled as follows. Referring to FIG. **5**, the columns can be seen without the bins attached. The view in FIG. **5** is from the front of the apparatus **10**, so the car will be traveling along the upper rail from the right to the left in the perspective of FIG. **5**. In the following discussion, the car is to be conveyed to a bin in the column designated C in FIG. **5**. Column C includes two pairs of vertical legs. The first pair is front and back vertical legs **130***c* on the left side of column C; the second pair is front and back vertical legs **130***d* on the right side of column C.

In order for the car to travel down column C, the wheels on the left side of the car travel down legs **130***c* and the right side wheels travel down legs **130***d*. Therefore, as the car approaches column C, the gates at the top of **130***d* are displaced to the closed position so that the left side wheels remain on the upper rail and pass over the right side legs **130***d*. After the left side wheels of the car pass over the right legs **130***c*, the gates **180** at the top of the right legs **130***d* are displaced into the open position so that the right side wheels can turn down legs **130***d*. Specifically, after the left side wheels pass right legs **130***d*, the central controller operates the solenoids **186** of the gates **180** at the top of legs **130** to displace the gates into the open position, as shown in FIG. **8** (note that the view in FIG. **8** is taken from the rear side of the apparatus so that the perspective of the gates is reversed relative to the front side). The gates **180** block the straight path through the intersection **170** and the curved inner race **182** of the gates direct the right side wheels down vertical legs **130***d*. Similarly, the gates **180** at the top of the left side legs **130***c* are displaced into the open position to direct the left side wheels down vertical legs **130***c*.

As the car approaches the intersections at the bottom of legs **130***c* and **130***d*, the gates are operated similarly to the above description, but in reverse. Specifically, as the car approaches the intersections **170** at the bottom of legs **130***c* and **130***d*, the gates **180** in the intersections are displaced into the opened position so that the gates direct the forward and leading wheels to turn down the lower rail. From the perspective of FIG. **5**, the car travels from left to right after the car reaches the lower rail. After the car passes though the intersections at the bottom of the rails **130***c*, **130***d*, the gates at the bottom of right side legs **130***d* are displaced into the closed position before the left side wheels of the car reach the intersection at the bottom of the right side legs **130***d*. In this way, the left side wheels of the car pass straight through the intersection at the bottom of legs **130***d* along the bottom rail **140**.

As discussed above, the central controller **350** controls the operation of the gates in response to the position of the car and more specifically in response to the position of the left hand and right hand wheels of the car. The gates are fired sequentially to ensure that the different pairs of wheels are directed down the proper vertical legs. Alternatively, the operation of the gates may be controlled by signals received from the cars. Specifically, the cars may include a transmitter that transmits a signal to the central controller indicating that it is in proximity to a gate that is to be fired. Further still, the car may include an indicator that may be scanned as the car approaches the gate. Based on the indicator and the know destination for the car, the gate may fire. Still further, the car may include an mechanical actuator that selectively triggers or actuates a gate to appropriately direct the car.

One of the advantages of the system as described above is that the orientation of the cars does not substantially change as the cars move from travelling horizontally (along the upper or lower rails) to vertically (down one of the columns). Specifically, when a car is travelling horizontally, the two front geared wheels **220** cooperate with the upper or lower horizontal rail **135** or **140** of the front track **115**, and the two rear geared wheels **220** cooperate with the corresponding upper or lower rail **135** or **140** of the rear track **120**. As the car passes through a gate and then into a column, the two front geared wheels engage a pair of vertical legs **130** in the front track **115**, and the two rear geared wheels engage the corresponding vertical legs in the rear track **120**.

As the car travels from the horizontal rails to the vertical columns or from vertical to horizontal, the tracks allow all four geared wheels to be positioned at the same height. In this way, as the car travels along the track it does not skew or tilt as it changes between moving horizontally and vertically. Additionally, it may be desirable to configure the cars with a single axle. In such a configuration, the car would be oriented generally vertically as opposed to the generally horizontal orientation of the cars described above. In the single axle configuration, the weight of the cars would maintain the orientation of the cars. However, when using a single axle car, the orientation of the sort locations would be re-configured to accommodate the vertical orientation of the cars. Similarly, the loading station would also be re-configured to load the pieces onto the cars in the vertical orientation.

Traffic Control

Since the system includes a number of cars **200**, the system controls the operation of the different cars to ensure the cars do not collide into one another. In the following discussion, this is referred to as traffic control.

A variety of methodologies can be used for traffic control. For instance, the traffic control can be a distributed system in which each car monitors its position relative to adjacent cars and the onboard controller controls the car accordingly. One example of such as system utilizes proximity sensors on each car. If the proximity sensor for a car detects a car within a predefined distance ahead of the car, the onboard controller for the trailing car may control the car by slowing down or stopping the trailing car. Similarly, if a car detects a car within a predefined distance behind the car, the lead car may speed up unless the lead car detects a car ahead of it within the predefined distance. In this way, the cars may control the speed of the cars independently based on the feedback from the proximity sensors.

Although the system may use a distributed system for traffic control, in the present instance, the system uses a centralized system for traffic control. Specifically, the central controller **350** tracks the position of each car **200** and provides traffic control signals to each car based on the position of each car relative to adjacent cars and based on the route for each car.

In the present instance, the central controller **350** operates as the traffic controller, continuously communicating with the cars as the cars travel along the track **110**. For each car, the central controller determines the distance that each car can travel, and communicates this information with the cars. For instance, if car B is following car A along the track, and car A is at point A, car B can safely travel to a point just before point A without crashing into car A. As car A advances to a subsequent point B along the track, car B can travel safely to a point just before point B without crashing into car A.

The cars continuously communicate with the central controller to provide information indicative of their positions, so that the central controller can continuously update the safe distances for each car as the cars advance around the track.

Although the foregoing discussion is limited to determining safe zones based on the positions of the various cars on the track, the determination of safe zones is based on other factors that affect the traffic. For instance, when calculating the safe distance for a car, the central controller considers the distance between the car and the next gate, as well as the distance to the destination bin for the car.

As can be seen from the foregoing, increasing the frequency of communication between the cars and the central controller increases the efficiency of the traffic flow along the track. Accordingly, in the present instance, the traffic control is designed to communicate with a car once for every inch the car travels along the track. Therefore, if a car travels at 25 inches per second, the central controller communicates with the car every 40 msec. Further, it is desirable to have the cars travel at up to 50 inch/sec. Therefore, it is desirable to configure the communications to allow the cars to communicate with the central controller every 20 msec.

In addition, to the foregoing variables used to calculate safe distances, information regarding the track profile ahead of each car is used to calculate safe distances. For instance, the central controller determines whether the path ahead of a car is sideways movement, uphill movement (i.e. movement vertically upwardly) or downhill movement (i.e. movement vertically downwardly).

One of the issues in traffic control relates to merging at intersections **170**. The problem arises when a car needs to merge onto the return rail **140**. If two cars will arrive at the intersection close enough to collide, one of the cars needs to have priority and the other car needs to wait or slow down to allow the first car to go through.

A first method for controlling merging traffic is based on determining the next gap large enough for a car to have time to pass through an intersection without colliding with another car. In other words, if a first car approaches an intersection and it is determined that the gap between the first car and a second car is not sufficient for the first car to pass through, the first car waits at the intersection until there is a gap large enough to allow the first car to pass through.

A second method for controlling merging traffic is based on determining which car is closest to the homing sensor at the loading station **310**. The car with the shortest distance to the homing sensor gets priority at the intersection.

Another factor that the traffic controller considers when calculating safe distances relates to the position of cars in adjacent columns. In the present instance, most of the adjacent columns share a common vertical rail. For instance, in FIG. **5**, the leftmost column uses vertical rails **130***a* and **130***b*. The column next to the leftmost column uses vertical rails **130***b* and **130***c*.

However, in the present instance, some of the columns may have two vertical rails **130** that are independent from the adjacent columns. For instance, the loading column **300** has two independent rails that are not shared with the adjacent column. Therefore, cars can travel up the loading column without regard to the position of cars in the column next to the loading column. Furthermore, as shown in FIG. **5**, it may be desirable to configure the column next to the loading column so that it also has two independent vertical rails. In this way, cars can more freely travel up the loading column and down the adjacent column to provide a buffer loop as described previously.

Accordingly, when calculating safe distances, the traffic controller evaluates the position of cars in adjacent columns if the cars share a common vertical rail to ensure that the two cars do not collide as the car travel down the adjacent columns.

In the foregoing discussion, the sorting of items was described in relation to an array of bins disposed on the front of the sorting station **100**. However, as illustrated in FIGS. **2** & **4**, the number of bins in the system can be doubled by attaching a rear array of bins on the back side of the sorting station. In this way, the cars can deliver items to bins on the front side of the sorting station by traveling to the bin and then rotating the conveyor on the car forwardly to eject the piece into the front bin. Alternatively, the cars can deliver items to bins on the rear side of the sorting station by traveling to the bin and then rotating the conveyor on the car rearwardly to eject the piece into the rear bin.

Additionally, the sorting station **100** is modular and can be readily expanded as necessary simply by attaching an additional section to the left end of the sorting station. Further, although the foregoing describes the array of bins as being essentially a two dimensional array in which the cars simply travel in X and Y directions, the sorting station can be expanded to add additional "runs" of track. Specifically, a separate sorting station parallel to or perpendicular to the sorting station illustrated in FIG. **2** may be connected to the sorting station. In this way, the car would travel in a third dimension relative to the X and Y directions of the sorting station illustrated in FIG. **2**. For instance, additional sections of track may be connected to the sorting station illustrated in FIG. **2** perpendicular to the illustrated sorting station, so that the additional track forms an L-shape intersecting the loading column. In such a configuration, gates selectively direct the cars either down the upper rail **135** or rearwardly toward the additional track. Similarly, a plurality of parallel rows of sorting stations can be interconnected so that the cars selectively travel along a crossover rail until the car reaches the appropriate row. The car then travels down the row until it reaches the appropriate column as described above.

It will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the broad inventive concepts of the invention. For instance, in the foregoing description, the operation of the sorting station is described as being centralized with the central controller. However, it may be desirable to have the cars control the operation of the gates. According to one alternative, the cars incorporate one or more mechanical actuators that cooperate with an operator on the gate. The actuators on the cars are operable between first and second positions. In a first position, the actuator engages the gate operator to displace the gate into the closed position. In a second position, the actuator engages the gate to displace the gate into the open position. Alternatively, the gate may be biased toward the opened position, so that when the car actuator is in the second position it does not engage the gate operator. In another alternative, each car includes a mechanism for communicating with each gate. If the gate needs to be pivoted to direct an approaching car along a particular path, the car sends a signal to the gate indicating whether the gate should be opened or closed. In response to the signal from the car, the gate pivots to the appropriate position.

Further, in the above description, the system uses a wireless communication between the cars and the central controller. In an alternative embodiment, a communication line may be installed on the track and the cars may communicate with the central controller over a hard wired communication link. Still further, the system has been described as being useful in sorting incoming mail. However, the system may also be utilized to sort and prepare outgoing mail. For instance, after determining a characteristic for a mail piece, the system may print a marking onto the mail piece. For instance, after determining the recipient's address for a mail piece, the system determines which bin the mail piece is to be sorted to. As the mail piece is conveyed to the bin, a printer prints the appropriate postnet bar code on the piece before sorting the piece. To provide the printing functionality, the system may include a printer disposed along the track. When the car approaches the printer the car stops and at least partially discharges the mail piece to extend the mail piece toward the printer. The printer then prints the appropriate postnet code. The car then reverses the conveyors to load the piece back onto the car all the way, and then travels to the appropriate bin. Similarly, the system may include a device for selectively applying labels to the pieces. Similar to the above example of printing markings onto the pieces, the labeler may be positioned along the track. The cars selectively stop at the labeler on route to the appropriate bin and at least partially discharge the mail piece toward the labeler. The labeler then applies a label onto the mail piece and the conveyor on the car then reverses to load the piece back onto the car.

In addition to outgoing mail applications, it may be desirable to incorporate a printer and/or a labeler in systems configured to process incoming mail. For instance, when sorting incoming mail pieces, it may be desirable to print certain information, such as sort codes, a time stamp or audit trail information onto some or all of the pieces being processed. In some instances such information may be printed directly onto the mail pieces. In other instances, a label may be applied to the mail pieces and the information may be printed on the label.

In addition to a printer and a labeler, the system may include a scale for weighing the mail pieces. The scale may be positioned along the track **110**, such as along the loading column. To weigh a piece, the car stops adjacent the scale, and ejects the piece from the car onto the scale by driving the conveyor belts **212**. Preferably, the scale includes a conveyor or transfer mechanism for discharging the piece from the scale and back onto the car or onto a subsequent car. When the piece is loaded onto the car from the scale, the car drives the conveyors to load the piece as discussed above in connection with the loading station.

It should therefore be understood that this invention is not limited to the particular embodiments described herein, but is intended to include all changes and modifications that are within the scope and spirit of the invention as set forth in the claims.

The invention claimed is:

1. A delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system, wherein the delivery vehicle comprises:

a transfer mechanism for transferring an item onto or off the vehicle, wherein the transfer mechanism has a support surface configured to support the item when the item is on the vehicle;

a pair of opposing walls spaced apart from one another so that the support surface is between the opposing walls with the walls projecting upwardly relative to the support surface, wherein the opposing walls are positioned to form a first opening to facilitate transfer of items onto the support surface through the first opening, and wherein the opposing walls form a second opening to facilitate transfer of items onto the support surface through the second opening;

a drive system cooperable with the guide system to guide the vehicle to the destination areas,

a motor for driving the drive system;

an electric storage element for storing electricity and providing power to the transfer mechanism and the motor; and

a controller for receiving signals for controlling the motor and the transfer mechanism to control the movement of the vehicles along the guide system and to control transfer of items onto and off of the vehicles.

2. The delivery vehicle of claim **1** wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel.

3. The delivery vehicle of claim **1** wherein the transfer mechanism is operable in a first direction to transfer items from the support surface through the first opening and wherein the transfer mechanism is operable in a second direction opposite the first direction to transfer items from the support surface through the second opening.

4. The delivery vehicle of claim **1** wherein the electric storage element comprises a rechargeable power source for powering the motor and the delivery vehicle comprises an electrical contact for contacting a charging rail along the guide system to recharge the rechargeable power source as the vehicle travels along the guide system to deliver an item.

5. The delivery vehicle of claim **1** wherein the delivery vehicle is configured to follow the guide system in first and second directions that are transverse one another and wherein the transfer mechanism is operable to displace items in a third direction that is transverse the first and second directions.

6. The delivery vehicle of claim **1** comprising a load sensor for detecting that an item is loaded onto the support surface.

7. The delivery vehicle of claim **6** wherein the load sensor comprises a pair of detectors wherein each of the detectors is operable to detect the presence of the item at a point along the support surface.

8. The delivery vehicle of claim **7** wherein the pair of detectors comprise a first sensor operable to detect a leading edge of the item when the item is moved in a first direction and a second sensor operable to detect a trailing edge of the item.

9. The delivery vehicle of claim **1** wherein the transfer mechanism comprises a conveyor belt.

10. A delivery vehicle operable with a material handling system having a plurality of destination areas, wherein the delivery vehicle comprises:

a drive system for driving the vehicle to one of the destination areas;

a motor for driving the drive system; and

a controller for receiving signals for controlling the motor to control the movement of the vehicle;

a transfer mechanism for transferring items between the vehicle and the destination areas wherein the transfer mechanism comprises a surface for receiving an item to be conveyed to one of the destination areas; and

a pair of opposing walls extending upwardly relative to the surface and spaced apart from one another so that at least a portion of the surface is between the opposing walls, wherein the opposing walls are dimensioned and arranged to facilitate transfer of items off the surface at a first end of the surface and to facilitate transfer of items off the surface at a second end of the surface.

11. The vehicle of claim **10** wherein the transfer mechanism comprises one or more conveyor belts and the surface comprises an upper surface of the one or more conveyor belts.

12. The vehicle of claim **10** wherein the transfer mechanism is operable in a first direction to transfer items off the surface at the first end and wherein the transfer mechanism is operable in a second direction opposite the first direction to transfer items off the surface at the second end.

13. The vehicle of claim **12** wherein the vehicle is configured to follow a guide system in first and second guide directions that are transverse one another and wherein the transfer mechanism is operable to displace items in a third direction that is transverse the first and second guide directions.

14. The vehicle of claim **10** wherein the surface is substantially horizontal.

15. A delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system, wherein the delivery vehicle comprises:

a transfer mechanism for transferring items between the vehicle and the destination areas wherein the transfer mechanism comprises a platform for receiving an item to be conveyed to one of the destination areas;

a first wall projecting upwardly along a first side of the platform;

a second wall projecting upwardly along a second side of the platform, wherein the second wall is spaced apart from the first wall so that a first transfer opening is formed between the first and second walls at a third side of the platform and a second transfer opening is formed between the first and second walls along a fourth side of the platform, wherein the first and second transfer openings are configured to facilitate transfer of items onto and off of the platform through the first and second transfer openings;

a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel;

a motor for driving the drive system; and

a controller for receiving signals for controlling the motor to control the movement of the vehicles along the guide system.

16. The vehicle of claim **15** wherein the transfer mechanism comprises one or more conveyor belts that form at least a portion of the platform.

17. The vehicle of claim **15** wherein the platform is substantially horizontal.

18. The vehicle of claim **14** wherein the transfer mechanism is operable in a first direction to transfer items off the platform through the first transfer opening and wherein the transfer mechanism is operable in a second direction opposite the first direction to transfer items off the platform through the second transfer opening.

19. The vehicle of claim **18** wherein the vehicle is configured to follow the guide system in first and second guide directions that are transverse one another and wherein the transfer mechanism is operable to displace items in a third direction that is transverse the first and second guide directions.

* * * * *

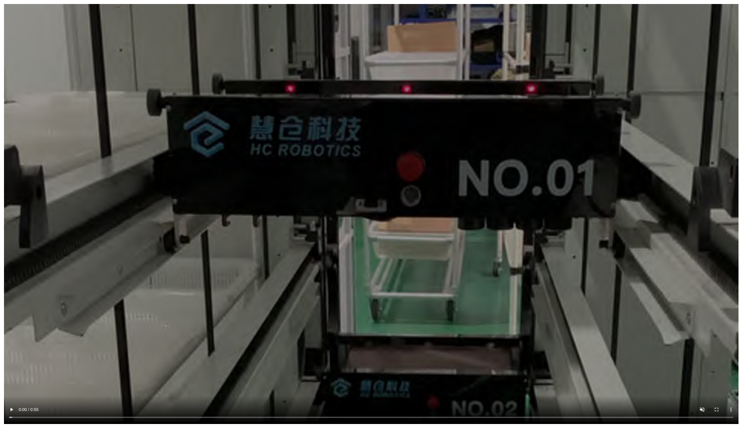
EXHIBIT H

OmniSort

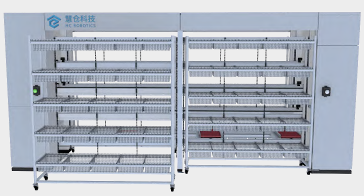
The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting.

Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment.

The OmniSort integrates easily with existing WMS systems to archive plug and play operation. Combining OmniSort with OminiStorage systems can realize fully automated order processing flow.

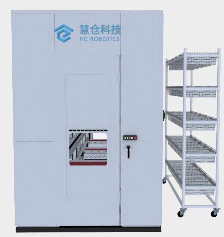


Product Features



Up to 2600 pcs/h

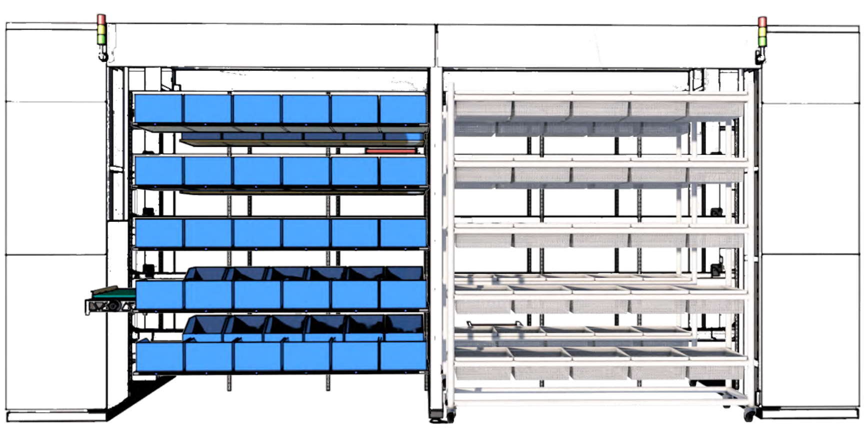
Automatic Barcode Scanning



Putaway Carts and/or Individual Bins

Key Features

Modular design, high mobility. Suitable for e-commerce warehouse, distribution center, etc. Support batch sorting and individual sorting. Highly scalable. High cost performance ratio. Maximum item weight 5kg. High picking throughput. Easily integrated with auto scanning and auto item picking systems.



Technical Specifications

Size	10 x 2 x 2.2 m (L x W x H,Customizable)	Picking Module	Multiple induction modules
Number of Delivery Bin			Easily integrated with auto scanning and auto picking systems
Delivery Bin	450 x 350 x 140 mm(Customizable)		
Number of Robots	10 - 20	Performance	Up to 2600 items/hour
Robot Load	5 kg		Deployment time is down to few hours
Robot Speed	2 - 4 m/s		

Download Product Literature>>

EXHIBIT I

Omni Sort
闪电播

立体化、灵活的高速立体分拣系统。适用于电商二次分拣、退货处理，以及门店配货等应用。

产品资料下载

闪电播系统
OmniSort

设备优点

- 智能化立体分拣系统
- "订单到人"工作原则
- 支持订单分拣及波次分拣
- 模块化设计，尺寸和效率可灵活扩展

- 轻量化接口，WMS快速对接
- 与摩天轮系统集成，支持复杂订单拣选

解决方案

物品准备

一次或波次拣选完毕的物品，送至闪电播入口处。

物品输入

人工将任意单件物品取出、放入闪电播系统供包机上。

分拣播种

自动扫码后，机器人接收物品并根据系统指令将物品搬运至对应分拣口位置，自动投入。

打包发货

分拣口位置订单物品分拣完成，发出灯光提示。人工根据提示取出对应物品打包发货。

设备参数

- 外形尺寸: 10×2×2.2m
- 格口数: 200
- 格口尺寸: 450×350×140mm
- 机器人数量: 10
- 物品尺寸: 400×310×200mm
- 载重: 5 kg
- 吞吐量: 1200-1800件 / 时
- 扫码方式: 顶扫或五面扫

如有需要，我们会尽快联系您

姓名*
电话*
公司*
职位*
邮箱*
需求*
信息*

联系我们

慧仓科技
HC ROBOTICS
浙江省杭州市滨江区滨康路101号海威大厦裙楼三层
400-099-2588
(0571)8610-0693
business@hcrobots.com
www.hcrobots.com

扫一扫关注公众号

TRANSPERFECT

City of New York, State of New York, County of New York

I, Shayna Himelfarb, hereby certify that the document "**闪电播系统 - 慧仓科技 _product**" is, to the best of my knowledge and belief, a true and accurate translation from Chinese into English.

Shayna Himelfarb

Sworn to before me this
December 10, 2021

Signature, Notary Public

WENDY POON
STATE OF NEW YORK
NOTARY PUBLIC
Qualified in Queens County
01PO6356754
MY COMMISSION EXPIRES 04-03-2025

Stamp, Notary Public

Omni Sort

闪电播

Flexible high-speed three-dimensional sorting system. It is suitable for e-commerce secondary sorting, return processing, store distribution, and other applications.

Product Documentation Download

Ferris wheel | Mini Library | OmniSort

[bilingual text]

OmniSort

HC Robotics

Homepage About HC Product Center News Center

Equipment Advantages

[bilingual text]

- The intelligent three-dimensional sorting system
- "Order to Person" working principle
- Support order sorting and echelon sorting
- Modular design, size and efficiency can be flexibly expanded

- Lightweight interface, fast docking with WMS
- Integrate with the Ferris wheel system to support complex order picking

Solution

Item preparation
The items sorted at one time or after the echelon sorting are delivered to the entrance of Omni Sort.

Item input
Manually take out any single item and put it into the sorting machine of Omni Sort system.

Sort and sow
After automatically scanning the code, the robot receives the items and transports the items to the corresponding sorting gate according to the system instructions, and automatically puts them in.

Pack and delivery
There will be a light prompt when the order items are sorted at the sorting gate. Manually take out the corresponding items according to the prompts and pack them for delivery.

Equipment parameters

- Dimensions: 10×2×2.2m
- Number of grids: 200
- Grid size: 450x350×140mm
- Number of robots: 10
- Item size: 400x310×200mm
- Load: 5 kg
- Throughput: 1200-1800 pcs/hour
- Scan code method: top scan or five-sided scan

If necessary, we will contact you as soon as possible

Name*
Tel*
Company*
Position*
Email*
Demand*
Information*

Contact us

[bilingual text]
HC ROBOTICS

3F, podium building, Haiwei building, No. 101, Binkang Road, Binjiang District, Hangzhou City, Zhejiang Province
400-099-2588
(0571)8610-0693
business@hcrobots.com
www.hcrobots.com

Scan to follow our public account

EXHIBIT J

Invata Automated Robotic Put Wall Solutions

Fill a Lot More Orders — a Whole Lot Faster!

The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than **doubles (2x+) the put rate of manual put walls** and increases the number of orders that can be processed at the same time by **over 700%.**

The impressive efficiencies of the automated put wall translate to **put rates of 1800 - 2200 units per hour** (human v. robotic induction) and processing capabilities for up to **500 orders at once**.

SCHEDULE A FREE DEMO

Benefit from Enhanced Picking Efficiencies without Even Trying...

Invata's Automated Robotic Put Wall Solutions change the way you fulfill orders and/or process returns. And the enhances operational efficiencies benefit all aspects of your operation.

The increase in processing capabilities yields 1.5-2x greater efficiencies in the pick process as more orders can be released to picking at the same time, which in turn creates a much denser pick path for pickers.

SHOW ME HOW

Let's Get Started...

- What's not working?
- What do you need to accomplish that you can't with the tools you have?
- What do you want to achieve?

Tell us about the challenges you face, and we can show you how we can help solve them.

Do you want to:

- [ ] Schedule a free demo of our capabilities?
- [ ] Have us call you to discuss your challenges?
- [ ] Plan an on-site tour to discuss your operation?

First Name *

Last Name *

Your Title

Company Name *

Your Email *

Phone (Optional, but very helpful)

We respect your privacy! We will never sell, rent, or share your personal information with any 3rd party outside our business network, unless required by law.

- [x] Add me to your mailing list!

Submit

EXHIBIT K

CONTACT INFO		
Type	Name	Address
CONSIGNEE	INVATA LLC	1010 SPRING MILL AVE SUITE 300,CONS HOHOCKEN PA 19428 19428,US
NOTIFY PARTY	-NOT AVAILABLE-	-NOT AVAILABLE-
SHIPPER	HANGZHOU HUICANG INFORMATION TECHNO Get Credit Report	101BINKANG ROAD, HIWELL BUILDING 3/ F PODIUM,BINJIANG ZHEJIANG, CHINA,HANGZHOU,CN

PRODUCT DETAILS	
Container No.	Description Area
EITU1349480	OMNISORT - ITEM SORTING MACHINE

TRANSIT DETAILS	
CARRIER	HGSO
SHIP REGISTERED IN	UNITED STATES
VESSEL	OOCL LONDON
VOYAGE	085E
US PORT	LONG BEACH, CALIFORNIA
FOREIGN PORT	SHANGHAI
COUNTRY OF ORIGIN	CHINA
PLACE OF RECEIPT	SHANGHAI
BILL OF LADING	HGSOGSOE21060374
ARRIVAL DATE	2021-07-04
QUANTITY	15 PKG
CONTAINER COUNT	1
WEIGHT (LB / KG)	12,857 / 5,844
CBM	0
HOUSE VS MASTER	H
MASTER BILL OF LADING	EGLV142102054543

OTHER INFO	
Container No.	Marks and Numbers Area
EITU1349480	N/M

RELATED B/L

Type (House/Master)	B / L
H	HGSOGSOE21060374

0.1862

EXHIBIT L

UNITED STATES INTERNATIONAL TRADE COMMISSION
WASHINGTON, D.C.

Before the Honorable ___________________
Administrative Law Judge

In the Matter of CERTAIN AUTOMATED PUT WALLS AND AUTOMATED STORAGE AND RETRIEVAL SYSTEMS, ASSOCIATED VEHICLES, ASSOCIATED CONTROL SOFTWARE, AND COMPONENT PARTS THEREOF	Investigation No. 337-TA-____

DECLARATION OF STACI DRESHER

I, Staci Dresher, hereby swear and affirm, subject to the penalty of perjury under the laws of the United States, all of the following:

1. I am a private investigator licensed to offer investigative services in the State of California (CA PI license no. 29132). I have worked as a private investigator since July 2006. I am the owner of Dresher Consulting & Investigations (d/b/a "DCI"). Staci Dresher is my maiden name. I also professionally go by Staci E. Freedman, which is my married name.

2. The facts set forth below are based upon my personal knowledge, as well as my own education, training and experience. If called to testify in this matter, I could and would competently testify as follows.

3. DCI is a research, consulting and private investigation firm, with an office in Oakland, California. DCI offers a variety of research and investigative services, including asset investigation and tracing, and evidence gathering in legal disputes often related to allegations of intellectual property infringement, corruption and fraud. With respect to my education, training and experience, I have extensive experience in finding hidden assets and connections, gathering cross-examination material on experts and adverse parties, and assisting counsel during white collar criminal defense matters.

4. DCI was retained by Desmarais LLP on behalf of its client, OPEX Corporation. DCI conducted an investigation into HC Robotics, a Chinese company, and Invata Intralogistics, d/b/a Invata, LLC ("Invata"), a U.S. Company.

5. In conducting this investigation, I performed initial online research on HC Robotics, Invata, automated put walls and automated storage and retrieval systems, and the warehouse automation industry more broadly. After conducting this initial research, I reached out to Invata via multiple channels, including online, by email, and by telephone.

6. In September of 2021, I spoke by telephone with Invata's Vice President of Sales. Invata's Vice President of Sales told me that Invata had recently made its first U.S. sale of its automated put wall solution to a customer in San Francisco, California, and the product was scheduled to "go live" on October 10, 2021. Based on the importation record showing a shipment of an Omnisort system from HC Robotics to Invata, delivered at Long Beach, California on July 4, 2021 (Exhibit 18 to OPEX's Complaint) and Invata's website advertising only one automated put wall, I am confident that the Invata automated put wall sold and installed in San Francisco in or around October of 2021 was an Omnisort. Invata's Vice President of Sales also told me that Invata had "four to six" additional U.S. customers who were scheduled to "go live" with their Invata automated put wall systems in the first half of 2022.

7. I hereby swear and affirm that all of the foregoing is true and correct to the best of my knowledge, information, and belief.

Sworn and affirmed on December 20, 2021
at Los Angeles, California

Staci Dresher

EXHIBIT M

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

U.S. Patent No. 7,861,844

Claim 5

Element	**Supporting Documentation**
A system for sorting or retrieving a plurality of items, comprising:	To the extent that the preamble is limiting, the Respondents' OmniSort system (hereinafter the "Accused Product") comprises a material handling system for sorting or retrieving a plurality of items. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*, Invata Intralogistics, https://www.invata.com/automated-put-wall-solutions/?li (last visited Dec. 2, 2021) (Exhibit J).[1]

[1] The illustrations in this claim chart are exemplary, and not intended to limit the scope or applicability of the claims. To the extent any element is not literally met by the Accused Product, it is met under the doctrine of equivalents, at least because the Accused Product performs the same function in the same way to achieve the same result.

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

Element	**Supporting Documentation**
	OmniSort The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort*, HC Robotics, http://en.hc-robots.com/omniSort (last visited Dec. 2, 2021) (hereinafter "*OmniSort English Webpage*") (Exhibit H).

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

a plurality of destination areas for receiving items, wherein the destination areas are arranged in a first array of columns or rows;	The Accused Product comprises a plurality of destination areas for receiving items, wherein the destination areas are arranged in a first array of columns or rows. 

	Items are sorted to location... SKU 123949928531 .11 lbs Sort: C-04-2032 NO. 05 invata	

Automated Put Wall Solutions.[2]

[2] Invata's relevant product page, and both of HC Robotics' relevant pages, consist primarily of embedded videos. OPEX will provide copies of those videos on request.

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

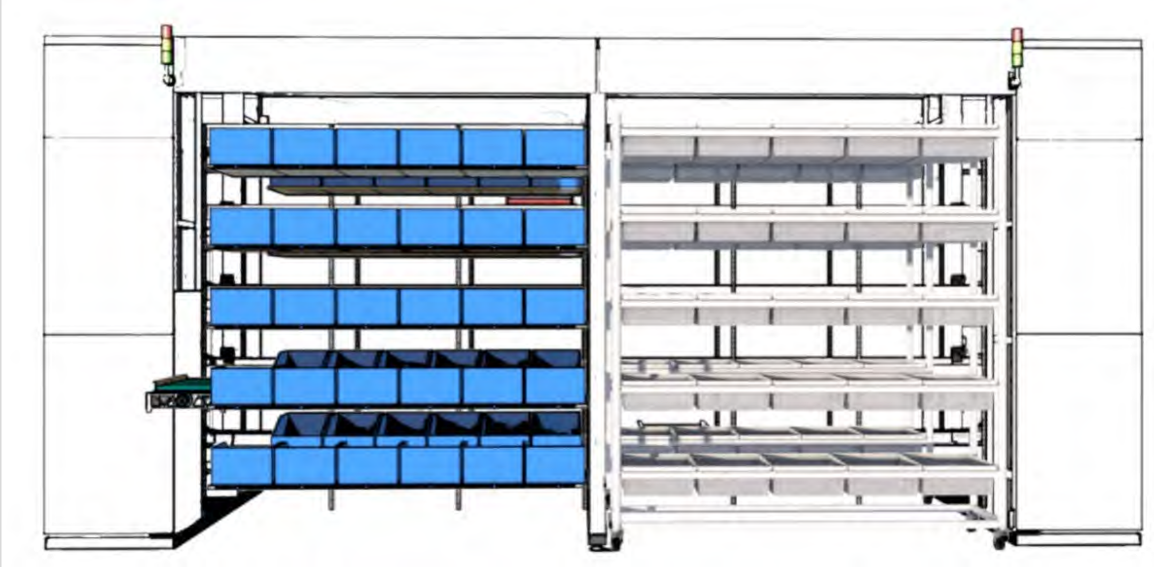
Element	Supporting Documentation
	 *OmniSort English Webpage.*

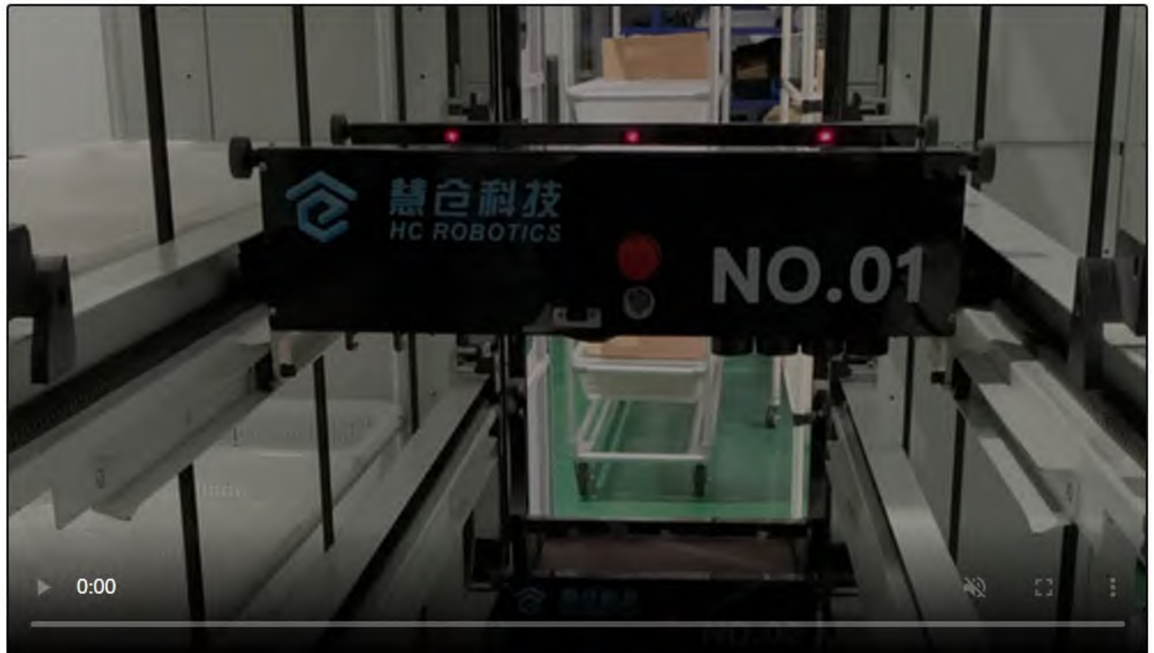
Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and	The Accused Product comprises a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle.  

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

Automated Put Wall Solutions.

Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment.


慧仓科技
HC ROBOTICS
NO.01
0:00

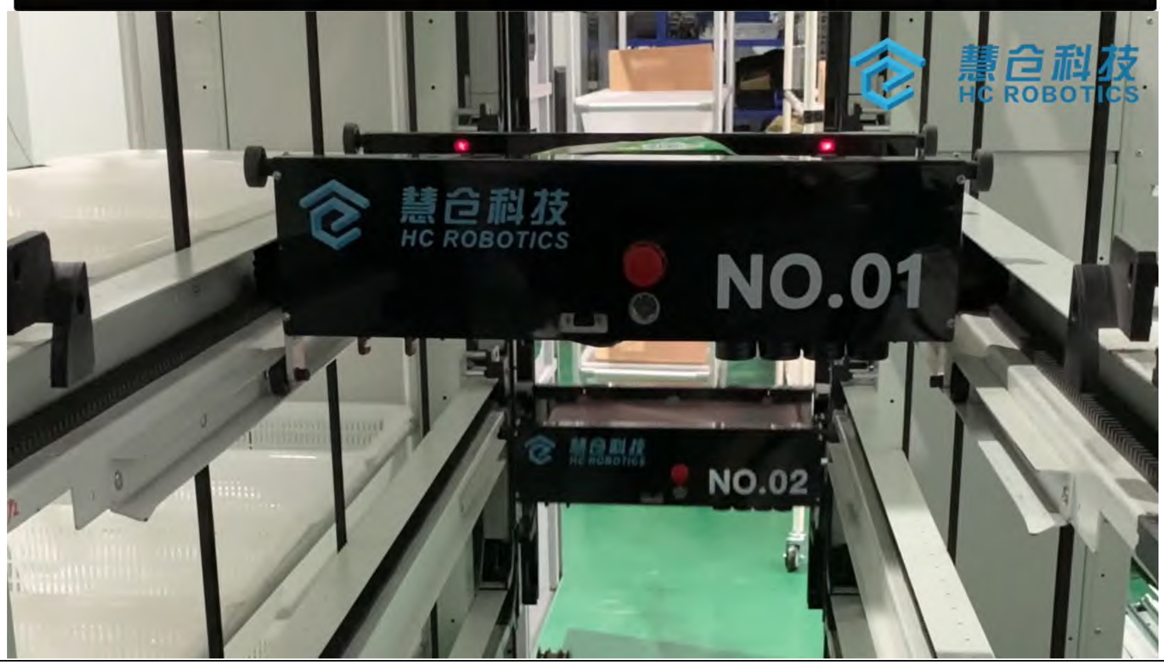

慧仓科技
HC ROBOTICS
慧仓科技
HC ROBOTICS
NO.01
NO.02

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

a track system for guiding the delivery vehicles to the destinations, wherein the track system forms a loop having a forward leg leading away from a loading station along the track where materials are loaded onto the delivery vehicles and a return leg leading back to the station,	The Accused Product comprises a track system for guiding the delivery vehicles to the destinations, wherein the track system forms a loop having a forward leg leading away from a loading station along the track where materials are loaded onto the delivery vehicles and a return leg leading back to the station.  *Automated Put Wall Solutions.*

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

Element	Supporting Documentation
wherein the track system comprises: an upper generally horizontal track section	The Accused Product comprises a track system for guiding the delivery vehicles to the destinations, wherein the track system comprises an upper generally horizontal track section.  *Automated Put Wall Solutions.*

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

Element	**Supporting Documentation**
a lower generally horizontal track section vertically spaced apart from the upper track section;	The Accused Product comprises a track system for guiding the delivery vehicles to the destinations, wherein the track system comprises a lower generally horizontal track section vertically spaced apart from the upper track section.  *Automated Put Wall Solutions.*

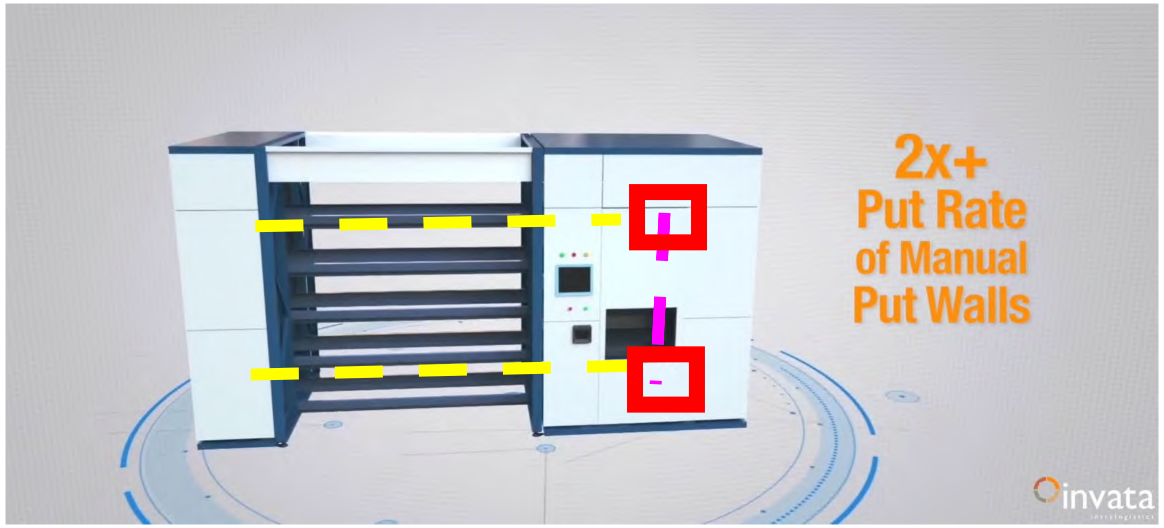
a first generally vertical track section intersecting the upper track section to form a first intersection, and intersecting the lower horizontal track section to form a second intersection;	The Accused Product comprises a track system for guiding the delivery vehicles to the destinations, wherein the track system comprises a first generally vertical track section intersecting the upper track section to form a first intersection, and intersecting the lower horizontal track section to form a second intersection.  *Automated Put Wall Solutions.*

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

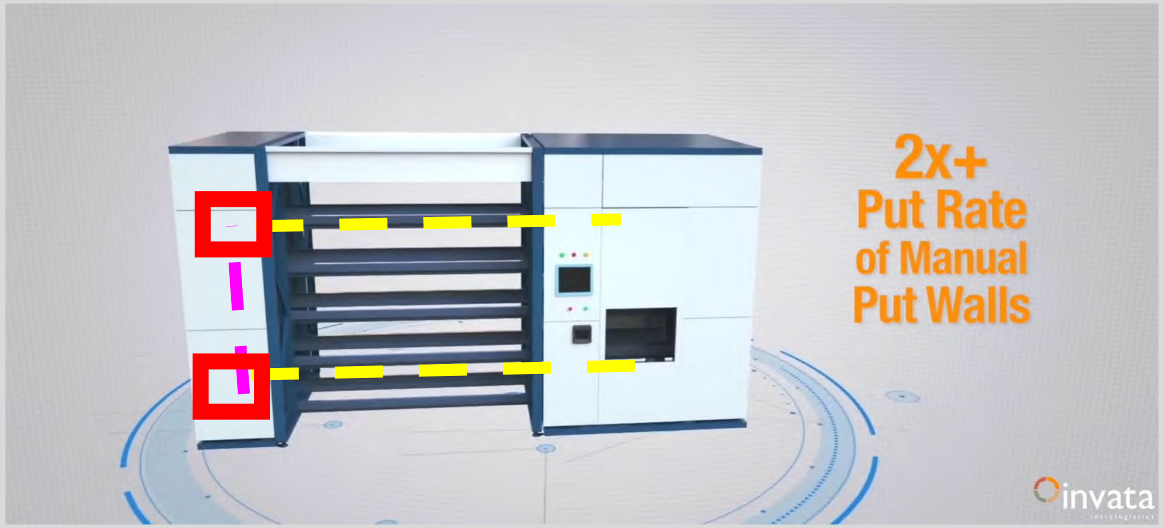
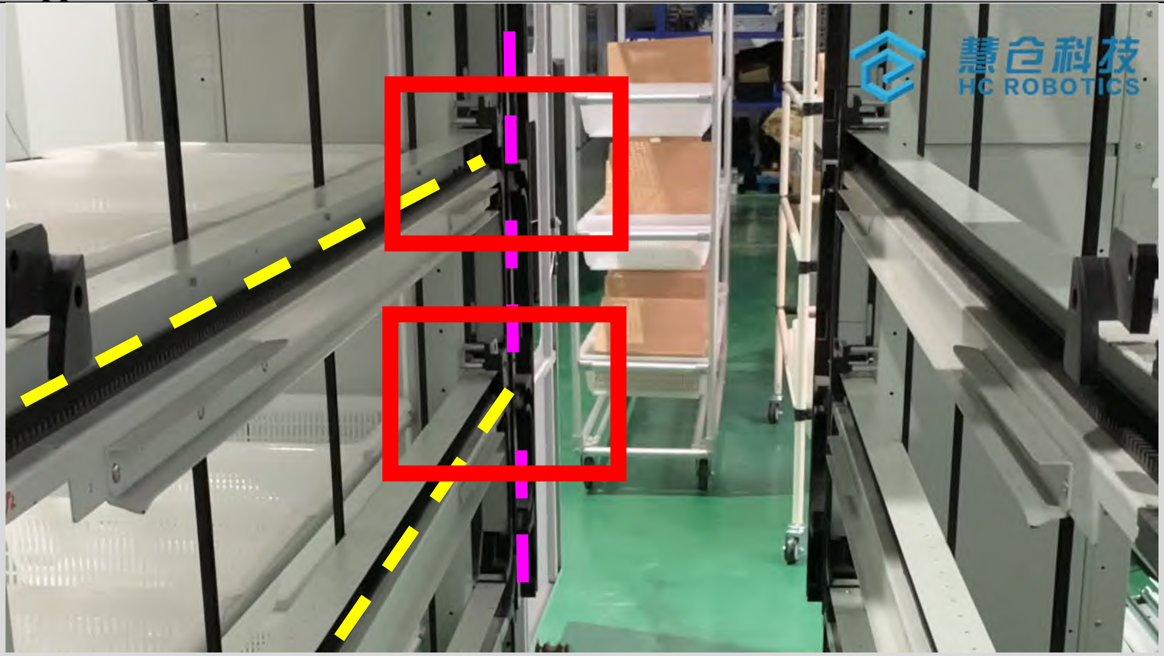
a second generally vertical track section intersecting the upper track section to form a third intersection, and intersecting the lower track section to form a fourth intersection;	The Accused Product comprises a track system for guiding the delivery vehicles to the destinations, wherein the track system comprises a second generally vertical track section intersecting the upper track section to form a third intersection, and intersecting the lower track section to form a fourth intersection.  *Automated Put Wall Solutions.*

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

wherein the intersections provide paths between a generally horizontal path of travel along one of the horizontal track sections, and a generally vertical path of travel along one of the vertical track sections;	The Accused Product comprises a track system for guiding the delivery vehicles to the destinations, wherein the intersections provide paths between a generally horizontal path of travel along one of the horizontal track sections, and a generally vertical path of travel along one of the vertical track sections.  

OmniSort English Webpage.

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

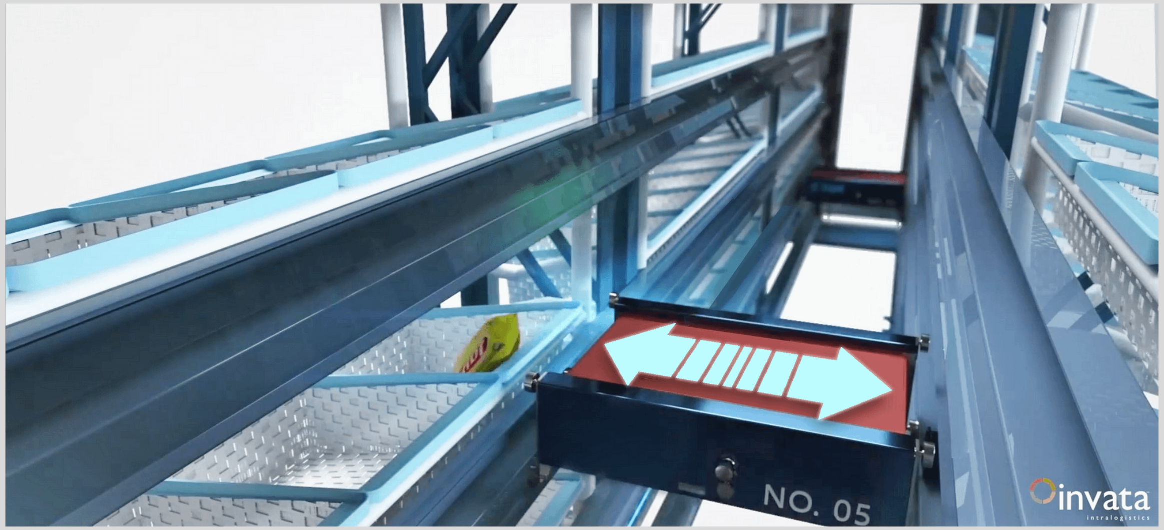
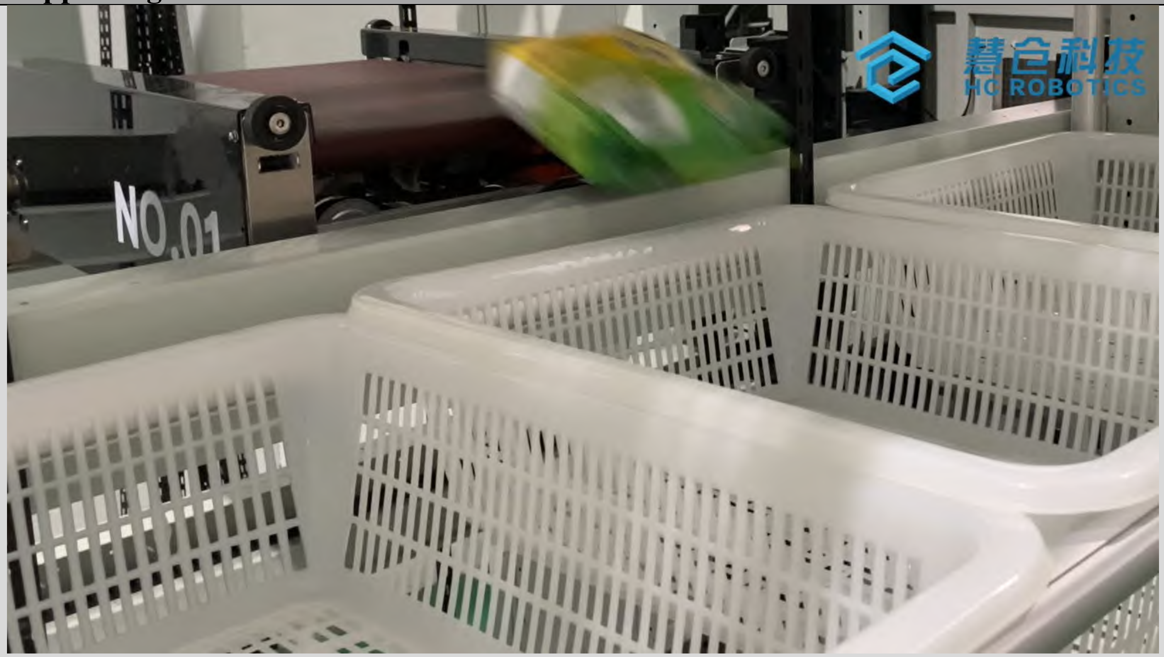
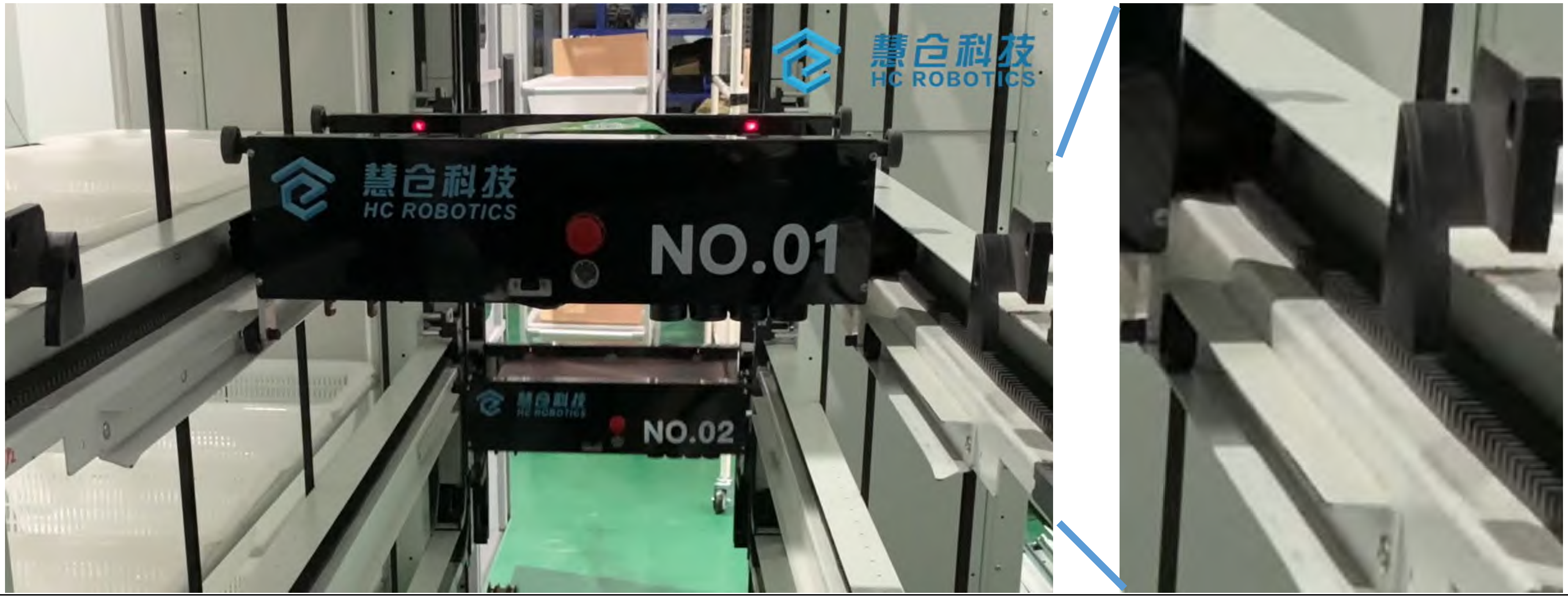
wherein the array of destination areas are positioned along the track system so that the flow of material between a delivery vehicle and a destination area is in a third direction that is transverse both the horizontal direction of the upper and lower track and the vertical direction of the first and second vertical track section;	The Accused Product comprises a plurality of destination areas for receiving items, wherein the array of destination areas are positioned along the track system so that the flow of material between a delivery vehicle and a destination area is in a third direction that is transverse both the horizontal direction of the upper and lower track and the vertical direction of the first and second vertical track section.  *Automated Put Wall Solutions.*

Exhibit M: Claim chart comparing U.S. Patent No. 7,861,844 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between a vertical track and a horizontal track.	The Accused Product comprises a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between a vertical track and a horizontal track. 

Element	Supporting Documentation
	  *OmniSort English Webpage.*

EXHIBIT N

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

U.S. Patent No. 8,104,601

Claim 1

Element	**Supporting Documentation**
A system for sorting or retrieving a plurality of items, comprising:	To the extent that the preamble is limiting, the Respondents' OmniSort system (hereinafter the "Accused Product") comprises a system for sorting or retrieving a plurality of items. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*, INVATA INTRALOGISTICS, https://www.invata.com/automated-put-wall-solutions/?li (last visited Dec. 2, 2021) (Exhibit 16).[1]

[1] The illustrations in this claim chart are exemplary, and not intended to limit the scope or applicability of the claims. To the extent any element is not literally met by the Accused Product, it is met under the doctrine of equivalents, at least because the Accused Product performs the same function in the same way to achieve the same result.

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

Element	Supporting Documentation
	OmniSort The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort*, HC ROBOTICS, http://en.hc-robots.com/omniSort (last visited Dec. 2, 2021) (hereinafter "*OmniSort English Webpage*") (Exhibit 17).

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

a plurality of destination areas for receiving the items, wherein the destination areas are arranged in a first array of columns or rows;	The Accused Product comprises a plurality of destination areas for receiving the items, wherein the destination areas are arranged in a first array of columns or rows. 

	Items are sorted to location... SKU 123949928531 .11 lbs Sort: C-04-2032 NO. 05 invata	

	 *Automated Put Wall Solutions.*[2]

[2] Invata's relevant product page, and both of HC Robotics' relevant pages, consist primarily of embedded videos. OPEX will provide copies of those videos on request.

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

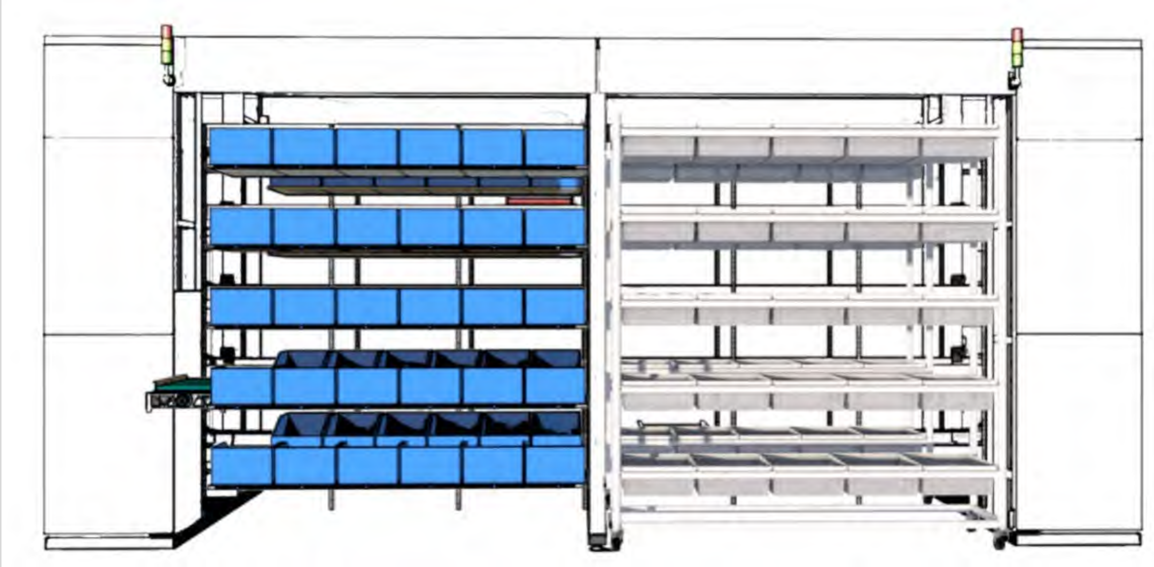
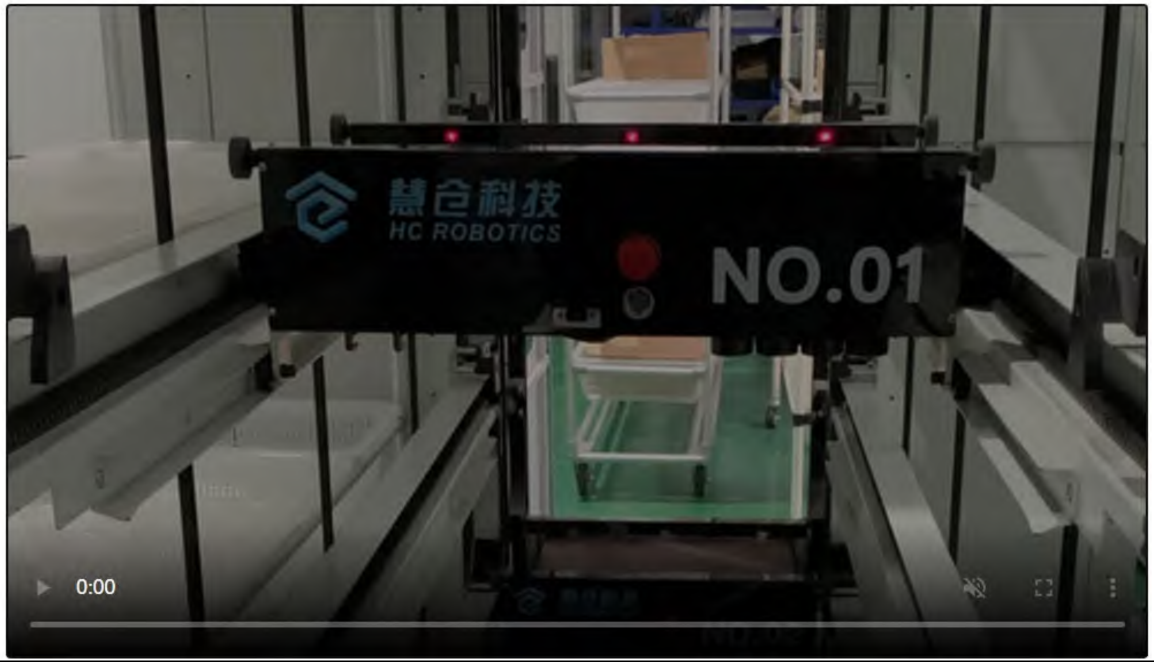
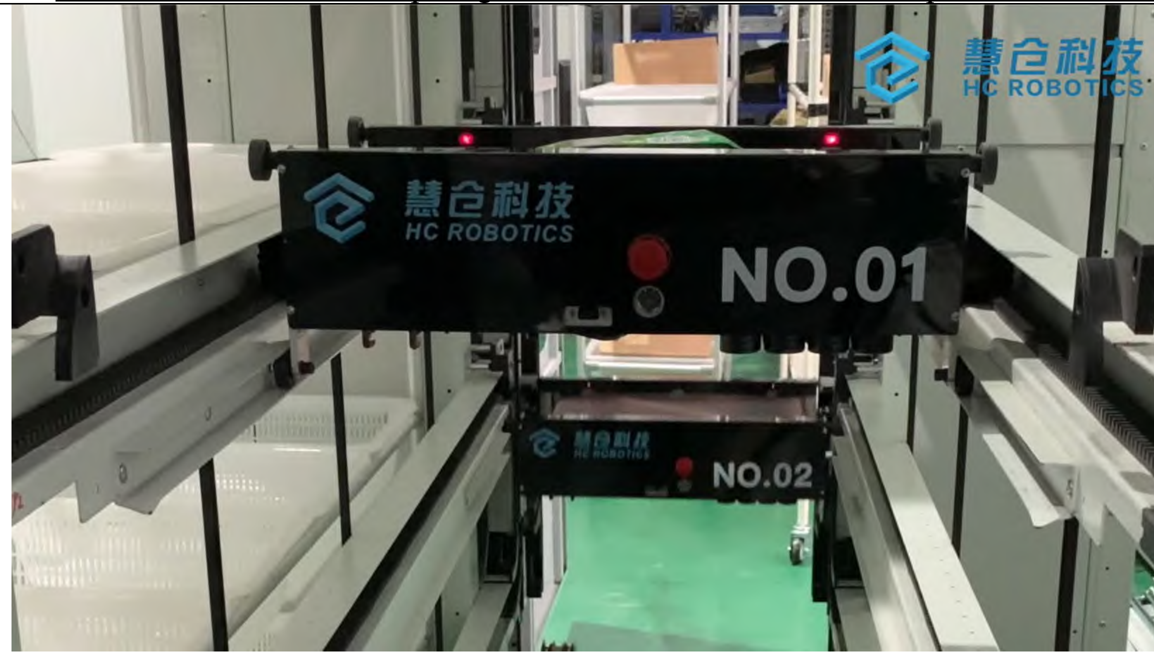
Element	**Supporting Documentation**
	 *OmniSort English Webpage.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and	The Accused Product comprises a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle.   *Automated Put Wall Solutions.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

	Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment. 



OmniSort English Webpage.

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

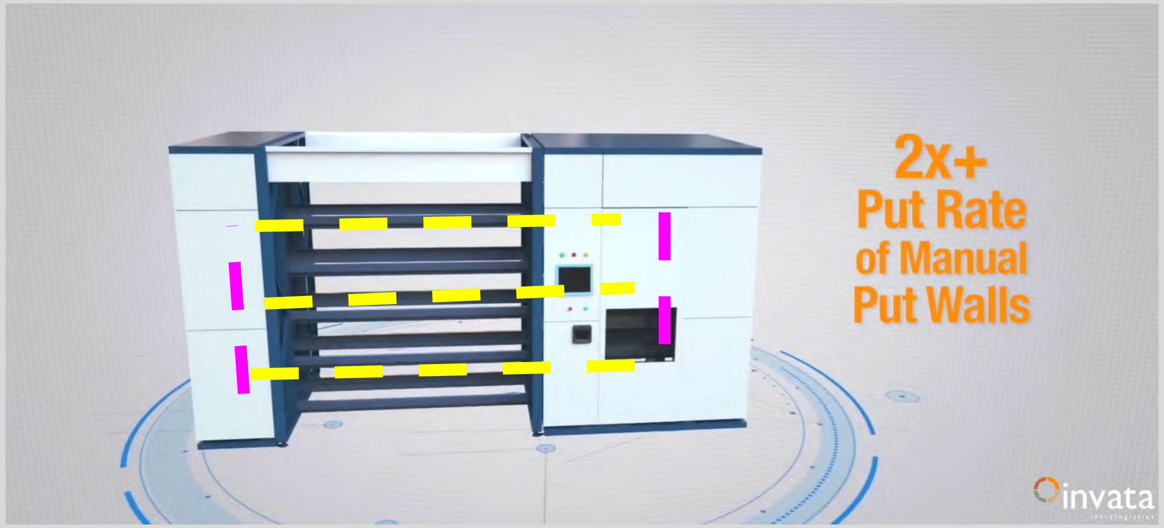
a track system for guiding the delivery vehicles to the destinations, wherein the track system forms a loop that the vehicles can circulate around,	The Accused Product comprises a track system for guiding the delivery vehicles to the destinations, wherein the track system forms a loop that the vehicles can circulate around.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

<table>
<tr><th>Element</th><th>Supporting Documentation</th></tr>
<tr><td>and the track system comprises:

a generally horizontal upper track section;</td><td>The Accused Product comprises a track system that comprises a generally horizontal upper track section.

Automated Put Wall Solutions.</td></tr>
<tr><td>a generally horizontal lower track section positioned at a lower height than the upper track;</td><td>The Accused Product comprises a track system that comprises a generally horizontal lower track section positioned at a lower height than the upper track.

Automated Put Wall Solutions.</td></tr>
</table>

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

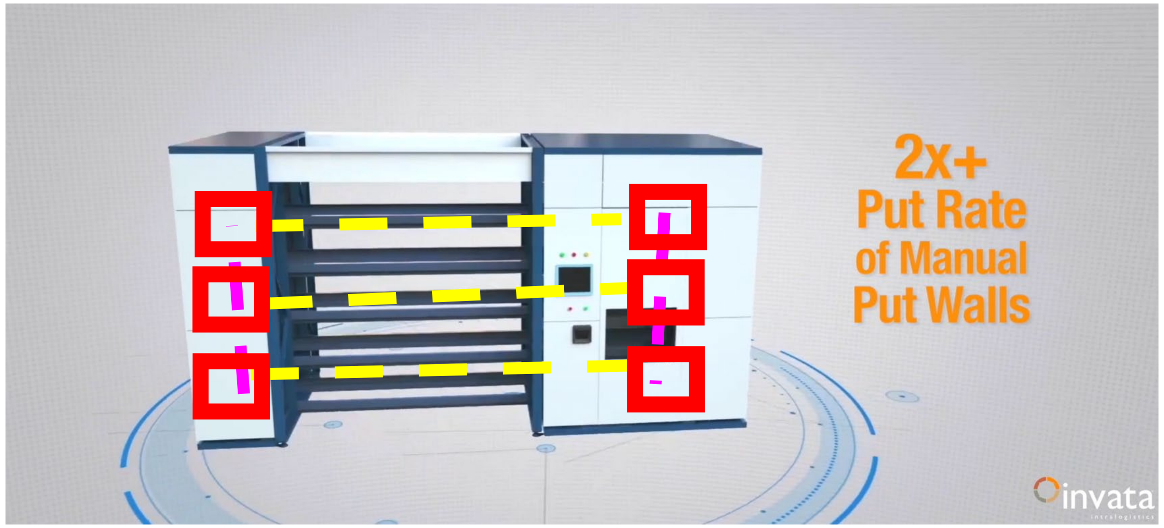
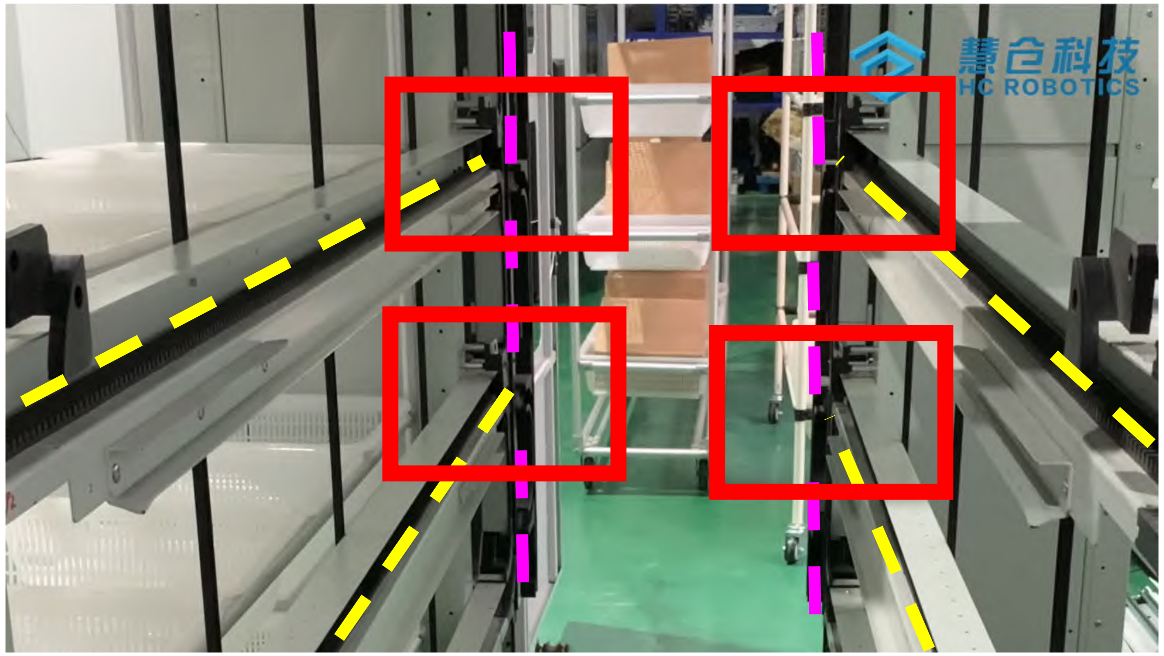
a plurality of generally vertical track sections intersecting the upper track and the lower track; and	The Accused Product comprises a track system that comprises a plurality of generally vertical track sections intersecting the upper track and the lower track.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

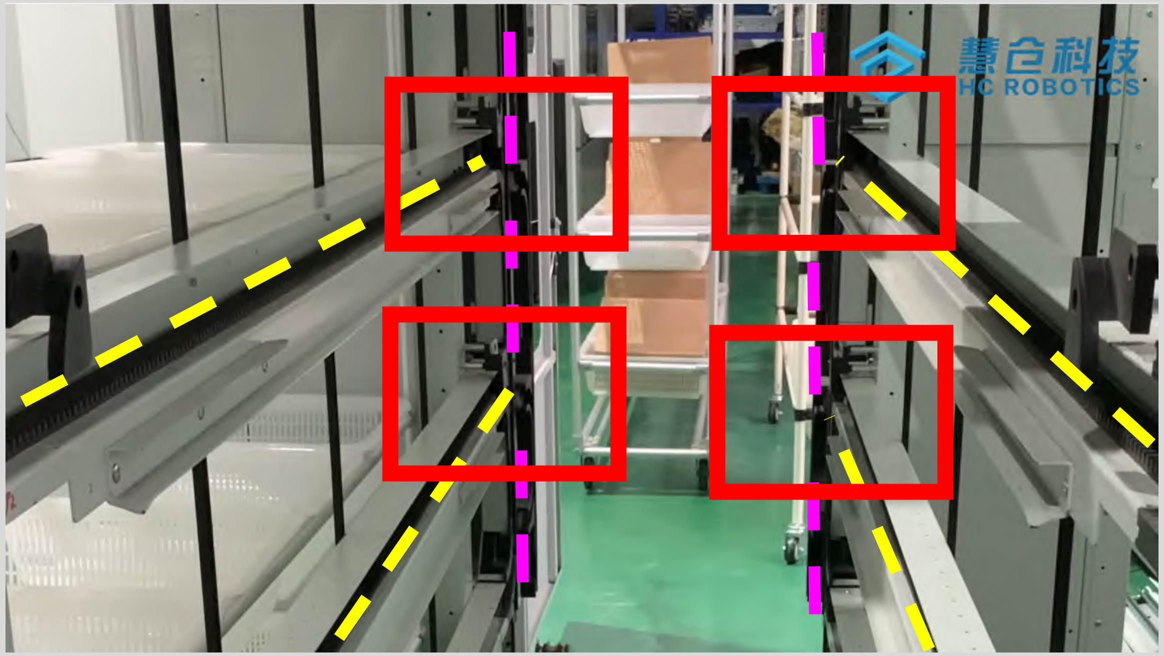
Element	Supporting Documentation
a plurality of intersections where the horizontal sections intersect the vertical sections, wherein the intersections provide paths between a generally horizontal path of travel along one of the upper or lower track, and a generally vertical path of travel along one of the vertical track sections;	The Accused Product comprises a track system that comprises a plurality of intersections where the horizontal sections intersect the vertical sections, wherein the intersections provide paths between a generally horizontal path of travel along one of the upper or lower track, and a generally vertical path of travel along one of the vertical track sections.  *OmniSort English Webpage*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

a first gate at an intersection of the upper track and a first one of the vertical track sections, wherein in a first position, the gate provides a first path through the intersection along one of either the upper track or the first vertical track while impeding travel along the other of the upper track and the first vertical track, and wherein in a second position, the gate provides a second path through the intersection substantially orthogonal to the first path to allow one of the delivery vehicles to change path direction;	The Accused Product comprises a track system that comprises a first gate at an intersection of the upper track and a first one of the vertical track sections, wherein in a first position, the gate provides a first path through the intersection along one of either the upper track or the first vertical track while impeding travel along the other of the upper track and the first vertical track, and wherein in a second position, the gate provides a second path through the intersection substantially orthogonal to the first path to allow one of the delivery vehicles to change path direction.  

OmniSort English Webpage.

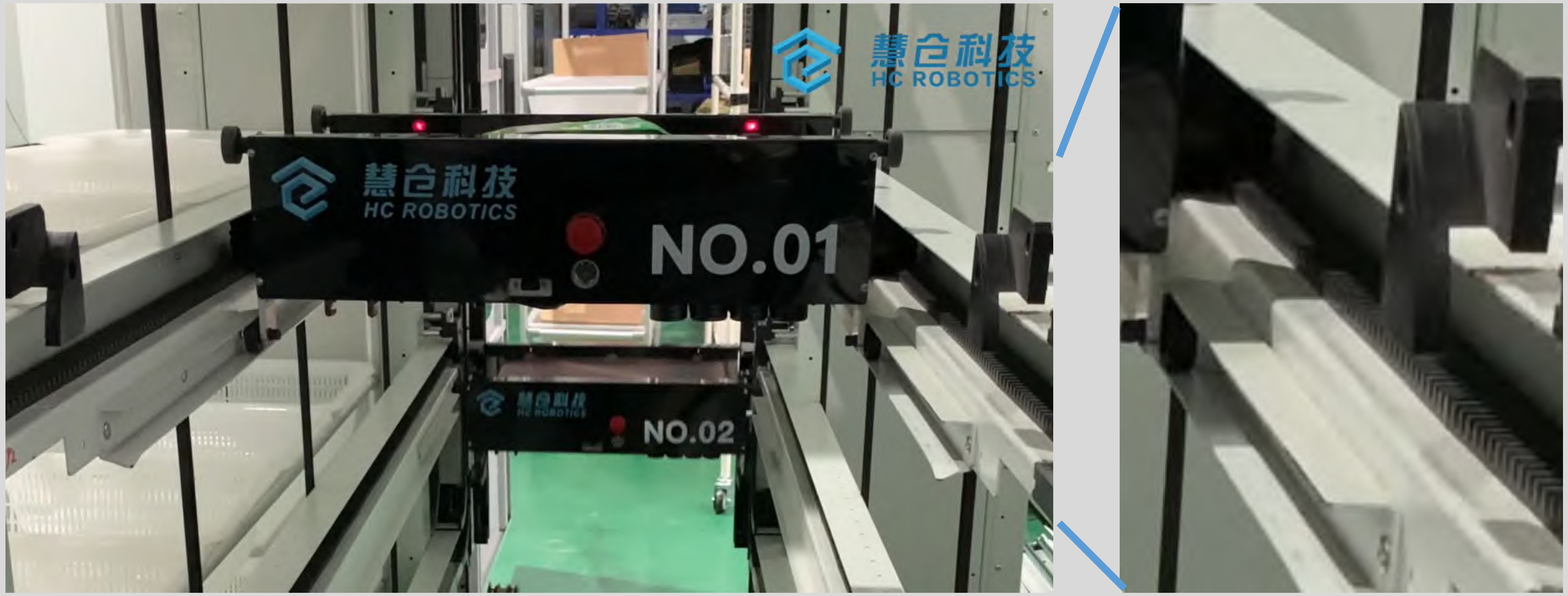
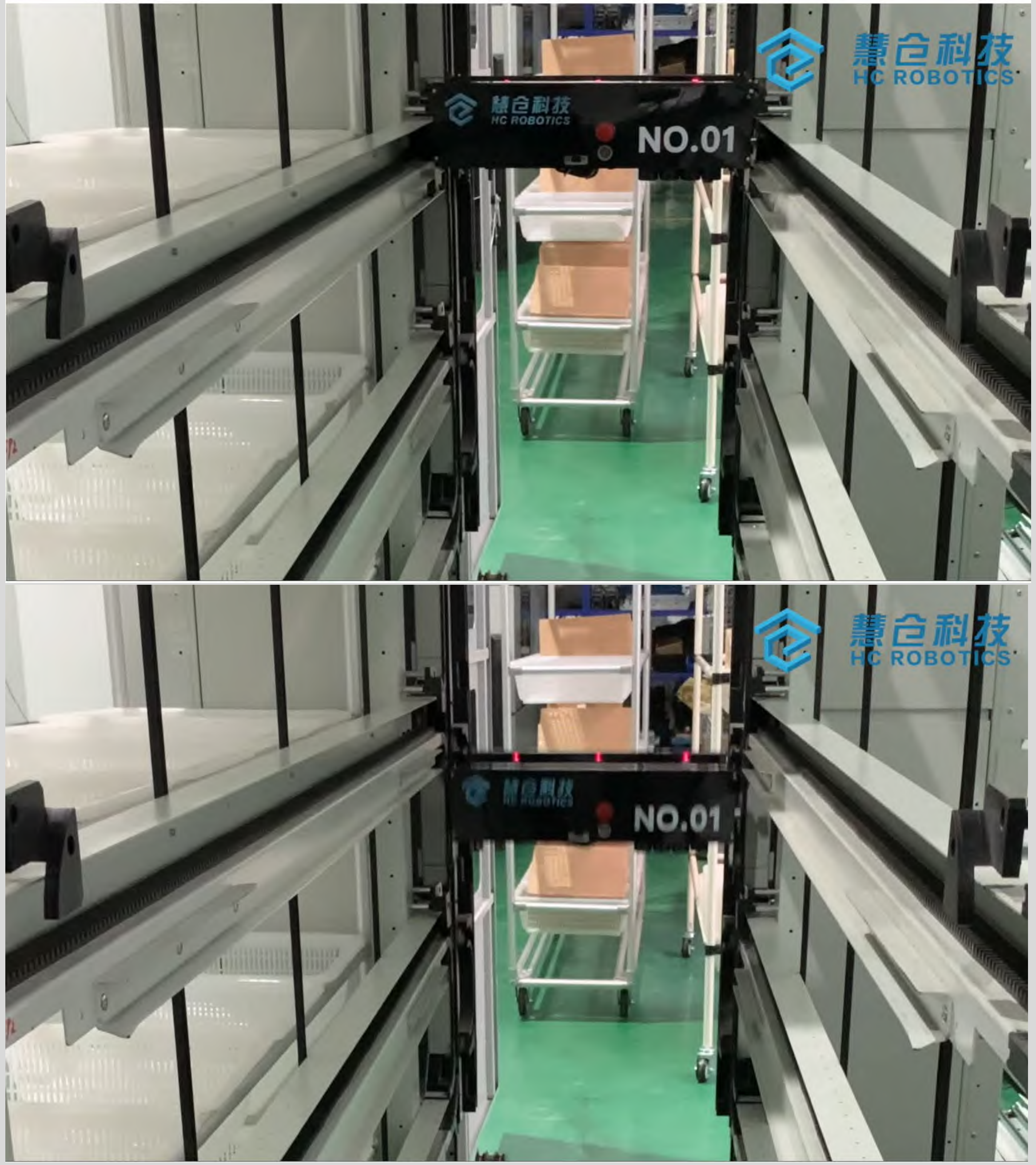
wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between a vertical track and a horizontal track.	The Accused Product comprises a track system that comprises wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between a vertical track and a horizontal track. 

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product



OmniSort English Webpage.

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

Claim 11

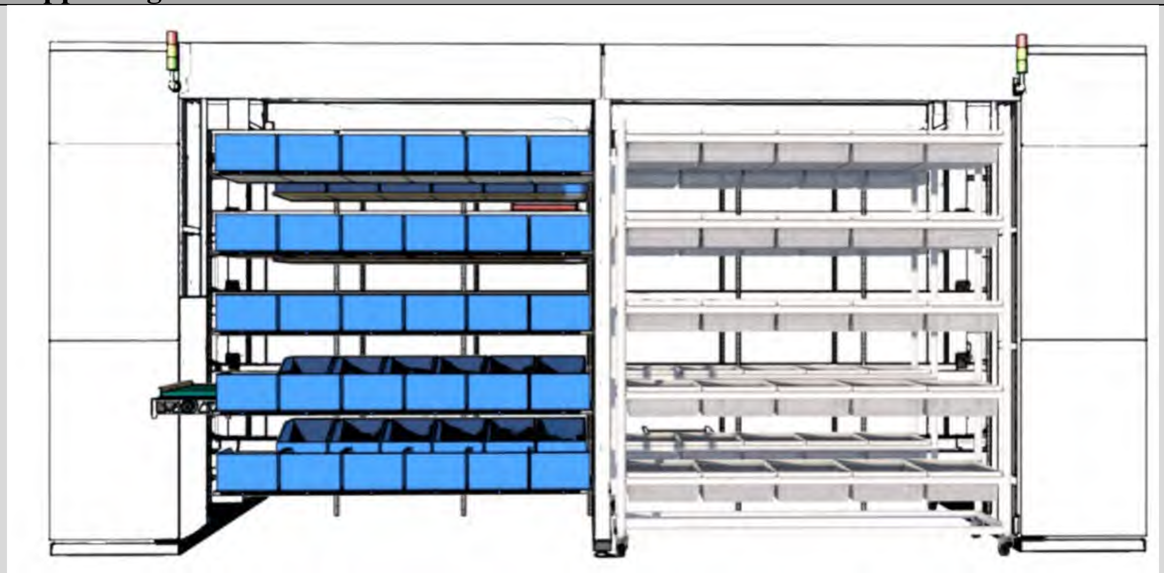
Element	Supporting Documentation
A system for sorting or retrieving a plurality of items, comprising:	To the extent that the preamble is limiting, the Accused Product comprises a system for sorting or retrieving a plurality of items. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*. OmniSort The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort English Webpage*.

a plurality of destination areas for receiving the items, wherein the destination areas are arranged in a first array of columns or rows;	The Accused Product comprises a plurality of destination areas for receiving the items, wherein the destination areas are arranged in a first array of columns or rows. 

	Items are sorted to location... SKU 123949928531 .11 lbs Sort: C-04-2032 NO. 05 invata	

	  *Automated Put Wall Solutions.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

<table>
<tr>
<td>a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and</td>
<td>The Accused Product comprises a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle.

Automated Put Wall Solutions.</td>
</tr>
</table>

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

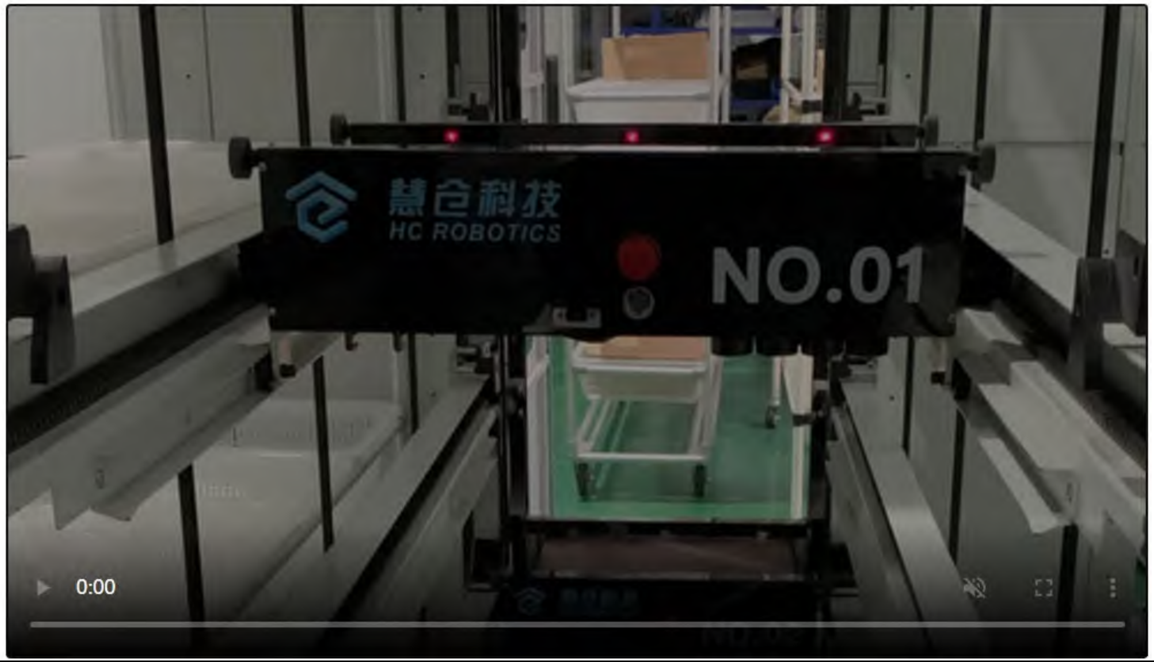
	Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment. 

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

OmniSort English Webpage.

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

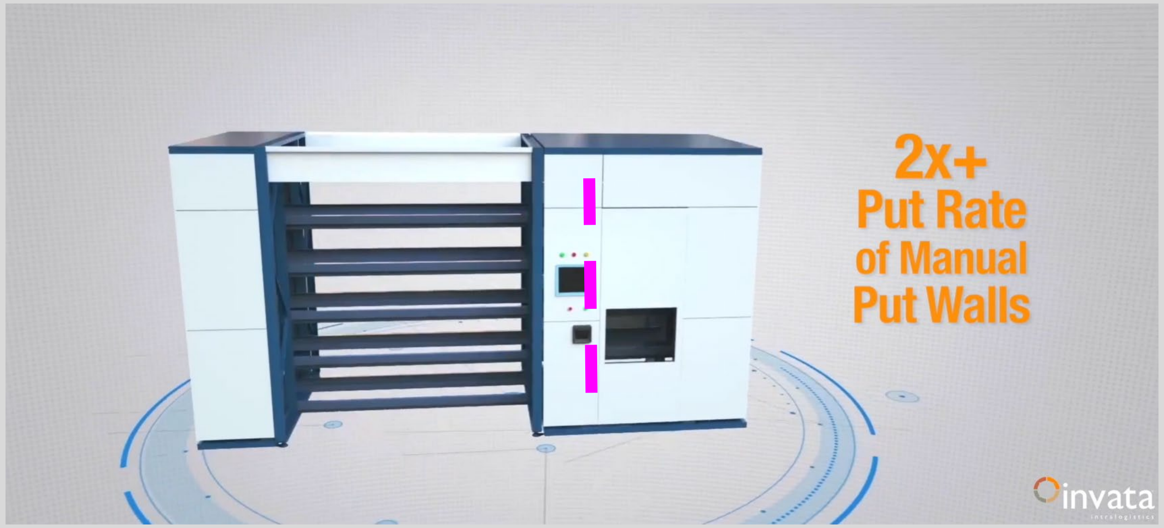
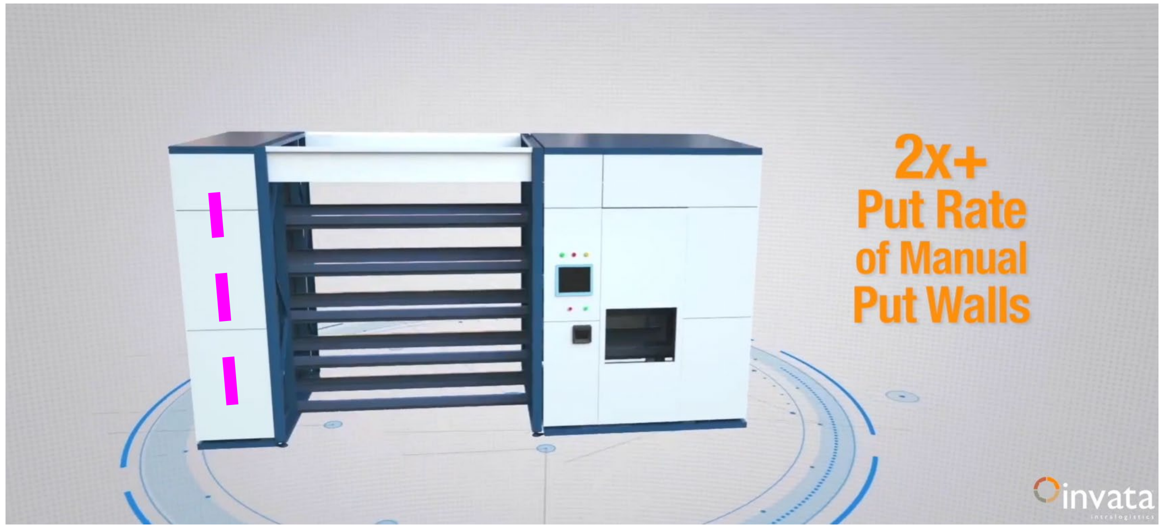
Element	Supporting Documentation
a track system for guiding the delivery vehicles to the destinations, wherein the track system forms a loop that the vehicles can circulate around, and the track system comprises: a first track section;	The Accused Product comprises a track system that comprises a first track section.  *Automated Put Wall Solutions.*
a second track section;	The Accused Product comprises a track system that comprises a second track section.  *Automated Put Wall Solutions.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

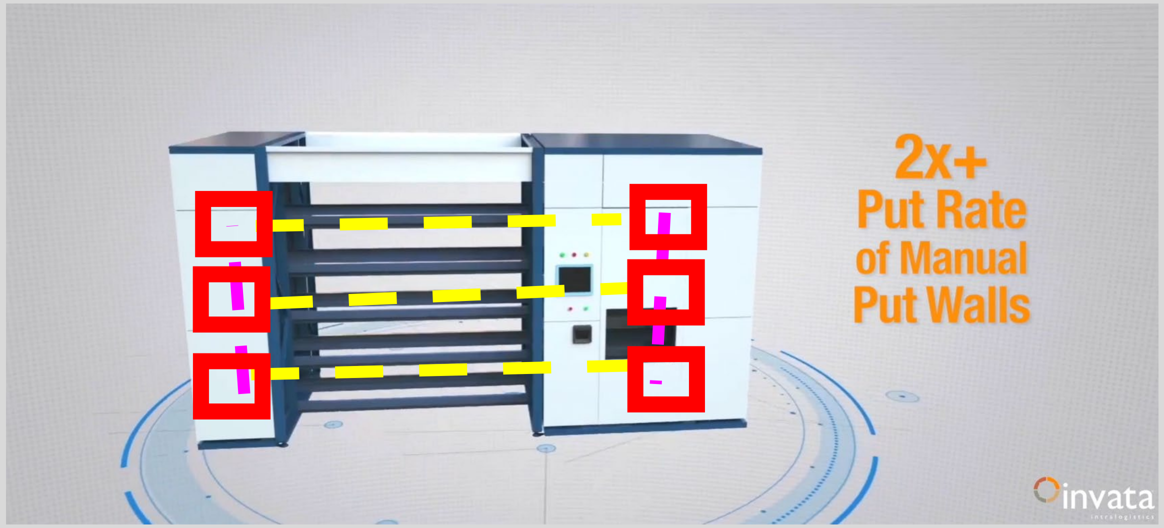
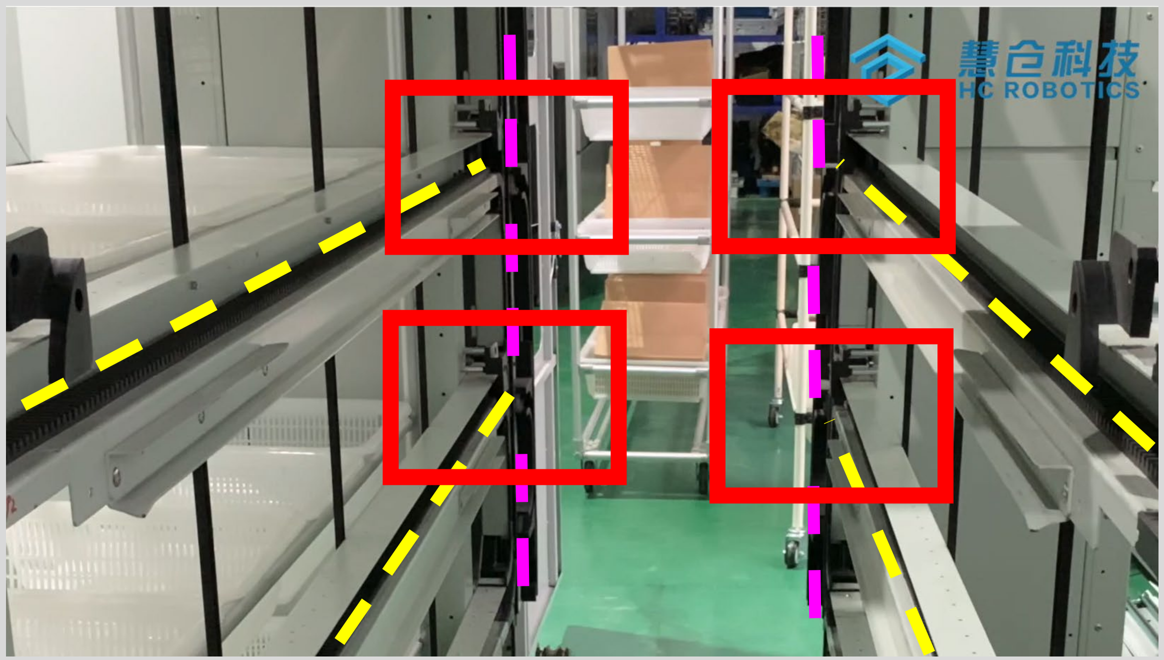
a plurality of transverse track sections intersecting the first and second track sections; and	The Accused Product comprises a track system that comprises a plurality of transverse track sections intersecting the first and second track sections.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

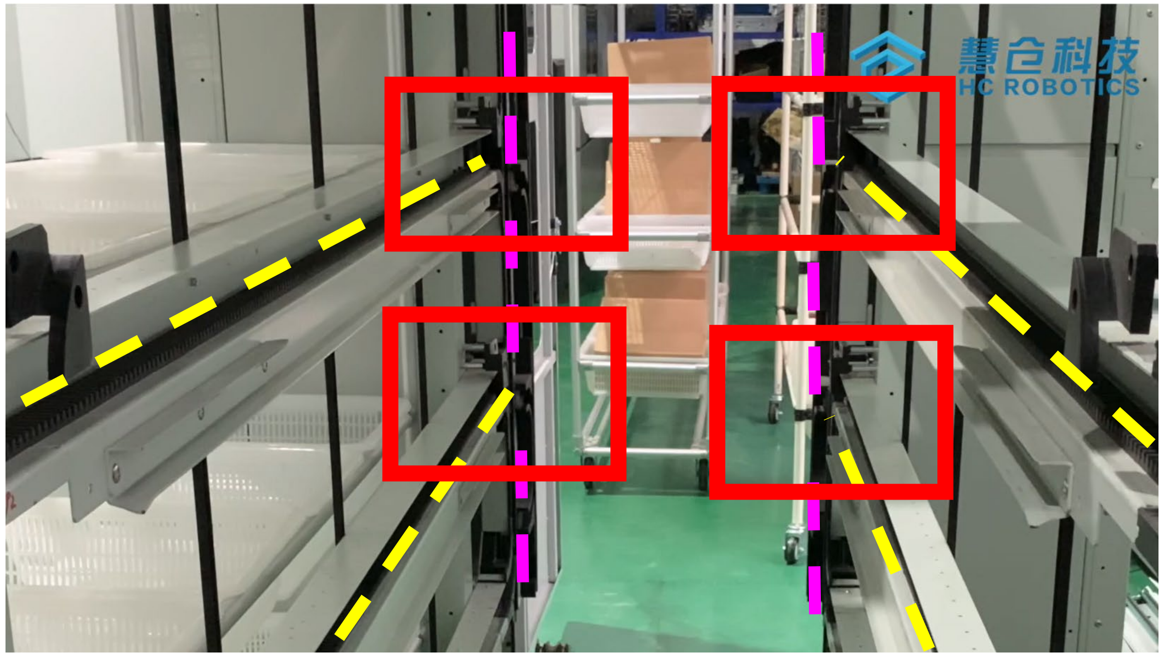
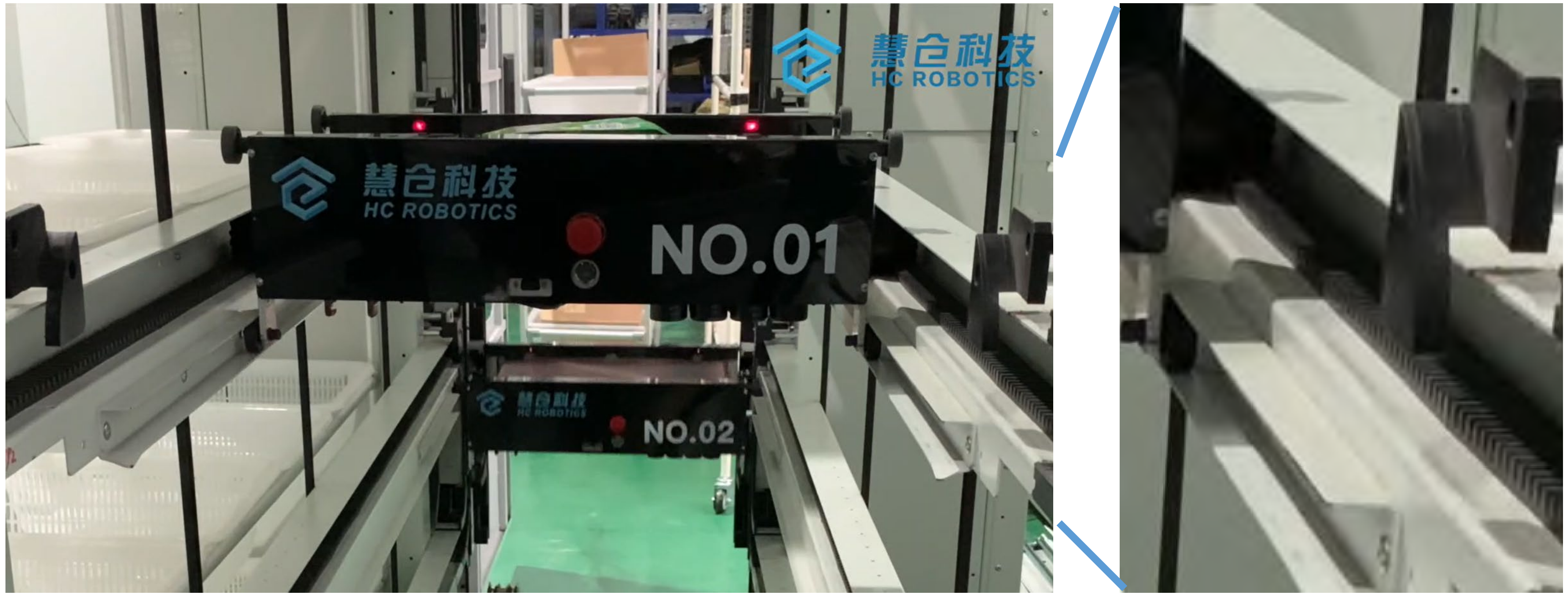
Element	Supporting Documentation
a plurality of intersections where one of the transverse track sections intersects the first track section or the second track section, wherein the intersections provide paths between a path of travel in a first direction along the first or second track, and a path of travel in a second direction along one of the transverse tracks;	The Accused Product comprises a track system that comprises a plurality of intersections where one of the transverse track sections intersects the first track section or the second track section, wherein the intersections provide paths between a path of travel in a first direction along the first or second track, and a path of travel in a second direction along one of the transverse tracks.  *OmniSort English Webpage*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

a first gate at an intersection of the first track section and a first one of the transverse track sections, wherein in a first position, the gate provides a first path through the intersection along one of either the first track or one of the transverse track sections while impeding travel along the other of the first track and the one transverse track sections, and wherein in a second position, the gate provides a second path through the intersection transverse the first path to allow one of the delivery vehicles to change path direction;	The Accused Product comprises a track system that comprises a first gate at an intersection of the first track section and a first one of the transverse track sections, wherein in a first position, the gate provides a first path through the intersection along one of either the first track or one of the transverse track sections while impeding travel along the other of the first track and the one transverse track sections, and wherein in a second position, the gate provides a second path through the intersection transverse the first path to allow one of the delivery vehicles to change path direction.  

	   *OmniSort English Webpage.*

wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between the first or second track section and one of the transverse tracks.	The Accused Product comprises a plurality of vehicles wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between the first or second track section and one of the transverse tracks. 

OmniSort English Webpage.

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

Claim 21

Element	Supporting Documentation
A system for sorting or retrieving a plurality of items, comprising:	To the extent that the preamble is limiting, the Accused Product comprises a system for sorting or retrieving a plurality of items. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*. OmniSort The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort English Webpage*.

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

a plurality of destination areas for receiving the items, wherein the destination areas are arranged in columns or rows;	The Accused Product comprises a plurality of destination areas for receiving the items, wherein the destination areas are arranged in columns or rows.  

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

	*Automated Put Wall Solutions.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

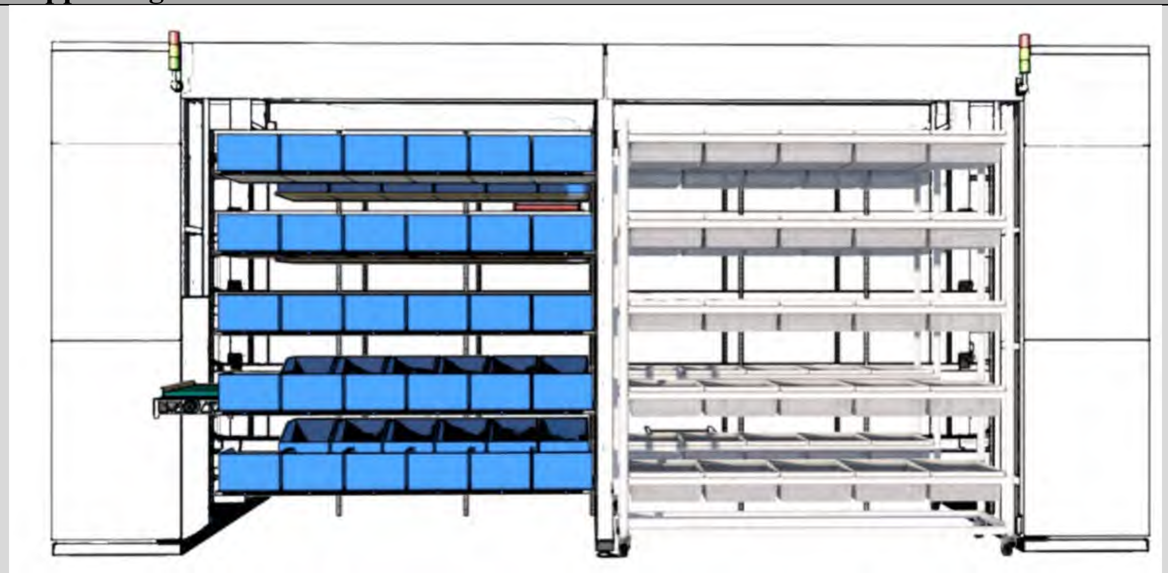
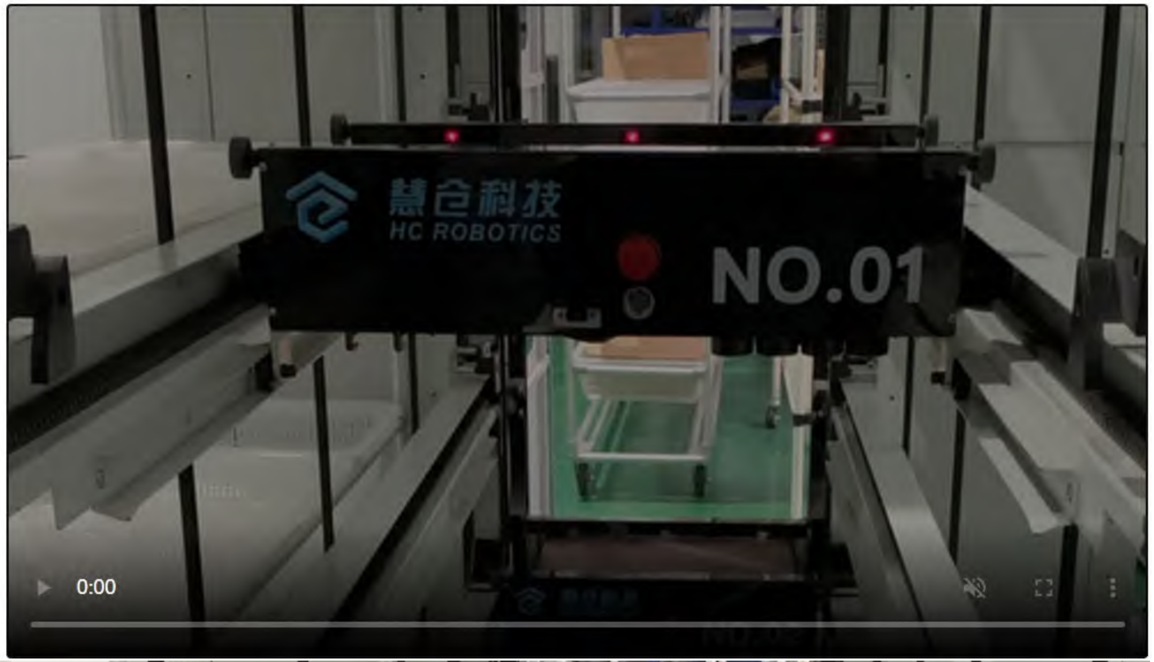
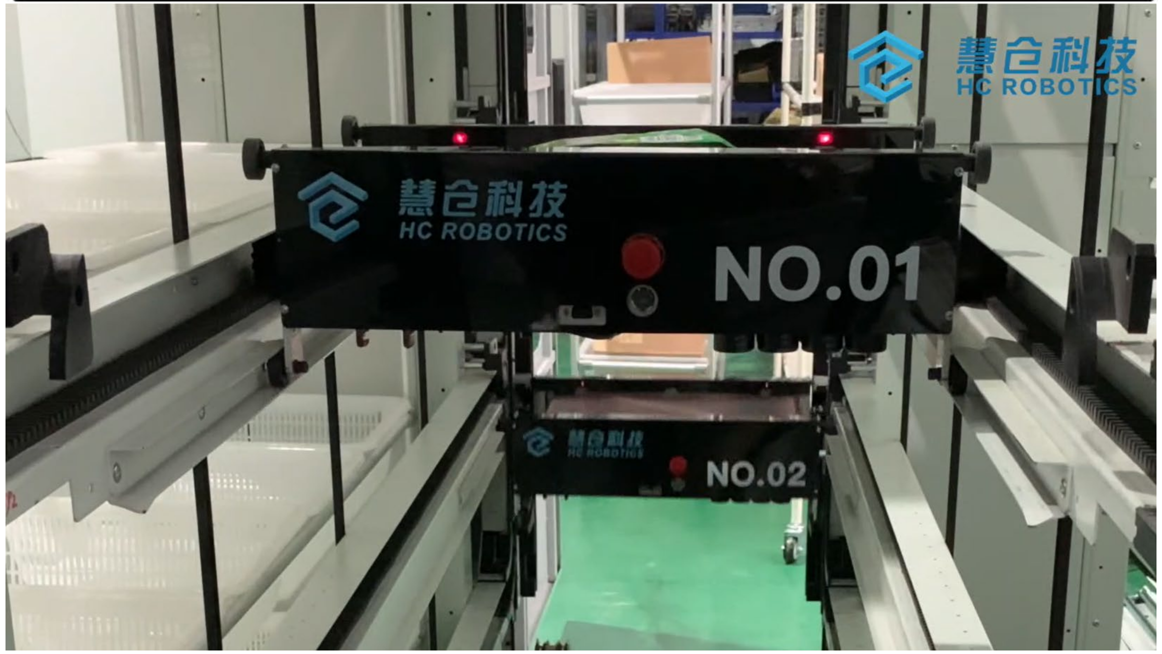
Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

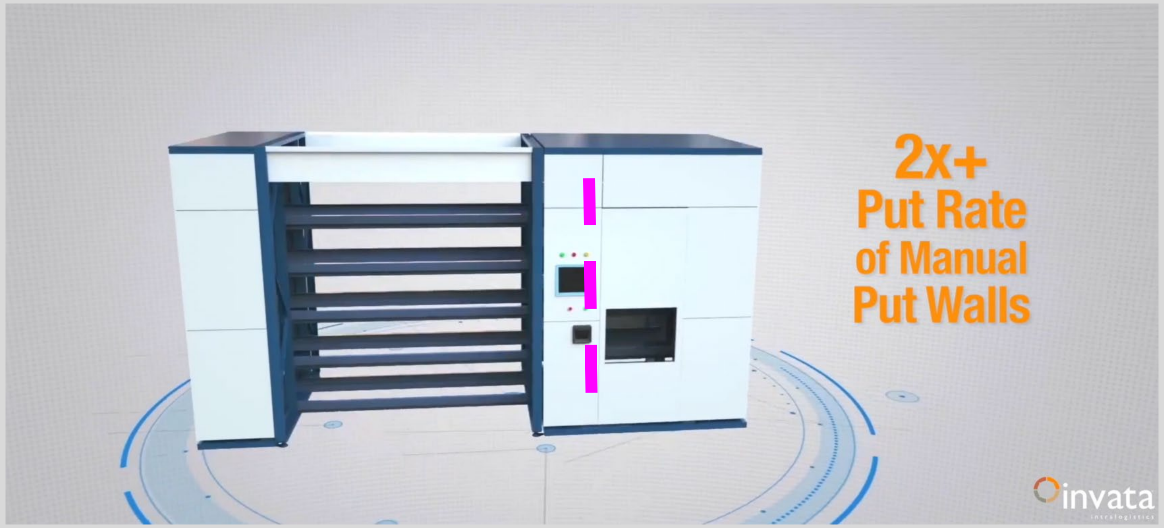
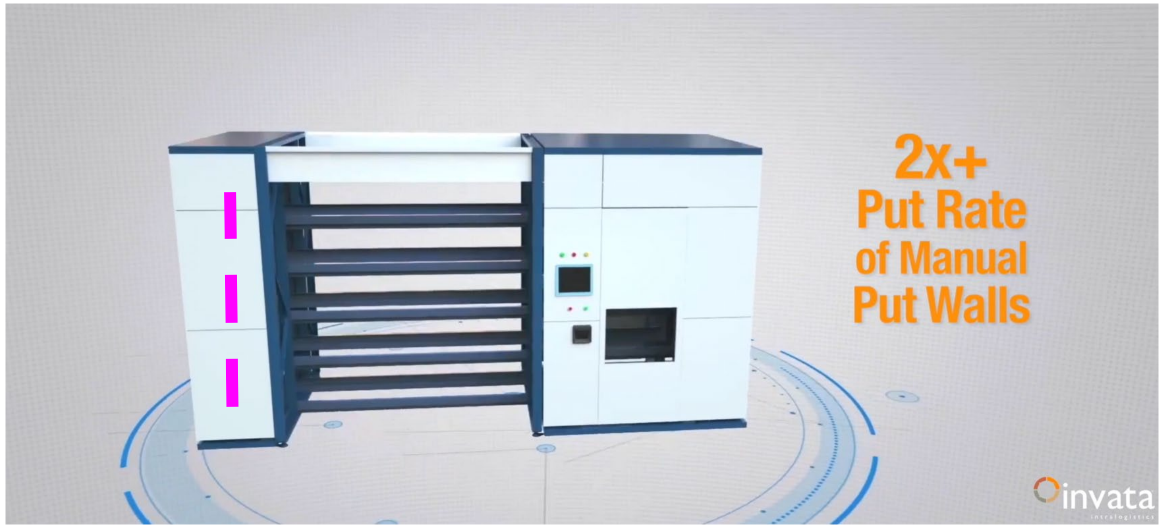
a plurality of vehicles for delivering the items to or from the destination areas, and	The Accused Product comprises a plurality of vehicles for delivering the items to or from the destination areas.   *Automated Put Wall Solutions.* Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment.





OmniSort English Webpage.

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

Element	Supporting Documentation
a track system for guiding the delivery vehicles to the destinations, wherein the track system comprises: a first track section;	The Accused Product comprises a track system that comprises a first track section.  *Automated Put Wall Solutions.*
a second track section;	The Accused Product comprises a track system that comprises a second track section.  *Automated Put Wall Solutions.*

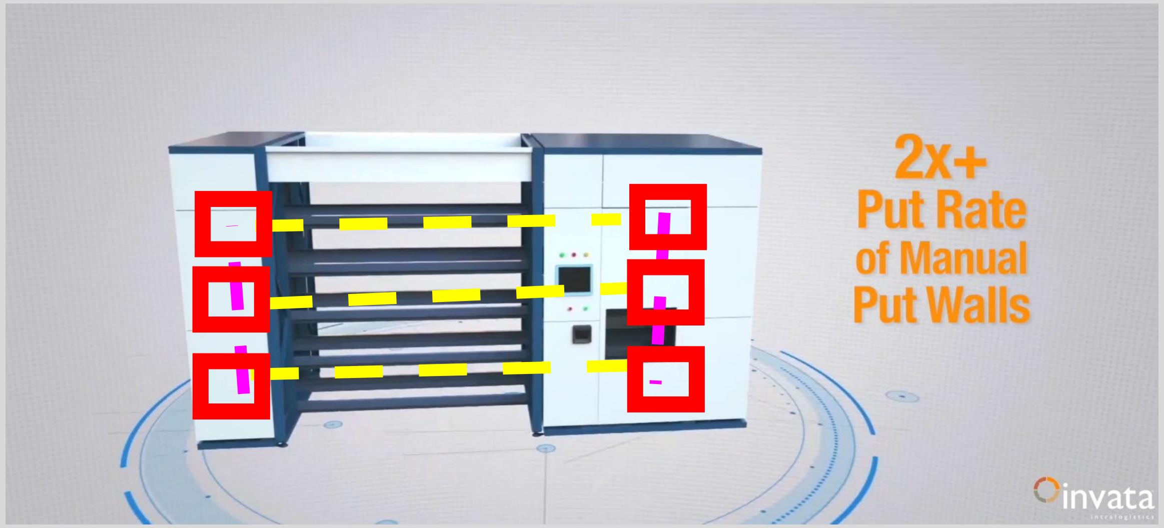
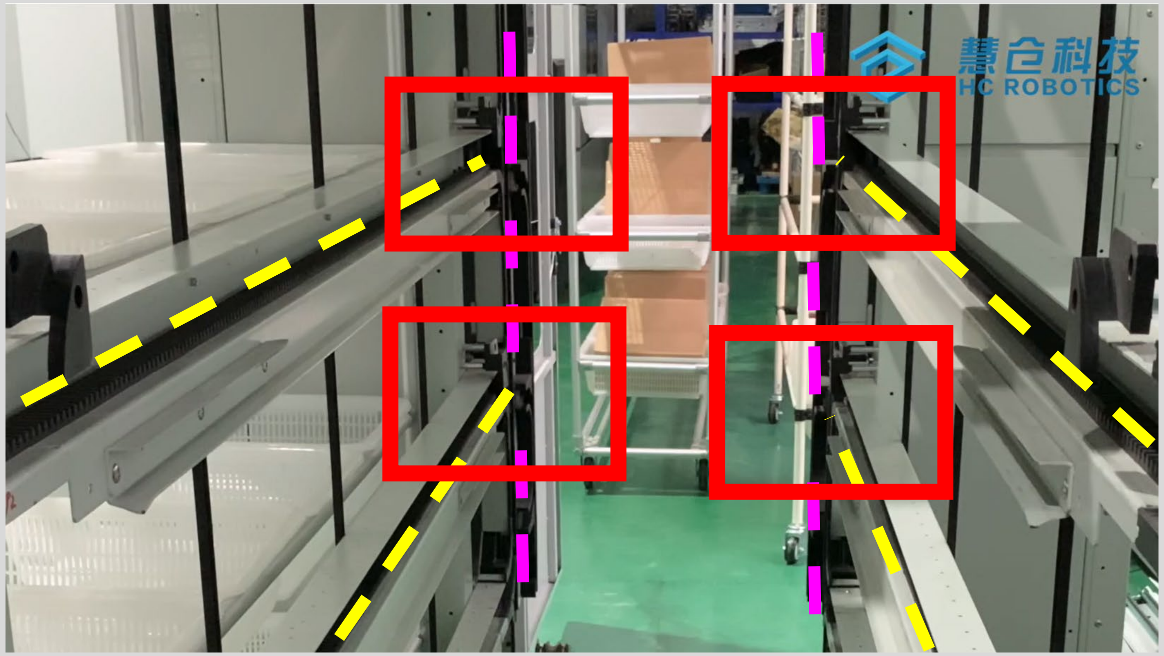
a plurality of transverse track sections intersecting the first and second track sections; and	The Accused Product comprises a track system that comprises a plurality of transverse track sections intersecting the first and second track sections.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

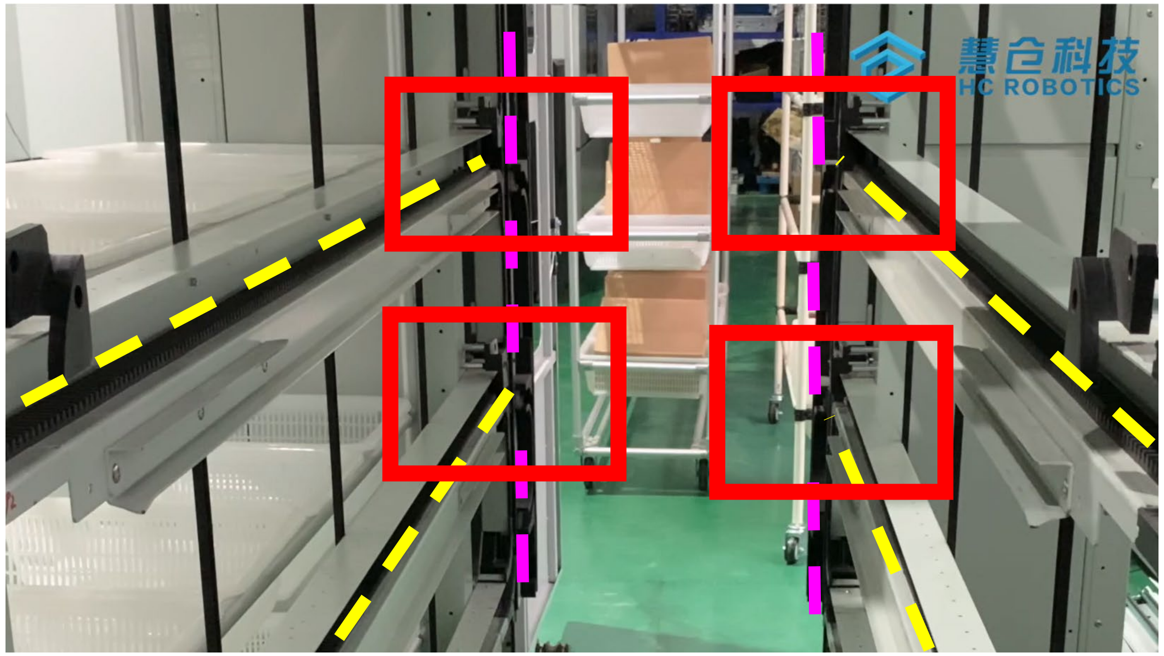
Element	Supporting Documentation
a plurality of intersections where one of the transverse track sections intersects the first track section or the second track section, wherein the intersections provide paths between a path of travel in a first direction along the first or second track, and a path of travel in a second direction along one of the transverse tracks;	The Accused Product comprises a track system that comprises a plurality of intersections where one of the transverse track sections intersects the first track section or the second track section, wherein the intersections provide paths between a path of travel in a first direction along the first or second track, and a path of travel in a second direction along one of the transverse tracks.  *OmniSort English Webpage*

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

a first gate at an intersection of the first track section and a first one of the transverse track sections, wherein in a first position, the gate provides a first path through the intersection along one of either the first track or one of the transverse track sections while impeding travel along the other of the first track and the one transverse track sections, and wherein in a second position, the gate provides a second path through the intersection transverse the first path to allow one of the delivery vehicles to change path direction;	The Accused Product comprises a track system that comprises a first gate at an intersection of the first track section and a first one of the transverse track sections, wherein in a first position, the gate provides a first path through the intersection along one of either the first track or one of the transverse track sections while impeding travel along the other of the first track and the one transverse track sections, and wherein in a second position, the gate provides a second path through the intersection transverse the first path to allow one of the delivery vehicles to change path direction.  

OmniSort English Webpage.

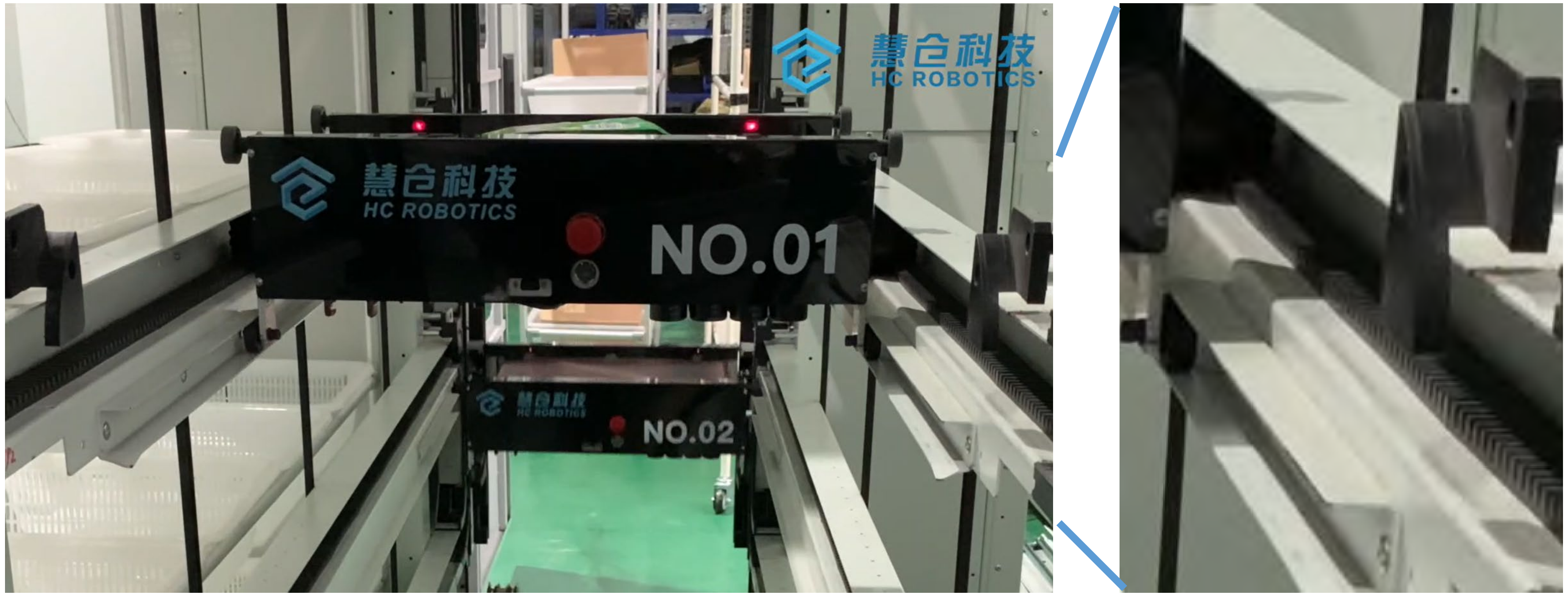
wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between the first or second track section and one of the transverse tracks.	The Accused Product comprises a plurality of vehicles wherein each vehicle comprises a drive element that interacts with the track system to maintain the general orientation of the vehicle relative to the horizon as the vehicle moves between the first or second track section and one of the transverse tracks. 

Exhibit N: Claim chart comparing U.S. Patent No. 8,104,601 to Respondents' OmniSort Product

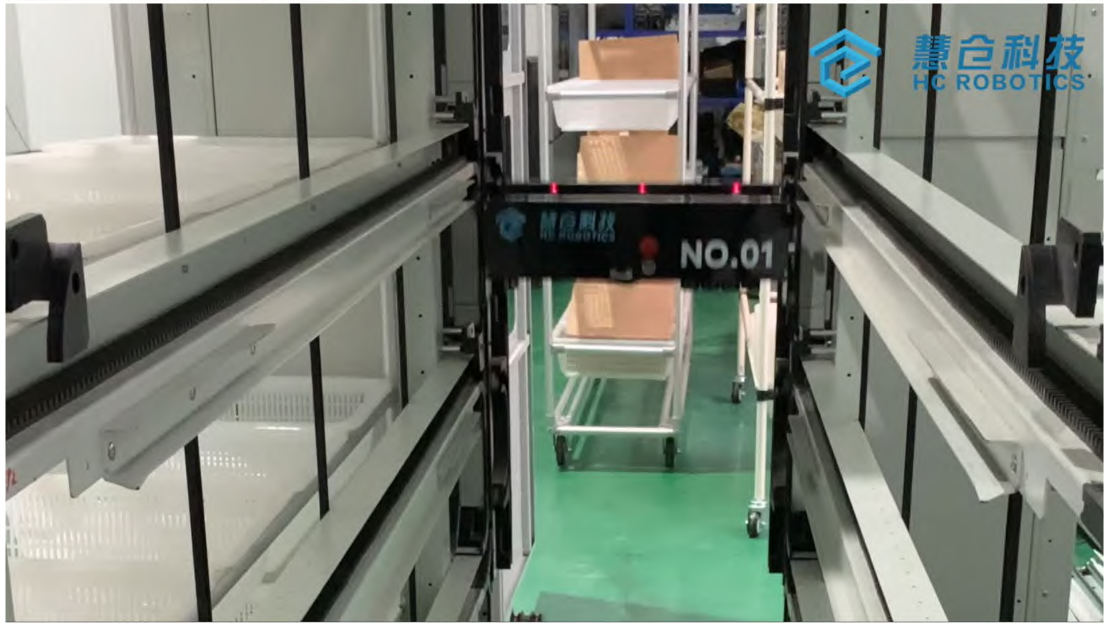
Element	Supporting Documentation
	*OmniSort English Webpage.*

EXHIBIT O

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

U.S. Patent No. 8,276,740

Claim 1

Element	**Supporting Documentation**
A material handling system for sorting or retrieving a plurality of items, comprising:	To the extent that the preamble is limiting, the Respondents' OmniSort system (hereinafter the "Accused Product") is a material handling system for sorting or retrieving a plurality of items. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*, INVATA INTRALOGISTICS, https://www.invata.com/automated-put-wall-solutions/?li (last visited Dec. 2, 2021) (Exhibit 16).[1]

[1] The illustrations in this claim chart are exemplary, and not intended to limit the scope or applicability of the claims. To the extent any element is not literally met by the Accused Product, it is met under the doctrine of equivalents, at least because the Accused Product performs the same function in the same way to achieve the same result.

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

Element	Supporting Documentation
	OmniSort The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort*, HC ROBOTICS, http://en.hc-robots.com/omniSort (last visited Dec. 2, 2021) (hereinafter "*OmniSort English Webpage*") (Exhibit 17).

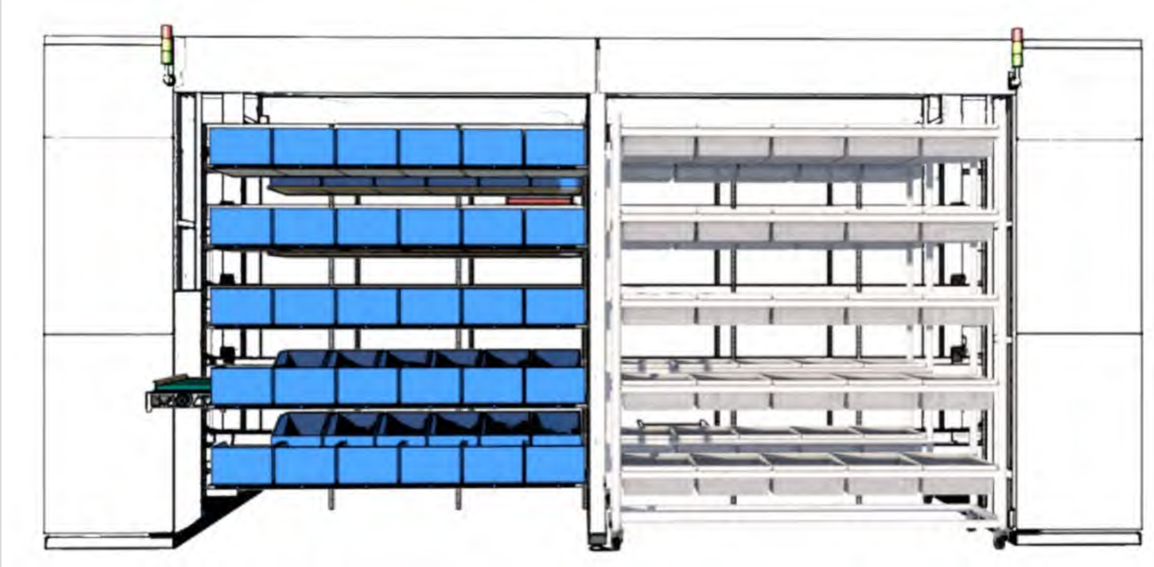
Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

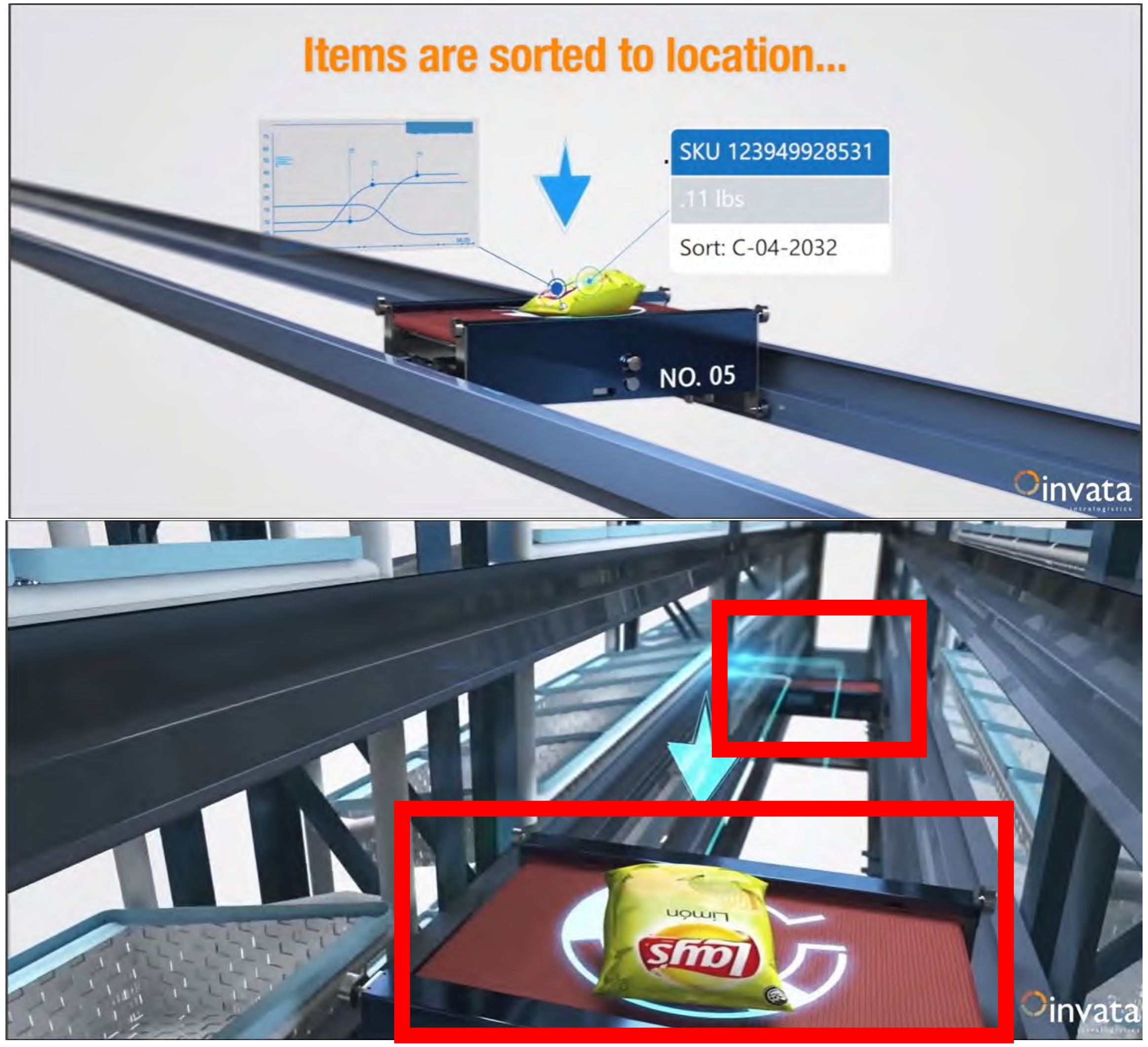
a plurality of destination areas for items, wherein the destination areas are arranged in a plurality of columns or rows;	The Accused Product comprises a plurality of destination areas for items, wherein the destination areas are arranged in a plurality of columns or rows.  

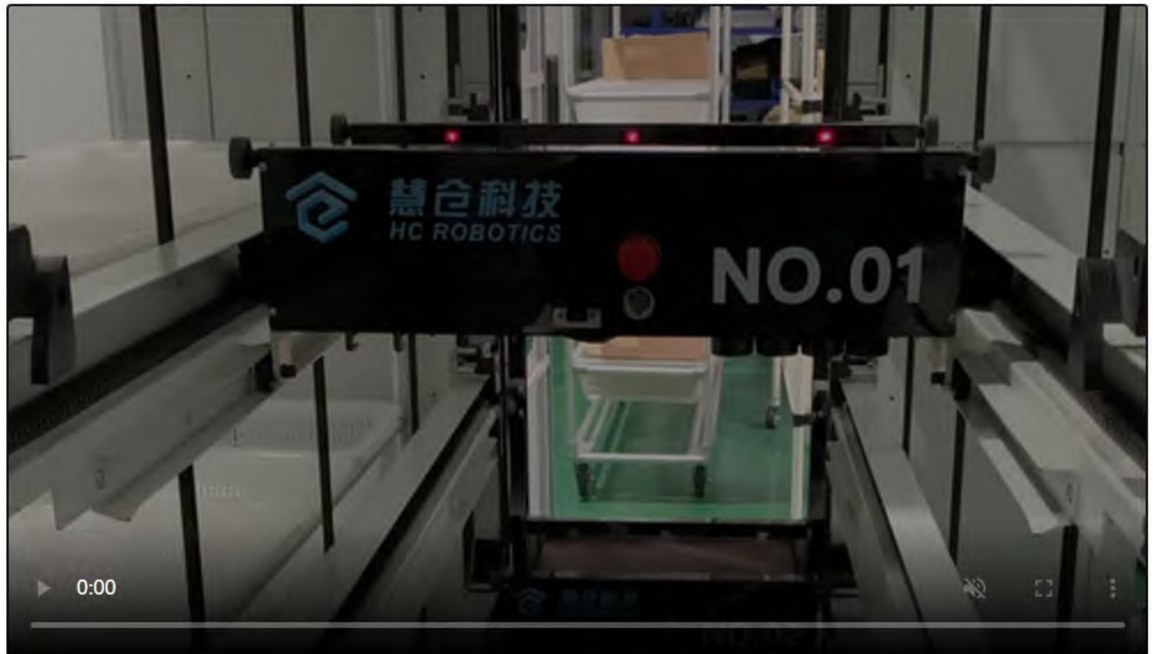
Automated Put Wall Solutions.[2]

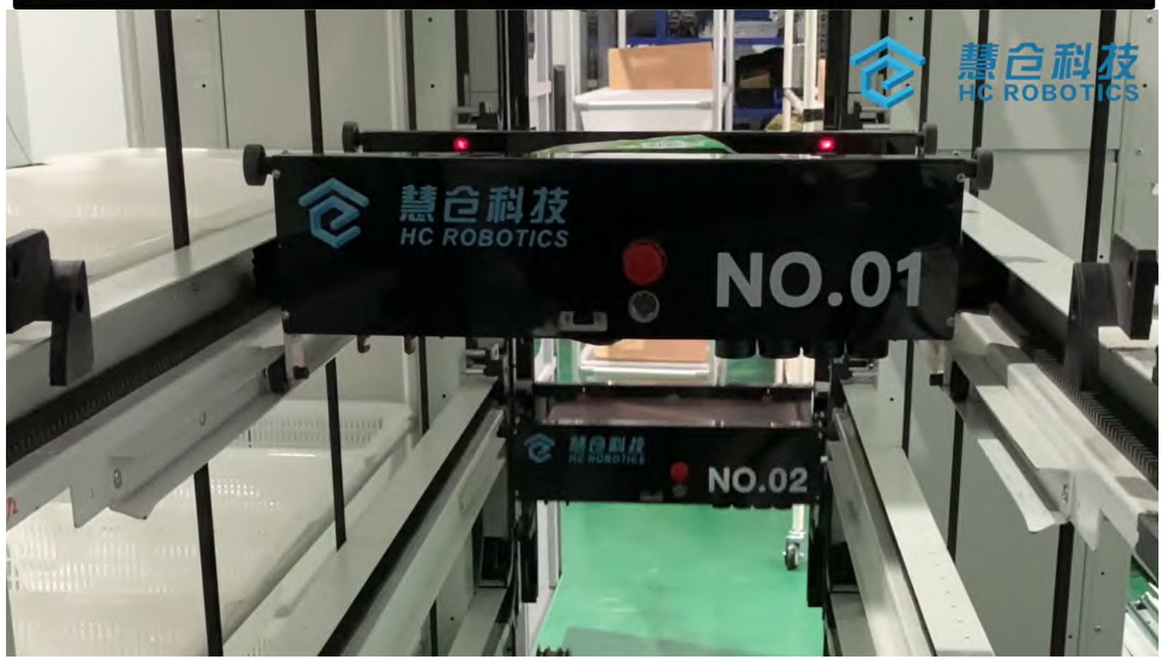
[2] Invata's relevant product page, and both of HC Robotics' relevant pages, consist primarily of embedded videos. OPEX will provide copies of those videos on request.

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

a plurality of vehicles for transporting items to or from the destination areas; and	The Accused Product comprises a plurality of vehicles for transporting items to or from the destination areas.  *Automated Put Wall Solutions.* Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment.



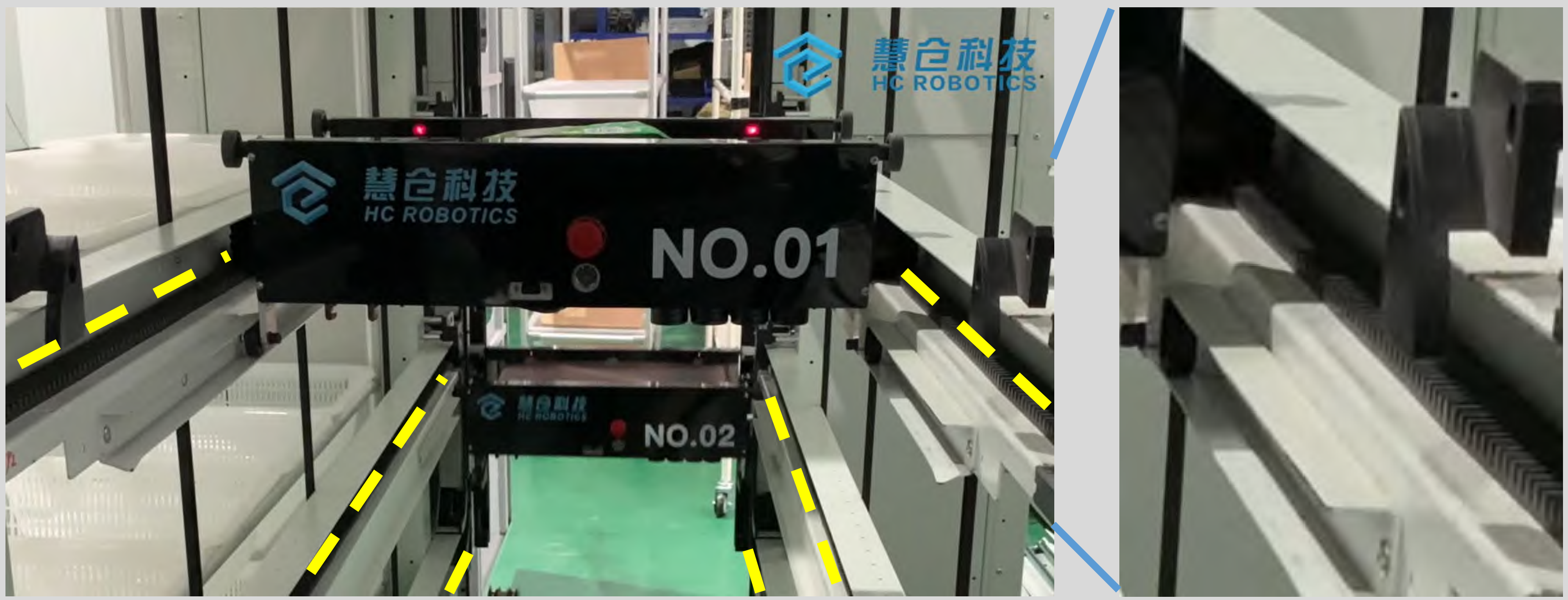


OmniSort English Webpage.

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

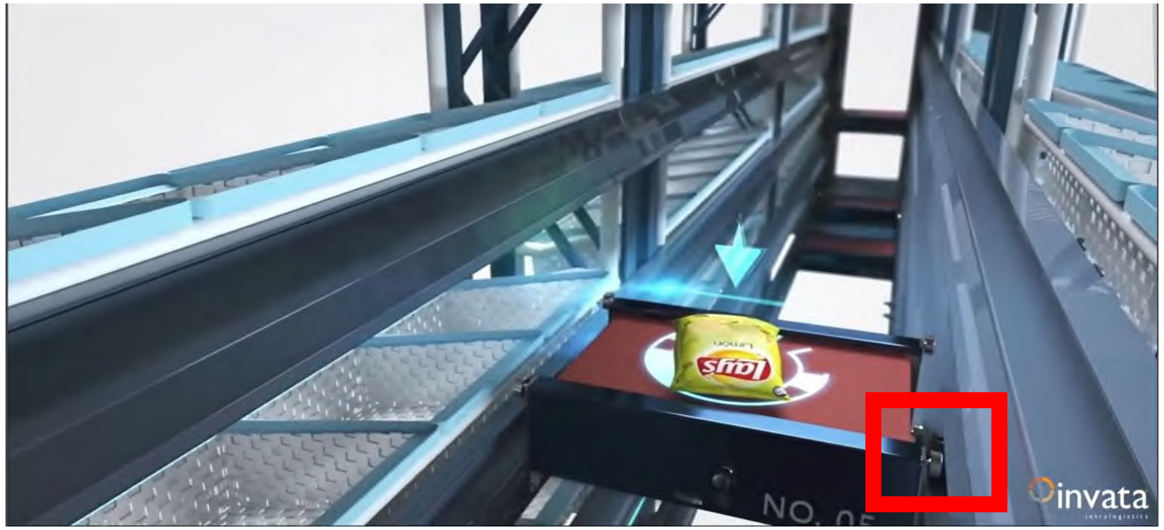
<table>
<tr>
<td>a track for guiding the delivery vehicles to the destination areas, wherein the track comprises a plurality of columns or rows adjacent the plurality of destination areas, wherein the track comprises engagement elements;</td>
<td>The Accused Product comprises a track for guiding the delivery vehicles to the destination areas, wherein the track comprises a plurality of columns or rows adjacent the plurality of destination areas, wherein the track comprises engagement elements.

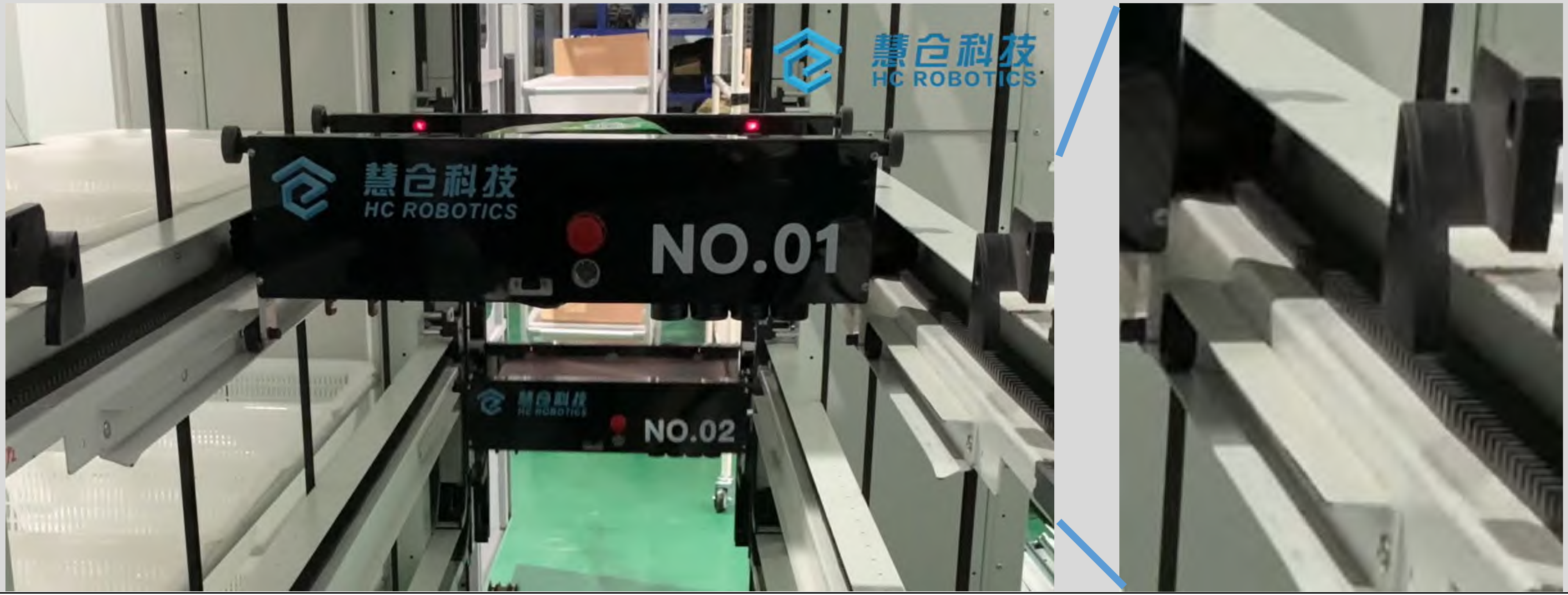
Automated Put Wall Solutions.



OmniSort English Webpage.</td>
</tr>
</table>

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

wherein at least one of the vehicles comprises: a motor for driving the vehicle to one of the destination areas;	The Accused Product comprises a plurality of vehicles wherein at least one of the vehicles comprises a motor for driving the vehicle to one of the destination areas.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

a drive system cooperable with the track to guide the vehicle to one of the destination areas, wherein the drive system comprises a plurality of teeth that mesh with the engagement elements on the track, and wherein the drive system is operable to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a first direction of travel to a second direction of travel, wherein the first direction is at an angle to the second direction; and	The Accused Product comprises a plurality of vehicles wherein at least one of the vehicles comprises a drive system cooperable with the track to guide the vehicle to one of the destination areas, wherein the drive system comprises a plurality of teeth that mesh with the engagement elements on the track, and wherein the drive system is operable to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a first direction of travel to a second direction of travel, wherein the first direction is at an angle to the second direction. 

	  *OmniSort English Webpage.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

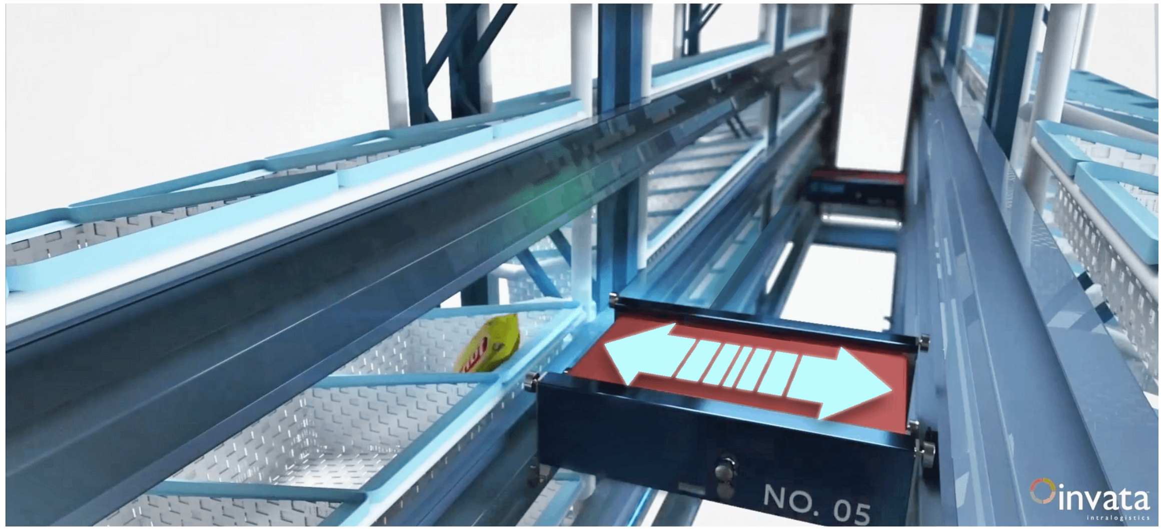
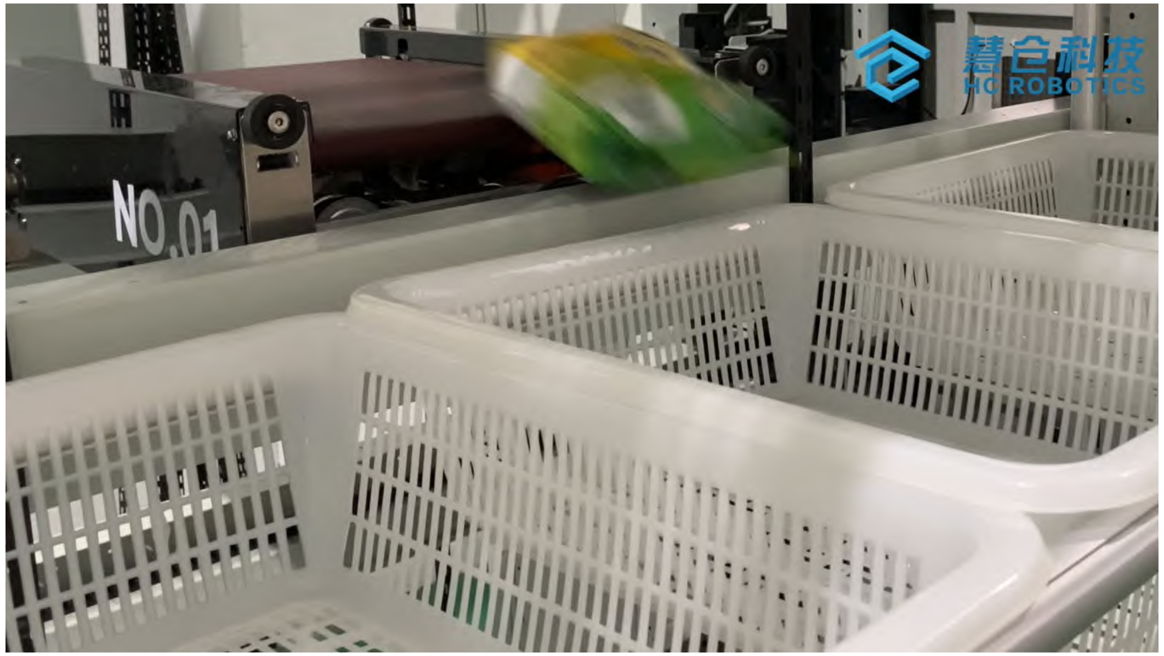
a transfer mechanism for transferring an item between the vehicle and one of the destination areas, wherein the transfer mechanism is operable to transfer the item along a third direction that is transverse both the first and second directions.	The Accused Product comprises a plurality of vehicles wherein at least one of the vehicles comprises a transfer mechanism for transferring an item between the vehicle and one of the destination areas, wherein the transfer mechanism is operable to transfer the item along a third direction that is transverse both the first and second directions.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

Claim 10

Element	**Supporting Documentation**
A material handling system for sorting or retrieving a plurality of items, comprising:	To the extent that the preamble is limiting, the Accused Product comprises a material handling system for sorting or retrieving a plurality of items. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*. OmniSort The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort English Webpage*.

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

a plurality of destination areas for items, wherein the destination areas are arranged in a plurality of columns or rows;	The Accused Product comprises a plurality of destination areas for items, wherein the destination areas are arranged in a plurality of columns or rows.  

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

	 *Automated Put Wall Solutions.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

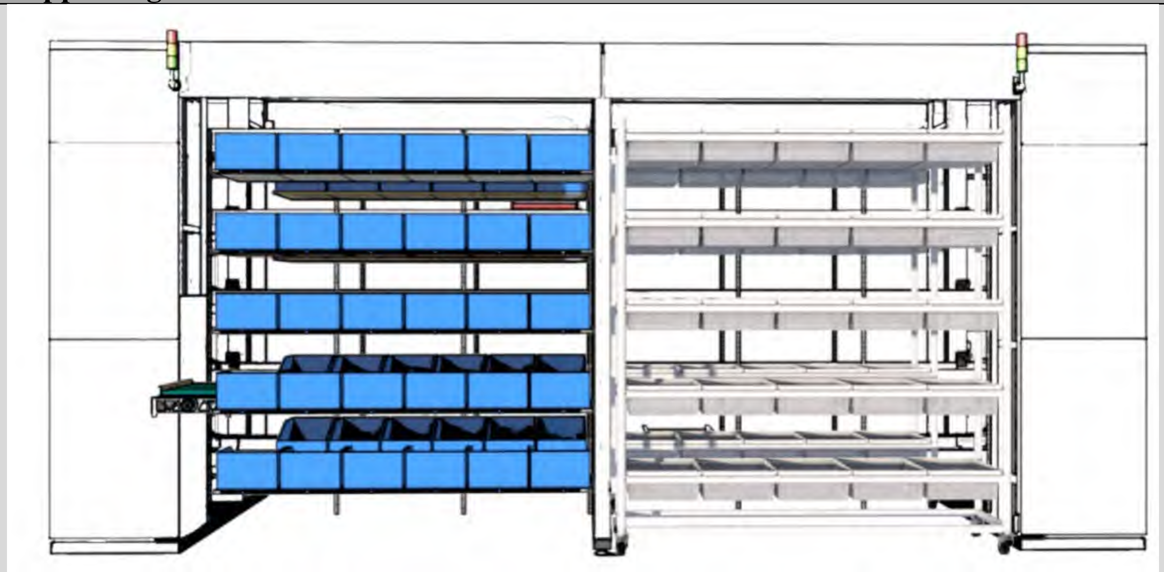
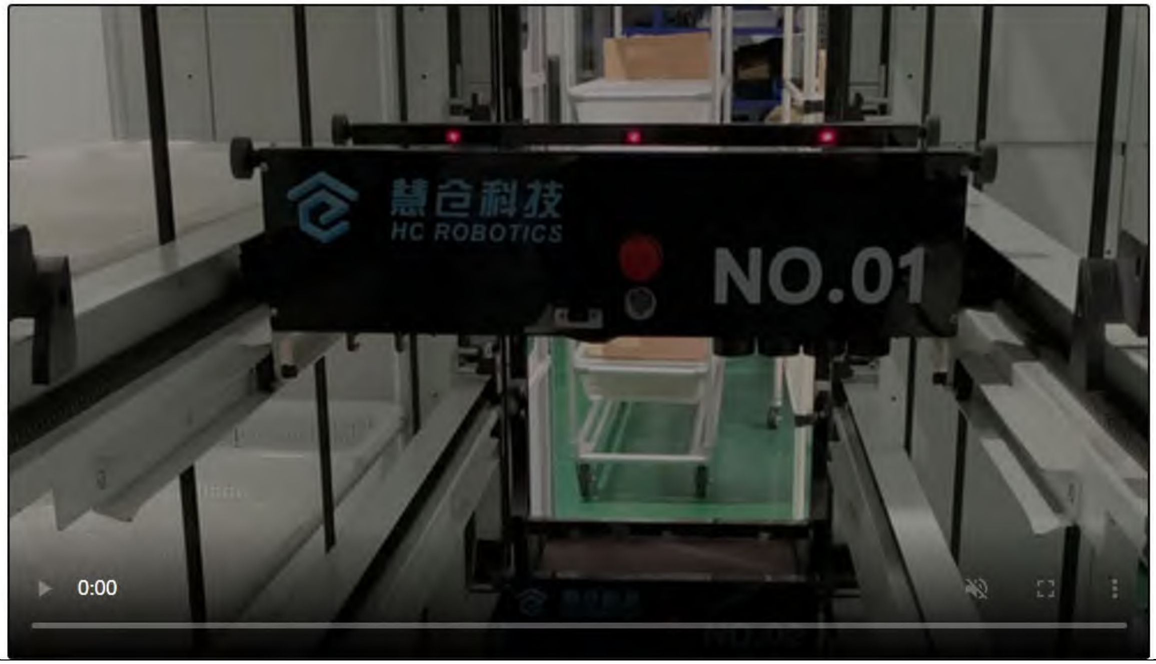
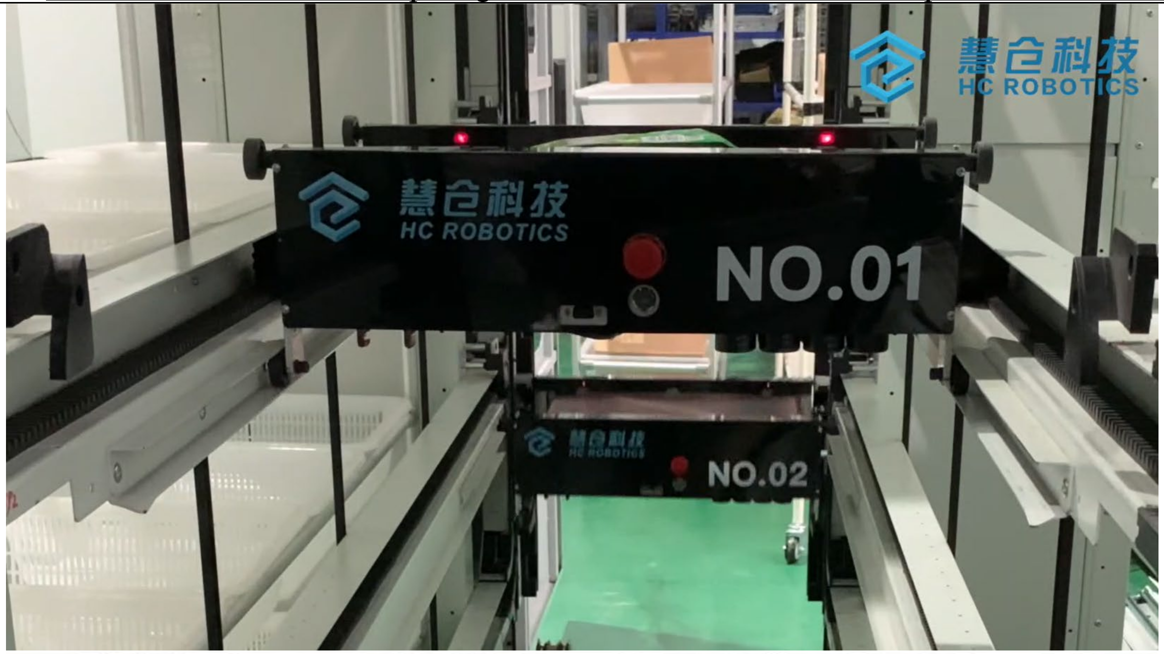
Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and	The Accused Product comprises a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle.   *Automated Put Wall Solutions.*

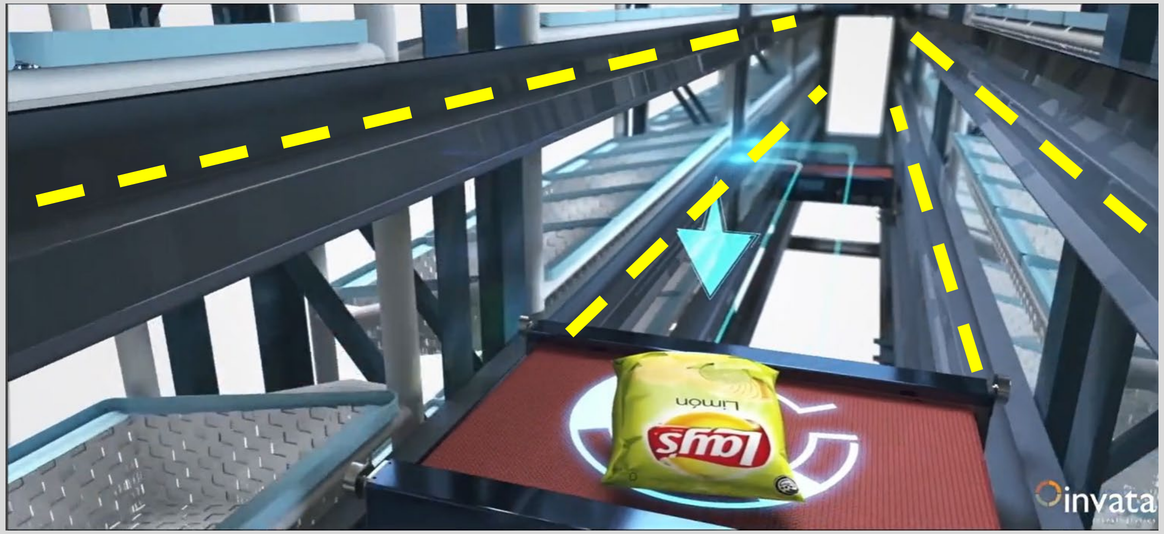
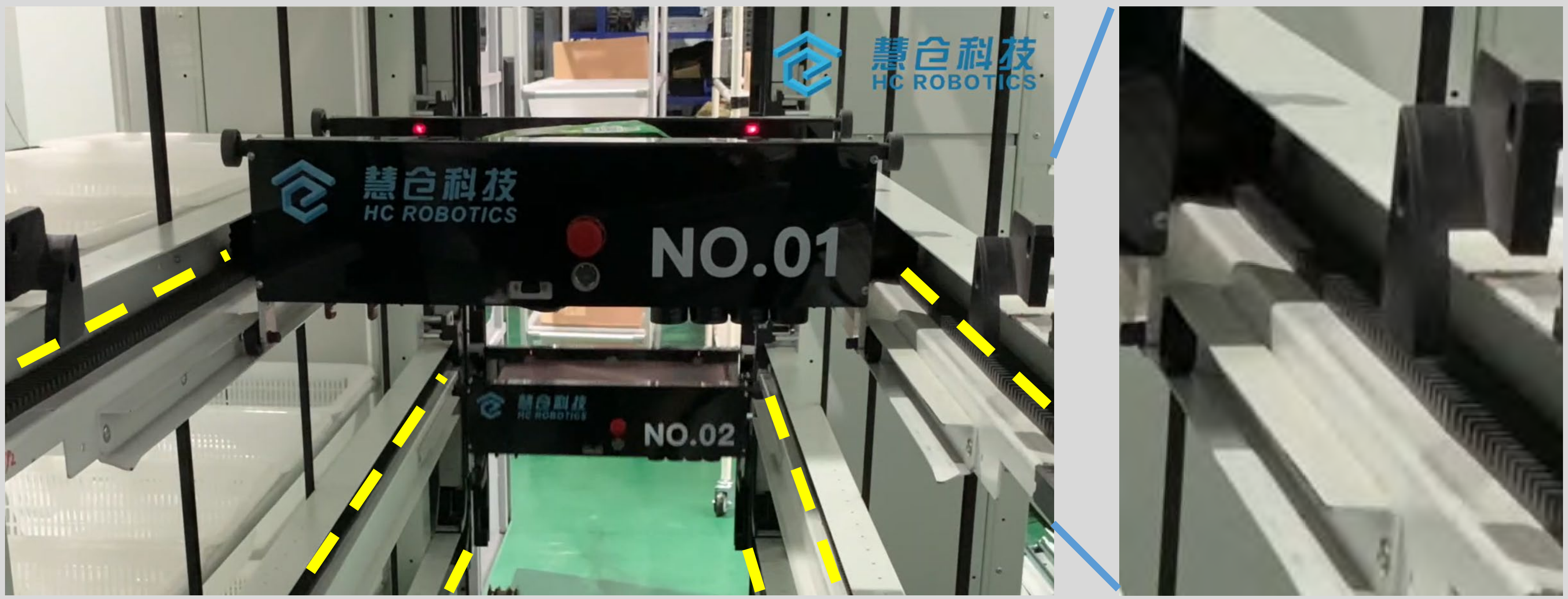
Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

	Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment. 



OmniSort English Webpage.

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

a plurality of horizontal track sections spaced apart from one another and extending in a generally horizontal direction;	The Accused Product comprises a plurality of horizontal track sections spaced apart from one another and extending in a generally horizontal direction.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

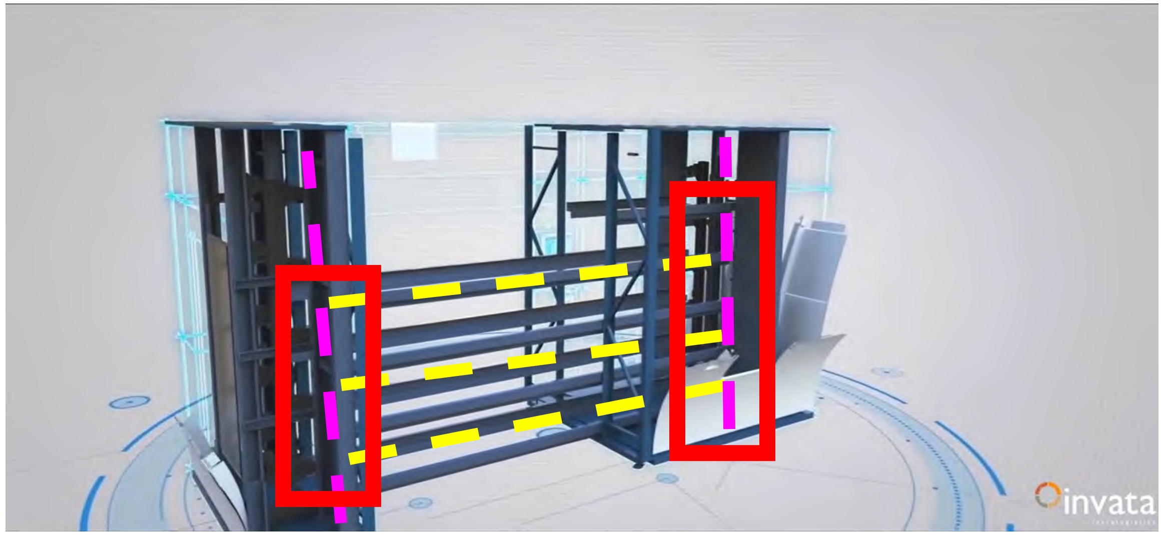
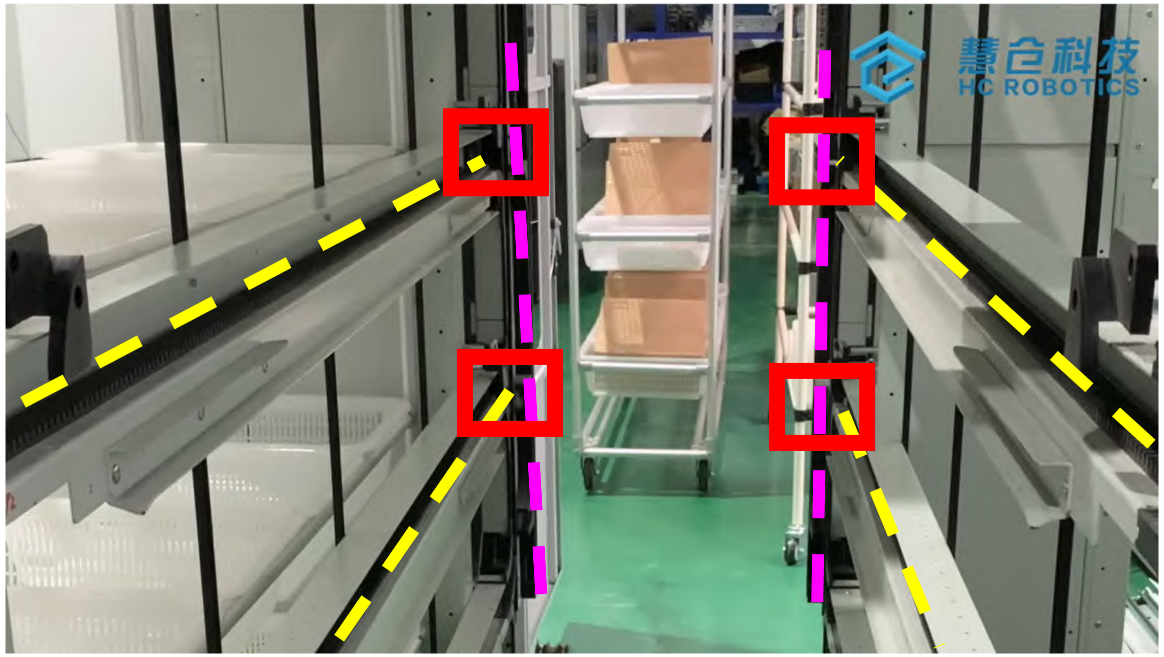
a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the horizontal track sections intersect vertical track sections; and	The Accused Product comprises a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the horizontal track sections intersect vertical track sections.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

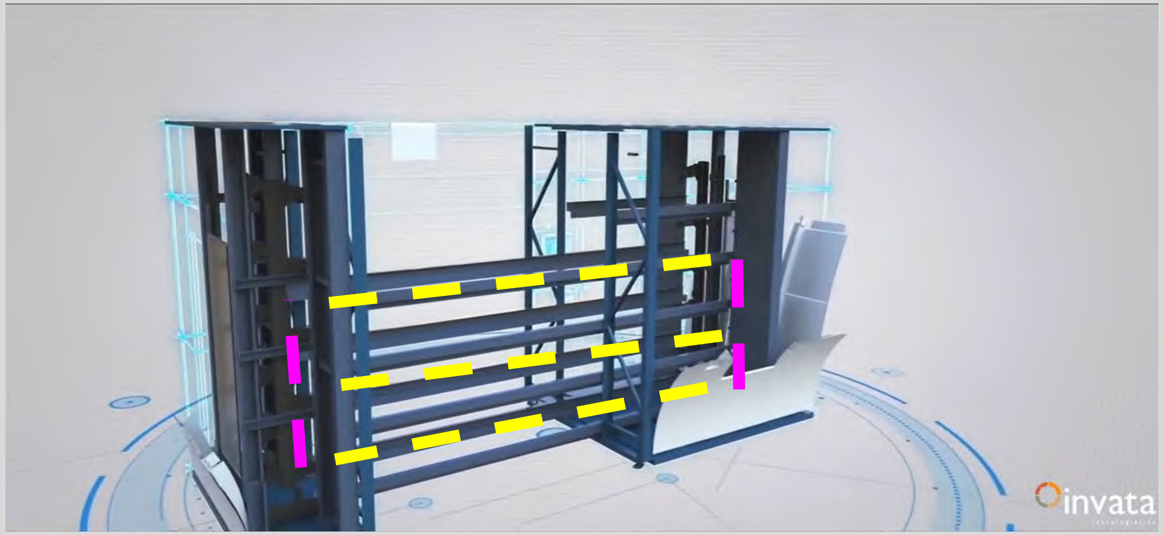
a plurality of intersections where the horizontal track sections intersect the vertical track sections, wherein the intersections provide a first path along the generally horizontal direction, and a second path along the generally vertical direction;	The Accused Product comprises a plurality of intersections where the horizontal track sections intersect the vertical track sections, wherein the intersections provide a first path along the generally horizontal direction, and a second path along the generally vertical direction.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

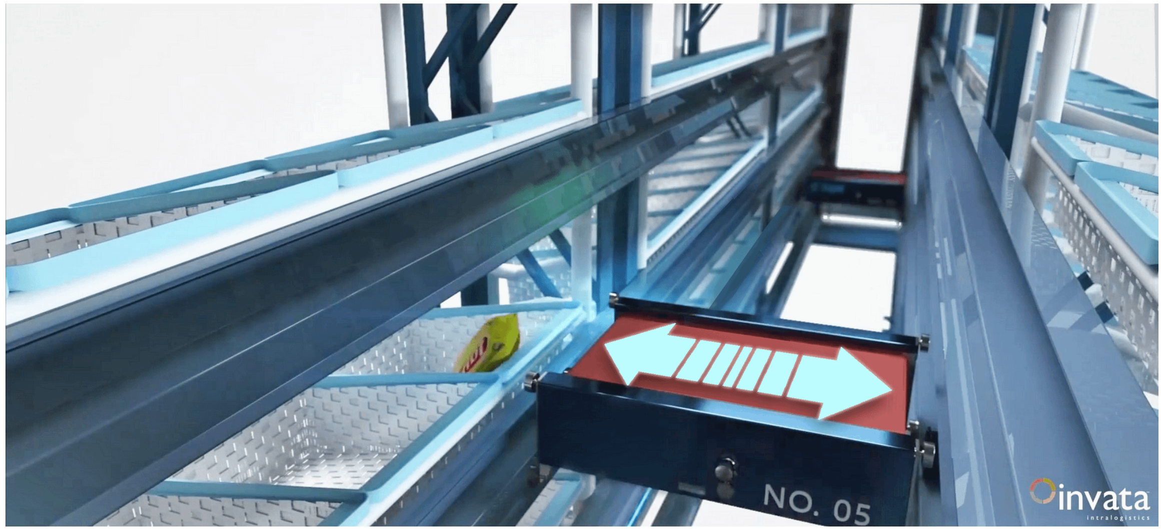
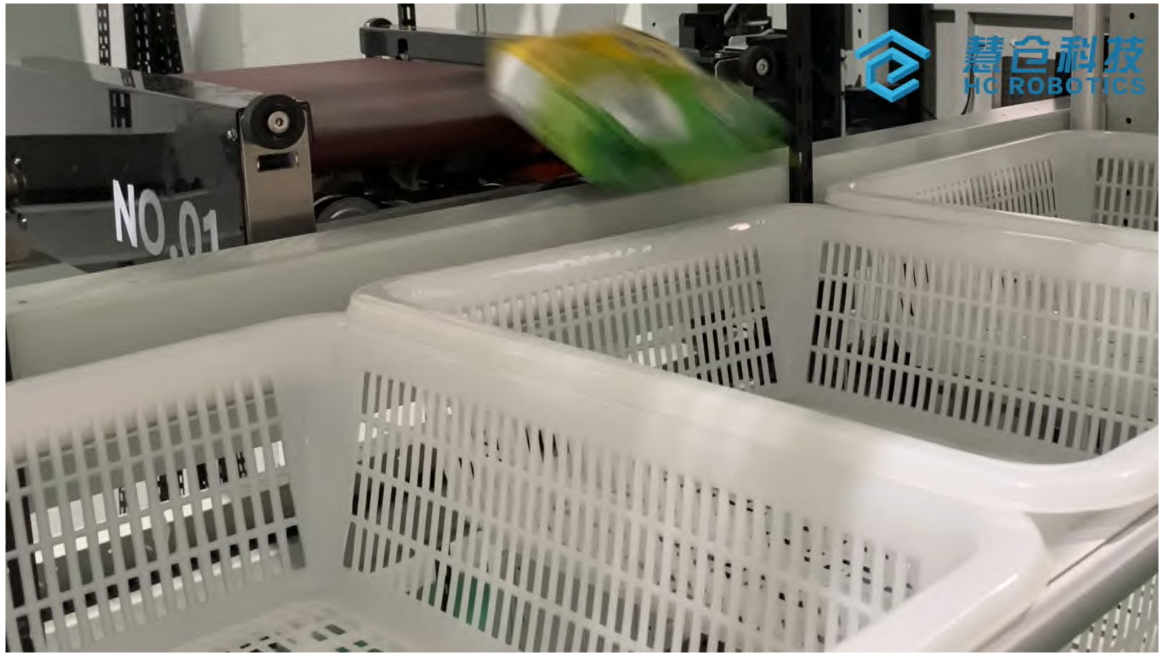
wherein at least one of the vehicles comprises a transfer mechanism for transferring an item between the vehicle and one of the destination areas, wherein the transfer mechanism is operable to transfer the item along a third direction that is transverse both the vertical track sections and the horizontal track sections.	The Accused Product comprises a plurality of vehicles wherein at least one of the vehicles comprises a transfer mechanism for transferring an item between the vehicle and one of the destination areas, wherein the transfer mechanism is operable to transfer the item along a third direction that is transverse both the vertical track sections and the horizontal track sections.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

Claim 18

Element	Supporting Documentation
A material handling system for sorting or retrieving a plurality of items, comprising:	To the extent that the preamble is limiting, the Accused Product is a material handling system for sorting or retrieving a plurality of items. **Fill a Lot More Orders — a Whole Lot Faster!** The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*, INVATA INTRALOGISTICS, https://www.invata.com/automated-put-wall-solutions/?li (last visited Dec. 2, 2021). **OmniSort** The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort*, HC ROBOTICS, http://en.hc-robots.com/omniSort (last visited Dec. 2, 2021) (hereinafter "*OmniSort English Webpage*").

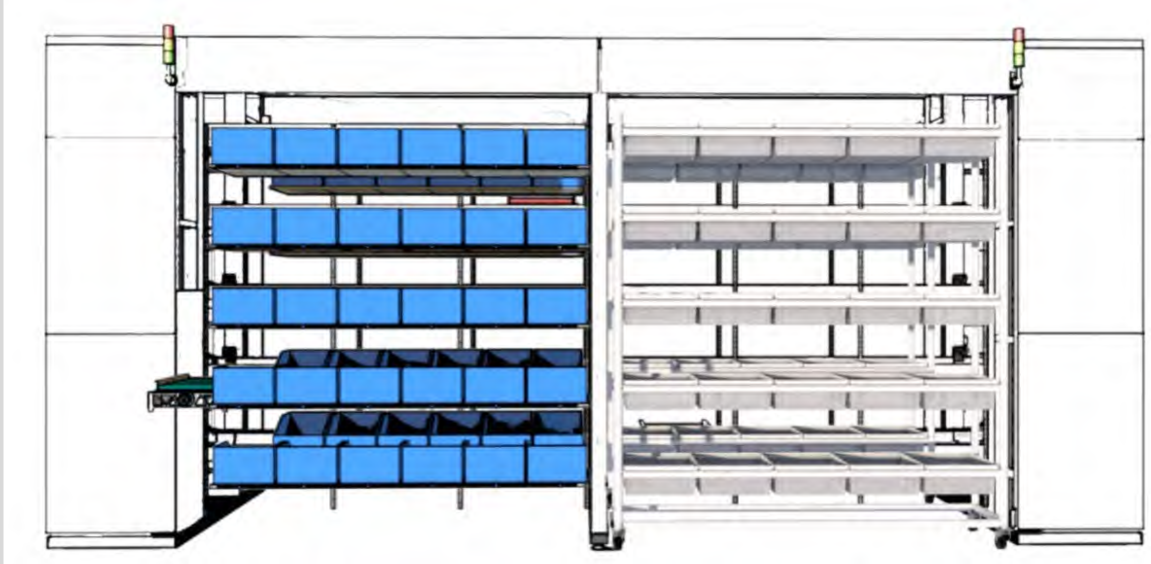
Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

a plurality of destination areas for items, wherein the destination areas are arranged in a plurality of columns or rows;	The Accused Product comprises a plurality of destination areas for items, wherein the destination areas are arranged in a plurality of columns or rows.  

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

	 *Automated Put Wall Solutions.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle; and	The Accused Product comprises a plurality of vehicles for delivering the items to or from the destination areas, wherein each vehicle comprises an on-board motor for driving the vehicle.   *Automated Put Wall Solutions.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

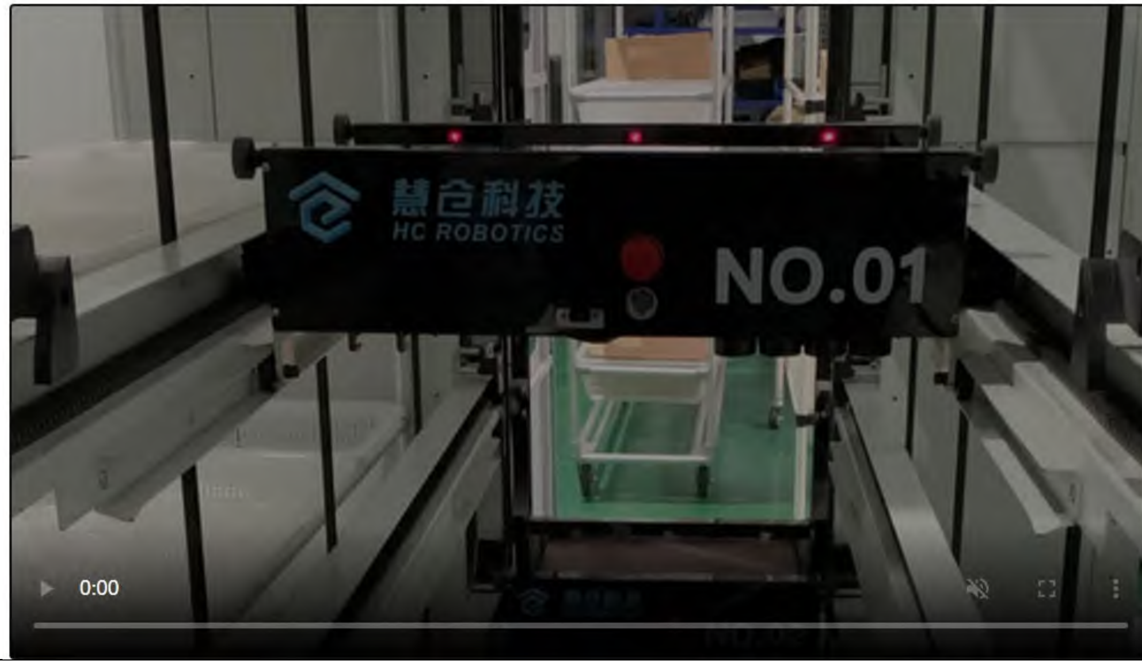
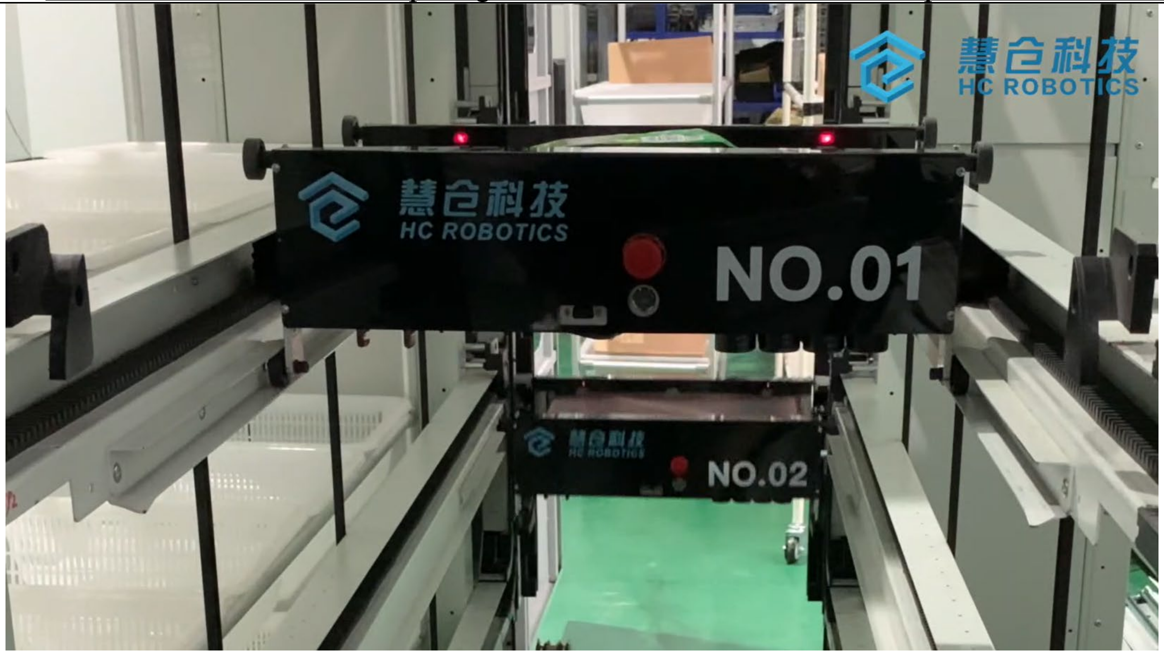
	Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment. 

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

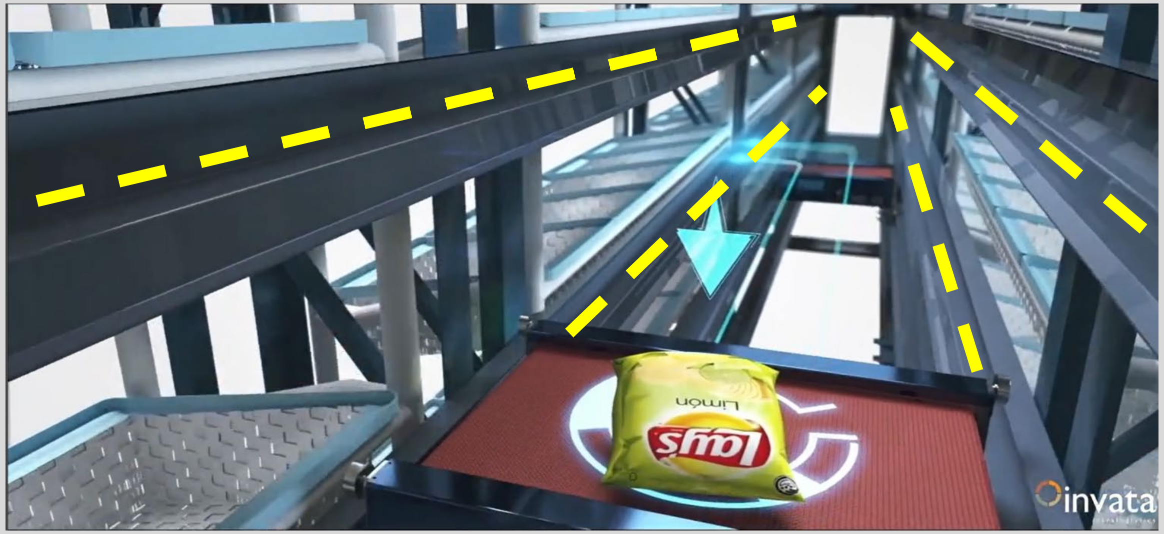
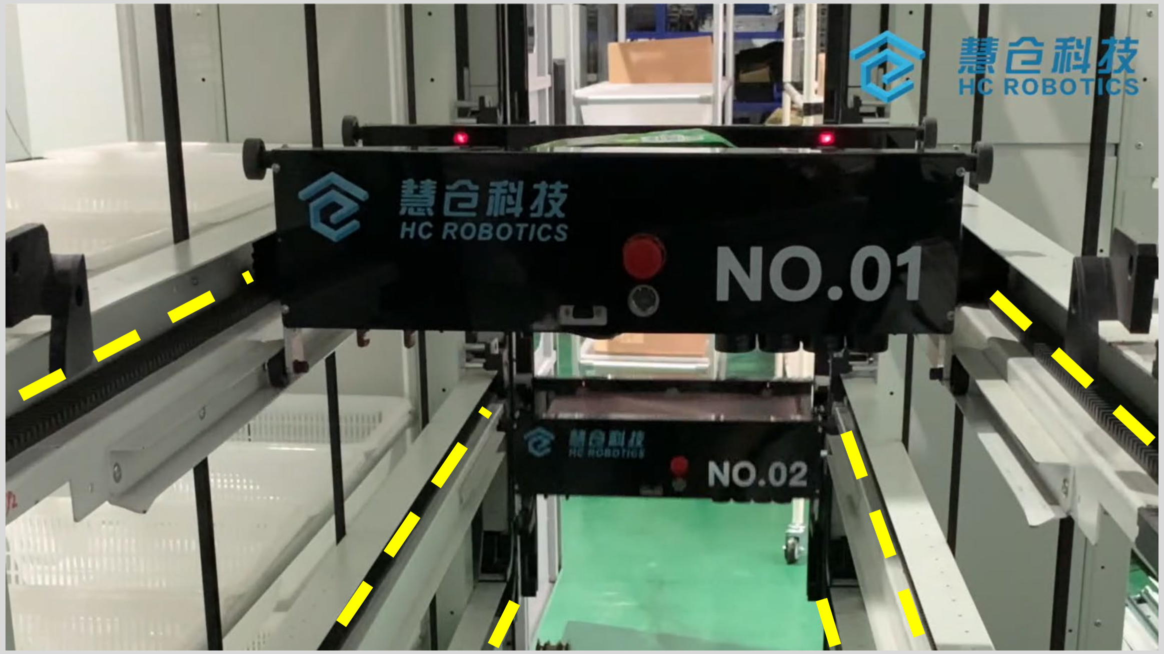


OmniSort English Webpage.

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

a plurality of horizontal track sections spaced apart from one another and extending in a generally horizontal direction;	The Accused Product comprises a plurality of horizontal track sections spaced apart from one another and extending in a generally horizontal direction.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

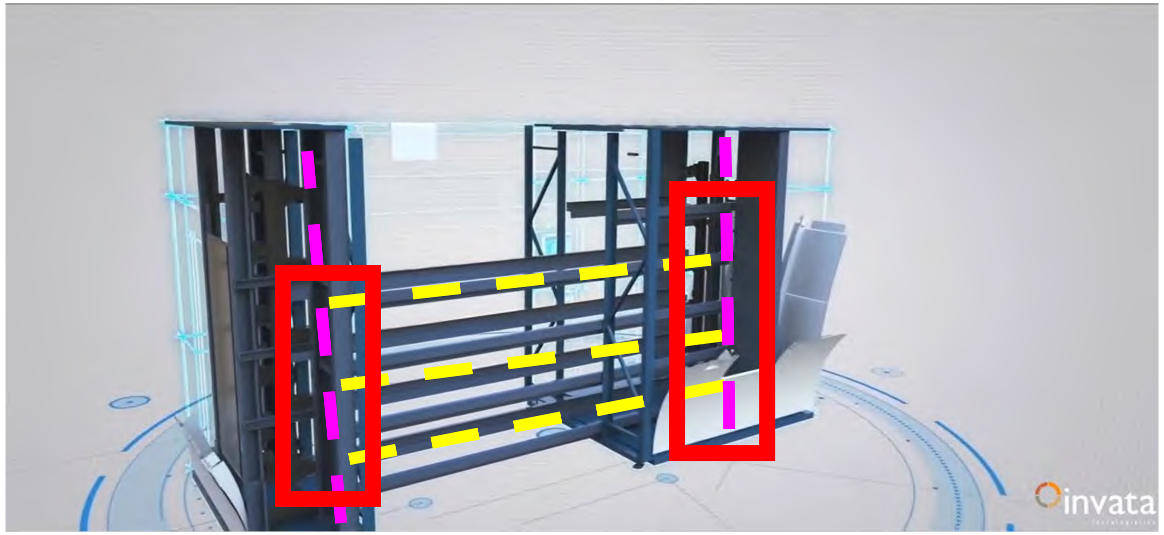
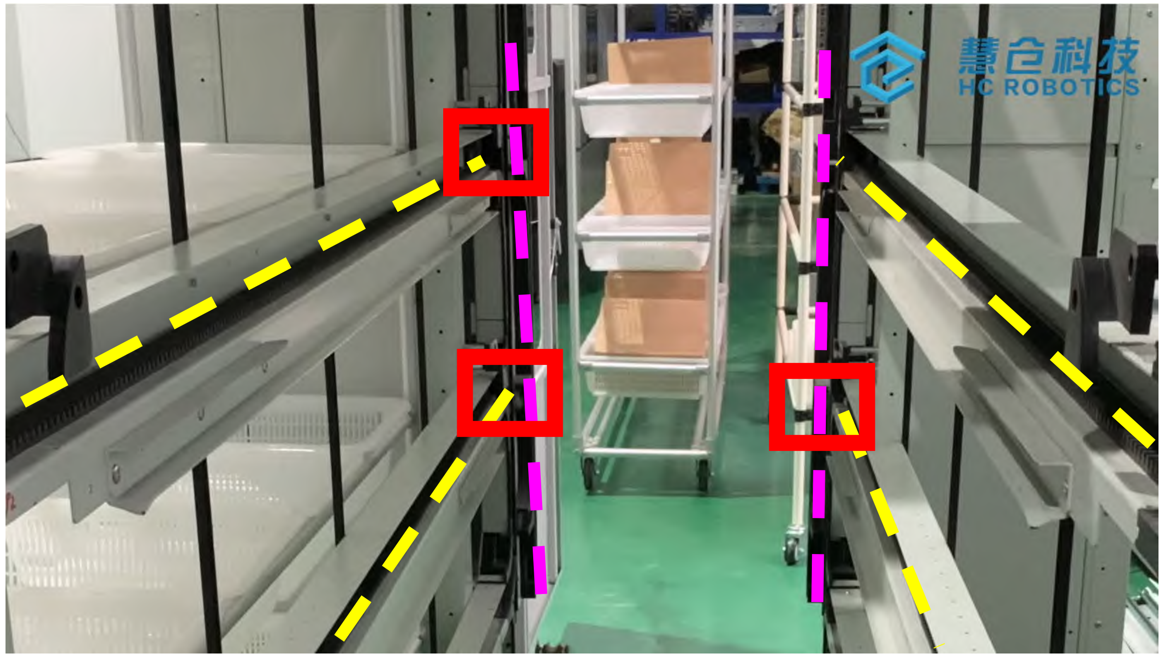
a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the horizontal track sections intersect the vertical track sections; and	The Accused Product comprises a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the horizontal track sections intersect the vertical track sections.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

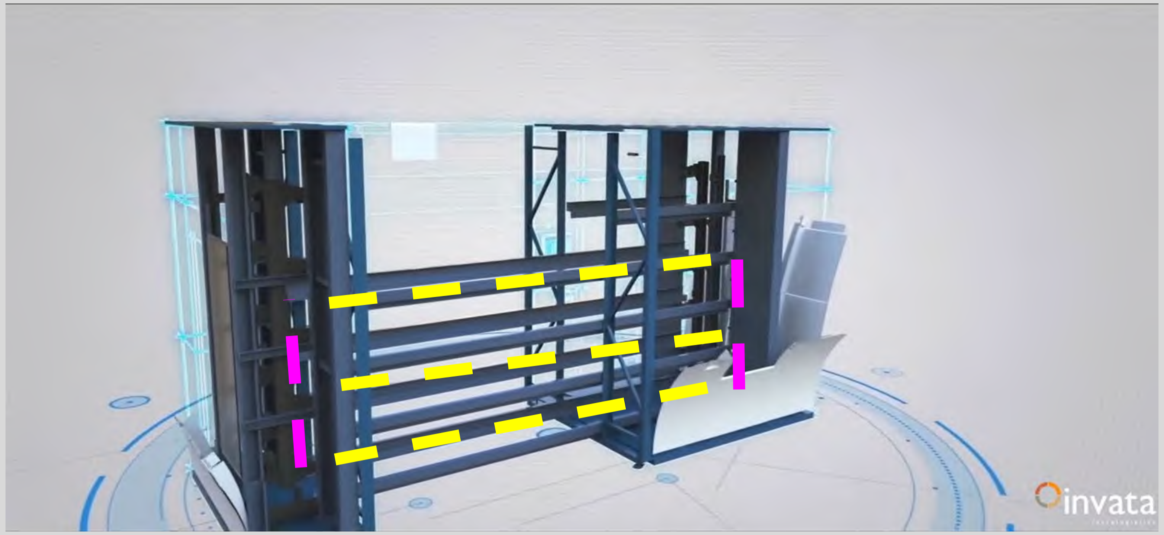
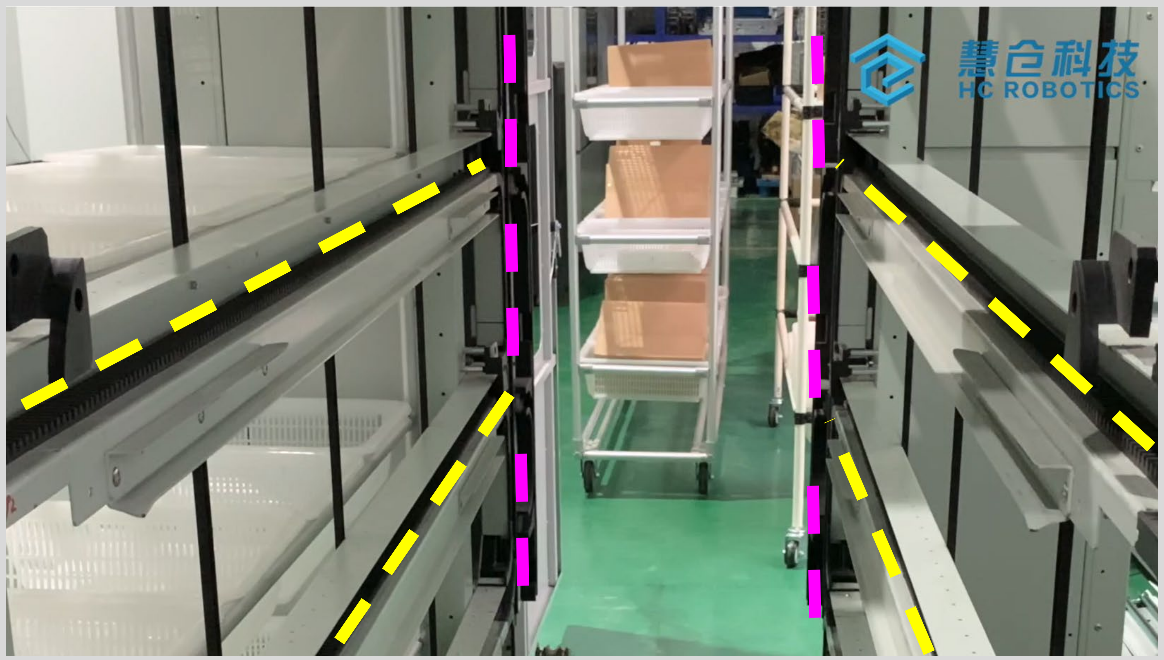
a plurality of intersections where the horizontal track sections intersect the vertical track sections, wherein the intersections provide a first path along the horizontal direction, and a second path along the vertical direction;	The Accused Product comprises a plurality of intersections where the horizontal track sections intersect the vertical track sections, wherein the intersections provide a first path along the horizontal direction, and a second path along the vertical direction.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

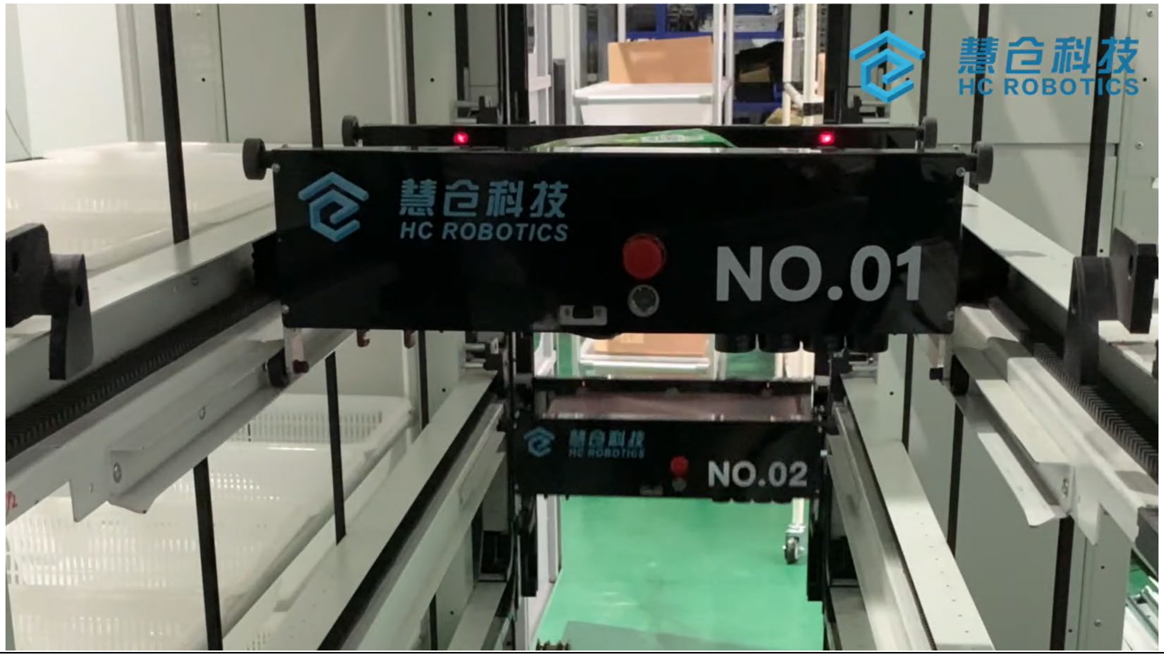
wherein at least one of the vehicles comprises a drive element that interacts with the track system to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between a horizontal track section and a vertical track section.	The Accused Product comprises a plurality of vehicles wherein at least one of the vehicles comprises a drive element that interacts with the track system to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between a horizontal track section and a vertical track section 

Exhibit O: Claim chart comparing U.S. Patent No. 8,276,740 to Respondents' OmniSort Product

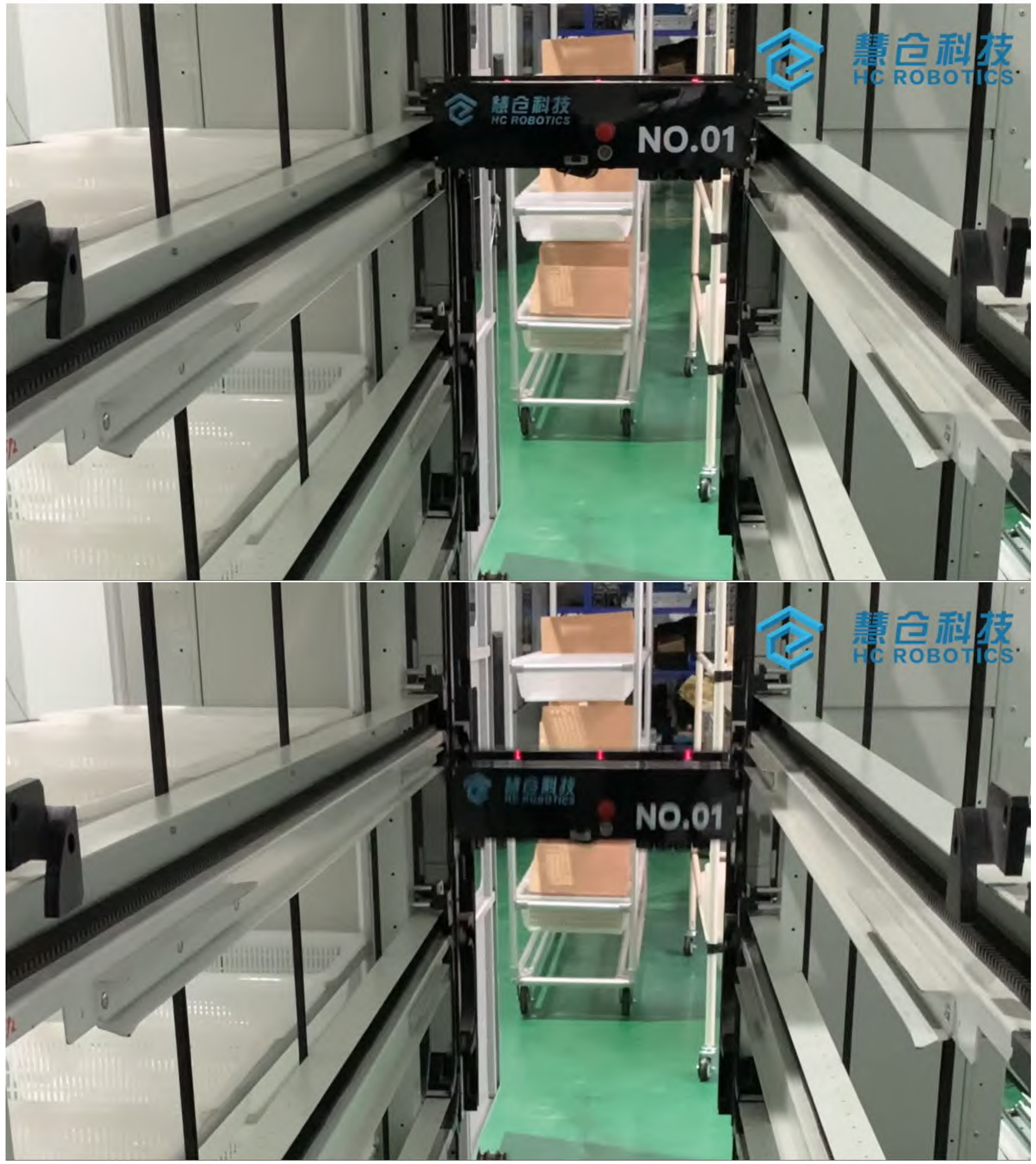
Element	Supporting Documentation
	 *OmniSort English Webpage.*

EXHIBIT P

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

U.S. Patent No. 8,622,194

Claim 1

Element	**Supporting Documentation**
A material handling system for delivering a plurality of items to or from a plurality of destination areas, comprising:	To the extent that the preamble is limiting, the Respondents' OmniSort system (hereinafter the "Accused Product") comprises a material handling system for delivering a plurality of items to or from a plurality of destination areas. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*, INVATA INTRALOGISTICS, https://www.invata.com/automated-put-wall-solutions/?li (last visited Dec. 2, 2021) (Exhibit 16).[1]

[1] The illustrations in this claim chart are exemplary, and not intended to limit the scope or applicability of the claims. To the extent any element is not literally met by the Accused Product, it is met under the doctrine of equivalents, at least because the Accused Product performs the same function in the same way to achieve the same result.

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

Element	Supporting Documentation
	OmniSort The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort*, HC ROBOTICS, http://en.hc-robots.com/omniSort (last visited Dec. 2, 2021) (hereinafter "*OmniSort English Webpage*") (Exhibit 17).

a plurality of delivery vehicles for delivering item to the destination areas,	The Accused Product comprises a plurality of delivery vehicles for delivering item to the destination areas.   *Automated Put Wall Solutions.*[2]

[2] Invata's relevant product page, and both of HC Robotics' relevant pages, consist primarily of embedded videos. OPEX will provide copies of those videos on request.

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

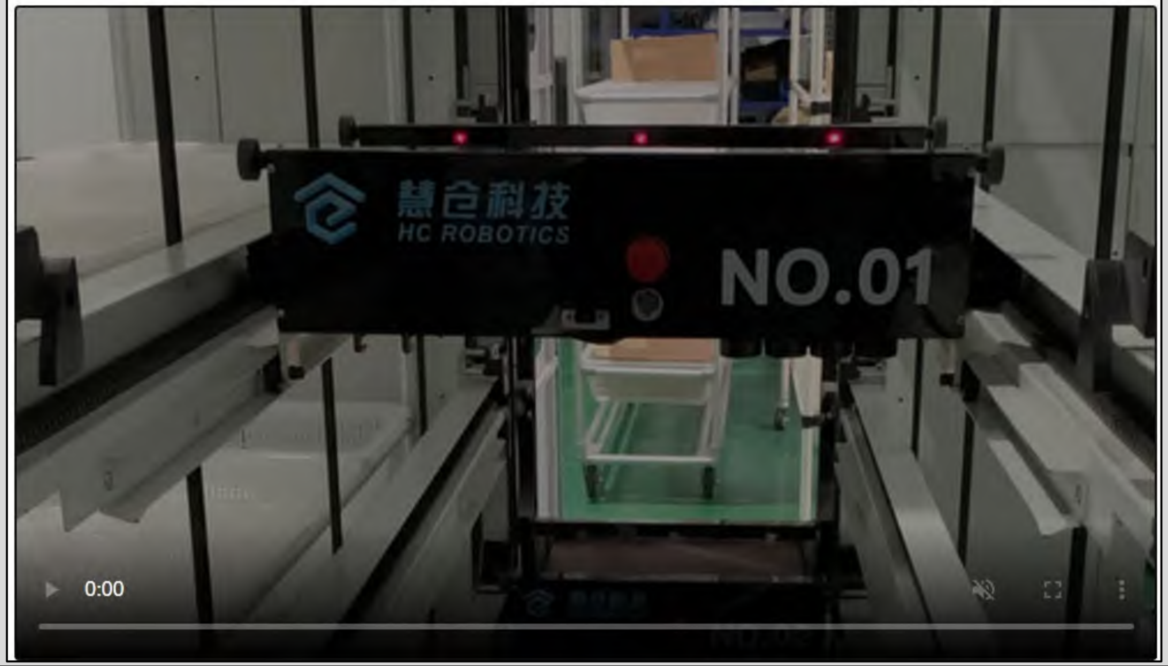
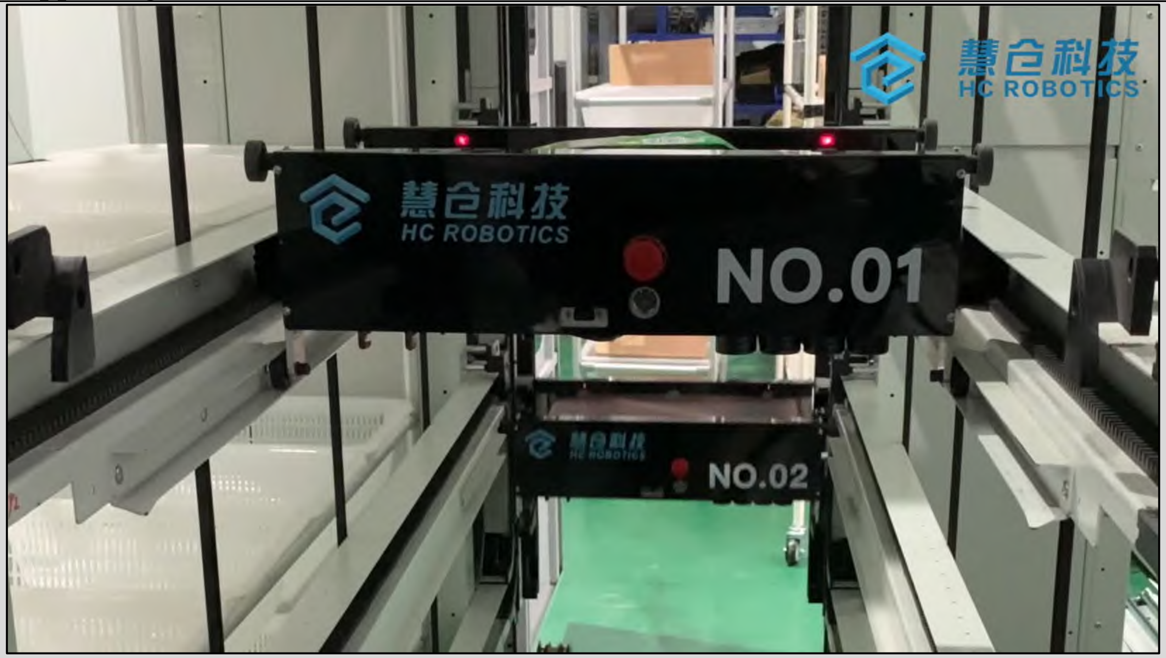
	Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment. 

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

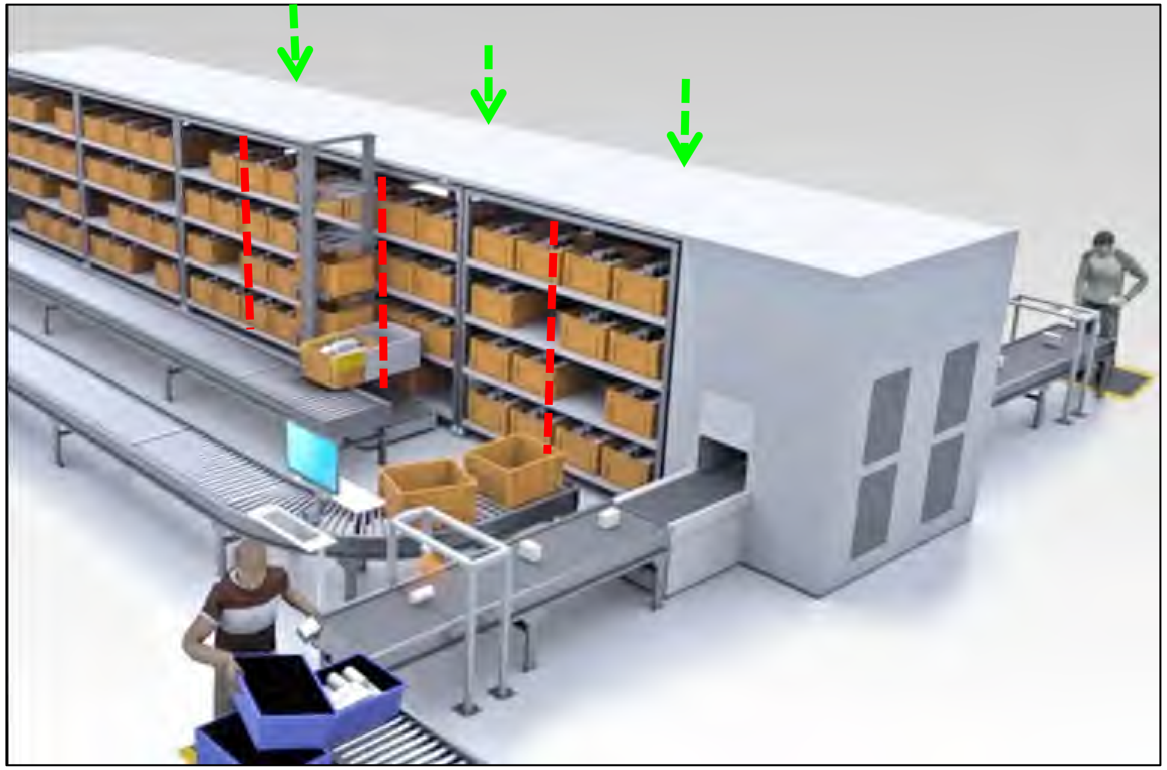
wherein the destination areas are arranged into a first series of columns extending generally vertically and a second series of columns extending generally vertically,	The Accused Product comprises wherein the destinations are arranged into a first series of columns extending generally vertically and a second series of columns extending generally vertically. 

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

	  *Automated Put Wall Solutions.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

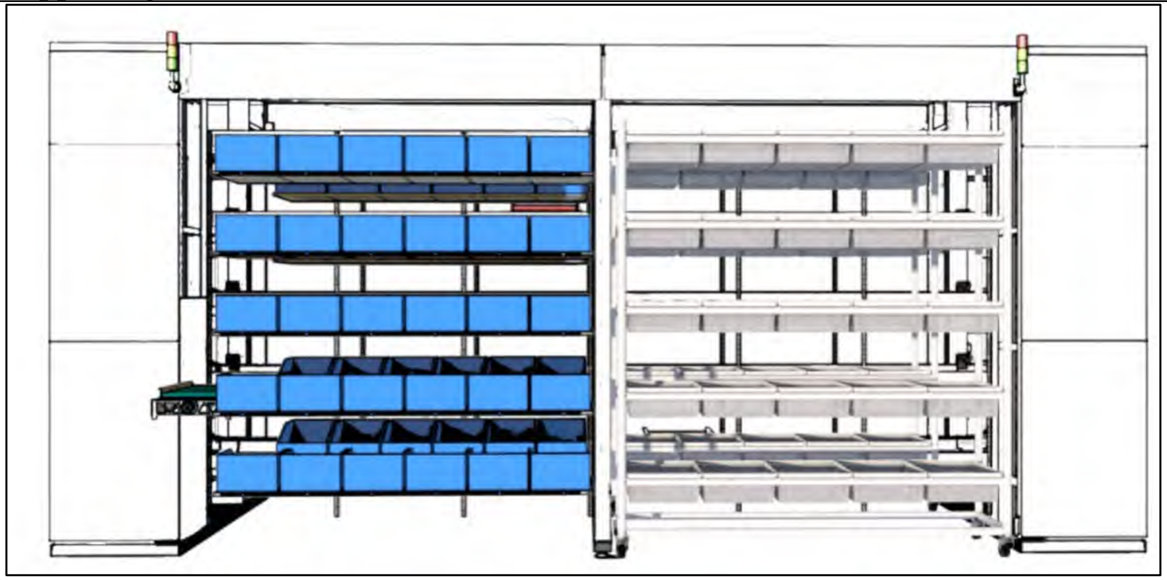
Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

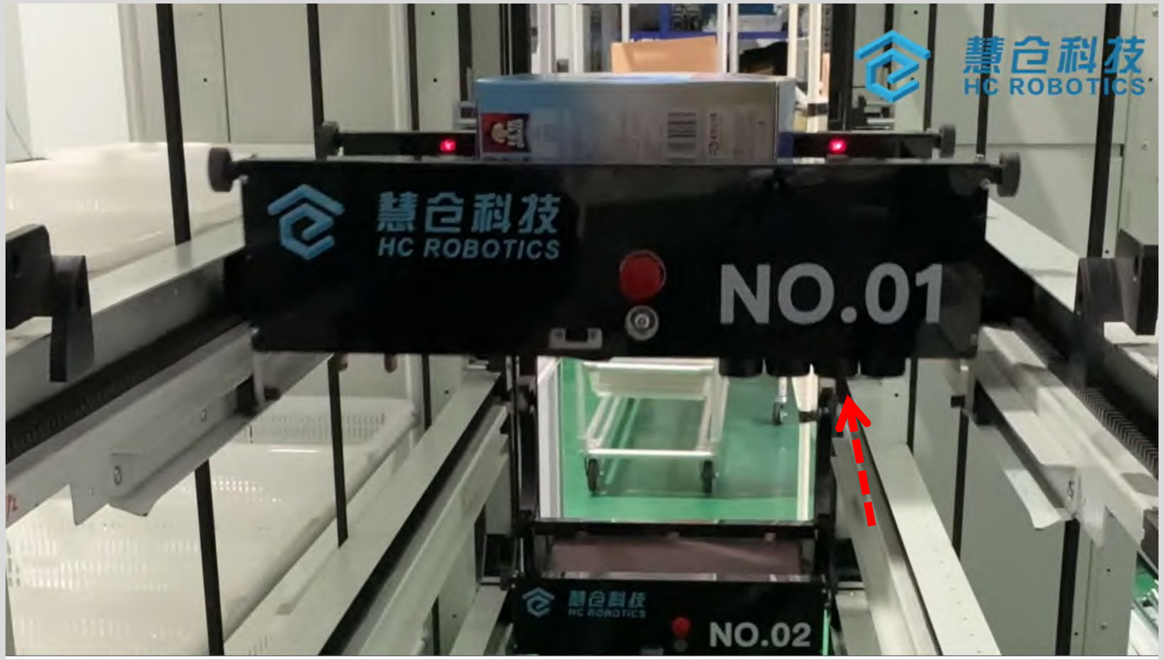
Element	**Supporting Documentation**
wherein each vehicle comprises: a power source for driving the vehicle; and	The Accused Product comprises a plurality of delivery vehicles wherein each vehicle comprises a power source for driving the vehicle.  *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

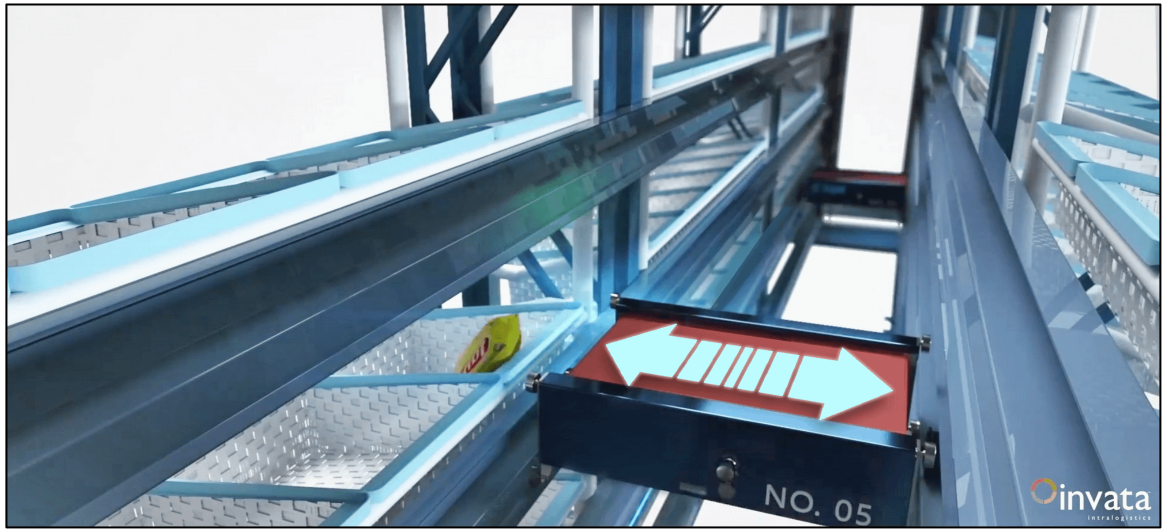
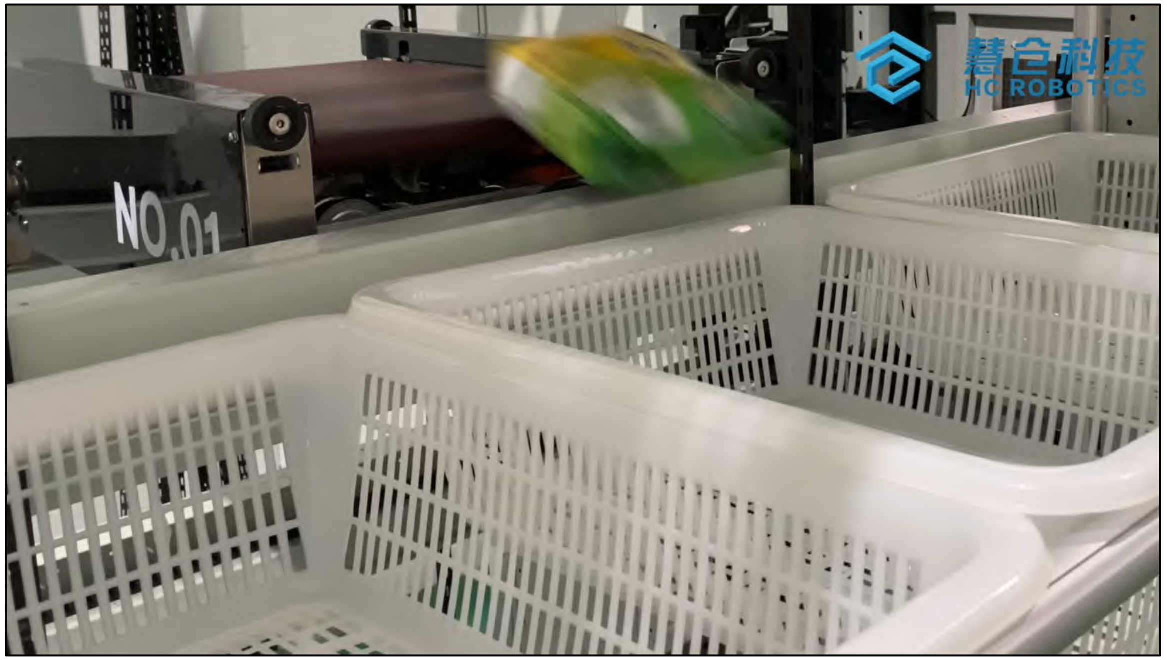
a transfer mechanism for transferring an item forwardly or rearwardly to transfer an item between the delivery vehicle and one of the destination areas;	The Accused Product comprises a plurality of delivery vehicles wherein each vehicle comprises a transfer mechanism for transferring an item forwardly or rearwardly to transfer an item between the delivery vehicle and one of the destination areas.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

a track for guiding the delivery vehicles to the destination areas, wherein the track is positioned between the first series of columns and the second series of columns so that a delivery vehicle can move vertically between the first series of columns and the second series of columns, and	The Accused Product comprises a track for guiding the delivery vehicles to the destination areas, wherein the track is positioned between the first series of columns and the second series of columns so that a delivery vehicle can move vertically between the first series of columns and the second series of columns.  *Automated Put Wall Solutions.* 

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

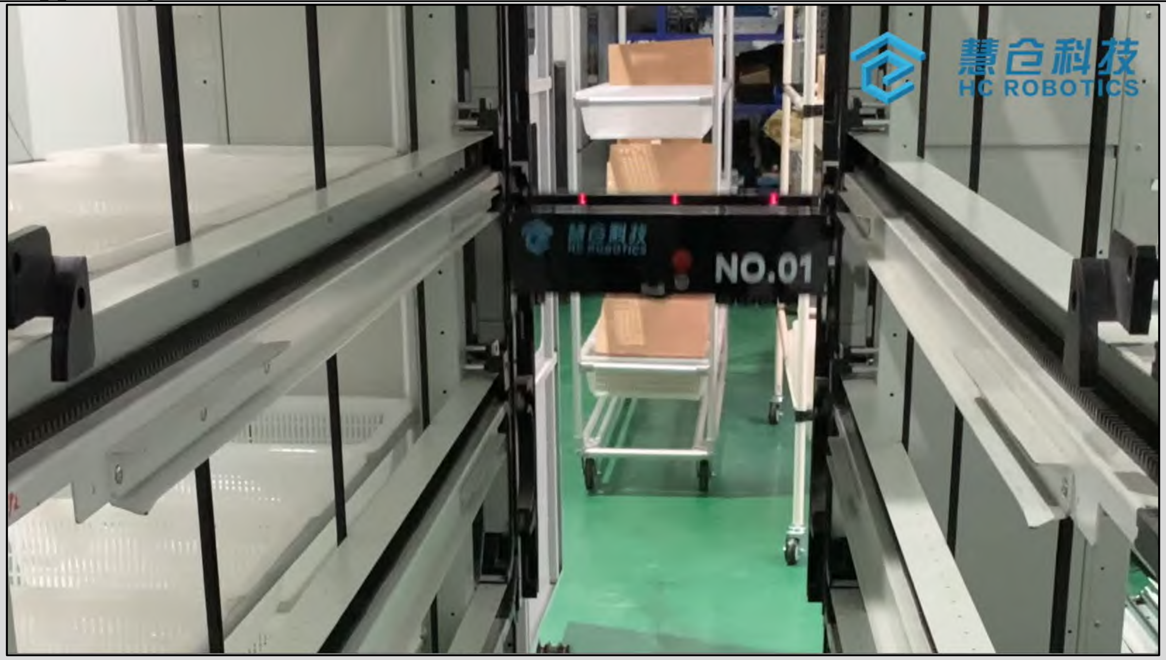
Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

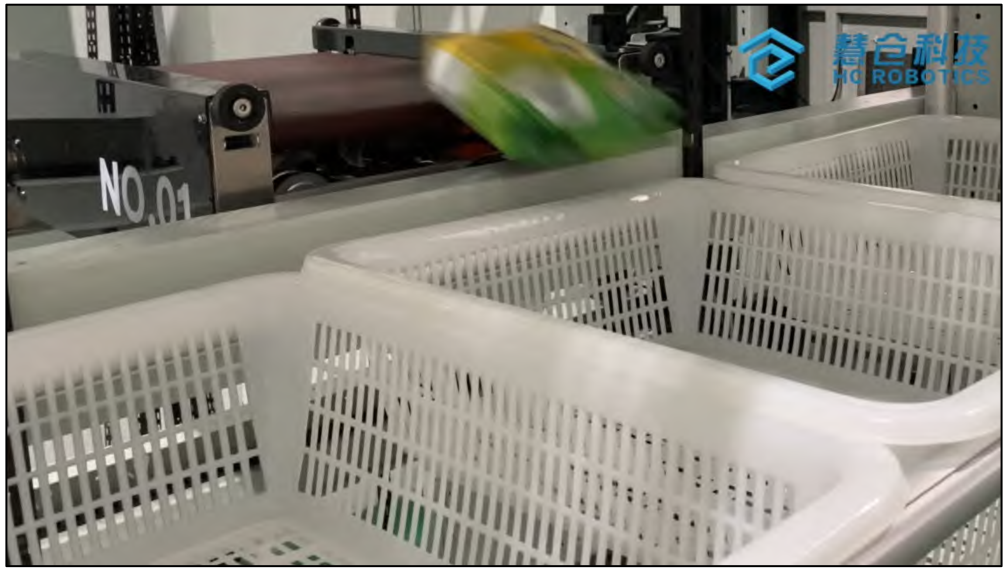
Element	Supporting Documentation
wherein when a delivery vehicle is stopped at a point along the track, the transfer mechanism can transfer an item forwardly between the vehicle and a destination area in the first series of columns and the transfer mechanism can transfer an item rearwardly between the vehicle and a destination in the second series of columns;	The Accused Product comprises a plurality of delivery vehicles, wherein when a delivery vehicle is stopped at a point along the track, a transfer mechanism that can transfer an item forwardly between the vehicle and a destination area in the first series of columns and the transfer mechanism can transfer an item rearwardly between the vehicle and a destination in the second series of columns.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

a destination module operable to identify the destination area to which one item is to be delivered to or retrieved by one of the delivery vehicles, wherein the destination module identifies the destination area based on a marking on the item; and	The Accused Product comprises a destination module operable to identify the destination area to which one item is to be delivered to or retrieved by one of the delivery vehicles, wherein the destination module identifies the destination area based on a marking on the item.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

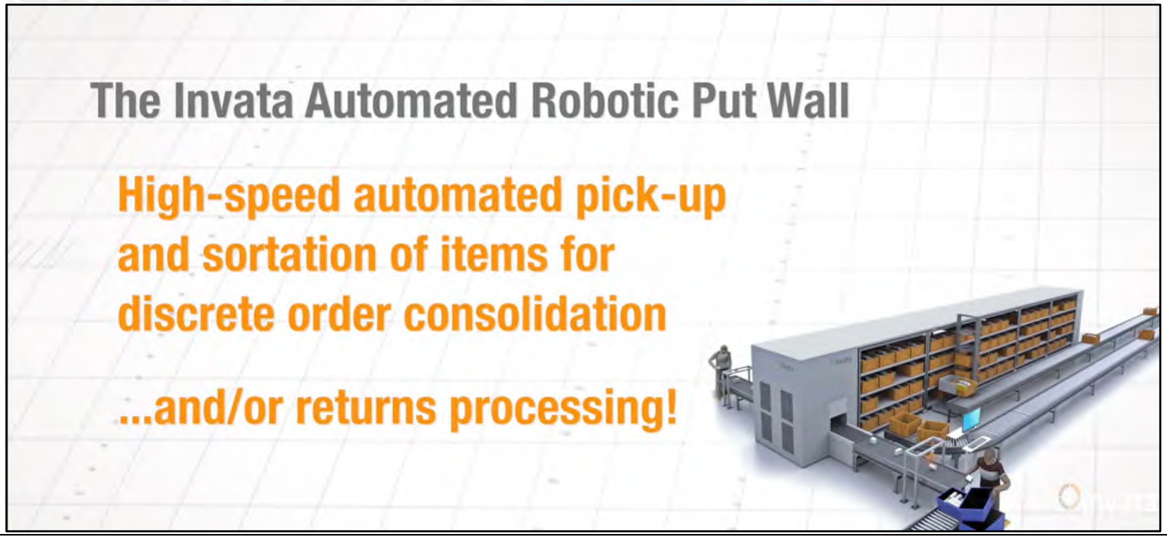
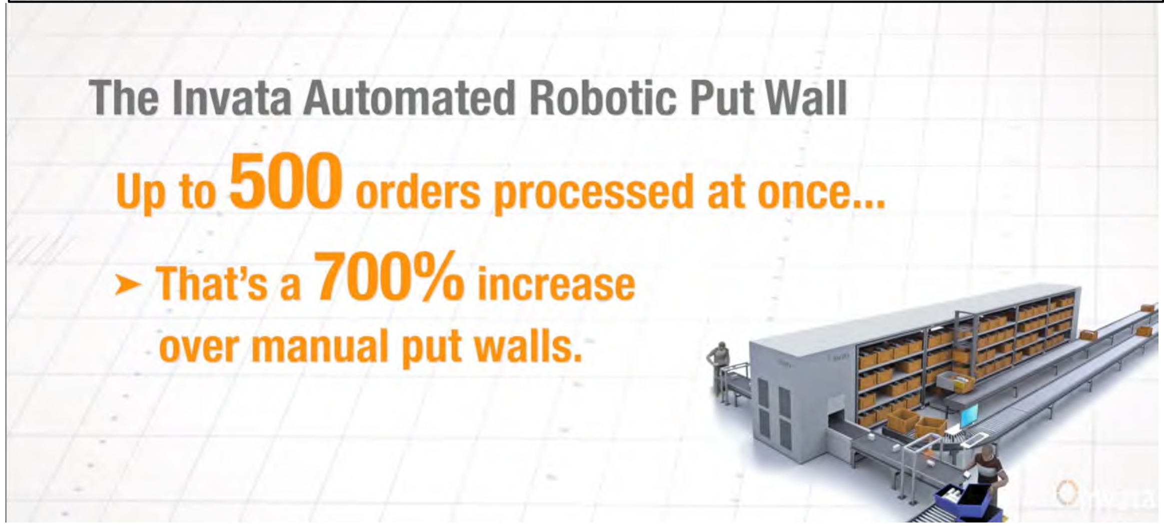
a controller for controlling the operation of the one vehicle as the vehicle delivers the item to the identified destination area.	The Accused Product comprises a controller for controlling the operation of the one vehicle as the vehicle delivers the item to the identified destination area. **Fill a Lot More Orders — a Whole Lot Faster!** The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. The impressive efficiencies of the automated put wall translate to put rates of 1800 - 2200 units per hour (human v. robotic induction) and processing capabilities for up to 500 orders at once. 

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

Element	Supporting Documentation
	  *Automated Put Wall Solutions.*

Claim 7

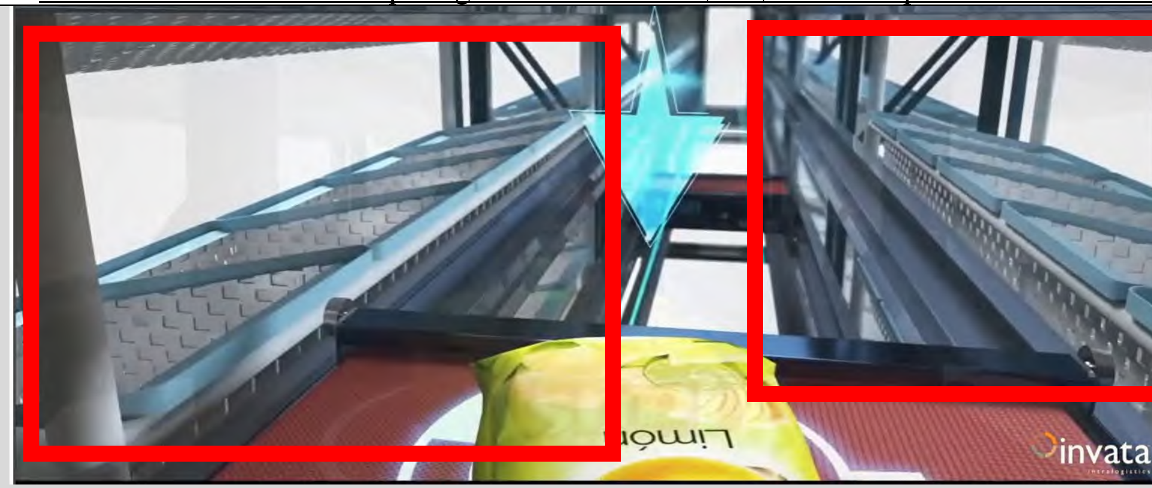
Element	Supporting Documentation
A material handling system for delivering a plurality of items to or from a plurality of destination areas, wherein the system comprises:	To the extent that the preamble is limiting, the Accused Product comprises a material handling system for delivering a plurality of items to or from a plurality of destination areas. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*. OmniSort The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort*.

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

a plurality of destination areas for receiving the items;	The Accused Product comprises a plurality of destination areas for receiving the items. 

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product



Automated Put Wall Solutions.

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

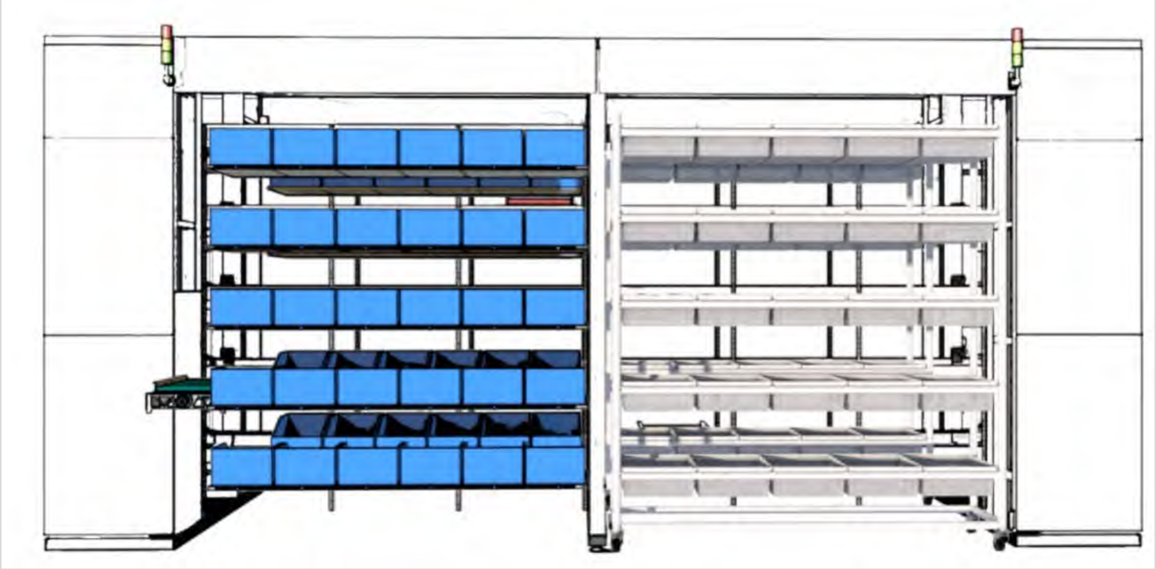
Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

a plurality of delivery vehicles for delivering the items, wherein each vehicle comprises an on-board motor for driving the vehicle and a rechargeable power source for powering the motor; and	The Accused Product comprises a plurality of delivery vehicles for delivering the items, wherein each vehicle comprises an on-board motor for driving the vehicle and a rechargeable power source for powering the motor.   *Automated Put Wall Solutions.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

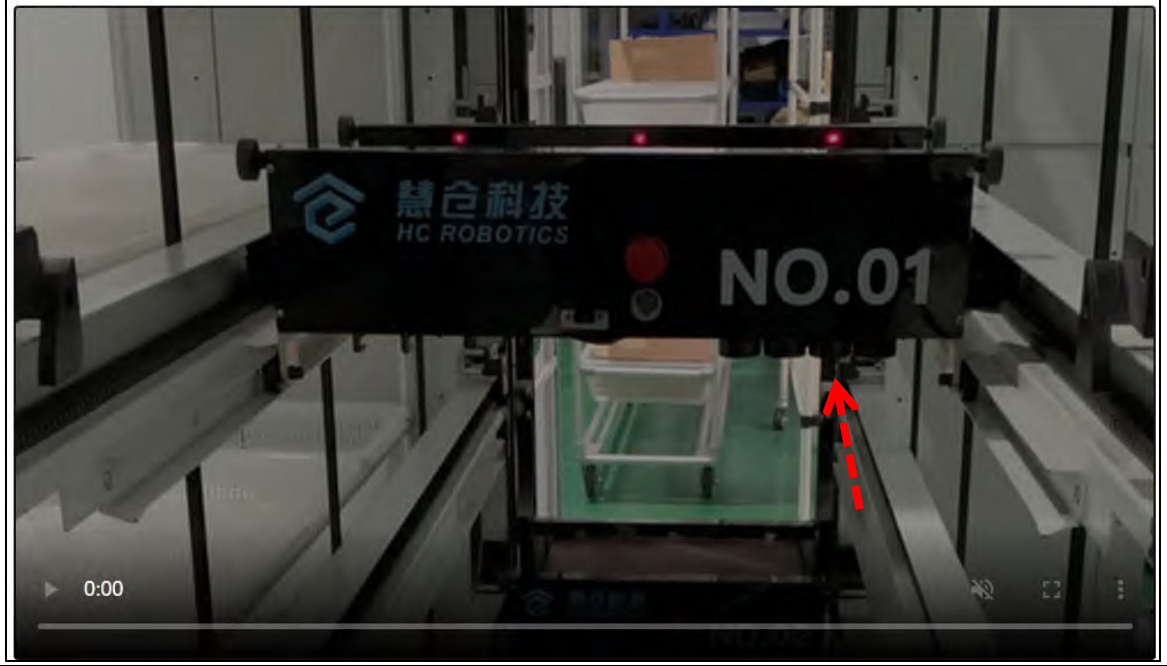
	Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment. 

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

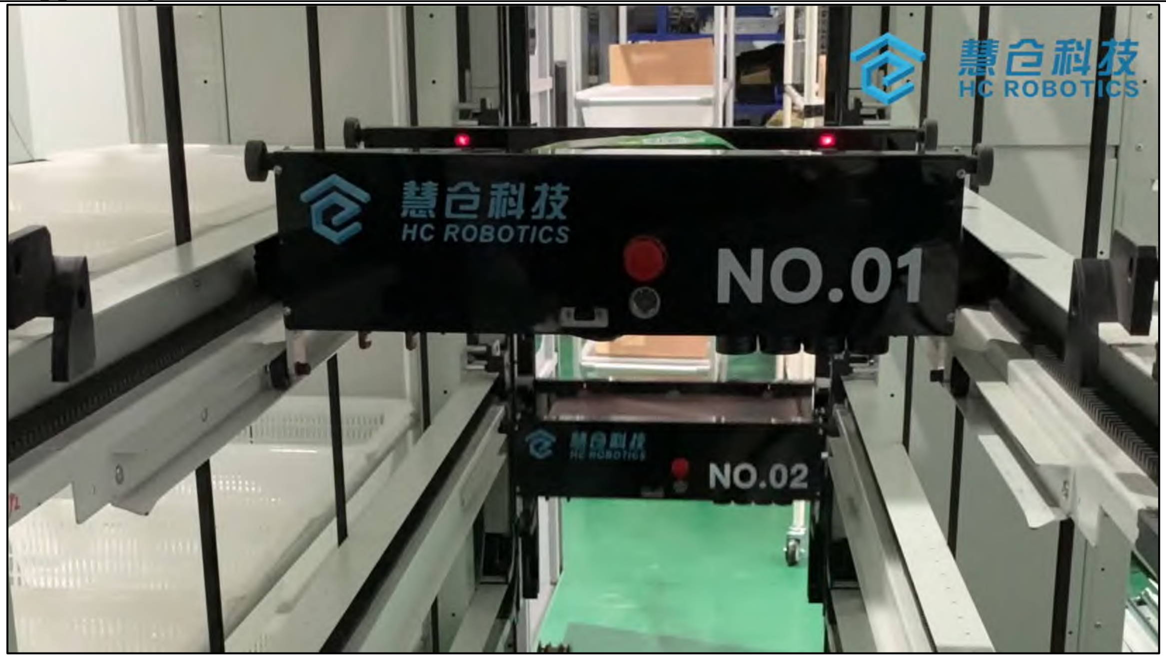
Element	Supporting Documentation
	
	Number of Robots 10 - 20
	OmniSort English Webpage.

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

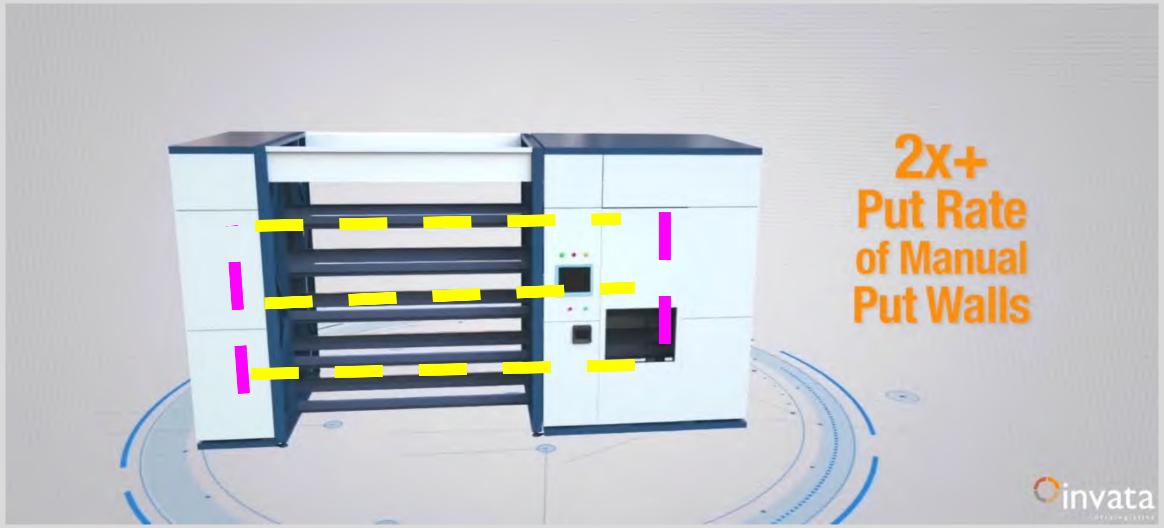
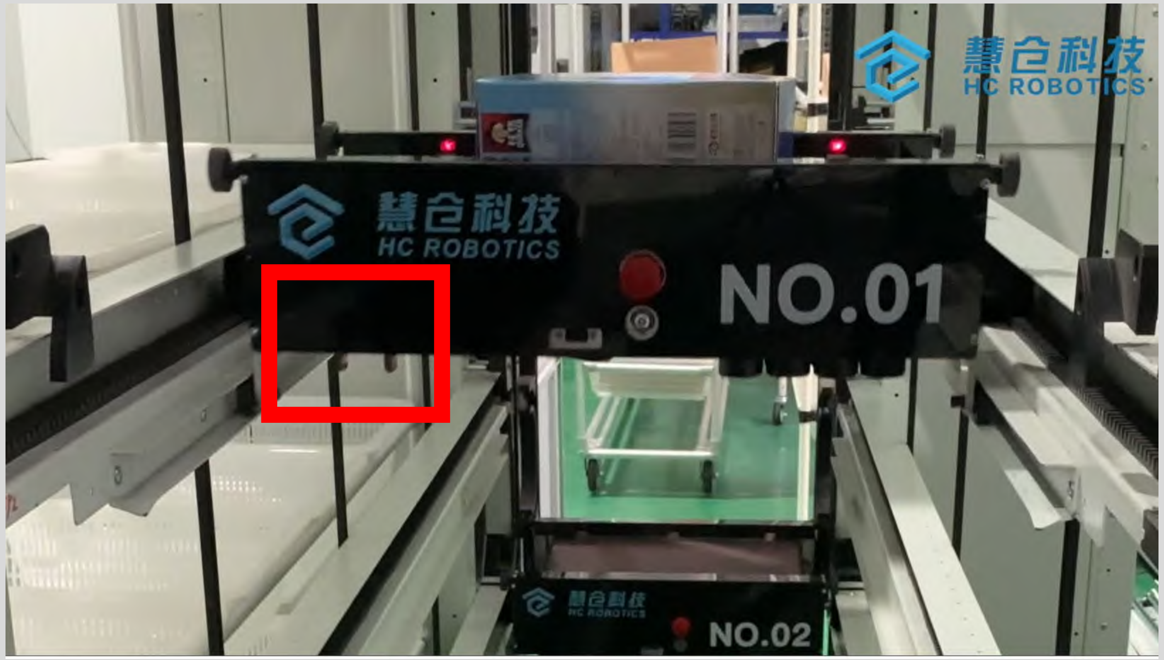
track for guiding the delivery vehicles, wherein the track comprises a substantially vertical portion and a horizontal portion providing a continuous path from horizontal to vertical direction,	The Accused Product comprises track for guiding the delivery vehicles, wherein the track comprises a substantially vertical portion and a horizontal portion providing a continuous path from horizontal to vertical direction.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

Element	**Supporting Documentation**
wherein the track comprises a charging strip along a track section and the charging strip terminates along the track section,	The Accused Product comprises track for guiding the delivery vehicles wherein the track comprises a charging strip along a track section and the charging strip terminates along the track section.  *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

Element	**Supporting Documentation**
wherein the charging strip is operable to recharge the rechargeable power source as the vehicle travels along the charging strip.	The Accused Product comprises track for guiding the delivery vehicles wherein the charging strip is operable to recharge the rechargeable power source as the vehicle travels along the charging strip.  *OmniSort English Webpage.*

Claim 10

<table>
<tr><th>Element</th><th>Supporting Documentation</th></tr>
<tr><td>A delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system, wherein the delivery vehicle comprises:</td><td>To the extent that the preamble is limiting, the Accused Product comprises a delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system.

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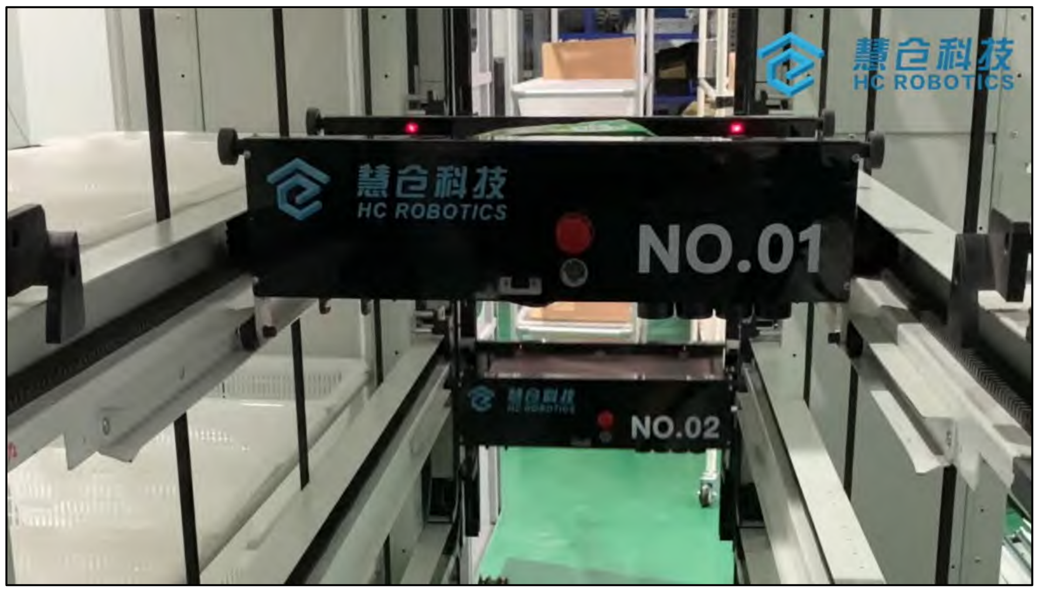


OmniSort English Webpage.</td></tr>
</table>

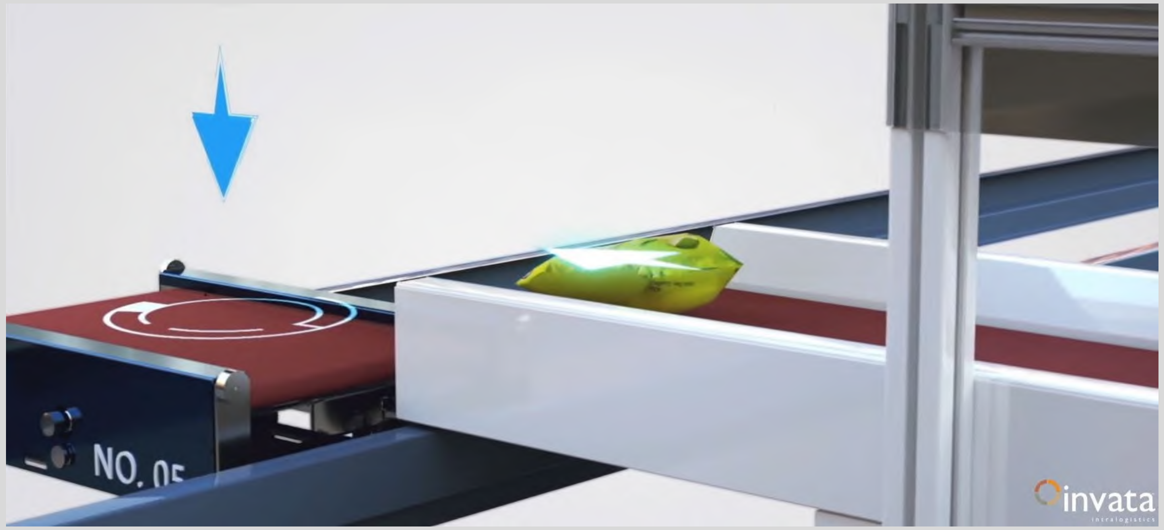
a platform for receiving an item to be conveyed to one of the destination areas;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a platform for receiving an item to be conveyed to one of the destination areas.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

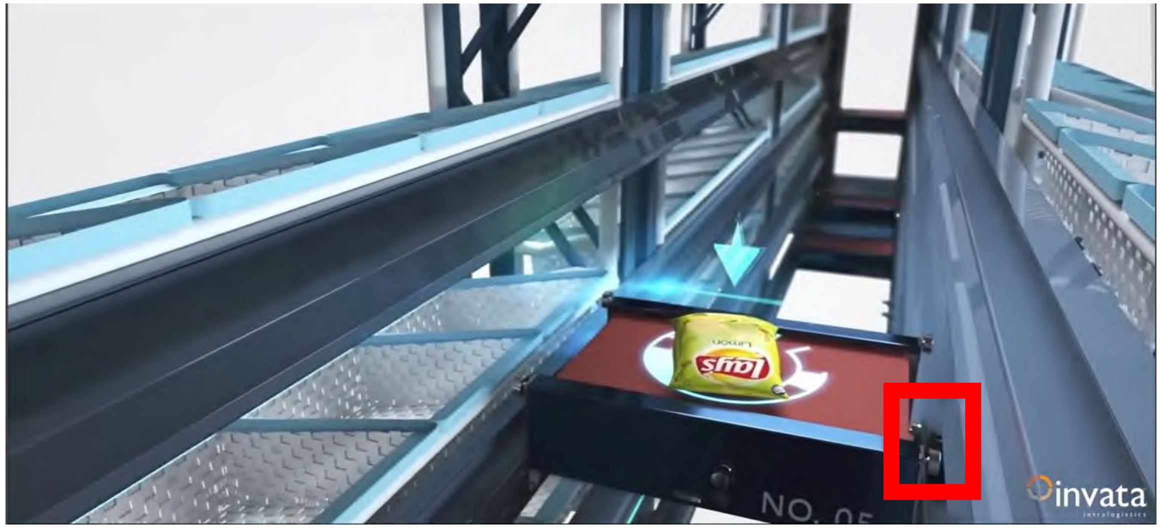
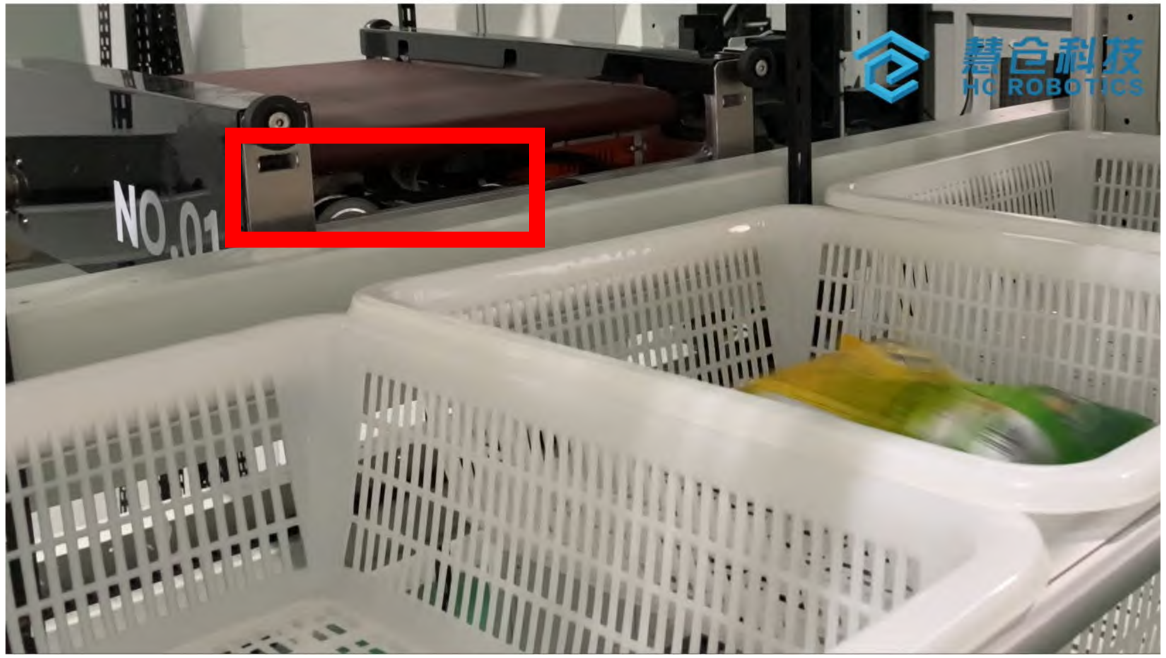
a motor for driving the vehicle to one of the destination areas;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a motor for driving the vehicle to one of the destination areas.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

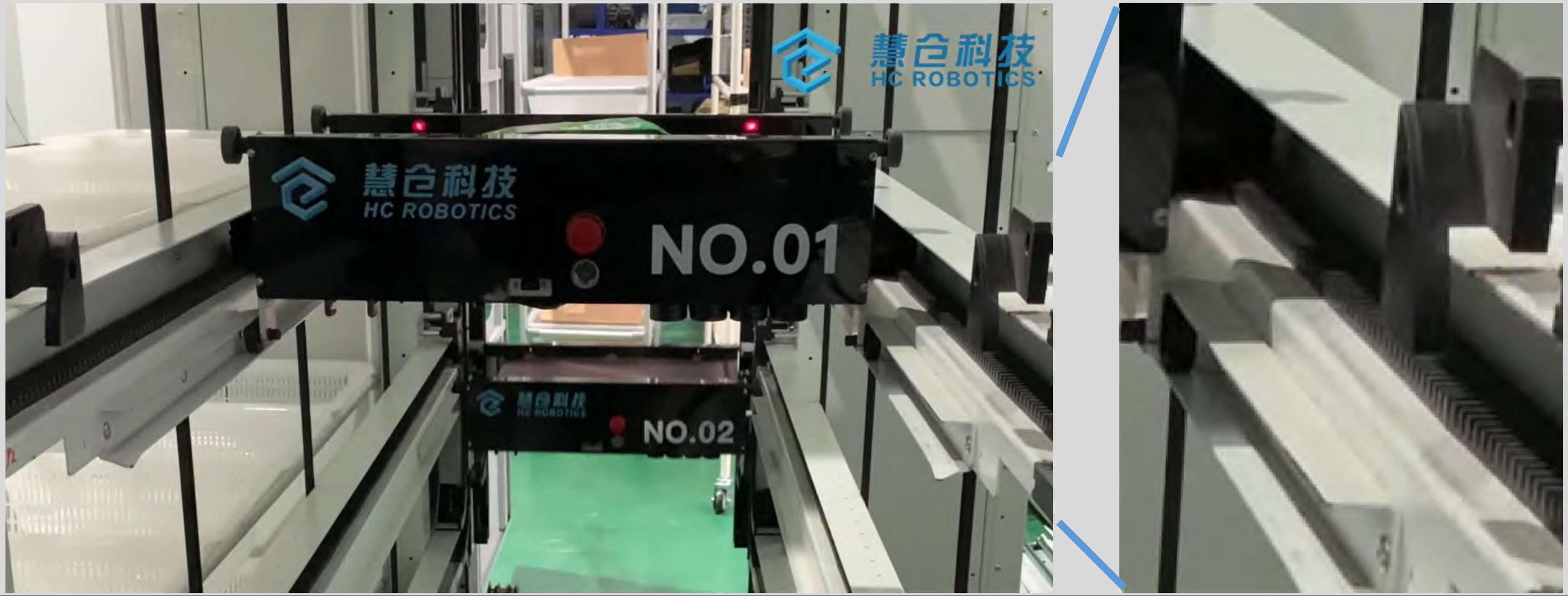
a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel, wherein the drive system comprises a plurality of driven gears that interact with the guide system to control the position of the vehicle along the guide system.	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel, wherein the drive system comprises a plurality of driven gears that interact with the guide system to control the position of the vehicle along the guide system. 

Exhibit P: Claim chart comparing U.S. Patent No. 8,622,194 to Respondents' OmniSort Product

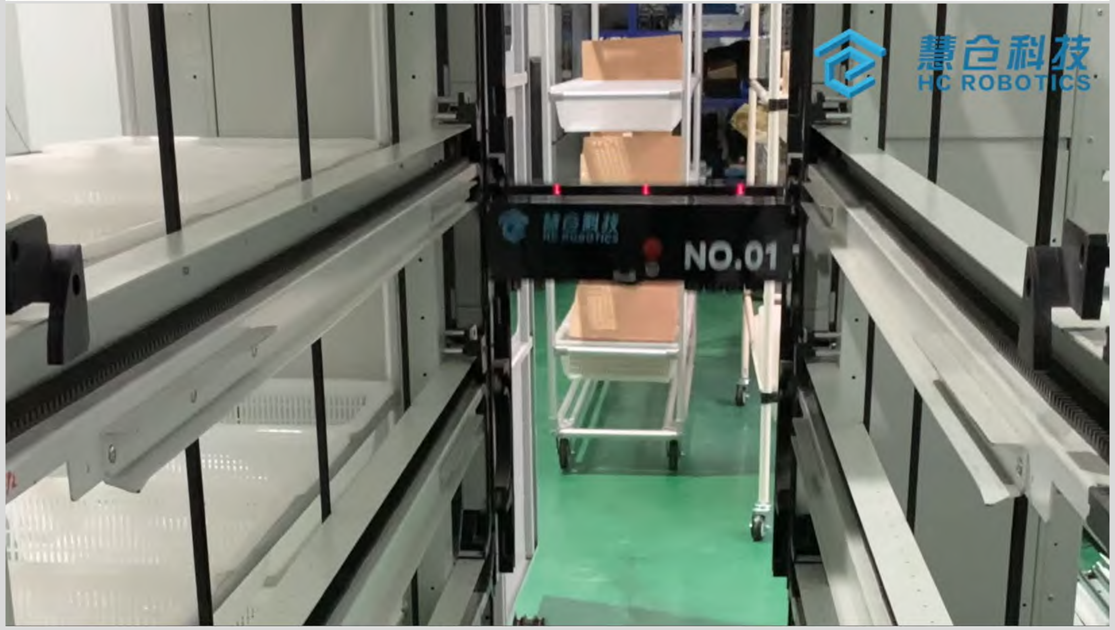
Element	**Supporting Documentation**
	  *OmniSort English Webpage.*

EXHIBIT Q

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

U.S. Patent No. 9,687,883

Claim 1

Element	Supporting Documentation
A material handling system for sorting or retrieving a plurality of items, comprising:	To the extent that the preamble is limiting, the Respondents' OmniSort system (hereinafter the "Accused Product") comprises a material handling system for sorting or retrieving a plurality of items. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2+x) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. *Automated Put Wall Solutions*, Invata Intralogistics, https://www.invata.com/automated-put-wall-solutions/?li (last visited Dec. 2, 2021) (Exhibit J).[1]

[1] The illustrations in this claim chart are exemplary, and not intended to limit the scope or applicability of the claims. To the extent any element is not literally met by the Accused Product, it is met under the doctrine of equivalents, at least because the Accused Product performs the same function in the same way to achieve the same result.

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

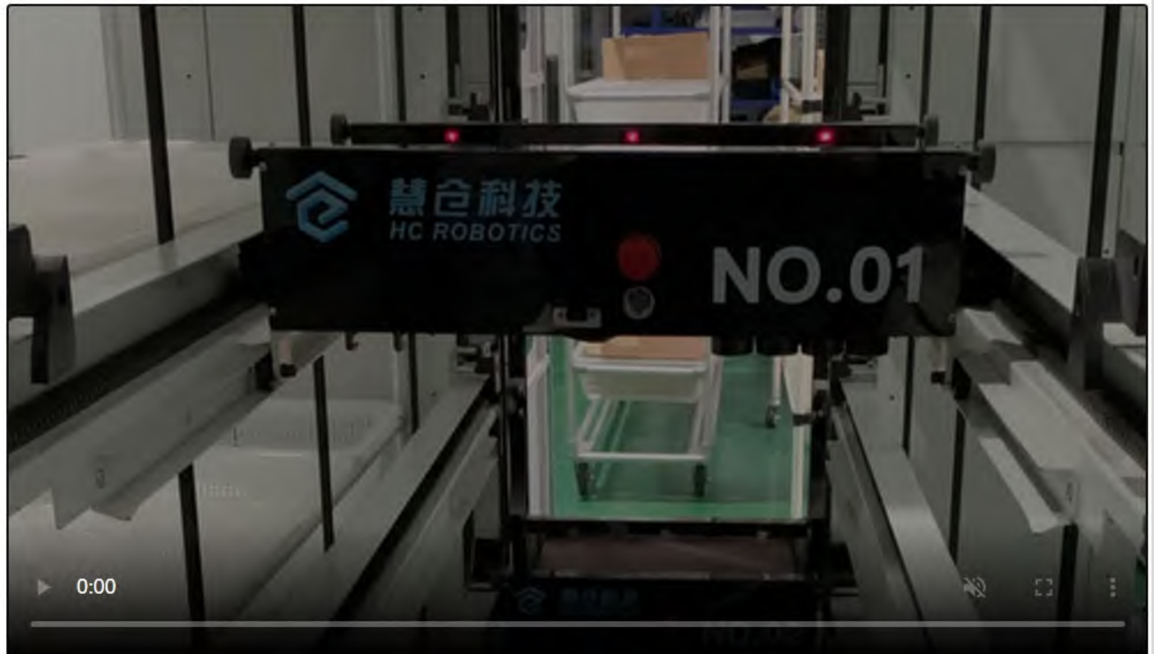
Element	Supporting Documentation
	OmniSort The OmniSort is a high-performance, modular and flexible automated sorting system. It can handle complex order scenarios and accurately deliver items to their designated locations at high speed. OmniSort supprts a variety of sorting modules, including batch sorting and individual sorting. It is many times faster than manual sorting. *OmniSort*, HC Robotics, http://en.hc-robots.com/omniSort (last visited Dec. 2, 2021) (hereinafter "*OmniSort English Webpage*") (Exhibit H).

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

a plurality of vehicles for delivering and retrieving items, wherein each vehicle delivers an item to a destination and;	The Accused Product comprises a plurality of vehicles for delivering and retrieving items, wherein each vehicle delivers an item to a destination.  

	 *Automated Put Wall Solutions.*[2] Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment.

[2] Invata's relevant product page, and both of HC Robotics' relevant pages, consist primarily of embedded videos. OPEX will provide copies of those videos on request.


慧仓科技
HC ROBOTICS
NO.01
0:00

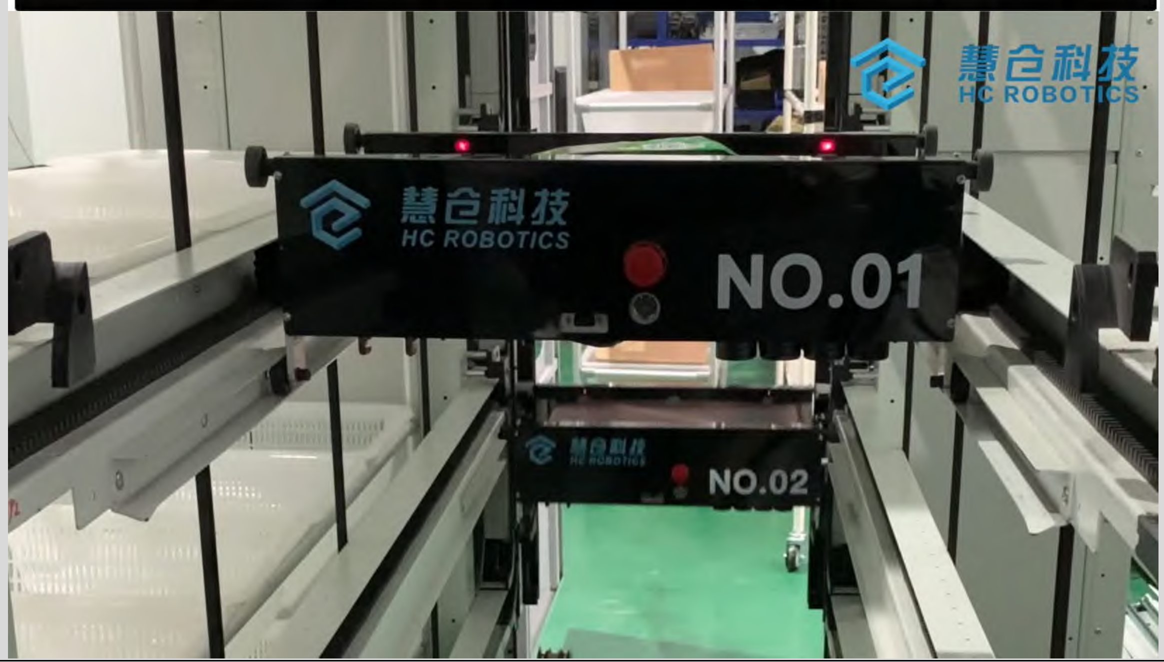

慧仓科技
HC ROBOTICS
慧仓科技
HC ROBOTICS
NO.01
NO.02

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

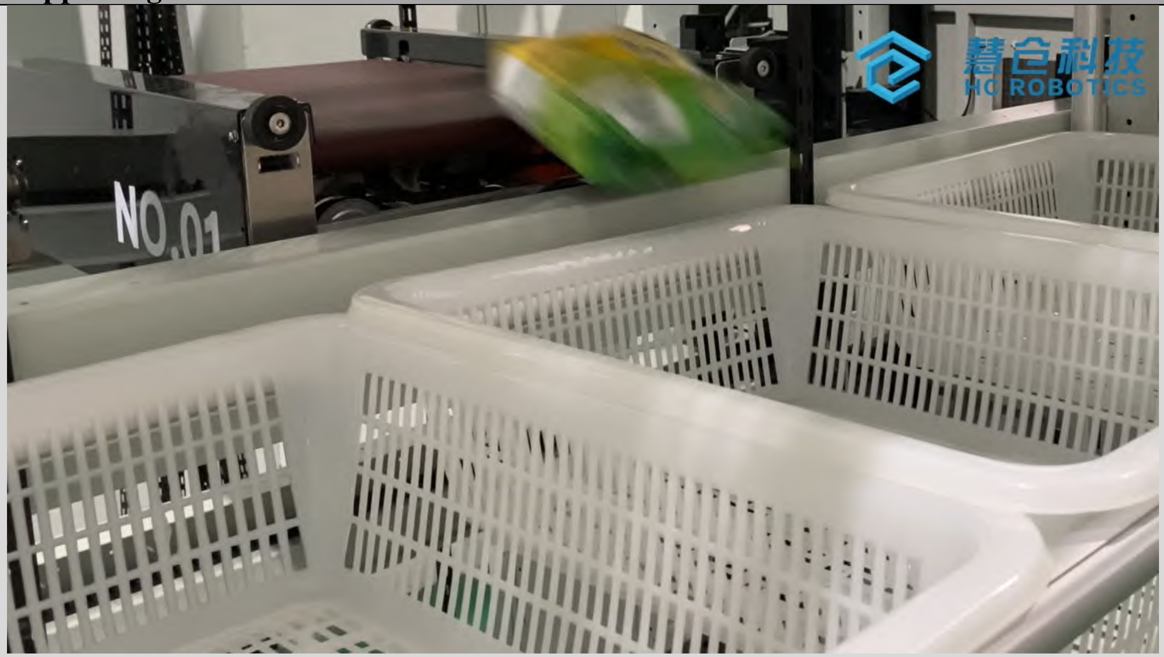
Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

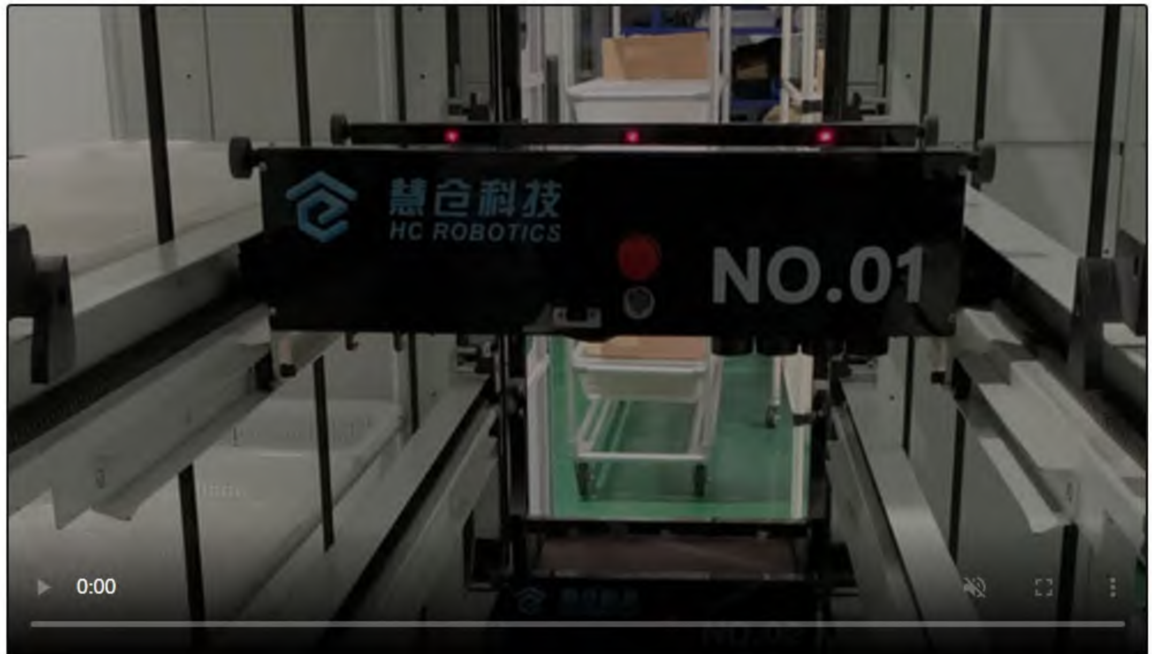
wherein each vehicle comprises an on-board motor for driving the vehicle	The Accused Product comprises a plurality of vehicles for delivering and retrieving items, wherein each vehicle comprises an on-board motor for driving the vehicle.  

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

Automated Put Wall Solutions.

Within OmniSort, a fleet of autonomous high speed robots are responsible for the delivery of items. It is highly scalable and configurable in size and thought. Multiple OmniSort can be easily integrated to meet demand of growing performance. Hence, OmniSort is ideal for both small and large warehouse for order fulfilment.

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product



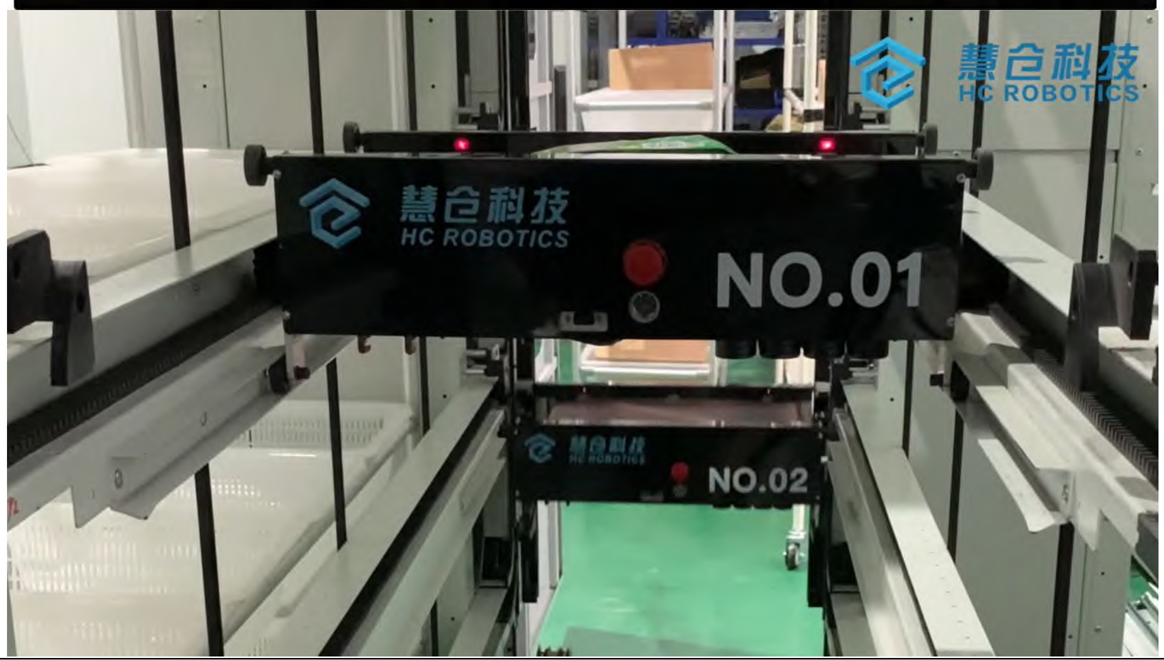
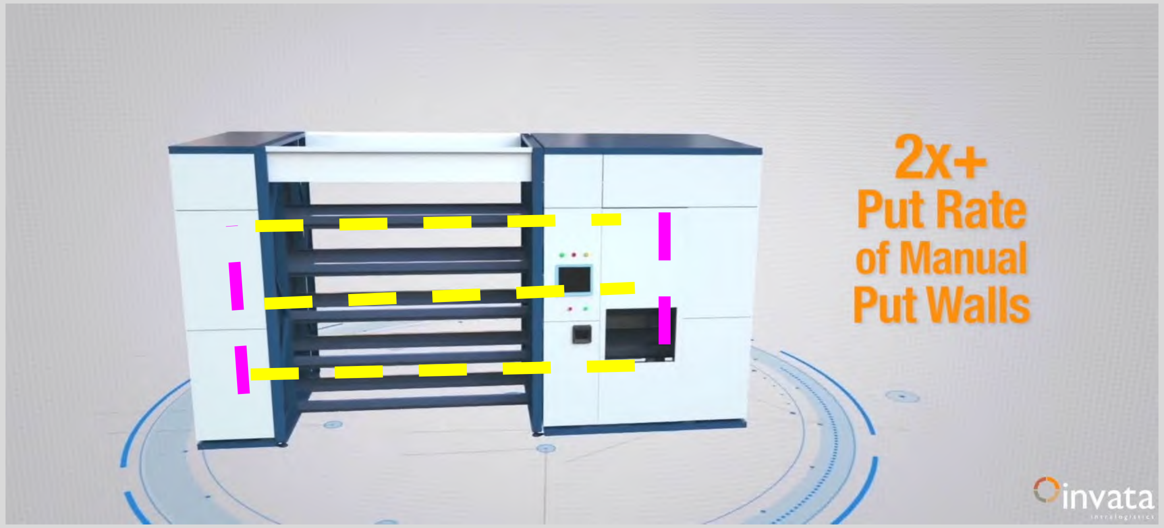


Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

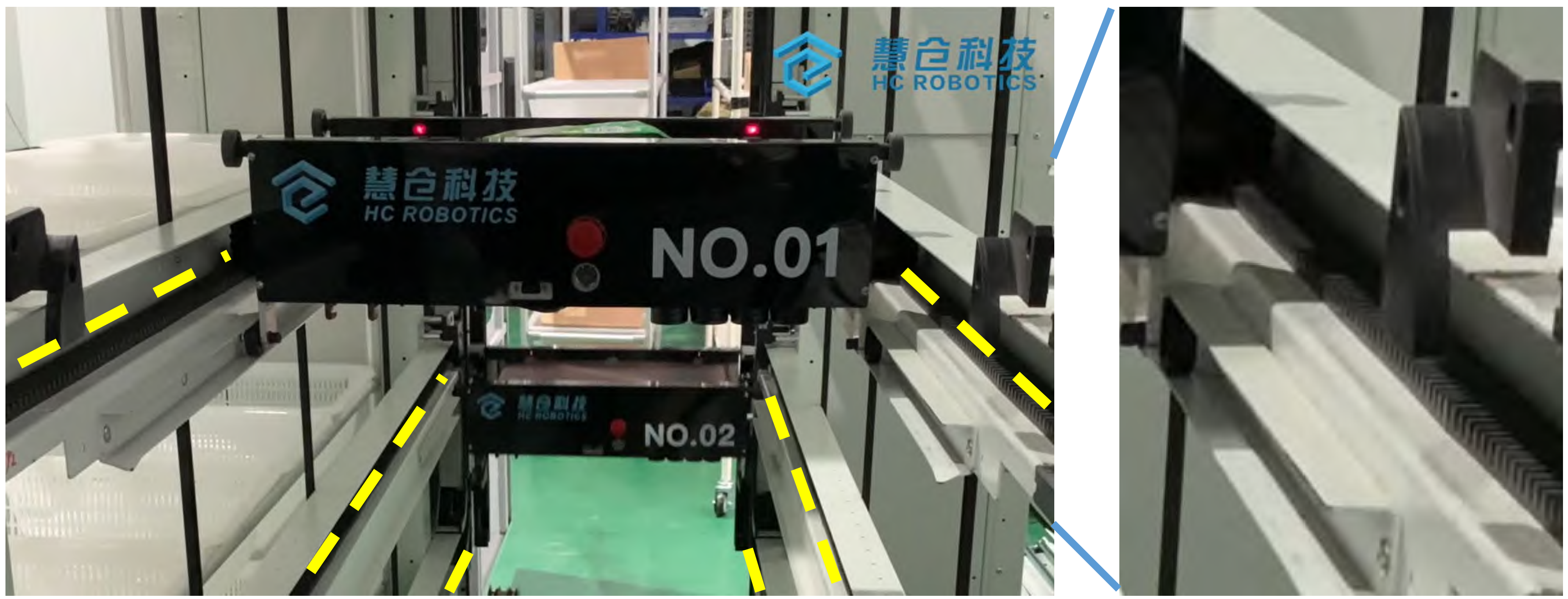
Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

a track for guiding the vehicles,	The Accused Product comprises a track for guiding the vehicles.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

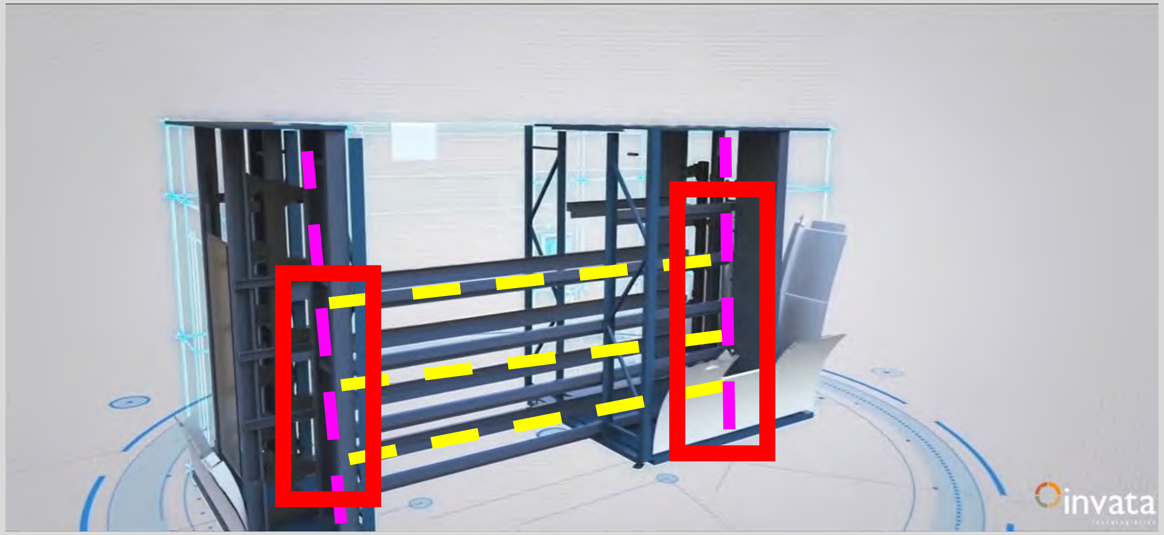
<table>
<tr>
<td>wherein the track comprises:

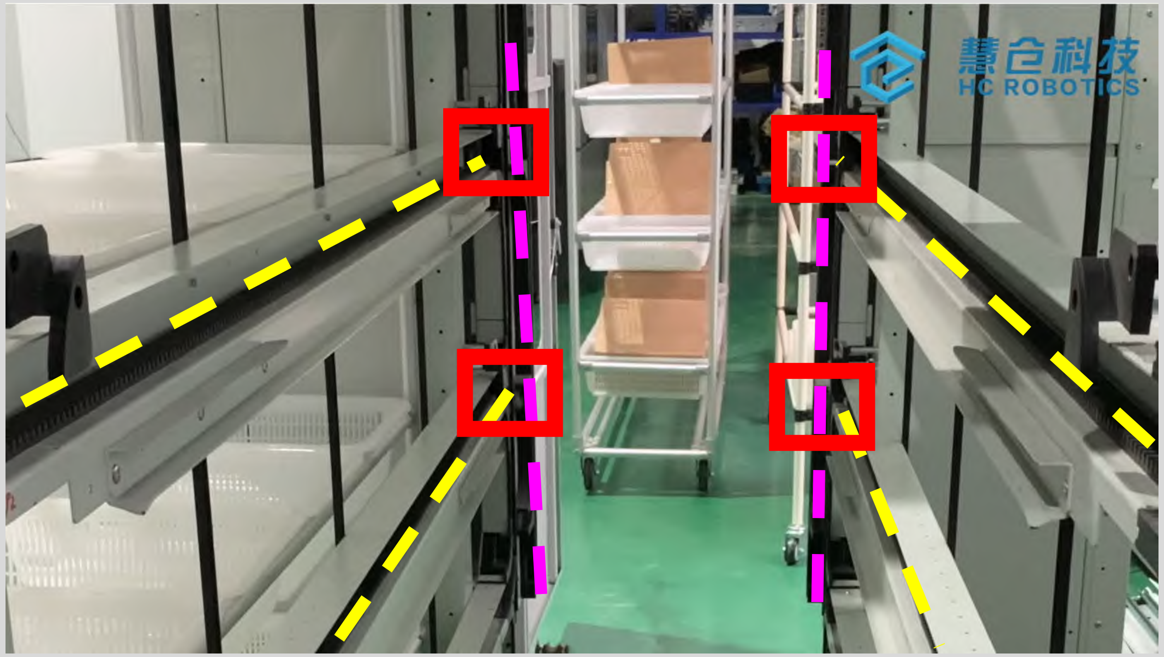
a plurality of horizontal track sections vertically spaced apart from one another and extending in a generally horizontal direction;</td>
<td>The Accused Product comprises a track for guiding the vehicles, wherein the track comprises a plurality of horizontal track sections vertically spaced apart from one another and extending in a generally horizontal direction.


Automated Put Wall Solutions.


OmniSort English Webpage.</td>
</tr>
</table>

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

<table>
<tr>
<td>a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the vertical track sections intersect the horizontal track sections to form a loop; and</td>
<td>The Accused Product comprises a track for guiding the vehicles, wherein the track comprises a plurality of vertical track sections spaced apart from one another and extending in a generally vertical direction, wherein the vertical track sections intersect the horizontal track sections to form a loop.


Automated Put Wall Solutions.


OmniSort English Webpage.</td>
</tr>
</table>

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

an intersection where one of the horizontal track sections intersects one of the vertical track sections, wherein the intersection provides a first path in a generally horizontal direction and a second path in a generally vertical direction;	The Accused Product comprises a track for guiding the vehicles, wherein the track comprises an intersection where one of the horizontal track sections intersects one of the vertical track sections, wherein the intersection provides a first path in a generally horizontal direction and a second path in a generally vertical direction.  

OmniSort English Webpage.

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

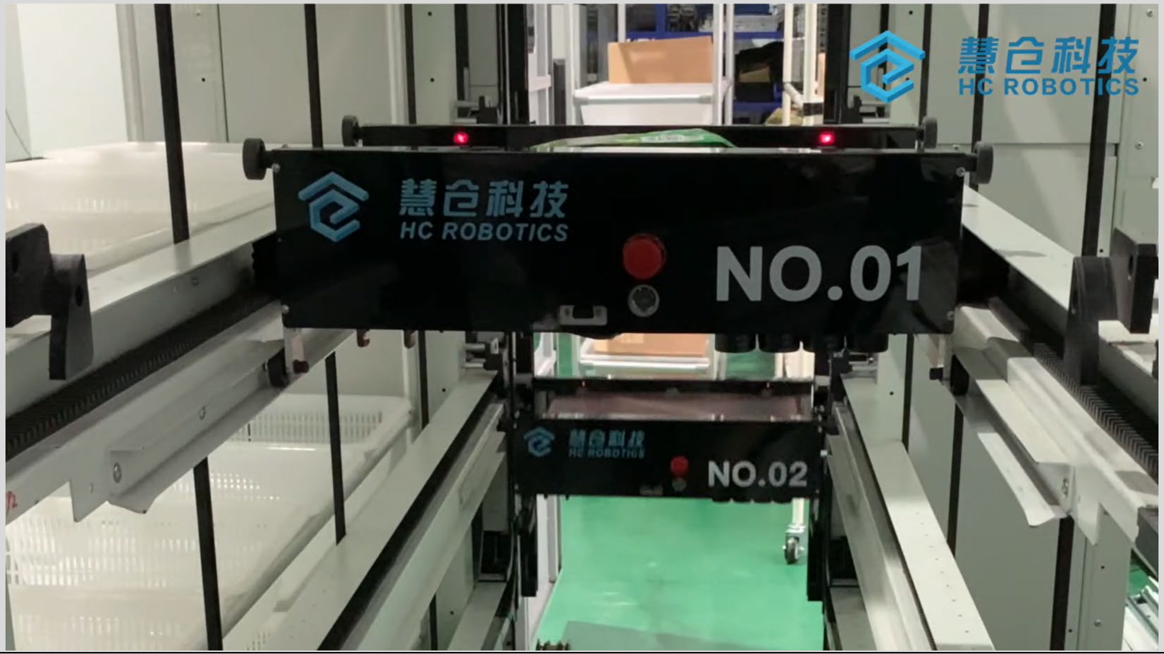
wherein at least one of the vehicles comprises a drive element that interacts with an engagement surface of one of the vertical track sections to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between one of the horizontal track sections and the one vertical track sections.	The Accused Product comprises a plurality of vehicles for delivering and retrieving items, wherein at least one of the vehicles comprises a drive element that interacts with an engagement surface of one of the vertical track sections to maintain the orientation of the vehicle relative to the horizon as the vehicle moves between one of the horizontal track sections and the one vertical track sections. 

Exhibit Q: Claim chart comparing U.S. Patent No. 9,687,883 to Respondents' OmniSort Product

Element	Supporting Documentation
	  *OmniSort English Webpage.*

EXHIBIT R

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

U.S. Patent No. 10,576,505

Claim 1

Element	Supporting Documentation
A delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system, wherein the delivery vehicle comprises:	To the extent that the preamble is limiting, the Respondents' OmniSort system (hereinafter the "Accused Product") comprises a delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system. 

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *Automated Put Wall Solutions*, INVATA INTRALOGISTICS, https://www.invata.com/automated-put-wall-solutions/?li (last visited Dec. 2, 2021) (Exhibit 16).[1]

[1] The illustrations in this claim chart are exemplary, and not intended to limit the scope or applicability of the claims. To the extent any element is not literally met by the Accused Product, it is met under the doctrine of equivalents, at least because the Accused Product performs the same function in the same way to achieve the same result.

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

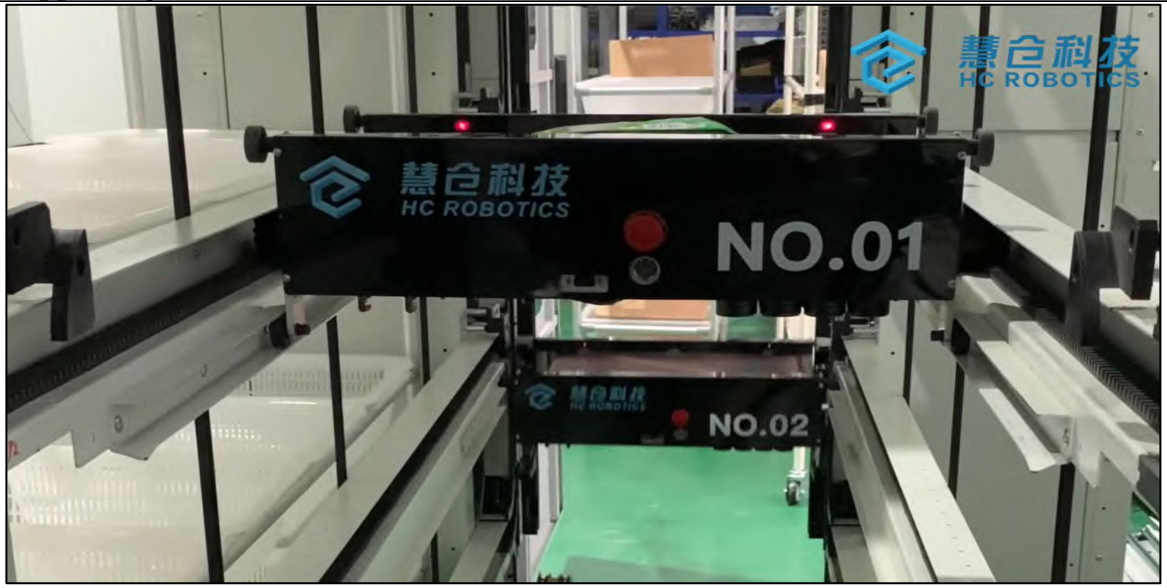
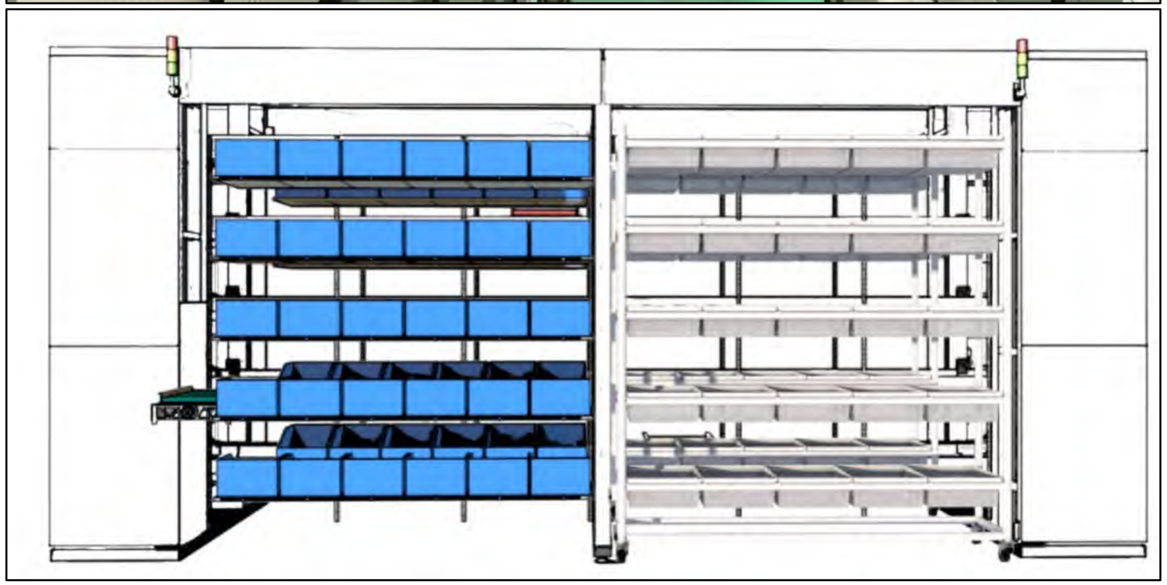
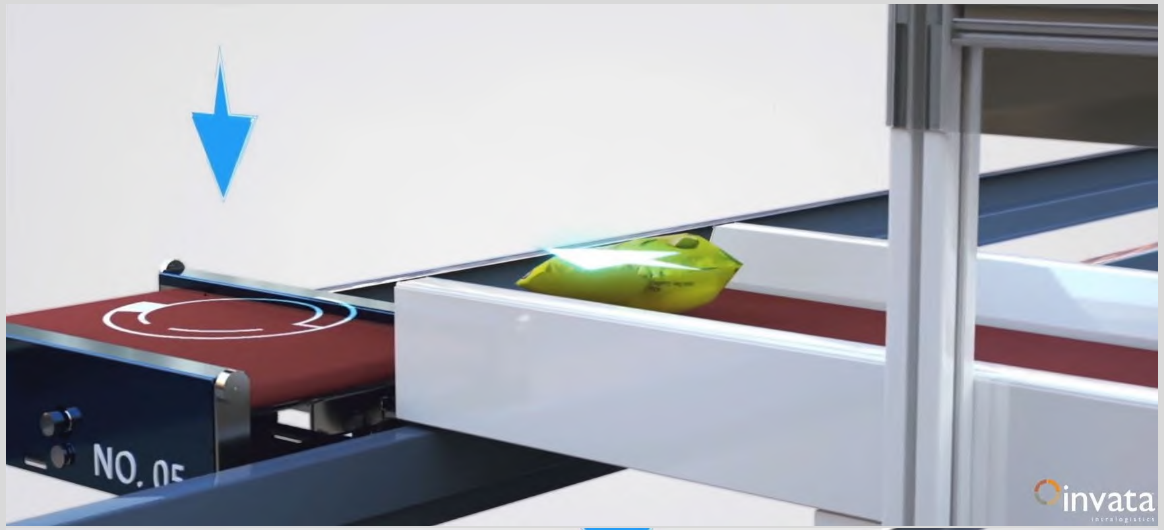
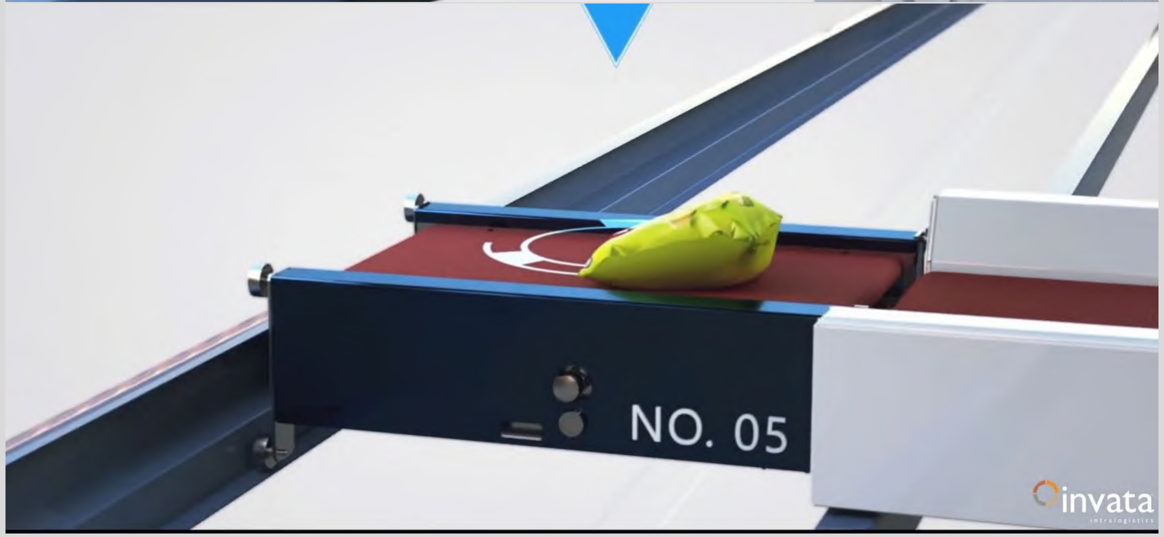
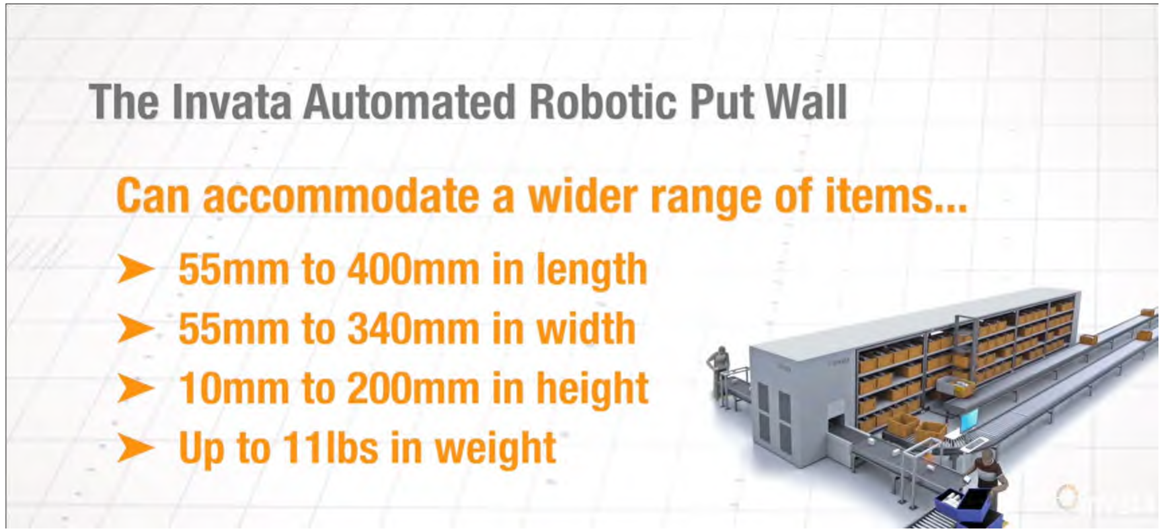
Element	Supporting Documentation
	  *OmniSort*, HC ROBOTICS, http://en.hc-robots.com/omniSort (last visited Dec. 2, 2021) (hereinafter "*OmniSort English Webpage*") (Exhibit 17).

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

a loading mechanism for loading an item onto the delivery vehicle, wherein the loading mechanism comprises: a conveyor having a length forming a substantially horizontal surface for receiving an item to be conveyed to one of the destination areas; and	The Accused Product comprises a delivery vehicle that comprises a loading mechanism for loading an item onto the delivery vehicle, wherein the loading mechanism comprises a conveyor having a length forming a substantially horizontal surface for receiving an item to be conveyed to one of the destination areas.   *Automated Put Wall Solutions.*[2]

[2] Invata's relevant product page, and both of HC Robotics' relevant pages, consist primarily of embedded videos. OPEX will provide copies of those videos on request.

	 *OmniSort English Webpage.*

<table>
<tr>
<td>a load controller for controlling operation of the conveyor to control the position of the item on the vehicle;</td>
<td>The Accused Product comprises a delivery vehicle that comprises a loading mechanism wherein the loading mechanism comprises a load controller for controlling operation of the conveyor to control the position of the item on the vehicle.


Automated Put Wall Solutions.


</td>
</tr>
</table>

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

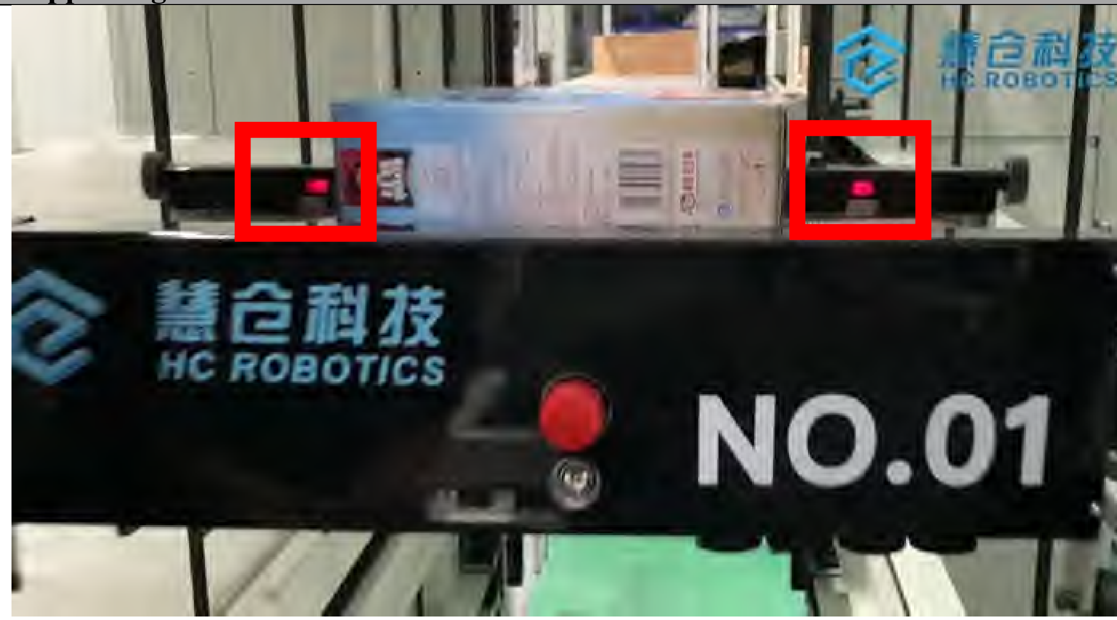
Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

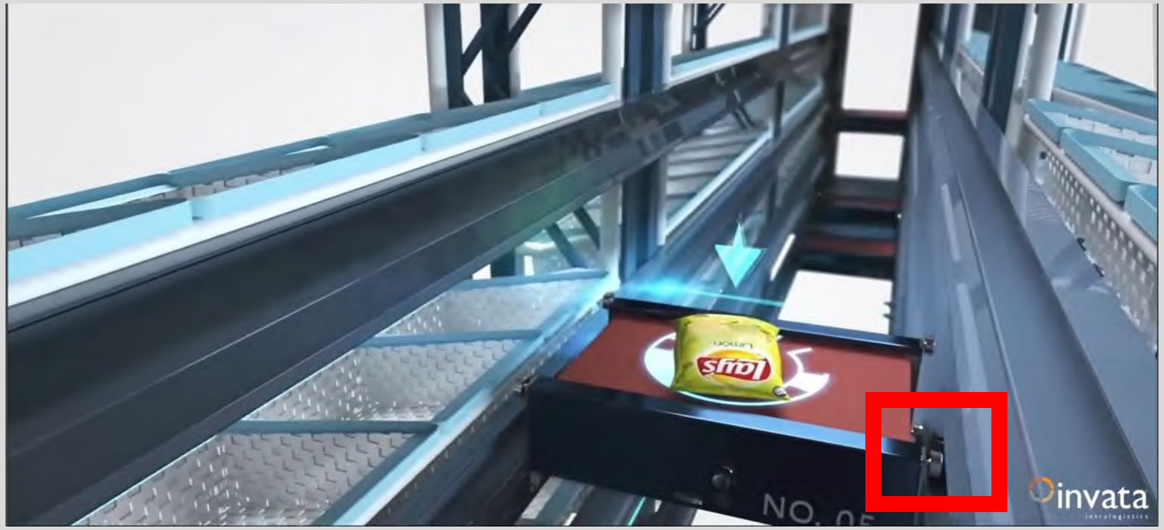
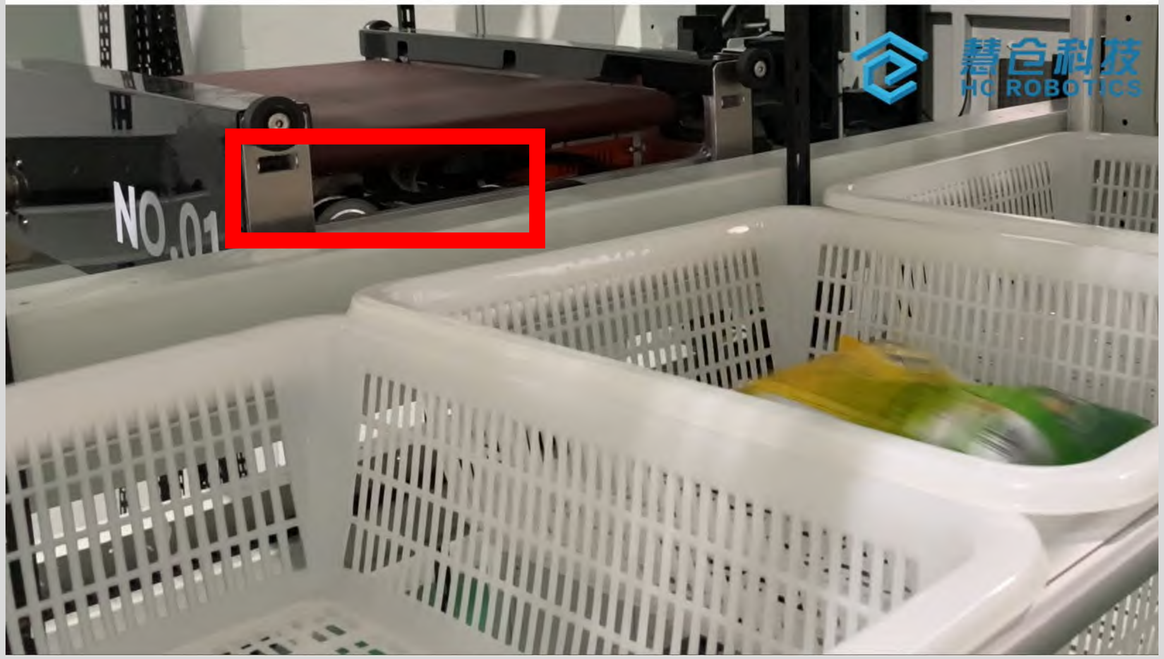
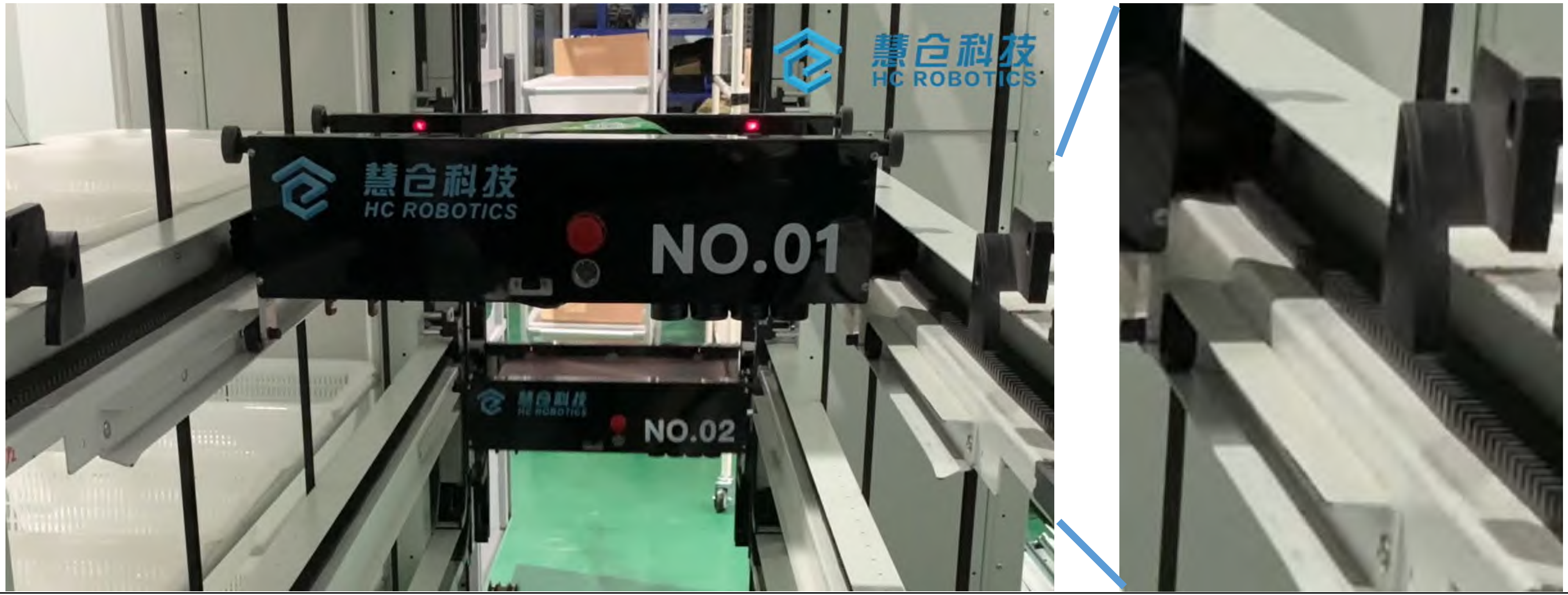
a motor for driving the vehicle to one of the destination areas;	The Accused Product comprises a delivery vehicle that comprises a motor for driving the vehicle to one of the destination areas.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel.	The Accused Product comprises a delivery vehicle that comprises a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel. 

	*OmniSort English Webpage.*

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

Claim 18

Element	Supporting Documentation
A delivery vehicle operable with a material handling system having a guide system comprising a track positioned along a plurality of destination areas, wherein the delivery vehicle comprises:	To the extent that the preamble is limiting, the Accused Product comprises a delivery vehicle operable with a material handling system having a guide system comprising a track positioned along a plurality of destination areas.   *Automated Put Wall Solutions.*

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

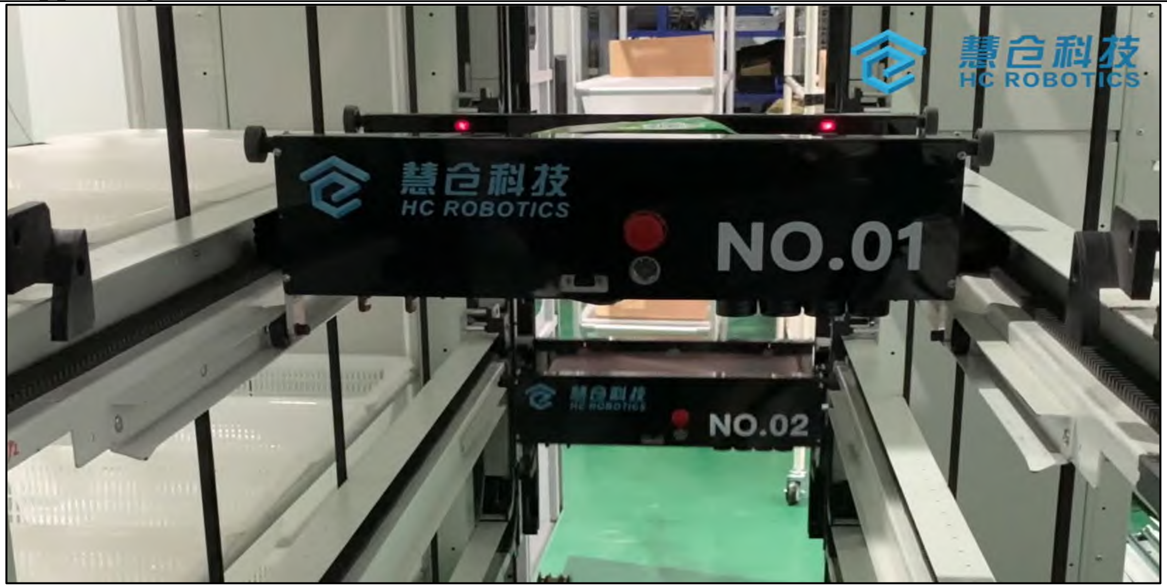
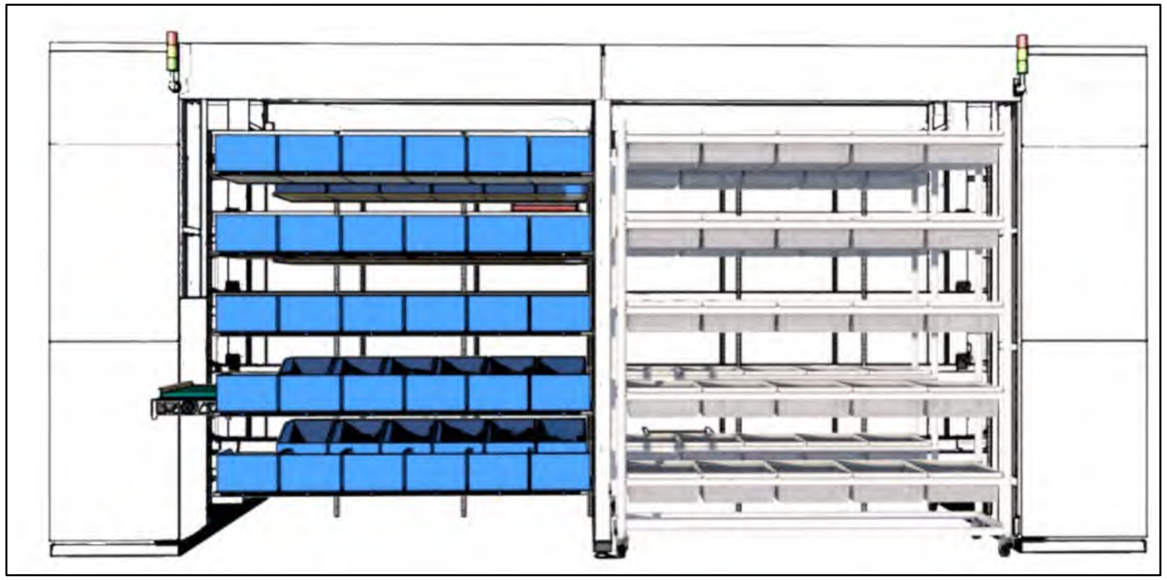
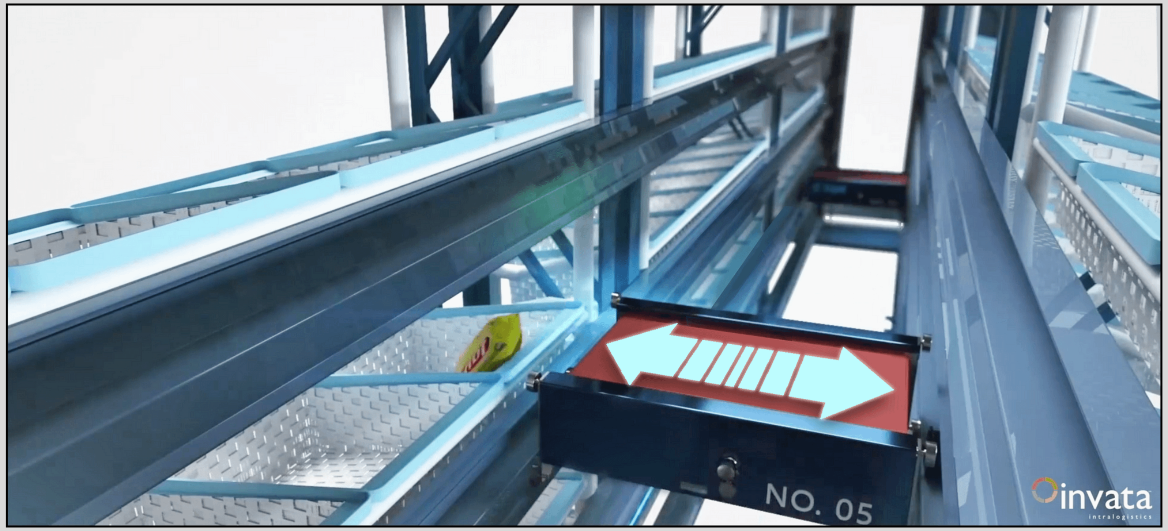
Element	Supporting Documentation
	  *OmniSort English Webpage.*

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

a transfer mechanism configured to load an item onto the delivery vehicle or eject the item from the vehicle into one of the destination areas, wherein the transfer mechanism comprises:	The Accused Product comprises a delivery vehicle that comprises a transfer mechanism configured to load an item onto the delivery vehicle or eject the item from the vehicle into one of the destination areas.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

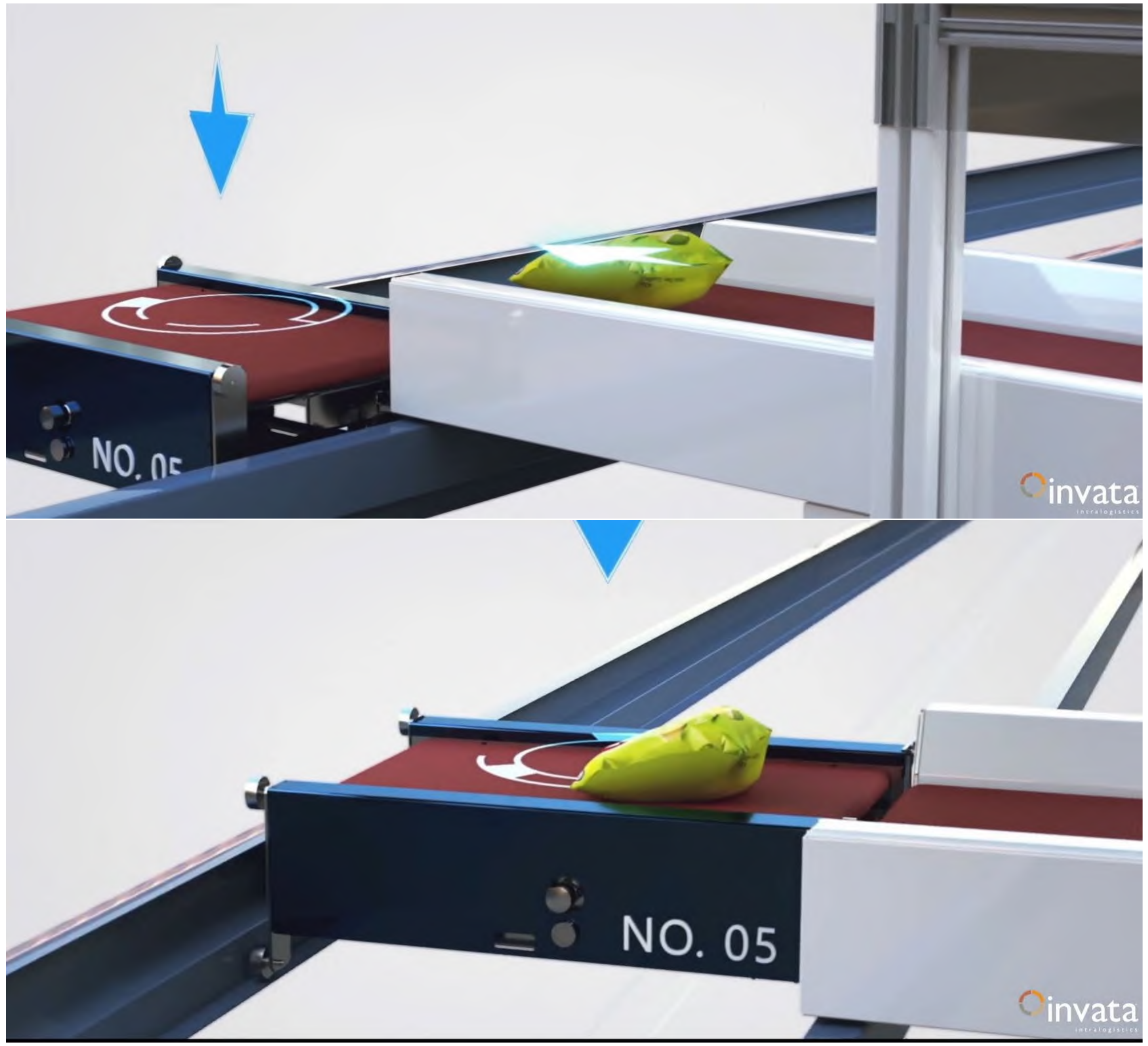
a conveyor having a length forming a substantially horizontal surface for receiving an item to be conveyed to one of the destination areas; and	The Accused Product comprises a delivery vehicle that comprises a transfer mechanism, wherein the transfer mechanism comprises a conveyor having a length forming a substantially horizontal surface for receiving an item to be conveyed to one of the destination areas.  *Automated Put Wall Solutions.*

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

OmniSort English Webpage.

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

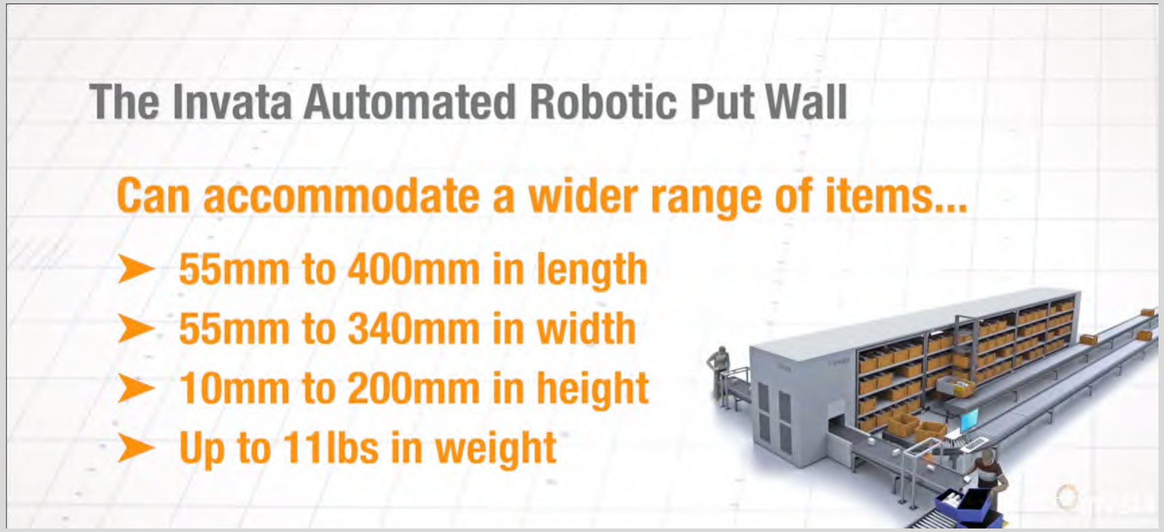
a conveyor controller for controlling operation of the conveyor to control the position of the item on the vehicle;	The Accused Product comprises a delivery vehicle that comprises a transfer mechanism, wherein the transfer mechanism comprises a conveyor controller for controlling operation of the conveyor to control the position of the item on the vehicle.  *Automated Put Wall Solutions.* 

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

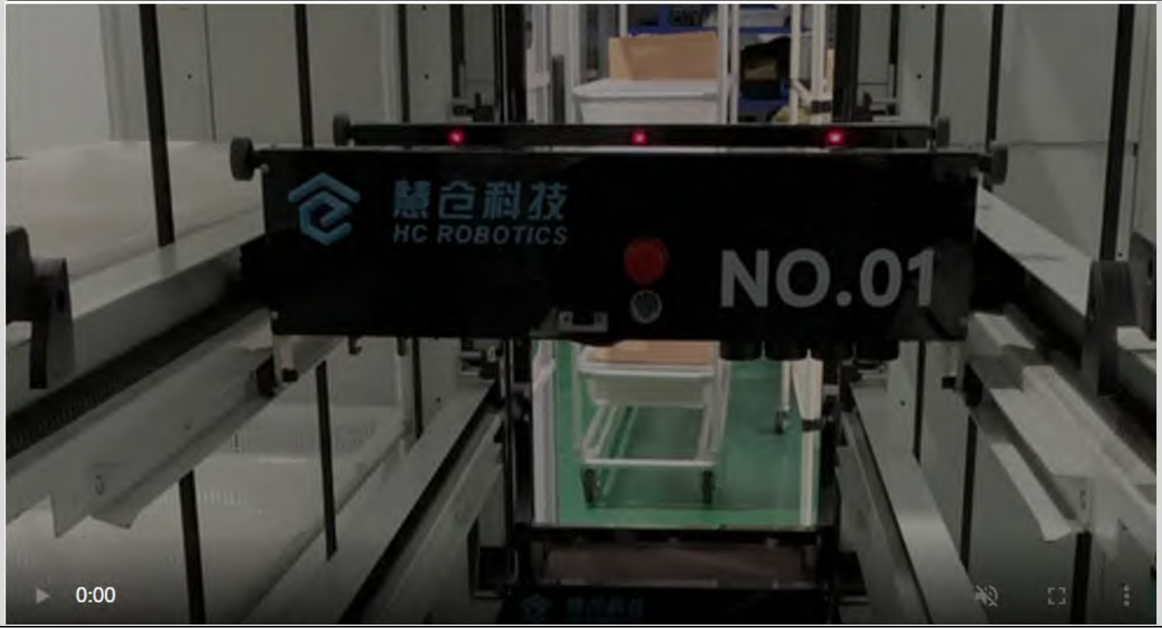


Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

Element	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

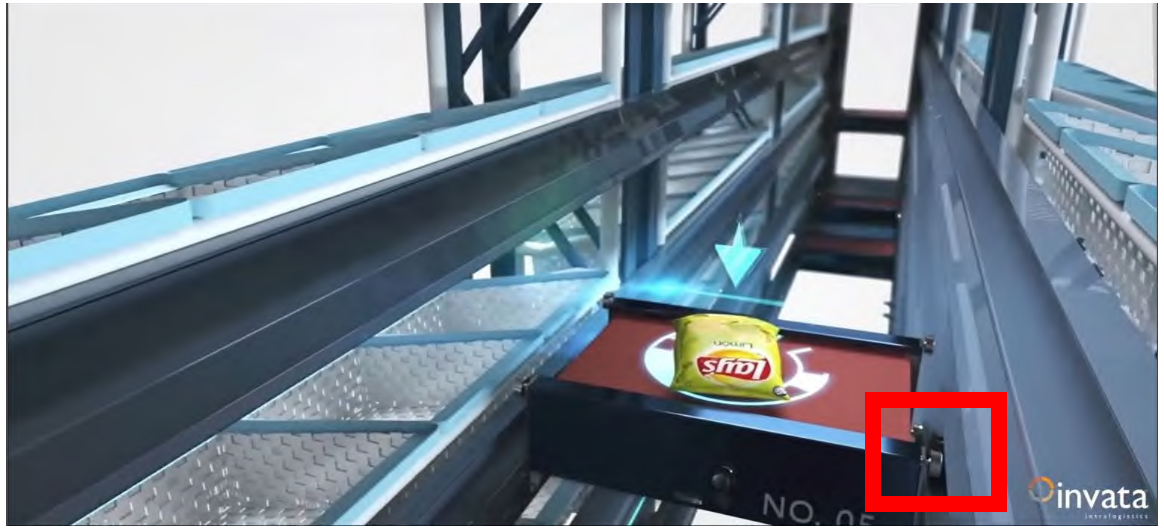
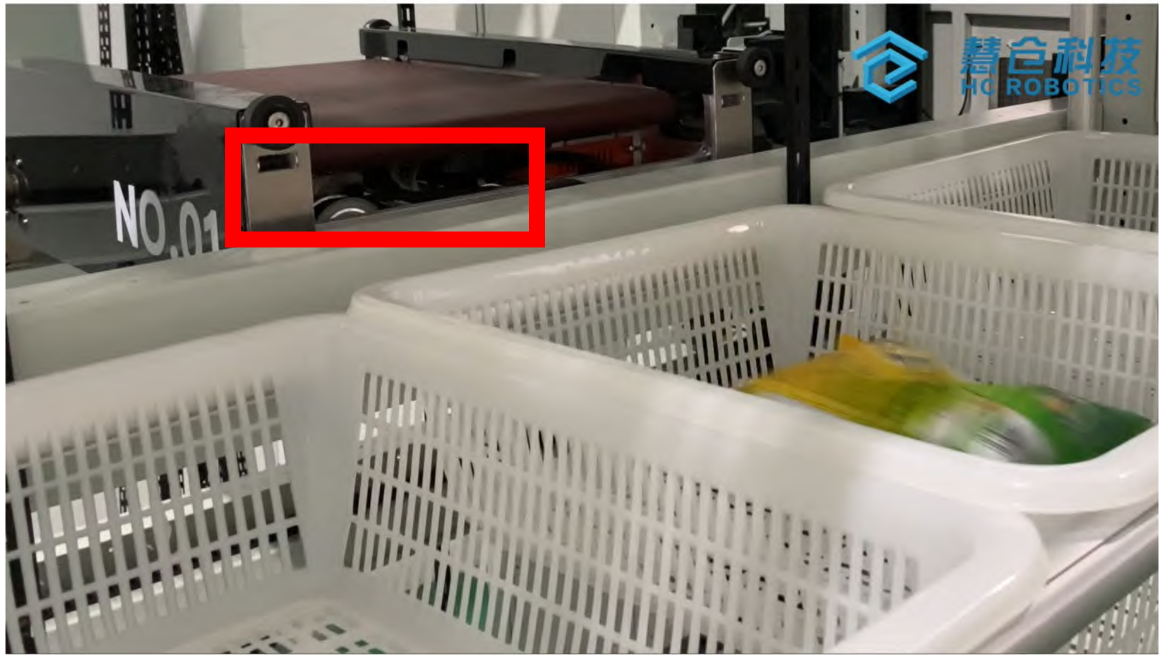
a motor for driving the vehicle to one of the destination areas;	The Accused Product comprises a delivery vehicle that comprises a motor for driving the vehicle to one of the destination areas.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

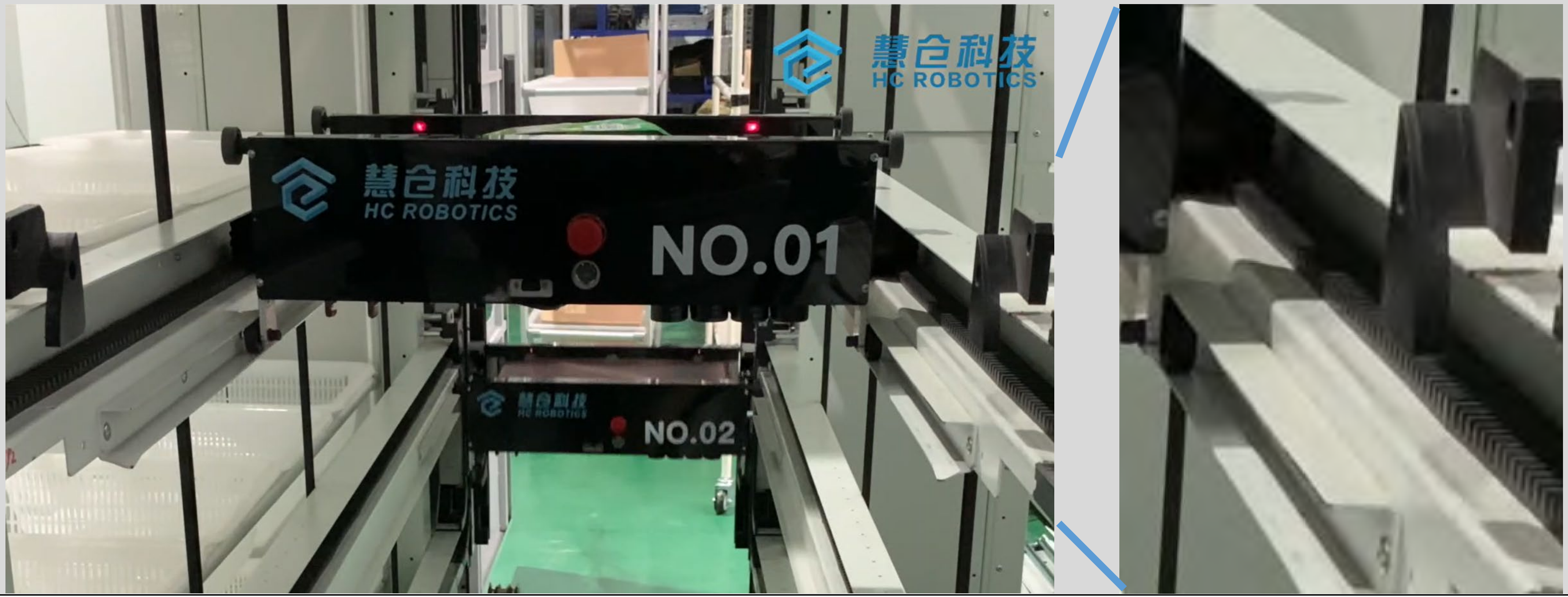
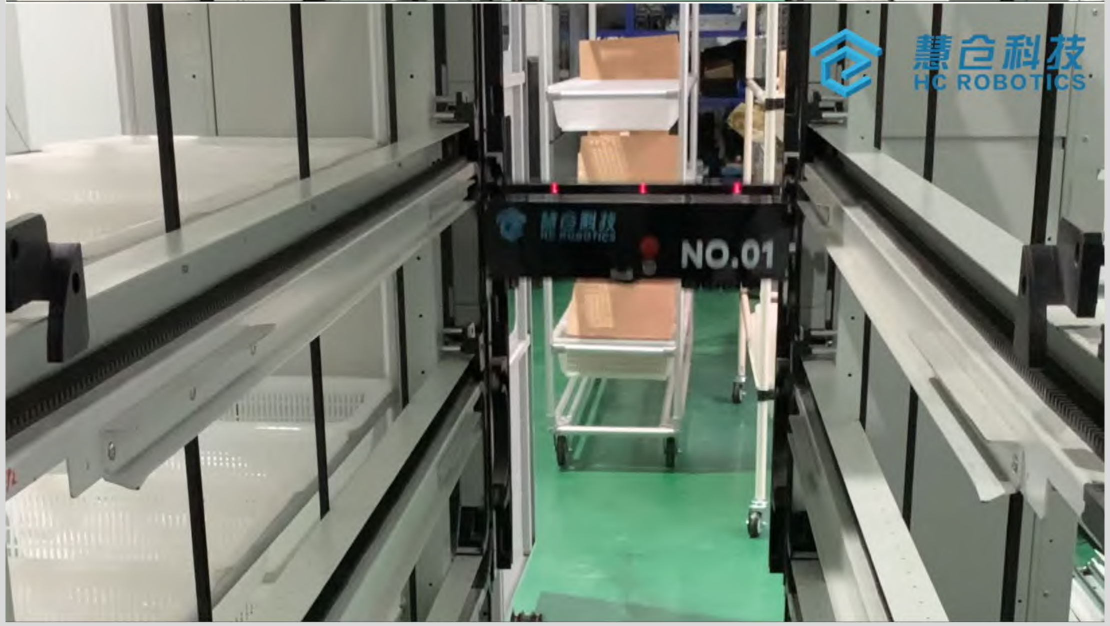
a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel.	The Accused Product comprises a delivery vehicle that comprises a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel. 

Exhibit R: Claim chart comparing U.S. Patent No. 10,576,505 to Respondents' OmniSort Product

<table>
<tr><th>Element</th><th>Supporting Documentation</th></tr>
<tr><td></td><td>



OmniSort English Webpage.</td></tr>
</table>

EXHIBIT S

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

U.S. Patent No. 11,192,144

Claim 1

<table>
<tr><th>Limitation</th><th>Supporting Documentation</th></tr>
<tr><td>A delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system, wherein the delivery vehicle comprises:</td><td>To the extent that the preamble is limiting, the Respondents' OmniSort system (hereinafter "Accused Product") comprises a delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system.

Automated Put Wall Solutions, INVATA INTRALOGISTICS, https://www.invata.com/automated-put-wall-solutions/?li (last visited Dec. 2, 2021) (Exhibit 16).[1]</td></tr>
</table>

[1] The illustrations in this claim chart are exemplary, and not intended to limit the scope or applicability of the claims. To the extent any element is not literally met by the Accused Product, it is met under the doctrine of equivalents, at least because the Accused Product performs the same function in the same way to achieve the same result.

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

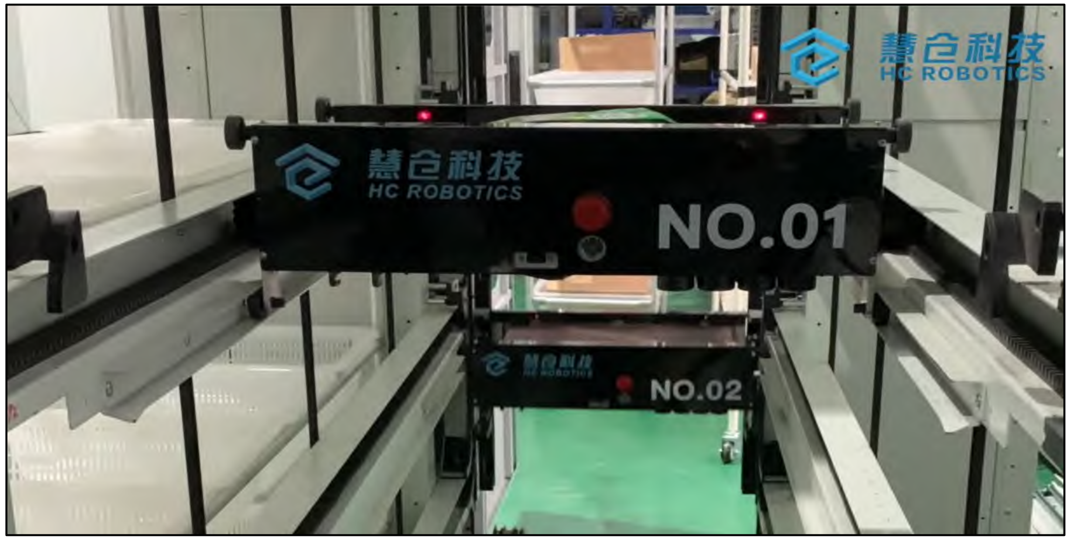
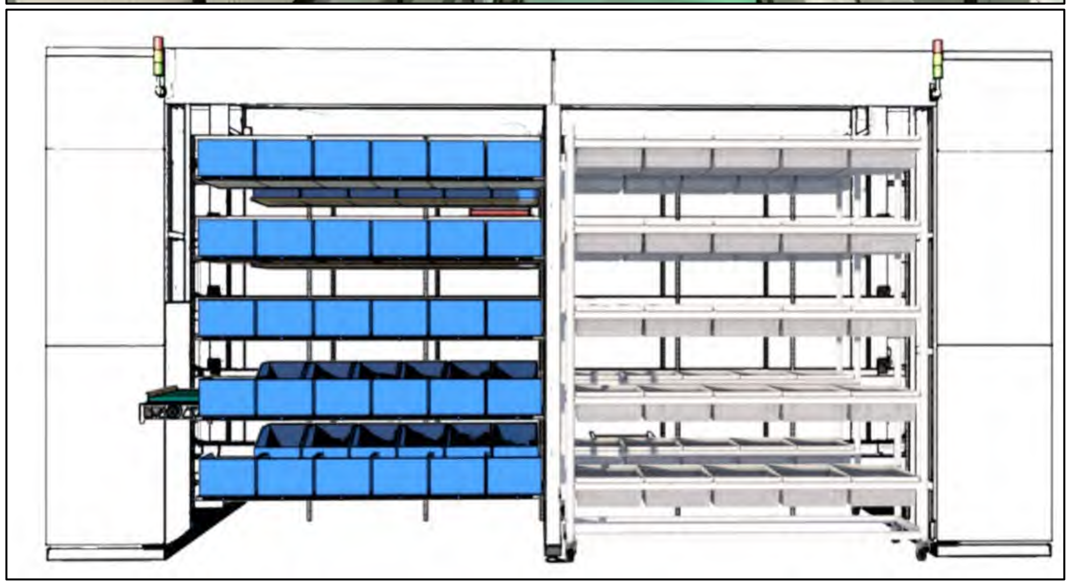
Limitation	**Supporting Documentation**
	  *OmniSort*, HC ROBOTICS, http://en.hc-robots.com/omniSort (last visited Dec. 2, 2021) (hereinafter "*OmniSort English Webpage*") (Exhibit 17).

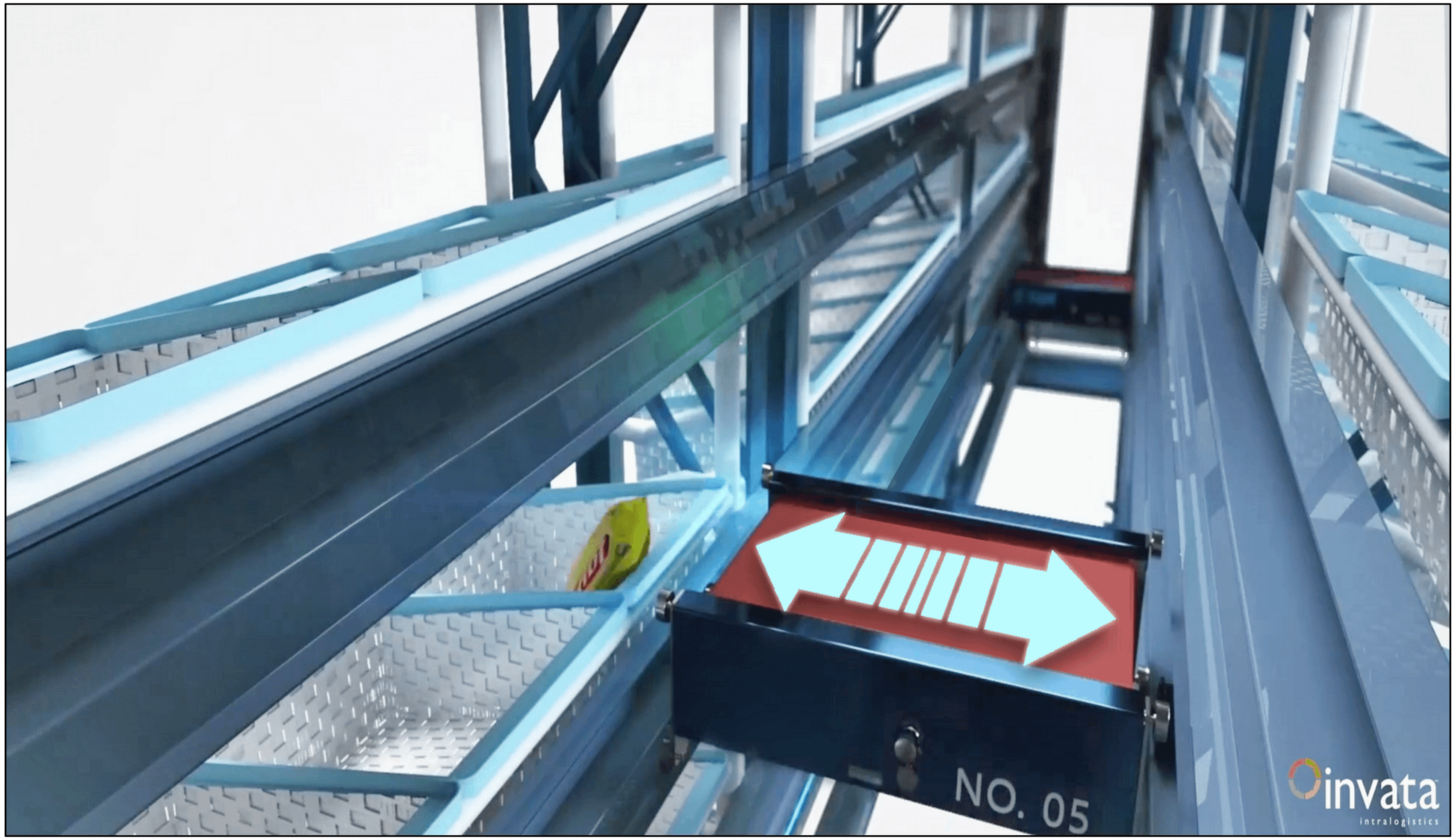
Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

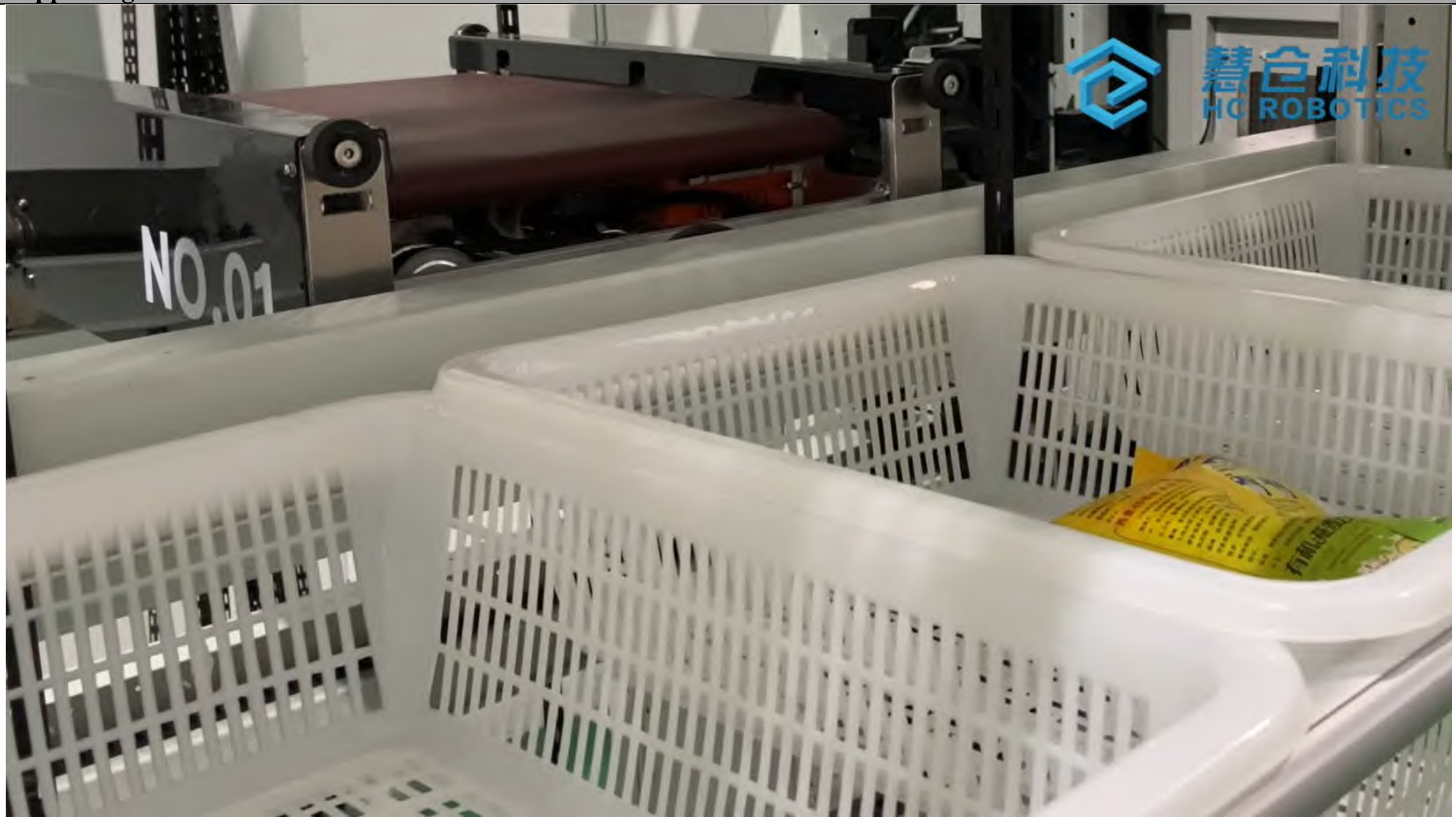
a transfer mechanism for transferring an item onto or off the vehicle, wherein the transfer mechanism has a support surface configured to support the item when the item is on the vehicle;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a transfer mechanism for transferring an item onto or off the vehicle, wherein the transfer mechanism has a support surface configured to support the item when the item is on the vehicle.  *Automated Put Wall Solutions.*[2]

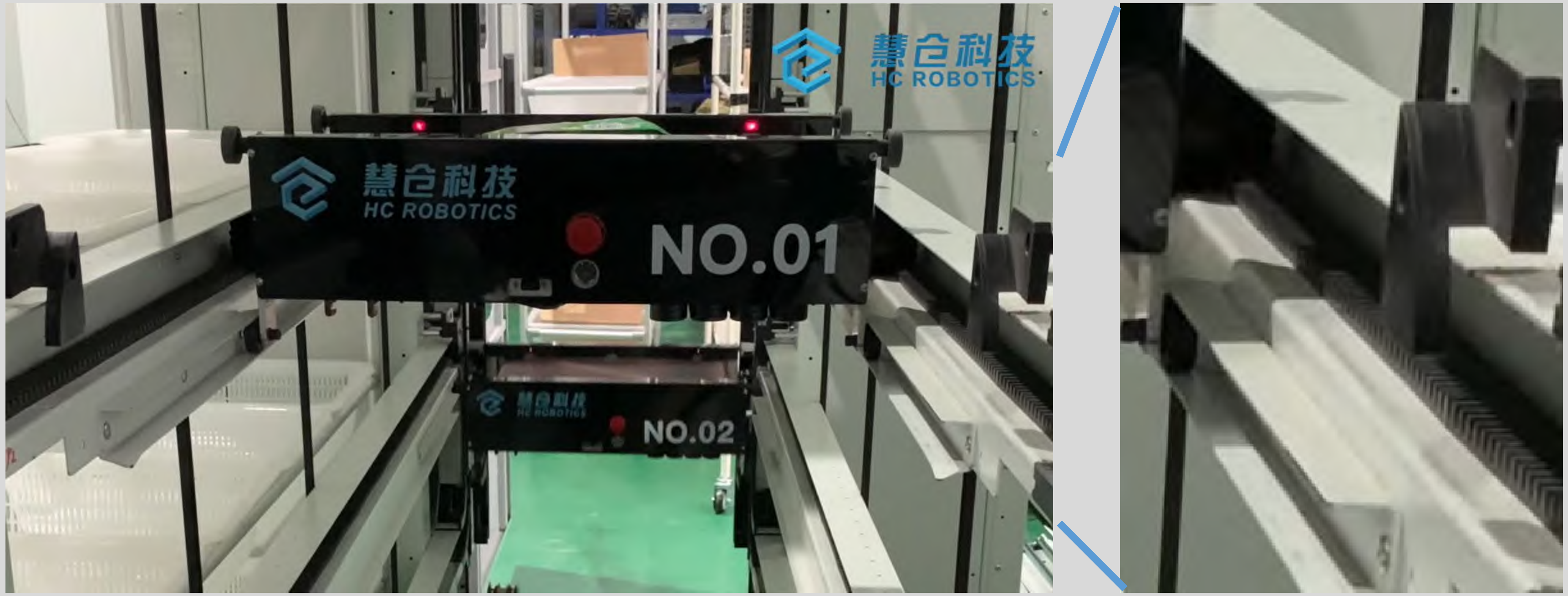
[2] Invata's relevant product page, and both of HC Robotics' relevant pages, consist primarily of embedded videos. OPEX will provide copies of those videos on request.

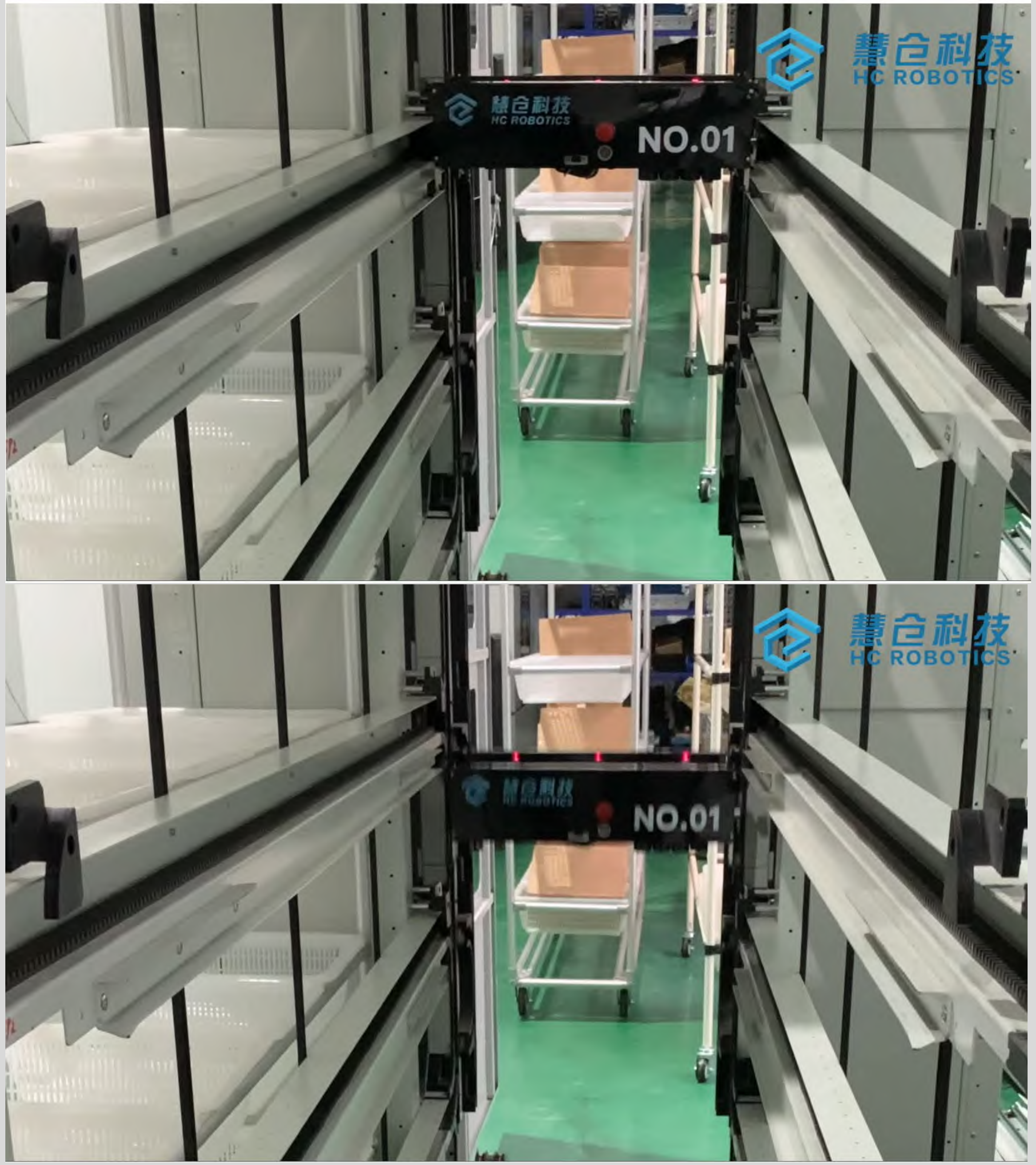
OmniSort English Webpage.

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

a pair of opposing walls spaced apart from one another so that the support surface is between the opposing walls with the walls projecting upwardly relative to the support surface, wherein the opposing walls are positioned to form a first opening to facilitate transfer of items onto the support surface through the first opening, and wherein the opposing walls form a second opening to facilitate transfer of items onto the support surface through the second opening;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a pair of opposing walls spaced apart from one another so that the support surface is between the opposing walls with the walls projecting upwardly relative to the support surface, wherein the opposing walls are positioned to form a first opening to facilitate transfer of items onto the support surface through the first opening, and wherein the opposing walls form a second opening to facilitate transfer of items onto the support surface through the second opening.  *Automated Put Wall Solutions.*

Limitation	Supporting Documentation
	 *OmniSort English Webpage.*

a drive system cooperable with the guide system to guide the vehicle to the destination areas,	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a drive system cooperable with the guide system to guide the vehicle to the destination areas. 



OmniSort English Webpage.

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

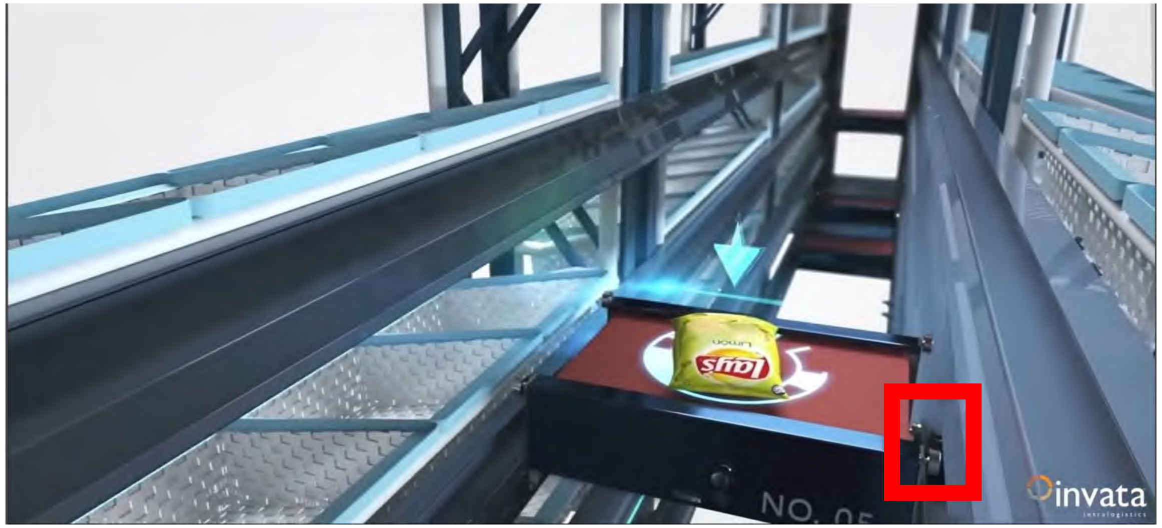
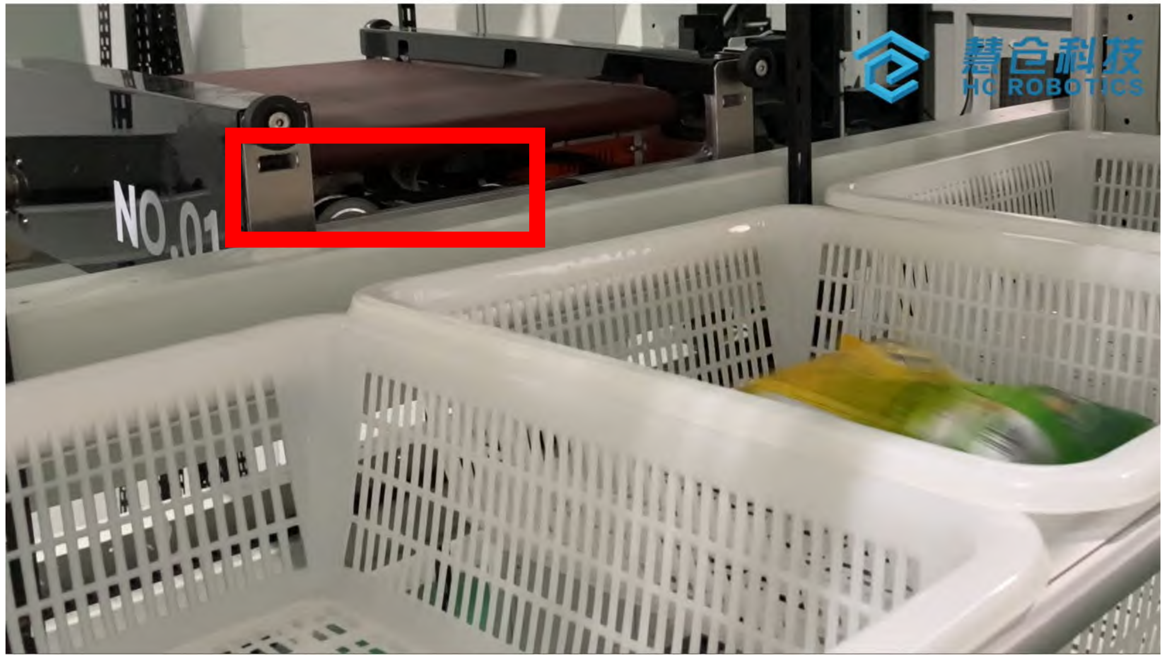
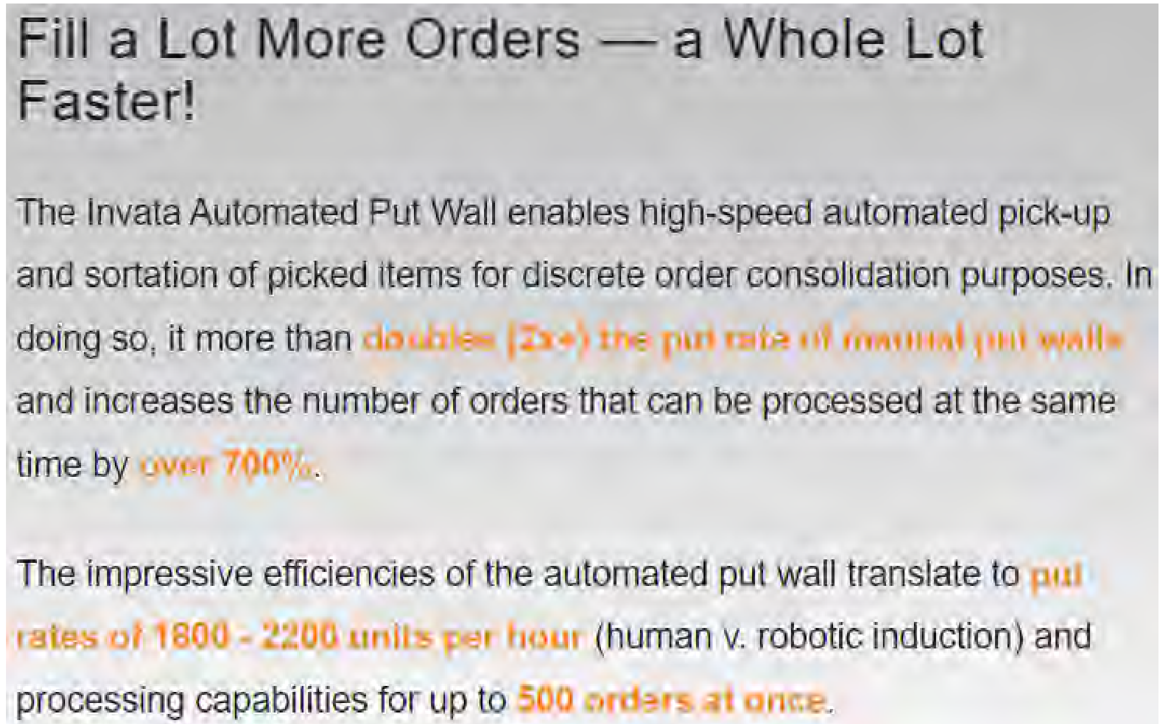
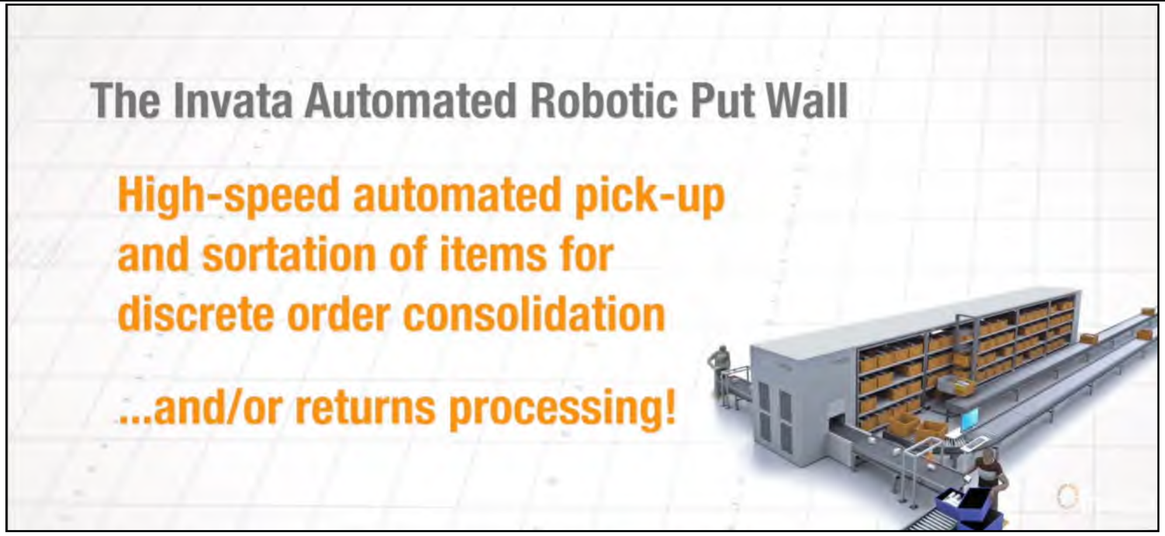
a motor for driving the drive system;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a motor for driving the drive system.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

Limitation	Supporting Documentation
an electric storage element for storing electricity and providing power to the transfer mechanism and the motor; and	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises an electric storage element for storing electricity and providing power to the transfer mechanism and the motor.  *OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

a controller for receiving signals for controlling the motor and the transfer mechanism to control the movement of the vehicles along the guide system and to control transfer of items onto and off of the vehicles.	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a controller for receiving signals for controlling the motor and the transfer mechanism to control the movement of the vehicles along the guide system and to control transfer of items onto and off of the vehicles.  Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. The impressive efficiencies of the automated put wall translate to put rates of 1800 - 2200 units per hour (human v. robotic induction) and processing capabilities for up to 500 orders at once.


The Invata Automated Robotic Put Wall
High-speed automated pick-up
and sortation of items for
discrete order consolidation
...and/or returns processing!


Up to 500 Orders Processed at Once
invata

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

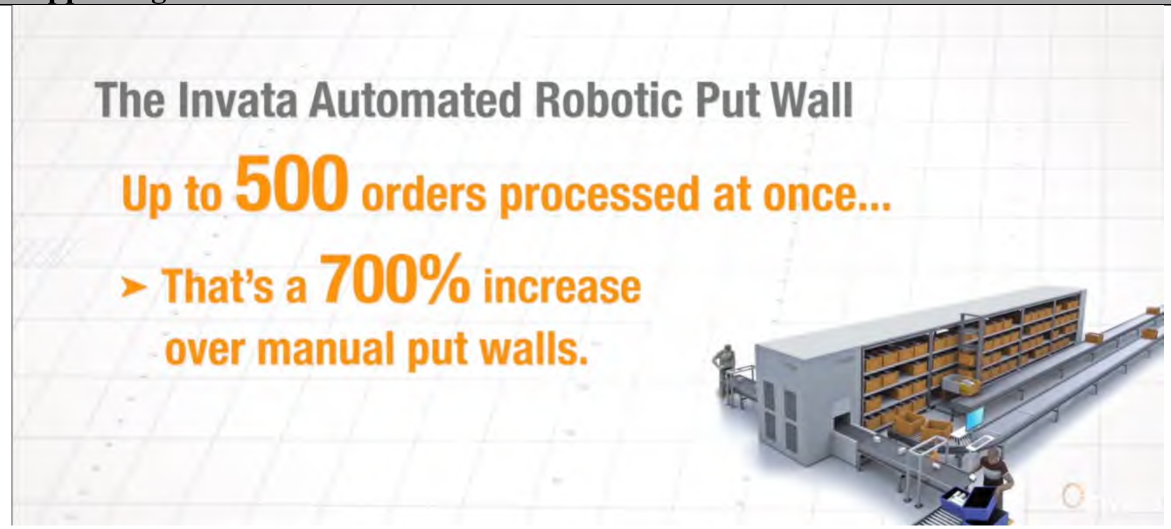
Limitation	Supporting Documentation
	 *Automated Put Wall Solutions.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

Claim 10

Limitation	Supporting Documentation
A delivery vehicle operable with a material handling system having a plurality of destination areas, wherein the delivery vehicle comprises:	The Accused Product comprises a delivery vehicle operable with a material handling system having a plurality of destination areas.   *Automated Put Wall Solutions.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

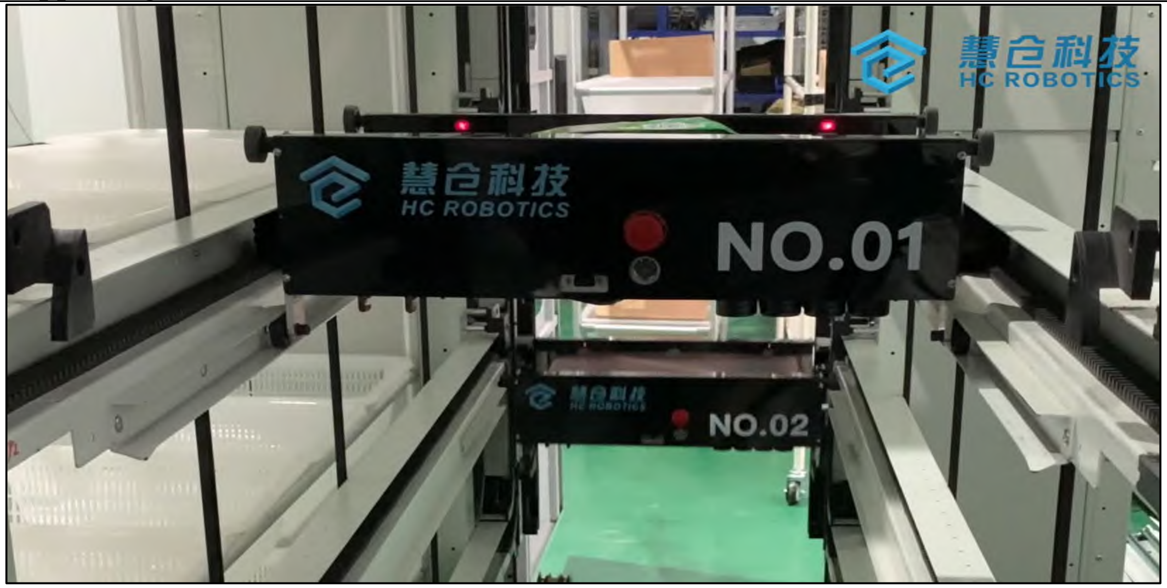
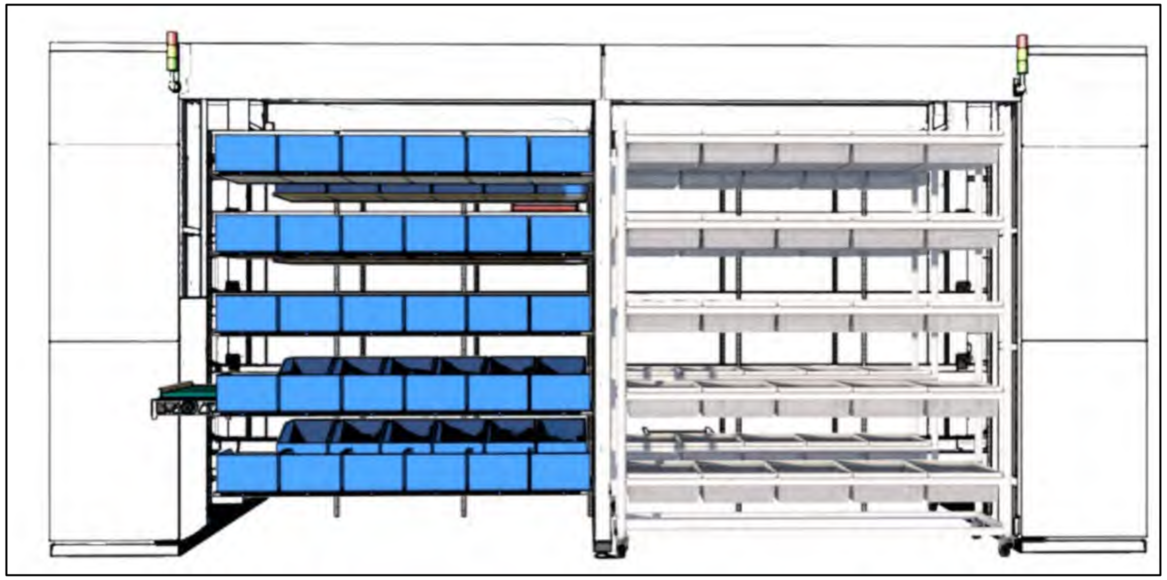
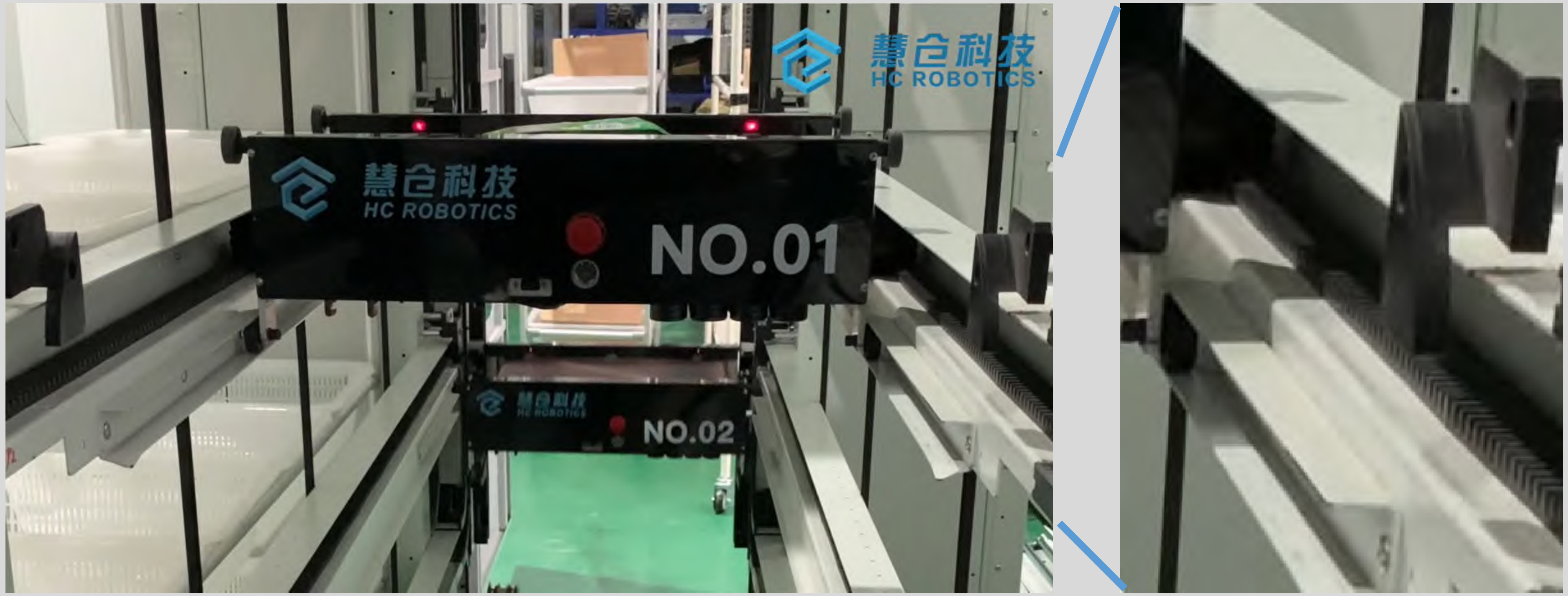
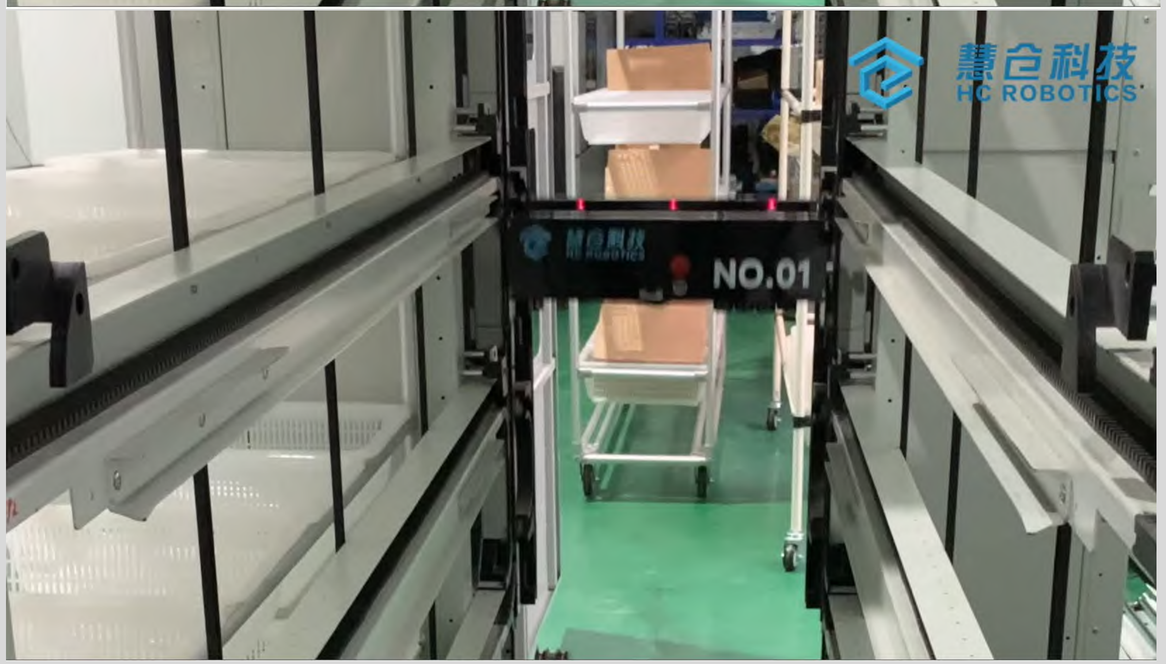
Limitation	Supporting Documentation
	  *OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

a drive system for driving the vehicle to one of the destination areas;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a drive system for driving the vehicle to one of the destination areas. 



OmniSort English Webpage.

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

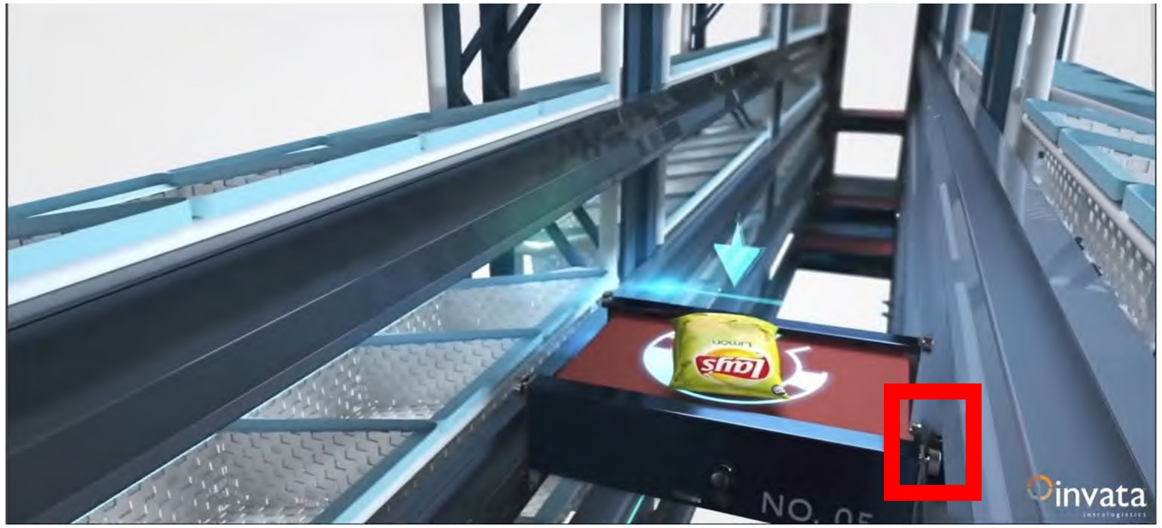
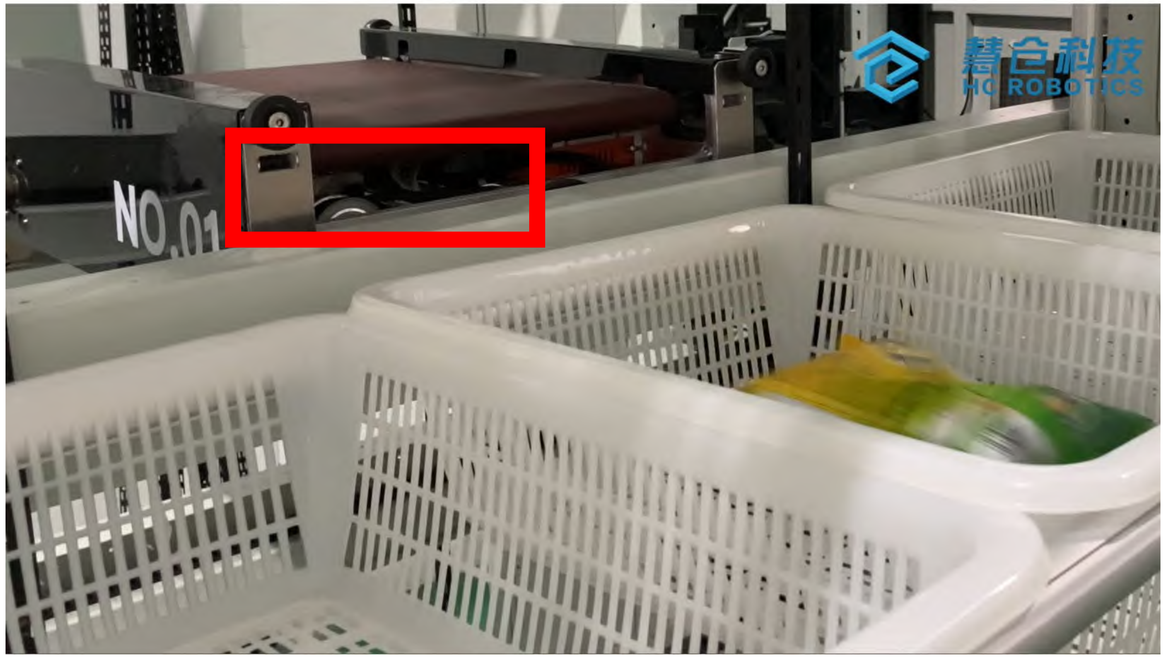
a motor for driving the drive system; and	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a motor for driving the drive system.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

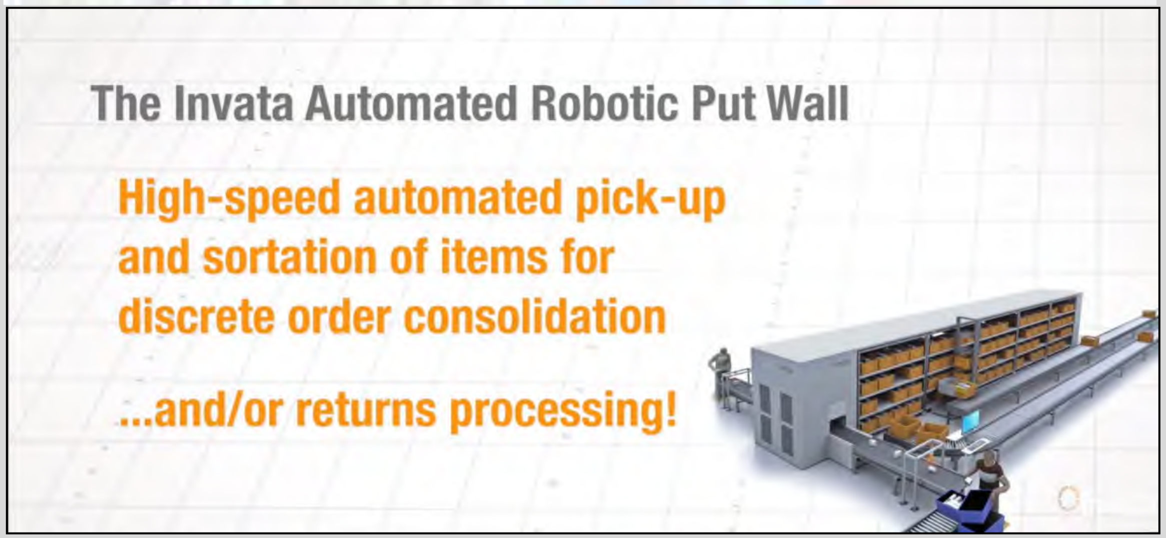
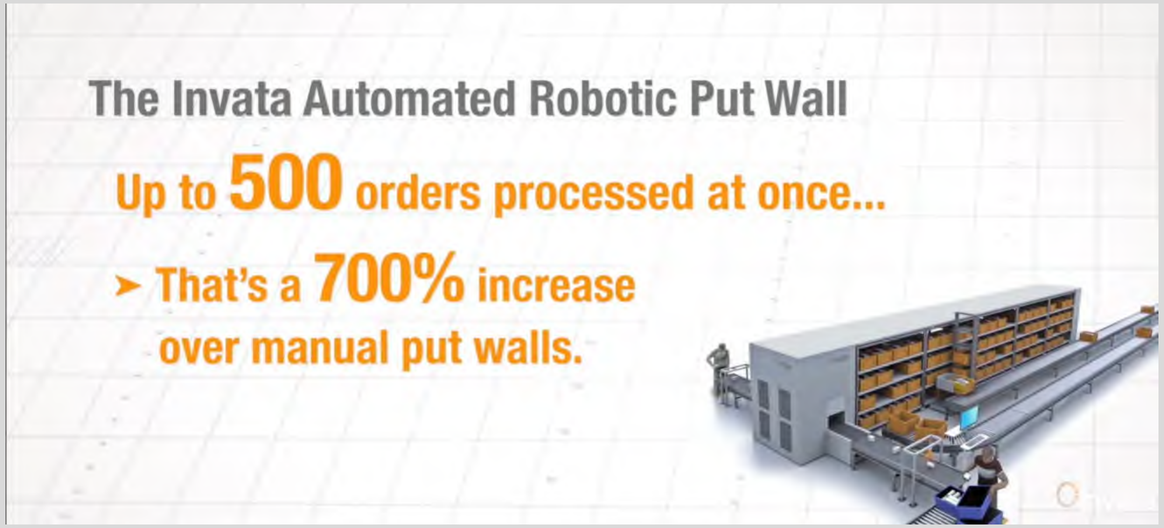
a controller for receiving signals for controlling the motor to control the movement of the vehicle;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a controller for receiving signals for controlling the motor to control the movement of the vehicle. **Fill a Lot More Orders — a Whole Lot Faster!** The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. The impressive efficiencies of the automated put wall translate to put rates of 1800 - 2200 units per hour (human v. robotic induction) and processing capabilities for up to 500 orders at once. 

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

Limitation	Supporting Documentation
	*Automated Put Wall Solutions.*

a transfer mechanism for transferring items between the vehicle and the destination areas wherein the transfer mechanism comprises a surface for receiving an item to be conveyed to one of the destination areas; and	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a transfer mechanism for transferring items between the vehicle and the destination areas wherein the transfer mechanism comprises a surface for receiving an item to be conveyed to one of the destination areas.   *Automated Put Wall Solutions.*

	*OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

a pair of opposing walls extending upwardly relative to the surface and spaced apart from one another so that at least a portion of the surface is between the opposing walls, wherein the opposing walls are dimensioned and arranged to facilitate transfer of items off the surface at a first end of the surface and to facilitate transfer of items off the surface at a second end of the surface.	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a pair of opposing walls extending upwardly relative to the surface and spaced apart from one another so that at least a portion of the surface is between the opposing walls, wherein the opposing walls are dimensioned and arranged to facilitate transfer of items off the surface at a first end of the surface and to facilitate transfer of items off the surface at a second end of the surface  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Claim 15

Limitation	Supporting Documentation
A delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system, wherein the delivery vehicle comprises:	The Accused Product comprises a delivery vehicle operable with a material handling system having a plurality of destination areas and a guide system.   *Automated Put Wall Solutions.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

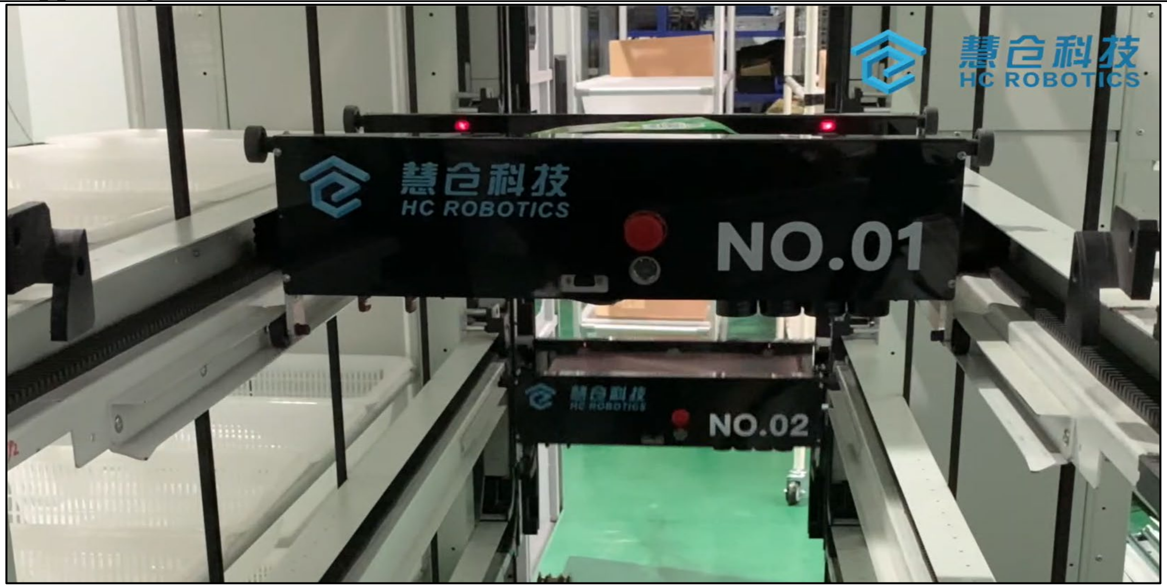
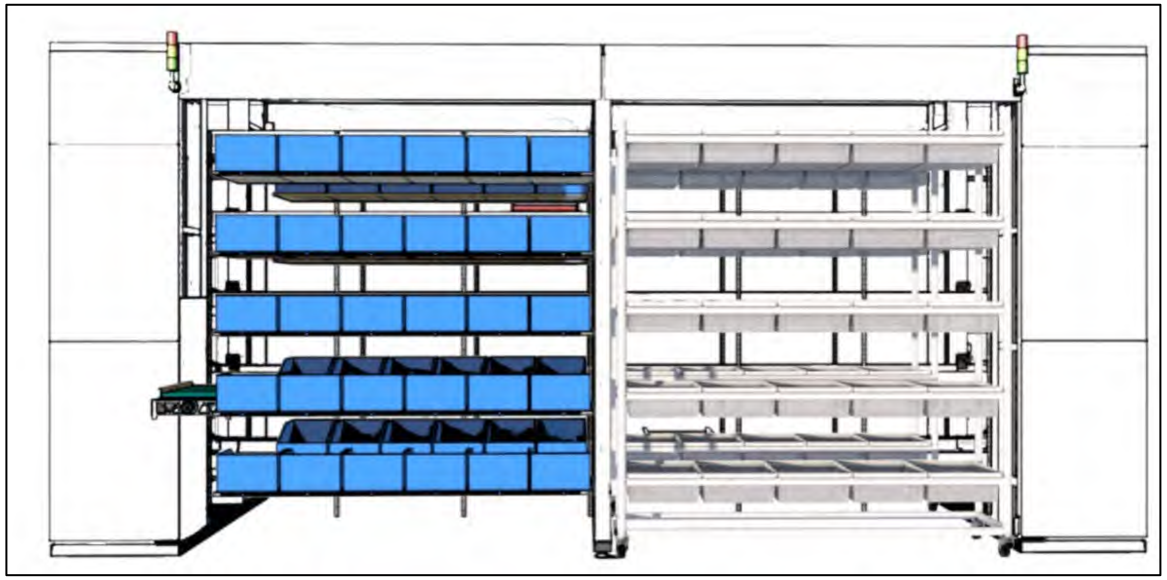
Limitation	Supporting Documentation
	 *OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

a transfer mechanism for transferring items between the vehicle and the destination areas wherein the transfer mechanism comprises a platform for receiving an item to be conveyed to one of the destination areas;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a transfer mechanism for transferring items between the vehicle and the destination areas wherein the transfer mechanism comprises a platform for receiving an item to be conveyed to one of the destination areas.   *Automated Put Wall Solutions.*

	*OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

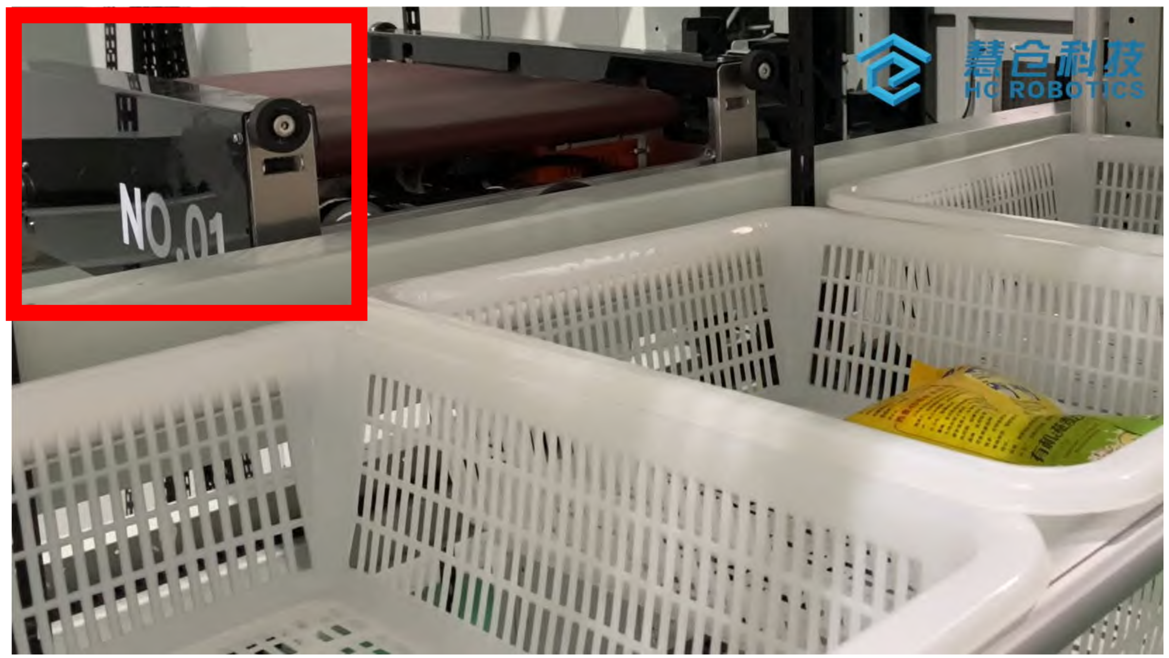
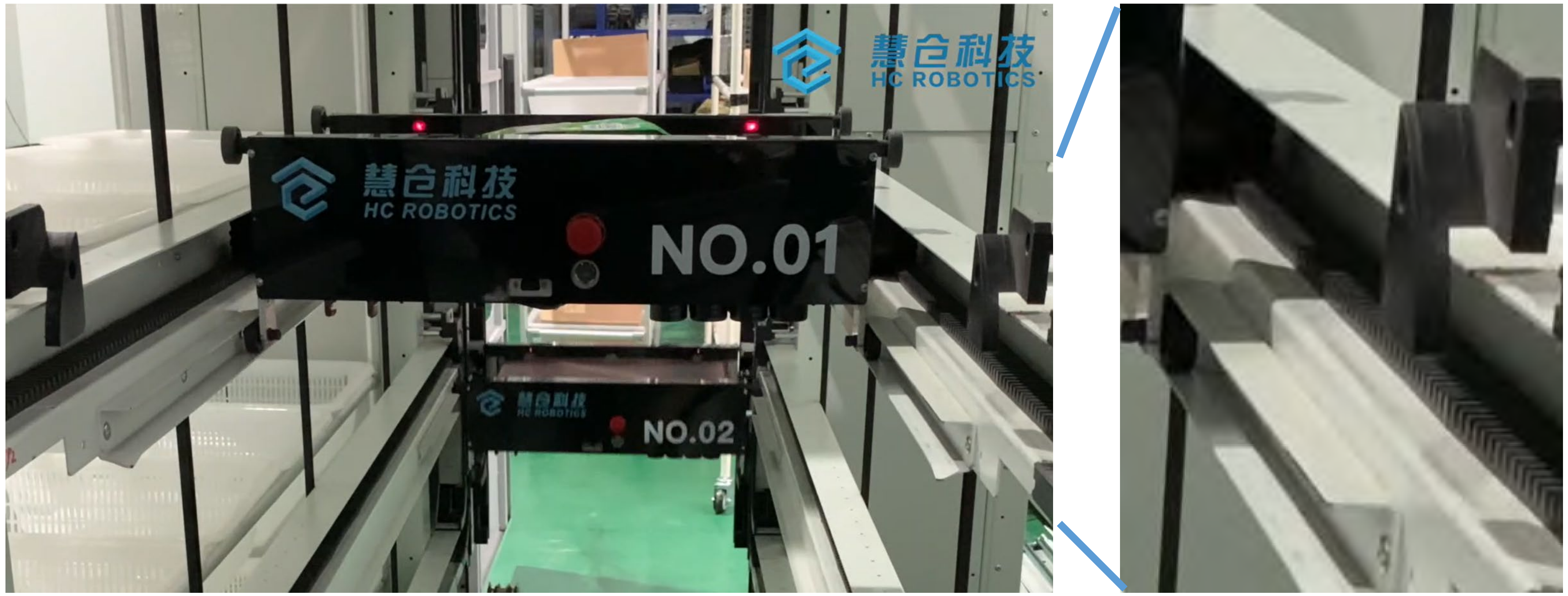
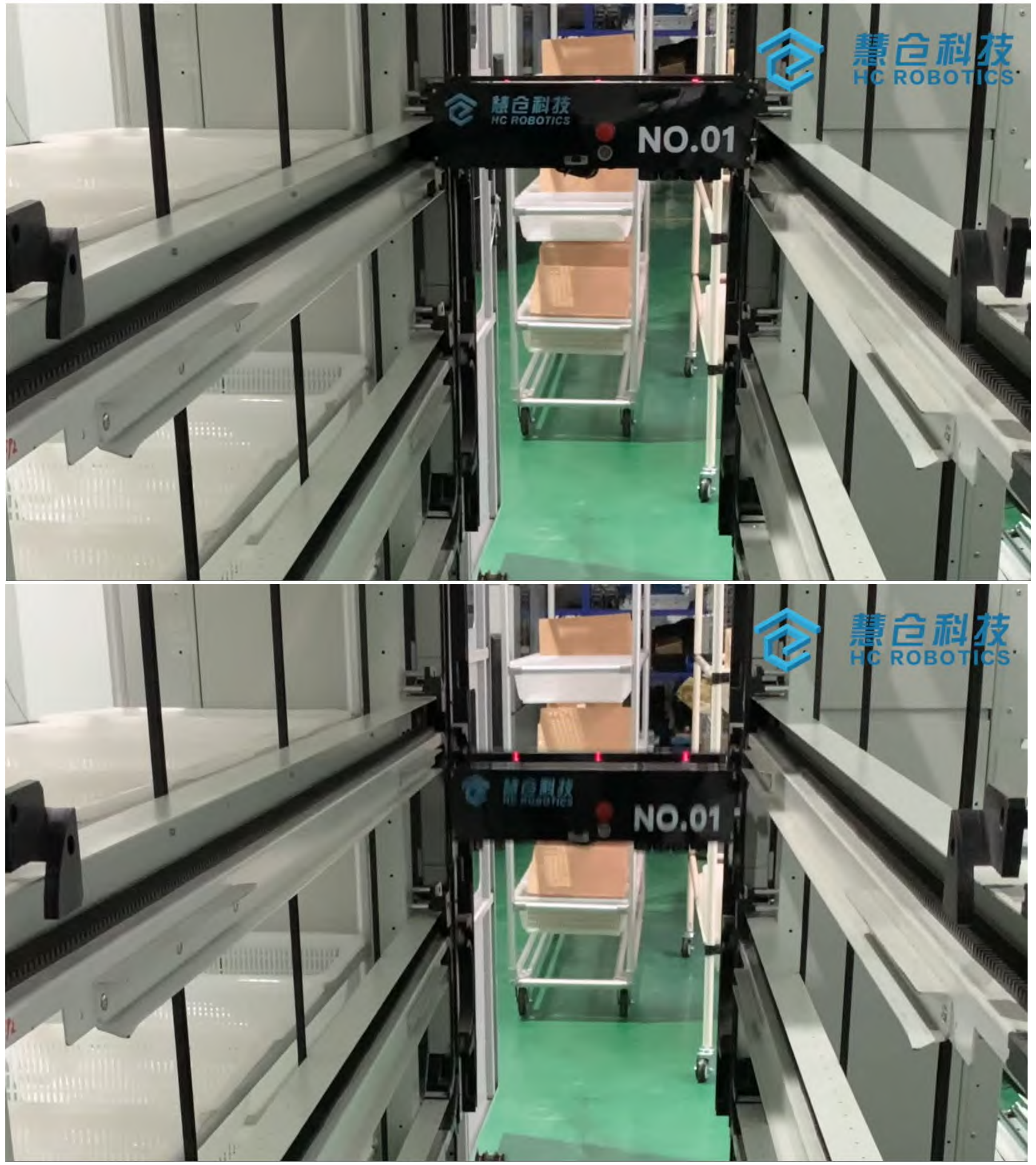
Limitation	Supporting Documentation
a first wall projecting upwardly along a first side of the platform;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a first wall projecting upwardly along a first side of the platform.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

Limitation	Supporting Documentation
a second wall projecting upwardly along a second side of the platform, wherein the second wall is spaced apart from the first wall so that a first transfer opening is formed between the first and second walls at a third side of the platform and a second transfer opening is formed between the first and second walls along a fourth side of the platform, wherein the first and second transfer openings are configured to facilitate transfer of items onto and off of the platform through the first and second transfer openings;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a second wall projecting upwardly along a second side of the platform, wherein the second wall is spaced apart from the first wall so that a first transfer opening is formed between the first and second walls at a third side of the platform and a second transfer opening is formed between the first and second walls along a fourth side of the platform, wherein the first and second transfer openings are configured to facilitate transfer of items onto and off of the platform through the first and second transfer openings.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel;	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a drive system cooperable with the guide system to guide the vehicle to one of the destination areas, wherein the drive system is configured to maintain the orientation of the vehicle relative to the horizon as the vehicle changes from a horizontal direction of travel to a vertical direction of travel. 



	OmniSort English Webpage.

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

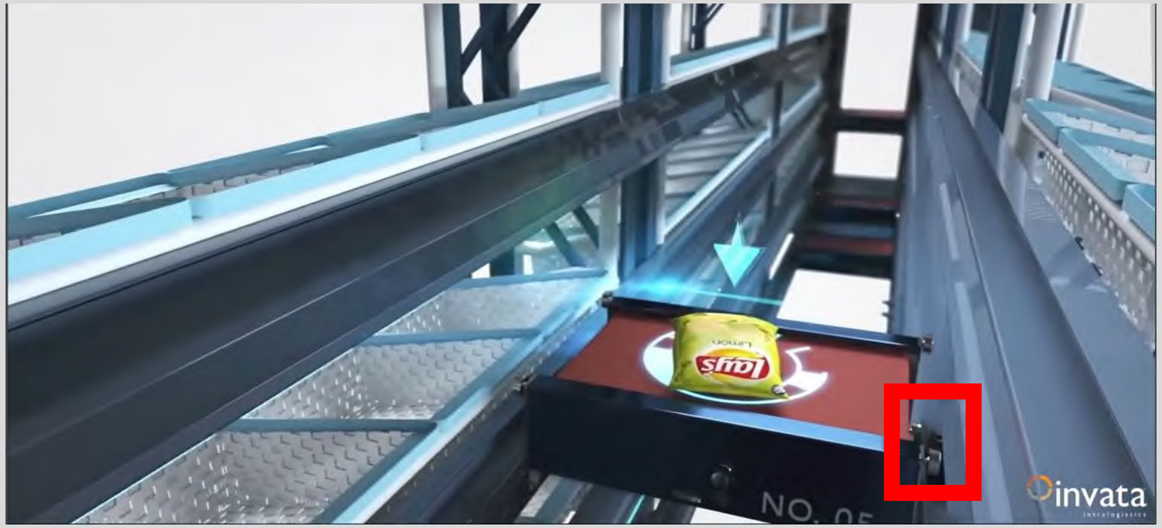
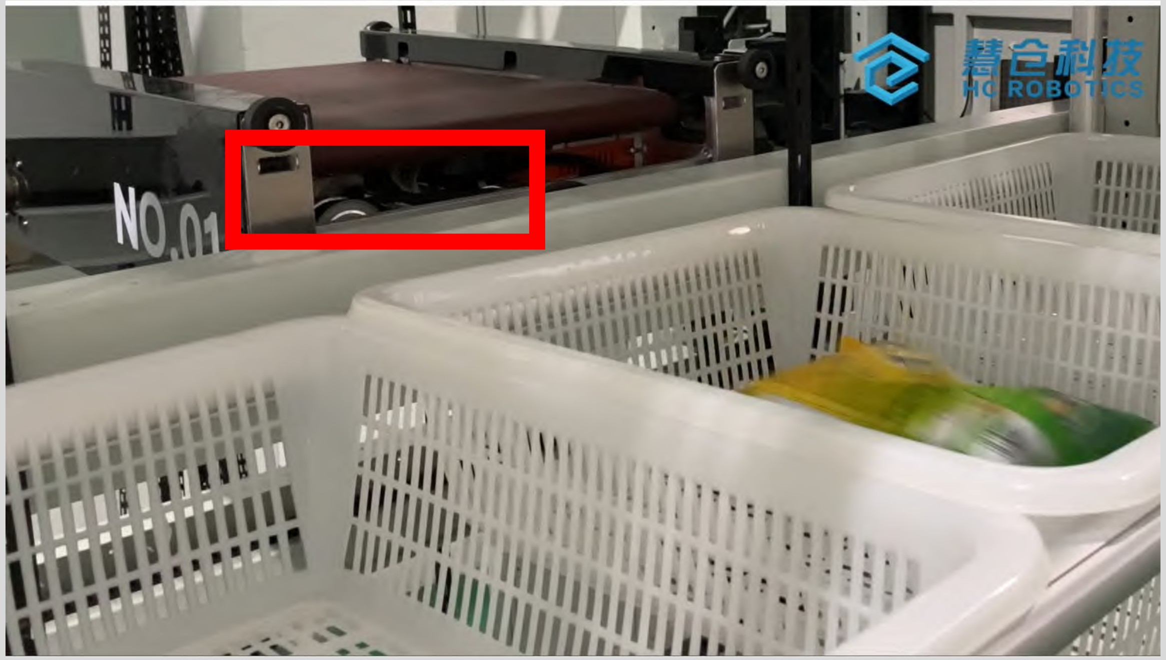
a motor for driving the drive system; and	The Accused Product comprises a motor for driving the drive system.  *Automated Put Wall Solutions.*  *OmniSort English Webpage.*

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

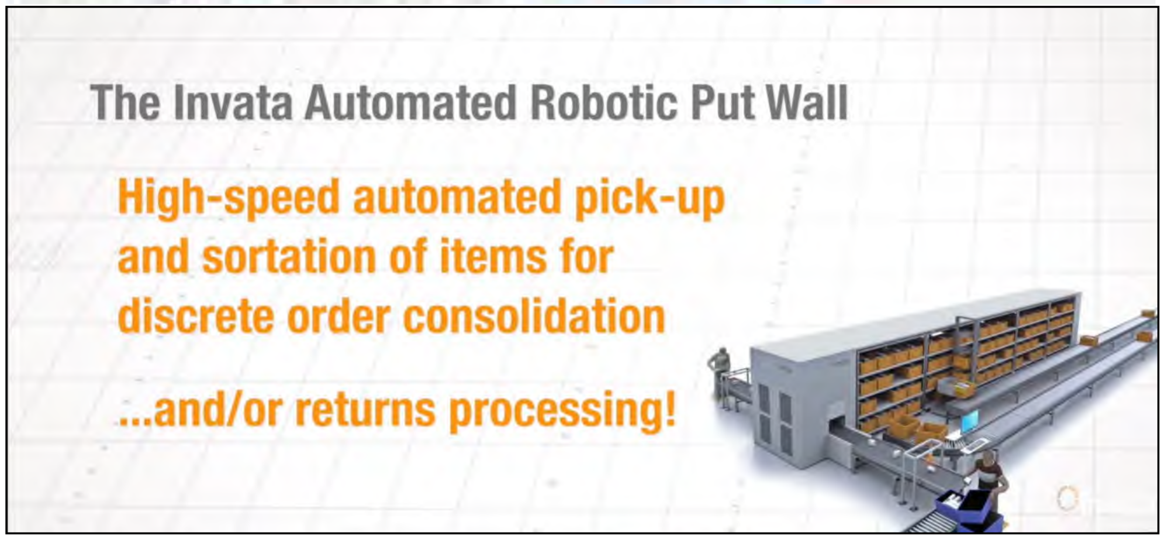
a controller for receiving signals for controlling the motor to control the movement of the vehicles along the guide system.	The Accused Product comprises a delivery vehicle wherein the delivery vehicle comprises a controller for receiving signals for controlling the motor to control the movement of the vehicles along the guide system. Fill a Lot More Orders — a Whole Lot Faster! The Invata Automated Put Wall enables high-speed automated pick-up and sortation of picked items for discrete order consolidation purposes. In doing so, it more than doubles (2x+) the put rate of manual put walls and increases the number of orders that can be processed at the same time by over 700%. The impressive efficiencies of the automated put wall translate to put rates of 1800 - 2200 units per hour (human v. robotic induction) and processing capabilities for up to 500 orders at once. 

Exhibit S: Claim chart comparing U.S. Patent No. 11,192,144 to Respondents' OmniSort Product

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	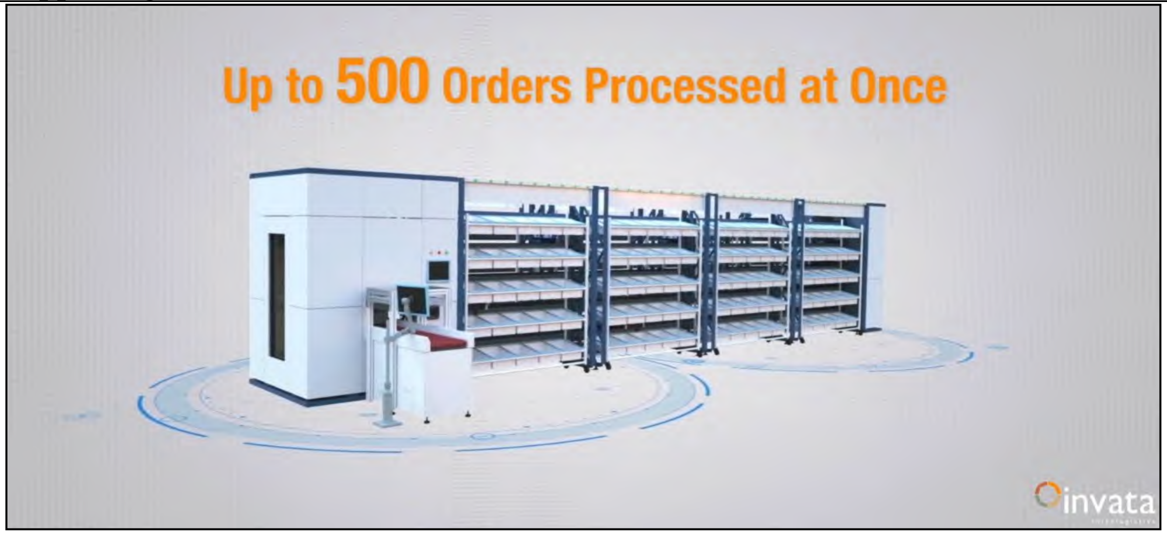 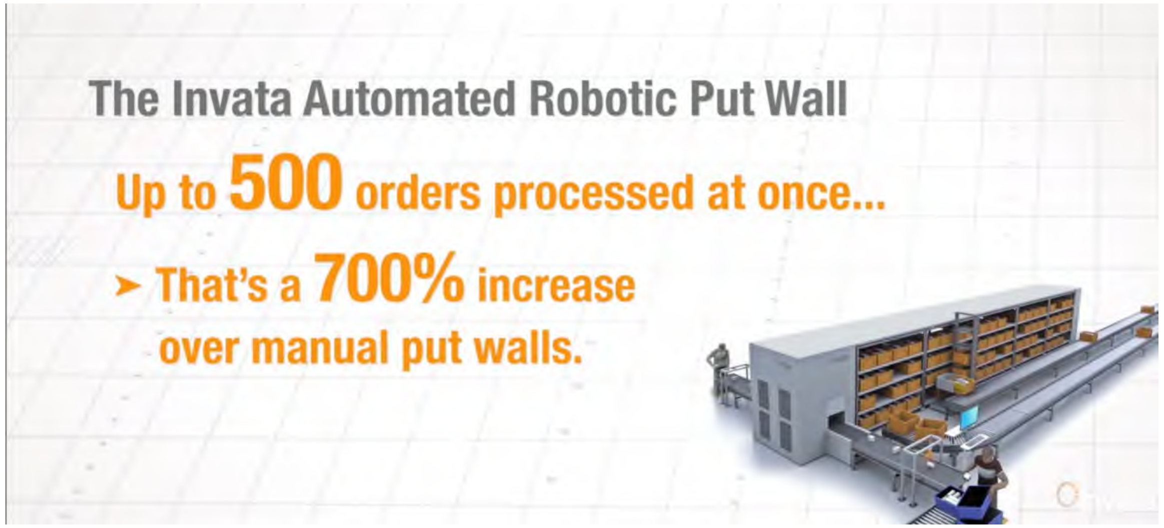 *Automated Put Wall Solutions.*