CLAIMS

We claim:

1. A method for delivering items to storage locations and retrieving items from storage locations, comprising the steps of:

providing a plurality of storage racks spaced apart from one another forming a plurality of aisles, wherein each storage rack comprises a plurality of columns and each column comprises a plurality of storage locations;

providing a plurality of delivery vehicles wherein each vehicle comprises a horizontal drive system operable to drive the vehicle along a horizontal surface, a vertical drive operable to drive the vehicle vertically and a transfer mechanism operable to transfer an item between the vehicle and one of the storage locations;

driving a first one of the vehicles to drive the first vehicle to the storage racks;

driving the first vehicle along a first path under a first one of the racks wherein the first rack is adjacent a first one of the aisles and wherein the first path extends in a direction parallel to the first aisle and spaced apart from the first aisle;

turning the first vehicle while the first vehicle is under the first rack;

driving the vehicle into the first aisle;

driving the first vehicle upwardly in the aisle to a first of the storage locations;

transferring an item between the first vehicle and the first storage location;

driving the first vehicle downwardly in the aisle until the vehicle is on a horizontal surface;

driving the first vehicle across the first aisle after the step of driving the first vehicle downwardly; and

driving the vehicle out from under the storage racks after the step of driving the first vehicle across the first aisle.

2. The method of claim 1 wherein a plurality of vertical posts form a first column of the first storage rack and wherein the first vehicle has a first width extending from a first side of the first vehicle to a second side of the first vehicle and wherein the vertical drive of the first vehicle projects outwardly from the first side and the second side so that the vehicle has a second width corresponding to the distance between outer edges of the vertical drive so that the second width is greater than the first width and wherein the vertical

posts of the first column are spaced apart a distance greater than the first width and less than the second width.

3. The method of claim 1 or 2 wherein a plurality of vertical tracks segments are attached to vertical posts of the first column and wherein the step of driving the first vehicle into the first aisle comprises aligning the vertical drive of the first vehicle with the vertical track segments.

4. The method of claim 3 wherein the step of driving the first vehicle into the aisle comprises driving a first portion of the vertical drive through the vertical track segment and driving a second part of the vertical drive into operative engagement with the vertical track segment.

5. The method of claim 1 wherein the first storage rack is formed of a plurality of vertical posts and the first vehicle has a length and a width and the length is greater than the width and wherein the step of driving the first vehicle along the first path comprises driving the vehicle along a path spaced apart from the vertical posts by a distance greater the half the length of the vehicle.

6. The method of any of claims 1-5 comprising the step of driving the first vehicle to a workstation to present an item to an operator after the step of driving the first vehicle out from under the storage racks.

7. The method of any of claims 1-6 wherein the step of driving the first vehicle across the aisle comprises driving the first vehicle under a second of the storage racks.

8. The method of any of claims 1-7 wherein the step of turning comprises rotating the first vehicle about a vertical axis that extends through the first vehicle.

9. The method of claim 8 wherein the vertical axis extends through the first path.

10. The method of any of claims 1-9 comprising the step of driving a second of the vehicles under the first rack along a second path parallel to the first path so that the second vehicle passes the first vehicle as the first vehicle travels along the first path.

11. A material handling system for delivering items to storage locations and retrieving items from storage locations, comprising:

a first storage rack having a plurality of columns each of which comprises a plurality of storage locations wherein the first storage rack is longitudinally elongated;

a second storage rack having a plurality of columns each of which comprises a plurality of storage locations wherein the second storage rack is longitudinally elongated, wherein the second storage rack is spaced apart from the first storage rack to provide an aisle between the first and second storage racks;

a plurality of delivery vehicles wherein each vehicle has a length and a width and each vehicle comprises:

a horizontal drive system operable to drive the vehicle along a horizontal surface;

a vertical drive operable to drive the vehicle vertically; and

a transfer mechanism operable to transfer an item between the vehicle and one of the storage locations;

a track positioned in the aisle wherein the vertical drive is configured to cooperate with the track to drive the vehicle vertically upwardly;

a first horizontal path that extends under the first rack in a direction parallel to the aisle;

a second horizontal path that extends under the first rack in a direction parallel to the aisle;

wherein the horizontal drive is configured to turn the vehicle under the first rack by rotating the vehicle about a vertical axis that extends through the vehicle;

wherein the storage rack comprises a plurality of vertical posts and the first and second horizontal paths are each spaced apart from the vertical posts a distance greater the one half the length of the vehicles;

wherein the first horizontal path under the path is spaced apart from the first horizontal path a distance greater than the width of the vehicles.

12. The system of claim 11 wherein the vertical drive comprises a plurality of rotatable elements that each rotate about a horizontal axis and wherein the horizontal drive comprises a plurality of rotatable elements that each rotate about a horizontal axis transverse the axes of rotation of the vertical drive elements.

13. The system of claim 12 wherein the plurality of vertical posts form a first column of the first storage rack and wherein the vehicles have a first width extending from a first side of the vehicle to a second side of the vehicle and wherein the vertical drive of the vehicle projects outwardly from the first side and the second side so that the vehicle has a second width corresponding to the distance between outer edges of the vertical drive so that the second width is greater than the first width and wherein the vertical posts of the first column are spaced apart a distance greater than the first width and less than the second width.

14. The system of any of claims 11-13 wherein the track comprises drive elements configured to cooperate with the vertical drive so that rotating the vertical drive about a horizontal axis operates to drive the vehicle upwardly along the track.

15. The system of claim 14 wherein the track comprises a lower section and an upper section wherein the drive elements are spaced apart further in the lower section then the upper section to provide gaps in the lower section.

16. The system of claim 15 wherein the gaps are configured to facilitate the vertical drive passing through the gaps without contacting the lower section when the vehicle is driven past the lower section.

17. A method for delivering items to storage locations and retrieving items from storage locations, comprising the steps of:

providing a vehicle having a horizontal drive and a vertical drive comprising a forward rotatable element adjacent a front end of the vehicle and a rearward rotatable element adjacent a rear end of the vehicle;

providing a first vertical track on a first side of a first column wherein the first vertical track has drive elements configured to cooperate with the forward rotatable element to drive the vehicle upwardly;

providing a second vertical track on a second side of the first column wherein the second vertical track has drive elements configured to cooperate with rearward rotatable element to drive the vehicle upwardly, wherein the vertical drive and the first and second vertical tracks are configured so that the vertical track impedes displacement of the vehicle along a horizontal path when the vertical drive is rotated into a position of misalignment;

aligning the vertical drive, wherein the step of aligning comprises the steps of:

rotating the forward rotatable element about a horizontal axis substantially parallel with the horizontal path to align the forward rotatable element with gaps in the first and second vertical tracks; and

rotating the rearward rotatable element about a horizontal axis substantially parallel with the horizontal path to align the rearward rotatable element with gaps in the first and second vertical tracks;

after the step of aligning, driving the vehicle along the horizontal path toward the first vertical track, wherein the step of driving comprises driving the vehicle so that the forward rotatable element passes through the gaps in the second vertical track;

continuing to drive the vehicle along the horizontal path to position the forward rotatable element in operative engagement with first track and the rearward rotatable element in operative engagement with the second track;

rotating the forward and rearward rotatable elements to drive the vehicle upwardly toward a first storage location;

transferring a first item from the first storage location to the vehicle;

driving the vehicle down with the first item;

driving the vehicle with the first item along the horizontal path so that the rearward rotatable element passes through gaps in the first vertical track.

18. The method of claim 17 wherein the step of rotating the forward and rearward rotatable elements comprises synchronously driving the forward and rearward rotatable elements to drive the vehicle vertically upwardly while maintaining the orientation of the vehicle relative to the horizon.

19. The method of claim 17 or 18 comprising the step of driving the vehicle out from under the track after the step of driving the vehicle with the first item along a horizontal path.

20. The method of any of claims 17-19 comprising the step of turning the vehicle to a path perpendicular to the horizontal path while the vehicle is under one of the racks.

21. The method of any of claims 17-20 comprising the step of driving the vehicle with the first item to a workstation to present the first item to an operator.

22. The method of any of claims 17-21 wherein the step of driving the vehicle along the horizontal path comprises driving a plurality of horizontal drive elements about a horizontal axis that is substantially perpendicular to the horizontal path.

23. A method for delivering items to storage locations and retrieving items from storage locations, comprising the steps of:

providing a plurality of storage racks spaced apart from one another forming a plurality of aisles, wherein each storage rack comprises a plurality of columns and each column comprises a plurality of storage locations;

providing a plurality of delivery vehicles wherein each vehicle comprises a horizontal drive system operable to drive the vehicle along a horizontal surface, a vertical drive operable to drive the vehicle vertically and a transfer mechanism operable to transfer an item between the vehicle and one of the storage locations;

driving a first of the vehicle under one or more of the storage racks along a path that crosses one or more aisle, wherein the step of driving the first vehicle includes driving the first vehicle into a first of the columns in a first of the aisles;

driving the first vehicle vertically upwardly within the first aisle until the first vehicle is adjacent a first of the storage locations;

transferring an item from the first storage location to the first vehicle;

driving the first vehicle vertically downwardly within the first aisle;

driving the vehicle out of the first aisle via a path that extends under at least one of the storage racks.

24. The method of claim 23 wherein the path includes a portion passing under one of the racks and extending parallel to one of the aisles.

25. The method of claim 24 comprising the step of driving a second of the vehicles past the first vehicle under the one rack as the first vehicle is driven along the portion of the path under the one of the racks.

26. The method of any of claims 23-25 comprising the step of turning the vehicle while the vehicle is under one of the racks, wherein the step of turning comprises turning the vehicle to align the vehicle with a path perpendicular to the first aisle.

27. The method of claim 26 wherein the step of turning the vehicle comprises rotating the vehicle about a vertical axis passing through the vehicle.