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Whitenack, Jr.

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[54] **SHUTTLE TRANSFER WITH SINE WAVE TIME/VELOCITY ACCELERATION**

[75] Inventor: **Taylor D. Whitenack, Jr.,** Bonita, Calif.

[73] Assignee: **Rohr Industries, Inc.,** Chula Vista, Calif.

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[52] **U.S. Cl.** .... **74/29,** 214/16.4 A

[51] **Int. Cl.** **F16h 19/04**

[58] **Field of Search** .... 74/29, 30, 422; 214/16.4 A, 16.1 C

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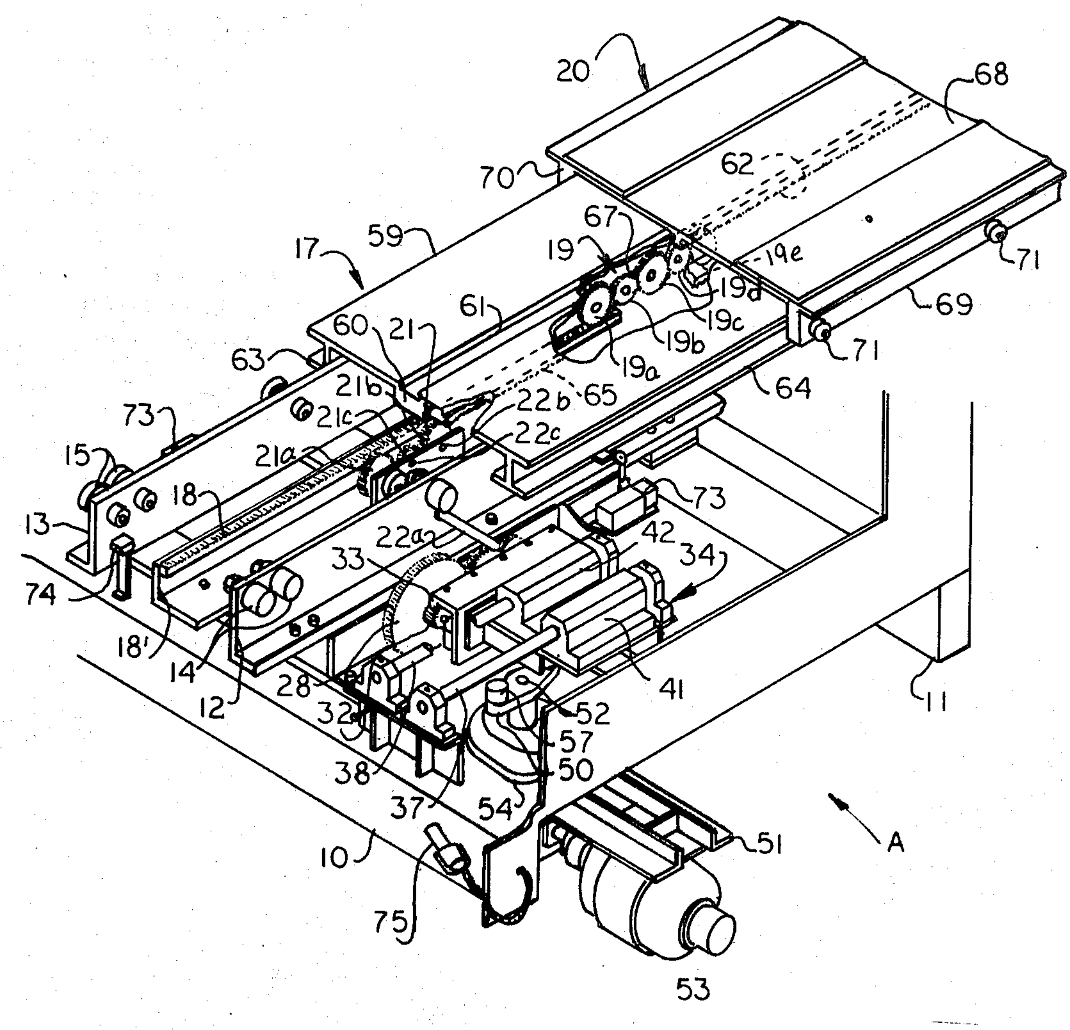
Primary Examiner—Manuel A. Antonakas
Assistant Examiner—Wesley S. Ratliff, Jr.
Attorney—George F. Pearson

[57] **ABSTRACT**

A stacker crane elevator has drive mechanism for extending a two-part load bearing shuttle from centered position on the elevator into a selected pigeonhole of an automated warehouse and vice versa. The drive mechanism accelerates and decelerates the shuttle in a sine curve time/velocity ratio by means of two crank-like drive pins mounted on a rotative head member and interposed one between each of two parallel drive faces. Orbital movement of the crank pins through circular arcs of 180° rotative movement of the head member produces acceleration of the shuttle from zero velocity through maximum and back to zero in a sine wave curve which tends to equalize acceleration throughout shuttle travel and thus to minimize displacement of a load on the shuttle.

10 Claims, 4 Drawing Figures



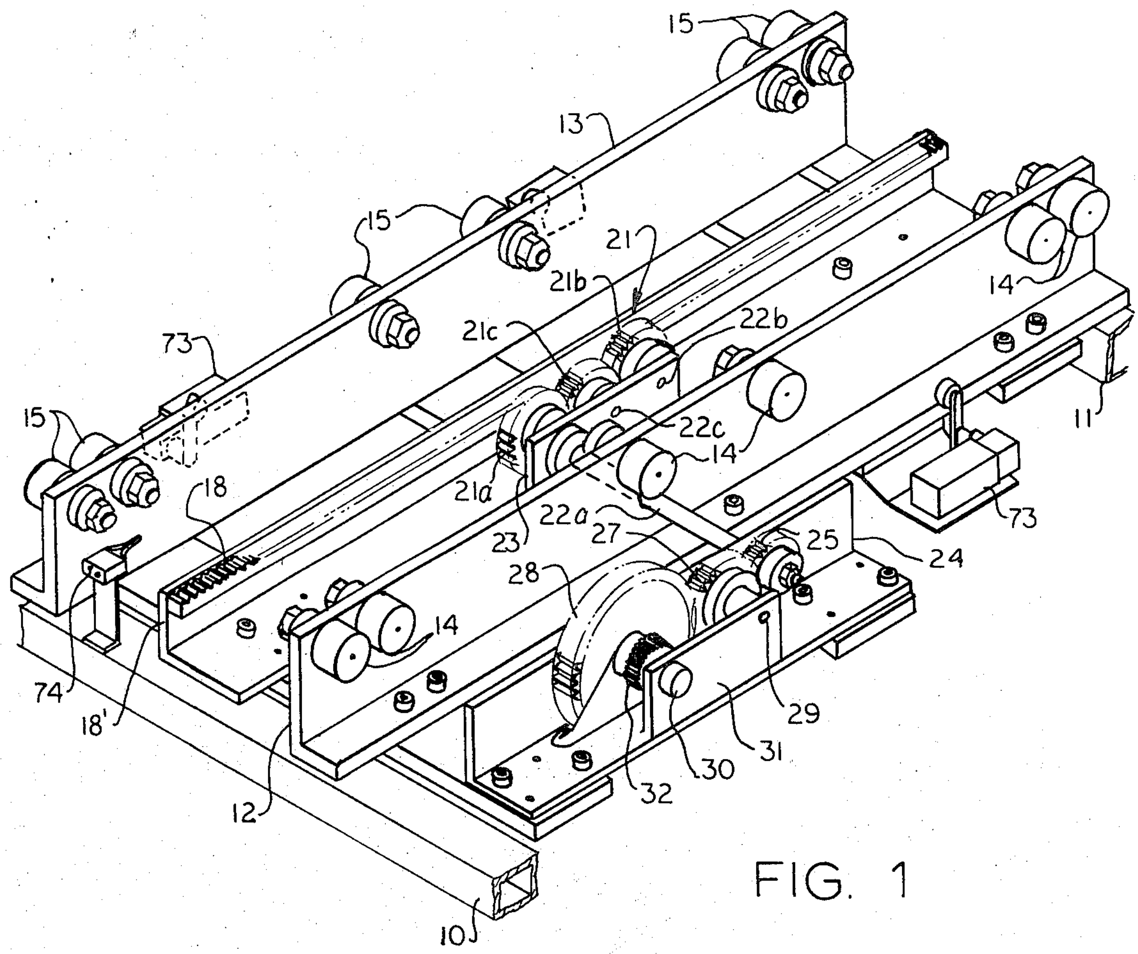

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FIG. 1

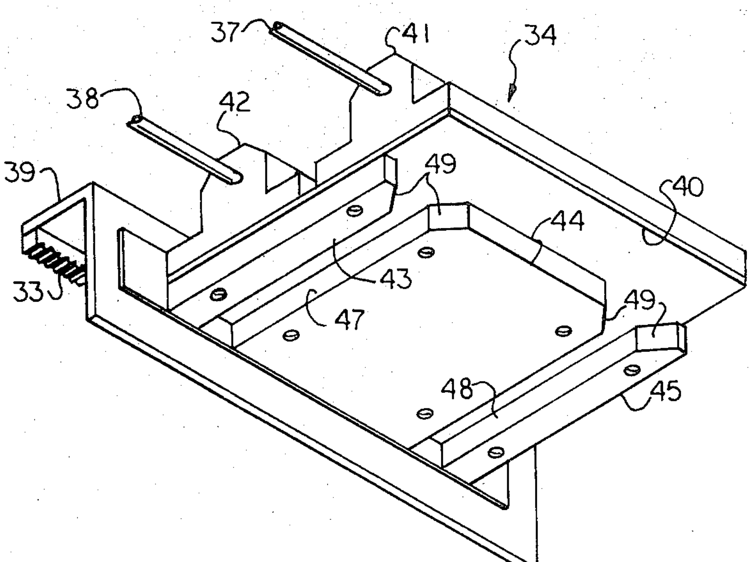
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FIG. 2

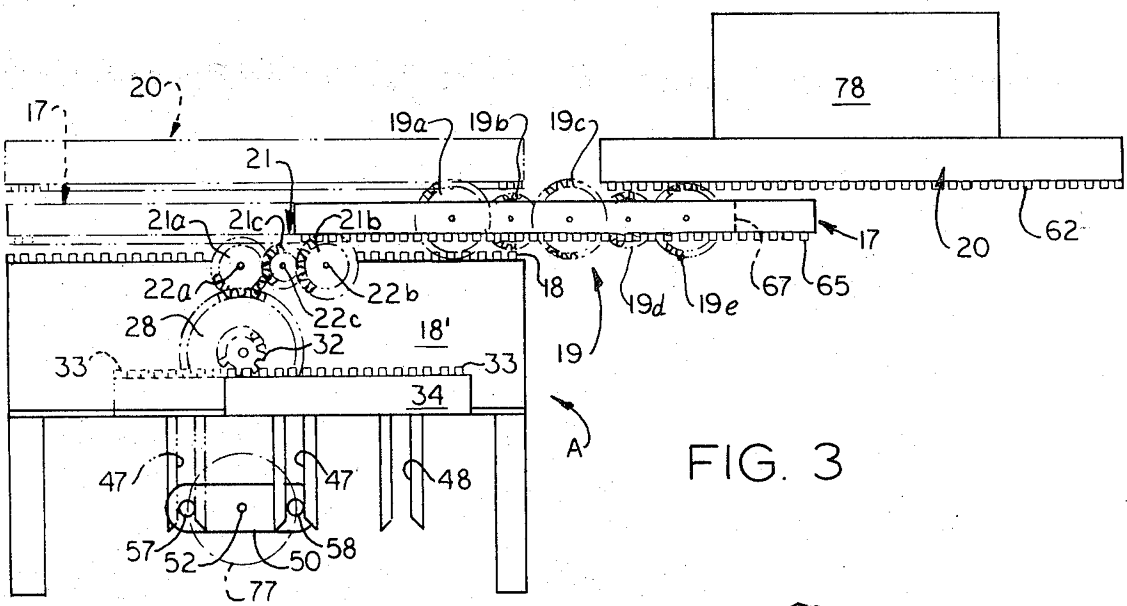
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FIG. 3

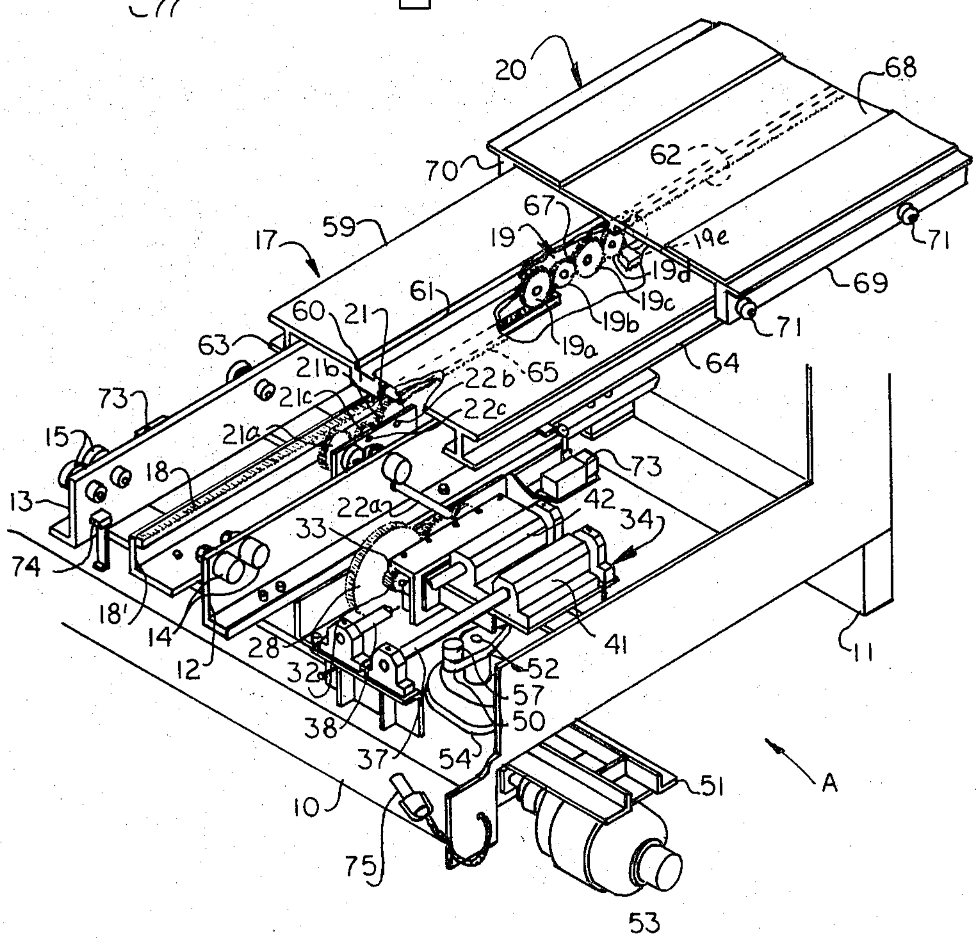
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FIG. 4

SHUTTLE TRANSFER WITH SINE WAVE TIME/VELOCITY ACCELERATION

BACKGROUND OF THE INVENTION

In an automated warehouse where loads are transferred from conveyors to stacker cranes and thence to selected pigeonholes in racks provided along aisles in which the stacker cranes operate, and vice versa, speed in all phases of the operation tends to minimize costs and maximize the utility of the installation. An important factor in the attainment of speed in the operation is the provision of a high speed shuttle on the usual elevator of the stacker crane which will quickly transfer a load between the elevator and a selected pigeonhole.

With conventional shuttle drive means, using a drive motor operating through gears or chains to transmit the driving force from the motor to the shuttle, and a brake or reverse drive mechanism to arrest shuttle motion at the terminal end of each shuttle movement, high acceleration and deceleration forces may be generated, tending to shift a pallet on the suttle and a load on its pallet. Many stacker cranes with high speed shuttles now use two-speed motors in an attempt to minimize such positioning errors, but even then displacement errors of ⅜ inch are normal, increasing to ½ inch in the case of a heavy load and light brake. In a prior development of mine, I produced a shuttle drive mechanism using crank pins and chains to produce a modified sine curve acceleration and deceleration of shuttle movement, but in that mechanism the sine curve ratio existed only during the initial and terminal portions of shuttle movement so that the acceleration forces were still higher than desired.

PURPOSE OF THE INVENTION

A primary objective of the present invention is to provide drive mechanism for a high speed shuttle for a warehouse stacker crane which will alternately accelerate and decelerate the shuttle on a sine wave time/velocity curve throughout the duration of each shuttle movement.

Another objective of the invention is to drive a loaded shuttle between substantially centered position on a stacker crane elevator platform, and extended position into a pigeonhole, and vice versa, in a minimum time interval and with low, and relatively constant, acceleration forces throughout such time interval to thereby minimize shifting of a load carried by the shuttle.

The invention also provides a high speed shuttle drive mechanism with a fixed dwell point at each limit of shuttle movement, which facilitates stopping the shuttle in an exact, predetermined position at each such limit of shuttle movement.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing objectives and advantages of the invention will be apparent from the following description and the accompanying drawings, wherein:

FIG. 1 is a perspective view of the base, or platform mounted portion of a shuttle drive mechanism embodying the invention as it appears when mounted on the elevator platform of a stacker crane.

FIG. 2 is a perspective view showing the under side of the drive block or slider of the entire mechanism shown in FIG. 4, portions of the slide rods upon which the drive block is mounted being broken away.

FIG. 3 is a diagrammatic view in the nature of a side elevational view of the shuttle drive mechanism, the intermediate and top shuttle members being shown retracted in broken lines, and extended toward the right in solid lines, intermediate, direction reversing pinions being omitted, some changes being present in the rack and drive gears for the sake of simplicity.

FIG. 4 is a perspective view of the shuttle and its drive mechanism with the shuttle extended toward the right, portions being broken away.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to the drawings in detail, a usual elevator A, see FIG. 3, of a stacker crane of a type used in automated warehouses comprises two side frame members **11** and **10.** A pair of guide roller support members **12** and **13** of steel angle material are secured transversely across the elevator frame members **10** and **11,** and two pluralities of guide rollers **14** and **15** are mounted in aligned, axially parallel rows along the outer sides of these roller support members to provide rolling support for an intermediate shuttle member **17,** see FIG. **4,** to be described in detail later herein.

An upwardly facing toothed rack **18** is secured to an angle member **18'** mounted parallel to the roller supports **12** and **13,** transversely across the frame members **10** and **11.** The rack **18** is positioned to drive a gear train **19,** see FIG. **4,** carried by the intermediate shuttle **17,** and in turn drives a load supporting shuttle **20** in a manner also to be described later herein.

A second gear train **21** comprises a pair of drive gears ***21a*** and ***21b*** of equal diameter with an intermediate idler pinion ***21c*** of smaller diameter therebetween. The gears ***21b*** and ***21c*** are journaled on stub shafts ***22b,*** and ***22c,*** respectively mounted on a plate **23** secured to the elevator frame.

The gear ***21a*** is secured to a shaft ***22a*** which extends through the plate **23** and also through the roller support member **12,** and an angle plate **24** is secured to the elevator frame as best shown in FIG. **1.** A pinion **25** is fixedly secured to the other end of this shaft ***22a*** from the gear **21a**, the pinion **25** being in mesh with an idler pinion **27,** which in turn is in mesh with a drive gear **28.** The idler pinion **27** and drive gear **28** are journaled on short shafts **29** and **30,** respectively, see FIG. **1,** mounted to extend between the angle member **24** and a plate **31** secured to said angle member. A pinion **32,** see FIGS. **2** and **3,** is also secured to the gear shaft **30,** and is in mesh with a drive rack **33,** see FIGS. **2** and **4,** which is part of a slider **34** mounted for slidable movement along a pair of parallel guide rods **37** and **38** rigidly mounted on the elevator frame.

The slider **34,** as best shown in FIG. **2,** comprises an angle member **39** to which the drive rack **33** is secured, and a plate portion **40** secured at right angles to an upright portion of the angle member **39.** A pair of slide bearings **41** and **42,** preferably of the well known ball bearing type, are secured in axially parallel relation to the upper side of the plate portion **40,** and three guide blocks **43, 44,** and **45** are secured to the lower side of the plate portion **40.** The guide blocks **43** and **45** are spaced equally from the center guide block **44** to provide therebetween two pairs of parallel drive faces **47** and **48** of equal width throughout their respective lengths with the exception of their open ends, which are flared by cutting corner portions from the blocks as at **49** for a purpose which will be apparent later herein.

The slider 34 is driven between selected positions along the guide rods 37 and 38 by a motor driven, rotatively mounted head member 50, see FIGS. 3 and 4, mounted on a sub-frame 51, see FIG. 4, secured to the elevator frame. The head member 50 is secured centrally thereof to a power driven shaft 52, which is reversibly driven in selected increments of 180° in either direction from a selected center position by an electric motor 53, see FIG. 4, driving through a conventional reduction gear transmission mechanism 54, also mounted on the sub-frame 51.

A pair of drive pins 57 and 58, which may be conventional ball bearings mounted on studs, are provided one on each end of the head member 50, axially parallel to, and at equal radial distances from the axis of the shaft 52. These drive pins are of a diameter to enter between the pairs of drive faces 47 and 48 with slight clearance therefrom, and are spaced apart by the same distance as the pairs of drive faces 47 and 48. The centered position of the head member 50 is with the pins 57 and 58 in the entrance ends between their respective pairs of drive faces 47 and 48 with the shuttles 17 and 20 in their centered position on the elevator as shown in broken lines in FIG. 3.

The intermediate shuttle 17, see FIGS. 3 and 4, comprises a horizontal plate portion 59, see FIG. 4, with a thickened central bottom rib 60 and a central top groove 61 extending in the direction of shuttle movement, the groove providing operating clearance for a rack 62 mounted on the under side of the top shuttle member 20. A pair of H-section members 63 and 64, see FIG. 4, are provided one along the under side of each side edge of the plate portion 59, and the rollers 14 and 15 on the angle members 12 and 13 are fitted for rolling, supporting movement within the inwardly open channels of these members.

A downwardly facing rack 65, see FIGS. 3 and 4, is secured to the under side of the plate portion 59 on the near side of the rib 60 as viewed in FIG. 4 to mesh with the drive gears 21*a* and 21*b* of the gear train 21 described previously herein. The idler pinion 21*c* between the drive gears 21a and 21b, being of smaller diameter, clears the rack 65. Thus, a 180° clockwise rotative movement of the head member 50 from its normal, centered position, see FIG. 3, by means of the pin 58 riding in the guideway 47, moves the slider 34 with its drive rack 33 from its broken line position of FIG. 3 to its solid line position of the same figure, which is also the position shown in FIG. 4. During this slider movement the drive rack 33, through the pinion 32, see FIGS. 2 and 4, drive gear 28, pinions 25 and 27, shaft 22*a* and gears 21*a* and 21*b*, drive the intermediate shuttle member 17 from its centered position on the elevator to its extended position of FIGS. 3 and 4. In the simplified diagram of FIG. 3, the drive rack 33 is shown as positioned below the pinion 32, and the gear 28 in mesh with the gear 21*a*. From the gear 21*a*, however, the mechanism of FIG. 3 operates similarly to that of FIG. 4.

An opening 67, see FIG. 4, is provided through the central rib 60 of the plate 59 medially of the length of the groove 61, and the gear train 19, comprising the three gears 19*a*, 19*c*, and 19*e*, with their smaller, intermediate idler pinions 19*b* and 19*d* interposed therebetween, are journaled on short shafts extending transversely across this opening 67, with the gears 19*a*, 19*c*, and 19*e* aligned to mesh with the fixed base rack 18, and also with the rack 62 of the top or load bearing shuttle 20.

The latter shuttle comprises a plate portion 68 with a pair of side bars 69 and 70 secured one along each side edge thereof. A row of aligned rollers, not shown, are journaled on mounting studs 71, see FIG. 4, along the inner side of each of the side bars 69 and 70, and ride with slight clearance in the outer grooves of the H-section side members 63 and 64 of the intermediate shuttle 17. These rollers support the top shuttle 20 for free relative movement along a path parallel to that of the intermediate shuttle 17.

Various safety features are provided in the illustrative embodiment of the invention, such as shuttle limit switches 73, see FIGS. 1 and 4, a supersonic sensor 74 which "sounds out" a pigeonhole to insure that it is not already occupied before operating the shuttle drive mechanism, and a photo cell 75, one of which is provided on each side of the elevator to insure that no part of the shuttle or its load is projecting beyond the platform before movement of the stacker crane is initiated. These devices, however, are not features of the present invention, and the details thereof are, therefore, omitted.

OPERATION

The operation of the illustrative form of the invention is best visualized by reference to the diagram of FIG. 3 which for simplicity, omits much of the supporting structure, including the shuttle supporting rollers, and also shows the drive rack 33 as mounted below the pinion 32, and the gear 28 in mesh directly with the gear 21*a*, omitting the intermediate pinions.

Assume that initially the head member 50 is in its illustrated position of FIG. 3, but reversed counterclockwise 180° so that the drive pin 58 is on the left. In such reversed position of the head member, the drive rack 33, the intermediate shuttle 17, and the top shuttle 20 are all in their retracted, broken line positions of the same figure.

Assume next that the head member 50 is rotatively driven clockwise 180° to achieve end-for-end reversal of the head member during which reversal the drive pin 58, which was initially at the left hand end of the head member, has now swung up and over along the broken line circle 77 of FIG. 3, riding in the left hand guideway 47, and moving the slider 34 to its right hand, olid line position of FIG. 3. During this movement of the slider with its drive rack 33, the drive gears 21*a* and 21*b* have been rotatively driven clockwise by the gear 28 to extend the intermediate shuttle 17, by means of its rack 65, to its right hand solid line position of FIGS. 3 and 4.

During this extending movement of the intermediate shuttle 17, the gears 19*a*, 19*c*, and 19*e*, carried by the intermediate shuttle 17 and in mesh with both the fixed rack 18 and the rack 62 of the top huttle 20, extend the top shuttle member 20 relative to the intermediate shuttle 17 to its right hand solid line position of FIGS. 3 and 4, which carries it and a load 78, see FIG. 3, supported thereon, into a pigeonhole, not shown, with which it is aligned.

Reverse or counterclockwise rotative movement of the head member 50 through an arc of 180° from its solid line position of FIGS. 3 and 4 returns the shuttle members 17 and 20 to their centered, broken line positions of FIG. 3, while a further 180° rotative movement, not shown, of the head member **50** in the same counterclockwise direction will extend the shuttles **17** and **20** toward the left in the same manner as described previously herein for their extension toward the right.

Assuming that the speed of rotative movement of the head member **50** is constant throughout each 180° of its movement, the rack and pinion drive mechanisms and the shuttles **17** and **20** will, in accordance with well known formulae, accelerate during the first 90° of rotative movement of the head member **50**, and will decelerate during the second 90° of such movement, in a time/velocity sine curve, so that acceleration and deceleration of the slider **34** and the shuttles **17** and **20** driven thereby will be substantially uniform throughout each 180° of head member movement. Also, since the drive pins **57** and **58** move substantially tangent to the faces of the guideways **47** and **48** which they contact at each end of each such 180°of head member rotation, there is thus provided at least a momentary dwell at each end of shuttle travel which facilitates an exact positioning of the shuttles **17** and **20** at each end of their travel. The clipped corners **49** of the blocks **43, 44,** and **45** at the entrance to each guideway act to guide the pins **57** and **58** into their respective guideways.

The invention provides a simple and positive shuttle drive mechanism, with smooth, sine curve acceleration and deceleration, wherein high speed can be achieved with minimized acceleration forces, and wherein exact positioning of the shuttle at each end of shuttle travel is easily achieved.

Having thus described my invention, what I claim as new and useful and desire to secure by U.S. letters Patent is:

1. A shuttle transfer for the elevator platform of a stacker crane comprising,
 an intermediate shuttle mounted on the elevator platform for guided movement along a path extending transversely of the platform,
 a load bearing shuttle mounted for guided movement along a path parallel to that of the intermediate shuttle,
 primary drive means to alternately accelerate and decelerate the shuttle on a sine wave time/velocity curve throughout the duration of each shuttle movement, said primary drive means acting between the elevator platform and the intermediate shuttle and comprising at least one pair of parallel drive faces mounted for guided movement along a path perpendicularly intersecting both drive faces of each pair thereof, the drive faces of each pair thereof spaced apart to receive a crank-like drive pin therebetween,
 a head member mounted for controlled rotative movement back and forth about an axis through an arc of 180° from a selected centered position,
 at least one crank-like drive pin mounted on the head member at a selected radial distance from the axis of head member rotation and interposed between one pair of said drive faces, a radius from the axis of head member rotation to each crank pin being perpendicular to its respective pair of drive faces with the head member in its selected, centered position,
 means operatively interconnecting the drive faces to the intermediate shuttle to move the intermediate shuttle with said sine wave time/velocity acceleration from centered position on the elevator platform along its path of movement in a direction determined by that of the drive faces upon each 180° rotation of the head member, and
 drive means responsive to movement of the intermediate shuttle and operatively connected to the load bearing shuttle to move the latter from centered position on the intermediate shuttle along its path of movement relative to, in the same direction as, and at a speed proportional to, the intermediate shuttle upon each movement of the intermediate shuttle along its path of movement.

2. A shuttle transfer as claimed in claim 1 wherein the primary drive means accelerates the intermediate shuttle at a substantially uniform rate during the first 90° and decelerates the intermediate shuttle at a substantially uniform rate during the second 90°, of each 180° rotative movement of the head member.

3. A shuttle transfer as claimed in claim 1 wherein the elevator platform is provided with relatively fixed, transversely extending support means, and the intermediate shuttle is supported in guided relation on said support means for travel back and forth along its path from a position wholly overlying the platform to a position extending in a selected direction laterally therebeyond.

4. A shuttle transfer as claimed in claim 1 wherein at least one support member extends transversely of the elevator platform, a plurality of rollers are mounted in operative relation between each support member and the intermediate shuttle to provide rolling, guiding support for the intermediate shuttle along its path, the drive means responsive to movement of the intermediate shuttle comprises a first rack fixedly mounted to the elevator platform and parallel to said at least one support member, a second rack facing, spaced from, and parallel to the first rack and carried by the load bearing shuttle, and at least one gear, journaled on the intermediate shuttle and in mesh with both of said racks.

5. A shuttle transfer as claimed in claim 4 wherein said at least one gear comprises a gear train consisting of a plurality of gears of equal size aligned in a direction parallel to the paths of movement of the shuttle members, adjacent gears of said train spaced apart and operatively interconnected by pinions of smaller diameter than said gears, all of such pinions being clear of both of the racks.

6. A shuttle transfer as claimed in claim 1 wherein the parallel drive faces are mounted on a slider, which is guided for selective back and forth movement along the path defined therefor in claim 1, a first rack is actuated by the slider, a second rack is mounted on the intermediate shuttle, and gearing in mesh with both racks transmits movement of the slider to move the intermediate shuttle in a selected direction along its path.

7. A shuttle transfer for the elevator platform of a stacker crane comprising,
 an intermediate shuttle mounted on the elevator platform for guided movement along a path extending transversely of the platform,
 a load bearing shuttle mounted on the intermediate shuttle for guided movement along a path parallel to that of the intermediate shuttle,
 primary drive means to alternately accelerate and decelerate the shuttle on a sine wave time/velocity curve throughout the duration of each shuttle movement, said primary drive means acting between the elevator platform and the intermediate shuttle and comprising two pairs of drive faces

mounted parallel to each other for guided movement along a path perpendicularly intersecting all of said drive faces, the drive faces of each pair thereof spaced apart to receive a crank-like drive pin therebetween,

a head member mounted for rotative movement about an axis through an arc of 180°, selectively in either direction from a known centered position,

a pair of crank-like drive pins mounted on the head member at equal radial distances from, and on opposite sides of, the axis of rotation of the head member, each drive pin being interposed between a pair of said drive faces, each drive pin being located adjacent an end of its respective pair of drive faces and the radii from the axis of head member rotation to the drive pins being perpendicular to the drive faces with the head member in its centered position,

means operatively interconnecting the drive faces to the intermediate shuttle to move the intermediate shuttle with said sine wave time/velocity acceleration from centered position on the elevator platform along its path of movement in a direction determined by that of the drive faces upon each 180° rotation of the head member, and

drive means responsive to movement of the intermediate shuttle operatively connected to the load bearing shuttle and moving the latter relative to the same direction as, and at a speed proportional to, the intermediate shuttle upon each movement of the intermediate shuttle along its path of movement.

8. A shuttle transfer as claimed in claim **7** wherein the primary drive means comprises a slider mounted for guided, slidable movement along a fixed guide track, a plurality of blocks are secured to the slider, said blocks having straight sides spaced apart in parallel relation, adjacent, facing sides of adjacent ones of said blocks comprising said drive faces.

9. A shuttle transfer as claimed in claim **8** wherein the means operatively interconnecting the drive faces to the intermediate shuttle comprises a first rack mounted on the slider parallel to the guide track, a pinion in mesh with the first rack is journaled on the elevator platform, a second rack is mounted on the intermediate shuttle, and gearing in mesh with both racks transmits movement of the first rack to the second rack.

10. A shuttle transfer as claimed in claim **7** wherein the end portions of each pair of drive faces adjacent which the drive pins are located with the head member in its centered position are flared to guide a drive pin therebetween when entering a guideway upon selected rotative movements of the head member.

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