ARCUATE ESCALATOR SYSTEM

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Filed: Oct. 18, 1971

Appl. No.: 190,214

U.S. Cl. 198/16 R; 198/17; 198/136

Int. Cl. B66h 9/12

Field of Search: 198/16, 17, 18, 204, 136, 198/137, 189, 181, 182

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ABSTRACT

An arcuate escalator system having a readily fabricated and reliable construction is provided that also has advantageous aesthetic aspects. In a specific example, the escalator is of helical configuration, arranged around a central axis. Tapered step segments meeting all established safety standards for size, configuration and entry and exit paths are advanced along the helical path in the desired direction. In the return path, the step segments turn through small radii of curvature into and out of an intermediate substantially linear portion, for which purpose they may be tilted and partially nested relative to each other. The principal return path is a linear portion of the path, in this example, and passes through a center column around which the helical structure is arranged. The drive mechanism comprises a guided chain drive having both lateral and vertical freedom of movement, and coupled to the step edges by pivotally connected step links. Guide means for the step edges and the chain drive system control the inclination and curvature of the path. Radial forces generated during movement of the system are absorbed by a roller guide system along the chain drive.

29 Claims, 11 Drawing Figures
ARCUATE ESCALATOR SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to escalator systems, and more particularly to novel and improved escalators in which the step elements do not remain in the same plane but move in an arcuate path.

Escalators of the types most widely used commercially have almost entirely been of the linear form. That is, although the step elements move within a closed loop, the elements nonetheless remain within a given vertical plane during both the exposed or operative portion of the path, and the hidden return portion of the path. The escalator industry and safety authorities have developed extensive safety standards for the step elements, their size and relationship, the manner in which they move through a comb structure at the entry and exit portion, the various clearances involved, and the extent of the horizontal portions at the entry and exit ends.

It will be apparent to those skilled in the art that for space or esthetic considerations, or both, a circular or arcuate escalator might often be preferable to a linear escalator. For example, it may be desired to utilize the stairwells or elevator wells of existing buildings for new escalator systems. However, the angle of inclination required for a linear escalator cannot generally be accommodated in the horizontal space available in such instances, whereas a circular escalator system might be able to make use of the space available. Space considerations are very important where a system must traverse many floors, and where floor to ceiling height is considerable, as between the ground and mezzanine floors of large commercial buildings, and in such buildings as department stores. In addition, a circular escalator can have an entirely different and much more attractive symmetry and appearance than a linear escalator, and often would be justified for these reasons alone.

The advantages of a circular escalator cannot be realized at any sacrifice of safety considerations from the standpoint of the persons using the elevator, or at any sacrifice of reliability or esthetic considerations in the structure and mechanism itself. For example, step in the entry and exit regions and the principal ascending or descending portions cannot be modified significantly from existing standards. The return path for the step elements cannot be obstructive, or require complex step or guiding structures that would cause reliability and cost problems. The significant radial forces that are generated during movement of such a circular system must also be accounted for without undue complexity.

Although the principal discussion herein relates to the particularly stringent requirements imposed on passenger escalators, it is evident that such escalators merely comprise one type of conveyor system. Novel systems and devices in accordance with the invention can be of utility in conveyor systems in which space or functional considerations may require that curvilinear paths, particularly those with different radii of curvature, are to be followed.

SUMMARY OF THE INVENTION

An arcuate escalator in accordance with the invention comprises a plurality of tapered step elements that are moved along a path having regions of different radii of curvature that may include a linear portion. In the regions of smallest radii of curvature, the step elements are tilted or shifted into a slightly nested relationship. A guided drive system moves substantially but not precisely parallel to the path of the step elements, and has both vertical and horizontal freedom of movement, so as to accommodate the different radii of curvature and the tilting action of the step elements.

The ability of this system to accommodate limited but meaningful changes in three dimensions of the relationships between adjacent steps permits a wide variety of system configurations. The operative portion may be continuous or segmented, for example, while the return path may be entirely curved or include a linear portion. The return path may be centrally disposed or offset relative to the remainder of the structure. The length of the path may be virtually arbitrarily long, so that one or a number of floors in a building may be traversed by the same closed loop chain and step element system.

In a preferred example of a system in accordance with the invention, a circular escalator having adjacent up and down step portions has an exposed or operative portion extending helically around a center column. The step elements move substantially vertically through the center column in a return path forming a complete closed loop. In the exposed operative portion the step elements are supported and guided on each lateral edge by guide tracks which bear the weight of the passengers. An adjacent chain drive for the step elements is driven in sprocket fashion and includes roller means for absorbing centripetal forces in the system. Step links are pivotally coupled to individual ones of the step elements and to different spaced apart elements of the chain drive, and provide the mechanical drive coupling for the step elements while also being guided so as to define the closed loop path and support the elements in the return path. The connection between the guide means, chain drive, step elements and step links controls the motion of the step elements in terms of vertical movement, curvature about the central axis, and tilting action.

A number of additional advantageous features are provided in systems in accordance with the invention. A chain drive having at least two orthogonally disposed degrees of freedom of movement in a plane perpendicular to the main longitudinal path of the chain drive comprises a number of substantially rectangular elements each having a pair of internal sockets and a side sprocket hole. The chain elements are interconnected by rod elements that have terminating ball portions disposed within the sockets and pivotally movable therein. A sprocket drive disposed along a substantially horizontal portion of the path of the step elements engages the elements of the chain drive in a planar portion of the chain path. A separate drive is provided for substantially conventional hand rails.

In another arrangement in accordance with the invention, spaced apart operative elevator segments of substantially helical configuration each traverse a different floor level. Substantially horizontal transition segments interconnect the helical segments, and a single return path is used between the highest and lowest points in the system.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the invention may be had by reference to the following description, taken in conjunction with the accompanying drawings, in which:
FIG. 1, comprising adjacent portions FIG. 1A and FIG. 1B that are to be laid side by side and viewed from the side with FIG. 1A above, comprises a broken away perspective view of an arcuate escalator system in accordance with the invention.

FIG. 2 is a simplified fragmentary view of a part of the system of FIG. 1, showing the relative dispositions of the stair elements as they traverse through the return path in the arrangement of FIG. 1.

FIG. 3 is a simplified perspective view of step elements and a chain drive in the system of FIG. 1, showing the relative dispositions thereof along a transitional portion of the stair element path.

FIG. 4 is a simplified sectional front elevation view of a part of one escalator path at an entry region in the system of FIG. 1.

FIG. 5 is a side view of a fragment of the system of FIG. 1 showing details of a hand rail drive that is utilized therein.

FIG. 6 is a perspective, partially exploded, view of a step element guide and drive assembly for the arrangement of FIG. 1.

FIG. 7 is an exploded perspective view of a portion of the chain drive system in the system of FIG. 1, showing details of a chain drive element.

FIG. 8 is a simplified plan view of inner and outer step elements used in the system of FIG. 1, showing the relative sizes and configurations thereof in a practical example, with the step elements being shifted to parallel positions for purposes of depiction.

FIG. 9 is a side view of individual step elements of FIG. 8.

FIG. 10 is a side elevation, partially broken away, of a different arcuate escalator system in accordance with the invention.

DETAILED DESCRIPTION

A preferred example of a system in accordance with the invention is shown in its essential aspects in FIG. 1, comprising FIGS. 1A and 1B, to which reference is now made. The drawings of FIGS. 1A and 1B are to be viewed from the long side, with FIG. 1A above and FIG. 1B immediately adjacent and below. It will be appreciated that the details of the support structure or reinforcing system, as well as exterior finish and construction, have not been shown in detail in order to simplify the representation and inasmuch as these may take a variety of different forms. However, it will also be appreciated that the system shown in FIG. 1 comprises a centrally supported, smoothly varying and uncluttered structure having a combination of linear and curvilinear shapes that presents a pleasing and unusual esthetic effect.

In FIG. 1, the arcuate escalator 10 includes a central vertical core 12 of substantial diameter, typically having a hollow interior and including a structural beam frame structure 14 about its periphery. Radial structural beam members 16 and radial trusses 17 coupled to the frame 14 within the core 12 are arranged to define an arcuate base structure 18 of smoothly varying elevation, here a helix, about the central axis of the core 12. A suitable architectural finish surface, such as a masonry surface 20 (shown only in dotted lines in order to reveal the interior portions) forms the visible exterior of this part of the escalator 10. Inasmuch as conventional support and finishing techniques may be used, and a wide variety of alternatives are available, these will not be further discussed herein.

The visible portion of the escalator 10 also comprises a pair of moving stair step structures 22, 24 concentrically mounted at varying radii about the central core 12 and disposed on the helical base structure 18. The inner stair step structure 22 comprises the ascending portion in this example, while the outer stair step structure 24 forms the descending portion. A helical central divider wall 26 having smooth side panels 27 separates the stair step structures 22, 24 along their lengths, and has a selected vertical height above the stair step level. The central divider wall 26 is surmounted by flexible moving hand rails 28, 30 for the descending and ascending sides respectively, these hand rails 28, 30 following smooth circular return arcs in a vertical plane at the upper and lower ends of the central divider wall 26. These terminal arcs are disposed in conventional fashion for passenger convenience at the loading and unloading points and in order to return the hand rails along a concealed path within the wall 26.

The side panels 27 merge smoothly into the stair step structures 22, 24, the respective step elements 32, 34 of which taper slightly outwardly but which are fully in accordance with established escalator standards. That is, the upper surfaces of the steps are within the predetermined and standardized width and depth range. These upper surfaces are grooved in conventional fashion, such details not being shown in FIG. 1. The front surfaces of the steps are smooth and the step height is also within the predetermined standardized range. The spacings or clearances between steps, and between steps and side panels, are also adequately small to meet the standards. Further, the loading and unloading portions of the exposed step paths taper smoothly into and out of flat paths at conventional entry and exit comb plates 36, 38 so as to merge into the angle of inclination in the helical central region. Thus, from the standpoint of the user, the only difference from the conventional linear escalator in use of the system is that an arcuate path is followed.

An inner side panel 40 and hand rail 42 are disposed adjacent the core 12 and facing the inner stair step structure 22, while an outermost side panel 44 and hand rail 46 are disposed in like fashion adjacent the outer side of the outer stair step structure 24.

FIG. 1 also depicts the principal internal operative elements of the system, details of given parts being shown in other views to which specific reference is made as appropriate. Inasmuch as the inner and outer structures 22, 24 are essentially alike, only portions of one (the outer structure 24) need be described in this example. The stair step elements 34, seen best in FIG. 6, each include pairs of transversely protruding upper and lower guide followers 48, 50 respectively on each side, beneath the side panels 27, 44. The guide followers 48, 50 are tapered end rollers resting in inner and outer arcuate guide beams 52, 54, each of which includes upper and lower tapered guide tracks 56, 58, each receiving a different associated end roller 48 or 50. The angle and separation of the guide tracks 56, 58 are constant along the helical portion of the path so that the upper surfaces of the step elements 34 remain horizontal, but can vary elsewhere to control, together with other elements, the direction of movement, curvature of path, and extent of tilt of the steps. It may be seen in FIG. 1 that the stair step elements 32, 34 follow
a non-uniform return path through the central core 12, in forming closed loop systems, and these non-uniform path portions involve the use of the tilting and shifting relationships.

The drive system for the stair step structure includes a drive chain 60 having substantial freedom of movement in at least two directions (horizontal and vertical) relative to its longitudinal axis. If the longitudinal axis is taken as the Z direction, the drive chain 60 has some freedom of movement in both the X and Y directions relative thereto. The drive chain is depicted generally in FIG. 1 and specifically in FIGS. 6 and 7 and essentially comprises substantially rectangular drive blocks 62, including inner side sprocket holes 64, and coupled serially by link rods 66 in a manner described below.

The drive chain 60 is disposed adjacent and below the stair step structure 24 along the approximate center of its path, each step 34 being coupled to a different one of the drive blocks 62 in regularly spaced fashion by a step link 68 lying normal to the top surface of the step 34. It is evident, however, that the drive chain 60 can be offset to one side and that the step link 68 may itself be an offset member. The step links 68 are symmetrical, but are of an approximately Y-shaped form and are pivotally coupled at the free end of a side arm 69 to the stair step 34 and pivotally coupled at the approximate junction of the Y to the associated drive block 62. The step links 68 are also guided and restrained by an arcuate step link guide beam 70 in a manner described in greater detail hereafter.

Referring also to FIG. 4, the drive chain 60 is confined in its selected path by the coupling to the step links 68 and the step link guide beam 70, which are disposed on the outer side of the drive blocks 62. On the inner side, the inner faces of the blocks 62 contact a plurality of guide rollers 72 mounted within the sides of a generally U-shaped channel 74 and facing the drive chain 60 as best seen in FIG. 6. The rollers 72 rotate around axes normal to the adjacent drive chain 60 path, such that the sides of the drive blocks 62 are tangential to the roller 72 surfaces.

Adjacent the outside edge of the drive chain 60 the step link guide beam 70 includes a pair of spaced apart guide tracks 76, 78 at different elevations. The step links 68 include spaced apart upper and lower guide followers 80, 81 extending outwardly with respect to the central axis of the system and each resting against and following a different track 76 or 78 of the step link guide beam 70. It will be noted that both the step link 68 and associated step 34 are thus positively guided along the helical path or exposed working portion. Passenger loops in this region are absorbed by the guide beams 52, 54. The guide beams 52, 54 and the step link guide beam 70 control the change from and to the entry and exit regions, but are so related that the relative dispositions of adjacent step elements can be shifted both as to radius of curvature and tilt.

The guide beams 52, 54 are not continuous in this example, although they may be so arranged. The guide beams 52, 54 are not disposed along the central region of the return path, guiding and support in this region being provided by the step link guide beam 70 and the guide rollers 74 alone.

Referring again specifically to FIG. 1, the drive system for each stair step structure 22, 24 further comprises a main drive sprocket wheel 82 disposed adjacent one of the linear path segments (here the upper or exit end for the ascending inner staircase 22 and the lower end for the outer staircase 24). The sprocket wheel 82 lies coplanar with the drive chain 60 path in this region, and the sprocket wheel teeth 83 are spaced to engage the side sprocket holes 64 in successive ones of the drive blocks 62. A concealed drive motor 84 of suitable power is coupled to the drive sprocket wheel 80, through a gear reduction system if desired. The lower drive sprocket wheel 86, shown only generally, is arranged in similar fashion relative to the outer stair step structure 24, to drive the stair steps from a concealed region below the principal structure.

A hand rail drive system 90 is also mounted in concealed fashion, as seen in FIG. 1 and FIG. 5. The example of a hand rail drive 90 that is shown is near the bottom of the inner stair step structure 22, for driving the inner hand rail 42. The flexible hand rail 42, along its concealed return path, tangentially engages a drive capstan 92 concentric with and coupled to a pulley 94 by a belt 96 driven by a pulley 98 mounted on the shaft of a drive motor 100. Again a gear reduction mechanism (not shown) may be utilized for providing a selected hand rail speed synchronized to the speed of the stair step mechanism. Adequate frictional contact between the hand rail 42 and the capstan 92 is assured by a pinch roller 102 engaging the hand rail 42 from the opposite side and urging it against the capstan 92. Similar drives are utilized for each of the other hand rails 26, 28, and 46.

Details of the arrangement of the individual elements 62 and 66 of the chain drive 60 are shown in clearest detail in FIG. 7. A chain drive block 62 comprises an upper block half 104 and a lower block half 106 arranged in split fashion in order to receive expanded ball ends 108 of each adjacent pair of link rods 66. Each link rod 66 includes, at each end, a ball end 108 whose outer end is a segment of spherical surface, the ball ends being integral with the central elongated portion of the link rod 66. Each block half 104, 106 includes a pair of partially spherical recesses 110 (only those for the lower block 106 being shown in FIG. 7) with each recess 110 being adjacent a different longitudinal end of the block, and each in communication with an end depression 112 that forms half of an end aperture when the block halves 104, 106 are coupled together. The end apertures receive the centrally elongated portion of the link rods 66 with adequate clearance to permit angular movement of the link rods 66 relative to the blocks 62.

The spherical arc segments of the ball ends 108 of the link rods 66 are journaled in the mating arc surfaces of the recesses 110, and are free to move, through a predetermined extent of angular movement, in either the vertical or horizontal directions relative to the longitudinal axis of the chain drive 60. At each point along the length of the chain drive 60, therefore, there is substantial freedom of movement in two mutually orthogonal directions (e.g., X and Y directions) normal to the longitudinal axis (Z) of the chain at that point.

The drive blocks 62 also include a face plate 114 of hardened material for defining the sprocket holes 64, with each block half 104, 106 including a side-facing tapered opening 116 communicating with the sprocket hole 64 and forming an interior extension thereof when the drive block 62 is assembled. Coupling to the associated step link 68 is made by a bearing pin 118, an enlarged head of which is received within a countersunk
hole 120 in an outer face plate 122. When the drive block 62 is assembled, the outwardly protruding portion of the bearing pin 118 shown in FIG. 7, rests in a central aperture 124 lying in the junction region of the approximately Y-shaped step link 68.

Relative to the step link 68 mechanism, best seen in FIG. 6, it should also be noted that the free end of the side arm 69 includes a second bearing aperture 126 for receiving a bearing pin 128 supported in mounting blocks 130 on the underside of the step element 34. The step link 68 thus provides a pivot mount for the step element 34 while the step link lies in a plane normal to the plane of the top surface of the step. The step link 68 is also pivotally coupled to the particular drive block 62 in the chain 60 with which it is associated. The drive force supplied by the chain 60 is transmitted to the step element 34, which is separately restrained in its helical path by the guide followers 48, 50 engaging the tracks 55, 58, respectively, on opposite sides. The relationship between the link rods 66 and the drive block 62 of the drive chain 60 nevertheless permit curvilinear movement of the drive chain 60 during advancement of the step elements 34.

Details of the stair steps themselves may best be appreciated by reference to the perspective view of FIG. 6, and the plan and side views of FIGS. 8 and 9, which are shown in approximate scale. A typical step 34, as shown only in FIG. 6, includes a grooved top surface 132 and a curved riser or front surface 134, together with shortened side surfaces 136 extending from the front surface for a limited distance, such that the top surface 132 also defines a rearwardly extending lip 138 facing the next adjacent step element on that side. The expressions “front” and “rear” are of course arbitrary, but these reference terms are used in the same sense throughout the specification and claims. The underside of the step element 134 thus forms a shell within which the mounting clocks 130, the bearing pin 128 and the step link 126 may be received.

As seen in the plan view of FIG. 8, the inner front-to-back dimensions of the top surfaces of the inner and outer stair steps 32, 34 respectively are essentially the same. However, the outwardly diverging taper (from one lateral side to the other) of the inner steps 32 is substantially greater than that of the outer steps 34, due to the different radial positions of these step elements. Consequently, the inner and outer stair step structures 22, 24 have different numbers of step elements, and the step elements follow different paths. Despite the differences, in the configurations of the stair step elements 32, 34, however, they meet the established standards for escalators, that are set for convenience and safety. In a practical example, the inner steps 32 and 16 inches from front to back at the inner radius, and 28 ½ inches at the outer radius, with a lateral dimension of 40 inches. The outer steps 34 and 16 inches from front to back at the inner radius and 22 inches at the outer radius, also having a lateral dimension of 40 inches. The heights of the stair steps (that is, the dimension along the front or riser surfaces) are 9 inches.

The handrail structures are guided so as to have curved paths in both the vertical and horizontal directions. As best seen in FIGS. 4 and 5, the flexible handrails are generally T-shaped, with a beaded edge 150 at the base of the T. An elongated guide member 152 extends along the path of the hand rail, and includes a groove for receiving the beaded edge 150. The hand rail and guide member 152 are received in an elongated, somewhat L-shaped channel member 153, a portion of which is exposed along the upper portion of the path, although only the base of the T-shaped hand rail is exposed to the user. A number of regularly spaced guide rollers 154 mounted in cut out portions 156 of the guide member 152 rotate about horizontal axes in engagement with the beaded edge of the hand rail, as seen in FIG. 5. For side restraint of the hand rail, as best seen in FIG. 4, a number of regularly spaced guide rollers 158 are mounted in extending lips along the channel member 153 to rotate about axes normal to the longitudinal axis of the hand rail at that point. These guide rollers 158 engage the inner side of the base leg of the T-shaped hand rail, and absorb the centripetal forces in the hand rail system while also providing the needed guiding in the horizontal direction.

In the operation of the system as a whole, considering the example of FIG. 1, the inner staircase structure 22 is driven so as to be ascending, while the outer staircase structure 24 is descending. The handrails are concurrently and synchronously driven in the same directions as the staircase structure with which they are associated. In the exposed portion of their paths, each of the staircase structures 22, 24 moves in conventional fashion from the standpoint of the passenger, except for following an arcuate path. That is, a stair step element, such as an outer stair step element 34, moves first under an entry comb plate 36 along a linear path that converts gradually into the helical arcuate path that is followed until the region of the exit comb plate 38 is reached, at which the path tapers again into a linear motion. In the concealed portion of path movement, however, the stair step elements 32, 34 and the associated drive system follow substantially more complex movements.

It will be appreciated that although a helical escalator is shown, a constant angle of inclination need not be utilized in the operative exposed portion. Similarly, although a vertical and substantially linear return path is shown, it will be apparent from the following description that other return paths may be utilized.

The system is shown as a passenger escalator because this is probably the most demanding and critical application of a conveyor system. However, those skilled in the art will recognize that the mechanism shown also satisfy every requirement for other types of conveyor systems. In typical industrial conveyors, requirements as to clearances, slope, entry and exit regions, and many other factors, can be substantially different inasmuch as the same safety considerations are not involved. Also, the standardized aspects of passenger escalators are not applicable.

Referring specifically to FIGS. 1 and 2, it is seen that the ascending escalator portion of the inner stair step structure 22 has a principal helical path, tapering into the level entry and exit portions 36, 38 respectively. Between these portions, the step elements 32 are in the return path, which includes an intermediate substantially vertical linear portion. The linear portion of the path is joined at each end to the associated end of the exposed working portion of the path in a closed loop configuration, by path segments of relatively small radius of curvature at the upper and lower parts of the structure pin respectively. The substantially vertical portion may be said to have a virtually infinite radius of curvature. The change of curvature relative to the central
axis is also accompanied by relative changes of elevation. The step elements 34 for the outer stair step structure 24 follow a similar path but the short radii of curvature portions are more gradual.

In this example, the ascending inner stair step structure 22 is returned, moving down, in side by side relation to the upward-moving return path for the descending outer stair step structure 24. To reduce the area (in plan) required for the system, the transition regions in the return path, which have the smallest radii of curvature, are held approximately the same for the two structures. This is accomplished by passing the outer stair step structure 24 under the inner structure 22 in these transition regions both at the upper end (FIG. 1A) and the lower end (FIG. 1B) of the system.

The general nature of these return path segments of the closed loop paths, and the relative relationships of the step elements 32, 34 through the return paths, are illustrated in idealized form in FIG. 2. The same general characteristics exist, and similar requirements must be met, although the step elements 32, 34 travel in opposite directions and, because of the different paths to be followed, have slightly different relative attitudes at the various points along the path.

In FIG. 2, the step elements 32, 34 have been shown as consisting only of a top flat portion and a front or riser portion, in order to simplify the representation. The step elements 32 are distinguished visually by the presence of an edge band that is not on the other elements 34. In the upper region of the return path, the downward moving inner step elements 32 are oriented such that the flat top portions form diverging angles between adjacent steps 32. It will be recalled that at the end of its travel at the exposed operative portion, the step element 32 is following a path lying in a substantially horizontal plane. With the forward edge of each inner step element 32 tilted upwardly, relative to the normal direction of travel, there is no interference between step elements 32 as they enter the small radius of curvature portion, so that the corner of one element may nest under the adjacent edge of the next element 32 in this region, as depicted also in FIG. 1. The reduced radius of curvature portion continues until merging with the downward arc which converts in this example to the substantially vertical downward path shown in FIGS. 1 and 2. There is a slight overhang or negative slope in both paths in view of the necessity for merging smoothly into the flat planar paths that lie at the entry and exit portions. This overhang permits the use of a smaller center well, but nevertheless this portion of the path may be referred to as substantially vertical, while along the virtually vertical portion, the wider surfaces of the elements 32 overlap, as best seen in FIG. 1.

Thereafter, the path of curvature of the downwardly moving step elements 32 again flares out toward the horizontal, as well as curving through the sharp radius of curvature toward the entry portion. Again it will be recognized that a three-dimensional depiction of both change in the radius of curvature relative to the central axis and the change of attitude along the vertical direction has not been attempted in FIG. 2. In this region of gradual flare-out toward the horizontal plane, however, the top surfaces of the step elements 32 lie along lines which form converging angles. Here the step elements 32 are tilted relative to each other so that they again overlap without relative interference. As the horizontal elements finally shift into the entry portion, they are changed in position so that they lie adjacent and in a common plane with minimum spacing between them. Although because of the different radii of curvature involved for the step elements 34 in the outer stair step structure, there are different angles of inclination and slightly different paths involved, essentially the same series of relationships exist but in reverse fashion for the ascending return path for these elements. That is, after leaving the lowermost exit portion on the operative exposed part of the stair step structure, the step elements 34 are moved through the smallest radius of curvature portion starting in a horizontal plane that tapers into a vertically upward movement in which the tops of the stair step elements 34 lie at converging angles relative to each other, followed by the vertically vertical portion which is followed by the curvature toward the horizontal plane, with the curvature in this region causing the tops of the stair step elements to define diverging angles relative to each other.

The step elements 32, 34 may be positively guided throughout this entire closed loop path, but there are not guided through most of the return path. The side track guides 52, 54 seen in FIGS. 1 and 6 are needed for load-bearing purposes only in the exposed operative portion of the ascending and descending stair step structure, and for attitude control only in the exit and entry regions. Otherwise, the step links 68 provide adequate hinged support for the stair step elements 32, 34. The tapered end rollers 48, 50 (referring to FIG. 4) rest on the tapered guide tracks 56, 58 at each side of a step element 34. Thus this guiding and load bearing system absorbs both vertical and axial loads. It also permits the step element 34 to be moved along a curvilinear path, with the tapered end rollers 48, 50 compensating for the curvature.

It will be noted, relative to FIG. 6, that the axis of the bearing pin 128 which couples the step element 34 to the step line 68 is off center relative to the center of gravity of the step element 34. Because the shell structure is supported by the bearing pin 128 near the midpoint in the front-to-back direction, and because the weight of the side plates 136 and the riser surface 134 substantially unbalance the weight toward the front or lip direction, the step elements 32, 34 will automatically tilt when free so that the extending lip 136 is directed partially upwardly. This tilt tendency is prevented by the tracking of the guide followers 48, 50 at the sides of the step element 34, or limited by the abutment of a portion of the step 34 against the free end of the step link 68. Therefore, although the guide system for the drive chain is continuous, and configured to follow a given path, the guide rails for the step elements 32, 34 need not be continuous.

As shown in FIG. 3, these guide rail paths for the step elements, indicated in dotted lines, may terminate at the end of the planar path followed by the step elements as they leave the exit region. With the step links 68 and the drive chain 60 guided so as to follow a slight dip, the step elements thus automatically tilt upwardly while curving about the central axis (it again being noted that this curvature is not depicted in FIG. 3). If desired, the guide followers 48, 50 may again engage guide tracks on a single guide beam in order to be directed into the overlapped nested relationship along the substantially linear return path. The step elements 32, 34 are thus reliably but simply directed through...
complex paths of movement involving both changes of curvature about the central axis of the helical structure, and changes in movement in the vertical direction, accompanied by substantial change in the relative disposition of adjacent step elements.

The step link 68 structure and combination with the other elements provide added control. In the entry and exit regions, and the exposed operative portion, the upper and lower guide followers 80, 81 (FIG. 4) engage the underside of the tracks 76, 78 to maintain the step link side arm 69 vertical. The step is not subjected to any tilting forces along this part of the path, but in other portions the step is merely supported by the associated step links. In the return path region the weight of the step elements is borne by the step links 68, which need not be guided in the substantially vertical portion of the return path.

The system will be observed to be essentially repetitive in character as to the individual parts, so that the parts may be readily fabricated on a production basis. Nevertheless, the structure is reliable and fully capable of supporting the loads and forces involved. The drive chain system 60 has the necessary degree of freedom of movement in both the horizontal and vertical directions orthogonal to the longitudinal axis movement of any point, by virtue of the seating of the balls ends of the link rods 60 in mating bearing apertures within the drive blocks 62. Centripetal forces which may exist are absorbed by the tapered guide followers 80 on the step link 68 that are coupled to the drive blocks 62 at spaced points. Centripetal forces, which can be substantial inasmuch as the drive chain 60 must be wrapped around the helical path and the drive mechanism are absorbed with distortion or high point loadings by the side rollers 72 which engage the flat faces of the drive blocks 62 continuously.

Another example of a system in accordance with the invention is depicted in simplified form in FIG. 10, the internal details of which may be the same as those for a single staircase structure in the example previously discussed, and therefore will not be depicted herein. FIG. 10 represents a different arrangement of an arcuate escalator, in which separate staircase segments 140, 141 and 142 arranged about a common central well 144 are arranged to provide separate ascending or descending paths for passengers. In this particular example the separate staircase structures 140, 141 and 142 are each illustrated as providing an ascending staircase, and each is of helical form, the return path being directed to and down the central well 144 and then back to the entry portion of the lowest staircase 140. Between the top of one staircase (e.g., 140) and the bottom of the next staircase (e.g., 141) in the sequence there is a substantially horizontal transition segment 146 concealed in the floor structure. For the descending escalator function, a similar staircase arrangement is provided at some spaced apart portion of the building, with an ascending series of staircase sections, each providing passage between one floor and the immediately superior floor.

Arrangements such as FIG. 10 have distinct aesthetic appeal, and meet other space considerations. In addition, they have the advantage of providing a substantially continuous path of movement along a relatively small floor space area, so that traffic flow is most efficient, and floor usage is optimized. This arrangement utilizes two different types of non-exposed staircases paths; one path being the transition between an adjacent pair of staircases and the other being the single return path for the system. One or a number of synchronized driving systems may be used with this arrangement.

A number of uses and alternative arrangements for systems in accordance with the invention will suggest themselves to those skilled in the art. The exposed operative portion is preferably helical for passenger use, but need not be precisely so. For other uses other paths may be followed. For all applications the return path can be other than the central axial core structure shown. Ascending and descending portions may be separated from each other, if desired, while the return path system may also be spaced apart from the operative portions at some distance. The return path can in fact include an operative exposed portion.

Where a conveyor system is not to be used for passengers, an entirely different exposed portion may be employed. This may consist merely for an adequate frame structure to receive specialized items or items in a particular range of sizes. It may consist alternatively of a substantially continuous resilient belt supported on or within a frame structure. The capability of systems in accordance with the invention for conforming to widely varying three dimensional paths permits adaptation of such systems to a variety of other conveyor uses. Although there have been described above and illustrated in the drawings various forms of arcuate escalators and structures thereof, it will be appreciated that a wide variety of other variations and modifications are feasible. Therefore, the invention is to be taken as encompassing all forms and variations within the spirit of the appended claims.

What is claimed is:

1. An escalator system for at least two successive floors comprising a passenger conveyor means comprising successive stair step structures each between a different pair of floors, said stair step structures defining a continuous closed loop including exposed operative portions, and including a sequence of step segments disposed along the loop, and drive means adjacent the loop;

2. The invention as set forth in claim 1 above, wherein the transition regions are substantially horizontal and the stair step structures have operative portions helically disposed about a central axis.

3. The invention as set forth in claim 2 above, including in addition a hollow core structure along the central axis, the return path extending within said hollow core structure.

4. An arcuate escalator comprising spaced apart guide means defining an arcuate escalator path within a closed loop path including operative and return path segments, the operative path being curved about an axis;

chain drive means centrally extending along and spaced apart but adjacent the closed loop path:
a plurality of step segments disposed along the path and each engaging the guide means along opposite sides thereof;
a plurality of coupling means mounted along said chain drive means and each pivotally coupled to a different individual one of said step segments;
drive means engaging said chain drive means for advancing said step segments in a selected direction;
and means along the return path segment for tilting and at least partially nesting the step segments relative to each other in the return path segment of said closed loop path.

5. The invention as set forth in claim 4 above, wherein said arcuate escalator path has different radii of curvature relative to the axis about which the path curves at different regions therealong and comprises a principal operative curved path having entry and exit portions at different levels, a substantially linear return path portion between the entry and exit portions, and a pair of transition return path portions curving directly between the opposite ends of the linear return path portion and the entry and exit portions respectively.

6. The invention as set forth in claim 4 above, wherein said arcuate escalator path comprises a helical path about a central axis, and wherein the return path segment comprises an essentially vertical and linear intermediate path and a pair of transition path portions having relatively small radii of curvature about the central axis and each joining a different opposite end of said linear intermediate path to an adjacent end of said helical path.

7. The invention as set forth in claim 5 above, wherein the closed loop path has an arcuate level portion lying in a chosen plane, said drive means engaging said chain drive means in the level portion.

8. The invention as set forth in claim 7 above, including in addition second guide means disposed along and adjacent to the closed loop path and in contact with said coupling means.

9. The invention as set forth in claim 8 above, wherein said step segments are disposed substantially transversely between said spaced apart guide means, and wherein said coupling means comprises step link means including guide follower means contacting said second guide means.

10. The invention as set forth in claim 9 above, wherein said spaced apart guide means comprise tapered guide track means, and wherein said step segments comprise tapered end roller means engaging said tapered guide track means.

11. The invention as set forth in claim 10 above, wherein said second guide means comprise tapered guide track means and wherein said guide follower means comprise tapered end roller means.

12. The invention as set forth in claim 8 above, including in addition centripetal force absorbing means including a plurality of rollers disposed adjacent and in contact with said chain drive means along the arcuate escalator path.

13. An escalator system comprising:

at least one loop of step segments disposed along an arcuate helical operative path about a central axis and having an entry region and an exit region at different elevations;
arcuate guide means disposed to support said step segments at least along said operative path;
means defining a return path having radii relative to the central axis and forming a closed loop path with the operative path, said return path comprising a substantially vertical portion substantially along the central axis and transition portions of varying radii of curvature joining the opposite ends of said substantially vertical portion to the entry and exit regions respectively, said transition portions curving in both the horizontal and vertical planes through angles no greater than substantially 90° in each plane and describing a horizontal path having a smaller radius of curvature than the helical path in each said transition portion;
and drive means coupled to said step segments for advancing said step segments continually along said paths.

14. The invention as set forth in claim 13 above, including in addition means operatively coupled to said step segments for shifting said step segments into and out of partially nested relation in the transition portions.

15. The invention as set forth in claim 14 above, wherein said means for shifting in the transition portions comprises support means at the exit region pivotally coupled to said step segments at regions spaced from the center thereof, said step segments being free of said guide means in such regions and shifting under the force of gravity, and said means for shifting in the transition portion further comprises said arcuate guide means at the entry region.

16. The invention as set forth in claim 13 above, wherein said system comprises a pair of adjacent stair step structures at different radii from the central axis, one ascending and the other descending, and each comprising a loop of step segments; and further includes a central hollow core structure, the return path for both step segment loops passing substantially vertically in side by side relation through said central core structure.

17. The invention as set forth in claim 16 above, wherein the loop of step segments from the outer stair step structure cross the loop of step segments from the inner stair step structure in passing into and out of the central core structure.

18. The invention as set forth in claim 13 above, wherein said drive means comprises a chain drive disposed along and under the path of the step segments and having freedom of movement along at least two mutually orthogonal axes normal to its length.

19. The invention as set forth in claim 18 above, wherein said chain drive comprises a series of substantially rectangular chain blocks having side sprocket holes, and interconnecting means coupling said chain blocks, and wherein said drive means further comprises sprocket wheel drive means positioned along the loop and engaging the sprocket holes.

20. A drive system for an escalator having a multiplicity of steps arranged to follow a selected curved path having radially inner and outer sides comprising:
a chain drive mechanism comprising a plurality of chain elements and having substantial freedom to move laterally as well as vertically with respect to its longitudinal path, said mechanism having a longitudinal path proximate to the selected path of the steps;
a plurality of step link means, each pivotally coupling a different one of said steps to a different one
of said chain elements and being pivotally coupled to said chain elements and steps; first guide means disposed on opposite lateral sides of said chain drive mechanism for maintaining said mechanism in its longitudinal path; drive means disposed along the longitudinal path of said chain drive mechanism and coupled thereto; and second guide means disposed along and engaging the step link means.

21. The invention as set forth in claim 20 above, wherein the longitudinal path of said chain drive mechanism comprises at least partially an arcuate path, and wherein said chain elements comprise rectangular members having forward and rear internal sockets open to end apertures in said rectangular members, and wherein said chain drive mechanism further includes a plurality of link rod elements having terminal ball means pivotally engaging the forward and rear sockets of a different adjacent pair of chain elements through the respective end apertures.

22. The invention as set forth in claim 21 above, wherein the sockets of said rectangular members and the terminal ball means of said link rod elements include mating spherical arc segment portions and said link rod elements have predetermined clearance relative to said end apertures.

23. The invention as set forth in claim 21 above, wherein said first guide means comprises a plurality of roller guide means disposed on the radially inner lateral side of said chain drive mechanism.

24. The invention as set forth in claim 21 above, wherein said step link means comprise generally Y-shaped link elements, said link elements being pivotally coupled in the region of the junction of the Y to the radially outer side of the associated rectangular member, and said step link means further comprises at least one guide follower means mounted on the side opposite the associated rectangular member, said first guide means comprising roller guide means disposed on the radially inner side of the path and engaging said rectangular elements and wherein said second guide means comprises guide track means disposed on the radially outer side of the path and engaging the guide follower means.

25. An escalator system for advancing a plurality of step elements along an arcuate path including an operative portion and having different radii of curvature at different regions therealong, comprising:

- first guide means receiving the lateral sides of said step elements and confining said step elements along at least the exposed portion of the selected path;
- continuous drive chain means including second guide means disposed proximate the first guide means, and spaced therefrom; and
- step link means pivotally coupling said step elements to said continuous drive chain means at a region spaced apart from the center of gravity and being in engagement with said second guide means, said first and second guide means being disposed to permit said step elements to tilt in those portions of the arcuate path having the smallest radii of curvature along the path.

26. The invention as set forth in claim 25 above, wherein said step elements have substantially planar top and front surfaces that are exposed along the operative portion of the escalator path, and the rear portion of said top surface defines an edge that is at least partially nestable relative to the adjacent step element.

27. The invention as set forth in claim 26 above, wherein the top surfaces of said steps taper outwardly from one lateral side to the other, and include a front surface and a rear lip extension.

28. The invention as set forth in claim 27 above, wherein said step elements each include a spaced apart pair of guide followers on each lateral side thereof, wherein said first guide means comprises a pair of guide tracks on each lateral side of said step elements, each guide follower being in operative engagement with a different guide track, wherein said step link means comprise a plurality of step link elements, each pivotally coupled to said drive chain means and to said step elements at spaced apart points, said step link means including at least one guide follower each extending therefrom, and wherein said second guide means comprises guide track means in engagement with said step link guide followers.

29. The invention as set forth in claim 28 above, wherein said pair of guide tracks and said guide track means comprise tapered tracks and said step element guide followers and step link guide followers comprise tapered end rollers.