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## (54) APPARATUS FOR FABRICATING WORKPIECES SUCH AS WELDED WIRE TRUSSES

(71) I, VICTOR PAUL WEISMANN, Citizen of the United States of America, domiciled at 430 Prospect Circle, South Pasadena, California 91030, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to the fabrication of workpieces such as welded wire trusses for use in welded wire frameworks suitable, inter alia, for use in manufacturing prefabricated modular building panels.

My United States Patent No. 3,305,991 describes a reinforced modular foam building panel, and my United States Patent No. 3,555,131 describes certain procedures and equipment for fabricating such panels. The panel is a composite of a three-dimensional welded wire matrix and of an insulative core provided within the matrix and bonded to strut members which traverse the interior of the matrix. Such panels have been approved for use by the International Conference of Building Officials, Pasadena, California, Report No. 2440, as structural and non-structural roof and wall panels for commercial and residential construction. These panels are characterized by their light weight, good thermal, moisture and acoustic insulative properties, their adaptability to efficient erection procedures, their compatibility with conventional construction techniques, and their strength. The strength of these panels is obtained in part from the intimate bonding relation provided between the core of the panels and the strut members of truss sections of the wire matrix.

So that these building panels may find widespread commercial acceptance, they must provide an economic alternative to conventional materials. Thus, these panels must be manufacturable at low cost, preferably by the use of automatic or semi-automatic equipment. To be certified as complying with various applicable building codes, it is necessary that these panels be uniform in their structural characteristics and dimen-

sional aspects; dimensional uniformity from panel to panel is desired to secure optimum flexibility in the use of the panels.

Because these panels are provided in rather large sizes, they are difficult and costly to ship in quantity over any considerable distance. Therefore, it is desirable that the panels be fabricated at locations close to their areas of ultimate use. The geographical areas in which the present panels find particular utility are often remote from established centers of manufacture, and such areas are often poorly serviced by transportation facilities capable of transporting large quantities of such building panels on a regular or economic basis. It is desirable, therefore, that standardized matrix fabrication equipment be available for dispatch to a panel fabrication site proximate to the area in which the panels are to be used. Since the panel fabrication site may be in an area served by unskilled or semi-skilled labor, the matrix fabrication equipment should desirably be automatic and should desirably be adjustable to produce panels of different lengths and widths.

To achieve the desired dimensional uniformity, it may be desirable to fabricate the dimensionally sensitive truss sections in a centralized place of manufacture and to transport these in a compact and readily transportable form to a remote fabrication site for assembly into the completed matrix preparatory to formation of the appropriate insulative core within the matrix. When this procedure is followed, it is desirable that the truss sections be identically dimensioned, within predetermined limits of manufacturing tolerance so that automatic matrix fabrication equipment may be insensitive to variations between the truss sections supplied to it.

It is apparent therefore, that a need exists for apparatus capable of rapidly and economically assembling the truss sections with uniform dimensional characteristics within predetermined limits.

The present invention broadly provides apparatus for fabricating a workpiece in-

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cluding a longitudinal member and additional component members connected to the longitudinal member at locations spaced apart along the longitudinal member within predetermined limits, the apparatus comprising connection stations, an endless conveyor belt for transporting the longitudinal member lengthwise through said connection stations for the attachment thereto of the additional component members, the belt defining locating means for said additional component members for locating said additional component members relative to the longitudinal member, and means operative during driving of the belt to alter the length of the belt, thereby to adjust the length of the belt between said locating means within said predetermined limits.

More specifically, the present invention provides apparatus for fabricating a welded wire truss comprising longitudinally extending wires interconnected by transverse wires predetermined ones of which are to be spaced apart along the truss within predetermined limits, the apparatus comprising welding stations, an endless conveyor belt for transporting the longitudinally extending wires lengthwise through said welding stations for the attachment thereto of the transverse wires, the belt defining locating means for said predetermined transverse wires for locating said predetermined transverse wires transversely of the longitudinal wires, and means operative during driving of the belt to alter the length of the belt, thereby to adjust the length of the belt between said locating means within said predetermined limits.

The invention is more fully set forth in the following description which is presented, by way of example, with reference to the accompanying drawings, wherein:

Fig. 1 is a perspective view of a portion of a building panel incorporating truss sections produced by apparatus embodying this invention;

Fig. 2 is a simplified elevation view of apparatus embodying the invention for fabricating truss sections of the panel shown in Fig. 1;

Fig. 3 is a top plan view of a portion of a conveyor belt illustrated in the apparatus shown in Fig. 2;

Fig. 4 is a side elevation view of the portion of the conveyor belt shown in Fig. 3;

Fig. 5 is a cross-section view taken along line 5—5 in Fig. 3;

Fig. 6 is a fragmentary elevation view partly in cross-section of another portion of the apparatus shown in Fig. 2;

Figs. 7, 8 and 9 illustrate different states of tolerance accumulation sensing equipment of the fabrication apparatus shown in Fig. 2;

Fig. 10 is an enlarged view taken along lines 10—10 in Fig. 4;

Fig. 11 is a cross-section view taken along lines 11—11 in Figs. 4 and 10;

Fig. 12 is a simplified elevation view of typical structure defining a conductive path between the welding electrodes at one of the welding stations in the apparatus shown in Fig. 2; and

Figs. 13 is a simplified top plan view of a portion of the apparatus shown in Fig. 2 illustrating a strip of truss sections at the location between adjacent truss sections in the strip as supported on the conveyor shown in Fig. 2.

Referring now to the accompanying drawings, as shown in Fig. 1, the principal components of a prefabricated modular building panel 10 are a matrix 11, and an insulative core 12 disposed within the matrix. The matrix is defined by a plurality of slender elongate rod-like wire elements. Conveniently, the matrix may be made up of elements defined by wire having a size of from 8 to 16 gauge AWG (American Wire Gauge) inclusive, and preferably the elements of the matrix are defined by 14 gauge wire. Preferably, the same size wire is used throughout matrix 11, but the wires used to define one group of elements of the matrix may be of a different size within the preferred range mentioned above from the elements defining the remainder or different groups of elements within the matrix.

The matrix includes a plurality of spaced parallel upper longitudinal elements 13 which are conveniently referred to as upper truss runners. A corresponding plurality of spaced lower longitudinal elements 14 define lower truss runners. The upper truss runners 13 are interconnected by a plurality of spaced parallel transverse members 15, and the lower truss runners are interconnected by a corresponding plurality of transverse members 16. In the finished matrix, the upper truss runners and their corresponding transverse members define an upper major surface of matrix 11. Similarly, the lower truss runners and their transverse members define a lower major surface of the matrix. Preferably, the upper and lower major surfaces of the matrix are parallel to each other and are flat. The major surfaces of the matrix are interconnected by a plurality of truss strut members 17 which traverse the interior of the matrix between corresponding pairs of upper and lower truss runners 13 and 14, and by close-out members 18 at opposite ends of the matrix between corresponding pairs of the upper and lower truss runners.

As shown in Fig. 1, a longitudinal element 13 is provided for each longitudinal element 14. Each combination of a pair of upper and lower longitudinal elements 13 and 14, and of the strut and close-out members 17 and 18 interconnected therebetween, 130

define a truss section 19. In matrix 11, several truss sections are spaced parallel to each other across the width of the matrix and are interconnected by transverse members 15 and 16 in the upper and lower major surfaces of the panel. The height of each truss section, i.e., the spacing between aligned pairs of upper and lower truss runners 13 and 14, defines the thickness of the complete matrix. The matrix has opposite ends and side surfaces disposed perpendicular to each other and to the matrix major surfaces.

As shown in Fig. 1, transverse elements 15 and 16 in the upper and lower major surfaces of the matrix are disposed perpendicular to the adjacent longitudinal elements 13 and 14 in the corresponding major surfaces of the matrix. The interconnecting elements 18 at opposite ends of each truss section 19 are perpendicular to the transverse and longitudinal elements in the opposite major surfaces of the matrix.

The strut members interconnected between the upper and lower truss runners in each truss section are disposed at spaced locations along the length of the truss section. The strut members are disposed at an angle of about 45° relative to the truss runners, and alternate ones of these strut members, proceeding along the length of each truss section, are disposed oppositely to each other. That is, strut members 17 in each truss section are disposed in alternate converging and diverging relationship to each other along the length of the truss section such that one strut member may slope at an angle of about 45° from left to right proceeding upwardly from lower truss runner 14 to upper truss runner 13, and the next strut member along the truss section to the right may slope from left to right proceeding downwardly from the upper truss runner to the lower truss runner, and so on throughout the length of the truss section. At any given position along the length of the entire matrix, it is preferred that the strut members of the several truss sections be disposed parallel to each other, although it is not essential that this relationship be present in the finished matrix.

In a presently preferred matrix, elements 13, 14, 15 and 16 are spaced apart from each other on 2 inch centers within their respective groups. Also, it is preferred that the aligned upper and lower truss runners 13 and 14 be spaced apart on 2 inch centers. Thus, matrix 11 is organized on a 2 inch cubical module and conveniently is fabricated in 4 foot widths in lengths of from 8 to 14 feet, the length of the panel within this range varying in 2 inch increments. It will be appreciated, however, that different spacing of the elements of matrix 11 may be used as desired, and that the matrix may be fabricated of different nominal width or length.

The insulative core 12 of panel 10 preferably is defined by a unitary mass of unicellular synthetic foam material such as polyurethane foam. The core preferably is disposed wholly within the matrix to extend from side to side and end to end of the matrix in spaced relation to the opposite major surfaces of the matrix. The thermally insulative material defining core 12 is bonded within the matrix to the strut members which traverse the interior of the matrix, thereby to give lateral support to the strut members and increase the strength of the strut members considered as columns. Where the insulative core is defined by polyurethane foam or the like, the bonding of the core to strut members 17 is assured by foaming the core material *in situ* within the matrix and allowing the foam material to bond to the strut members as the synthetic foam material sets to a rigid or semi-rigid state. If desired, however, core 12 may be defined by a plurality of strips of preformed unicellular material, such as polystyrene foam, inserted into desired positions within the matrix and secured to the strut members by a suitable bonding agent such as a latex-based bonding agent, or a layer of polyurethane foam foamed *in situ* within the matrix over the inserted insulative elements and hard set within the matrix to securely position the inserted insulative elements within the matrix. My United States Patent No. 3,555,131 describes procedures and equipment which may be used to provide the preferred foamed *in situ* polyurethane insulative core of panel 10.

The overall manufacturing process of panel 10 may be carried out at a single location, or it may be subdivided to be performed at several locations in which the product produced by one operation is processed in succeeding operations at a different location, as desired. Thus, the overall manufacturing process involves the initial fabrication of truss sections 19 at a truss fabrication station wherein the truss sections are fabricated as a continuous strip 21 (see Fig. 13, for example) of end-to-end interconnected truss sections. The strip of truss sections may pass either directly from the truss fabrication station to a matrix fabrication station at the same site as the truss fabrication station, or the strip may be passed from the truss fabrication station to a coiling station. From the coiling station, coils of truss section may be transported to a storage location either at the site of the truss fabrication station or at the site of the matrix fabrication station. From the storage location, coils of truss section are passed to an uncoiling station associated with matrix fabrication station. Also, at the matrix fabrication station, a quantity of stock material for transverse elements 15 and 16 of

matrix 11 is provided at a transverse stock supply station from which the material for the matrix transverse elements is passed to an uncoiling station and thence to the matrix fabrication station. From the matrix fabrication station, the completed matrix may be passed directly to a core formation station at the same site as the matrix fabrication station. On the other hand, the finished matrix may be held in a storage location associated with either the matrix fabrication station or the core formation station, as desired, and from which completed matrices are withdrawn as desired.

At the truss fabrication station which embodies the present invention, a pair of coils 30, only one of which is shown in Fig. 2, of stock wire 31 for truss runners 13 and 14 are disposed to supply truss runner stock wire to an uncoiling and straightening station 32 from which parallel lengths of straightened truss runner wire is supplied to the upper portion of a conveyor belt 33 engaged between a drive pulley 34 and an idler pulley 35. Preferably the idler pulley is disposed adjacent wire straightening station 32; whereas drive pulley 34 is disposed adjacent a truss section coiling station 23. Drive pulley 34 is driven by a suitable motor 36 so that the upper portion of the loop of conveyor belt 33 between pulleys 34 and 35 is driven toward a coiling station. As a given point on conveyor belt 33 moves from idler pulley 35 toward drive pulley 34, it passes, in sequence, the following components of truss fabrication station 20: a dispenser station 37 for dispensing precut close-out members 18 to the belt, a dispenser station 38 for dispensing precut strut members 17 to the belt (dispenser station 38 is provided for dispensing those of strut members 17 which are inclined in one direction relative to truss runners 13 and 14), a dispensing station 39 for dispensing precut strut members corresponding to those strut members of the truss section which are inclined in the opposite direction to the truss runners from the strut members dispensed at station 38; a belt length adjusting station 40 disposed on a foundation 41, through a close-out member welding station 42 comprised of a welding assembly 43 above belt 33 and a back-up assembly 44 below the belt on foundation 41; through a first strut member welding station 45 comprised of a welding assembly 46 above the belt and a backup assembly 47 below the belt on foundation 41, and then through a second strut member welding station 48 comprised of a welding assembly 49 and a back-up assembly 50 similar to the corresponding elements of first strut member welding station 45. As the belt passes out of second strut member welding station 48, the strip 21 of truss sections is complete. Strip 21 is passed from belt 33 to coiling station 23 past a tolerance

cumulation scanning station 51 which is operatively connected (as represented by dashed line 52 in Fig. 2) to belt length adjustment station 40.

Figures 3, 4, 5 and 6 show conveyor belt 33 which is of the chain type. Specifically, conveyor belt 33 resembles a conventional bicycle chain having a plurality of regularly spaced axle pins including two end axle pin assemblies 53 and a plurality of intermediate axle pins 54 disposed at regularly spaced locations along the belt. The end axle pin assemblies are disposed at opposite ends 55 of the belt. Adjacent axle pins along the length of the belt are interconnected by a pair of link members, the link members being comprised of outer link members 56 and inner members 57. In the case of each intermediate axle pin 54, the axle pin is journaled at about its midpoint by a spacer bushing 58 and by the adjacent ends of each of a pair of outer link members 56 and a pair of inner link members 57. The axle pin projects outwardly on either side of outer link members 56 where it carries a bearing bushing 59. Preferably drive pulley 34 and idler pulley 35 are each defined as a pair of circumferentially toothed sprocket wheels (see Fig. 6) spaced coaxially apart from each other a distance corresponding to the spacing of bearing bushings 59 along each intermediate axle pin 54. The sprocket wheels of each of pulleys 34 and 35 engage bearing bushings 59. Alternate adjacent pairs of axle pins in conveyor belt 33 are interconnected by outer link members 56 and the remaining adjacent pairs of axle pins are interconnected by inner link members 57. All link members are rotatable about the axle pins with which they are engaged. Intermediate axle pins 54 extend continuously across the width of belt 33.

As shown best in Fig. 3, each of the end axle pin assemblies 53 is provided as a pair of stub axle pins which extend coaxially in opposite directions from a central block 60. Each block 60 has an internally threaded hole 61 formed through it normal to the common axis 163 of the stub axle pins; each intermediate axle pin 54 has an axis 163'. Each hole 61 defines internal threads which are opposite in handedness to the threads in the hole formed in the block 60 at the other end of belt 33, and these threads cooperate with oppositely handed external threads 62 formed at the opposite ends of a screw shaft 63 engaged between blocks 60 to interconnect the opposite ends 55 of belt 33 to form a continuous belt loop. Shaft 63 carries a pinion gear 64 (see Fig. 4) between threads 62 for cooperation with a worm 65 rotatably mounted in a support block 66 which also journals shaft 63 on either side of gear 64. Worm 65

is carried on a shaft 67 which extends through support block 66. One end of shaft 67 is rotatably engaged within a hole 68 formed in a positioning link 69. An operating wheel 70, defining a plurality of radial spur teeth 71, is affixed to the opposite end of worm shaft 67, as shown best in Fig. 5. Positioning link 69 is provided between belt end axle pin assemblies 53 for maintaining worm shaft 67 in a desired position relative to the adjacent belt end axle pins, as shown best in Fig. 4. The opposite ends of positioning link 69 define aligned slot apertures 72 through which the stub axle pins are passed, as shown in Fig. 3. The opposite ends of positioning link 69 are disposed between the corresponding block 60 and the adjacent end of the corresponding outer link 56.

An examination of Figs. 3, 4, and 5 will show that screw shaft 63, worm 65, support block 66 and positioning link 69 constitute a variable length interconnection mechanism 73 between blocks 60 such that the distance along belt 33 between axle axes 163 is adjustable in response to rotation of wheel 70 to rotate worm 65. The slot apertures 72 formed in positioning link 69 accommodate linear movement of axle pin assemblies 53 toward and away from each other to vary the effective length of belt 33.

Variable length connection mechanism 73 cooperates with an actuating mechanism 74 located at belt length adjustment station 40. The actuating mechanism includes a pair of solenoids 75 and 76 having reciprocable armatures 77 and 78, respectively. The solenoids are disposed parallel to each other and their armatures are supported in a guide 79 secured to foundation 41. Solenoid armatures 77 and 78 are disposed to cooperate with the upper and lower portions of operating wheel 70 as the wheel passes belt length adjustment station 40 in response to operation of drive pulley 34. Each solenoid armature is biased away from cooperation with wheel 70 by a spring 80 cooperating between guide 79 and the armature. Solenoids 75 and 76 are disposed such that when either solenoid is energized, the armature thereof is extended, from the unenergized position thereof shown in Fig. 6, toward the path of movement of belt 33 sufficiently to move into interfering relationship with the spur teeth 71 defined by wheel 70. Thus, engagement of solenoid armature 77 with wheel 70 causes the upper portion of the wheel to tend to remain stationary momentarily relative to foundation 41 as belt 33 is driven past the actuating mechanism, thereby turning worm 65 in a direction productive of movement of blocks 60 toward each other. Conversely, cooperation between solenoid armature 78 and the lower portion of wheel 70

produces rotation of worm 65 in a direction productive of increased distance between blocks 60. Such rotation of wheel 70 occurs only momentarily as the wheel is moved past actuating mechanism 74, and thus a single instance of cooperation of actuating mechanism 74 with variable link connection mechanism 73 produces a predetermined small change in the effective length of conveyor belt 33.

Energization current for solenoids 75 and 76 is provided to the solenoids via conductors 81 and 82, respectively, which conductors constitute a portion of connection 52 between belt length adjustment station 40 and tolerance cumulation scanning station 51. Connection 52 includes a control circuit 83 which receives signals from scanning station 51 and controls the energization of conductors 81 and 82 dependent upon the nature of the signal received by the control circuit from scanning station 51.

A plurality of carrier blocks are carried by conveyor belt 33. The carrier blocks include a plurality of intermediate carrier blocks 84 disposed one between each adjacent pair of intermediate axle pins 54, and a pair of end carrier blocks 85 connected to the belt between each end axle pin assembly 53 and the adjacent intermediate axle pin 54. This is shown best in Fig. 13. All intermediate carrier blocks 84 are substantially identical to each other and end carrier blocks 85 are identical to each other. As shown in best in Fig. 11, each carrier block 84 is fabricated of electrically non-conductive, dimensionally stable material, and has a body 86 which is of generally cubical configuration. A projection 87 of rectangular cross-section extends downwardly from the central portion of body 86 and is sized to fit snugly between spacer bushings 58 and the link members associated with each adjacent pair of intermediate axle pins 54. Thus, half of the plurality of intermediate carrier blocks have projections 87 sized to fit in the opening defined between inner link members 57, as shown in Fig. 3, and the remaining intermediate carrier blocks have projections 87 sized to fit in the space bounded by a pair of outer link members 56. The length of each projection 87 is slightly less than the height of link members 56 and 57. A downwardly open, internally threaded hole 88 is formed centrally of each projection to accommodate an externally threaded stud 89 to facilitate connection of the carrier block to conveyor belt 33 by means of a washer 90 and a nut 91 as shown in Fig. 11. Washer 90 has a diameter sufficient to engage the lower edges of the pertinent link members between which projection 87 is disposed when the carrier block is connected to belt 33. Each block 84 also defines a side

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flange 93 which extends laterally from opposite side surfaces 94 of body 86. The upper surface of each flange is coplanar with a top surface 95 of body 86. The distance between the underside of each side flange 93 and block bottom surface 92 is greater than the distance of the top of wheel 70 above the top of conveyor belt 33 as defined by link members 56 and 57, as shown in Fig. 4.

A pair of parallel grooves 96 are formed in the top surface of each intermediate carrier block 84 and of each end carrier block 85. The centers of grooves 96 are spaced apart by a distance which is equal to the distance between the centers of truss runners 13 and 14 in truss section strip 21. Each groove has a depth from block top surface 95 which is equal to the diameter of the wire used to define truss runners 13 and 14, plus about one-half of the diameter of the wire used to define strut members 17 and close-out members 18. Grooves 96 are disposed between the side surfaces 94 of each carrier block. Each of grooves 96 extend across the entire length of the carrier block between opposite end surfaces 97 of the block; the end surfaces of end carrier blocks 85 are designated 98 for the purposes of distinction between the intermediate and end carrier blocks. Grooves 96 in all carrier blocks disposed across the top of conveyor belt loop 33 between pulleys 34 and 35 are aligned with each other, and wire uncoiling and straightening stations 32 are aligned with the grooves to feed parallel strands of wire 31 from coils 30 into grooves 96.

Each carrier block 84 further defines a groove 99 across its top surface 95 at an angle to grooves 96, the angle corresponds to the angle of inclination of strut member 17 to truss runners 13 and 14. Each groove 99 has a length somewhat greater than the length of each strut member 17 and is sufficiently deep that when truss runners 13 and 14 are disposed in their respective grooves 96, the upper portions of the truss runners traverse the lower portions of grooves 99 inside the opposite ends of grooves 99. Grooves 99 are provided for receiving and properly positioning precut wire lengths used to define strut members 17.

Each intermediate carrier block 84 also includes an electrically conductive bus member embedded within the electrically non-conductive body of the carrier block. The bus member is disposed in alignment with groove 99 and is spaced below block top surface 95 so that the bottom portions of grooves 96 are coplanar with the upper surface of the bus member at the opposite ends of the bus member. Thus, when truss runners 13 and 14 are disposed in grooves 96, each truss runner conductively engages

bus member 100 below the location where strut member grooves 99 cross the truss runner grooves.

Each groove 99 has a depth which is less than the diameter of the wire used to define strut members 17. Thus, when a precut strut member element is disposed in groove 99, the upper surface of the element lies above top surface 95. Intermediate carrier blocks 84 are connected to conveyor belt 33 so that grooves 99 in adjacent carrier blocks converge and diverge from each other in the manner described above concerning the disposition of strut members 17 in each truss section 19.

If desired, the distance between end surfaces 97 of each intermediate carrier block 84 may be equal to or less than, but not greater than, the distance between the axes 163<sup>1</sup> of adjacent intermediate axle pins of conveyor belt 33. Where the spacing between block end surfaces 97 equals the spacing between axes 163<sup>1</sup>, the end surfaces of adjacent carrier blocks intimately engage each other along the upper portion of the belt loop to impart to the belt between the pulleys some measure of resistance to deflection in response to loads applied downwardly to the belt. If desired, such cooperation between the end surfaces of adjacent carrier blocks may be relied upon to provide all back-up force required in association with the operation of welding assemblies 43, 46 and 49 as strut members 17 and close-out members 18 are welded to truss runners 13 and 14. Preferably, however, back-up assemblies 44, 47 and 50 are provided to cooperate with the bottom surfaces of side flanges 93 to provide the back-up force associated with the operation of welding assemblies 43, 46 and 49.

Each end carrier block 85 incorporates all of the features described above concerning intermediate carrier blocks 84. From an examination of Fig. 3, it will be apparent that the cross-sectional dimensions of the lower projection 87 of each end carrier block are defined with reference to the opening between outer link members 56, block 60 and spacer bushing 58 at each end 55 of belt 33. Also, the distance between the end surfaces 98 of each end carrier block is on the order of 140 percent greater than the distance between adjacent intermediate axle pin axes 163<sup>1</sup>. Each end carrier block 85 defines a pair of parallel grooves 96, a groove 99 for receipt of a strut member 17, and a bus member 100 below and parallel to the strut member receiving groove. Further, each end carrier block defines a transverse groove 101 in its top surface aligned perpendicular to truss runner grooves 96 and of about the same depth as the adjacent strut member receiving groove 99. Grooves 101 are provided for receiving and properly

positioning precut close-out members 18. A conductive bus member 102 (see Fig. 12) is provided below and parallel to each close-out member receiving groove 101 to be engaged adjacent its opposite ends by the corresponding truss runner 13 or 14. Bus members 100 and 102 in the end carrier blocks are separated from each other by the non-conductive material of the carrier block.

As shown best in Figs. 10 and 13, the opposite ends of each strut member receiving groove 99 are disposed inwardly of carrier block 84 from the opposite end surfaces 97 of the carrier block. The same situation exists with the ends of the strut member receiving grooves in the end carrier blocks relative to the adjacent end surfaces 98. This position of the strut member receiving grooves in the several carrier blocks on belt 33 results in the proximate ends of adjacent strut members in each truss section 19 being spaced from each other by a predetermined distance along truss runners 13 and 14. In the presently preferred matrix 11 organized on a 2 inch cubical module, the spacing along each truss runner between the converging ends of adjacent strut members is approximately 1 inch. This spacing is desired in order to provide the necessary clearance and desired tolerance between the adjacent ends of the strut members to permit engagement of the electrodes in matrix fabrication station 22 with truss runners 13 and 14.

The distance between end surfaces 98 of the end carrier blocks is defined at an amount less than  $1\frac{1}{2}$  times the distance between adjacent axes 163<sup>1</sup> to accommodate movement of the end carrier blocks toward and away from each other in response to the operation of variable length connection mechanism 73.

The effective length of conveyor belt 33 is equal to the effective length of one truss unit section 19, plus an additional amount determined by the width of cut made by a matrix cutting assembly 150 provided in matrix fabrication apparatus 115 described below. Thus, if matrix 11 is to be provided with an effective length of 10 feet, then the effective length of conveyor belt 33 is slightly greater than 10 feet.

From the foregoing description, it will be apparent that, by the nature of conveyor belt 33 and of the carrier blocks carried by it, strip 21 of end-to-end interconnected truss sections 19, may be fabricated rapidly and essentially automatically at truss fabrication station 20. As the belt is driven through the truss fabrication station, dispensing station 37 is effective to dispense precut lengths of suitable wire stock into close-out member receiving and positioning grooves 101, and dispensing stations 38 and 39 are effective to dispense suitably precut lengths of wire into strut member receiving and

positioning grooves 99. As the strut members and close-out members are dispensed onto belt 33, they make contact adjacent their ends with the upper portions of truss runners 13 and 14, which have previously been positioned within their receiving grooves 96 by operation of uncoiling and straightening stations 32. As a dispensed close-out member passes weld station 42, welding assembly 43 is operated to drive a pair of electrodes 103 into contact with the opposite ends of the close-out member, thereby to establish a conductive path between the electrodes through the close-out member, truss runners and bus member 102. During such contact a pulse of welding current (represented by arrow 104 in Fig. 12) is passed between the electrodes to resistance weld close-out member 18 at its opposite ends to truss runners 13 and 14, respectively; thereafter, electrodes 103 are withdrawn from the close-out member.

Similarly, as strut members 17 pass strut member welding stations 45 and 48, a pair of welding electrodes (similar to electrodes 103) at each station are brought into contact with the opposite ends of the dispensed strut members to establish a conductive path between the electrodes via bus members 100. Welding station 45 is provided for welding to the truss runners those strut members which, when conveyor belt 33 is viewed from the top, slope from left to right between truss runners 14 and 13. Conversely, welding station 48 is provided for welding to the truss runners those strut members which slope from right to left proceeding from truss runner 13 to truss runner 14. The appropriate periods at which welding assemblies 43, 46 and 49 are operated to weld the close-out and strut members to the truss runners are controlled by conventional equipment which does not itself form a part of this invention. If desired, the controlling equipment for the welding assemblies may be regulated by suitable stops, pins or the like carried by the corresponding carrier blocks and the operation of dispensing stations 37, 38 and 39 may be regulated in the same manner by the same or a different set of stop pins or the like.

For most efficient operation, it is desired that conveyor belt 33 be driven continuously. Accordingly, welding assemblies 43, 46 and 49 are mounted for limited movement relative to the back-up assemblies 44, 47, 50 along the path of belt 33 so that the electrodes of these welding assemblies may be stationary relative to the belt during those intervals when the electrodes are in physical contact with the close-out and strut members, respectively.

The strips of truss sections 19 is wound onto a coil 111.

An examination of Fig. 1 will show that each matrix 11 requires a plurality of truss

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sections 19. Where matrix 11 is defined on the 2 inch cubical module defined above and has a width of 4 feet, it is apparent that twenty-five truss sections 19 are provided in each matrix. Thus, if operation of matrix fabrication station produces matrix 11 at the rate of 1 foot per minute, it is necessary that truss sections 19 must be fabricated at the rate of 25 feet per minute. As a practical matter, plural truss fabrication stations are preferred in an overall installation to supply sufficient truss section strip material to a matrix fabrication station operated at maximum rate. It is important that the matrix fabrication station accommodate strips of truss section fed to it from one or more truss fabrication stations. Since, as a practical matter, plural truss fabrication stations are used, and since precise dimensional identity between plural truss fabrication stations is virtually impossible to achieve, the belt length adjustment station 40 provided in each truss fabrication station assures that the truss sections 19 produced at each of a plurality of truss fabrication stations are of uniform length within small predetermined limits of permissible length variation. The factors which, but for the presence of belt length adjusting mechanisms 40 at each truss fabrication station, could lead to variations in the effective length of truss sections 19 include the temperature of the environment at each truss fabrication station at the time of manufacture of any given truss section, differences in wear between different truss fabrication stations, and differences in tolerance in dimension, position and the like between corresponding components of different truss fabrication stations.

As noted above, the belt length adjusting mechanism at each truss fabrication station is operated in response to suitable control signals supplied by control circuit 83 which receives tolerance cumulation signals from a tolerance cumulation scanning station 51 disposed between conveyor belt 33 and coiling station 23. As shown best in Figs. 7, 8 and 9, scanning station 51 includes a pair of position sensors 104 and 105 which cooperate with selected elements of strip 21, preferably close-out members 18. Each position sensor 104 and 105 includes a scanning device 106 sensitive to the position of a close-out member 18<sup>1</sup> relative to a center plane 107 of a space 108 provided between the sensing heads. The width of space 108 is defined with reference to the permissible range by which the total length of a predetermined number of end-to-end interconnected truss sections 19 of strip 21 may vary. Scanning devices 106 may be of the magnetic type or optical type, or any other type suitable, dependent upon the degree of control to be exercised over the amount of di-

mensional tolerance which can be cumulated in the length of the predetermined number of truss sections before a correction is made in the effective length of belt 33 by operation of variable length connection mechanism 73. Preferably, scanning devices 106 are disposed below strip 21 between conveyor belt 33 and coiling station 23 and are connected by suitable conductors (not shown) to control circuit 83.

Fig. 7 shows a close-out element 18<sup>1</sup> disposed essentially within center plane 107 of space 108 between scanning devices 106. In this case, the output signals from position sensors 105 and 104 are essentially equal to each other, thereby indicating that close-out member 18<sup>1</sup> is disposed sufficiently close to plane 107 that no corrective action need be taken upon the effective length of belt 33.

In Fig. 8, however, close-out member 18<sup>1</sup> is disposed sufficiently far to the right of center plane 107 that the output of sensor 104 significantly exceeds the output of sensor 105. Under these circumstances, the difference in signals between sensors 104 and 105 is indicative of the fact that the truss section of which close-out member 18<sup>1</sup> forms a part (and of the adjacent truss sections within strip 21) is somewhat shorter than the optimum desired length of a truss section by an amount which is within the amount of tolerance acceptable in truss fabrication station 20, but which is sufficiently close to the limit of tolerance acceptable that a correction in the effective length of belt 33 should be accomplished, to increase the effective length of a truss section. In this situation, control circuit 83 is effective to generate a signal, via connection 52, to belt length adjustment station 40 effective to operate solenoid 76, thereby to increase the spacing between axes 163.

Fig. 9, on the other hand, illustrates the reverse of the situation shown in Fig. 8. In this case, the signal from sensor 105 significantly exceeds the value of the signal from sensor 104. Circuit 83, therefore, is effective to generate a control signal which is applied to solenoid 75 to produce operation of variable length connection mechanism 73 to reduce the distance between axes 163.

For example, it may be desired to control the length of each truss section at 10 feet plus or minus 0.0025 inch. Under such circumstances, sensors 105 and 104 may be arranged to produce belt lengthening or shortening output signals from circuit 83 if the close-out members 18 at the end of every fifth truss section in strip 21 deviates by more than 0.010 inch from the position which that close-out member would occupy (a position within center plane 107) if all five truss sections within the group of five truss sections were precisely 10 feet in length. A deviation of 0.010 inch in the position of

close-out member 18<sup>1</sup> from precise alignment in center plane 107 means that the five truss sections in the group of five represented by close-out member 18<sup>1</sup> are 0.0020 inch shorter than the desired length of 10 feet 0.000 inches. Thus, as indicated in Fig. 8, sensors 104 and 105 are arranged to produce a belt lengthening control signal from circuit 83 when the difference between the signals generated at sensors 104 and 105 shows that close-out member 18<sup>1</sup> is disposed 0.010 inch or more out of precise alignment with center plane 107 to the right of the center plane. Conversely, if close-out member 18<sup>1</sup> is disposed 0.010 inch or more to the left out of precise alignment with center plane 107, the value of the signal from sensor 105 sufficiently exceeds the value of the signal from sensor 104 that a belt shortening signal is produced by circuit 83.

Variable length connection mechanism 73 and actuating mechanism 74 are arranged so that, when the actuating mechanism receives a control signal from circuit 83 at either solenoid 75 or solenoid 76, the actuating mechanism is effective, via variable length connection system 73, to produce a 0.010 inch change in the effective length of conveyor belt 33. Preferably, control circuit 83 includes a suitable sampling circuit arranged to produce scanning operation by sensors 104 and 105 of the position of, say, every fifth close-out member 18<sup>1</sup> relative to center plane 107. In this manner, belt length adjusting station 40 is operated at a maximum interval corresponding to every five truss sections fabricated at station 20, rather than at intervals corresponding to each complete cycle of belt 33 through the fabrication station.

It will be understood that the alterations of belt length effected by the mechanism 73 are sufficiently small to be accommodated by the conveyor structure 33, 34, 35 and in particular by the slack return run of the belt.

Reference is directed to my co-pending Patent Application No. 13479/73 (Serial No. 1,430,246) from which the present application is divided and which claims matrix fabricating apparatus in combination with apparatus as described herein.

#### WHAT I CLAIM IS:—

1. Apparatus for fabricating a workpiece including a longitudinal member and additional component members connected to the longitudinal member at locations spaced apart along the longitudinal member within predetermined limits, the apparatus comprising connection stations, an endless conveyor belt for transporting the longitudinal member lengthwise through said connection

stations for the attachment thereto of the additional component members, the belt defining locating means for said additional component members for locating said additional component members relative to the longitudinal member, and means operative during driving of the belt to alter the length of the belt, thereby to adjust the length of the belt between said locating means within said predetermined limits.

2. Apparatus for fabricating a welded wire truss comprising longitudinally extending wires interconnected by transverse wires predetermined ones of which are to be spaced apart along the truss within predetermined limits, the apparatus comprising welding stations, an endless conveyor belt for transporting the longitudinally extending wires lengthwise through said welding stations for the attachment thereto of the transverse wires, the belt defining locating means for said predetermined transverse wires for locating said predetermined transverse wires transversely of the longitudinal wires, and means operative during driving of the belt to alter the length of the belt, thereby to adjust the length of the belt between said locating means within said predetermined limits.

3. Apparatus according to claim 1 or 2 including means for generating a signal when the distance along the belt between said locating means differs by more than a predetermined amount within said predetermined limits, and means responsive to the signal for operating the belt length altering means to reduce the difference.

4. Apparatus according to claim 1, 2 or 3, wherein the belt length altering means includes means for interconnecting opposite ends of the belt to define the belt loop.

5. Apparatus according to claim 2 or claim 3 or 4 when dependent upon claim 2, wherein the belt defines a locating means for each transverse wire of the truss and also an electrically conductive path for welding current for welding the wire simultaneously to two longitudinally extending wires of the truss.

6. Apparatus according to claim 5, wherein the belt comprises a plurality of electrically non-conductive carrier blocks having grooves for receiving and positioning the longitudinally extending wires and the transverse wires with the transverse wires resting on top of the longitudinally extending wires, and said electrically conductive paths are defined by conductors embedded in the blocks.

7. Apparatus according to claim 6, wherein the belt comprises a length of link

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close-out member 18<sup>1</sup> from precise alignment in center plane 107 means that the five truss sections in the group of five represented by close-out member 18<sup>1</sup> are 0.0020 inch shorter than the desired length of 10 feet 0.000 inches. Thus, as indicated in Fig. 8, sensors 104 and 105 are arranged to produce a belt lengthening control signal from circuit 83 when the difference between the signals generated at sensors 104 and 105 shows that close-out member 18<sup>1</sup> is disposed 0.010 inch or more out of precise alignment with center plane 107 to the right of the center plane. Conversely, if close-out member 18<sup>1</sup> is disposed 0.010 inch or more to the left out of precise alignment with center plane 107, the value of the signal from sensor 105 sufficiently exceeds the value of the signal from sensor 104 that a belt shortening signal is produced by circuit 83.

Variable length connection mechanism 73 and actuating mechanism 74 are arranged so that, when the actuating mechanism receives a control signal from circuit 83 at either solenoid 75 or solenoid 76, the actuating mechanism is effective, via variable length connection system 73, to produce a 0.010 inch change in the effective length of conveyor belt 33. Preferably, control circuit 83 includes a suitable sampling circuit arranged to produce scanning operation by sensors 104 and 105 of the position of, say, every fifth close-out member 18<sup>1</sup> relative to center plane 107. In this manner, belt length adjusting station 40 is operated at a maximum interval corresponding to every five truss sections fabricated at station 20, rather than at intervals corresponding to each complete cycle of belt 33 through the fabrication station.

It will be understood that the alterations of belt length effected by the mechanism 73 are sufficiently small to be accommodated by the conveyor structure 33, 34, 35 and in particular by the slack return run of the belt.

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#### WHAT I CLAIM IS:—

1. Apparatus for fabricating a workpiece including a longitudinal member and additional component members connected to the longitudinal member at locations spaced apart along the longitudinal member within predetermined limits, the apparatus comprising connection stations, an endless conveyor belt for transporting the longitudinal member lengthwise through said connection

stations for the attachment thereto of the additional component members, the belt defining locating means for said additional component members for locating said additional component members relative to the longitudinal member, and means operative during driving of the belt to alter the length of the belt, thereby to adjust the length of the belt between said locating means within said predetermined limits.

2. Apparatus for fabricating a welded wire truss comprising longitudinally extending wires interconnected by transverse wires predetermined ones of which are to be spaced apart along the truss within predetermined limits, the apparatus comprising welding stations, an endless conveyor belt for transporting the longitudinally extending wires lengthwise through said welding stations for the attachment thereto of the transverse wires, the belt defining locating means for said predetermined transverse wires for locating said predetermined transverse wires transversely of the longitudinal wires, and means operative during driving of the belt to alter the length of the belt, thereby to adjust the length of the belt between said locating means within said predetermined limits.

3. Apparatus according to claim 1 or 2 including means for generating a signal when the distance along the belt between said locating means differs by more than a predetermined amount within said predetermined limits, and means responsive to the signal for operating the belt length altering means to reduce the difference.

4. Apparatus according to claim 1, 2 or 3, wherein the belt length altering means includes means for interconnecting opposite ends of the belt to define the belt loop.

5. Apparatus according to claim 2 or claim 3 or 4 when dependent upon claim 2, wherein the belt defines a locating means for each transverse wire of the truss and also an electrically conductive path for welding current for welding the wire simultaneously to two longitudinally extending wires of the truss.

6. Apparatus according to claim 5, wherein the belt comprises a plurality of electrically non-conductive carrier blocks having grooves for receiving and positioning the longitudinally extending wires and the transverse wires with the transverse wires resting on top of the longitudinally extending wires, and said electrically conductive paths are defined by conductors embedded in the blocks.

7. Apparatus according to claim 6, wherein the belt comprises a length of link

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chain to which the carrier blocks are mounted.

8. Apparatus for fabricating a welded wire truss, substantially as hereinbefore described with reference to, and as shown in, Figs. 2 to 13 of the accompanying drawings.
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