May 3, 1966 N. E. HEDEEN 3,249,238

BOOM COMPRISED OF SECTIONS OF DIFFERING CROSS SECTION HAVING ALIGNED ELASTIC CENTERS

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Fig. 1

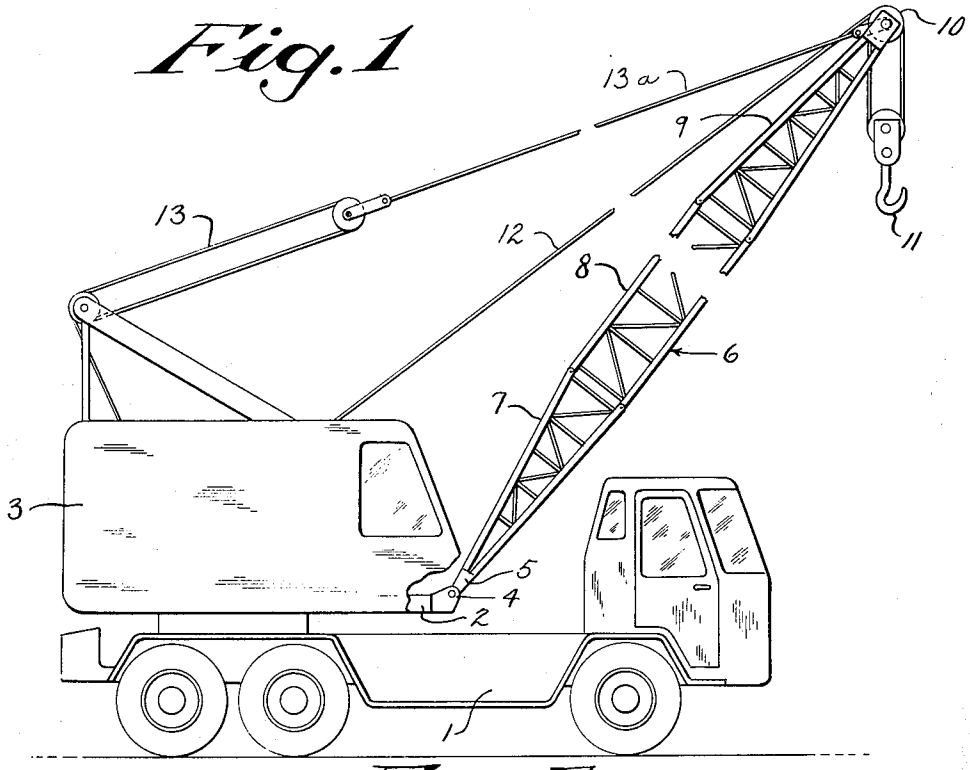


Fig. 7

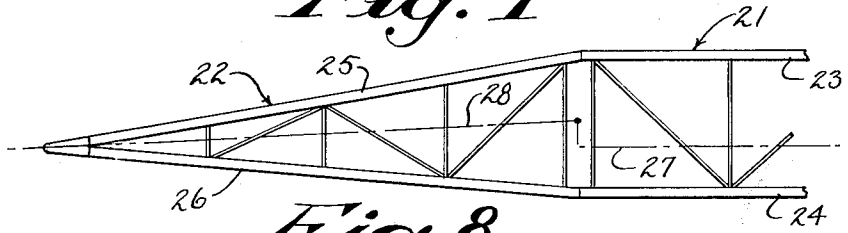


Fig. 8

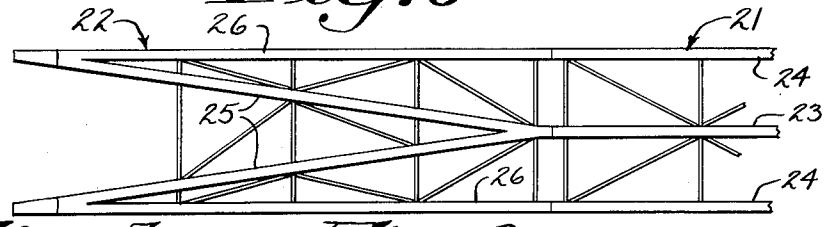


Fig. 5

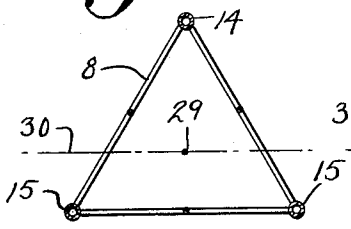
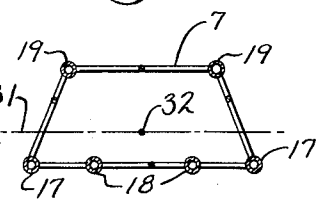


Fig. 6



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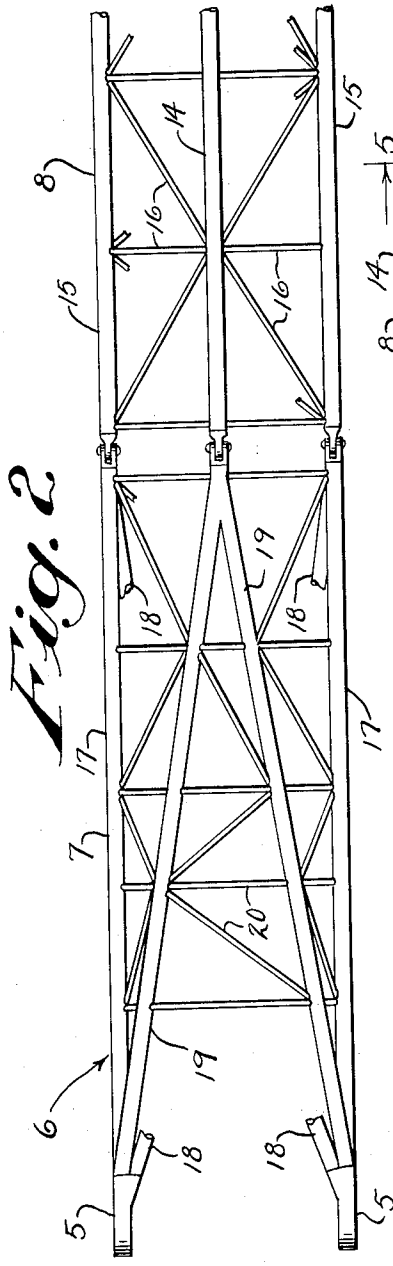


Fig. 2

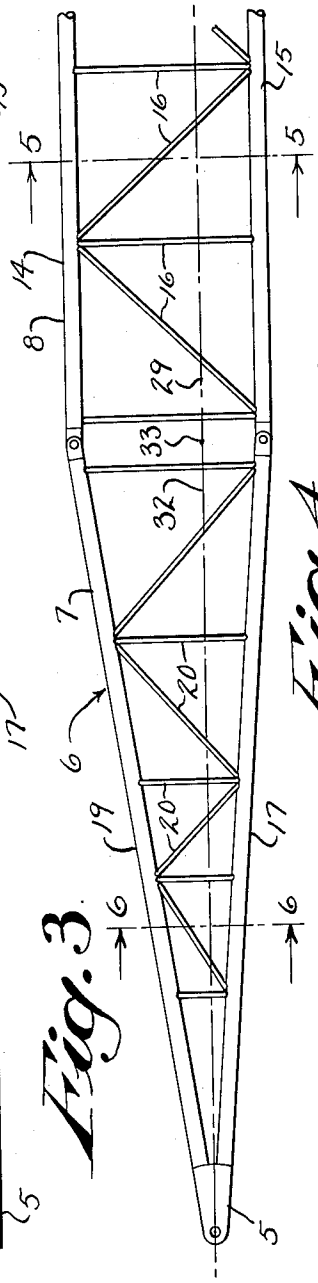


Fig. 3

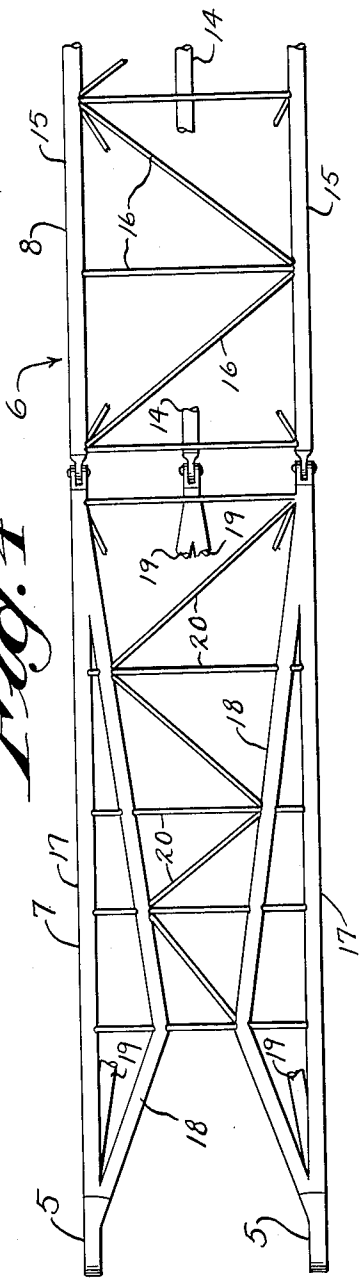


Fig. 4

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BOOM COMPRISED OF SECTIONS OF DIFFERING CROSS SECTION HAVING ALIGNED ELASTIC CENTERS

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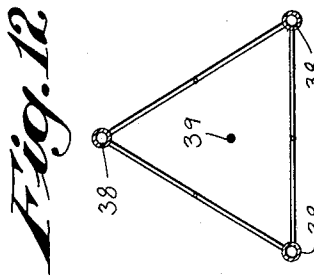


Fig. 12

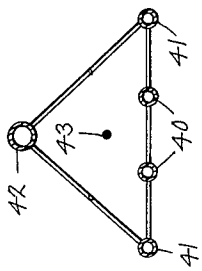


Fig. 13

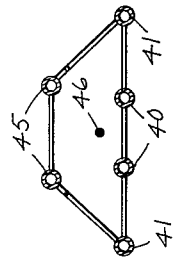


Fig. 14

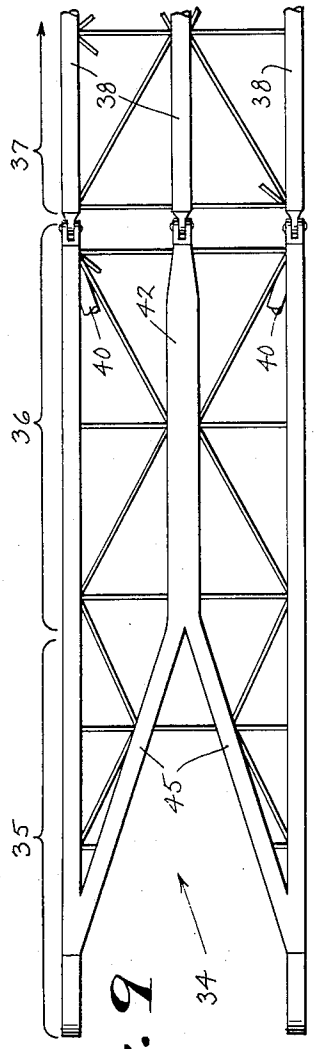


Fig. 9

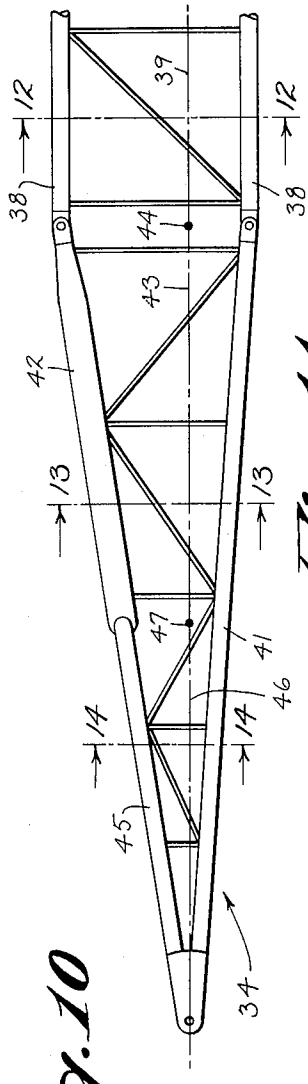


Fig. 10

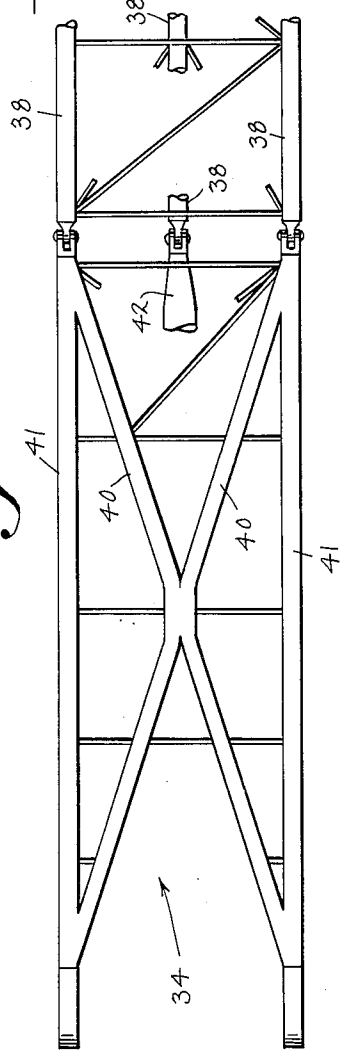


Fig. 11

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BOOM COMPRISED OF SECTIONS OF DIFFERING CROSS SECTION HAVING ALIGNED ELASTIC CENTERS

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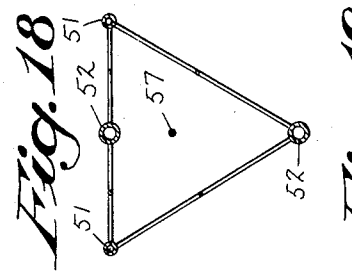


Fig. 18

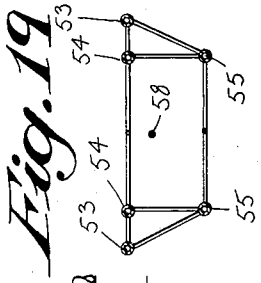


Fig. 19

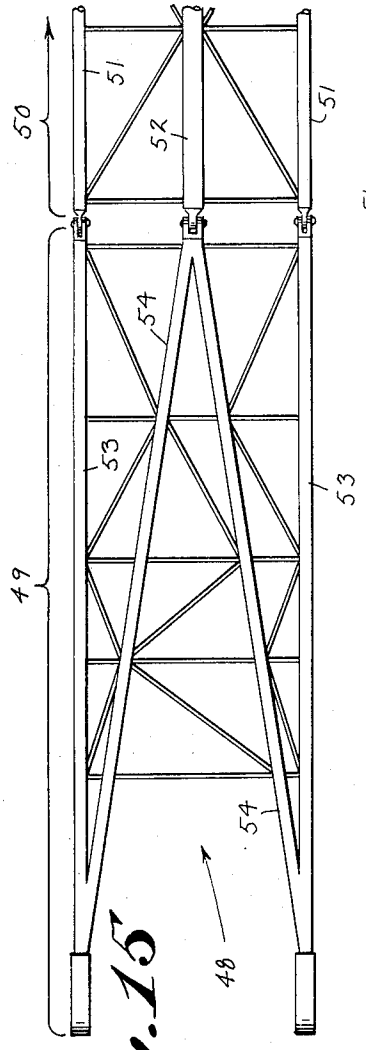


Fig. 15

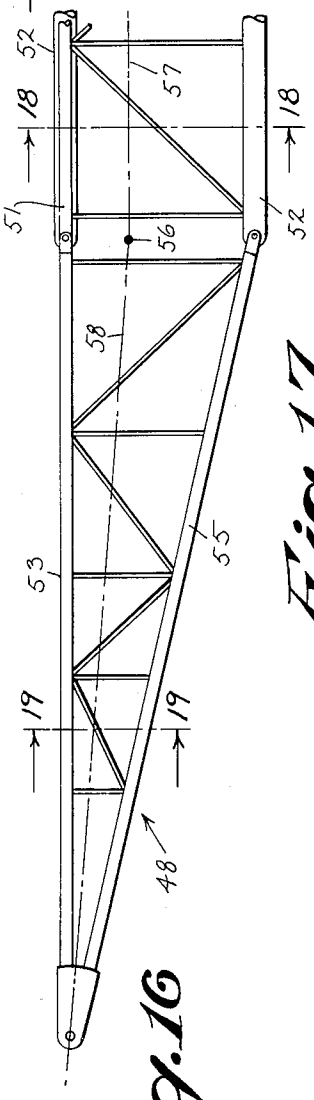


Fig. 16

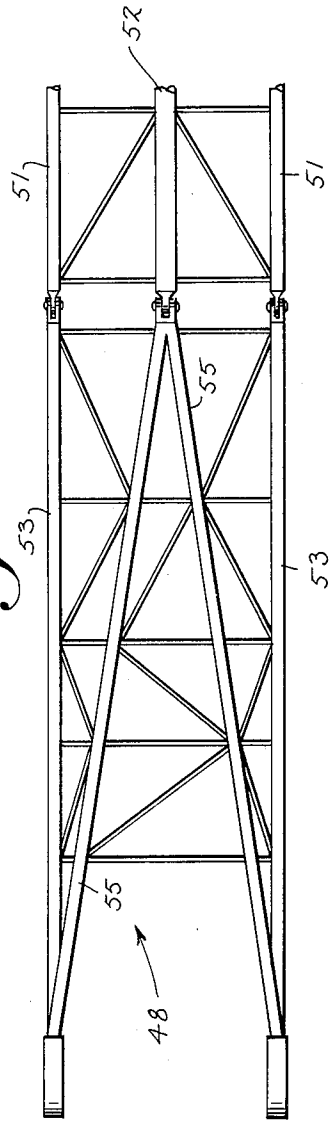


Fig. 17

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BOOM COMPRISED OF SECTIONS OF DIFFERING CROSS SECTION HAVING ALIGNED ELASTIC CENTERS

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Fig. 20

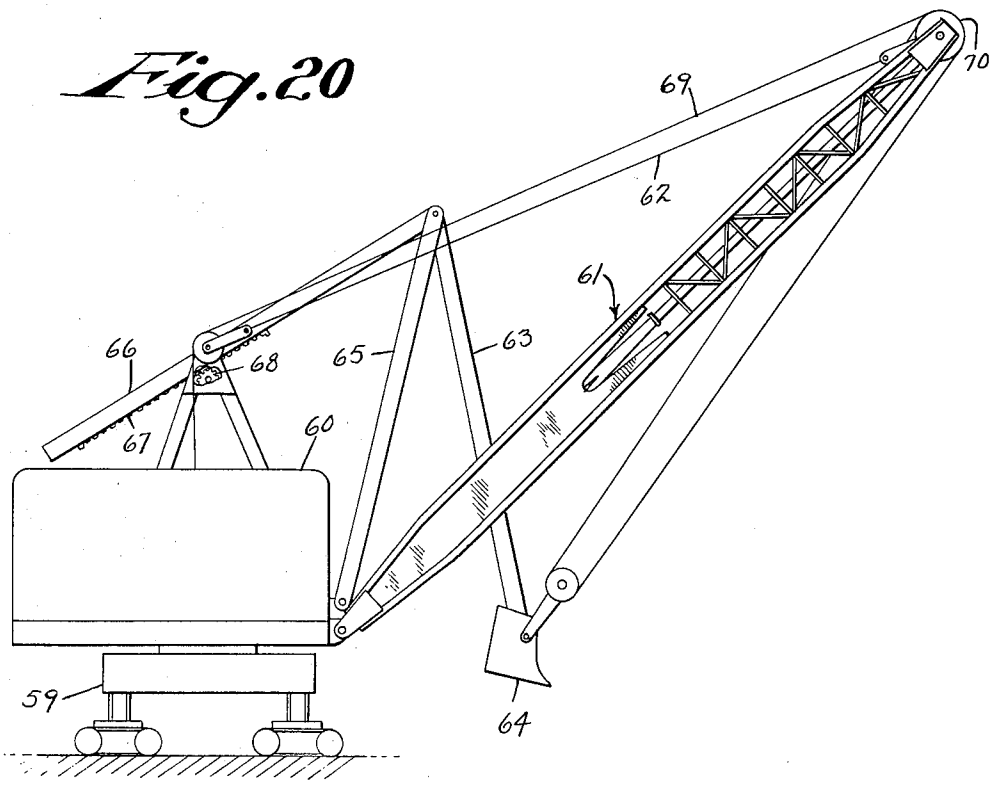


Fig. 27

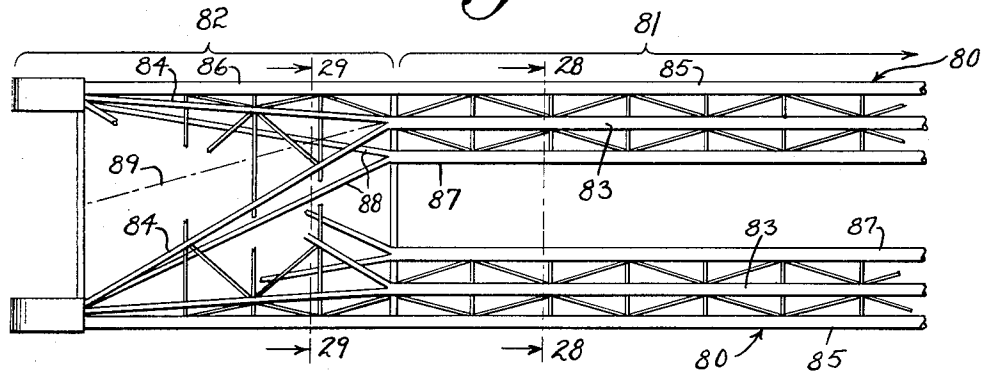


Fig. 28

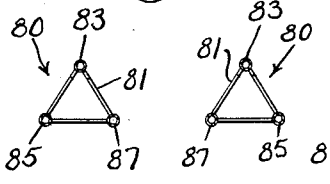
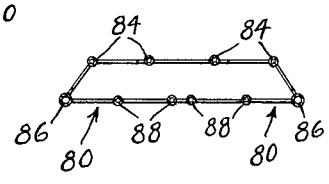


Fig. 29



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BOOM COMPRISED OF SECTIONS OF DIFFERING CROSS SECTION HAVING ALIGNED ELASTIC CENTERS

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Fig. 23

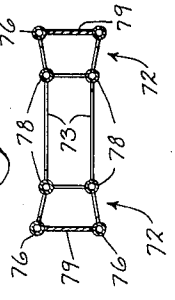


Fig. 24

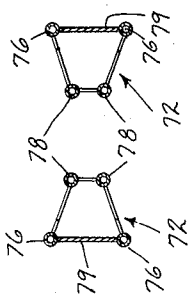


Fig. 21



Fig. 22

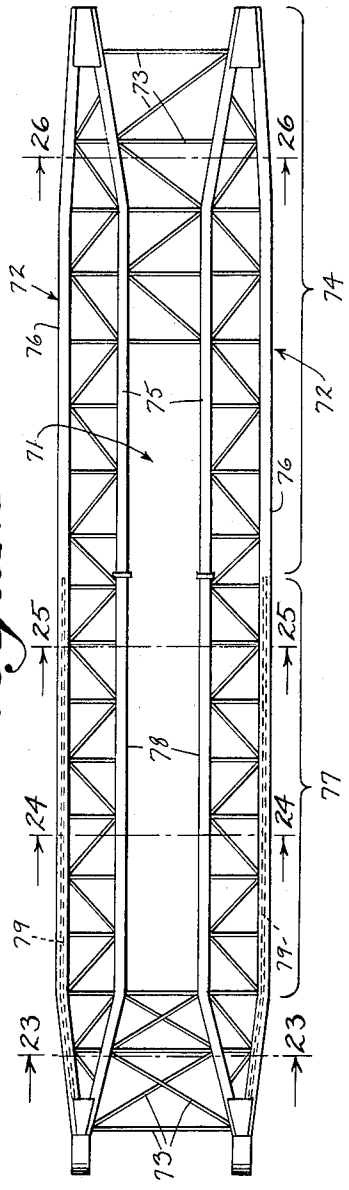


Fig. 26

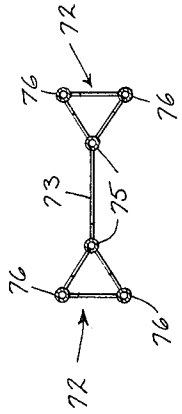
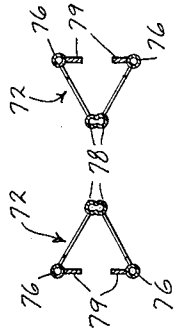


Fig. 25



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United States Patent Office

3,249,238

Patented May 3, 1966

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BOOM COMPRISED OF SECTIONS OF DIFFERING CROSS SECTION HAVING ALIGNED ELASTIC CENTERS

Nils E. Hedeen, Milwaukee, Wis., assignor to Bucyrus-Erie Company, South Milwaukee, Wis., a corporation of Delaware

Filed Feb. 14, 1964, Ser. No. 344,922
15 Claims. (Cl. 212—144)

This invention relates to booms useful in cranes, excavators and similar structures, and it more specifically resides in a boom having longitudinal chords that define a first cross section geometry along a part of its length and a second cross section geometry along another part of its length, in which the chords of the differing sections are arranged so that at the transition between sections the line of action for a load imposing a uniform strain in one section is in substantial alignment with the line of action for a load imposing a uniform strain in the other section.

Booms for material handling apparatus are subject to large compression loading, and it is a problem to effectively transmit longitudinal loads along a boom without developing a curvature that might decrease boom strength. This becomes a particular problem when a boom is comprised of sections that have different cross section geometries. A specific example is a crane boom having a long center section made up of three chords that define a triangular cross section, and a base section which terminates in two spaced boom feet. The chords in the base section normally present a quadrilateral cross section geometry, and a load imposing a uniform strain in one section will have a line of action displaced with respect to the line of action of a load for the other section which also imposes a uniform strain. This offset between the lines of action creates an undesirable flexure stress within the boom, and it is a purpose of this invention to minimize such internal flexure stress.

With particular respect to the example of a triangular configuration, it has some preferred characteristics over other forms, such as booms of rectangular cross section, but usually the triangular configuration cannot be maintained along the entire length of a boom. This is due to the termination at the base end in a pair of spaced boom feet that are received by boom foot brackets at the front of the machinery platform. The longitudinal chords forming the boom terminate at these feet, and also the center of the boom at the base end is kept open for the mounting of machinery or sheaves, or for the passing of cables. Hence, in a boom of triangular cross section the chord forming the apex of the triangle must split near the base end of the boom into a pair of chords, with one chord extending to one boom foot and the other chord extending to the other boom foot. The two chords forming the side of the triangle opposite the apex each extend to a single boom foot, and hence the cross section geometry becomes quadrilateral in that sections where the apex chord is split. As a result, the boom has a base section with a quadrilateral cross section and a center section with a triangular cross section, and at the transition between the two geometries, triangular and quadrilateral, compressive loading forces are not transferred evenly.

In the present invention the cross section areas of the chords of each section of the boom are selected and placed in such positions that at the transition between the two geometries the line of action of a load imposing a uniform strain on one section meets with the line of action of a load imposing a similar uniform strain in the adjacent section. Upon achieving this registry of the lines of action an improved boom is obtained in which

the base section, carrying the boom feet, matches the remainder of the boom for optimum transmission of compressive loading. This can be accomplished in booms having different geometric figures than triangular and quadrilateral, and can be applied in booms for various uses.

In those applications where all chords of the boom are of like material the lines of action for loads imposing uniform strains are coincident with the neutral axes, and therefor in these particular applications the areas of the chords and their positions are selected to have the neutral axis of one section meet, or be in close registry with, the neutral axis of the adjacent section at the transition between sections. The neutral axis is that line about which the summation of the area moments of the chords is zero, and when each chord has a modulus of elasticity like that of other chords a load acting through this axis will be distributed with a uniform stress in the chords as well as a uniform strain.

In an application where materials of different moduli of elasticity are used in the chords the relationship of neutral axes and area moments is modified. The chord areas and their positions are then selected to have registry, at the transition between geometries, between points in each section about which the summation of the products of each area moment and its respective modulus of elasticity is zero. These products are termed herein as "elastic moment areas" and the point about which the summation is zero is termed the "elastic center."

It is therefore an object of this invention to provide a boom for material handling apparatus and the like comprised of sections of different cross section geometry in which the elastic centers of adjacent sections are in substantial alignment with one another at the transition between sections.

It is another object of this invention to provide a boom having sections of different characteristics in which the strains under loads are such that the boom remains substantially straight.

It is another object of this invention to provide a boom in which internal flexure stress is minimized.

It is another object of this invention to provide an improved triangular boom, for use in cranes and the like, to take advantage of the rigidity and inherent strength of this form of construction.

It is another object of this invention to provide a boom which presents small resistance to wind, to thereby improve the stability of a device of which it is a part.

It is a further object of this invention to transmit compressive loading in a boom with substantially uniformly distributed stress through the chords that comprise the principal structural elements of the boom.

It is a still further object of the invention to provide a boom of triangular cross section with a base section of quadrilateral cross section in which the neutral axes of the triangular and quadrilateral sections substantially align with one another at the point of transition between the two geometries.

The foregoing and other objects and advantages of this invention will appear from the description to follow. In the description reference is made to the accompanying drawings which form a part hereof and in which there is shown by way of illustration several specific embodiments of the invention. These embodiments will be described in sufficient detail to enable those skilled in the art to practice this invention. The invention may also reside in other embodiments and various modifications and rearrangements, as may occur to one practicing the art. Consequently, the following detailed description is not to be taken in a limiting sense; instead the scope of the invention is best defined by the claims at the end of this specification.

In the drawings:

FIG. 1 is a side view in elevation of a truck crane employing a boom embodying the invention,

FIG. 2 is a fragmentary top view of the boom in FIG. 1 showing the base section and a portion of the triangular center section, with chords and lacings at the bottom broken away to clarify the arrangment of the upper chords,

FIG. 3 is a side view in elevation of the boom of FIG. 1,

FIG. 4 is a bottom view of the boom of FIG. 1, with upper chords and lacings at the top of the boom broken away to clarify the arrangement of the lower chords,

FIG. 5 is a view in section of the boom taken in the plane 5—5 designated in FIG. 3,

FIG. 6 is a view in section taken in the plane 6—6 designated in FIG. 3,

FIG. 7 is a side view in elevation of the quadrilateral base section and of a part of the triangular center section of a boom in which the neutral axes of the respective portions are offset from one another at the transition from one across section geometry to the other,

FIG. 8 is a top view of the boom of FIG. 7,

FIG. 9 is a top view of a second embodiment of the invention, with chords and lacings at the bottom broken away for clarification,

FIG. 10 is a side view of the second embodiment,

FIG. 11 is a bottom view of the second embodiment, with chords and lacings at the top broken away for clarification,

FIG. 12 is a view in section of the second embodiment taken through the plane 12—12 to show the triangular center section,

FIG. 13 is a view in section of the second embodiment taken through the plane 13—13 to show a triangular section functioning as a transition section,

FIG. 14 is a view in section of the second embodiment taken through the plane 14—14 to show the quadrilateral base section,

FIG. 15 is a top view of a third embodiment of the invention, with chords and lacings at the bottom removed for the purpose of clarifying the arrangement of the top,

FIG. 16 is a side view of the third embodiment,

FIG. 17 is a bottom view of the third embodiment, with chords and lacings at the top removed for the purpose of clarifying the arrangement of the bottom,

FIG. 18 is a view in section of the third embodiment taken through the plane 18—18 to show the triangular center section,

FIG. 19 is a view in section of the third embodiment taken through the plane 19—19 to show the quadrilateral base section,

FIG. 20 is a side view in elevation of a power shovel having a boom embodying the invention,

FIG, 21 is a side view of the boom in FIG. 20,

FIG. 22 is a top view of the boom in FIG. 20,

FIG. 23 is a view in cross section of the boom of FIG. 20 taken through the plane 23—23 showing the base section of the boom,

FIG. 24 is a view in cross section of the boom of FIG. 20 taken through the plane 24—24 showing a dual quadrilateral section of the boom,

FIG. 25 is another view in cross section of the dual quadrilateral section,

FIG. 26 is a view in cross section of the boom of FIG. 20 taken through the plane 24—24 showing a dual triangular section of the boom,

FIG. 27 is a fragmentary top view of another embodiment in which the boom is comprised of parallel subcolumns,

FIG. 28 is a view in cross section of the boom of FIG. 27 showing two triangular sections, and

FIG. 29 is a view in cross section of the boom of FIG. 27 showing overlapping base sections.

Referring now to the drawings, FIG. 1 shows a truck crane having a mobile chassis 1 mounting a revolving machinery platform 2 covered by a cab 3. The front end of the machinery platform 2 has spaced boom receiving brackets 4 to which are pinned the boom feet 5 of a boom 6. The boom 6 is made up of a base section 7, which tapers divergently from the boom feet 5, as viewed from the side, to increase in depth to match that of a center section 8. The center section 8 extends upwardly from the base section 7, and connects with a peak section 9 that narrows down to an outer end mounting a sheave 10 from which there is suspended a hook 11. The hook 11 is manipulated by the usual cable 12, and the outer end of the boom 6 is held by the cables 13 and 13*a*.

The base section 7 and a portion of the adjacent center section 8 of the boom 6 are shown in FIGS. 2–6. The center section 8 is of triangular construction, with a single upper chord 14 forming an apex for the triangular geometry, and a pair of lower chords 15 defining the bottom corners of the triangular geometry. The chord 14 has been omitted in FIG. 4, so that this particular figure more clearly portrays the bottom of the boom when viewed from the underside. The chords 14 and 15 are connected to one another through intermediate lacings 16 which give torsional strength to the boom.

In the base section 7, there is a pair of lower chords 17 which form continuations of the chords 15, and which each connect to one of the boom feet 5 at the base end of the boom. There is also a second pair of lower chords 18, shown in FIGS. 4 and 6, which lie alongside the chords 17 and connect therewith at their ends. Thus, each chord 18 connects with a chord 17 at a common point of connection with a chord 15, then diverges from the chord 17 to be alongside thereof, and then reunites with its associated chord 17 at the respective boom foot 5. The base section 7 also includes a pair of upper chords 19. Each of these chords 19 connects at one end with the chord 14 of the triangular section 8, and then diverges to connect at its opposite end with one of the boom feet 5. Hence, the base section 7 has a quadrilateral cross section, as seen in FIG. 6, with the upper chords 19 defining upper corners of the quadrilateral, and the chords 17, 18 lying in the bottom line of the quadrilateral with the chords 17 defining the lower corners. The chords 17–19 are tied together and strengthened by intermediate lacings 20. These and other lacings are shown as simple struts, so that the chord configurations are readily observed in the drawings, but in actual practice they can be larger, or of different shape to meet particular requirements. Also, for the purposes of clarity the chords 18 are not shown in FIG. 2, and the chords 19 are not shown in FIG. 4, thereby giving clearer representations of the top and bottom respectively.

From the foregoing description, it is apparent that the boom 6 is made up of sections of dissimilar cross section configuration, with the center section 8 being of one geometry and the base section 7 being of a different geometry. The particular geometries illustrated are triangular for the center section 8 and quadrilateral for the base section 7, and the general appellation for the boom 6 is "triangular," since the greatest portion of its length is made up of the triangular center section 8. Also, the peak section 9 is of triangular cross section, with all of its chords merging with one another at the outer end of the boom. A triangular boom has particular advantages over a square or rectangular geometry, in that there is less wind resistance and it is a more stable geometry of greater strength for a given amount of material.

A boom is loaded primarily in compression, and it is one purpose of this invention to provide a design that permits substantially equal distribution of the loading in all the chords of each section. In a boom having different geometries along its length there can be discontinuities at the points of transition from one geometry to the other, which create internal flexure stresses that might cause curvature and lessen boom strength. This problem can

be illustrated by reference to FIGS. 7 and 8, wherein there is schematically shown a boom with a triangular center section **21** and a quadrilateral base section **22** not embodying the construction of this invention. The triangular section **21** has an upper chord **23** and a pair of lower chords **24**, while the section **22** has a pair of upper chords **25** and a pair of lower chords **26**. There are no supplementary lower chords in the base section **22**, and all of the chords under consideration are of the same cross section area and of the same modulus of elasticity. As shown in FIG. 7, at the transition between the geometries of dissimilar cross section the neutral axis **27** of the triangular center section **21** is at a different elevation than that of the neutral axis **28** of the quadrilateral base section **22**. With this lack of registry, a longitudinal load acting along the axis of either section is applied to the adjacent section at an offset from its neutral axis, and this causes an undesirable flexure stress, or bending moment, within the boom. There is a mismatch between the two sections, which can be shown by a simple illustration.

Assume a compressive load of 30,000 lbs. For an even distribution of this load in the triangular section **21**, each of the three chords would have a stress of 10,000 lbs. However, for the base section **22** an even distribution of the load would place 7500 lbs. on each chord, and it is seen that there is a discontinuity between each lower chord **24** of the center section **21** and the lower chord **26** of the base section **22** to which it joins. There is also a discontinuity between the chord **23** of the center section **21** and the pair of chords **25** which connect therewith. This mismatch is accompanied by the flexure stress noted above, and special design is required for the chords to retain uniform strain throughout the boom.

As has hereinbefore been stated, in the practice of the invention the desired line of action for an applied load on one section is brought into registry with the desired line of action for a load applied on the adjacent section. When the materials used for the longitudinal chords have similar moduli of elasticity, the positions and areas of the chords of two adjacent geometries are arranged such that at the transition between geometries the neutral axis of one geometry is in substantial registry or alignment with the neutral axis of the other geometry. This can be stated in another fashion, namely, that for each section the reference point in the plane of transition between the geometries about which the summation of the area moments is zero coincides with, or substantially coincides with, the similar point of the adjacent section.

The term "area moment" is used in its usual sense: at a given cross section in the boom each differential area of the chord material multiplied by the distance from a reference point, in this instance the neutral axis, is an area moment.

In the embodiment illustrated in FIGS. 2–6, which has a similar moduli of elasticity in all chords, the neutral axes are brought into registry as follows: Referring first to the triangular center section **8**, which is shown in cross section in FIG. 5, each of the chords **14**, **15** is of the same cross section area, and the neutral axis **29** for this triangular geometry is at the level of the plane **30**, such plane **30** being at a height ⅓ the vertical distance from the lower chords **15** to the upper apex chord **14**. The base section **7**, shown in cross section in FIG. 6, has chords **17**, **18** and **19** which are all of equal cross section area, and in the illustration they are also of the same cross section area as the chords **14**, **15**. The presence of two upper chords **19**, which connect to the single chord **14**, doubles the area of the upper chords in the quadrilateral base section **7** over that of the single upper chord **14** in the triangular section **8**. Absent the chords **18**, this area of the upper chords **19** would equal the area of the two lower chords **17**, and the neutral axis of the base section **7** would be at the mid-point of its height. This would be above the plane **31**, which plane **31** is drawn in FIG. 6 at ⅓ the height of the quadrilateral geometry. At the point of transition between the two geometries the neutral axes would in such case not meet, or be in registry, and the condition of FIG. 7 would exist.

The invention introduces the two lower chords **18**, to thereby have two chords **17** and **18** extending from each lower chord **15** of the triangular center section **8**. This doubles the cross section area along the bottom line of the quadrilateral geometry, and the ratio of the areas above the plane **31** to the areas below the plane **31** is now the same as the ratio in FIG. 5. The neutral axis **32** of the base section **7** is now also in a plane ⅓ the height of the section. Hence, at the transition between the two geometries the neutral axis **32** for the quadrilateral geometry meets the neutral axis **29** of the triangular cross section at the point **33** indicated in FIG. 3, such point **33** being at the transition between the geometries. For a 30,000 lb. total compressive load which is distributed uniformly in the triangular center section **8**, the 10,000 lbs. carried by the upper chord **14** will now be evenly transmitted to the two chords **19** of the quadrilateral base section **7**, with each of these chords carrying a 5000 lb. load. Similarly, the 10,000 lb. loads of each of the lower chords **15** of the triangular section **8** will be transmitted to a pair of chords **17**, **18** in the quadrilateral section **7**, each chord **17**, **18** sustaining a 5000 lb. load. Thus, the two dissimilar sections **7** and **8** are matched for load transmission.

For this condition of having the two neutral axes **29**, **32** substantially meet, or be in substantial registry, a load applied to one section that acts along the neutral axis will be transmitted symmetrically as a compression load to the adjacent section. Internal flexure stress is thus minimized, and also the transmission of compressive loads can be readily calculated for the chords of both geometries, and the chords themselves can be readily designed.

In the particular illustration of FIGS. 2–6 the base section **7** is pinned to the section **8**, in order to have a boom that can be disassembled into convenient lengths. The extent of the quadrilateral section **7**, or conversely of the triangular section **8**, need not be co-extensive with the points at which the boom is pinned. The points of disassembly can be at entirely different positions, and the word "section" as used herein refers to a portion of a particular cross section geometry without reference to points of disassembly.

It becomes apparent that the individual chords of the quadrilateral section **7** need not be of the same area as the chords in the triangular section **8**. For example, the cross section area of each of the chords **17**, **18** and **19** could be one-half of that illustrated, and for this arrangement the summation of the area moments about the axis **32** would remain zero, so that the neutral axes **29**, **32** would still meet at the transition between the geometries.

Another alternative is to eliminate the chords **18** and have each chord **19** one half the area shown in FIG. 6. Then, the total area of the upper chords **19** would be the same as for upper chord **14** of the triangular cross section of FIG. 5, and the chords **17** would be of the same area as that of the chords **15**. Since the vertical heights of the areas are the same as before, the relation of area moments is preserved, and the neutral axes will meet at the transition between the triangular and quadrilateral geometries.

In FIGS. 9–14 there is shown another embodiment for the invention, in which triangular and quadrilateral geometries are again utilized. In this embodiment a boom **34** has a base section **35**, a triangular transition section **36**, and a center triangular section **37**. The chord materials again have like moduli of elasticity, and the neutral axes of the sections are in registry with one another. The triangular center section **37** has three like chords **38** and a neutral axis **39**. The triangular transition section **36** has a pair of diagonally extending chords **40** along its bottom in addition to the chords **41** forming the bottom corners of the triangle. This group of four chords doubles the area moment of the bottom chords, and to balance this increase a large upper chord **42** is used which has twice

the area of the upper chord 38. Hence, the neutral axis 43 of the transition section 36 meets with the neutral axis 39 at the point 44 at the transition between sections.

The base section 35 has two upper chords 45 which branch from the chord 42, with each being one half the area of the chord 42, that is, of the same area as all other chords. The bottom of the base section 35 comprises continuations of the chords 41 and of the chords 40, and the neutral axis 46 of the base section 35 registers with the axis 43 at the point 47. In this embodiment the sections 35, 36 are not pinned to one another, but constitute integral continuations of chords which change in their cross section geometry. In the event a diagonal chord, such as 40 or 45, is at an angle which materially affects its loading and longitudinal deflection, it is within the purview of the invention to alter chord dimensions accordingly.

In FIGS. 15–19 another embodment is shown, in which a boom 48 has a quadrilateral base section 49 and a triangular center section 50 that is inverted from the position of the first two embodiments. Again, materials of similar elasticity are considered as being utilized. The center triangular section 50 has two outside chords 51 of smaller cross section than two large chords 52. Each of these outside chords 51 connects with a chord 53 in the base section 49, the large upper chord 52 splits into two chords 54 that are each one-half the area of the chord 52, and the lower chord 52 divides into a pair of chords 55 which are each one-half the area of their associated chord 52. Hence, the relation of area moments is retained and at the point 56, shown in FIG. 16, the neutral axes 57 and 58 meet. The axis 58 is not a straight continuation of the axis 57, for it angles upwardly to the boom feet which are in the plane of the top chords of the boom. An alignment, or registry, of two axes at the transition between two dissimilar geometries does not require that both axes lie in a common line.

The invention also comprehends the use of chords of dissimilar moduli of elasticity, and the embodiments described in which uniform moduli are employed may be considered as particular situations of this more general proposition. With different moduli of elasticity in the chords of a section the point of the section which should be in registry with a like point of an adjacent section is that at which the summation of the elastic area moments is zero, an elastic area moment being the product of an area moment and its modulus of elasticity. These are the elastic centers, and a load having a line of action through the elastic center will impose uniform strain in the section. With a common modulus of elasticity elastic centers coincide with the neutral axis.

Referring again to FIGS. 2–6, if the apex, or upper chord 14 were of a material having a modulus of elasticity differing from that of the other chords the prescription of the foregoing paragraph can be followed by changing the cross section area of the chord 14. For example, a lower modulus would call for a greater cross section area in the chord. While this will shift the neutral axis of the triangular section 8 upward, and thereby produce an offset with respect to the neutral axis of the base section 7, the elastic center is retained in proper registry with the base section 7. Also, the strain in the chord 14 will be maintained equal to that in the other chords 15 for a load having a line of action through the elastic center.

Referring now to FIG. 20 there is shown a power shovel with a mobile underframe 59 mounting a rotatable cab 60 that has a boom 61 extending upwardly at the front of the machine. The boom 61 is held in its oblique position by a cable 62, and the associated dipper stick 63 and dipper 64 are supported from a tiltable mast 65. A long operating bar 66 extends rearwardly from the top of the mast 65, and through a rack 67 and a pinion 68 the bar 66 is moved back and forth to shift the dipper stick 63 and mast 65. A hoist cable 69 passes around a sheave 70 at

the outer end of the boom 61 for manipulating the dipper 64.

As seen in FIG. 22, the boom 61 has an open center 71 of extended length which receives the dipper stick 63, and flanking each side of the open center 71 is a sub-column 72 extending for the entire length of the boom 61. The sub-columns 72 are tied together by cross lacings 73, and they are mirror images of one another, so that like reference numerals are applied to each. Each sub-column 72 has a triangular section 74, and as shown in FIG. 26 these sections 74 have their apex chords 75 facing one another. Chords 76, one above the other, complete the triangular geometries, and appropriate lacings in each sub-column 72 tie the chords of the sub-column together.

Connecting with the triangular sections 74 are quadrilateral sections 77. As shown in FIGS. 24 and 25, the quadrilateral sections 77 each have two chords 78 which connect with and diverge from an apex chord 75 of the associated triangular section 74. To compensate for the increased area of these chords 78, which chords are introduced to strengthen the lower end of the boom 61, a chord 79 in the form of a longitudinal plate is inserted at the opposite side of the quadrilateral. The relationship of area moments is thus preserved, and the neutral axis of each quadrilateral section 77 will meet with the neutral axis of the associated triangular section 74. As particularly indicated in FIG. 25, in that portion of each quadrilateral section 77 where the chords 78 are diverging, and the cross section area is increasing, the associated plate type chord 79 is also increasing in area to have a smooth transition, and as shown in FIG. 21 the outer end of each chord 79 is accordingly bifurcated with a taper. Further, if chords of different moduli of elasticity are employed the areas are selected that retain elastic centers in registry.

The embodiment of boom 61 illustrates that the invention is applicable to component parts, such as the sub-columns 72, of a boom as well as a complete boom itself, and the claims are to be interpreted with this in mind. Also, plates and similar members, as well as usual tubular members, may be utilized as chords, and the term chord is inclusive of these various forms of structural members.

FIGS. 27–29 illustrate another double column boom, in which the two sub-columns 80 each have a triangular center section 81, as shown in cross section in FIG. 28. Each triangular section 81 joins a quadrilateral base section 82, and in FIG. 29 the chords of the starboard base section 82 are broken away to render the chords of the port base section 82 clear and definite. Each base section 82 is a mirror image of the other, and an explanation of one is appositive of the other.

The apex chord 83 of the port triangular section 81 joins two upper chords 84 each one-half the area of the chord 83. The outer bottom chord 85 of the triangular section 81 continues in a like chord 86 in the port base section 82, and the inner bottom chord 87 of the triangular section 81 joins two lower chords 88 that are each one-half the area of the chord 87. One chord 84 and one chord 88 extend to one boom foot, and the other of these chords 84, 88 extend to the other boom foot. The areas of the chords, as described above, provide alignment of the neutral axes of each triangular center section 81 and its associated base section 82, although the neutral axis of the base section 82 will extend to the center line of the boom, as illustrated by the broken line 89 in FIG. 27. In the event different moduli of elasticity are employed in the chords the respective chord areas are proportioned to have the elastic centers coincide at the transition between sections, and the boom of FIGS. 27–29 illustrates a use of the invention in which two base sections overlap one another and their chords cross.

While the specific illustrations emphasize triangular and quadrilateral cross section geometries others can be employed, as will occur to those in the art. The dissimilar cross section geometries of adjacent boom sections will

normally be figures with different numbers of sides, but the same principles may be applied to different sizes of the same shape or figure. Also, adjacent geometries may have very rigid, short elements between them, such as plates or their equivalent, but the geometries are still considered as adjacent with a zone of transition between them. In its various forms, the invention arranges the various chords to eliminate discontinuities in load distribution as between differing cross section geometries to provide an improved boom.

I claim:

1. In a boom the combination comprising:
a first section of length; and
a second section of length with a cross section geometry differing from that of the first section of length, and with the elastic center of the second section in substantial registry with the elastic center of the first section at the transition between sections.

2. In a boom the combination comprising:
a first section of length having a substantially uniform modulus of elasticity in lengthwise members thereof; and
a second section of length with a cross section geometry differing from that of the first section of length that also has a substantially uniform modulus of elasticity in lengthwise members thereof, and with the neutral axis of the second section in substantial registry with the neutral axis of the first section at the transition between sections.

3. In a boom the combination comprising:
a first section with longitudinal chords of similar elasticity forming a cross section geometry and establishing a neutral axis along the length thereof; and
a second section adjacent and attached to said first section with longitudinal chords of similar elasticity forming a cross section geometry differing from that of said first section, said chords of said second section having areas and locations establishing a neutral axis along the length thereof that is in substantial alignment with the neutral axis of said first section at the transition between sections.

4. In a boom the combination comprising:
a first section having a cross section geometry formed by a plurality of chords of similar elasticity;
a second section joining the first section having a second cross section geometry formed by a plurality of chords of similar elasticity; and
wherein at the transition between sections the point in each section about which the summation of the area moments is zero is in substantial registry with the like point of the other section.

5. In a boom the combination comprising:
a first section having a cross section geometry formed by a plurality of chords comprised of materials of different moduli of elasticity;
a second section joined to said first section having a cross section geometry formed by a plurality of chords that is different than the geometry of said first section; and
wherein at the transition between sections the point in each section, about which the summation of the elastic area moments is zero, is in substantial registry with the like point of the other section.

6. In a boom the combination comprising:
a first section of chords having a substantially uniform modulus of elasticity of triangular cross section; and
a second section continuing from the first section that is of a cross section configuration differing from triangular of chords and having a substantially uniform modulus of elasticity, the neutral axis of said second section being in substantial registry with the neutral axis of the first section at the transition between the first and second sections.

7. In a boom the combination comprising:
a first section with a single upper chord at the top of the section and a pair of lower chords at the bottom of the section; and
a second section having one end connecting with the first section and terminating at its other end in a pair of spaced boom feet, said second section having a pair of upper chords each joined with the single upper chord of said first section and diverging from one another with each connected to one of said boom feet, and a set of four lower chords with a pair of each boom foot in which each chord of a pair connects between one of said lower chords of said first section and its associated boom foot.

8. A boom in accordance with claim 7 in which the cross section area of the upper chord of the first section equals the cross section area of the upper chords of the second section, and the cross section area of the lower chords of the first section equals the cross section area of the lower chords of the second section.

9. In a boom the combination comprising:
a first section of triangular cross section with an apex chord and a pair of bottom chords; and
a second section of quadrilateral cross section with a pair of chords joining said apex chord and a plurality of bottom chords joining the bottom chords of the first section;
wherein at the transition between the two sections, the point where the area moment of the apex chord of the first section is equal to the area moment of the pair of bottom chords of the first section is substantially at the point where the area moment of said pair of chords of the second section is equal to the area moment of the bottom chords of the second section.

10. In a boom the combination comprising:
a first portion of length having an apex chord, a set of opposite chords, and intermediate lacings tying the chords together;
a second portion of length having a pair of boom feet, a pair of chords each connected to the apex chord of said first portion of length and extending to one of said boom feet, a set of chords connected between said set of opposite chords of said first portion of length and said boom feet, and intermediate lacings tying the chords of said second portion of length together;
the elastic center of said first portion of length at the transition between lengths being in substantially the same position as the elastic center of said second portion of length at the transition between lengths.

11. A boom in accordance with claim 10 in which the neutral axis of the first portion of length is in substantial alignment with the neutral axis of said second portion of length.

12. In a boom the combination comprising:
a pair of spaced sub-columns disposed alongside one another;
lacings tying said sub-columns to one another; and
each of said sub-columns having a first section formed of chords defining a cross section geometry, a second section joined to said first section formed of chords defining a cross section geometry different than that of said first section, and the elastic center of said first section being in substantial registry with the elastic center of said second section at the transition between sections.

13. A boom as in claim 12 wherein in each sub-column the neutral axis of the two sections meet at the transition between sections.

14. In a boom the combination comprising:
a pair of sub-columns disposed alongside one another, each of said sub-columns having:
a first section formed of chords defining a cross section geometry, a second section joined to said first section formed of chords defining a cross section geometry different than that of said first section, and the elastic center of said first section being in substantial

registry with the elastic center of said second section at the transition between sections;

wherein the chords of the first section of each sub-column diverge and terminate in two boom feet, each of said boom feet being common to both said sub-columns.

15. In a boom the combination comprising:

a first section of length having a first form of cross section geometry that has a line of action for a load imposing a uniform strain; and

a second section of length extending from the first section which has a second form of cross section geometry and which presents a line of action for a load

imposing a uniform strain that is in substantial registry with the line of action of the first section at the transition between sections.

References Cited by the Examiner

UNITED STATES PATENTS

1,941,952	1/1934	Nickles	212—144
2,139,254	12/1938	Bixby	212—144 X
3,021,014	2/1962	Korensky et al.	212—144

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