Feb. 21, 1961 T. LEARMONT 2,972,199

DRAGLINE EXCAVATOR

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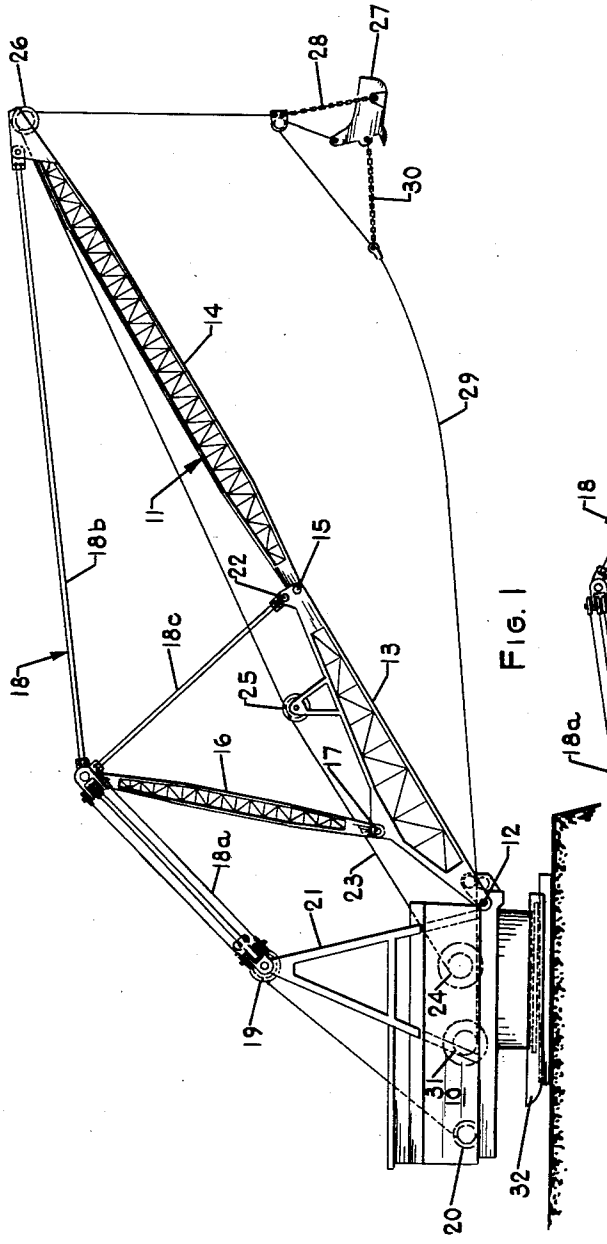


FIG. 1

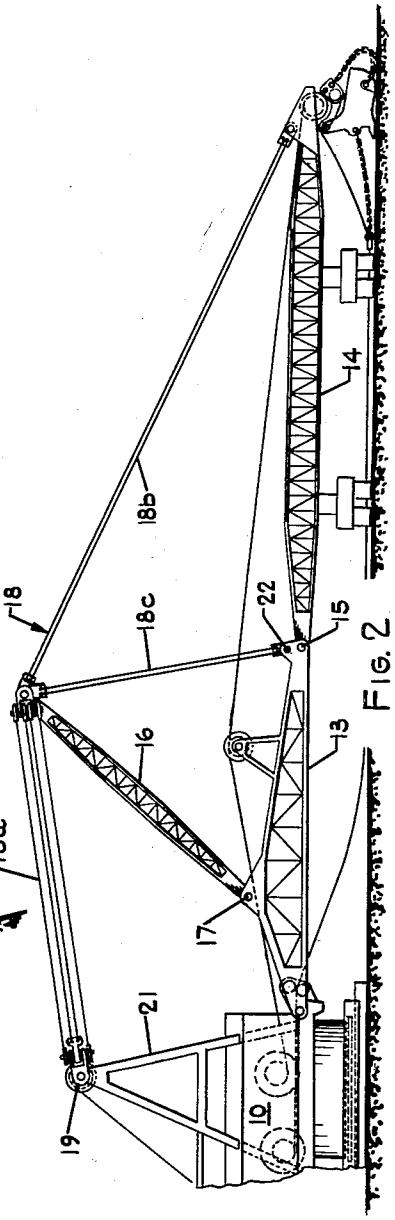


FIG. 2

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DRAGLINE EXCAVATOR

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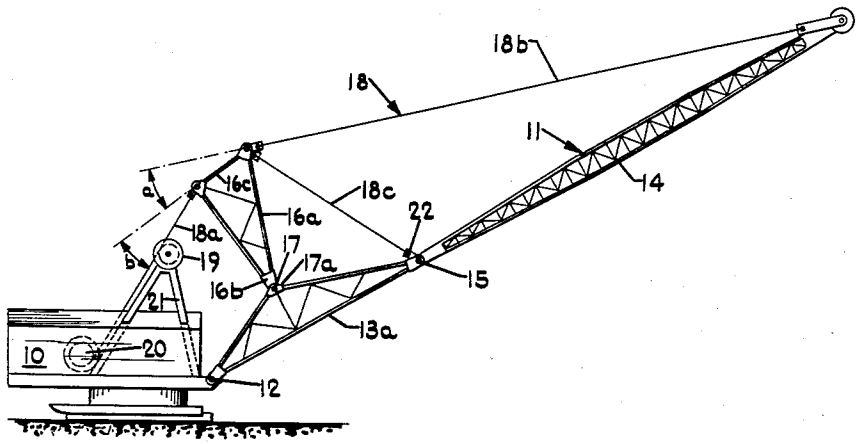


FIG. 3

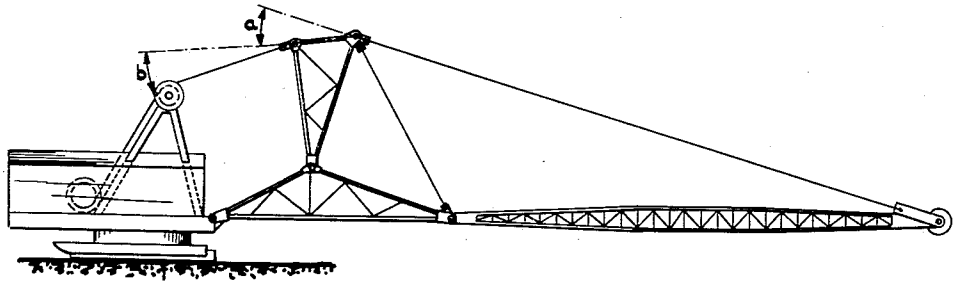


FIG. 4

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2,972,199

DRAGLINE EXCAVATOR

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9 Claims. (Cl. 37—116)

This invention relates to dragline excavators, particularly the boom construction and suspension means. It is particularly adapted to ovecome the problems of recoil of the boom caused by a sudden release of the hoisted load and the reaction forces in the boom and suspension.

It is the usual practice in boom construction for draglines to employ an integral boom, of a given length, pivoted at its foot on a main frame, and to support the boom near its outer end by suitable suspension tackle. The suspension tackle is anchored to the main frame and is usually trained over a mast, A-frame or other means, to provide a greater moment arm about the boom-foot pivot.

With such construction, any sudden release of a hoisted load results in a recoil of the boom and suspension tackle because of reaction forces in those components. This recoil causes a flexing of the intermediate portion, particularly the central portion, of the boom; if a severe recoil is encountered, or if a sufficient number of flexing stresses are encountered repeatedly, failure of the boom will result.

An obvious method of overcoming this problem is to provide a sufficiently rigid boom and thereby prevent any critical flexing of the central portion; however, this results in a boom construction of such weight as to reduce the efficiency of the machine.

Therefore, it is the principal object of the present invention to provide a dragline excavator with a boom and suspension means in which the boom is of great length in relation to total weight and overcomes the problems associated with boom recoil.

In the past, certain types of boom constructions have been devised to minimize bending stresses in the central portion of a long boom. Examples of such constructions are disclosed in U.S. Patent No. 2,015,629 to Knox and in U.S. Patent No. 2,080,163 to Busick. Both of these patents illustrate a type of boom designed specifically for use with power shovels which employ an extendible dipper stick; neither construction is very desirable for use as a boom on a crane or a dragline excavator.

Generally, a dragline excavator requires a much longer boom than a power shovel of the same rated load capacity. Also in a multiple-section boom employed in a shovel, that boom section which supports the shipper shaft requires a rigid member of the boom suspension means to be connected to that same boom section at a point closely adjacent the shipper shaft. This member must be rigid since it withstands compression forces caused by reaction of the dipper stick during crowding operations. In a dragline excavator such reaction forces are not encountered; and consequently rigid, heavy boom constructions, such as those illustrated in the above Knox and Busick patents, are unnecessary as well as undesirable.

Therefore, it is also an object of the present invention to provide a dragline excavator with a multiple-section boom and suspension which eliminates the need for any heavy, rigid member or strut at the juncture of the boom sections, and still prevents any objectionable results caused by boom recoil.

A further object of the invention is to provide a dragline excavator having such a boom with an inner boom section which has stability in a vertical plane when a hoisted load is released suddenly.

A further object is to provide a dragline excavator with a multiple section boom and suspension means including a mast mounted on the boom comprising short, light components thereby facilitating the assembly and erection of the boom and suspension system.

In addition to my principal objects, above stated, I have worked out a number of novel and useful details, which will be readily evident as the description progresses.

My invention consists in the novel parts and in the combination and arrangements thereof, which are defined in the appended claims, and of which different embodiments are exemplified in the accompanying drawings which are hereinafter particularly described and explained.

Throughout the description, the same reference number is applied to the same member or to similar members.

Figure 1 is a side elevation of one embodiment of my invention illustrating a dragline excavator in which the boom has been elevated to a working height.

Figure 2 is the same as Figure 1, except that the boom is in a substantially horizontal position.

Figure 3 is a side elevation of another embodiment in which the boom is elevated to a working height.

Figure 4 is like Figure 3 except that the boom is in a substantially horizontal position.

Referring to Figures 1 and 2 which illustrate the first embodiment of this invention, a dragline excavator is shown having a main supporting frame 10 as a supporting base to which a boom and suspension can be attached. A boom 11 is pivotally supported at its foot on the main frame by a suitable pivot pin 12 to permit angular movement of the boom about the pivot in a vertical plane.

The boom 11 comprises an inner section 13 and an outer section 14 pivotally connected to each other by a joining pin 15. An upwardly inclined strut or "mast" 16 is pivotally connected to the inner boom section 13 intermediate the ends of the inner section. The mast-to-boom connection may be any suitable means such as pin 17; however, the location of this mast-to-boom connection 17 must be spaced a sufficient distance outboard from the boom-foot pivot 12 and the mast must be inclined in relation to the boom to result in a downward moment about the boom pivot 12 acting upon the inner section 13 when the boom is in an elevated working position such as is shown in Figure 1. At the same time, the location of the connection 17 should not be placed so far outboard as to result in excessive bending stresses on the inner section.

Suspension means for the boom is provided by suspension tackle, indicated at 18, between an anchorage 19 and the boom 11. The anchorage for the suspension tackle 18 is carried on the main frame at an elevated point above the boom pivot 12; as illustrated, the anchorage 19 comprises cable reeling apparatus operably connected to a cable winding drum 20 and mounted preferably upon an A-frame or gantry 21. The suspension means may be of fixed-length tension members, such as ropes, cables, rods or the like, but preferably includes variable-length boom-hoist tackle indicated at 18*a* connected between the anchorage 19 and the upper end of the mast 16, and a fixed-length tension member 18*b*, such as a rope or cable, connected between the top of the strut 16 and the outer boom section 14 adjacent the boom point. Intermediate tension means 18*c* is also provided between a point near the top of the mast 16 and the boom 11 at a connection point 22 adjacent the joining pin 15 carried

by the inner section 13. It is important that tension members 18*b* and 18*c* of the suspension means are both of fixed length and preferably consisting of flexible ropes or cables. Since the relative lengths determine, to a certain degree, the alignment of the longitudinal axes of the inner and outer boom sections 13 and 14 it is extremely important that these relative lengths be fixed after determining the proper proportionate dimensions.

With the boom 11 and suspension means employed in a dragline excavator structure as shown, a load hoist line 23 is operably connected to a second cable winding drum 24 on the main frame. The load line is then trained over guide sheaves 25 supported on the boom and thence about a boom point sheave 26 to be attached to a drag bucket 27 by suitable means generally indicated at 28. A drag rope or cable 29 is also attached to the bucket 26 by chains 30 and is also operably connected to a third cable winding drum 31.

The main frame 10 may be supported on any suitable ground engaging members indicated conventionally at 32 and is usually provided with propelling means (not shown) as well as means to rotate the main frame about a center support (not shown) which remains fixed in relation to the ground engaging members.

It can be seen that the mast 16 is interposed between the suspension means 18 and the boom 11 to provide a greater boom suspension moment arm about the boom-foot pivot 12 and thereby decrease the force required to raise the boom and to support it in the elevated position shown in Figure 1. The length of the mast 16 in relation to the length of the boom 11 is also dimensioned to provide a satisfactory angle between the suspension means 18*b* and the boom to thereby minimize the compression forces in the boom in any position without the use of such a long mast which would cause a shallow angle between the mast and its suspension tackle 18*a*. The respective locations of the anchorage 19, the boom pivot 12, and the mast-to-boom connection 17 as well as the length of the mast 16 are also proportioned to provide a relatively-wide angle between the mast 16 and the suspension means 18*a* strung between the anchorage 19 and the mast when the boom is in a substantially horizontal position shown in Figure 2 and to substantially maintain such wide angle when the boom is raised to the position shown in Figure 1. Since the compression forces in structures such as booms and masts, which are pivoted at their inner end and supported by means of tension members at their outer ends, is proportional to the relative angle between such structure and the tension member, it is imperative that this angle be established at a satisfactorily wide angle and substantially maintained throughout the range of movement. With the structure shown, a relative angle in the range of 25 to 40 degrees has been determined to be satisfactory to keep compressive forces in the boom and mast at a sufficiently low value and thereby permit the use of lighter constructions and increase the over-all efficiency of the dragline excavator. This proportionate dimensioning of and location of these elements results in lower compression forces in the mast 16. Thus it can be seen that a structure has been devised which minimizes compression forces in the boom and also in the mast when the boom is substantially horizontal, a position when maximum compression forces are usually encountered in those members, as well as when the boom is in raised position. Consequently, this wide angle is maintained substantially throughout the range of working elevations of the boom when employed in a dragline excavator. The preferable range of locations of the mast-to-boom connection 17 and the inclination of the mast 16 relative to the boom 11 is such that the moment arm about the boom-foot pivot 12 of the line of action through the mast is not less than one-tenth ($\frac{1}{10}$) nor greater than one-half ($\frac{1}{2}$) of the moment arm of the line of action of the intermediate suspension member 18*c* supporting

the outer end of the inner boom section 13. By employing a mast so located and so inclined within the above range, a downward moment acting upon the inner section 13 of the boom is insured without imposing excessive bending stresses on the inner section.

By referring to Figure 2, a dragline excavator is provided with a boom and suspension means utilizing shorter, lighter components than conventional draglines which have integral booms and in which the mast is located adjacent the boom foot. With the present invention the components may be positioned and handled easily during assembly and erection of the boom. The usual sequence is to first join the inner section 13 to the main base and then connect the outer section 14 to the inner section 13. One end of the mast 16 is pivotally connected to the boom at 17 and the suspension means 18*a* is strung between the anchorage 19 and the free end of the mast and attached to cable drum 20. The flexible tension member 18*b*, of fixed length, may then be connected between the variable length tension member 18*a* and the boom near the boom point. The flexible, fixed length tension member 18*c* should then be attached at one end to the mast 16, preferably near the top of the mast, and at the other end at a point 22 adjacent the connection 15 of the boom sections.

Subsequent operation of the cable-winding drum 20 will reel in cable of 18*a* to shorten the length of suspension member 18*a* to raise the mast 16 to a position where members 18*b* and 18*c* are in tension; further reeling in of the cable of 18*a* will elevate the boom as shown in Figure 1.

The length of the mast 16, the tension members 18*b* and 18*c* and the outer section 14 as well as the inclination of the mast in relation to the boom are proportioned so as to result in substantial alignment of the longitudinal axes of both boom sections 13 and 14.

Referring to Figures 3 and 4, another embodiment of the invention is illustrated as having a boom 11 pivotally supported by the main frame 10, and suspension means 18 strung between a connection with the boom adjacent the boom point and an elevated anchorage 19. A mast 16*a* is connected between the suspension means and the boom and intermediate suspension means 18*c* between the mast 16*a* and the boom are provided being connected to the intermediate portion of the boom at 22. Any suitable hoisting mechanism may be provided which includes a cable-winding drum and a load hoist line operably attached to the drum and trained over a boom point sheave such as illustrated in Figures 1 and 2. To more clearly illustrate the boom and suspension means, none of the hoisting mechanism is shown in Figures 3 and 4.

In this embodiment the boom 11 comprises an inner section 13*a* and an outer section 14 pivotally connected to each other at 15. The inner section 13*a* is of trussed skeleton construction in the form of a triangle having a broad base and includes an apex 17*a* intermediate the ends of the inner section 13*a*. The preferred embodiment positions this apex 17*a* closer to the boom-foot pivot 12 than the outer end of section 13*a*. The position of 17*a* is selected to provide a location for a mast-to-boom connection 17 which will increase the vertical stability of the inner section without imparting critical bending stresses to this member.

The mast 16*a* is also of trussed construction and preferably is positioned, as shown in Figures 3 and 4, as an inverted triangle having an apex 16*b* connected to the boom at 17 and a base 16*c* connected to the suspension means 18.

It is also desirable to divide equally the total compression load carried by the two sides of the triangular-shaped mast 16*a* when the boom is in an elevated operating position as shown in Figure 3. The angle of elevation of the boom during digging operations is within a range of 30° to 40°. To accomplish this approximate load division, the dimensions and positioning of the tri-

angular mast 16*a*, the length of the boom 11 and the respective locations of the anchorage 19, the connection between the suspension means and the boom, the boom pivot 12 and the mast-to-boom connection 17 are so proportioned that approximately equal angles "*a*" and "*b*" result between the base 16*c* of the triangular mast and lines drawn through the lines of action of the suspension members 18*a* and 18*b* on both sides of the mast when the boom is in an elevated operating position. The forces down each leg of the triangular mast and the truss construction of the mast result in both legs supporting each other as a column. Consequently, the compressive load is imposed on a construction which is the equivalent of a straight column thus eliminating any tendency to buckle.

By forming the inner section 13*a* of the boom 11 as a triangle and by locating the mast-to-boom connection at the upper apex 17*a* of this triangle, the mast components are thereby shortened. This results in a more rigid mast which reduces the total weight on the boom and consequently the front end moment of the entire machine.

The mast 16*a* need not be constructed entirely of rigid struts since the base 16*c* encounters tension stresses only. Therefore the mast 16*a* may comprise a plurality of struts angularly spaced in a vertical longitudinal plane of the boom and each of the struts connected at one end to the inner boom section by means of the mast-to-boom connection 17. The upper ends of the struts may be connected by a portion of the suspension means 18 and stiffening members interposed between the struts to interconnect the struts at a plurality of points intermediate the ends of the struts. Thus the forces down each strut and the stiffening members interconnecting the struts result in the struts supporting each other as a column and reduces any tendency to buckle.

In both Figures 2 and 4, the forms of the invention disclose a boom and suspension means which provide a relatively wide angle between the mast and that portion of the suspension means 18*a* between the mast and the anchorage 19. This wide angle is desirable since compression stresses are thereby decreased in the mast. Conventionally constructed boom suspensions locate the mast on or adjacent the main frame resulting in a relatively short distance between the anchorage and the lower end of the mast. By locating the mast-to-boom connection outwardly a sufficient distance on the boom so that the distance between the anchorage 19 and the mast-to-boom connection 17 is greater than the distance between the anchorage 19 and the boom pivot 12 when the boom is substantially horizontal, a relatively wide angle is provided between the mast and that portion of the suspension means 18*a* between the mast and the anchorage. This reduces compression stresses in the mast and permits the use of a lighter weight mast construction.

The dragline excavators provided with the boom and suspension systems shown in Figures 1 and 3 overcome the objectionable results caused by boom recoil upon a sudden release of the hoisted load, as in dragline operation. Both constructions illustrated are capable of supporting a hoisted load by means of a suitable load hoist line such as 22 in Figure 1. The load line is in turn supported at the boom point by cooperation of the boom 11, the suspension means 18, anchorage 19, mast 16 or 16*a*, and the main frame 10. The weight of any hoisted bucket and load tends to stretch the tension members 18*a*, 18*b*, and 18*c* of the suspension means and tends to deflect downwardly the outer section 14 of the boom 11; the degree of deflection being determined by the relative elasticity of these members in relation to total weight.

Dumping the bucket during conventional dragline operations causes a sudden release of the strain energy present in the tension members 18*a*, 18*b* and 18*c* during the loaded condition, as well as a release of the energy in the slightly-deflected boom section 14. This sudden release of energy results in a reaction known as boom recoil and causes the outer end of the outer section 14 to whip upwardly. Since tension member 18*b* is flexible and boom section 14 is pivotally connected at 15 to the inner section, the boom recoil forces can be dissipated in the outer boom section. As the outer section returns from its recoiled position to its static unloaded position, an upward secondary reaction force is imparted to the inner end of section 14 and the entire boom tends to jack-knife at the pivotal connection 15. However, since the weight of the mast and the weight of the supported components of the suspension system, as well as the resultant of the suspension forces acting down the mast, are all carried by the inner boom section 13, a downward moment is imparted at all times to the inner section. Consequently, any tendency of the boom to jack-knife is prevented by the stability of the inner section 13. A dragline excavator is thus provided with a boom construction and suspension which safely dissipates the forces causing boom recoil, while still maintaining stability of the inner section of the boom.

Since the intermediate portion of the boom which is usually subjected to flexing stresses is jointed in the present invention rather than consisting of a heavy, rigid structure, a much lighter boom construction is possible, thereby permitting an increase in the total length of the boom without an increase in weight.

Having now described and illustrated two forms of the invention, it is to be understood that this invention is not to be limited to the specific form or arrangement of parts herein shown and described.

What is claimed is:

1. In a dragline excavator having a main frame and a digging bucket supported by a hoist line and moved for digging by a dragline the combination therewith of: a multiple-section boom having a boom foot and a boom point; a boom-pivot connection with the main frame; said boom comprising an inner section and an outer section having their longitudinal axes substantially in alignment; a pivotal connection between the inner and the outer boom sections; suspension means between the main frame and the outer end of the boom; an upwardly-inclined mast interposed between the suspension means and the inner boom section; a mast-to-boom connection joining the mast to the inner boom section; a fixed-length flexible tension member between the mast at a point near the top of the mast and the boom at a point adjacent the pivotal connection between the inner and the outer boom sections; said suspension means comprising variable-length boom-hoist tackle between the main frame and the mast and comprising a fixed-length flexible tension member between the mast and the boom adjacent the boom point; both of said fixed-length flexible tension members being dimensioned proportionately in such a manner that the boom sections are maintained in substantial alignment; and the said mast-to-boom connection being so located outwardly from the boom-foot pivot a substantial predetermined distance and the mast inclined in such a manner that the line of action through the mast imparts a downward moment to the inner boom section and thereby maintains the tension member in tension at all times throughout the range of boom positions.

2. In a dragline excavator, the construction according to claim 1, further characterized by the fact that the mast comprises a plurality of struts angularly spaced in a vertical longitudinal plane of the boom each being connected at one end to the inner boom section by means of the mast-to-boom connection, the upper ends being connected by a portion of the suspension means, and a plurality of stiffening members interconnecting said struts at a plurality of points intermediate the ends of said struts.

3. A dragline excavator according to claim 1, further characterized by the fact that the downward moment imparted to the inner boom section through the line of action of the mast is not less than one-tenth nor greater than one-half of the upward moment through the line

of action of the tension member connected to the mast and supporting the boom adjacent the pivotal connection of the boom sections.

4. In a dragline excavator: a multiple section boom and suspension means, comprising a main support base; an elevated anchorage on the main base; a boom having an inner section and an outer section; a pivotal connection between the said boom sections; a boom pivot connection between the inner section and the base; suspension means connecting the anchorage and the boom; an upwardly-inclined mast interposed between the suspension means and the said inner boom section; a fixed-length flexible tension member connecting the mast near its upper end and the boom adjacent the pivotal connection of the boom sections; a mast-to-boom connection pivotally joining the mast to said inner section and located at a point intermediate the ends of said inner boom section; the respective locations of the anchorage, the boom pivot connection, and the mast-to-boom connection being spaced in such a manner that for a horizontal position of the boom, the distance between the anchorage and the mast-to-boom connection is greater than the distance between the anchorage and the boom pivot thereby providing a wide angle between the mast and that portion of the suspension means between the mast and the anchorage and reducing the compression stress on the mast.

5. In a dragline excavator, the construction according to claim 4, further characterized by the fact that the mast in a vertical plane passing through the longitudinal axis of the boom is in the form of an inverted triangle.

6. In a dragline excavator, the construction according to claim 5, further characterized by the fact that the inner section of the boom in a vertical plane passing through the longitudinal axis of the boom is in the form of an upright triangle.

7. In a dragline excavator: a boom and suspension means, comprising a main support base; an elevated anchorage on the main base; a boom having a boom foot and a boom point; said boom comprising an inner section and an outer section; a pivotal connection between said sections; a boom-pivot connection between the main base and the boom, adjacent the foot of the boom; suspension means for the boom connecting the anchorage and the boom; an upwardly-inclined mast interposed between the suspension means and the boom; a fixed-length tension member connecting the mast near its upper end and the boom adjacent the pivotal connection of the boom sections; a mast-to-boom connection pivotally joining the

mast to the inner boom section; said mast-to-boom connection being spaced outwardly from the boom foot a sufficient distance so that a downward moment is imparted to the inner boom section about the boom foot; the mast in a vertical plane passing through the longitudinal axis of the boom being in the form of an inverted triangle; the base of said inverted triangularly-shaped mast being connected to the suspension means; the apex of said mast being connected to the inner boom section; and the dimensions of the triangular mast, the length of the boom and the respective locations of the anchorage, the connection between the suspension means and the boom, the boom foot pivot and the mast-to-boom connection being so proportioned that approximately equal angles result between the base of the triangular mast and lines drawn through the lines of action of the suspension means on both sides of the mast when the boom is in an elevated, operating position.

8. In a dragline excavator, the construction according to claim 7, further characterized by the fact that the inner section of the boom in a vertical plane passing through the longitudinal axis of the boom is in the form of an upright triangle.

9. In a dragline excavator, a multiple section boom and suspension means comprising a boom having an inner section and an outer section; a pivotal connection between said inner and outer sections; a main supporting base; a pivotal connection between the main base and the inner section of the boom; an upwardly inclined mast connected to the inner section intermediate the ends of said inner section; suspension means between the main base and the upper end of the mast; suspension means between the upper end of the mast and the outer end of said outer boom section; and intermediate fixed-length flexible tension means between the mast and a point on the boom adjacent the juncture of said inner and outer sections.

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