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[54] GRINDING MACHINE

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[52] **U.S. Cl.** **51/32,** 51/35, 51/47

[51] **Int. Cl.**.....**B24b 7/02,** B24b 27/04

[58] **Field of Search**.....51/33 R, 47, 35, 32, 178

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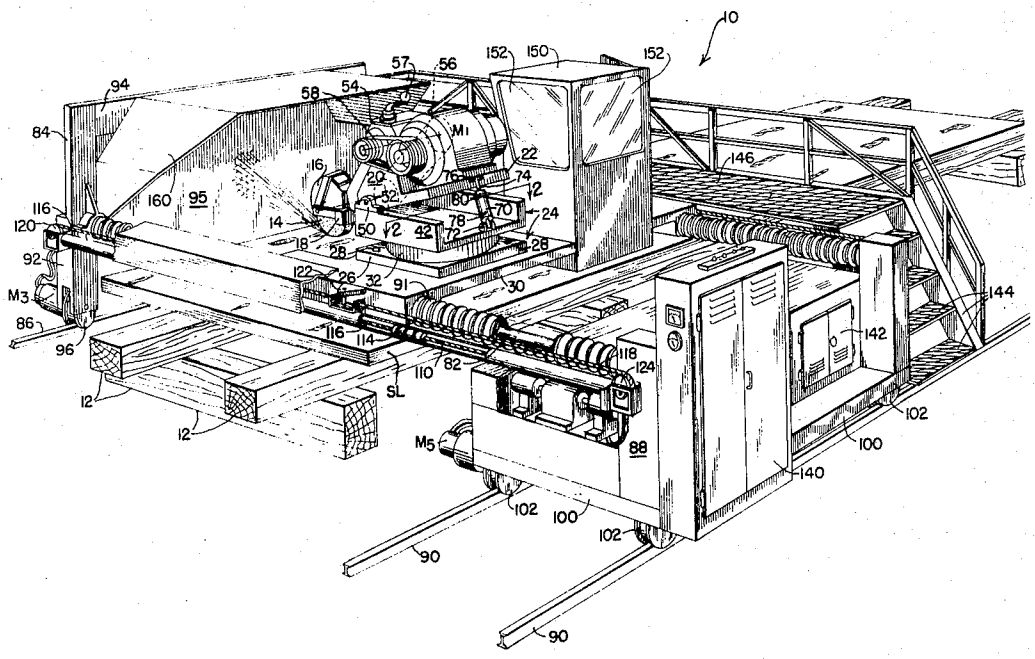
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[57] **ABSTRACT**

A grinding machine for conditioning the surfaces of steel slabs, billets, or the like to remove scale, exposed or hidden cracks and other surface irregularities. The entire grinding machine including the grinding wheel head and its supporting carriage travels on rails so that the grinding wheel may traverse the work. A rotary turret pivottally supports the boom housing for fore and aft rocking movements, and the grinding head is carried at the outer end of a relatively short boom which is fixed to and projects outwardly from the housing so that controlled angular movements of the turret will swing the grinding head and its associated grinding wheel over the surface of the work in order that the rotating grinding wheel may be shifted to an angular position wherein the grinding direction at the periphery of the wheel matches or nearly matches the longitudinal direction of any surface cracks which are undergoing spot eradication. The operator's control cab is positioned on the movable grinding machine carriage at a location where the grinding head is clearly and closely visible at all times.

7 Claims, 4 Drawing Figures



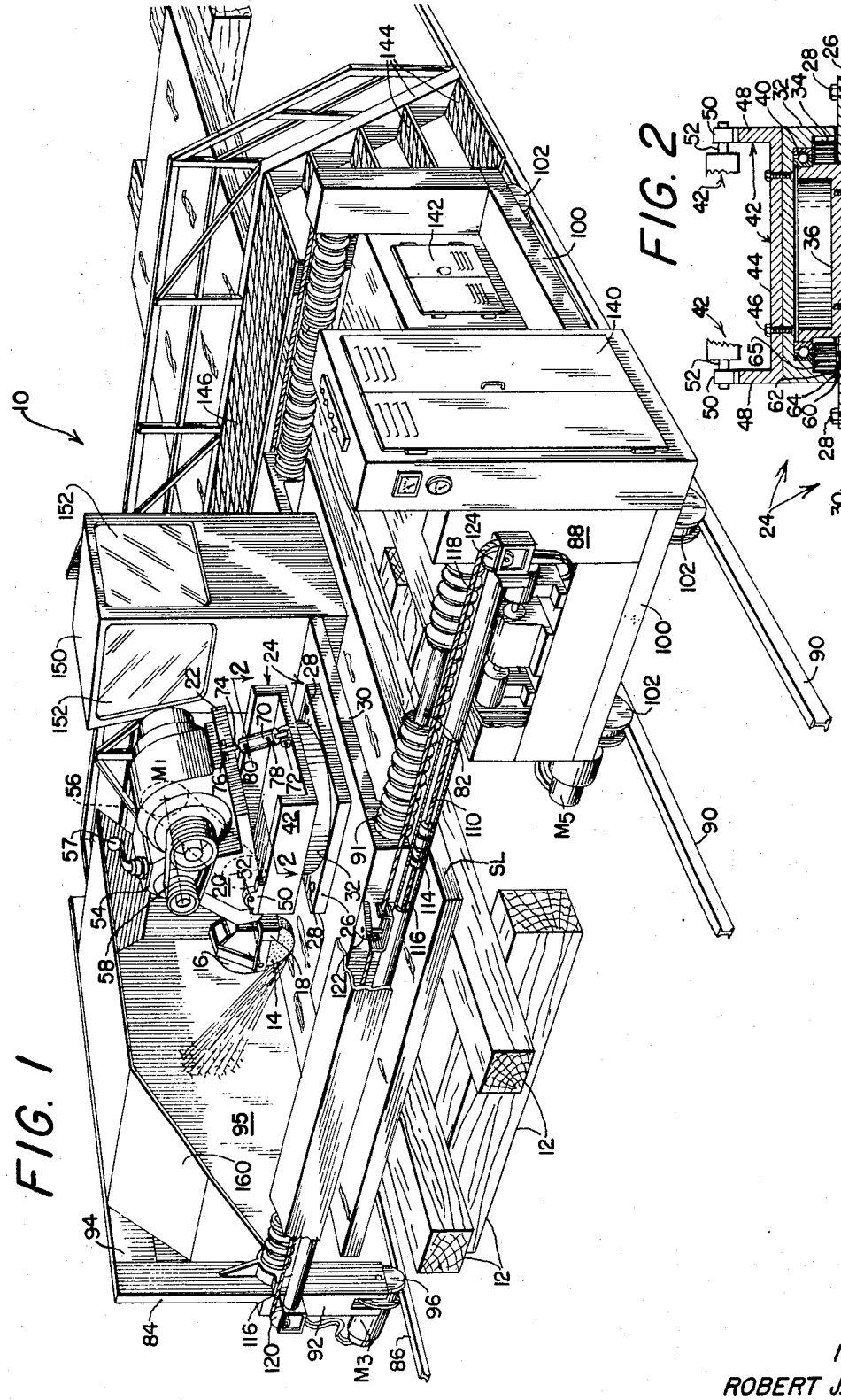


FIG. 1

FIG. 2

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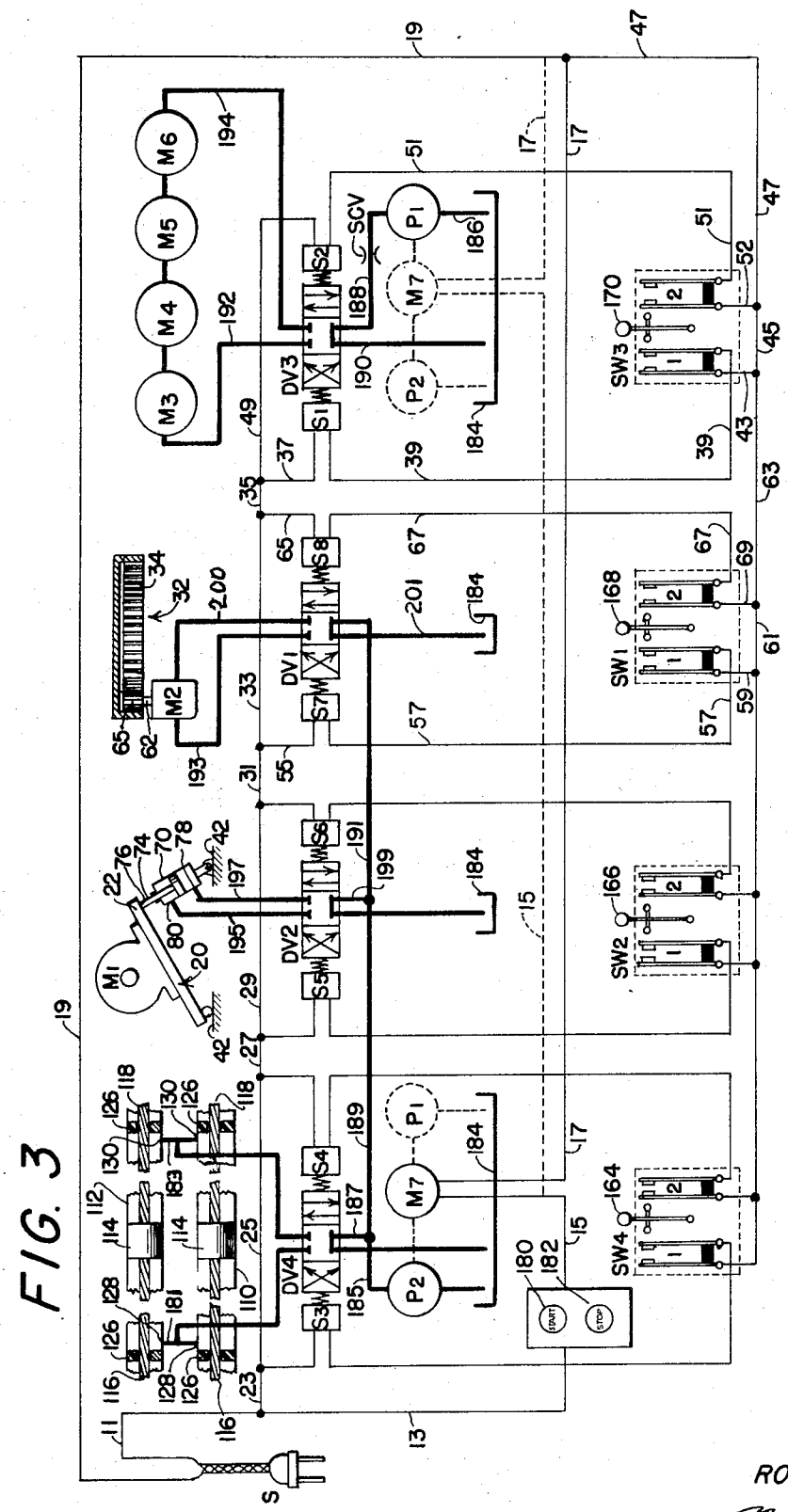


FIG. 3

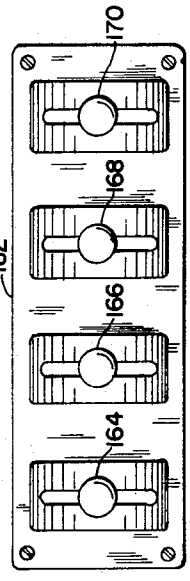


FIG. 4

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GRINDING MACHINE

The present invention relates to a grinding machine for conditioning metal surfaces, as, for example, the surfaces of a steel slab, in order to remove scale, i.e., the usual decarburized surface layer, and reveal any cracks or seams which may be hidden by such layer, such conditioning taking place preliminary to removal of such cracks or seams by a spot-grinding operation if necessary.

In the treatment of slabs and particularly slabs of stainless alloy and carbon steels, it is desirable to remove the above-noted defects from slabs and billets before advancing them to the finishing stages of processing. If such defects are not removed by grinding or otherwise, they take on a predominant aspect in the finished product. The usual grinding wheel traversing operations across the surface of a slab may remove the scale or decarburized layer adhering to such surface, but such operations seldom will remove all localized defects such as cracks, seams, inclusions and the like, and after surface conditioning by grinding wheel traversing operations it is necessary individually to spot-grind these localized defects by returning the grinding wheel selectively to the vicinity thereof.

Heretofore, in connection with a grinding machine which is capable of traversing the work (steel slab) or of being traversed by the work during the grinding operation, the grinding wheel which is associated therewith possesses fixed orientation with respect to the direction of traverse, the orientation invariably being such that the grinding direction is at right angles to the direction of traverse or, in other words, is a transverse direction with respect to the longitudinal axis of the slab or billet undergoing grinding. Thus, when during normal grinding operations there is encountered an elongated crack or seam which extends at a wide angle with respect to the rotational plane of the grinding wheel, the periphery of the grinding wheel acts on the remote edges of such crack or seam and tends to chip such edge away, thus widening the defect instead of eradicating it. For proper crack or seam eradication, it is well known that coincident grinding along the axis of a crack produces optimum results since there is no tendency for the crack to open up and the opposite edges of the crack are worn away evenly until the crack disappears. Thus, the operation of a conventional grinding machine is frequently augmented by subsequent hand operation or spotting wherein an operator attends to such cracks or seams as have been widened during normal machine grinding by hand-spotting these cracks with a small portable grinder which can be directed to treat the cracks in a longitudinal grinding direction.

There has recently been developed a fully automatic grinding machine which endeavors to treat cracks which have been widened during normal grinding machine traversing operations by the provision of facilities whereby the operator may return the grinding wheel to any given localized region in the vicinity of a crack or other flaw in the work and then set the machine into a grinding wheel oscillating cycle where the rotating grinding wheel rocks back and forth about a horizontal axis which extends transversely of the billet or slab. Such a machine forms the subject matter of U.S. Pat. No. 3,253,368, granted on May 31, 1966 and entitled "SURFACE CONDITIONING GRINDING MACHINE." This type of crack treatment, although it obliterates the cracks, requires careful and detailed oscillation control involving considerable skill, and it is not altogether satisfactory in that, to remove any given crack, a wide swath or trough must be created to envelop the crack, thus removing more material than otherwise would be necessary. This is because, although the grinding wheel is capable of oscillation about a horizontal axis, such axis at all times extends at a right angle to the direction of traverse. Additionally, to provide for such grinding wheel oscillation requires complicated oscillating mechanism including a special oscillating motor and a linkage arrangement whereby the grinding wheel boom may be caused to oscillate.

The present grinding machine is designed to overcome the above-noted limitations that are attendant upon the treatment of cracks during regular work traverse operations, or, if necessary, during subsequent spotting operations. Accordingly, the invention contemplates the provision of a grinding machine wherein the boom housing in its entirety is mounted on a rotatable turret or turntable, the latter being carried by the grinding machine carriage and capable of being rotated about a vertical axis during grinding operations and without necessitating lifting of the grinding wheel from the work. The grinding wheel boom which is associated with such boom housing is relatively short so that the swinging movements thereof incident to controlled rotation of the turret will not swing the grinding wheel on the outer end thereof off the edge of the slab or other work, even when the turret is rotated throughout an angle of 90° in either direction away from the direction of traverse, i.e., the longitudinal axis of the billet or slab. In order to give the operator a close-up view of the work at all times, an operator's control cab is mounted on the grinding machine carriage at a region which is close to the operating region of the grinding wheel, the cab moving bodily with the carriage and thus preserving its proximity to the grinding wheel at all times regardless of the region of the slab being operated upon.

Specifically, the present grinding machine is of the general type which is illustrated and described in aforementioned U.S. Pat. No. 3,253,368 in that it is similarly distinguished from a conventional swing-type grinding machine by utilizing a carriage which, in addition to its traverse movements, is capable of moving back and forth transversely of the work and over such work, and in close proximity to the upper surface thereof so that the machine can be operated with extremely low head room and possesses a low center of gravity. The present grinding machine adopts many of the advantageous features of the patented grinding machine such as the attaining of a close grouping of such operating points as are effective, first, to support the grinding wheel when it is not in contact with the work and, second, to afford such necessary reaction force to downward grinding pressure on the grinding wheel that effective wheel stabilization, both during the grinding operation and grinding wheel idling, will at all times be maintained. By reason of these features, high-speed grinding at relatively high pressures with a minimum of vibration is made possible regardless of whether normal traverse operations or subsequent spotting operations are in progress.

The grinding machine of the present invention is, therefore, an improvement over the patented grinding machine in that it superimposes thereon additional advantageous functions which effect a more satisfactory method of crack or seam treatment. As will become apparent when the nature of the invention is better understood, the basic structure of the patented grinding machine has been retained, as also have many of its functional operating characteristics, as, for example, the use of a supporting bridge structure for the boom carriage which slides on guide tubes which, in turn, are carried on movable front and rear main and tail stock carriages which straddle the work and travel in unison on rails. On the other hand, certain of the features of the patented grinding machine have been omitted from the present grinding machine since the utilization of a turret, which enables the grinding wheel to change its grinding direction as heretofore outlined, renders such features unnecessary. For example, with longitudinal crack or seam spotting made possible, grinding wheel oscillation as set forth above is no longer required. Still other features of the patented grinding machine have been omitted from the disclosure of the present machine inasmuch as they bear no direct relation to the rotating turret or its control mechanism. However, if desired, these features are readily capable of being applied to the present machine as disclosed.

The provision of a grinding machine such as has briefly been outlined above, and possessing the stated advantages, constitutes the principal object of the present invention. Numerous other objects and advantages, not at this time enumerated, will readily suggest themselves as the following description ensues.

The invention consists in the several novel features which are hereinafter described and are more particularly defined by the claims at the conclusion hereof.

In the accompanying two sheets of drawings forming a part of this specification, one illustrative embodiment of the invention is shown.

In these drawings:

FIG. 1 is a front perspective view of a grinding machine embodying the principles of the present invention, the machine being illustrated as being in operation upon a steel slab;

FIG. 2 is an enlarged sectional view taken substantially on the vertical plane indicated by the line 2—2 and in the direction of the arrows;

FIG. 3 is a combined electrical and hydraulic circuit diagram of the grinding machine control mechanism; and

FIG. 4 is a front elevational view of a control panel which is employed in connection with the manual operation of the electrical instrumentalities of FIG. 3.

GRINDING MACHINE STRUCTURE IN GENERAL

Referring now to the drawings in detail and in particular to FIG. 1, an exemplary form of grinding machine for conditioning the surface of a steel slab or other similar piece of work having a horizontal planar upper surface is illustrated in its entirety and designated by the reference numeral **10**. The disclosure of FIG. 1 is somewhat schematic in its representation inasmuch as certain instrumentalities such as the cabinet-enclosed electrical relays and similar devices, hydraulic piping, electrical lead wires, minor manual controls and adjusting mechanism, and other associated parts which bear no relation to the present invention have been omitted in the interests of clarity and are considered to fall within the scope of engineering development work during grinding machine production.

The grinding machine **10** is shown in the drawings as being in operation upon the top or upwardly facing surface of a steel slab SL which is operatively supported on any suitable work support as exemplified by the wooden base structure **12**. The latter may be erected in piecemeal fashion on the floor or other supporting surface of the establishment where the grinding machine is in use in order to accommodate the placement of the slab as to height, longitudinal and transverse span, etc. The supporting structure, although it may be erected separately at the grinding region or area of the machine **10**, may for descriptive purposes be regarded as a functional part of the machine.

The present grinding machine **10** utilizes a single grinding wheel **14** which normally is designed for rotation about a horizontal axis extending parallel to the longitudinal axis or center line of the elongated slab SL or other piece of work to be operated upon. However, according to the present invention, and as will be made clear subsequently, means are provided whereby the grinding wheel may be caused to deviate from such parallel axis for crack or spot grinding operations when such operations are required. The grinding wheel **14** constitutes the operative grinding element of a more or less conventional grinding wheel head **16** which is carried at the forward or distal end of a relatively short boom **18**, the boom being carried on a boom housing **20** which is shown in the drawings as being in the form of a tiltable casting. The latter has a ledge portion **22** which constitutes a support for an electric grinding wheel drive motor **M1**.

The boom housing **20** is mounted for limited fore and aft rocking movement on a turret assembly **24** (see FIG. **2** as well as FIG. **1**) which is supported for rotation about a vertical axis on a rectangular non-rotatable turret base **26**, the latter being secured by bolts **28** to a main boom carriage **30** which is in the form of a relatively massive plate-like platform. The turret assembly **24** comprises a rotatable turret body **32** which is in the form of an inverted cup-shaped casting, the lower rim region of which is shaped to form an internal ring gear **34**. The rotatable turret body **32** is centered on a fixed bearing support **36** of upright cup-shape design, such support being fixedly secured by bolts **38** to the turret base **26**. A combined thrust and radial bearing **40** is effective between the rim region of the bearing support **36** and the turret body **32** to center the rotatable turret body on the fixed support **36**. As shown in the drawings, said bearing **40** consists of inner and outer circular races and an annular series of balls between the two races. The turret assembly further comprises an upper supporting cradle **42** having a flat base portion **44** that is fixedly secured by bolts **46** to the turret body **32**. Said cradle also has an upstanding marginal flange **48** on which there are disposed two bearing block assemblies **50**. The latter are disposed diagonally opposite one another and receive therein horizontal trunnions **52** which project laterally in opposite directions from the forward corner regions of the boom housing **20**.

The aforementioned electric motor M1 which is carried on the ledge portion 22 of the boom housing 20 operates through a multiple speed step-up transmission 54 to drive the grinding wheel 14, the transmission being connected to the grinding wheel by a belt and pulley arrangement 56 and having a gear ratio change handle 57 associated therewith. A multiple belt and pulley arrangement 58 serves to connect the motor M1 to the transmission 54. It is to be noted that the grinding wheel head 16 and its boom 18 are disposed on one side of the pivotal axis of rocking movement of the boom housing 20, while the electric motor M1 is disposed on the other side of such axis, the transmission 54 being positioned substantially directly above the said pivotal axis. The net result of this is that the grinding wheel head 16 and the motor M1 to a large extent counterbalance each other and lend a degree of stable equilibrium to the grinding wheel assembly as a whole. Since the boom 18 is extremely short, there is no appreciable framework deflection between the grinding wheel 14 and the pivotal axis of the boom 14. As will be described in greater detail presently when the operation of the grinding machine is set forth, the distance between the effective point of contact of the grinding wheel 14 on the slab SL and the vertical axis of rotation of the turret assembly 24 is sufficiently short that upon angular turning movement of the turret assembly 24 a wide arcuate sweeping movement of the grinding wheel over the surface of the slab SL may be attained whereby the grinding direction of the wheel may be shifted from its normal transverse direction across the slab, 90° in either direction to bring the grinding direction into parallelism with the axis of the slab. It will be understood, of course, that the turret may be stopped in any intermediate position, in which case the direction of grinding of the grinding wheel 14 will extend at an angle to the longitudinal axis of the slab SL.

Rotation of the turret body 32 is accomplished under the control of a reversible hydraulic turret motor M2 (see FIG. 2) which is secured by bolts 58a to the underneath side of the fixed turret base 26 and seats within a recess 60 in said turret base. The motor M2 is provided with a motor shaft 62 which projects upwardly through an opening 64 in the turret base 26 and carries a pinion 65. The latter as shown in FIG. 2 meshes with the ring gear 34. The motor M2 is of the rotary vane-type and, being reversible, it is provided with a pair of fluid ports 66 and 68 (see also FIG. 3) for the admission and expulsion of motive fluid to and from the motor under the control of a directional valve DV1, the nature of which will be described subsequently when the hydraulic and electric circuit diagram of FIG. 3 is described in detail.

In order to impart tilting movements to the boom housing 20 as a whole and thus effect raising and lowering movement of the grinding wheel 14 from and to the slab SL or other piece of work being operated upon, as well as to supply the necessary grinding pressure of the grinding wheel to the work, an hydraulic motor in the form of an upwardly and forwardly inclined boom cylinder 70 has its lower end pivotally connected as indicated at 72 to the rear edge region of the upper supporting cradle 42. A plunger 74 projects upwardly from the cylinder 70 and has its upper end connected as at 76 to the rear edge of the boom housing 20. Operating fluid is selectively supplied to the cylinder 70 through lower and upper ports 78 and 80 (see FIG. 3) in order to tilt the boom housing 20 in opposite directions under the control of a second directional valve DV2 in a manner that also will be described in connection with the circuit diagram of FIG. 3.

The various grinding machine parts thus far described, i.e., the grinding wheel 14, the tiltable boom housing 20, the motor M1, the transmission 54, and the turret assembly 24 constitute an assembly of parts which will hereinafter be referred to as the boom and turret assembly, this assembly being mounted on and movable bodily with the aforementioned boom carriage 30. The latter is slidable in a forward and rearward direction on a pair of horizontally extending guide rods 82 which may be in the form of hollow guide tubes which overlie the slab-supporting base structure 12 and constitute a supporting bridge structure for the boom and turret assembly (20, M1, 54, 24). The front ends of the guide rails 82 are suitably supported on a tail stock carriage 84 which travels endwise and longitudinally on a single horizontally extending ground rail 86. The rear ends of the guide rails 82 are supported in the upper regions of a machine base assembly which is designated in its entirety by the reference numeral 88 and constitutes a main grinding machine carriage that travels on two ground rails 90 in unison with the tail stock carriage 84. Flexible accordion boots 91 surround the guide rods 82 in protective relationship and extend between the main boom carriage 30 and the machine base assembly 88.

The tail stock carriage 84 is in the form of an inverted U-shaped frame having vertical supporting legs 92, the upper ends of which are connected by a horizontal beam 94. A back wall 95 projects across the framework of the tail stock carriage 84. The lower ends of the legs 92 carry dual-flanged traction wheels 96 which travel on the ground rail 86. The wheels 96 are power-driven under the control of individual reversible hydraulic motors M3 and M4 of the legs 92 and being operable in unison under the control of a directional valve DV3.

The main grinding machine carriage 88 is in the form of a wheeled vehicle and it constitutes a support for a large number of the grinding machine components, the nature of which will be described presently. Said main grinding machine carriage 88 includes a generally rectangular base frame 100 which is supported at its four corners by dual-flanged traction wheels 102, the pair of wheels at one end of the base frame 100 being driven by a common reversible hydraulic vane-type motor M5 and the pair of wheels at the other end of the base frame being driven by a similar common hydraulic motor M6. The four traction wheels 102 are adapted to travel in opposite directions on the ground rails 90.

The previously mentioned grinding machine components which are carried on the main grinding machine carriage 88 include two hydraulic pumps P1 and P2, together with a common electric motor M7. The pump P1 serves the various wheel motors M3, M4, M5 and M6 which are disposed in series relationship so that the four traction wheels 102 which control the reversible movements of the main grinding machine carriage 88 as well as the two traction wheels 96 which control the reversible movements of the tail stock carriage 84 are all six driven in unison and in the same

direction. By causing these various traction wheels to operate simultaneously not only is positive motion of the entire grinding machine along the rails assured but also binding of the machine on the rails due to unequal displacements of the main grinding machine carriage **88** and the tail stock carriage **84** is prevented.

The hydraulic pump P2 serves all of the hydraulic motors and cylinders which are associated with the grinding machine exclusive, of course, of the reversible hydraulic wheel motors M3, M4, M5 and M6 which are served by the pump P1. The hydraulic devices or units which are served by the pump P2 include the previously mentioned boom cylinder **70** and the reversible turret motor M2 as well as two additional hydraulic motors or cylinders **110** and **112**, these latter cylinders serving to effect forward and rearward movement of the main boom carriage **30** on the guide rods **82**. The cylinders **110** and **112** have their opposite end regions suitably supported on the tail stock carriage **84** and the main grinding machine carriage **88**, respectively. A piston **114** is slidably disposed in each of the cylinders **110** and **112** and constitutes the reaction member of an endless cable loop which is established by means of a pair of cable sections **116** and **118**, the cable section **116** being secured to the piston **114** and passing outwardly through the forward end of the cylinder. Each cable section **116** passes around an idler pulley **120** and is anchored to a fixedly mounted reaction bracket **122** on a side edge of the main boom carriage **30**. Each cable section **118** similarly passes around an idler pulley **124** and is anchored to the associated bracket **122**. As shown in FIG. 3, conventional cable seals **126** are provided at the opposite ends of the two cylinders **110** and **112**, such seals being of the lip seal type and serving to prevent egress of motive fluid from the cylinders **110** and **112** as the cable sections slide through such seals into and out of the cylinders **110** and **112**. Fluid ports **128** and **130** (see FIG. 3) are provided at the opposite ends of each of the cylinders **110** and **112** and are connected in parallel relationship to the pump P2 by way of a directional valve DV4 (see also FIG. 3), as will be described subsequently.

From the above description, it will be appreciated that when pressure fluid is supplied to the ports **128**, the pistons **114** will be driven or forced rearwardly in their respective cylinders, thus causing the cable sections **116** and **118** to travel over their respective pulleys **120** and **124** in such directions as to apply tension to the cable sections **116** and thus pull forwardly the brackets **122** and, consequently, the main boom carriage **30**. When the pressure fluid is supplied to the ports **130**, the pistons **114** will move forwardly and place the cable sections **118** under such tension as to shift said carriage **30** rearwardly.

In addition to the principal functional grinding machine instrumentalities or parts thus far described, the grinding machine is possessed of certain advantageous design features which are associated with the boom carriage **30** and the main grinding machine carriage **88**. These features include the the provision of a control panel cabinet **140** which is suitably mounted on and travels with said main grinding machine within which there is housed a control panel (not shown) on which are mounted certain of the various electrical components which are associated with the machine. A convenience and storage cabinet **142** for tools and other loose equipment is mounted on and travels with the main grinding machine carriage **88**. A series of steps **144** leading to an elevated platform **146** affords convenient access by the operator to a control cab **150** which is mounted on and travels with the main boom carriage **30**. The cab **150** is provided with transparent protective and viewing windows **152**, one of which affords the operator a close-up view of the grinding wheel **14** when it is in operation on the slab SL as well as affording a clear view of the upper surface of the slab so that spotting operations may be conducted with precision. A novel feature of the present invention consists in locating the operator's cab **150** in a position where it is relatively close to the grinding wheel **14** and where it travels with the main boom carriage **30** to the end that regardless of the particular position of the grinding wheel along the longitudinal extent of the slab neither the viewing angle nor the viewing distance of the operator from the working area of the machine is varied. An additional advantageous feature of the present grinding machine resides in the provision of a dust shield **160** which projects rearwardly from the back wall **95** of the tail stock carriage **84**.

ELECTRIC AND HYDRAULIC CONTROL MECHANISM

The main hydraulic circuitry and the electrical control means therefor whereby the electric motor M1 is energized to drive the grinding wheel **14**; whereby the electric motor M7 is energized to drive the pumps P1 and P2; whereby the pump P1 is caused to drive the various wheel motors M3, M4, M5 and M6 in unison in either direction for operating the traction wheels **96** and **102**; whereby the pump P2 is caused selectively to operate the boom cylinder **70** and tilt the boom housing **42** bodily about the axis of the aligned or coaxial trunnions **52** for grinding wheel raising and lowering purposes; whereby said pump P2 actuates the cylinders **110** and **112** for boom carriage movements in forward and rearward directions; and whereby the pump P2 actuates the rotary hydraulic motor M2 to rotate the turret assembly **24** in opposite directions, have not been illustrated in detail herein, the representation of such control means at various places in FIG. 1 being purely schematic. It is pointed out, however, that all control functions are effected by the operator from the control cab **150** on the boom carriage **30** and are accommodated by the provision within said control cab of a control panel **162** such as is illustrated in FIG. 4, such control panel including four movable control handles **164, 166, 168** and **170**, the function of which is schematically illustrated in FIG. 3. These control handles are merely exemplary of a convenient control system and, obviously, other controls, whether pedal or manually operated, are contemplated according to the invention.

Referring now to FIG. 3 wherein the electrically controlled hydraulic circuitry for effecting the various grinding machine operations are schematically illustrated, the heavy lines represent hydraulic fluid lines or piping while the light lines represent circuit lead lines or conductor wires.

(The Machine Carriage and Tail Stock Carriage Drive)

Upon depression of a start button **180** which is associated with a conventional relay-actuated switch box **182**, current is made available for all of the necessary electrical machine functions and there is completed an electric circuit for energizing the motor **M7** to drive the hydraulic pump **P1** which, in turn, supplies fluid under pressure to the various reversible hydraulic wheel motors **M3**, **M4**, **M5** and **M6**. This circuit extends from a current source S (which may be a commercial power line) through a pair of leads **11,13**, the relay-operated contacts (not shown) of the start button **180**, a lead **15**, the motor **M7**, and a pair of leads **17**, **19** back to the source S. Energization of the motor **M7** serves to drive the pump **P1** and also to establish a normal idling circuit extending from a reservoir or sump **184** through a line **186**, the pump **P1**, a line **188**, the directional valve **DV3**, and a line **190** back to the sump **184**. A speed control valve SCV is disposed in the line **188** and serves a purpose that will be made clear presently.

Actually, the motors **M3**, **M4**, **M5** and **M6** have internal gear reduction facilities associated with them and directional control of these motors, all of which are disposed in series relationship, is effected under the control of the previously mentioned directional valve **DV3**, the solenoid of which is of the dual-acting type and has dual windings **S1** and **S2**. Under normal idling conditions when the main grinding machine carriage **88** and the tail stock carriage **84** are motionless on their respective rails **90** and **86**, both windings **S1** and **S2** of the valve **DV3** remain deenergized and the previously described hydraulic circuit through the valve **DV3** and the pump **P1** obtains. However, if either solenoid winding of the directional valve **DV3** is energized to the exclusion of the other, said valve will direct a flow of motive or pressure fluid through the series arranged motors **M3**, **M4**, **M5** and **M6** to set the various traction wheels **102** and **96** into motion in one direction or the other. If, for example, it is desired to shift the carriages **84** and **88** to the right as viewed in FIG. **1**, the solenoid **S1** will be energized, thus establishing an hydraulic circuit extending from the sump **184**, through the line **186**, the pump **P1**, the line **188**, the directional valve **DV3**, a line **192**, the four serially arranged motors **M3**, **M4**, **M5** and **M6**, a line **194**, the directional valve **DV3**, and the line **190** back to the sump. For reverse rotation of the four wheel motors, a similar hydraulic circuit becomes effective upon energization of the solenoid winding **S2** to the exclusion of the solenoid winding **S1**, the pressure fluid passing through the four motors **M3**, **M4**, **M5** and **M6** in the opposite direction. The speed control valve SCV is provided for the purpose of regulating the traveling speed of the two carriages **84** and **88**.

The two solenoid windings **S1** and **S2** of the directional valve **DV3** are selectively energizeable by manipulation of the control handle **170** on the control panel **162** in the operator's cab **150**. Energization of the solenoid **S1** is effectived by shifting such handle **170** downwardly as illustrated in FIG. **4** or to the left as illustrated in FIG. **3**, thus establishing an electric circuit from the source S, through the lead **11**, a plurality of leads **23**, **25**, **27**, **29**, **31**, **33**, **35**, **37**, the solenoid winding **S1**, a lead **39**, the No. **1** contacts (now closed) of a dual throw, dual contact switch assembly **SW3** in associated relation with the control handle **170**, a plurality of leads **41**, **43**, **45**, **47** and the lead **19** back to the source S. Energization of the solenoid winding **S2** of the directional valve **DV3** is effected by shifting the handle **170** upwardly as illustrated in FIG. **4** or to the right as illustrated in FIG. **3**, thus establishing a similar circuit through the winding **S2**, this circuit extending from the source S, through leads **11**, **23**, **25**, **27**, **29**, **31**, **33** and **35**, a lead **49**, the solenoid winding **S2**, a lead **51**, the No. **2** contacts of the switch assembly **SW3** (now closed), a lead **53** and its leads **45** and **19** back to the source.

(The Boom Carriage Drive)

Fore and aft movements of the main boom carriage **30** along the two guide rods **82** is effected under the control of the directional valve **DV4**. It will be remembered that at the time the electric motor **M7** was initially energized, both pumps **P1** and **P2** were actuated by such motor, the pump **P2** serving to supply pressure fluid selectively through the directional valve **DV4** to the opposite ends of the cylinders **110** and **112**. Operation of the directional valve **DV4** is effected under the control of the handle **164** on the control panel **162**, downward movement of the handle serving to effect closing of the No. **1** contacts of a switch assembly **SW4**, and upward movement thereof serving to close the No. **2** contact of such switch assembly. The directional valve **DV4** is identical to the directional valve **DV3** and the dual contact switch assembly **SW4** which is associated therewith is identical to the previously described switch assembly **SW3**. The hydraulic circuitry leading from the sump **184** through the pump **P2** and the directional valve **DV4** and extending to the ports **128** and **130** at the opposite ends of the cylinders **110** and **112** and back to the sump is similar to the previously described hydraulic circuit extending from the sump **184** through the pump **P1** and the directional valve **DV3** to the motors **M3**, **M4**, **M5** and **M6** and back to the sump and, consequently, a detailed tracing of such hydraulic circuitry is not deemed to be necessary, it being sufficient to state that the pressure fluid flow to and from the ports **128** and **130** takes place through branch conduits or lines **181** and **183**. Similarly, the electrical circuitry for selectively energizing the solonoid windings **S3** and **S4** of the directional valve **DV4** under the control of the No. **1** and No. **2** contacts of the switch assembly **SW4** remains substantially the same as that previously described in connection with the switch assembly **SW3** and the directional valve **DV3** and will not be described herein. It is deemed adequate to point out that by moving the control handle **164** upwardly as illustrated in FIG. **4** or to the left as illustrated in FIG. **3**, the No. **1** contacts of the switch assembly **SW4** become closed and establish the necessary circuit through the solenoid winding **S3** for shifting the directional valve **DV4** to such position that pressure fluid is caused to enter the ports **128** of the cylinders **110** and **112** and drive the pistons **114** rearwardly as viewed in FIG. **1**, thereby shifting the main boom carriage **30** forwardly on the guide rods **82** in the manner previously described. Similarly, reversal of the control handle **164** causes pressure fluid to enter the ports **130** of the cylinders **110** and **112** and drive the pistons **114** forwardly in order to effect rearward movement of the boom carriage.

(Boom Housing Tilting Operations)

Tilting of the boom housing **20** in opposite directions to lower and raise the grinding wheel **14** into and of contact with the work is effected under the control of the directional valve DV2 and its associated switch assembly SW2, the latter being controlled by the handle **166** on the control panel **162**. The directional valve DV2 and the switch assembly SW2 are identical to the previously described directional valves and switch assemblies and the electrical and hydraulic circuitry which is associated therewith remains substantially the same and, therefore, requires no detailed description. It is deemed sufficient to point out that a parallel arrangement of both electrical and hydraulic circuitry exists as between the directional valves DV2 and DV4, these two valves being connected to the common pump P2 by fluid lines **185** and **187** in the case of the directional valve DV4, and by fluid lines **189** and **199** in the case of the directional valve DV2. Fluid lines **195** and **197** lead from the directional valve DV2 to the fluid ports **80** and **78**, respectively, for actuating the plunger **74** in opposite directions for grinding wheel raising and lowering movements as the case may be. Tilting of the boom housing **20** in opposite directions is selectively controlled by manipulation of the control handle **166** of the switch assembly SW2 to close the No. 1 and No. 2 contacts thereof, each to the exclusion of the other.

(The Turret Drive)

Rotation of the turret assembly **24** in opposite directions for varying the angular disposition of the grinding wheel **14** and, consequently, the operative grinding direction as previously described is effected under the control of the handle **168** which is associated with the switch assembly SW1. This switch assembly controls the selective energization of the solenoid windings S7 and S8 of the directional valve DV1, the latter valve being identical to the directional valves DV2, DV3 and DV4 and serving to control the pressure fluid flow from the pump P2 to the turret motor M2.

In order to rotate the turret assembly **24** in a clockwise direction as viewed in FIG. 1, the operator will move the control handle **168** downwardly as viewed in FIG. 4 or to the left as viewed in FIG. 3, thus closing the No. 1 contacts of the switch SW1 and establishing an electrical circuit extending from the source S, through leads **11**, **23**, **25**, **27**, **29** and **31**, a lead **55**, the solenoid winding S7 of the valve DV1, a lead **57**, the No. 1 contacts of the switch SW1, a sequence of leads **59**, **61**, **63**, the leads **45**, **47** and **19** back to the source. Energization of the solenoid winding S7 shifts the directional valve DV1 so that pressure fluid flows from the sump **184**, through the pump P2, the lines **185** and **189**, a line **199**, the directional valve DV1, a line **193**, the boom motor M2, a line **200**, the directional valve DV1 and a line **201** back to the sump. Such energization of the boom motor M2 serves to rotate the boom turret assembly **24** in a clockwise direction. Reverse rotation of the boom motor M2 is effected by moving the control handle **168** so as to close the No. 2 contacts of the switch assembly SW1, thereby establishing a circuit through the solenoid winding S8 of the directional valve DV1, the circuit extending from the source S, through the leads **11**, **23**, **25**, **27**, **29**, **31**, **33**, a lead **65**, the solenoid winding S8, a lead **67**, the No. 2 contacts of the switch SW1, a lead **69**, and the leads **63**, **45**, **47** and **19** back to the source. Energization of the solenoid winding S8 shifts the directional valve DV1 so that fluid flows from the sump **184**, through the pump P2, the lines **185**, **189**, **191**, the directional valve DV1, the line **200**, the boom motor M2, the line **193**, the directional valve DV1, and a line **201** back to the sump.

GRINDING MACHINE OPERATION

From the above description, it is believed that the operation of the grinding machine **10** will to a large extent be readily apparent without further description. Assuming a slab such as the slab SL to be positioned on the slab-supporting structure **12**, depression of the start button **180** will set the motors M1 and M7 into operation, after which the operator may variously manipulate the control handles **164**, **166** and **170** as required to effect the required boom carriage placement, boom housing inclination, and main carriage travel respectively for conventional traverse operations of the grinding wheel back and forth along the longitudinal extent of the slab SL, After the required number of passes have been made and it is desired to spot grind localized regions of the slab in order to remove various forms of defects, these same control handles **164**, **166** and **170** may be variously manipulated to bring the grinding wheel **14** to the proper location for such spot grinding operations, the plane of the grinding wheel remaining normal or at a right angle to the direction of traverse.

When an elongated crack or seam is encountered which requires grinding in a longitudinal direction as previously described, the operator may, by manipulating the control handle **168** to close either the No. 1 and No. 2 contacts of the switch SW1 each to the exclusion of the other, cause rotation of the turret assembly **24** in one direction or the other to bring the plane of the grinding wheel into coincidence with the vertical plane of the crack or seam, after which the control handles **164**, **166** and **170** may be variously manipulated so as to lower the grinding wheel into contact with the work at the vicinity of the crack or seam and to shift the main machine carriage **88** and the boom carriage **30** in such proportionate relationship that the grinding wheel will follow the crack or seam line. It will be understood that the central or medial positions of the various control handles are idle positions wherein neither the No. 1 nor the No. 2 contacts which are respectively associated with the switches SW1, SW2, SW3 and SW4 are closed.

The invention is not to be limited to the exact arrangement of parts shown in the accompanying drawings or described in this specification as various changes in the details of construction may be resorted to without departing from the spirit or scope of the invention. Therefore, only insofar as the invention has particularly been pointed out in the accompanying claims is the same to be limited.

Having thus described the invention what I claim as new and desire to secure by letters patent is:

1. In a machine for conditioning the upper surface of an elongated workpiece such as a slab, in combination, a work support for the workpiece, a main carriage, a pair of widely spaced overhead parallel guide rods mounted on said main carriage and completely overly-

ing and extending in a fore and aft direction transversely of the work support, lying in a common horizontal plane above the level of the work support, and overhanging the longitudinal side edges of the latter, reversible motor-actuated means for effecting relative movement between the carriage and work support in the longitudinal direction of the workpiece on the support, a boom carriage slidable in a fore and aft direction on said rods and disposed above the level thereof, reversible motor-actuated means for selectively effecting sliding movements of the boom carriage on said rods, a turret mounted on said boom carriage above the level thereof for rotation about a vertical axis, reversible motor-actuated means mounted on the boom carriage for selectively effecting rotational movements of the turret in either direction throughout an angle of approximately 90° a boom housing pivotally mounted on the turret for fore and aft rocking movements about a horizontal axis, reversible motor-actuated means extending between the boom carriage and boom housing for rocking the latter, a boom rigidly supported on the boom housing and projecting outwardly a slight distance therefrom, a grinding wheel rotatably mounted on the outer end of the boom in work piece traversing relationship, a drive motor fixedly mounted on the boom housing and operatively connected to the grinding wheel in driving relationship, the length of said boom being such that the grinding wheel assumes a position in sufficiently close proximity to the vertical axis of rotation of the turret that it is constrained at all times to traverse the workpiece at a region which lies between the vertical planes of said widely spaced parallel guide rods, and control means for selectively actuating said reversible motor-actuated means individually and in unison.

2. In a conditioning machine, the combination set forth in claim 1 and wherein said reversible motor-actuated means for effecting rocking movements of the boom housing includes an extensible and contractible hydraulic cylinder and plunger assembly connected at one end to a fixed point on the boom carriage adjacent the rear end thereof and at the other end to the boom housing at a point adjacent to the rear end of the latter.

3. In a machine for conditioning the surface of an elongated workpiece such as a slab, in combination, a fixed support for the workpiece, track rail structures positioned forwardly and rearwardly of the work support and extending lengthwise thereof, a main carriage adapted to travel on the rear track rail structure, a tail stock carriage adapted to travel on the forward track rail structure, a pair of overhead widely spaced parallel guide rods completely overlying and extending in a fore and aft direction transversely of the work support, lying in a common horizontal plane above the level of said work support, and overhanging the longitudinal side edges of the latter, said rods having their rear ends secured to the main carriage and their forward ends secured to the tail stock carriage, individual reversible motor-actuated means for impelling each carriage along its associated track rail structure selectively in opposite directions, a boom carriage slidable in a fore and aft direction on said guide rods and disposed above the level thereof, reversible motor-actuated means for selectively effecting sliding movements of the boom carriage on said guide rods, a turret on said boom carriage above the level thereof for rotation about a vertical axis, reversible motor-actuated means mounted on the boom carriage for selectively effecting rotational movements of the turret in either direction throughout an angle of approximately 90°, a boom housing pivotally mounted on the turret for fore and aft rocking movements about a horizontal axis, reversible motor-actuated means extending between the boom carriage and boom housing for rocking the latter, a boom rigidly supported on one end of the boom housing and projecting outwardly a slight distance therefrom, a grinding wheel rotatably mounted on the outer end of the boom in workpiece traversing relationship, and an electric drive motor mounted on the boom housing at the other end thereof in counterbalancing relationship with respect to the boom, and means operatively connecting said drive motor to the grinding wheel in driving relationship, the length of said boom being such that the grinding wheel assumes a position in sufficiently close proximity to the vertical axis of rotation of the turret that it is constrained at all times to traverse the workpiece at a region which lies between the vertical planes of said widely spaced parallel guide rods, and control means for selectively actuating said reversible motor-actuated means individually and in unison.

4. In a conditioning machine, the combination set forth in claim 3 and wherein the reversible motor-actuated means for effecting sliding movements of the boom carriage on said guide rods comprises a cylinder positioned in close proximity to each guide rod and having one end thereof secured to the main carriage and the other end secured to the tail stock carriage, a piston slidable in said cylinder, a cable seal effectively closing each end of the cylinder, a pair of cable sections secured to the opposite sides of the piston and passing outwardly of the opposite ends of the cylinder and through said cable seals, a pulley for each cable section, one pulley being mounted on the main carriage and the other pulley being mounted on the tail stock carriage, said cable sections passing around said pulleys and secured to the boom carriage, an hydraulic pump mounted on the main carriage and operatively connected to the opposite ends of each of said cylinders, means for reversing the flow of hydraulic fluid from said hydraulic pump to said cylinders, and means connecting said pump to said electric motor.

5. In a conditioning machine, the combination set forth in claim 3 and wherein said reversible motor-actuated means for effecting rotational movements of the turret comprises a reversible rotary hydraulic motor operatively connected to the turret in driving relationship, an hydraulic pump on said main carriage, flexible hydraulic connections between said pump and rotary motor, and means for reversing the flow of hydraulic fluid from said pump to said rotary motor.

6. A conditioning machine as set forth in claim 3 and wherein the reversible motor-actuated means for impelling the main carriage along its associated track rails includes a first hydraulic motor operatively connected in driving relationship to such carriage, the reversible motor-actuated means for impelling the tail stock carriage along its associated track rail includes a second hydraulic motor operatively connected in driving relationship to such carriage, the reversible motor-actuated means for effecting sliding movements of the boom car-

riage includes a third hydraulic motor operatively connected in driving relationship thereto, the reversible motor-actuated means for effecting rotational movements of the turret includes a fourth hydraulic motor operatively connected in driving relationship thereto, the reversible motor-actuated means for rocking the boom housing includes a fifth hydraulic motor operatively connected in driving relationship thereto, the conditioning machine further including a first pump for supplying actuating fluid to said first and second hydraulic motors, a second pump for supplying actuating fluid to said second, third, fourth and fifth hydraulic motors, and an electric motor common to said pumps and operatively connected thereto in driving relationship, said pumps and electric drive motor being mounted on the main carriage.

7. A conditioning machine as set forth in claim 3 and including, additionally, an operator's cab mounted on the boom carriage in close proximity to said boom, substantially at the horizontal level of the boom housing and between said widely spaced parallel guide rods, said cab being movable bodily with the boom carriage, said cab being provided with operating controls for selectively reversing the flow of actuating fluid from each pump to its associated hydraulic motors.

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