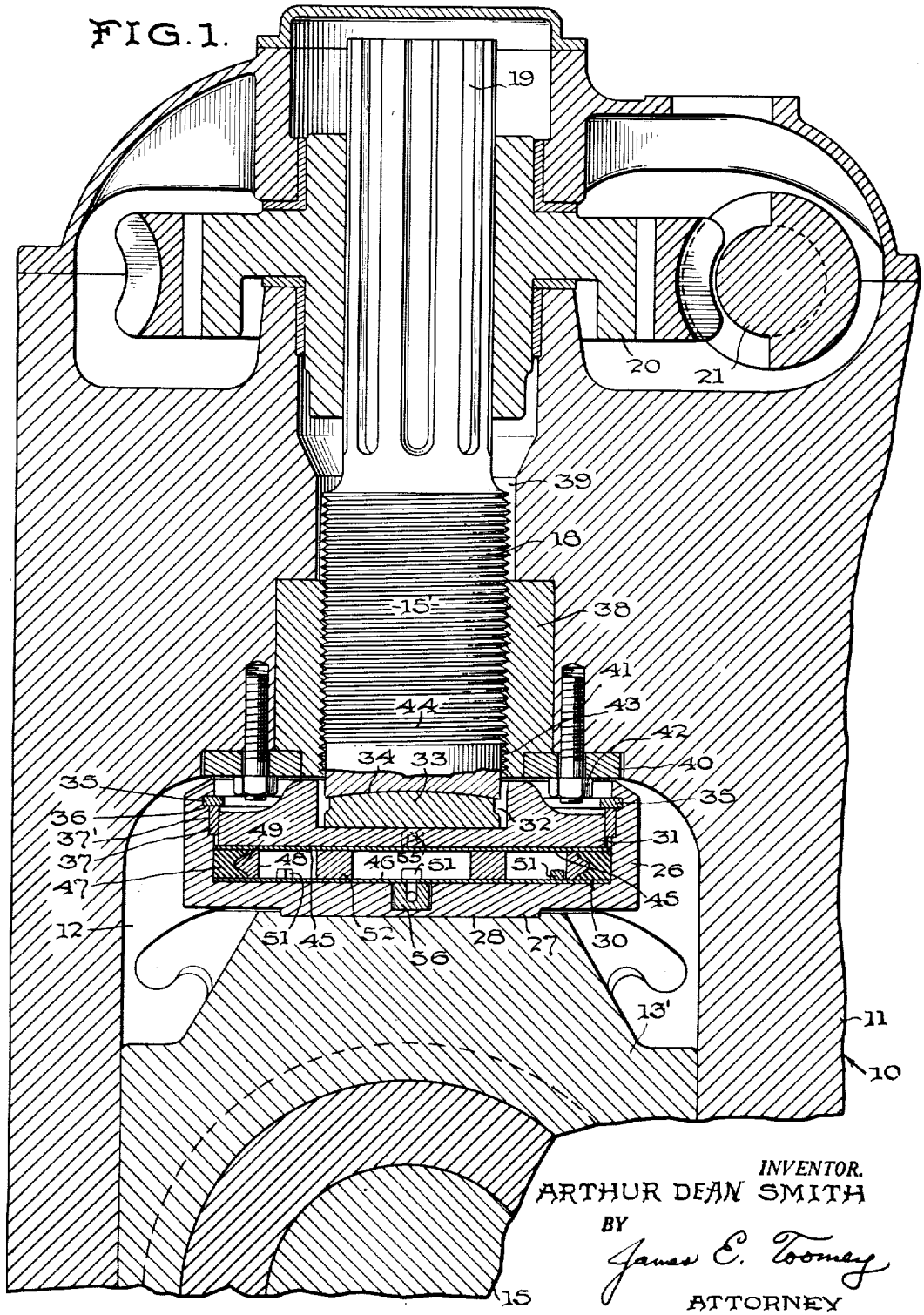
Feb. 14, 1956 A. D. SMITH 2,734,407

TAPER ROLLING MILL

Filed Nov. 8, 1951 4 Sheets-Sheet 1

FIG. 1.



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TAPER ROLLING MILL

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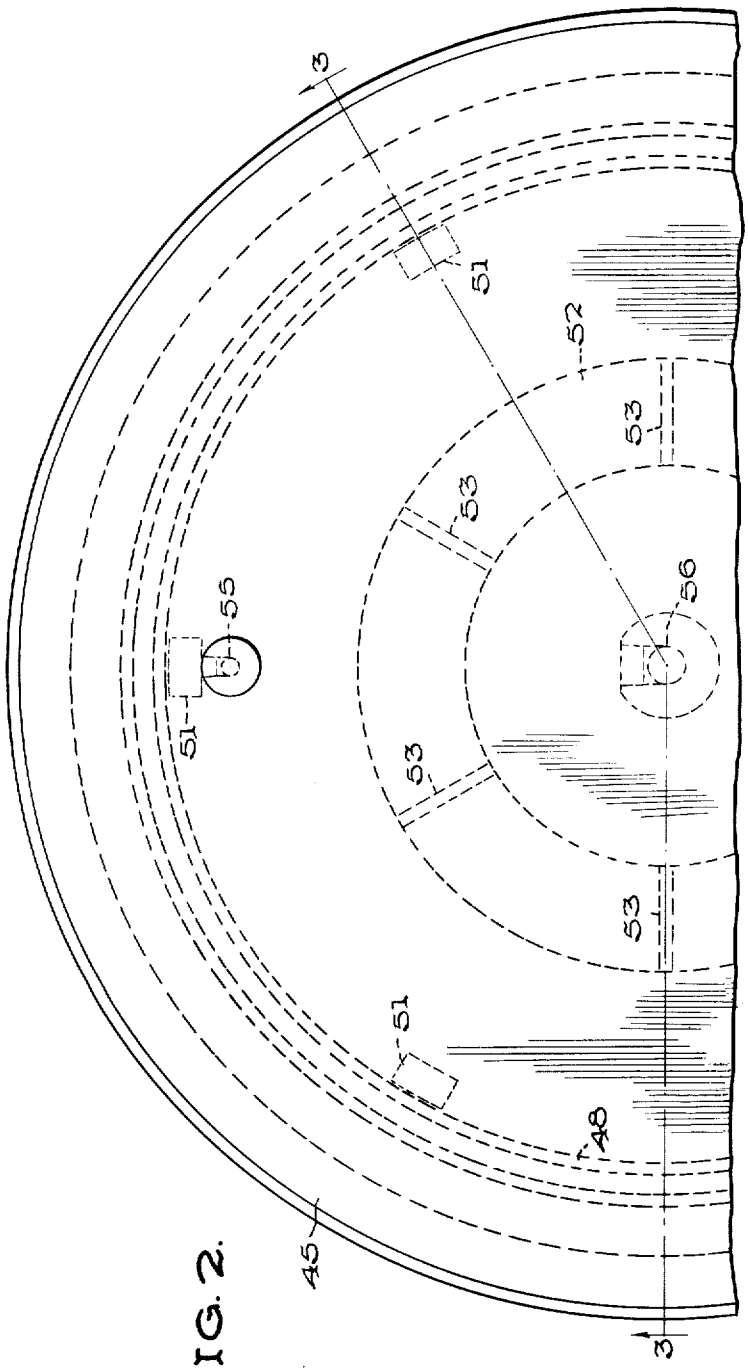


FIG. 2.

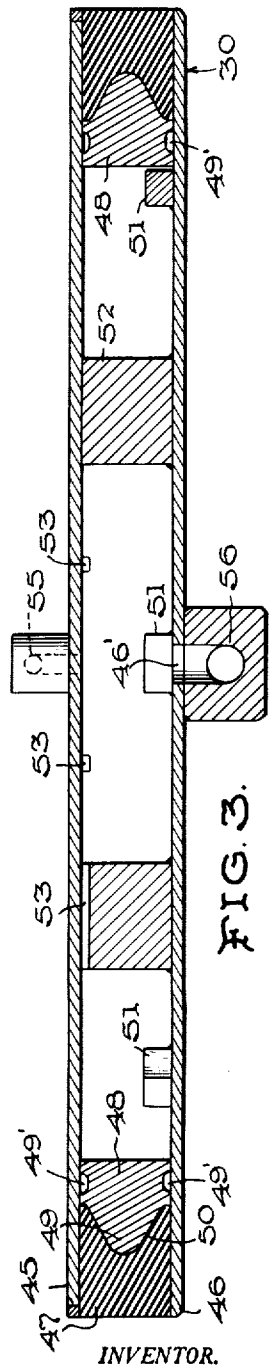


FIG. 3.

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TAPER ROLLING MILL

Filed Nov. 8, 1951 4 Sheets-Sheet 3

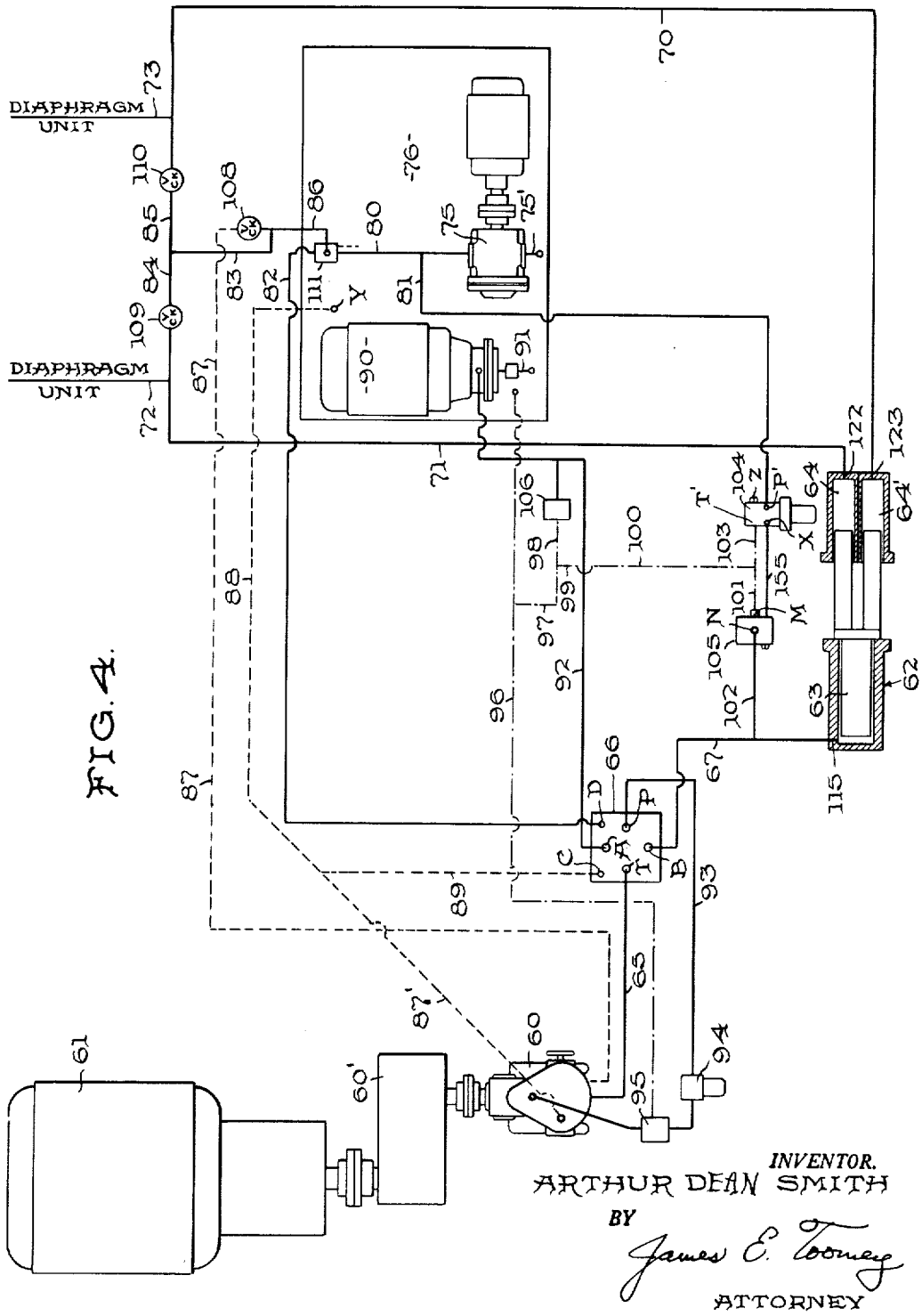


FIG. 4.

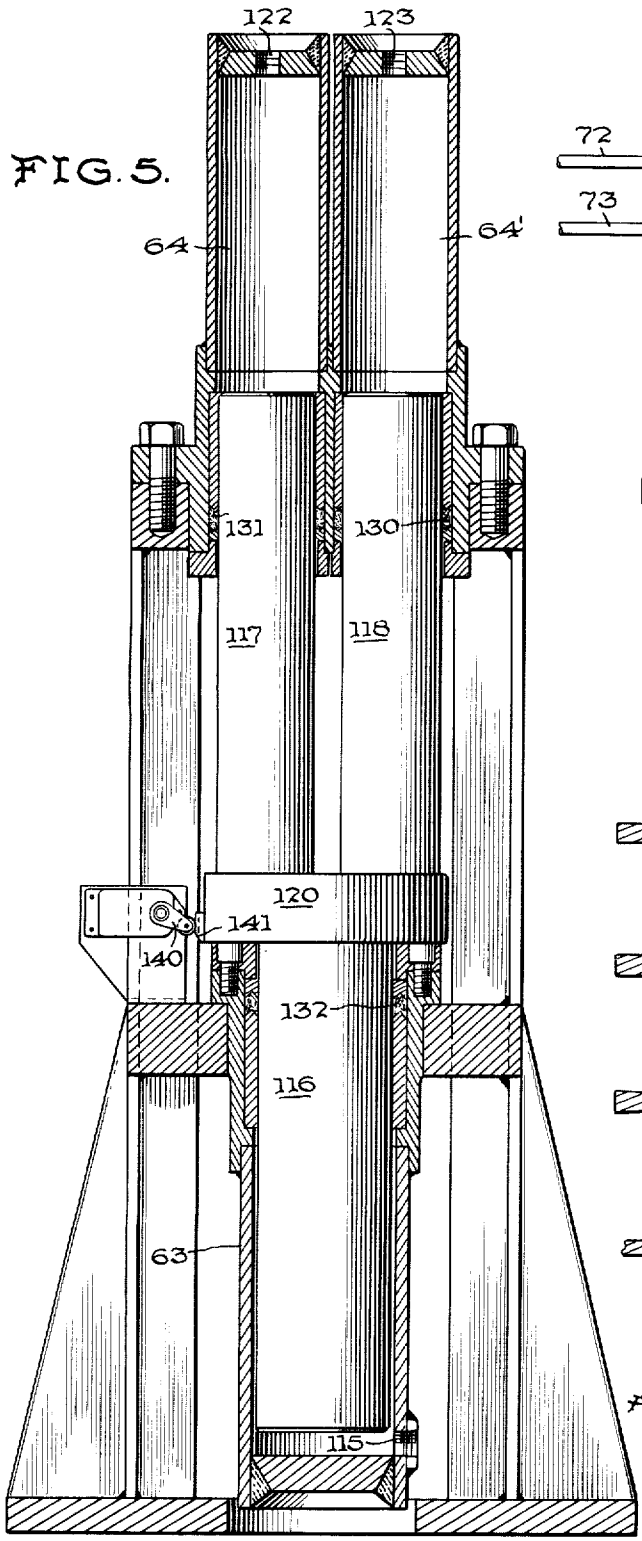
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TAPER ROLLING MILL

Filed Nov. 8, 1951 4 Sheets-Sheet 4

FIG. 5.



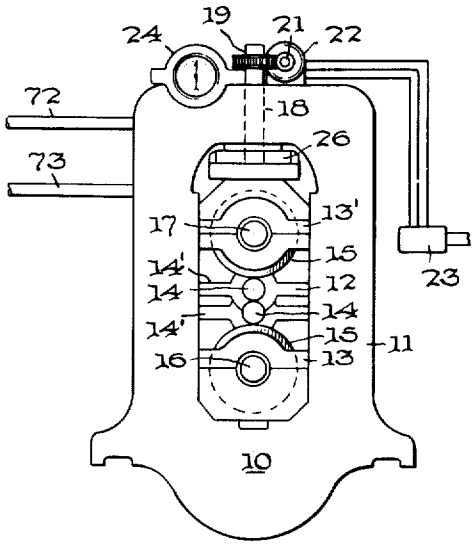


FIG. 6.



FIG. 7.



FIG. 8.

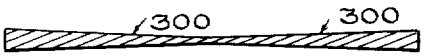


FIG. 9.

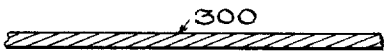


FIG. 10.

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United States Patent Office 2,734,407 Patented Feb. 14, 1956

2,734,407

TAPER ROLLING MILL

Arthur Dean Smith, Spokane, Wash., assignor to Kaiser Aluminum & Chemical Corporation, Oakland, Calif., a corporation of Delaware

Application November 8, 1951, Serial No. 255,368

11 Claims. (Cl. 80—56)

This invention relates to the rolling of sheet material in a rolling mill. More particularly, it is concerned with providing a method and apparatus for rolling sheet metal in such a manner that a given unit length of sheet material passing through the mill will have either a continuous, predetermined, graduated increase or a continuous, predetermined, graduated decrease in thickness or gauge rather than a uniform thickness throughout the entire length thereof, i. e., the thickness of the sheet will be tapered along its length.

Although unit lengths of sheet metal having a uniform gauge or thickness is the usual type of sheet that is produced and sold today, since it is the more conventional type of sheet material used in most industries, there are certain industrial fields where the use of tapered metal sheet or sheet material having a graduated, uniform increase or decrease in thickness for a given length is most advantageous. In some instances, it is also desirable to produce a unit length of sheet, one section of which has a uniform thickness or gauge and another section of which has a graduated taper. For example, one half of a unit length of sheet can have a uniform gauge while the last half may be tapered or vice versa. One field that has use for such sheet is the aircraft industry.

In the manufacture and production of aeroplanes, for example, tapered or partially tapered aluminum sheets instead of sheets having a uniform thickness along the entire length thereof are in great demand since they lend themselves advantageously for use as the outer skins or coverings of airfoils, such as wings, ailerons, and the various elements that constitute the tail assemblies of aeroplanes.

As a result of the fact that the type of sheet material, which has been most in demand in the past, has been sheet material having a uniform gauge or thickness for a given length, most of the problems that have been encountered in the rolling of sheet metal have had to do with maintaining the working rolls of a rolling mill at a constant setting or at the same predetermined distance from one another during the entire rolling operation so that the sheet metal passing between the rolls will have a uniform thickness or gauge along its entire length.

Many devices have been proposed and used in conjunction with a rolling mill assembly to correct any deviation that would occur in the original, predetermined setting of the rolls. However, because these devices were concerned with correcting only discrepancies in the original setting of the rolls, they are not adaptable for use in rolling tapered metal sheets or sheets having a continuous graduated and uniform increase or decrease along a unit length thereof, nor are the same devices suitable for use in rolling sheets, one section of which has a uniform gauge and another part of which is uniformly tapered along its length.

Although some attempts have been made in the past to construct an apparatus which could be used in conjunction with a rolling mill assembly and which would

permit the mill to properly roll tapered sheet metal, they have not met with success primarily because of the difficulties encountered in designing an apparatus which could be accurately controlled and which would in turn function efficiently to produce a constant, uniform and gradual increase or decrease in pressure on the working rolls at the proper times so that they would gradually open or close in a uniform and constant manner and thereby produce a suitable longitudinal taper in the sheet.

It is an object of this invention, therefore, to provide a novel apparatus which can be incorporated in a conventional rolling mill assembly and which is adapted to continuously and gradually increase the pressure upon the working rolls of the mill assembly during the rolling operation in a constant, uniform manner and at a predetermined rate, so that the working rolls will close in a gradual, uniform and continuous manner and at a predetermined rate, thereby producing a uniform taper or decrease in the thickness or gauge of a unit length of material being rolled.

Another object of this invention is to provide a novel method for rolling a unit length of continuously tapered sheet or alternately a unit length of sheet which is partially tapered and partially of a uniform gauge along its length.

It is a further object of this invention to provide a novel apparatus to be used in conjunction with the conventional screw down of a rolling mill employed to obtain the original setting of the rolls, which is adapted to increase the initial pressure placed upon the rolls by the screw down assembly during the rolling operation in a gradual, constant and continuous manner and at a predetermined rate thereby producing a uniformly tapered unit length of sheet material.

A further object of this invention is to provide a novel apparatus to be used in conjunction with the conventional screw down of a rolling mill ordinarily employed to obtain the original setting of the rolls, which is adapted to increase the initial pressure placed upon the rolls by the screw down assembly during the rolling operation or alternately to reduce and remove increments in pressure previously placed on the work rolls so as to bring the pressure on the rolls back to that originally placed thereon by the screw down, which increase or reduction in pressure upon the rolls is made in a continuous, gradual, uniform manner and at a predetermined rate, whereby unit lengths of sheet passing through the mill will have a uniform taper in thickness or gauge.

Another object of this invention is to provide a pair of horizontally aligned novel expansible diaphragm units, which are adapted to be interposed between the pressure adjusting screw and the chock blocks in a rolling mill which support the upper backing roll, which units are adapted to be alternately simultaneously expanded to increase the initial pressure placed upon the chock block and roll by the pressure screw and then to be simultaneously contracted so as to reduce this increment in pressure and to bring the pressure on the chock block and roll back to that initially placed thereon by the pressure screw, this alternate expansion and contraction of the diaphragm units being accomplished in a continuous, gradual, uniform manner and at a predetermined rate whereby unit lengths of sheet material passing through the mill will have a uniform taper in the thickness or gauge thereof.

Another object of this invention is to provide novel means for expanding and contracting these diaphragm units.

A further object of this invention is to provide a novel method for altering the distance between the work rolls in a rolling mill during the rolling operation in a uni-

form, gradual and constant manner and at a predetermined rate so as to cause a unit length of sheet material passing between the rolls to have a graduated, uniform, tapered thickness or gauge.

Another object of this invention is to provide novel means for expanding and contracting each diaphragm unit whereby the expansion and contraction of the units will be synchronized with the speed of the mill motor.

Another object of this invention is to provide novel means for accurately and efficiently altering the distance between the work rolls during the rolling operation in a uniform, constant, gradual manner and at a predetermined rate whereby unit lengths of sheet material passing through the mill will have a uniformly tapered thickness.

These and other objects are accomplished by providing, in combination with a rolling mill having a pair of cooperating rolls and a housing for the rolls, chock blocks for one of the rolls adjustably carried by the housing and adjusting screws used for applying initial pressure to the chock blocks. A plurality of hydraulically operated expansible diaphragm units are interposed between the adjusting screws and the chock blocks. A control unit is employed for actuating the diaphragm units. This control unit includes a master cylinder and a plurality of auxiliary cylinders. Each auxiliary cylinder is connected to an individual diaphragm unit and all the auxiliary cylinders are so connected to the master cylinder that they are all adapted to be simultaneously and uniformly actuated by the master cylinder so that an equal amount of fluid may be alternately pumped into or bled out of each of the diaphragm units simultaneously and at a uniform predetermined rate, whereby the pressure applied to the chock blocks by the diaphragm units will be alternately increased or this increment in pressure reduced in a constant, uniform manner and at a predetermined rate, so that sheet material passing through said rolling mill will have a constant and graduated decrease or increase in thickness along a predetermined longitudinal distance. Means such as a variable volume delivery pump and an auxiliary pump are also used for actuating the master cylinder of the control unit to expand and contract the diaphragm units and the operational speed of the former pump is synchronized with the speed of the mill motor.

These and other objects will be more apparent from a consideration of the following detailed description, when taken in conjunction with the drawings wherein:

Figure 1 is a side elevational sectional view of the upper part of a conventional mill housing, disclosing one arrangement for mounting the diaphragm units;

Figure 2 is a broken plan view of a diaphragm unit shown in Figure 1;

Figure 3 is a sectional view of a diaphragm unit taken along line 3—3 of Figure 2;

Figure 4 is a schematic diagram of a suitable hydraulic system for pumping fluid into or bleeding fluid out of the individual diaphragm units to expand and contract the same;

Figure 5 is a sectional elevational view of the control unit for the diaphragm units, comprised of a main cylinder and two auxiliary cylinders;

Figure 6 is a side elevational view of a conventional 4 high roll assembly with the diaphragm units attached thereto;

Figures 7, 8 and 9 show various forms of tapered sheet which may be rolled in a rolling mill equipped with the novel diaphragm units; and

Figure 10 is a sectional view of sheet shown in Figure 7 when taken along lines 10—10 thereof.

With further reference to the drawings and particularly Figures 1 and 6, a conventional rolling mill assembly **10** is shown wherein a housing **11** is provided with windows **12**, which accommodate the lower and upper chock blocks **13** and **13'** for the back-up rolls **15**. The mill is further provided with working rolls **14** which cooperate with the back-up rolls **15**, these rolls **14** being mounted in the chock blocks **14'**. The necks **16** of the bottom backing roll are mounted in lower chock blocks **13** at the bottom of the window **12** and the necks **17** of the upper backing roll are mounted in upper chock blocks **13'**, which are vertically adjustable in the upper portion of windows **12** so as to obtain the desired setting for the rolls.

The vertical position of the upper chock blocks **13'** is initially and primarily determined by a plurality of conventional screw down assemblies **15'**, one for each side of the mill assembly. Each screw down is comprised of a pressure screw **18** driven through the conventional gearing **19**, **20** and **21** by a screw down motor **22** manually controlled through the medium of a control switch **23**. An indicating dial **24** may be used to show the setting of the rolls.

Disposed between each pressure screw **18** and the upper chock blocks **13'** located in the upper portion of windows **12** is a separate relatively large and preferably cup-shaped body **26**. The outside, bottom surface of this cup-shaped body is provided with a central, annular shoulder **27**, which rests in an annular hollowed out portion **28** in the upper part of chock blocks **13'**. Located within each cup-shaped body **26** is a diaphragm unit **30**, which will be hereinafter more fully described, and a large bearing block **31**, this last-mentioned element being arranged within the body **26** on top of the diaphragm unit **30**.

Bearing block **31** is provided with an annular crater or bowl portion **32** and freely and removably mounted within this crater or bowl portion **32** is a pressure block **33**. This pressure block is provided with a spherical top which cooperates with a hollowed-out seat portion **34** in the lower part of the adjusting screw **18**. Each adjusting screw thus has positive mechanical engagement with the upper chock blocks **13'** for exerting pressure thereon and in turn upon the upper backing and working rolls so as to give the working rolls their initial setting.

It will also be observed in referring to Figure 1 that the bearing block **31** is held in proper position within the cup-shaped member **26** by means of a retainer ring **35** which is inserted within a groove **36** located in the upper portion of the inner wall of the body **26**. This ring also prevents hydraulic pressure from expanding the diaphragm unit **30** to such an extent as to rupture it.

A suitable key or dowel pin **37** may also be inserted in an opening or recess **37'** in one part of the inner wall of body **26** directly below ring **35** in such a manner as to become wedged in between the inner wall of body **26** and the outer portion of bearing member **31**. Key **37** prevents rotary movement of the bearing member **31** and the diaphragm unit **30** from turning because of the friction of the screw **18**, when it is turned against the pressure block **33**. The cup-shaped member **26** itself is held in proper position above upper chock block by means of the screw **18** when it is seated upon the pressure block **33**.

The relatively large contacting surface areas of each cup-shaped member **26** and of the other elements located therein ultimately provide a substantial area over which pressure may be applied to the chock block, and rolls, and also permits a more even and uniform distribution of the pressure upon the backing and working rolls at each side thereof.

It will be further observed from a reference to Figure 1, that the means for holding each pressure adjusting screw **18** in a proper vertical plane and at the proper height depending upon the amount of pressure to be applied to the rolls consists of a hollow cylinder **38** mounted within a cylindrical shaft or opening **39** in the housing **11** by means of a flat, annular retaining plate **40**, the latter plate being held in position through the medium of a series of stud bolts **41** and nuts **42**.

The hollow interior **43** of cylinder **38** is provided with threads, which engage and coact with the threaded por-

tion 44 on the adjusting screw and serve to hold the adjusting screw at the proper predetermined height, when this screw is turned to give the mill rolls their proper setting.

All of the aforesaid elements with the exception of the diaphragm units 30 are more or less conventional parts of a standard rolling mill, and serve as the means for applying initial pressure to the rolls to obtain the desired roll setting.

The diaphragm units 30, however, are of novel construction. Each unit is placed within an individual cup-shaped member 26, there being one unit for each side of the mill assembly. Since they are both similarly constructed a description of one will suffice for both. Each unit 30 is preferably comprised of two circular metal discs or plates 45 and 46 joined together along their outer peripheries by means of an annular fluid resistant rubber ring 47, which is vulcanized to the insides of the two plates adjacent their outer peripheries. A metal floating ring 48 is also located within the diaphragm unit, and this ring is provided with a tapered projecting nose portion 49, which is adapted to be normally seated within a groove portion 50 in the rubber ring 47. The upper and lower portions of metal ring 48 are also adapted to contact the inner surfaces of discs 45 and 46 when the diaphragm is contracted or at rest. The primary purpose of ring 48 and the centering blocks 51 for this ring 48, which are welded to the inner surface of the lower disc 46, is to hold the rubber ring 47 in place during the time it is being vulcanized to plates or discs 45 and 46, ring 48 acting as a dam or backstop. It also acts to shape the rubber ring 47 so as to give it an expandible configuration. Prior to the vulcanization of the rubber ring 47 to discs 45 and 46, the nose portion 49 of ring 48 is coated with a suitable material to prevent the rubber ring 47 from being vulcanized thereto. The small grooves 49' in the bottom and top portions of the ring 48 are for the purpose of permitting the excess rubber of ring 47 to be displaced, when it is heated during vulcanization.

The interior of the diaphragm unit is also further provided with a second metal ring 52 concentrically arranged within ring 48 and welded to the upper surface of disc 46. A plurality of grooves 53 are located in the upper part of this ring 52, so that when fluid or the like is pumped into or out of the diaphragm it will flow in a constant uniform manner and at a predetermined rate simultaneously to or from all parts of the diaphragm and cause the diaphragm as a whole to uniformly contract or expand rather than only one part thereof.

When installed the inner ring 52 and outer ring 48 advantageously protect plates 45 and 46 and the diaphragm as a whole by absorbing the load of the screw 18 against the chock blocks 13', when there is no oil or fluid pressure in the diaphragm 30, such as when fluid has been evacuated therefrom so that the mill rolls can be leveled prior to the rolling of tapered sheet.

Affixed to the top of disc 45 is a discharge port 55 for the diaphragm unit 30. This port 55 is in open communication with the interior of the diaphragm through the medium of opening 55' in the upper disc 45 and it acts as an air bleed port for allowing air to escape from the diaphragm during the time it is initially filled with fluid.

A second port 56 is dependingly affixed to the bottom of disc 46. This port is also in open communication with an opening 46' in the disc 46, which opening leads into the interior of the diaphragm unit. Port 56 is connected to the hydraulic system for expanding and contracting the diaphragm unit and it is employed to pump fluid into or to bleed fluid out of the diaphragm unit 30 as the case may be.

These diaphragm units are preferably hydraulically operated, and, accordingly, one hydraulic system suitable for this purpose is diagrammatically shown in Figure 4.

It is preferably comprised of a variable volume delivery pump 60 connected to and adapted to be driven through a suitable gear reducer mechanism 60' by the main mill motor 61. This pump is connected to the diaphragm control unit 62 comprised of a main master cylinder 63 and two auxiliary cylinders 64 and 64' through the medium of a conduit 65, a conduit or line 67 and a control valve 66, having openings or ports A, B, C, D, P and T therein. Each auxiliary cylinder is directly connected to a separate diaphragm unit 30 through the medium of pipes 70 and 71, 72 and 73. A vane-type pump 75 may also be used to draw fluid from a fluid storage tank 76 and to force the fluid through a series of connecting pipes 80, 81, 82, 83, 84, 85, 86 and 87, ball-type check valves 108, 109 and 110, and a relief valve 111 to keep a positive predetermined pressure in each of the diaphragm units so that any leakage in the system during the operation thereof is immediately compensated for and to eliminate the possibility of air getting into the system around the packing of the various pumps, and the diaphragm control unit, etc.

Pipe 88 is used, along with branch pipe 89, to connect the opening C in valve 66 with port Y in tank 76.

A centrifugal auxiliary pump 90 may be employed to put a positive pressure on the suction side of the variable volume delivery pump 60. This pump 90 is connected to storage tank 76 through the medium of a conduit 91 and to port A of valve 66 through the medium of line 92.

A conduit 93, having an oil filter 94 and a relief valve 95 therein, also is used to connect control valve 66 with the variable volume delivery pump 60. Valve 95 is also connected to a pipe 96 leading to tank 76. Pipe 96 in turn is connected to pipe 92 leading from the centrifugal pump 90 through the medium of pipes 97 and 98 and relief valve 106. A conduit 99 connected to pipes 97 and 98 communicates with line 67 leading to the main cylinder of the control unit 62 through the medium of pipes 100, 101, 102 and check valve 105 and indirectly with line 81 leading from the vane-type pump 75 through the medium of a pipe 103 and a pilot valve 104.

Valve 66 may be a solenoid controlled, pilot-operated, four-way valve, and by properly shifting this valve it is possible to control the operation of the mill after the initial setting of the rolls by the screw down assembly. By shifting the valve in one direction the variable volume delivery pump 60 acts as a pump and forces fluid, such as oil, into the several diaphragm units expanding them and causing the rolls to gradually squeeze shut and to operate as a taper rolling unit. Alternately the shifting of the valve in the other direction will cause the variable volume delivery pump 60 to act as a rotary bleed-out valve for bleeding fluid out of the diaphragm units to contract them and thereby permitting the mill bite to gradually open so as to give that portion of the sheet passing through the mill at the time a gradual uniform longitudinal taper in its thickness.

It will be observed by referring to Figure 4 that as stated before the variable volume delivery pump is attached to the main mill drive by a suitable gear reducer 60'. This means that for each revolution of the main mill motor, the pump will make a predetermined plurality of revolutions. The ratio of revolutions of the pump to the revolutions of the mill motor will depend upon the results desired, for example, the ratio may be six to one. The discharge from this pump may be varied by means of a hand control so that for each revolution of the pump the rate of cubic inches of oil being delivered by the pump will be constant for any given setting. This in turn means that for each revolution of the mill motor or for each unit length of strip passing through the mill, a given cubic inches of fluid is passing into or out of the diaphragm units located beneath the adjusting screws according to the setting of the hand

control valve on the pump which results in a uniform rate of taper per unit length of sheet. This rate of taper thus can be controlled by altering the setting on the variable volume delivery pump.

It will also be observed by referring to Figure 5 that the control unit **62** mounted in a vertical or upright position is generally comprised of an upright main cylinder **63** and two auxiliary cylinders **64** and **64'**, each one of which is connected to a separate diaphragm unit. This arrangement provides for an exact amount of fluid in cubic inches being simultaneously delivered into or bled out of each diaphragm unit. This results in the mill remaining level at all times since each end of the mill roll will be located in substantially the same horizontal plane at all times. The main master cylinder **63** connected to pipe **67** through the medium of an opening **115** has a main piston **116** therein, which is suitably connected to each of the auxiliary pistons **117** and **118**, which reciprocate in cylinders **64** and **64'**, respectively, by means of the connecting bar **120**. Cylinders **64** and **64'** are connected to individual diaphragm units by means of the openings **122** and **123** therein leading to pipes **71** and **70**. The two auxiliary cylinders **64** and **64'** are of identical diameter and the pistons therein have the exact same strokes, so that each one will simultaneously displace the same amount of cubic inches of oil to the individual diaphragm unit associated therewith, the only possibility of error being the leakage of one set of packing versus the leakage from the other set of packing about these auxiliary cylinders. Each of these auxiliary cylinders are polished to a fine finish and are provided along with the main cylinder with a chevron-type of packing **130**, **131** and **132** to minimize leakage in the cylinders. Since the taper desired is usually very gradual the strokes of the main and auxiliary control cylinders are very short.

The taper producing operation may consist of a cycle operation comprised of two steps, the first step being to continuously and gradually decrease the opening between the rolls by expanding the diaphragm units **30** so as to produce a continuous and gradual taper on one unit length of sheet and then to continuously and gradually increase the opening between the rolls by contracting the diaphragm units, thereby opening the rolls and restoring the pressure on the work rolls to the amount initially placed thereon by the screw down assembly. Thus, a continuous, gradual decreasing taper is produced on the first unit length of sheet, while a gradual and continuous increase in taper is produced on the second unit length of sheet.

The operation begins when the sheet is first started through the mill, the initial gauge or thickness of the sheet being regulated by the screw down assembly with the main cylinder of the control unit **62** being bottomed and with zero oil pressure in the diaphragm units **30** and with the variable volume delivery pump connected to the mill motor so as to be driven thereby. Pump **90** is also actuated by suitable means.

When valve **66** has been properly adjusted, port A thereof is connected to port P while port T is connected with port B therein. Fluid is then drawn from the tank **76** through line **91** into the suction side of pump **90**, then out of the discharge port therein through line **92** to port A of valve **66**. The oil passes through valve **66** from port A, out of port P and through line **93**, oil filter **94**, and relief valve **95**, and into the suction side of pump **60**. The oil is then discharged under pressure out of pump **60** through line **65** to port T of valve **66**. The oil passes through valve **66** from port T to port B and out of port B through line **67** to control cylinder **62**, through line **67** and port **115** into master cylinder **63**. This oil displaces the piston **116** in cylinder **63** which is connected as previously described, to cylinders **64** and **64'**. The fluid in cylinders **64** and **64'** is then forced out of these cylinders through lines **70**, **71**, **72**, and **73** to the several diaphragms, each of the latter pipes being suitably connected to a port **56** of an individual diaphragm unit. The fluid passing through these lines will gradually and uniformly expand the diaphragm units, thereby decreasing the opening between the work rolls of the mill.

During this time vane pump **75** is also operated, and runs at a predetermined setting.

This vane pump **75** has three functions. One of these is to circulate oil within the case of the variable delivery pump **60** for the purpose of lubricating the pump and putting an air seal on the pump by pumping fluid from the tank from pipe **75'** and then through lines **80**, **86** and **87** into pump **60** and out of pump **60** through lines **87'** and **88** back to the tank. The second purpose is to maintain the resistance of check valve **108** great enough to put approximately five pounds pressure on line **83**, **84**, and **85** to keep the diaphragms and their supply lines and the auxiliary control cylinders **64** and **64'** full of oil at all times, and yet at a pressure low enough so that the hydraulic roll balance cylinders in the mill are always able to overcome this five pounds pressure in the large diaphragms. The third purpose of this pump is to provide, by means of line **82**, pilot pressure for operating valve **66** through port D so that the solenoid pilot valves on this control valve will have pressure to move the spool of the valve at all times, line **89** leading from port C of this control valve to line **88** being merely a drain line to the tank for preventing a hydraulic lock from occurring on the control valve **66**.

When it is desirable to perform the second step of the rolling cycle, i. e., to continuously and gradually contract the diaphragm units, thereby gradually and continuously increasing the gap between the work rolls so as to restore the original setting placed thereon by the pressure adjusting screw **18** and to produce a taper in another unit length of sheet, which taper runs in a direction opposite to that of the first unit rolled as indicated in Figure 9 of the drawings, all that it is necessary to do is to shift valve **66** in the opposite direction at the desired time. In some instances depending on the degree and length of taper desired in unit lengths of sheet the diaphragm units may be filled with liquid until they are expanded to their fullest limit forcing bearing member **31** against stop **35**, Figure 1. This is accomplished by having valve **66** shifted as described above and expanding the diaphragm units to their limit. Shifting of valve **66** in the opposite direction connects port T to port A and port B to port P, thereby connecting line **67** to line **93**. The fluid will then be bled back into valve **66** through port B and out through port P of valve **66** into line **93**, and then into pump **60**, after which it will pass through pump **60** into line **65** through port T of valve **66** and out through port A into line **92**, and from line **92** through relief valve **106**, lines **98**, **97** and **96**, back to the tank **76**. During this cycle pump **90** has been taking oil from tank **76** and transmitting it from line **91** through pump **90** and into line **92**, and then through relief valve **106**, lines **98**, **97** and **96**, back to tank **76**. When the fluid in line **67** reverses being bled back through the pump **60** and into valve **66**, the master cylinder **63** retracts and gravitates downward allowing oil to flow into cylinders **64** and **64'** from the lines **70**, **71**, **72** and **73**, thereby causing the diaphragms to contract uniformly and gradually so as to gradually increase the opening on the rolls and increase the thickness of the sheet passing through the mill in a continuous and uniform manner.

To prevent the pump **60** from starving for lack of oil when the master cylinder bottoms at the end of each cycle or at the time when the control unit is operated to bleed fluid out of the diaphragm units, a solenoid switch **140** mounted on the side of the control unit **62** is tripped by a lug **141** located on the bar **120** connecting the master piston **116** with auxiliary pistons **117** and **118**. As the bar **120** moves downward the tripping of

switch 140 causes the energization of the pilot valve 104. Energizing pilot valve 104 permits oil to flow from pump 75 through lines 80 and 81 to port P' of valve 104. With pilot valve 104 energized, port P' is connected to port X and port T' would be connected to port Z, which is plugged. Oil flows through lines 80 and 81 to port P' and through pilot valve 104 to line 155 and into the pilot-operated check valve 105. This opens valve 105 permitting oil to flow from line 96 through lines 97, 99, 100 and 101, through valve 105 to line 102 into line 67, and then to port B of valve 66, since when valve 105 is operated port M therein becomes connected to the port N of the valve. From port B it passes to port P, and then into line 93 and through oil filter 94, relief valve 95 into the suction side of pump 60, thus supplying pump 60 with oil after cylinder 63 has been exhausted. This prevents the pump from starving and permits it to circulate oil at no pressure if the mill continues to run after the sheet has passed through. This is a safety feature when operating the mill under the above conditions.

It will be readily observed from the above description that a simple, accurate, efficient and practical apparatus has been devised for rolling sheet metal having a gradual, uniform and constant increase or decrease in thickness. Althouh the diaphragm units have been described as being preferably located between the screw down assembly and the upper backing roll, it is also contemplated that satisfactory results could be obtained if the diaphragm units were located in the bottom of the mill immediately below the bottom back-up roll.

As indicated in Figures 7–10, a portion of a unit length of the sheet 300 rolled in a rolling mill equipped with the above-described diaphragms will have a uniform and gradual longitudinal increase or decrease in thickness or taper depending upon what period in the rolling cycle the sheet passes through the mill.

It will also be observed from the above description that by properly operating and controlling the expansion and contraction of the diaphragm units, various types of sheet material can be rolled; for example, part of the sheet may be of uniform thickness and another portion may be tapered as indicated in Figure 8.

The use of the various auxiliary pumps and valves in conjunction with the main control valve and the variable volume delivery pump helps to control the volume in the various parts of the hydraulic circuit, and to keep the lines filled and serves to maintain the proper predetermined pressure therein at all times.

An advantageous embodiment of the invention has been shown and described, and it is understood that various changes may be made therein without departing from the spirit and scope thereof as defined by the following claims:

I claim:

1. In a rolling mill having a pair of cooperating rolls and a housing for the said rolls, the combination of an adjustable chock block for one of the said rolls mounted in the housing, means for rotating said rolls, an adjusting screw for applying an initial pressure to the chock block and in turn to one of the rolls to obtain a predetermined roll setting, a hydraulically operated expandable diaphragm unit interposed directly between the said adjusting screw and the said chock block in linearly aligned relationship with said screw and said block and means including a master cylinder for selectively expanding and then contracting said diaphragm unit by alternately pumping fluid into and then bleeding fluid out of the said diaphragm unit in a continuous, gradual and uniform manner, whereby additional pressure may be alternately applied to the said chock block and in turn to the said roll by the said diaphragm unit and then this increment in pressure removed in a constant, gradual and uniform manner so that unit lengths of sheet material passing through said rolling mill will have a continuous, gradual tapered thickness from one longitudinal edge thereof to another and pump means connected to and synchronized with said roll rotating means for causing the actuation of said master cylinder and the expansion and contraction of said diaphragm unit.

2. In a rolling mill, the combination of a roll housing, a pair of cooperating rolls mounted in the said housing, a roll neck supporting adjustable chock block mounted in a window in the said housing and adapted to support one of the said rolls, driving means for the said rolls, an adjusting screw for initially applying pressure to said chock block and in turn to the roll carried thereby to obtain an initial roll setting, and means for increasing in a continuous, uniform and gradual manner the initial pressure placed upon said chock block and the roll carried thereby by said adjusting screw, said means including an expandable diaphragm unit mounted directly between said adjusting screw and said chock block in linearly aligned relationship with both said screw and said block, whereby upon expansion of said diaphragm unit in a continuous, gradual and uniform manner additional pressure will be applied to said chock block and in turn to the roll carried thereby in a constant, gradual uniform manner so that a unit length of sheet material passing through the said rolling mill will have a continuous uniform and gradual tapered thickness from one longitudinal edge thereof to the other, and pump means connected to and synchronized with said roll driving means for expanding the said diaphragm unit.

3. In a rolling mill, the combination of a roll housing, a pair of cooperating rolls mounted in the said housing, a roll neck supporting adjustable chock block mounted in a window in said housing and adapted to support one of the said rolls, a motor for operating the said rolls, an adjusting screw for initially applying pressure to said chock block and in turn to the roll carried thereby to obtain an initial roll setting, means for increasing the initial pressure placed upon said chock block and the roll carried thereby by said adjusting screw, said means including an expandable diaphragm unit interposed between said adjusting screw and said chock block, whereby upon expansion of said diaphragm unit in a continuous, uniform and gradual manner additional pressure will be applied to said chock block and the roll carried thereby in a continuous, gradual and uniform manner so that the thickness of a unit length of sheet material passing through said rolling mill will have a continuous, uniform, gradual taper from one longitudinal edge thereof to another, a variable volume delivery pump and a hydraulically operated control cylinder for expanding said diaphragm unit, and means for connecting said pump to the said motor and for synchronizing their movements one with another.

4. In a rolling mill having a pair of cooperating rolls and a housing for said rolls, the combination of vertically adjustable chock blocks for one of the rolls carried by the housing, driving means for the said rolls, adjusting screws for initially applying pressure to the chock blocks to obtain an initial predetermined roll setting, a plurality of horizontally aligned hydraulically operated diaphragm units interposed directly between said adjusting screws and said chock blocks in linearly aligned relationship with both said screws and said blocks and hydraulic means including a master cylinder for selectively pumping fluid simultaneously and in equal amounts into and then bleeding fluid out of said diaphragm units in a continuous, uniform and gradual manner and at a predetermined rate, whereby additional external pressure can be applied to the said chock blocks and in turn to one of the said rolls, and then this additional pressure removed in a constant, uniform and gradual manner and at a predetermined rate so that unit lengths of sheet material passing through said rolling mill will have constant and graduated increases in thickness along their entire lengths, and pump means connected to and synchronized with the said roll driving

means for selectively expanding and contracting the said diaphragm units in unison.

5. In a rolling mill having a pair of cooperating rolls and a housing for said rolls, the combination of vertically adjustable chock blocks for one of the rolls mounted in the said housing, adjusting screws for initially applying pressure to the chock blocks to obtain an initial predetermined roll setting, a plurality of horizontally aligned and hydraulically operated expandable diaphragm units interposed between said adjusting screws and said chock blocks, hydraulic means including a control unit for regulating the expansion and contraction of said diaphragm units, said control unit including a master cylinder and a plurality of auxiliary cylinders connected thereto, each of said auxiliary cylinders in turn being connected to an individual diaphragm unit, a piston reciprocating in said master cylinder, a separate piston reciprocating in each of said auxiliary cylinders and adapted to be simultaneously and uniformly actuated upon actuation of said piston in said master cylinder, so that fluid may be alternately pumped into and then bled out of each of said diaphragm units simultaneously and in a uniform, continuous and gradual manner, whereby the pressure applied to said chock blocks and to said roll by said diaphragm units can be alternately increased and then this increment in pressure decreased in a constant, uniform and gradual manner so that unit lengths of sheet material passing through said rolling mill will have constant and graduated tapered thicknesses along their entire lengths.

6. In a rolling mill having a pair of cooperating rolls and a housing for said rolls, the combination of vertically adjustable chock blocks for one of the rolls mounted in the said housing, adjusting screws for initially applying pressure to the chock blocks to obtain an initial predetermined roll setting, a plurality of cup-shaped members interposed between said adjusting screws and said chock blocks, a separate hydraulically operated expandable diaphragm unit located within each of said cup-shaped members and below one of said adjusting screws, a control unit for regulating the expansion and contraction of said diaphragm units, said control unit including a master cylinder and a plurality of auxiliary cylinders connected thereto, each of said auxiliary cylinders in turn being connected to an individual diaphragm unit, a piston reciprocating in said master cylinder, a separate piston reciprocating in each of said auxiliary cylinders and adapted to be simultaneously and uniformly actuated upon the actuation of said piston in said master cylinder, so that fluid may be alternately pumped into and then bled out of each of said diaphragm units simultaneously and in a uniform, continuous and gradual manner, whereby the pressure applied to said chock blocks and to said roll by the diaphragm units will be alternately increased and then decreased in a constant, uniform and gradual manner so that unit lengths of sheet material passing through said rolling mill will have constant and gradual tapered thicknesses along their entire lengths and means including a variable volume delivery pump for actuating said control unit to expand and contract said diaphragm units.

7. The combination as claimed in claim 6, wherein the means for actuating said control unit include an auxiliary pump adapted to a place a positive pressure upon the suction side of said variable volume delivery pump.

8. In a rolling mill having a pair of cooperating rolls and a housing for said rolls, the combination of vertically adjustable chock blocks for one of the rolls mounted in the said housing, adjusting screws for initially applying pressure to the chock blocks to obtain an initial predetermined roll setting, a plurality of horizontally aligned, hydraulically operated expandable diaphragm units interposed between said adjusting screws and said chock blocks, a control unit for regulating the expansion and contraction of said diaphragm units, said control unit including a master cylinder and a plurality of auxiliary cylinders connected thereto, each of said auxiliary cylinders in turn being connected to an individual diaphragm unit, a piston reciprocating in said master cylinder, a separate piston reciprocating in each of said auxiliary cylinders and adapted to be simultaneously and uniformly actuated by said piston in said master cylinder, so that fluid may be alternately pumped into and then bled out of each of said diaphragm units simultaneously and in a uniform and continuous manner, whereby the pressure applied to said chock blocks and to said roll by said diaphragm units can be alternately increased and then decreased in a constant and uniform manner and unit lengths of sheet material passing through said rolling mill will have a constant and graduated decrease and increase in thickness along their lengths, means including a pump for actuating said piston in said master cylinder to expand and contract said diaphragm units, and means for controlling the flow of fluid to said pump when the piston in the master cylinder has bottomed and the diaphragm units have been contracted.

9. In a rolling mill having a pair of cooperating rolls and a housing for said rolls, the combination of vertically adjustable chock blocks for one of the rolls mounted in the said housing, adjusting screws for initially applying pressure to the chock blocks to obtain an initial predetermined roll setting, a motor for said rolls, a plurality of horizontally aligned and hydraulically operated expandable diaphragm units directly interposed between said adjusting screws and said chock blocks in linearly aligned relationship, hydraulic means including a control unit for regulating the expansion and contraction of said diaphragm units, said control unit including a master cylinder and a plurality of auxiliary cylinders connected thereto, each of said auxiliary cylinders in turn being connected to an individual diaphragm unit, a piston reciprocating in said master cylinder, a separate piston reciprocating in each of said auxiliary cylinders and adapted to be simultaneously and uniformly actuated upon actuation of said piston in said master cylinder so that fluid may be alternately pumped into and then bled out of each of said diaphragm units simultaneously and in a uniform and continuous gradual manner whereby the pressure applied to said chock blocks and to said roll by said diaphragm units can be alternately increased and then this increment pressure decreased in a constant, uniform and gradual manner so that unit lengths of sheet material passing through said rolling mill will have constant and graduated tapered thicknesses along their entire lengths, means including a variable volume delivery pump for actuating said control unit to expand and contract said diaphragm units, and means for connecting said pump to said motor and for synchronizing their movements one with another.

10. In a rolling mill the combination of a roll housing, a pair of cooperating rolls mounted in the said housing, a roll neck supporting adjustable chock block mounted in a window in said housing and adapted to support one of the said rolls, a motor for operating the said rolls, an adjusting screw for initially applying pressure to said chock block and in turn to the roll carried thereby to obtain an initial roll setting, means for increasing the initial pressure placed upon said chock block and the roll carried thereby by said adjusting screw, said means including an expandable diaphragm unit interposed directly between said adjusting screw and said chock block in linearly aligned relationship both with said screw and said chock block whereby upon expansion of said diaphragm unit in a continuous, uniform and gradual manner additional pressure will be applied to said chock block and the roll carried thereby in a continuous, gradual and uniform manner so that the thickness of the unit length of sheet material passing through said rolling mill will have a continuous, uniform gradual taper from one longitudinal edge thereof to another, a variable volume delivery pump and a hydraulically operated control cylinder for expanding said diaphragm unit and means for connecting said

pump to said motor and for synchronizing their movements one with another.

11. In a rolling mill having a pair of cooperating rolls and a housing for the said rolls, the combination of chock block means for adjustably mounting one of the said rolls in said housing, adjustable screw means for applying an initial pressure to said chock block means and in turn to one of the rolls to obtain a predetermined roll setting, motor means for driving said rolls, hydraulically operated means interposed directly between said screw means and said chock block means in linearly aligned relationship with both said screw means and said chock block means and means including a master cylinder and pump means for alternately expanding and contracting said hydraulically operated means, whereby additional pressure can be alternately applied to said chock block means and in turn to said roll and then this increment in pressure removed in a constant, gradual, and uniform manner so

that unit lengths of sheet material passing through said rolling mill will have a continuous gradual tapered thickness from one longitudinal edge thereof to another, and means for connecting said pump means to said motor means and for synchronizing their movements one with another.

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