

Feb. 2, 1971

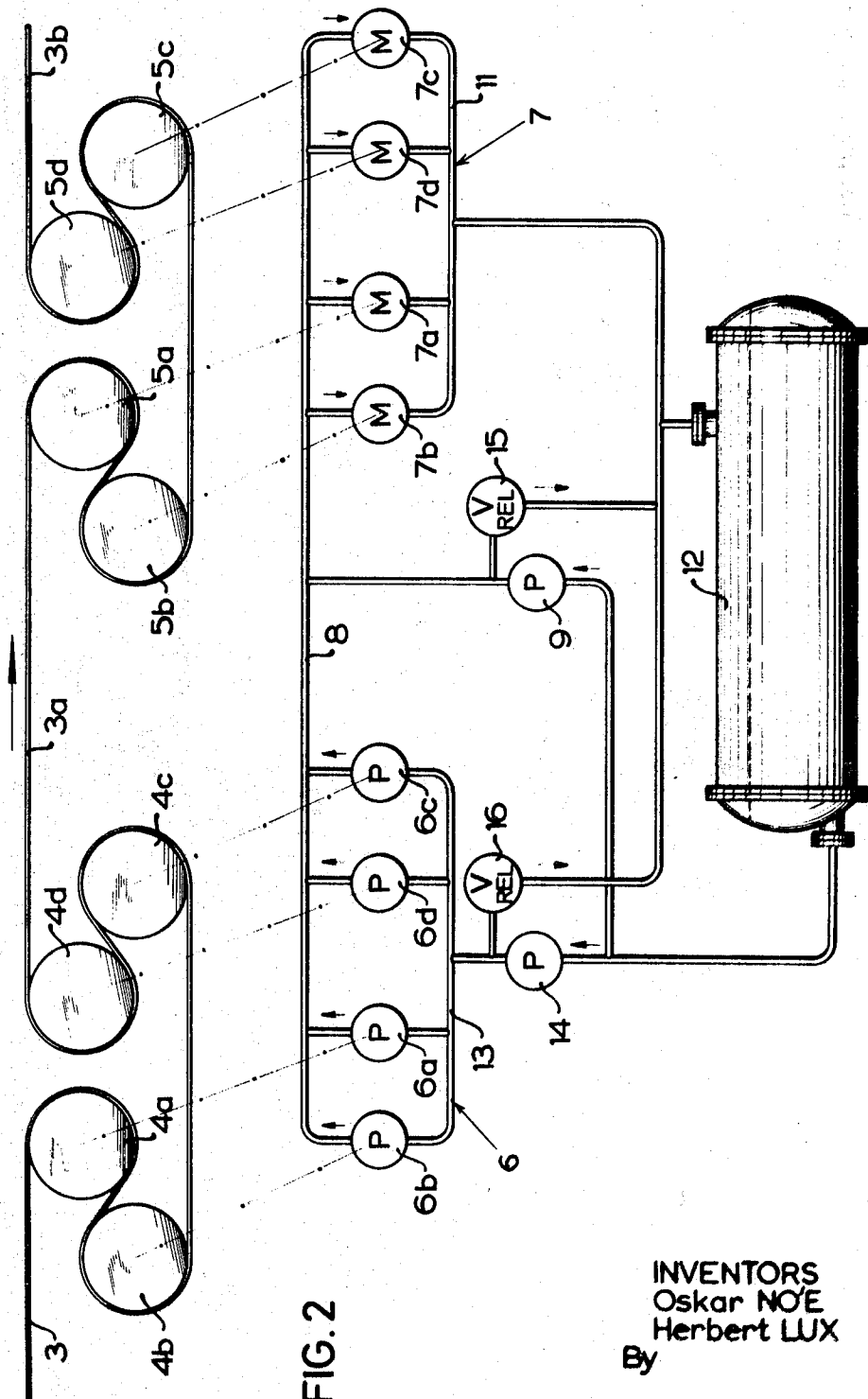
O. NQE ET AL

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APPARATUS FOR STRETCHING CONTINUOUS BANDS

Filed Feb. 17, 1969

3 Sheets-Sheet 2



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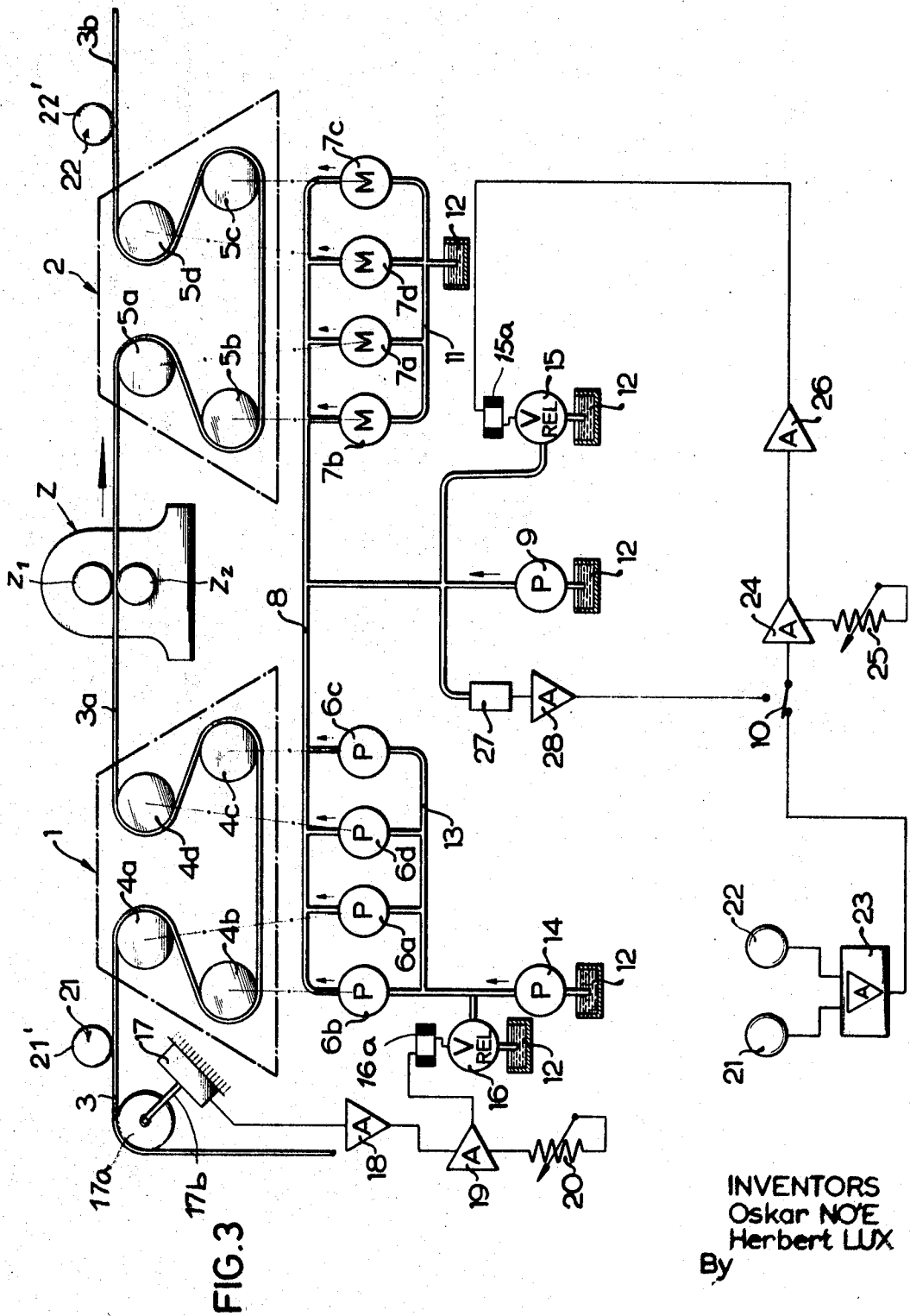
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**APPARATUS FOR STRETCHING
CONTINUOUS BANDS**

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Filed Feb. 17, 1969, Ser. No. 799,635
Claims priority, application Germany, Feb. 15, 1968,
P 16 52 615.1
Int. Cl. B21b 37/06

U.S. Cl. 72—8

12 Claims

ABSTRACT OF THE DISCLOSURE

In a tensioning arrangement for the continuous stretching of metallic bands in which an upstream roller assembly frictionally retards the band as it passes through this roller assembly and a downstream roller assembly passes the band at a higher velocity whereby tension is applied to the band between the assemblies. The upstream roller assembly is connected with at least one torque-controlling hydraulic pump whose high-pressure side is connected to the high-pressure side of a torque-controlling hydraulic motor driving the downstream roller assembly. A pressure-regulating pump supplies hydraulic fluid under pressure in common to the high-pressure sides of pump and motor while a counterpressure pump is provided in the return line from the commonly connected low-pressure sides of torque-controlling pump and motor. When the roller assemblies each include a number of rolls about which the band is passed with as large a contact angle as possible, the rolls of the upstream assembly have hydraulic pumps of progressively increasing torque output whereas the rolls of the downstream assembly traversed in succession by the band have hydraulic motors of correspondingly stepped decreasing torque.

Our present invention relates to a tension system for the continuous stretching of metallic, e.g. steel, bands and, more particularly, to a system in which a continuous band is engaged frictionally by a pair of roller assemblies spaced apart in the direction of travel of the band with tension applied by the rolls of the assemblies and between the assemblies themselves.

It has already been proposed to treat metallic bands or continuous strip as derived from a continuous casting, rolling or other type of band mill under continuous tension to stretch the band at high velocities and in a continuous manner. Such systems have hitherto been provided with at least two spaced-apart tensioning assemblies with rolls about which the band passes (over relatively large arcs) so that the frictional interaction of the roll with the band is capable of applying either a retarding or an advancing force thereto, depending upon whether the roll is driven or barked.

The downstream assembly is so dimensioned with respect to the upstream assembly that the velocity of the band is increased, thereby stretching the band between the assemblies and applying the desired degree of stretching force of tension in the region between the two assemblies.

Each assembly of such prior-art systems may include a frame or support structure in which one or more rolls are journaled, the band passing through these assemblies and being looped about the rolls. In the space between the tensioning roller assemblies, further processing stages can be provided. For example, dressing rolls may be provided to finish the band, heating units can be applied to effect a heat treatment to modify characteristics of the

lattice structure of the metal making up the band or to modify surface or interior characteristics, coating arrangements may be provided for applying various substances to the band surface (e.g. zinc coating troughs for forming galvanized steel strip), or straightening apparatus can be interposed along the path of the band for alternately bending the band from side to side and thereby eliminate kinks, bands or corrugations formed in the band during processing operations.

Stretching assemblies of various types have been provided heretofore. In one such arrangement, hydraulic pistons are provided to apply tension pressure to one of the assemblies relative to the other while both assemblies frictionally engage the band. In another arrangement, the downstream assembly is operated at a higher peripheral speed than the upstream assembly so that the tension applied to the band and the stretch factor factor is a function of the difference in speed. In the latter case, the rolls of the first or upstream assembly are generally coupled with the rolls of the second or downstream assembly by a gear transmission or gear train for precisely related rotation; infact, the two sets of rolls can be considered to be rigidly coupled. A differential mechanism may be provided between the two sets of rolls for operation by a drive motor.

A construction in which a gear train with or without a differential between the sets of rolls has the disadvantage that it fails to take into consideration the stretch generated between the rolls of each tension assembly. This latter stretch, which is a consequence of the frictional engagement of the first and following rolls of each assembly with the band, the torque applied by the rolls to the band, and the yieldability or elongatability of the band, may require a higher peripheral speed of the output roll, as compared with the input roll, of each of the spaced-apart assemblies. The requisite compensation cannot be effected conveniently and under all operating conditions using a gear coupling of the two assemblies.

Still another disadvantage of such systems is that the torque applied by the rolls and the elongation of the band between them is uncontrolled so that one or two rolls of each assembly may be stressed with the major part of the forces while other rolls of the same assembly provide no torque. This nonuniform distribution of the forces may overload the gear coupling, the differential drive, the bearings of the rolls and the drive motor, and may also lead to binding of the tension rolls.

In other systems, friction clutches responsive to torque (i.e. torque couplings) are provided between the tension-roll shafts and the positive gear drive to distribute the torque and stress. Because such clutches are affected by various factors including temperature variations and variations in frictional coefficient, they do not always operate as desired and are thus incapable of completely eliminating the aforementioned disadvantages. Moreover, the couplings require resetting when bands of various widths are processed, thereby rendering the preparation of the apparatus time-consuming or leading to restricted use of the system. Finally, torque-responsive clutches require frequent repair and are comparatively expensive.

Still another prior-art arrangement makes use of a respective electric motor connected to each tension roll and circuits for controlling the motors of each assembly to provide the desired torque at each of the rolls to accommodate the preferred tension forces between each pair of rolls. This arrangement is inefficient from the point of view of energy consumption, requires high capital expenditure and is expensive to operate; in addition, it requires frequent repair and, when the more common type of D.C. motors are used, cannot allow simultaneous control of angular velocity or rotary speed and torque.

Finally, it must be noted that the control and regulation of conventional tensioning assemblies is time-consuming, difficult and relatively expensive. Such control arrangements are generally responsive either to the band tension or band elongation. When band-tension controls are used, the tension stress between the assemblies is monitored with relatively expensive equipment. Elongation-responsive controls of the types hitherto employed are often coupled with the tension assembly via gear arrangements or planetary transmissions and are adversely affected by the lack of combination between rolls of an assembly as described above.

It is, therefore, the principal object of the present invention to provide an improved system for stretching continuous metallic bands whereby the aforementioned disadvantages can be avoided.

A more specific object of our invention is the provision of an installation for the stretching of continuous metallic bands, using spaced-apart tension-roller assemblies frictionally engageable with the bands, and improved low-cost means for coupling these assemblies together whereby the defects of rigid or mechanical-differential coupling can be avoided, stepped torques can be provided between rolls of each assembly, and the characteristics of the coupling of the assemblies can be controlled economically and accurately with a minimum of difficulty.

Yet a further object of the instant invention is the provision of an improved coupling between tension-roller assemblies of the character described, wherein the downstream assembly is rotated with a peripheral speed in excess of that of the upstream assembly, and whereby the disadvantages of gear-coupling and electric coupling of such assemblies are avoided.

Still further, it is an object of our invention to provide an improved monitoring system, responsive to the stretching of the sheet-metal band, for regulating the operation of a pair of spaced-apart tension-roller assemblies.

Another object of this invention is the provision of an accurately controllable, low-cost, improved drive arrangement for tension-roller assemblies of the general character described above.

These objects and others which will become apparent hereinafter, are attained in accordance with the present invention, by the provision of a band-stretching arrangement of the continuous-operation type, which comprises a pair of tension-roller assemblies spaced-apart along the band through which the band is threaded, the assemblies including an upstream assembly operating at a relatively low peripheral speed and a downstream assembly operating at a higher peripheral speed; the control arrangement for the two assemblies includes at least one hydraulic motor coupled with a roll of the downstream assembly and a common high-pressure network connecting the high pressure sides of pump and motor while control is effected via a variable-capacity pressure pump connected to the high-pressure network.

According to a specific feature of this invention, each of the tension-roll assemblies comprises a plurality of tension rolls about which the band is looped as it threads through the assembly over a relatively large arc of each roll, the rolls being journaled in a common support and having parallel axes. Hence each assembly may have an input roll which is under-slung by the band as it enters the assembly, an output roll over-slung by the band as it leaves the assembly and one or more intermediate rolls successively past by the band and about which the band is looped, between the input and output rolls.

We have found that it is possible, in such a system, to step up the torque of the rolls of the upstream or first tension-roll assembly from the input roll to the output roll by a constant factor, e.g. a factor of 2 and to step down the torque from input to output roll of the downstream assembly by the same factor when each of the rolls of each assembly includes a hydraulic machine (i.e. a pump in the case of the rolls of the upstream assembly

and a motor in the case of the rolls of the downstream assembly) when these hydraulic machines have correspondingly dimensioned torques and the machines of each assembly are connected in parallel to the same high-pressure network and low-pressure network.

Since the high-pressure sides of the pumps are connected to the high-pressure network in common with the high-pressure sides of the motors, the low-pressure networks of the pumps and motors, the low-pressure networks of the pumps and motors may be separate.

The aforedescribed hydraulic coupling of the tension rolls of the upstream assembly with each other and with the tension rolls of the downstream assembly has the important advantage that each tension roll is braked or driven in dependence upon the tension force operating thereon between the roll and the band portion looped therearound. At the braking stage, i.e. at the upstream or first tension assembly, the hydraulic pumps are of staggered or stepped output so that the relative torque relationships, discussed above, are maintained while the torques themselves are determined by the fluid-pressure differential across these pumps. The same holds true for the driven side of the system, i.e. the downstream assembly, in which the hydraulic motors are of stepped capacity. Hence, if it is desired to attain a tension of 32 metric tons across the gap between the two assemblies, one can provide a tension at the input roll of the upstream assembly of 2 tons; the frictional strain applied when four tension rolls are used in the initial assembly can be treated in terms of the friction value e^{μ} of 2, whereby the stress applied by the four rolls are stepped from 4 to 8 to 16 and finally to 32 from the input roll to the output roll of the assembly.

Between the input roll and the next intermediate roll about which the band is slung, the tension force is increased to 4 tons, between the second and third rolls the tension force is increased to 8 tons, and between the third and fourth rolls the tension force is increased by 16 tons.

Correspondingly, the band is elongated and each succeeding roll is driven at a correspondingly higher velocity. When using hydraulic motors and pumps, according to the present invention, of stepped torque and capacity, it is possible to accomplish this staged increase in tension force while earlier systems are incapable of similar operation.

Still another important advantage of this system is that between two tension-roller assemblies, the desired tension force can be established and controlled relatively simply by modifying the pressure of the pump connected to the high-pressure network. The pressure in this network, which connects the high-pressure sides of the pumps collectively with the high-pressure sides of the motors, controls on the one hand, the braking action of the upstream assembly and, on the other hand, the rate at which the rolls are driven by the hydraulic motors at the downstream assembly. Consequently, the torque-controlling hydraulic pumps and motors have their retardation and driving torque increased with increasing pressure in the network and decreased when the pressure in the high-pressure network is correspondingly decreased. This pressure relationship also pertains when the band is drawn through both assemblies by a drive system independent of the hydraulic arrangement, when the hydraulic motors serve as the drive arrangement or when a separate hydraulic drive motor is provided.

The common interconnection of all the hydraulic motors and all the hydraulic pumps with the high-pressure network ensures a corresponding equalization of stress between the rolls regardless of the source of motive power for the band and compensatorily adjusts the speeds of the rolls once the output speed is established. The additional hydraulic fluid required for the motors, as a consequence of the higher peripheral speed at the downstream assembly, is delivered by the adjustable pressure pump to the high-pressure network.

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The primary drive for the band can be a coiling system in which the band is rolled into coils and which simultaneously pulls the band through the assemblies. However, when the hydraulic motors of the downstream assembly are used to advance the band, it is found to be desirable to control the pressure differential across the pumps of the upstream assembly by some means other than the pump connected with the high-pressure network.

Accordingly, the high-pressure pump has its output connected with the high-pressure network while its input draws fluid from a reservoir to which the output network of the parallel-connected motors is returned. Between the reservoir and the input or low-pressure network of the torque-controlling pumps, however, we provide a counter-pressure or back-pressure pump for establishing the desired pressure differential across the hydraulic pumps of the upstream rolls.

The high-pressure pump connected to the common high-pressure network of the torque-controlling hydraulic machines of the rolls and the counterpressure pump connected to the low-pressure network of the hydraulic pump machines of the upstream assembly are both of the adjustable-capacity and variable-pressure type. This arrangement allows the motors of the downstream assembly to be operated at full torque and capacity and at the full output of the control pump connected with the high-pressure network while the drag or retardation of the upstream assembly is regulated by the counter-pressure pump.

The band is drawn through the upstream assembly as it is driven by the downstream assembly and thus rotates the rolls of the upstream assembly to drive the hydraulic pumps. The drag and the tension are, consequently, a function of the outputs of these hydraulic pumps and thus the pressure differential as regulated by the counter-pressure pump. The adjustable pumps connected to the common networks eliminate the need for variable-capacity hydraulic pumps or motors at the rolls, although such variable capacity machines may be used when the counter-pressure pump is to be omitted.

According to a further feature of our invention, the control arrangement for the band-stretching system includes a sensing device responsive to the band tension ahead of the input roll of the upstream assembly, means for comparing a signal representing this parameter with a reference signal representing the desired level of tension, and producing an error signal representing the difference or the comparison product, the error signal being used, in turn, to control the pressure at the low-pressure or input network of the pumps or for controlling the counter-pressure pump itself.

This arrangement can be used in conjunction with a system for the completely automatic control of the band-stretching installation.

The input-tension-responsive device may include a strain gauge positioned ahead of the input roll of the upstream assembly and carry a roller about which the band passes. The electrical output of this strain gauge is a function of the band tension at the input roll and is compared, as indicated earlier, with a predetermined reference voltage representing the desired tension level to yield, via a differential amplifier, an error signal controlling the relief valve which leads the output side of the counterpressure pump to the reservoir and thus regulates the pressure drop across the pumps. A variation in the tension of the incoming sheet-metal band, assuming a constant rotary speed and torque of the motors of the downstream assembly, will result in a compensatory adjustment of the brake moment or torque at the upstream assembly to re-establish the original tension force at the incoming band. This device automatically coordinates the band-stretching installation to accommodate variations in the output of the band from error-producing machines. In other words, a variation in the output speed of these band-making or band-processing machines will vary the tension at the input roll to result in a compensatory adjustment

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via the counter-pressure pump as previously mentioned and thus accommodate the stretching installation to the band-making system without complex synchronizing mechanisms.

Furthermore, we also prefer to provide a control means for the high-pressure pump in response to the degree of stretch or the tension of the band between the roller assemblies. A stretch-measuring means may thus be provided to produce an electrical output signal proportional to the degree of elongation for comparison with a reference corresponding to the predetermined desired stretch value or elongation limit.

The stretch-measuring device preferably comprises a pair of band-speed-responsive pulse generators engaging the band ahead of the upstream assembly and behind the downstream assembly to produce pulse trains representing band velocity. The difference between these velocities is related to the degree of stretch of the band and, in accordance with this invention, the pulse trains are fed to a differential pulse counter adapted to produce an output voltage which, when compared with a reference voltage representing the predetermined degree of stretch, yields an error signal adapted to control a valve connecting the output side of the high-pressure pump with the reservoir or the low-pressure network of the motor. This control arrangement maintains a predetermined degree of elongation between the two assemblies.

Should, for example, the degree of elongation change as a result of fluctuations in the band thickness, characteristics of the material constituting the band or the like, the control or monitoring system responds immediately to adjust the rate at which the hydraulic motors drive the band and the degree to which the hydraulic pumps brake its advance.

The control of the stretch may also be accomplished by regulating the pressure at the high-pressure network and to this end an electrical pressure-measuring device is provided to monitor the pressure in this network and compare it with a reference representing the desired pressure level to produce, via differential amplifier, the error signal controlling the valve interconnecting the pressure side of the high-pressure pump with the low-pressure network.

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is a perspective view, partly in diagrammatic form of a band-stretching installation in accordance with the present invention;

FIG. 2 is a diagram showing the hydraulic circuit of the system of FIG. 1; and

FIG. 3 is a diagram of the control system for the stretching installation.

The tension installation of the present invention comprises two spaced apart tension-roller assemblies 1 and 2 through which the sheet-metal band 3 is threaded. Between the assemblies 1 and 2, hereinafter referred to respectively as the first or upstream assembly and the second or downstream assembly, the sheet-metal band is tensioned to a predetermined extent and stretched. Stretching occurs predominantly in the region 3a of the band between the assemblies 1 and 2 while the fully stretched band, represented at 3b, is shown as it leaves the downstream assembly 2. The roller constructions themselves may be of the type described generally in German Pat. 840,985, German Auslegeschrift 1,229,025, U.S. Pats. 2,432,828 and 2,504,292.

In each of the tension-roller assemblies (as illustrated for the upstream assembly 1) the rolls are journaled in bearing blocks 1a (only the rear bearing block being illustrated for each roll) secured to a common support 1b. The latter has a base 1c from which a post 1d rises to terminate in a crossbar 1e overlying the input roll (4a) of the upstream assembly. A corresponding arm 2e overhangs the output roll 5d of the downstream assembly 2.

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From the arms 1e, 2e, deflecting rollers 1f and 2f are provided to hold the band 3 against rolls 4a and 5d, the rollers 1f, 2f being journaled in the ends of piston rods 1g, 2g whose pistons are vertically displaceable in hydraulic cylinders 1h, 2h. Hydraulic fluid can be supplied to these cylinders to regulate the pressure with which the bands are held against the rolls 4a and 5d in the conventional manner.

The first or upstream tension-roller assembly 1 is provided with four tension rolls 4a-4d, the rolls 4a and 4d constituting the input and output rolls, respectively, of this assembly. The rolls 4a-4d are so positioned as to conserve space and provided maximum sling angles or arcs over which the band 3 can be looped about these rolls. A preferred construction disposes the intermediate rolls 4b and 4c with their axes of rotation in a common horizontal plane below the horizontal plate of the axes of the input and output rolls 4a and 4d which are, in effect, cradled between the intermediate rolls. However, the vertical spacing between these horizontal planes is less than the sum of the radii of the rolls 4a and 4b or 4d and 4c so that the band 3 first passes over somewhat more than 180° about the input roll 4a, is then slung about intermediate roll 4b again over more than 180°, passes about intermediate 4c over more than 180° and finally is underslung about the output roll 4d from which it passes to the input roll 5a of the downstream assembly 2.

Similarly, the downstream assembly 2 receives the band 3 which is looped over more than 180° about the input roll 5a and then passes about the intermediate roll 5b, the intermediate roll 5c and the output roll 5d until it leaves the assembly at 3b. The input and output rolls 5a and 5d are cradled between the intermediate rolls 5b and 5c as described in connection with the assembly 1.

The upstream assembly 1 performs a braking function tending to retard the band 3 as it enters the stretching region 3a and thus has a peripheral speed (considered in terms of the peripheral speed of the output roll 4d) which is less than the peripheral speed of the drive assembly 2 (considered in terms with the peripheral velocity of the input roll 5a), the speed differential being made up by the elongation of the band 3 in the region 3a.

In accordance with the principles of the present invention, a hydraulic coupling is provided between the upstream assembly 1 and the downstream assembly 2 in the form of a hydraulic-pump arrangement (generally designated at 6) whose high-pressure side is coupled via the line 8 with the high-pressure side of a hydraulic motor arrangement 7 connected with the roll or rolls of the downstream assembly 2. The hydraulic machines represented at 6 and 7 and pumps and motors which will be described in greater detail hereinbelow.

The torque-controlling hydraulic pumps 6a-6d are coupled with the rolls 4a-4d, respectively, and are mounted on the journal blocks 1a, etc. so as to be driven by the rolls, the latter being rotated by the band as it is drawn through the upstream assembly 1. The motor arrangement 7 comprises torque-controlling hydraulic motors 7a-7d, also mounted on the journal blocks of the respective rolls 5a-5d for driving same.

The hydraulic pumps 6a-6d are of stepped torque and capacity, the stepped relationship being determined by the tensile force to be applied between the respective tension rolls as previously discussed. The tension force is of course related to the friction applied between the roll and the band loop extending therearound and the retarding force or torque developed at each of the hydraulic pumps.

Assume, therefore, a tension force of the incoming band of 2 tons and a frictional resistance value $e^{\mu a}$ at each roll of about 2. Thus between the input roll 4a and the successive intermediate roll 4b, the tension force applied to the band is raised to 4 tons, between rolls 4b and 4c the tension force is raised to 8 tons, between rolls 4c and 4d the tension force is raised to 16 tons and, finally, be-

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tween the rolls 4d and 5a, the tension force is maintained at 32 tons. The tension force at the input side of the system is thus stepped in the ratio of 2:4:8:16.

The braking torque or moment of the pumps is correspondingly (i.e. in the same ratio) stepped. As a result, pump 6a has an output which is smaller than that of pump 6b which, in turn, has an output smaller than that of pump 6c, etc. The pumps 6a-6d are represented with 3, 4, 5 and 6 radial pistons to illustrate this relationship.

While any pumping arrangement in which the pumps may have this stepped output may be used for the hydraulic pumps, we prefer to use radial piston pumps of the type described at pages 105-109 of Fluid Power, U.S. Government Printing Office, Washington, D.C., 1956. In the converse manner, the ratios of the forces applied between the rolls of the downstream or second assembly 2 are 16:8:4:2 and the capacities of motors 7a-7d are correspondingly stepped. The motors 7a-7d of the radial piston type described at pages 197-199 of Fluid Power, op. cit.

The high-pressure sides (i.e. the output sides of pumps 6a-6d and the input sides of the motors 7a-7d) of the hydraulic-pump arrangement 6 and the hydraulic-motor arrangement 7 are connected by a common high-pressure network 8 in parallel. Hence the outputs of all of these pumps and the inputs of all of these motors are tied in common to the high pressure network 8 in which the pressure is regulated by a controllable pump 9 driven by a motor 9a at a rate which may be established by a handwheel 9a' or by a servomotor responsive to an electrical signal and controlling same.

A control valve 15 connects the high pressure output side 9' of the pump with a return line 12' running to a reservoir 12 from which the pump 9 draws hydraulic fluid via inlet line 9". Valve 15 may be an electrically controlled pressure relief valve maintaining a predetermined pressure differential between the high-pressure network 8 and the common output or low-pressure network 11 of the hydraulic motors 7a-7d.

The low pressure network 13 connected to the input sides of the pumps 6a-6d in parallel, is returned via line 14' to the reservoir 12 via a counter pressure pump 14 driven by the electric motor 14a and having a counter pressure regulatable by the handwheel 14a. An electrically operable pressure-relief valve 16 connects the input and output sides of the pump 14 to bypass excessive pressure from network 13 and maintain a predetermined counter pressure in the latter.

From FIG. 3, it will be apparent that the incoming band 3 passes over a band-tension-responsive device represented at 17 prior to its engagement with the input roll 4a. The tension-measuring device 17 comprises a deflecting roller 17a which is mounted upon the rod 17b of a strain gauge which may be of the type shown at page 16-10 of Marks' Mechanical Engineer Handbook, McGraw-Hill Book Co., New York, 1964. The electrical output of the strain gauge is delivered to an amplifier 18 (see pages 177-197 of Servomechanism Practice, McGraw-Hill Book Co., New York, 1960) with the amplified signal being applied to a differential amplifier 19, serving as a comparison circuit (see pages 256 ff. of Pulse, Digital and Switching Waveforms, McGraw-Hill Book Co., New York, 1965).

The other input to the differential amplifier 19 is a variable voltage divider represented as a potentiometer 20 which supplies an adjustable reference signal and establishes the desired input band tension. The error signal resulting from the differential amplifier 19 is applied to the solenoid 16a of the valve 16 which may be of the type described in pages 186 ff. of Fluid Power (op. cit.). The valve 16 is thus controlled in dependence upon deviations of the detected input band tension from the predetermined tension to alter the pressure delivered by the counter pressure pump 14 to the low pressure or input

network 13 of the pumps 6a-6d. In a corresponding manner, the error signal from amplifier 19 may be applied to control the motor 14a driving pump 14 directly, whereupon valve 16 may be a simple pressure relief valve (see pages 157-159 of Fluid Power) (op. cit.).

FIG. 3 indicates also that a processing stage (represented at Z) may be provided between the upstream assembly 1 and the downstream assembly 2. The processing stage is here represented as having a pair of dressing rolls Z₁ and Z₂ between which the intermediate region 3a of the band passes.

The electrical control system further includes an elongation-measuring circuit which, in the embodiment illustrated in FIG. 3, comprises a pair of pulse generators 21 and 22 whose rollers 21' and 22' respectively engage the band 3 ahead of the upstream assembly 1 and behind the downstream assembly 2. The pulse generators may be rate generators (see pages 315-332 of Servomechanism Practice op. cit.) which deliver respective pulse trains, with a pulse frequency proportional to band speed, to a differential counter 23, whose analog output voltage is applied as the input to a differential amplifier 24.

The other input to this amplifier is a reference signal represented at 25 which may be adjusted to set the desired degree of elongation. Amplifier 24 thus constitutes a comparison circuit which accepts an input from differential counter 23 and compares it with the reference (at 25) to produce an error signal upon deviation of the actual elongation from the desired value.

This output or control signal is supplied via an amplifier 26 to the coil 15a of valve 15 to regulate the pressure delivered by pump 9 to the high pressure network 8. Here also the output of amplifier 26 may be applied to the motor 9a to control the pump 9 directly, whereupon the valve 15 may be a simple relief valve of the type described above.

The control system also includes a hydraulic-pressure measuring device 27 responsive to the pressure in the high pressure network 8. The electrical output of the pressure gauge (see page 16-11 of Marks' Mechanical Engineer Handbook, op. cit.) is delivered to an operational amplifier 28 which via a switch 10 may be connected to the differential amplifier 24 to provide the input value which is compared with the reference 25 to indicate any variations in the tension across the stretch 3a of the band and compensatorily adjust the pressure in the high pressure network via valve 25 or the motor 9a of pump 9 as previously described.

In operation, the sheet-metal band is threaded through the tension assemblies 1 and 2 as illustrated in FIGS. 1-3 and is drawn through them while the desired band tension is set via the high pressure pump 9, the counter pressure pump 14 and the reference-signal sources 20 and 25.

The high-pressure pump 9 generates in the high pressure network 8 a corresponding hydraulic pressure which drives 7a-7d to advance the band 3 while acting in the opposite sense upon the pumps 6a-6d to retard passage of the band through the upstream assembly 1. As a consequence, the region 3a between the assemblies 1 and 2 is tensioned and stretched as it continuously moves through the installation.

The fluid pressure in network 8 corresponds to a certain elongation of the stretch 3a of the band as well as a certain tension force which can be empirically determined. Any deviations from the predetermined value are compensated by the networks 27 and 28 as previously described. The elongation of stretch 3a gives rise to a corresponding relationship between the opposing torques of the pumps and the motors connected to the tension rolls and requires energy which is supplied by the pressure pump 9. In the same manner, a tension and stretching of the band is established between the individual rolls of each of the roller assemblies 1 and 2. Here, however, the rolls are driven at various rates in parallel in ac-

cordance with the stepped torques of the pumps and motors with compensation to equalize the strain through the parallel connection of the pumps and motors.

The band entering the upstream assembly passes over the tension-measuring device 17 and produces a pressure in the strain gauge which either corresponds to the reference set at 20 or deviates therefrom when the input tension of the band deviates from its predetermined value. Upon such deviation, the differential amplifier operates the valve 15 to control the pressure in the lower pressure network 13 supplying the torque-controlling pumps 6a-6d, thereby regulating the degree of retardation of the band in the upstream assembly 1.

The motors 7a-7d of the downstream assembly are, as indicated in FIGS. 2 and 3, fed by the reservoir 12 and thus have a higher pressure differential across them. A corresponding higher torque is developed at the rolls 5a-5d and the difference between the tensile stress corresponding to the torques at the assemblies 1 and 2 determines the stretch between them. The band portion 3b may be paid off onto a coiling reel on which the band is wound or onto some other processing apparatus which may be provided with drawing rolls or drive means to pull the band through the assemblies 1 and 2.

The incoming band 3 may be delivered from a coil-holding reel or an earlier processing machine undergoing delivery-speed variations. Such variations give rise to a change to the incoming band tensioning and are detected by the tension measuring device 17 to modify the counter pressure in low pressure network 13, thereby allowing the motors 7a-7d to draw the band at a correspondingly adjusted rate through the upstream assembly 1 and thereby re-establish the predetermined tension of the incoming band. This automatic or self-adjustment will be possible as long as motors 7a-7d are able to apply a greater torque than the retarding torque of pumps 4a-4d.

The band passes from the upstream assembly 1 through the processing stage Z which need not have any independent drive means. As a result, the energy necessary to draw the band between the dressing rolls Z₁ and Z₂ must be supplied at the downstream assembly 2. Any variations in the movement of the band through this processing stage will be detected by the tension measuring device 17 as it effects the tension of the incoming band and permits adjustment of the braking moment of the pumps 6a-6d to compensate for these variations.

To maintain a constant degree of stretching throughout the system, the impulse generators 21 and 22 feed pulse trains of a frequency proportional to the band speed on either side of the stretching installation to the differential counter 23 to produce an output at the latter which represents the velocity increase from the input side to the output side of the installation. The desired velocity increase is compared with the measured velocity increase and the pressure at the high pressure network 8 is adjusted correspondingly.

The system illustrated in FIGS. 1-3 constitutes a preferred control arrangement but it should be noted that modifications may be made within the scope of the basic concept. For example, the band may be driven by means not shown in which case the pumps and motors act as brakes with different degrees of torque. Furthermore, the input line or low pressure network of the pumps may be connected directly to the reservoir in this case since the external motive force may be used to control the stretch and the input tension. A modified arrangement of this type constitutes of the pumps and motors connected with the rolls, a hydraulic coupling between the upstream and downstream assemblies. Moreover, instead of the counter pressure pump 14 either the pumps 6a-6d or the motors 7a-7d may be of the variable-capacity type (see pages 109-112 and 199-200 of Fluid Power, op. cit.).

The improvement described and illustrated is believed to admit of many modifications within the ability of persons skilled in the art, all such modifications being con-

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sidered within the spirit and scope of the invention except as limited by the appended claims.

We claim:

1. A tensioning installation for the continuous stretching of a band, comprising:

a pair of tension-roller assemblies spaced along said band and frictionally engaging same for applying tractive force across said band to stretch same, said assemblies including an upstream and a downstream assembly;

hydraulic-pump means driven by said upstream assembly,

hydraulic-motor means operatively connected with said downstream assembly, said hydraulic-pump means and said hydraulic-motor means each having a high-pressure side and a low-pressure side;

a high-pressure network interconnecting the high-pressure sides of said hydraulic-pump means and said hydraulic-motor means; and

a regulating pump for controlling the effective torques of said hydraulic-pump means and said hydraulic-motor means connected with said high-pressure network for adjusting the pressure therein.

2. The tensioning installation defined in claim 1 wherein:

each of said assemblies comprises a plurality of rolls having said band looped at least partly therearound and including an input roll engaging an incoming portion of the band and an output roll engaging an outgoing portion of the band traversing each assembly; said hydraulic-pump means comprises a respective torque-controlling pump connected with each of the rolls of said upstream assembly;

said hydraulic-motor means includes a respective torque-controlling motor connected with each of the rolls of said downstream assembly;

the torque capacities of the torque-controlling pumps of the rolls of said upstream assembly are stepped up from the input roll to the output roll of said upstream assembly; and

said torque-controlling motors of said downstream assembly torque capacities stepped down from the input roll to the output roll of said downstream assembly.

3. The tensioning installation defined in claim 2 wherein:

said torque-controlling pumps have a common low-pressure network connected with their low-pressure sides and communicating with a reservoir; and said installation further comprises a counterpressure pump between said low-pressure network and said reservoir for regulating the pressure differential across said torque-controlling pumps.

4. The tensioning installation defined in claim 3, further comprising control means responsive to the tension of said band upon its engagement with the input roll of said upstream assembly for regulating the pressure in said low-pressure network.

5. The tensioning installation defined in claim 4 wherein said control means includes:

a tension-measuring device engaging said band ahead of said input roll of said upstream assembly for producing an electrical signal related to the tension of the band;

an adjustable reference source settable to produce a reference electrical signal representing a selected predetermined band tension;

differential amplifier means connected with said device and with said source for producing an output signal representing deviation of the band tension measured by said device from said predetermined band tension; and

means operable by said output signal for controlling the fluid pressure in said low-pressure network.

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6. The tensioning installation defined in claim 3, further comprising control means responsive to the pressure in said high-pressure network for regulating the tension force applied to said band between said assemblies.

7. The tensioning installation defined in claim 6 wherein said control means includes:

a pressure-measuring device communicating with said high-pressure network and producing an electrical signal related to the tractive force applied to said band by said assemblies;

a reference source adjustable to produce an electrical reference signal representing a selected predetermined tractive force;

differential amplifier means connected with said device and with said source for producing an output signal representing deviation of the tractive force detected by said device from said predetermined tractive force; and

means responsive to said output signal for controlling the pressure in said high-pressure network.

8. The tensioning installation defined in claim 3, further comprising control means responsive to the degree of elongation of said band for adjusting the pressure in said high-pressure network.

9. The tensioning installation defined in claim 8 wherein said control means includes:

a band-speed-measuring device engageable with said band ahead of said upstream assembly and behind said downstream assembly for producing an electrical signal related to an increase in velocity of said band upon its passage through said assemblies;

a reference source adjustable to produce an electrical reference signal representing a selected predetermined degree of elongation of said band;

a differential amplifier connected with said device and said source and responsive to said signals for producing the output signal upon deviation of the actual degree of elongation of said band from said predetermined elongation; and

means responsive to said output signal for regulating the pressure in said high-pressure network.

10. The tensioning installation defined in claim 9 wherein said device includes:

a first pulse generator engageable with said band ahead of said upstream assembly for generating a pulse train of a pulse frequency is proportional to the velocity of said band prior to its introduction into said upstream assembly;

a second pulse generator engageable with said band upon its emergence from said downstream assembly for producing a pulse train of a pulse frequency proportional to the velocity of the band emerging from said downstream assembly; and

a differential counter connected with said generators for producing said output signal and imparting thereto an amplitude related to the difference in frequency of said pulse trains.

11. The tensioning installation defined in claim 2 wherein said torque-controlling motors are variable-capacity motors.

12. The tensioning installation defined in claim 2 wherein said torque controlling pumps are variable-capacity pumps.

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U.S. Cl. X.R.

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