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Cummens et al.

[11] **3,728,597**

[45] **Apr. 17, 1973**

[54] **SERVO MOTOR CONTROLLED TRANSFER SYSTEM FOR AUTOMATIC PRESS LINE**

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[73] Assignee: **Danly Machine Corporation,** Chicago, Ill.

[22] Filed: **July 8, 1971**

[21] Appl. No.: **160,799**

[52] **U.S. Cl.** **318/85,** 318/39, 318/578

[51] **Int. Cl.**.....**H02p 5/52**

[58] **Field of Search**.....318/85, 578, 39

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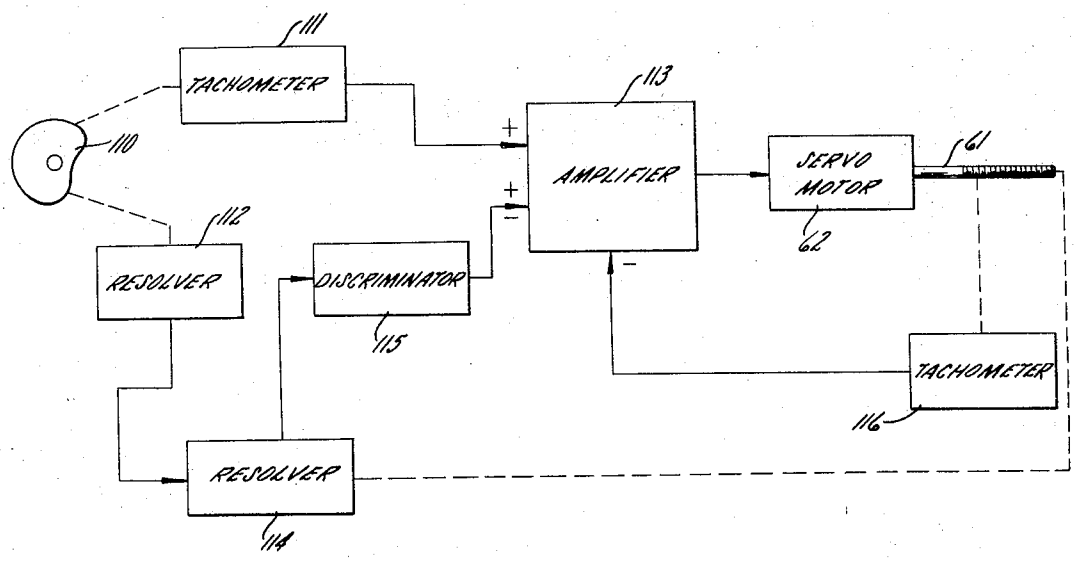
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[57] **ABSTRACT**

A transfer system for an automatic press line which includes a gripper for transferring workpieces between presses. The gripper is supported on the ends of a pair of transfer arms projecting from a corresponding pair of pantographs. The pantographs are manipulated by a pair of ball screw assemblies operated by a corresponding pair of servo motors. The servo motors are electrically connected to the press drive for synchronizing movement of the transfer assembly with the press line. A pair of cams connected to the press drive are associated with a tachometer and a resolver for generating electrical input signals for the control system associated with the servo motors.

5 Claims, 11 Drawing Figures



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SHEET 1 OF 6

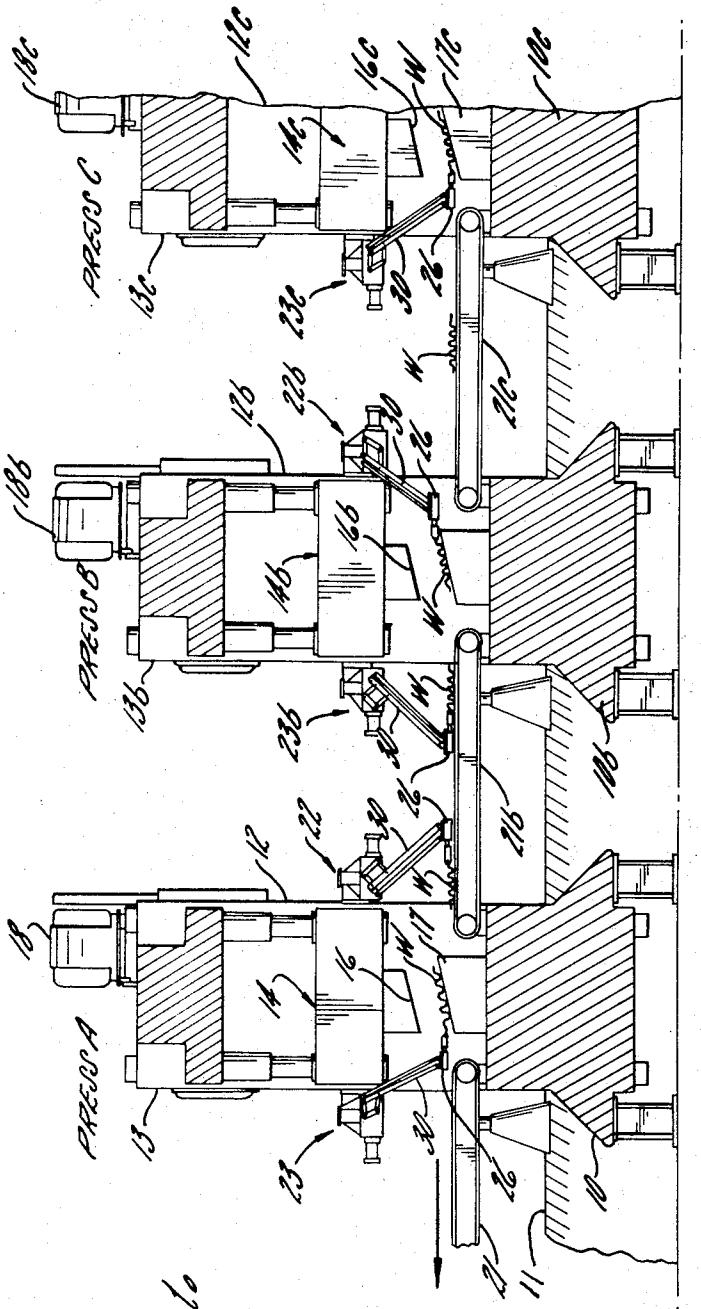


FIG. 1a

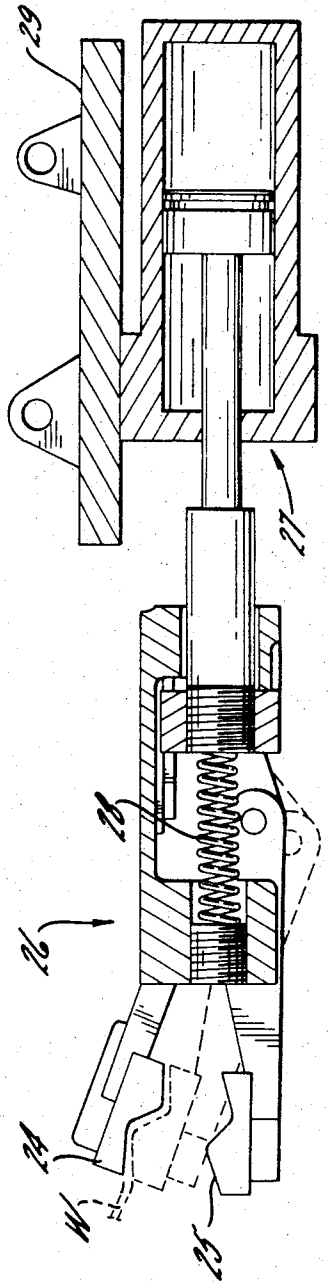


FIG. 2

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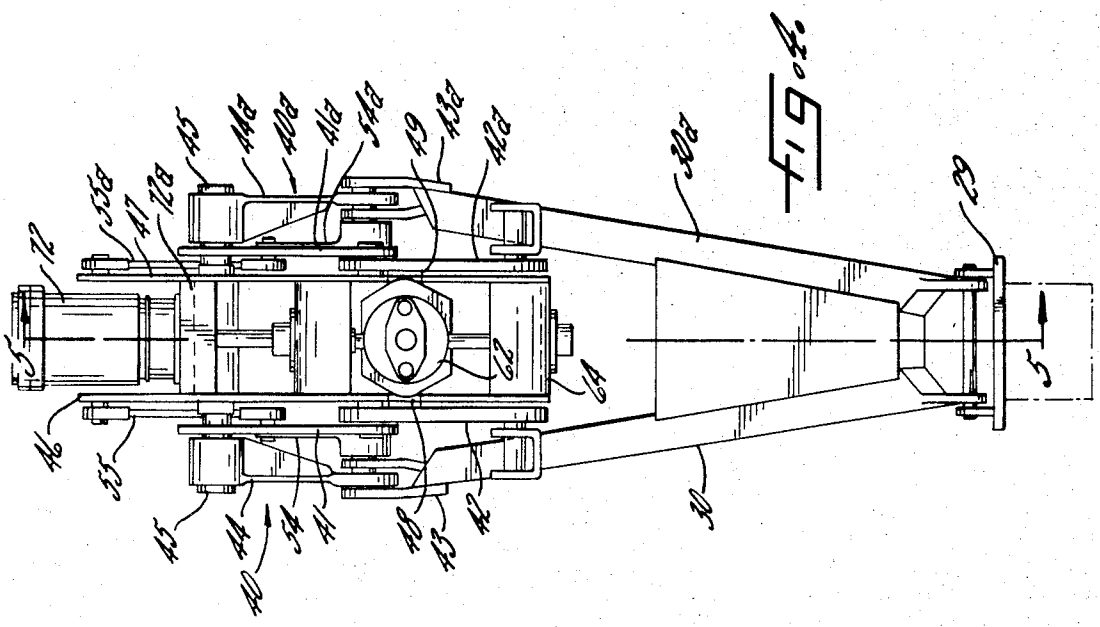


FIG. 4.

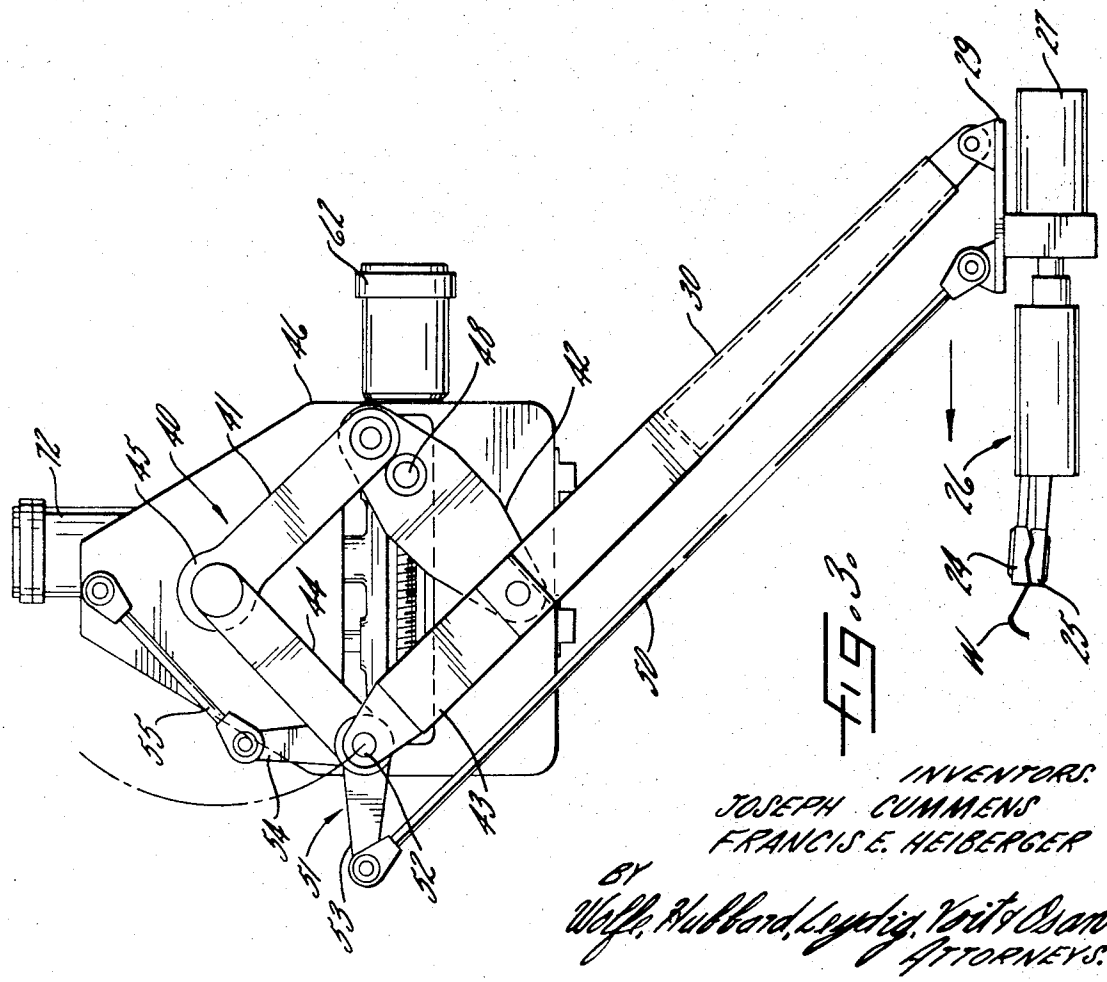


FIG. 3.

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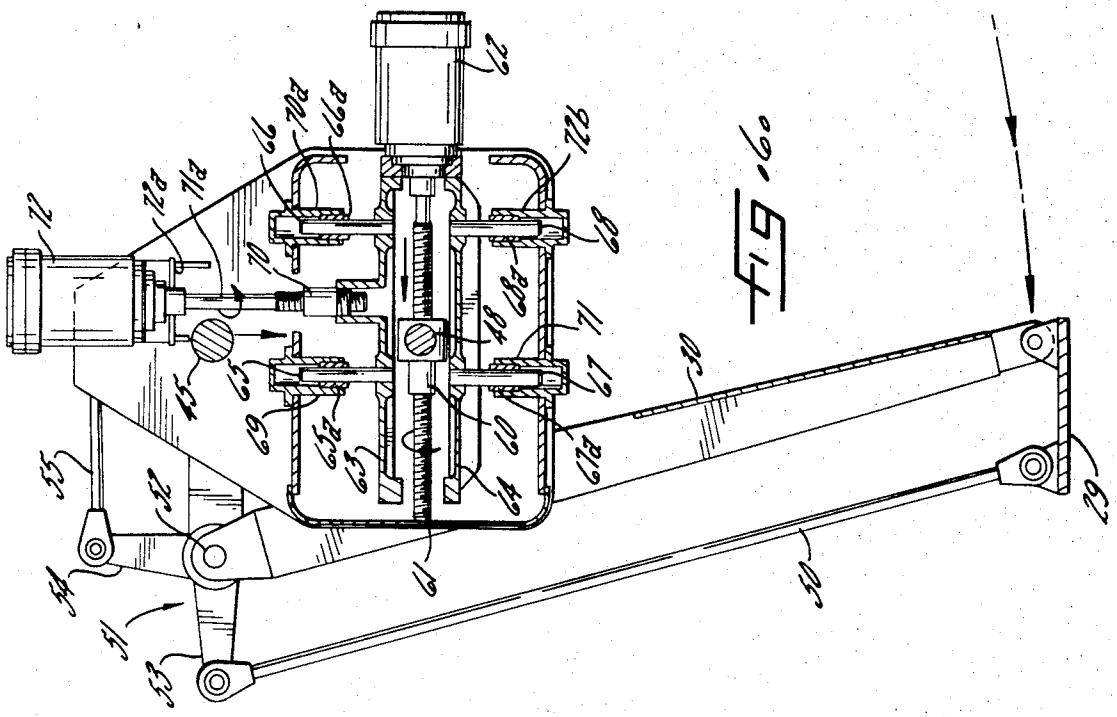


FIG. 6a

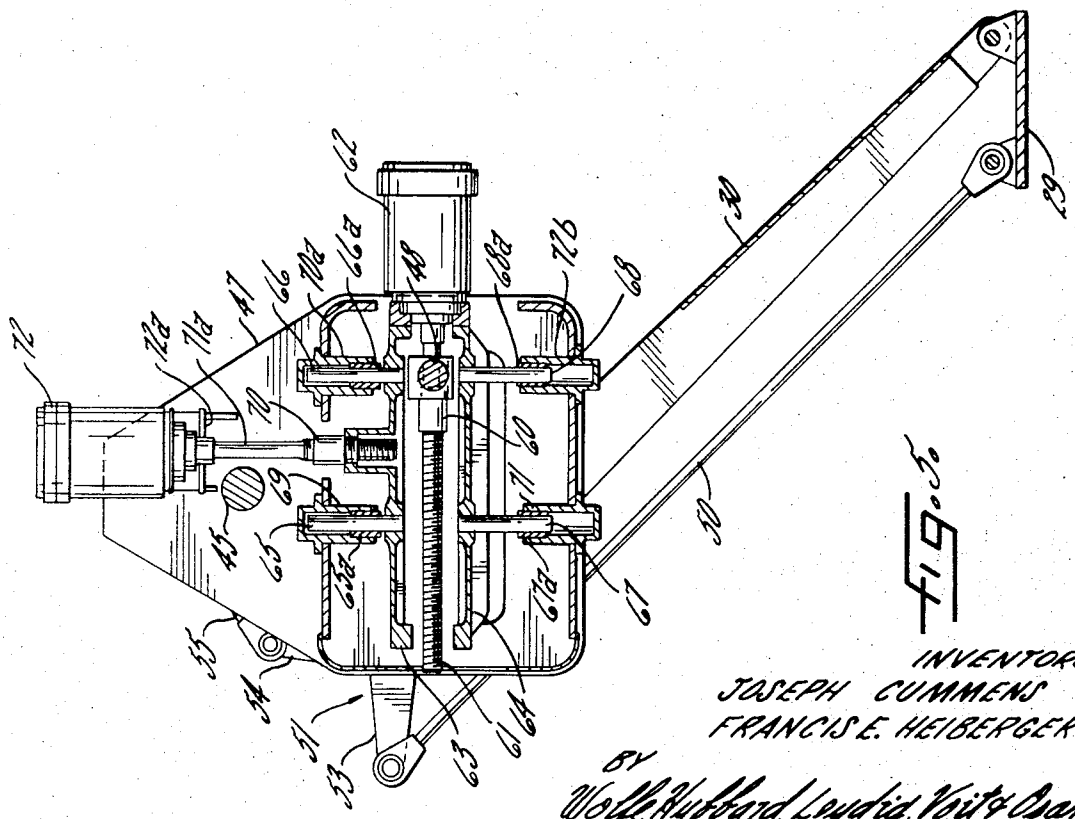


FIG. 6b

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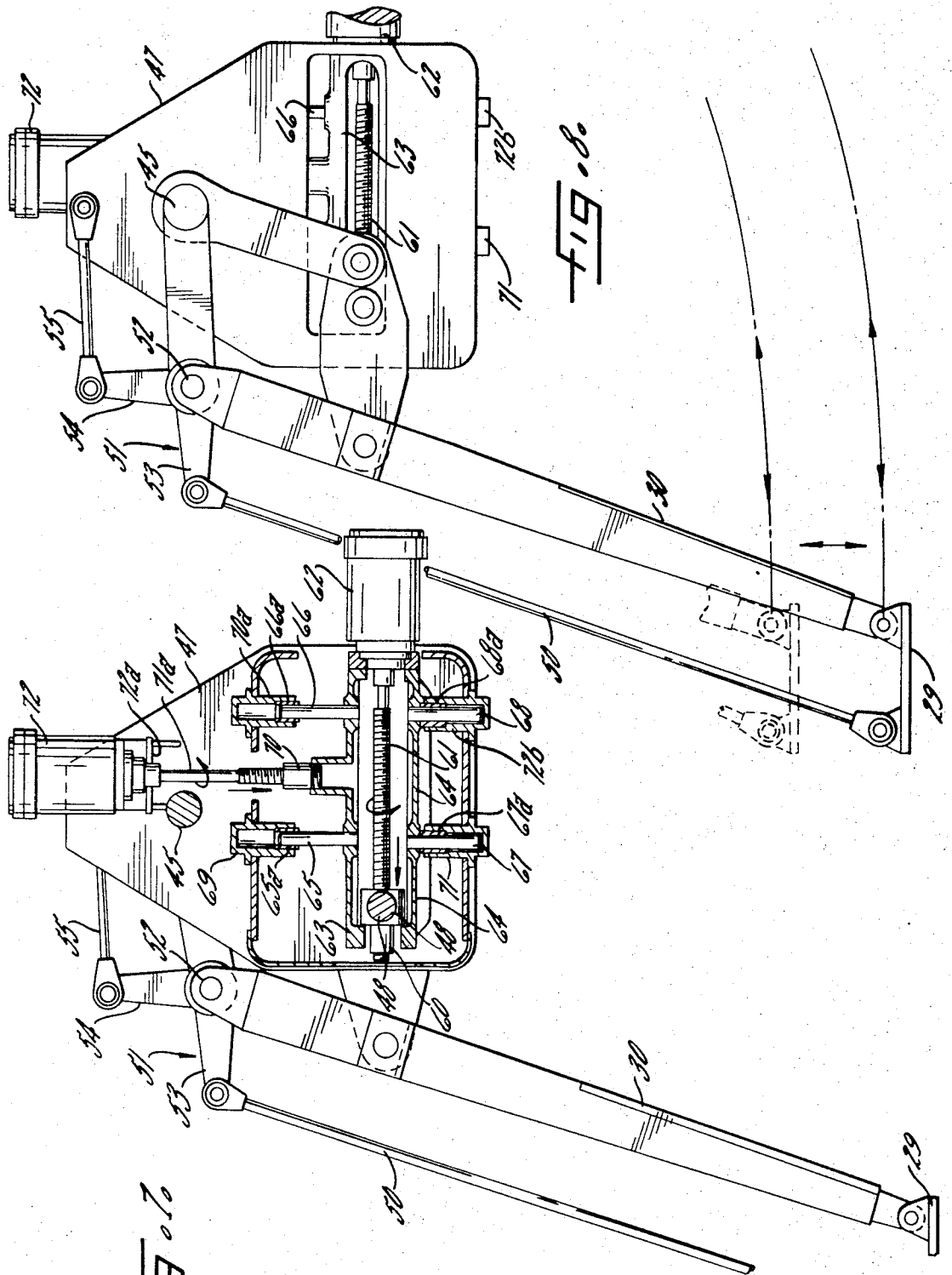


FIG. 1.

FIG. 2.

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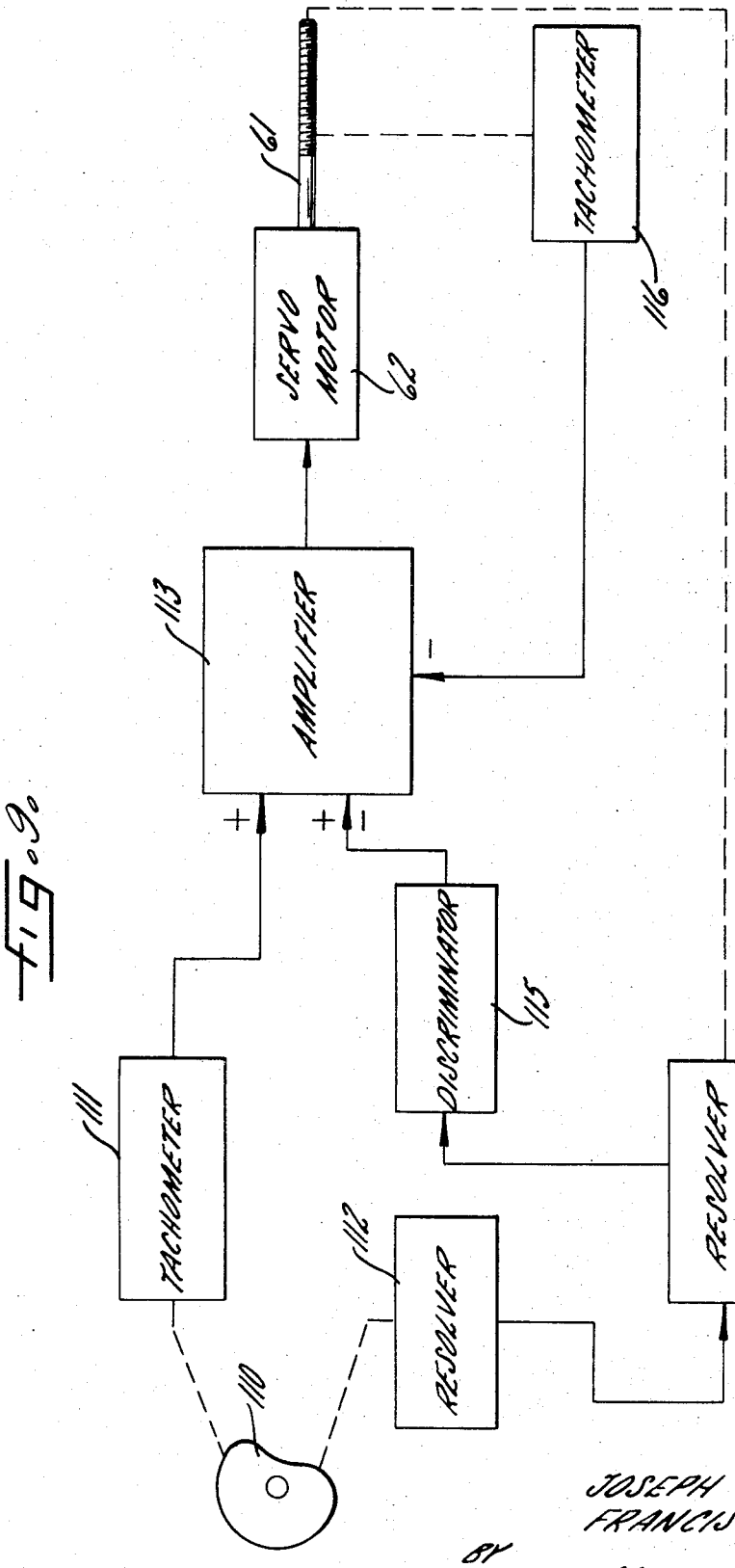


FIG. 9.

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Fig. 10.

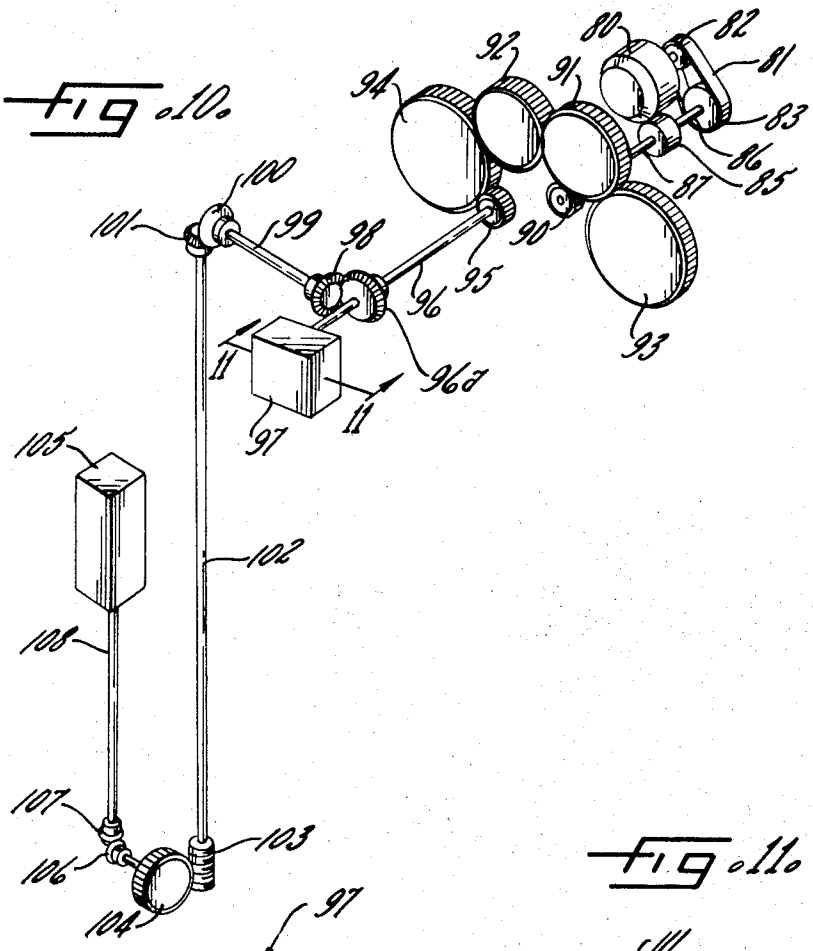
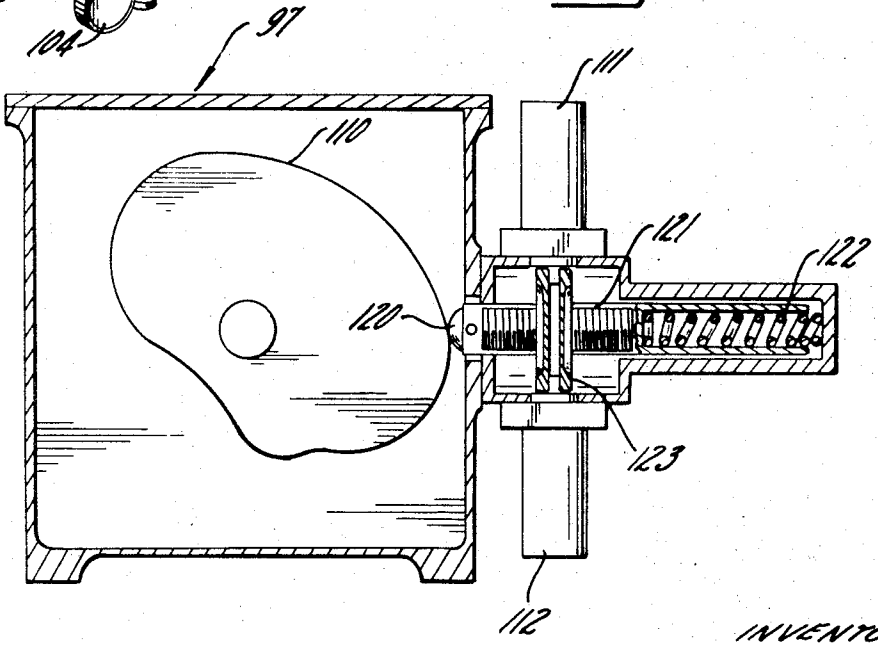


Fig. 11.



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SERVO MOTOR CONTROLLED TRANSFER SYSTEM FOR AUTOMATIC PRESS LINE

DESCRIPTION OF THE INVENTION

The present invention relates generally to transfer mechanisms for power presses and, more particularly, to an improved transfer mechanism for an automatic press line, and an improved control system for synchronizing the operation of the transfer mechanism with operation of the press line.

In U.S. Pat. No. 3,199,439 to James C. Danly, a system is disclosed for synchronizing the operation of a line of independently driven presses, each equipped with a variable speed drive, at any desired operating speed up to a limit imposed by the mechanical capabilities of the presses. The synchronization is achieved by feeding back to each press drive a phase error signal obtained by continuously comparing the press phase position with an externally generated reference phase position. With that arrangement, if any given press tends to get out of step, a phase error signal is supplied to the press drive to increase or decrease the press speed as necessary to maintain the press in step. Thus, any corrective action required is provided when only minor changes in press speed suffice and, therefore, the necessary corrections are readily made despite the high inertias of the presses.

Although the control system described in the aforementioned patent provides excellent synchronization, it is relatively costly in that it requires a complex power take-off from the main press drive.

Accordingly, it is one of the primary objects of the present invention to provide an improved transfer mechanism and control system, for use with a synchronized automatic press line, which simplifies the power take-off from the main press drive system.

It is another object of the invention to provide such an improved transfer mechanism, and associated control system, which has minimum power requirement.

It is a further object of the invention to provide such an improved transfer mechanism and control system which can be efficiently and economically manufactured, installed, and operated.

Yet another object of the invention is to provide such a transfer mechanism and control system which is relatively light in weight, and well balanced.

A still further object of the invention is to provide such an improved transfer mechanism and control system which has good working rigidity and in which the travel of the actuating component is relatively short in comparison with the travel of the working components. In this connection, a related object of the invention is to provide such a mechanism which can provide any desired working stroke.

Still another object of the invention is to provide such an improved transfer mechanism which can be easily and quickly adjusted or modified to transfer different types of work pieces, and to provide accurate positioning of the work pieces.

A further object of the invention is to provide such an improved transfer mechanism which has a compact overall assembly, thereby permitting relatively close spacing of adjacent presses, with attendant reductions in floor space requirements.

Other objects and advantages of the invention will become apparent from the following detailed description taken in conjunction with the attached drawings, in which:

FIG. **1** is a side elevation, partially in section and partially diagrammatic, illustrating a portion of a typical press line embodying the present invention;

FIG. **2** is an enlarged vertical cross section of one of the gripper assemblies utilized in the press line of FIG. **1**;

FIG. **3** is an enlarged side elevation of one of the transfer mechanism assemblies utilized in the press line of FIG. **1**;

FIG. **4** is an enlarged end elevation of the assembly shown in FIG. **3**;

FIG. **5** is a section taken along line **5—5** in FIG. **4**;

FIG. **6** is a section also taken along the line **5—5** in FIG. **4**, but with the transfer mechanism in a different operative position;

FIG. **7** is a section also taken along the line **5—5** in FIG. **4**, but with the transfer mechanism in another different operative position;

FIG. **8** is a side elevation of the same transfer mechanism shown in FIG. **3**, but in a different operating position;

FIG. **9** is a block diagram of an electronic control system associated with one of the servo motors included in the transfer mechanism assembly shown in FIGS. **1** through **8**;

FIG. **10** is a diagrammatic perspective of the driving mechanism for one of the presses shown in FIG. **1**; and

FIG. **11** is an enlarged vertical cross-section taken along line **11—11** looking into the cam box in FIG. **10**.

While the invention will be described in connection with one particular embodiment, it is to be understood that it is not intended to limit the invention to any particular embodiment. To the contrary, the intention is to cover all alternatives, modifications and equivalents falling within the spirit and scope of the invention.

Turning now to the drawings, and referring first to FIG. **1**, there is shown a portion of an automated press line intended for performing successive operations on a workpiece W. For purposes of illustration, only three presses have been shown, indicated as press A, press B, and press C, together with their associated transfer and conveyor mechanisms, but it will be understood that the press line may in practice be extended to include any number of similar units.

As here illustrated, the presses are identical and of generally conventional construction. For example, the press A includes a massive base **10** which is anchored below the floor **11** and a frame **12** topped by a crown **13**. Reciprocatingly mounted in the press frame **12** is a slide **14** with cooperating upper and lower dies **16** and **17**, respectively. To drive the press A, a motor **18** is mounted on the press crown **13** and coupled to the press drive which, in turn, is coupled to the press slide **14**. For clarity, corresponding parts in the three presses have been identified in the drawings by identical reference numerals with the addition of the distinguishing suffix *b* for elements of press B, and suffix *c* for elements of press C.

The coupling between the press motor, press drive, and slide **14** is not shown in detail, since it may be entirely conventional. If the details of this drive system and coupling are of interest, reference may be had to the trade brochures and descriptive bulletins of the

press manufacturers, as well as to Danly U.S. Pat. Nos. 3,199,439 and 3,199,443. For the present purposes it suffices to simply note that the press drive motor and its associated speed controls provide an electrically responsive, variable speed drive for the presses A, B, C, and that the drive for the press A is independent of the similar variable speed drives provided for presses B and C and the other presses in the line.

As illustrated, for transporting the workpieces W down the press line, there are respective conveyors **21** leading up to and away from the input and output sides of each press. Further, each press is equipped with an input transfer mechanism **22** and an output transfer mechanism **23**. In the illustrative transfer mechanism, the workpiece W is gripped between a pair of jaws **24** and **25** (FIG. 2) in a conventional gripper assembly **26**. Since the gripper assembly **26** does not form a part of the present invention, it need not be described in detail herein, and it will suffice to simply note that when the pneumatic actuator **27** for the movable lower jaw is advanced, the jaw **25** is pivoted upwardly to grip the workpiece against the underside of the upper jaw **24**, as illustrated by the broken line drawing of jaw **25** in FIG. 2. When the movement of the pneumatic actuator **27** is reversed, the movable jaw **25** is returned to its open position by means of a biasing spring **28**. The entire gripper assembly is mounted on a gripper mounting plate **29** carried on the lower end of a transfer arm **30** which is an integral part of the transfer mechanism to be described in more detail below.

In accordance with one important aspect of the present invention, the transfer mechanism includes a pantograph comprising four pivotally interconnected links, with the elongated transfer arm extending from one of the links of the pantograph and carrying the gripper assembly on the end thereof. Thus, in the illustrative arrangement, a pair of pantographs **40** and **40*a*** which are mirror images of each other are interconnected to work together in unison. Each pantograph **40** and **40*a*** comprises four pivotally interconnected links **41**, **42**, **43** and **44**, and **41*a***, **42*a***, **43*a***, and **44*a***, respectively. Both pantographs **40** and **40*a*** are mounted on a common main pivot shaft **45** which extends through, and is rigidly connected to, a pair of spaced frame plates **46** and **47**.

For the purpose of actuating the pantographs **40** and **40*a***, the links **42** and **42*a*** thereof are connected to a pair of integrally connected pins **48** and **49** which can be displaced both vertically and horizontally, relative to the main pivot shaft **45**, by means of a biaxial ball screw drive arrangement mounted between the spaced frame plates **46** and **47**. When the pins **48** and **49** are moved either vertically or horizontally, the entire pantograph **40** is pivoted around the fixed pivot shaft **45**, and the individual links of the pantograph are pivoted relative to each other about the four pivot points at the four corners of the pantograph where the links are connected to each other.

One of the advantages of the pantographic linkage between the biaxial drive system and the gripper assembly **26** is that the pantograph amplifies any given displacement of the pins **48** and **49** by the biaxial drive system. Consequently, the actuating portion of the transfer mechanism, i.e., the biaxial drive system connected to the pins **48** and **49** between the frame plates **46** and **47**, is operated at a lower velocity and acceleration than the working portion of the mechanism, i.e., the gripper assembly **26**. For example, if a working stroke of **72** inches is desired for the gripper assembly **26** mounted on the end of the transfer arm **30**, the pantograph **40** may be designed to provide a 4-to-1 amplification, so that an actuating movement of only **18** inches is required at the pins **48** and **49** to provide the maximum working stroke.

A further advantage of the illustrative arrangement is that the two pantographs **40** and **40*a*** are mounted on opposite sides of the spaced frame plates **46** and **47**, thereby providing a relative wide spread between the bearings of the pantograph links, while still providing a relatively compact overall assembly. This spacing of the two pantographs, combined with the relatively wide spread of the interconnections between the various pantograph links, provides desirable stability and rigidity to the overall system, while still maintaining a relatively compact size.

For the purpose of further stabilizing the pantograph assembly **40**, a first stabilizing rod **50** is mounted in parallel with the transfer arms **30**. The lower end of the stabilizing rod **50** is pivotally connected to the gripper mounting plate **29**, while the upper end of the rod is pivotally connected to an L-shaped bracket **51** which is rigidly mounted on a pin **52** interconnecting links **43** and **44** of the pantograph. As can be seen most clearly from the sequential views in FIGS. **5** and **6**, the bracket **51** is always maintained in a fixed vertical-horizontal orientation, regardless of the position of the pantograph assembly, so that the horizontal leg **53** of the bracket effectively maintains the gripper mounting plate **29** in a corresponding horizontal position. That is, the horizontal arm **53** of the bracket and the gripper mounting plate **29** always remain horizontal, with the transfer arm **30** and the stabilizing rod **50** pivoting therebetween as the pantograph assembly is displaced, e.g., from the position illustrated in FIG. **5** to the position illustrated in FIG. **6**.

To further stabilize the pantograph assembly, and to maintain the bracket **51** in the desired orientation, the vertical leg **54** of the bracket is connected to a second stabilizing rod **55**, the upper end of which is pivotally connected to a fixed point on the frame plate **46**, with the lower end of the rod **55** being pivotally connected to the upper end of the vertical leg **54** of the bracket **51**.

It will be appreciated that a similar arrangement of stabilizing rods is associated with the second pantograph **40*a***, which is a complete mirror image of the first pantograph **40**.

Turning next to the biaxial drive system that is mounted between the frame plates **46** and **47**, for the purpose of driving the pins **48** and **49** both horizontally and vertically, the drive system basically comprises a pair of ball screw units operated by a pair of servo motors **62** and **72**. The horizontal ball screw unit comprises a ball screw nut **60** threaded on a horizontal drive screw **61**. The screw **61** is rotated in either direction by means of a reversible horizontal servo motor **62** which is rigidly mounted on the end of a housing having an upper section **63** and a lower section **64**. The housing formed by the sections **63** and **64** is mounted between the frame plates **46** and **47** for verti-

cal movement relative thereto, as will be described in more detail below. When the horizontal servo motor is actuated to turn the screw **61**, the ball screw nut **60** is moved horizontally along the screw **61**, with the direction of movement being determined by the direction of rotation of the drive screw **61** by the reversible servo motor **62**. The pins **48** and **49** which couple the ball screw drive unit to the pantograph assembly are formed as integral parts of the ball screw nut **60**, so that any movement of the nut **60** causes a corresponding movement of the pantographs **40** and **40***a*.

For the purpose of moving the pantograph in the vertical direction, a second ball screw unit includes a ball screw nut **70** fixed to the upper housing section **63** and threaded on a vertical drive screw **71**. Rotation of the vertical drive screw **71** is controlled by means of a reversible vertical servo motor **72** rigidly mounted on the frame plates **46** and **47** via plate **72***a*. As the drive screw **71** is rotated by the motor **72**, the ball screw nut **70** is moved vertically along the screw **71**, thereby effecting vertical displacement of the entire horizontal ball screw unit including the housing sections **63** and **64** and the motor **62**. Of course, the vertical movement of the horizontal ball screw unit also moves the pins **48** and **49** connected to the pantographs **40** and **40***a*, thereby effecting corresponding vertical movement of the pantographs.

To permit vertical movement of the horizontal ball screw unit, the two housing sections **63** and **64** are provided with a plurality of vertical guide rods **65**, **66** and **67**, **68** which are slidably mounted in corresponding bushings **65***a*, **66***a*, **67***a*, **68***a* within a plurality of corresponding guide cylinders **69**, **70** and **71**, **72**. The guide cylinders **69–72** are rigidly mounted in a housing assembly including a pair of plates **73** and **74** connected between the frame plates **46** and **47**, substantially enclosing the horizontal ball screw unit.

As can be seen in FIG. **3**, windows are formed in opposite sides of the housing formed by sections **63** and **64** to permit horizontal movement of the coupling pins **48** and **49**, and a similar window, larger in the vertical dimension, is formed in the frame plates **46** and **47** to permit vertical movement of the coupling pins **48** and **49**. Whenever the vertical servo motor **72** is operated, the entire horizontal ball screw unit, including the housing sections **63** and **64**, is displaced vertically, with the guide rods **65–68** sliding up and down within the bushings **65**a-**68**a in the guide cylinders **69–72**. The electrical system for controlling and driving the servo motors **62** and **72** is synchronized with the main press drive system, a portion of which is illustrated in FIG. **9**. Knowledge of only the main elements of a power press will permit full understanding of the present invention, and for the details of a commercial or practical press, cross-reference may be made to the trade literature and descriptive brochures of press manufacturers. Referring to FIG. **10**, the press driving motor **80** is shown feeding a step down drive connection including a belt **81** and pulleys **82**, **83**. Pulley **83** is connected to a clutch **85** having an input shaft **86** and an output shaft **87**. The clutch output shaft **87** is coupled to an output pinion **90** which drives a pair of intermediate gears **91**, **92** which mesh with the main press drive gears **93**, **94** respectively. In a conventional press, such gears are connected to the press pitman, and the movement and phasing of the slide are under the joint control of timing cams and operating pushbuttons which, through appropriate and interlocked circuitry, control the energization of the clutch **85**.

One of the main press drive gears, in this case the gear **94**, is meshed with a power take-off pinion **95** secured to a horizontally extending power take-off shaft **96**. For driving the first transfer mechanism, the power shaft is coupled to a servo cam box **97** to be described in more detail below. The shaft **96** also drives a bevel gear **96***a*, which meshes with a bevel gear **98** having a horizontal shaft **99** which is coupled, via a pair of bevel gears **100**, **101**, to a rotary cam limit switch drive shaft **102**. At is lower end the latter carries a worm gear **103** meshing with a worm wheel **104** which drives a timing cam assembly **105**. The assembly **105** may correspond to timing cams used for interlock purposes in a regular power press, and is driven via bevel gears **106**, **107** which rotate a vertical shaft **108**.

Returning now to the servo cam box **97**, one of the cams in this box, illustrated as cam **110** in FIG. **9**, drives a tachometer **111** (e.g., a model No. SU–780D–1 "Servo-Tek" tachometer) and a resolver **112**, for the purpose of generating electrical input signals for controlling the servo motor **62**. More particularly, the tachometer **111** responds to rotation of the cam **110** to generate a d-c. signal representing both the magnitude and direction of the velocity desired at the output of the servo motor **62**. This d-c. signal from the tachometer **111** is supplied to an amplifier **113** which drives the servo motor **62**, with the magnitude of the d-c. signal being proportional to the magnitude of the velocity of the servo motor **62**, and the polarity of the d-c. signal determining the direction of the velocity. More specifically, the slope of the cam **110** controls the magnitude and polarity of the d-c. output from the tachometer **111** which causes the amplifier **113** to drive the servo motor **62**.

In order to provide a position feedback loop to compensate for system errors, such as might be caused by drift of the amplifier **113** for example, the resolver **112** is connected to a second resolver **114** driven by the servo motor output screw **61**. (It will be understood that both resolvers **112** and **114** are electromechanical transducers which develop output voltages proportional to the input voltages and sine of the angles of displacement of the input shaft.) As long as the mechanical output displacement sensed by the resolver **114** corresponds to the mechanical displacement of the cam **110**, the two resolvers **112** and **114** are balanced and, consequently, there is no output signal from the resolver **114**. However, whenever a differential exists between the two mechanical inputs to the resolvers **112** and **114**, the resolver **114** generates an a-c. output signal which is supplied to a discriminator **115**. The discriminator **115** converts the a-c. signal to a d-c. signal, which is supplied to the amplifier **113** to compensate for any system errors.

For the purpose of preventing the servo-motor **62** from overshooting the commanded displacement, which in turn would result in hunting of the system, the servo motor output screw **61** is mechanically coupled to a tachometer **116** which produces a feedback signal to the servo motor **62**.

In FIG. 11, one illustrative arrangement for providing a mechanical connection between the cam 110 in the servo cam box 97 and the tachometer 111 and the resolver 112 is shown in more detail. In this arrangement, the cam 110 cooperates with a cam follower on the end of a rack 121 which is biased against the cam surface by means of a spring 122. As the rack 121 is moved linearly in response to rotation of the cam 110, the rack turns a pinion 123 which is connected at opposite ends to the mechanical input shafts of the tachometer 111 and the resolver 112, respectively. As described previously, rotation of the input shafts to the tachometer and resolver results in electrical output signals representing both the magnitude and direction of movement of the cam 110.

It will be understood that the control system of FIG. 9 controls only the servo motor 62, and that a similar control system, driven by a second cam in the servo cam box 97, controls the vertical servo motor 72. It will also be understood that the entire control system, including both the pantograph and the servo motors associated therewith, have been described with reference to the control of only one transfer assembly, since the control systems for the other transfer assemblies are identical, and thus the description of the one exemplary control system is equally applicable to the control system as applied to any of the other assemblies.

Since the cam unit 97 controls the cyclic movement of the servo motors 62 and 72, and thus the transfer assembly, it will be appreciated that the transfer assembly may be programmed to follow different cyclic paths simply by substituting different cams in the unit 97. This is a relatively low cost substitution, in comparison with the overall system, and thus it does not impose any great economic burden on the user to have different cams for each different part that is to be operated on by the press line. Moreover, substituting one set of cams for another is a relatively quick and easy operation.

We claim as our invention:

1. A transfer system for an automatic press line comprising the combination of a transfer arm having gripper means mounted on one end thereof for gripping the workpieces to be transferred, said transfer arm being mounted on a pantograph comprising four pivotally interconnected links for both vertical and horizontal movement, a pair of servo motors operatively connnected to said pantograph for effecting both vertical and horizontal movement of said pantograph, said pantograph and said transfer arm being dimensioned to amplify any movement of said pantograph effected by said servo motors, and a servo control system for each of said servo motors including program means connected to the automatic press line for generating electrical control signals according to a predetermined program in synchronization with said press line, said control signals including both a velocity signal and a displacement signal, means for driving said servo motor in response to said control signals, velocity feedback means responsive to the velocity of the mechanical output of said servo motor for generating a velocity feedback signal, displacement feedback means responsive to the displacement of the mechanical output of said servo motor for generating a displacement feedback signal, and means for combining said feedback signals with said control signals to modify the effect of said signals on said driving means.

2. A transfer system as set forth in claim 1 wherein said servo motors are located at said transfer arm and said program means is located at the drive means for the press line with said servo motors and said program means being electrically connected.

3. A transfer system as set forth in claim 1 wherein said program means includes a pair of cams connected to said press drive means means, one of said cams varying the electrical signals controlling operation of one of said servo motors, and the other cam varying the electrical signals controlling operation of the other servo motor.

4. A transfer system as set forth in claim 3 which includes a pair of racks driven by said cams and a pair of pinions driven by said racks, and a pair of tachometers operatively connected to said pinions for generating electrical control signals in response to rotation of said pinions.

5. A transfer system as set forth in claim 1 which includes a pair of ball screw drive units both connected to said pantograph at a common connecting point, said ball screw drive units being driven by said servo motors for pivoting said pantograph in response to operation of said servo motors.

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