DESCRIPTION • OPERATION • MAINTENANCE

INSTRUCTIONS

MECHANICAL DIFFERENTIAL SPEED ERROR DETECTING UNIT

DESCRIPTION

General. The MECHANICAL DIFFERENTIAL SPEED ERROR DETECTING UNIT (Figure 1) is an electro-mechanical device for speed matching two rotating elements. These elements are usually rotating shafts of electrical machines.

The mechanical differential speed error detecting unit is used with an external amplifier to directly control the fields of either generators or motors. The unit will detect any error in the speed matching of two rotating elements.

Each unit has the following components:

1. Rigid mounting base with slide rails.
2. Basic mechanical differential error detecting unit.
3. Provision for remote draw control.
4. Provision for slack take-up feature.
5. Pilot generator.
6. Position inductor.
7. The necessary gearing and mounting supports.
8. Drip proof cover to completely enclose the components.
9. Synchronous reference motor.

Draw Range. The amount of speed variation possible by using the remote draw control is ±12 percent maximum by means of the belt shifting mechanism excluding any circuit limitations.

Gears. All gears have been induction hardened to provide minimum wear. Machining has been held to close tolerances to minimize backlash, thus reducing wear and increasing the accuracy of the unit.

Bearings. All bearings are prelubricated sealed ball bearings to provide extreme reliability and long life.

BASIC MECHANICAL DIFFERENTIAL ERROR DETECTING UNIT

The mechanical differential error detecting unit (Figure 2) consists of a drive cone, a differential or driven cone, and a belt coupling between the two cones. A bedplate and a combination housing and bearing provides a support for the components of the unit.

The drive cone shaft is supported at the housing and has attached to it a 15-inch pitch diameter, single groove sheave for belting to the rotating shaft of the controlled machine.

The differential cone contains the planetary gear system which furnishes rotation of the differential output shaft. The differential cone is supported at the housing and obtains its rotation from the drive cone through the belt coupling.

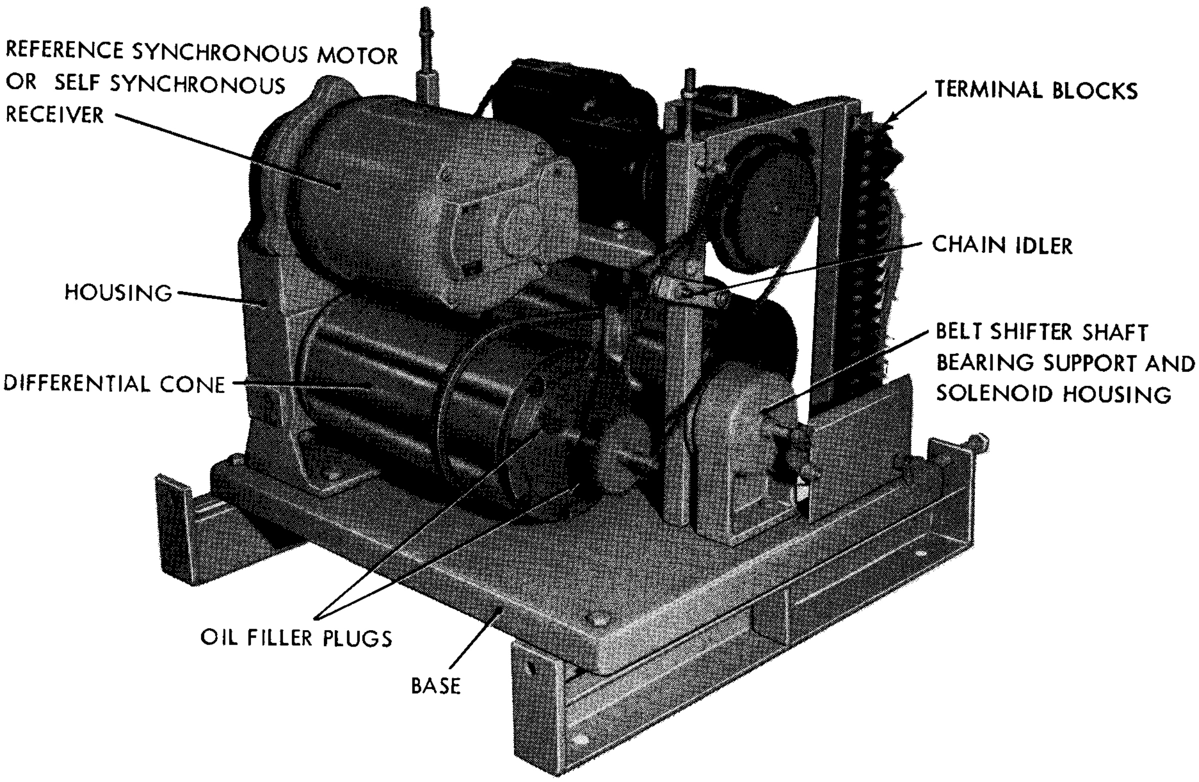
The reference speed is introduced into the unit through the shaft attached to the 56-tooth gear. This 56-tooth gear drives a 72-tooth idler gear which in turn drives a second 56-tooth gear attached to the sun gear shaft. At the opposite end of the differential cone, the 26-tooth sun gear is attached to the sun gear shaft. A 78-tooth ring gear is fitted to the inside of the differential cone in line with the sun gear. A 26-tooth planetary gear revolves on its shaft between the sun gear and the ring gear and is meshed to both of these gears. The planetary gear drives the output shaft through a mechanical crank as shown in Figure 2. A 40-tooth chain sprocket is attached to the output shaft and drives a gear train connected to the position inductor and pilot generator Figure 4.

For the output shaft to remain motionless, the sun gear must rotate exactly three times as fast as, and in the opposite direction to, the ring gear.

Any deviation in the above ratios of speed will cause motion of the output shaft and this motion will persist until the exact relationship is re-established through corrective action of the regulating system.

The relationship of these three gears is such that if the sun gear reference shafts were held motionless, four revolutions of the ring gear would produce three revolutions of the differential output shaft. Conversely, if the cone is held motionless, four revolutions of the sun gear are required to produce one revolution of the output shaft.

The drive cone and the differential cone are identical in external size and shape, but are mounted to the housing with their tapers facing in opposite directions.



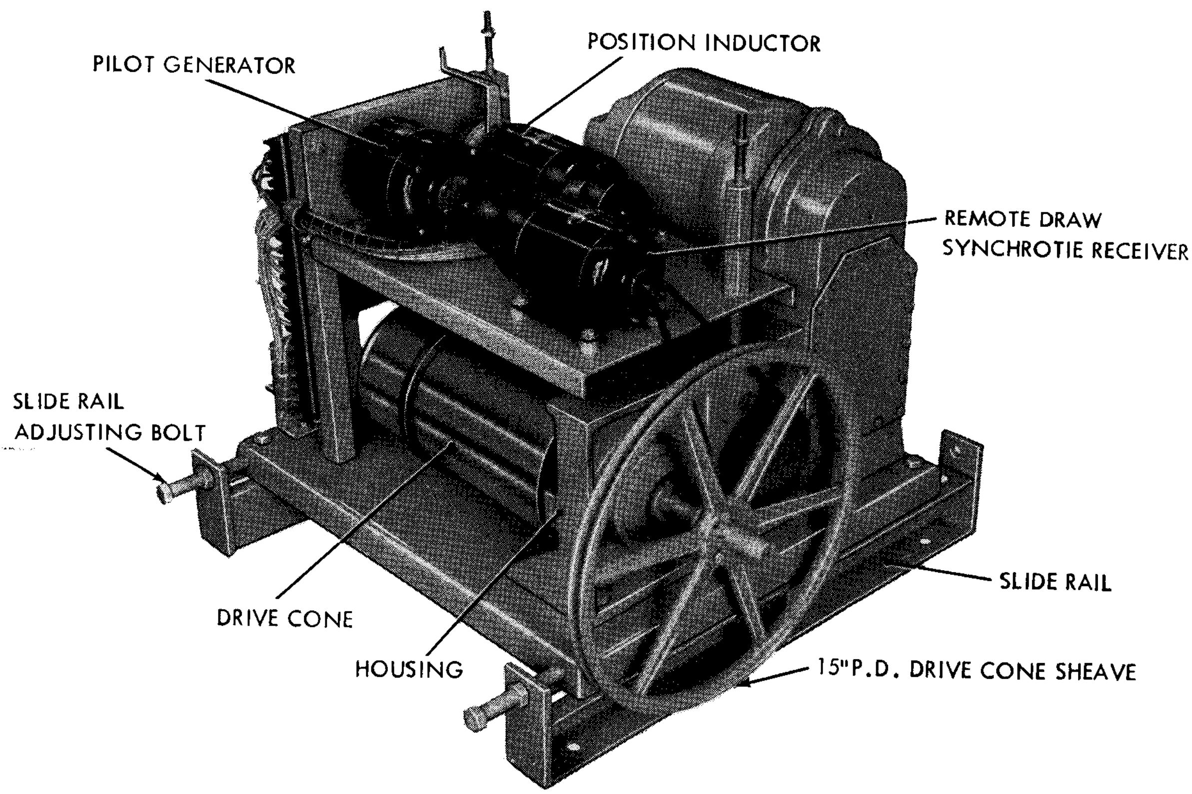


FIG. 1. Mechanical Differential Speed Error Detecting Unit

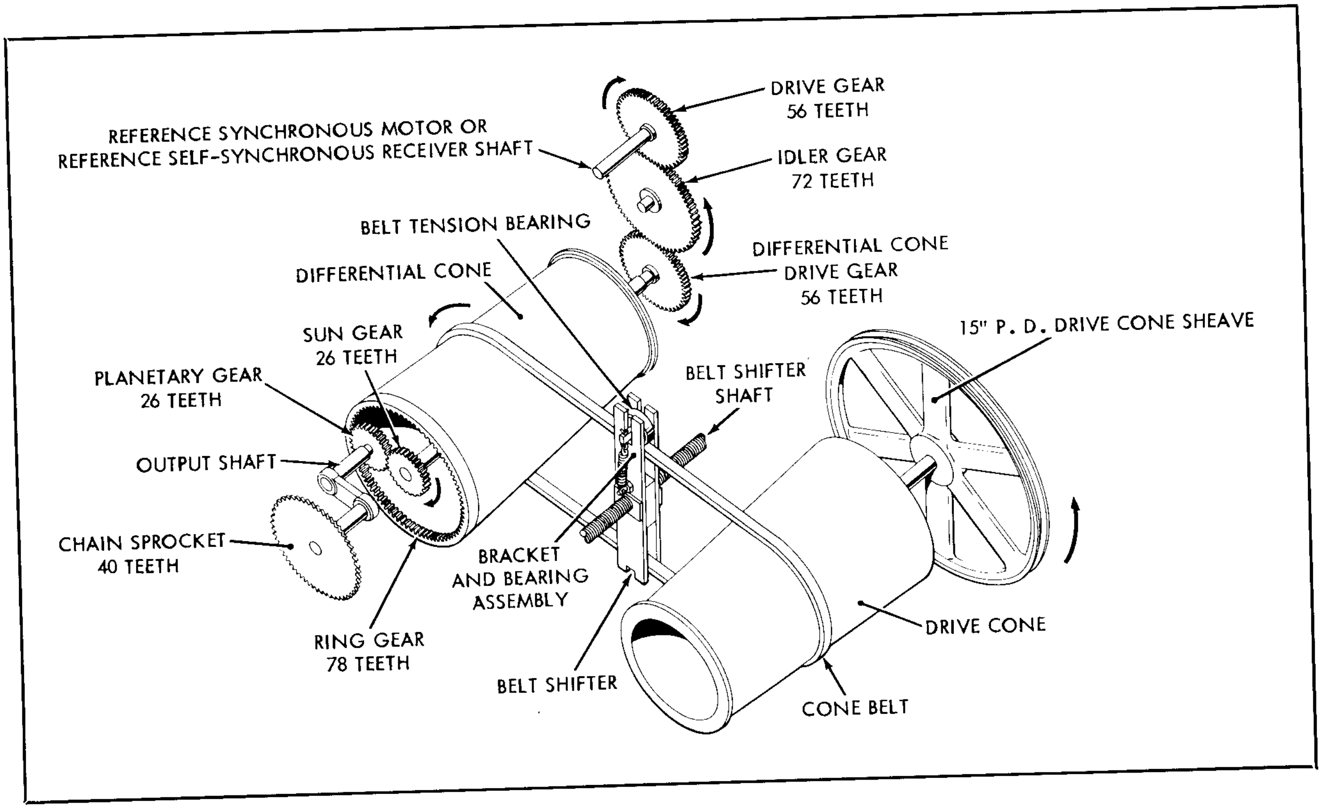


FIG. 2. Basic Mechanical Differential Error Detecting Unit

The ratio at the exact center is one-to-one. Moving the belt to the extreme end towards the housing forces the differential cone to turn faster by the ratio of the drive cone diameter to the differential cone diameter. This is the ratio of $\frac{7.125 \text{ (large end diam.)}}{6.125 \text{ (small end diam.)}}$

Moving the belt to the other extreme end forces the differential cone to turn slower by the ratio of $\frac{6.125}{7.125}$. The overall draw range possible is $\pm 12\frac{1}{2}\%$.

REMOTE DRAW CONTROL

The shifting of the belt along the taper of the cones is performed by the remote draw control as shown in Figure 3. This control consists of a belt shifter, a slack take-up feature, a remote draw Synchrotie receiver mounted to the housing, a remote draw Synchrotie transmitter remotely located in a control cabinet, and a slack take-up pushbutton mounted near the transmitter handle.

The draw adjuster mechanism consists of a belt guide mounted on a threaded shaft. This shaft has 16 threads per inch of length. One revolution of the shaft will provide a resultant change of 0.15 percent in relative speeds of the cones. The shaft is supported at one end by the housing and at the other end by a removable bearing support which also contains a solenoid. A small crank handle is secured to the end of the shaft for manual operation of the belt shifter during installation or adjustment procedures.

The shaft has freedom of movement in the horizontal direction through its bearings. Attached to the shaft ¼-inch from the removable bearing support is the slack take-up armature (circular disc). The distance between the disc and the bearing support is maintained by a compression spring. An electromagnet is contained within the bearing support.

The belt shifter consists of two parallel arms secured together at the bracket and bearing assembly. The belt passes over the drums and between the parallel arms. A downward force is applied to the belt at this point by a spring-loaded ball bearing which applies tension as it rides on top of the belt.

The belt guide is limited in its travel along the belt shifter shaft by the limit nuts. The position of these limit nuts prevents the belt from slipping from the drum.

A guide bar, secured to the base and parallel to the belt shifter shaft, prevents the belt shifter from rotating about the shaft axis as the belt is moved along the cones.

The belt shifter shaft which extends through the housing has a chain sprocket attached to it. Mounted above the drive cone on a horizontal plate attached to the housing is a remote draw Synchrotie receiver. The receiver shaft is connected to the belt shifter shaft by a link chain drive.

A remote draw Synchrotie transmitter is mounted in a location convenient to the machine operator. The remote draw transmitter and receiver are duplicate units, providing a one-for-one revolution relationship. Each unit has a 110-volt single-phase primary wound on its rotor, and a 55-volt, 3-phase secondary on the stator. For normal operation, it is excited at 80 to 100 volts on the primary in order to provide long life and reduced temperature operating conditions. Therefore, a direct control of the cone ratios is obtained remotely by the remote draw Synchrotie transmitter and receiver system.

A pushbutton mounted near the remote draw Synchrotie transmitter provides an automatic, momentary slack take-up feature to change the differential cone speed. Depressing the pushbutton energizes the solenoid contained within the belt shifter shaft bearing housing. The magnetic force created by the solenoid attracts the slack take-up armature to the bearing housing. The metal disc moves 1/4 inch which provides a relative speed change of 0.60 percent. This speed change will persist only as long as the SLACK TAKE-UP pushbutton is held depressed.

MECHANICAL DIFFERENTIAL SPEED ERROR DETECTING UNIT

Additions to the basic mechanical differential error detecting unit are shown in Figure 4 and are listed below:

1. A reference synchronous motor or Synchrotie receiver. Provides a mechanical reference input into the differential cone.

2. A position inductor. This inductor supplies voltage proportional to position and is applied to an external amplifier for signal indications.

3. A d-c pilot generator. This generator supplies voltage proportional to the rate of change of position

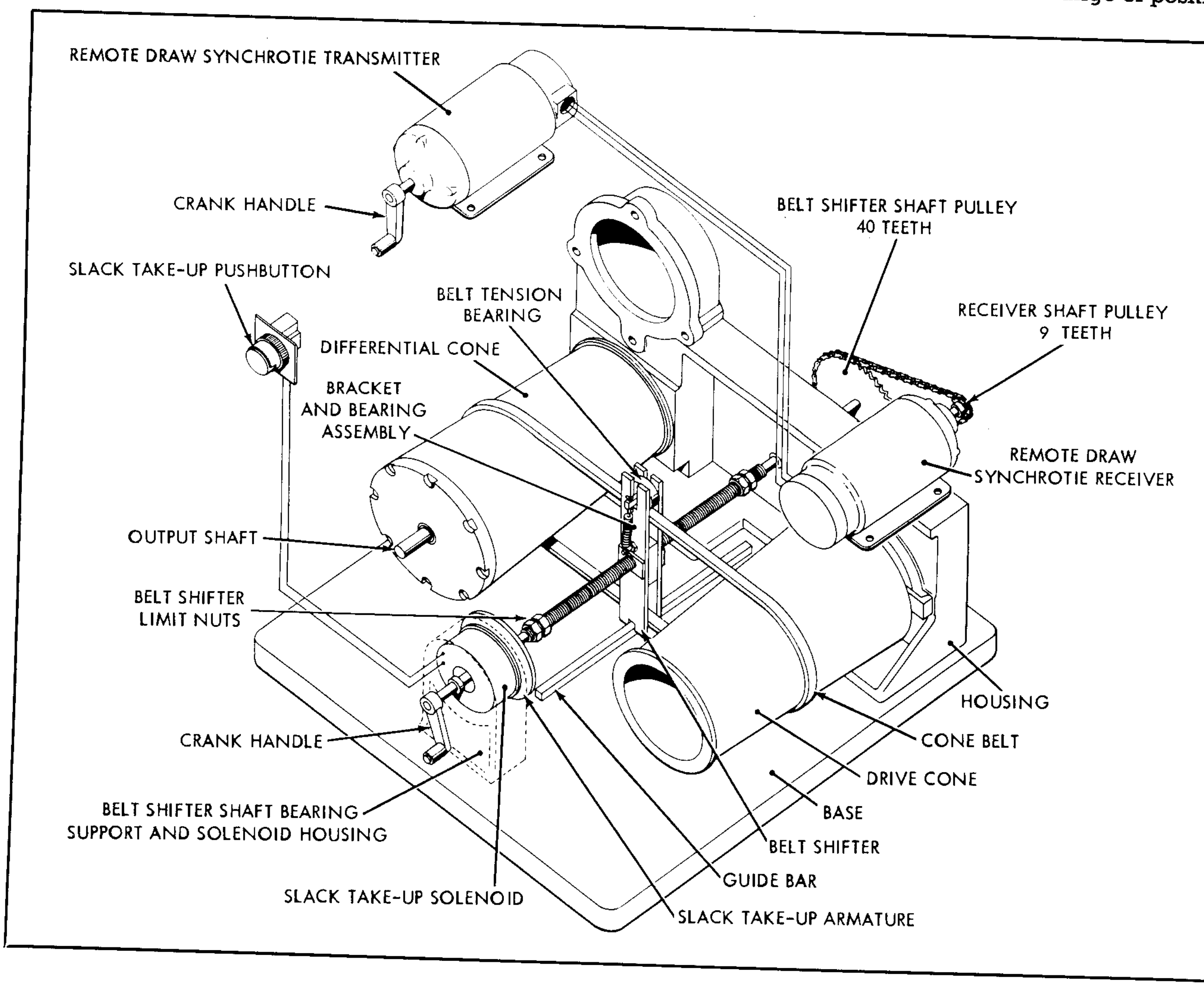


FIG. 3. Remote Draw Control Components

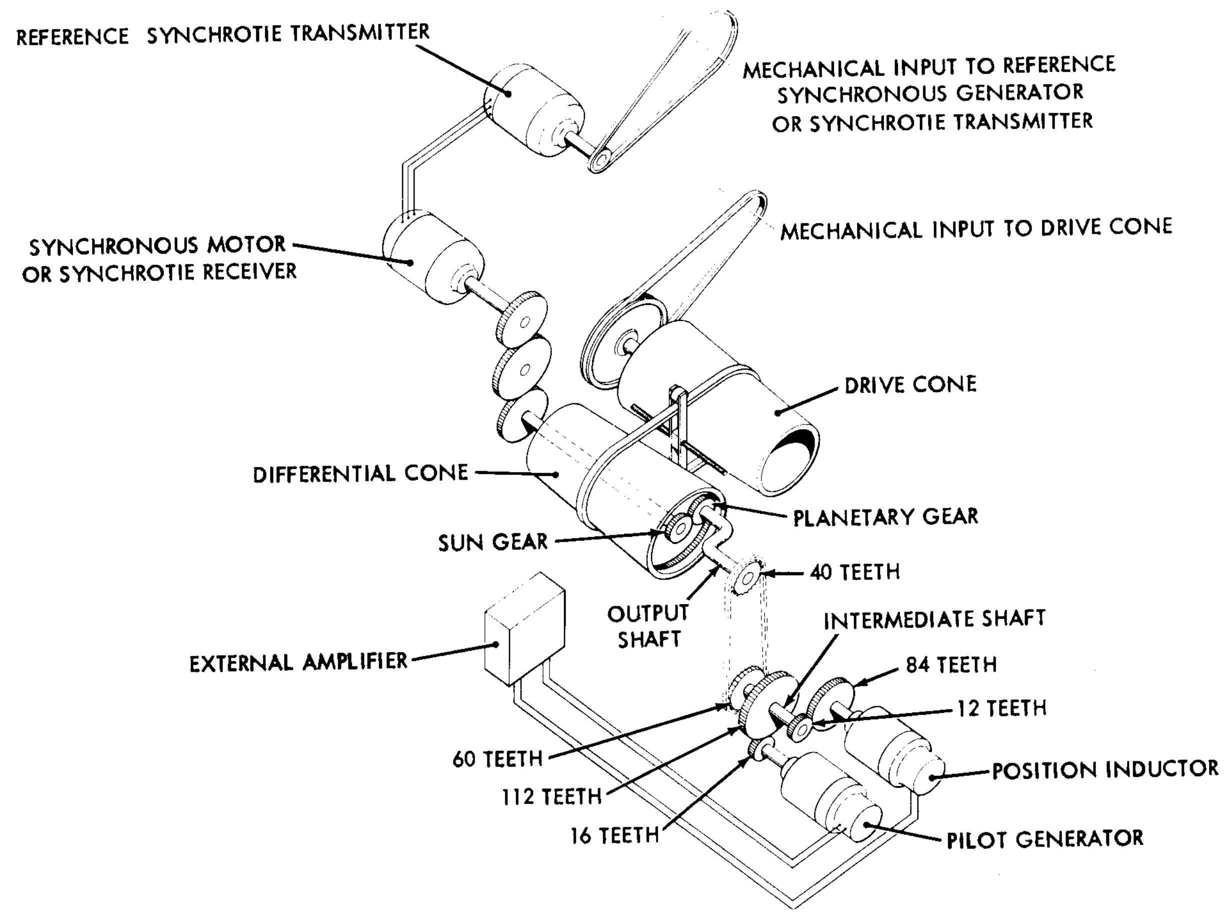


FIG. 4. Simplified Control Circuit Incorporating Mechanical Differential Speed Error Detecting Unit

and is also applied to an external amplifier for signal indications.

A typical simplified control circuit as shown in Figure 4 will be described to illustrate the operation when using the mechanical differential speed error detecting unit.

A mechanical drive input to the reference synchronous generator or Synchrotie transmitter provides the reference speed for the unit. This generator or transmitter supplies power to the reference synchronous motor or Synchrotie receiver. This motor or receiver drives the sun gear of the differential cone at a reference speed.

A mechanical input to the drive cone provides the variable speed to the unit. The drive cone imparts a rotation to the differential cone and its ring gear through the movement of the cone belt. A one-to-one ratio of drive cone speed to differential cone speed will be considered first.

The electrical output of the position inductor and d-c pilot generator can be connected to any conventional voltage or power amplifier; e.g., **magnetic amplifier, electronic amplifier or rotating amplifier** to provide additional gain and control ability.

If the ring gear is rotating at a speed other than one-third the speed of the sun gear, the planetary gear will rotate the output shaft. The chain connection turns the intermediate shaft which rotates the armatures of the position inductor and d-c pilot generator. The movement of the position inductor rotor supplies a change in voltage to the external amplifier in proportion to the new angular position of the output shaft. The rotation of the d-c pilot generator armature supplies a voltage to the external amplifier proportional to the rate of position change of the output shaft.

The amplifier is energized by these two separate signals to change the speed of the machine providing the mechanical input to the drive cone.

The above sequence will take place until the ring gear is rotating exactly one-third as fast as the sun gear. At this point, the mechanical input to the drive cone is speed matched to the mechanical input by the reference.

If it is required to change the speed matching of the reference machine to the controlled machine, movement of the cone belt in the proper direction will accomplish this requirement.

INSTALLATION

The following installation instructions are to be performed before initial adjustments and operation:

1. Check the alignment of the motor mounted or driven mechanical input sheave and drive cone sheave. Alignment of these sheaves should be as perfect as physically possible. True alignment will eliminate sidewise flexing and whip and will increase the belt life.

2. Check the mechanical input and drive cone sheaves for play between sheave and shaft. The sheave must be securely fastened to the shaft. No play, axially or radially, can be tolerated. If play exists between the drive cone sheave and the drive cone shaft, tighten the split taper bushing on the sheave. If play exists between the motor mounted sheave and its shaft, tighten the mounting.

3. Check sheave V-belt tension. The V-belt should be tightened sufficiently to eliminate slippage. Too much tension will overload the bearings of the basic mechanical differential error detecting unit.

NOTE: It is recommended that the purchaser supply a gravity-loaded or spring-loaded roller to maintain tension of the V-belt.

Usually the motor will be coupled to the machine so that this check may be accomplished by trying to turn the drive cone sheave (in the direction the motor will drive it) with the belt in place. Should the belt slip, shift the base support on its slide rails by turning the threaded adjusting bolts in the slide rail ends. If the motor is uncoupled, restrain the armature and check as outlined above.

NOTE: When possible, it is preferable to rotate the drive cone sheave in a direction such that the drive belt is taut on the bottom and slack on the top.

4. Check the V-belt for uniformity of width. The belt should have a uniform width throughout its total length. If the motor is coupled, this check will have to be deferred until the machine is run at slow (inch)speed. Rotate the armature slowly and observe the position of the belt in the sheave slot. The belt rides up and down in the slot if it is not uniform in width. A non-uniformity of a minor nature will not usually affect the operation of the unit, but will cause action to appear erratic. Belts that are uneven or have a permanent set or deflection should not be used.

5. Remove the light coat of oil from the cone surfaces with a suitable solvent. Surfaces must be clean and dry to prevent slippage.

6. Check the cone belt tension bearing. This bearing should be free to move perpendicularly from the mid-point of the bracket slots. The belt tension should be sufficient to eliminate slippage. A deflection of 1/4 inch at normal ambient temperature indicates sufficient tightness. Excessive tension will overload or bind the cone bearings. If necessary to adjust the range of the belt tension bearing, loosen the three eccentric bearing mounting bolts (Figure 5). To tighten the cone belt, turn the eccentric bearing in a clockwise direction with a suitable spanner wrench. To loosen the cone belt, turn the eccentric bearing in a counterclockwise direction.

NOTE: Do not remove eccentric bearing clamps from housing.

Tighten securely the three eccentric mounting bolts.

By means of the eccentric mounting bearing the drive cone can be moved a distance of one inch in the horizontal direction to obtain the proper belt tension.

7. Check the differential gear train for binding, backlash and play. Release the chain tightener and remove the drive chain. Hold the differential cone and rotate the differential output shaft. Rotation should be uniform and smooth with no backlash in the gearing.

8. Check the position inductor drive gearing and friction clutch. With the drive chain removed, rotate the 60-tooth sprocket and observe the gear train. Rotation should be smooth and require uniform torque (when the position inductor is in range). The pilot generator and position inductor are mounted in slotted holes to permit adjustment of their position to obtain snug mesh of gears. Backlash in the gearing can be minimized by adjusting the positions of the pilot generator and the position inductor.

CAUTION: When the receiver goes out of range, the friction clutch should slip with little additional applied torque. Check for constant friction in the clutch by rotating it through one complete revolution.

9. Check the oil level. Rotate the differential cone until one of the two filler plugs is directly below the output shaft. Remove the plug and check the oil level. The housing gear case should be filled with SAE-140 or equivalent weight oil until level with the bottom edge of the filler plug hole. Replace the plug. The chain drive idler and gear train should have a light coating of light weight machine oil.

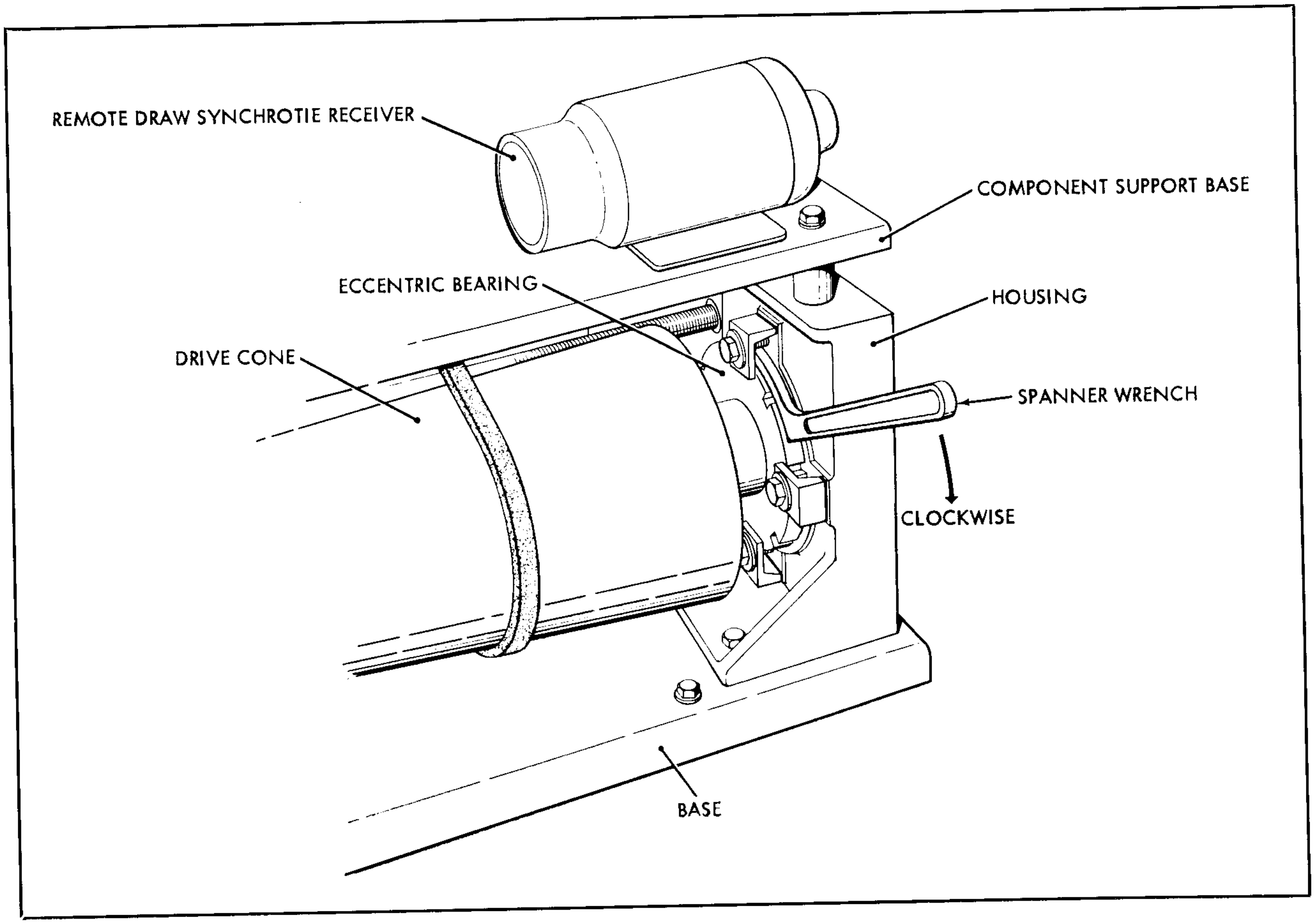


FIG. 5. Adjustment of Drive Cone Eccentric

10. Check the belt shifter for binding and mechanical interference. Rotate the cones and move the belt shifter throughout its complete range by the draw adjusting crank handle. The belt should move freely to the extreme ends of the cones.

11. Slack Take-up. Check the belt shifter shaft for freedom of movement in the horizontal direction.

ADJUSTMENTS

The following adjustments for setting up and/or checking the electrical components of the unit are to be performed before actual operation:

Pilot Generator. Check the two brushes for type and fit. They should be No. AGC-10 silver graphite brushes. Move the brushes in and out of the brush holders. **There must be neither binding nor excessive clearance.** Measure the shunt field voltage—this should be approximately 90 to 100 volts. Disconnect the PGP (Figure 6) lead on the pilot generator side of the terminal block and measure the pilot generator armature voltage as the drive cone sheave is turned in the direction the mechanical input sheave will drive it. The PGP lead should be positive. If the polarity is wrong, reverse either the armature or the field leads. With the control circuit deenergized, measure the resistance of the circuit to the external amplifier. (This should be 2 ohms maximum unless the normally closed contact of the Transfer relay (refer to main schematic diagram) is not making good contact.)

Position Inductor. Rotate the drive cone sheave in the direction that the mechanical input sheave will drive it. Note the direction the pointer moves and mark this side "FAST." Mark the opposite side "SLOW." These designations refer to section motor speed; for example, if the section motor is running too slow, the pointer will move toward "SLOW." Excite the position inductor with the voltage specified by the main schematic diagram and measure the voltage of the phase connected to the **external** amplifier. When the pointer is in "FAST" position, the a-c voltage should be zero, and should increase as the pointer is moved to the "SLOW" position. If the output is not zero, remove the pointer on the clutch assembly and relocate it so that zero (or essentially zero) volts are obtained when the pointer is in the "FAST" position. The voltage must not reverse as the pointer is moved through its range.

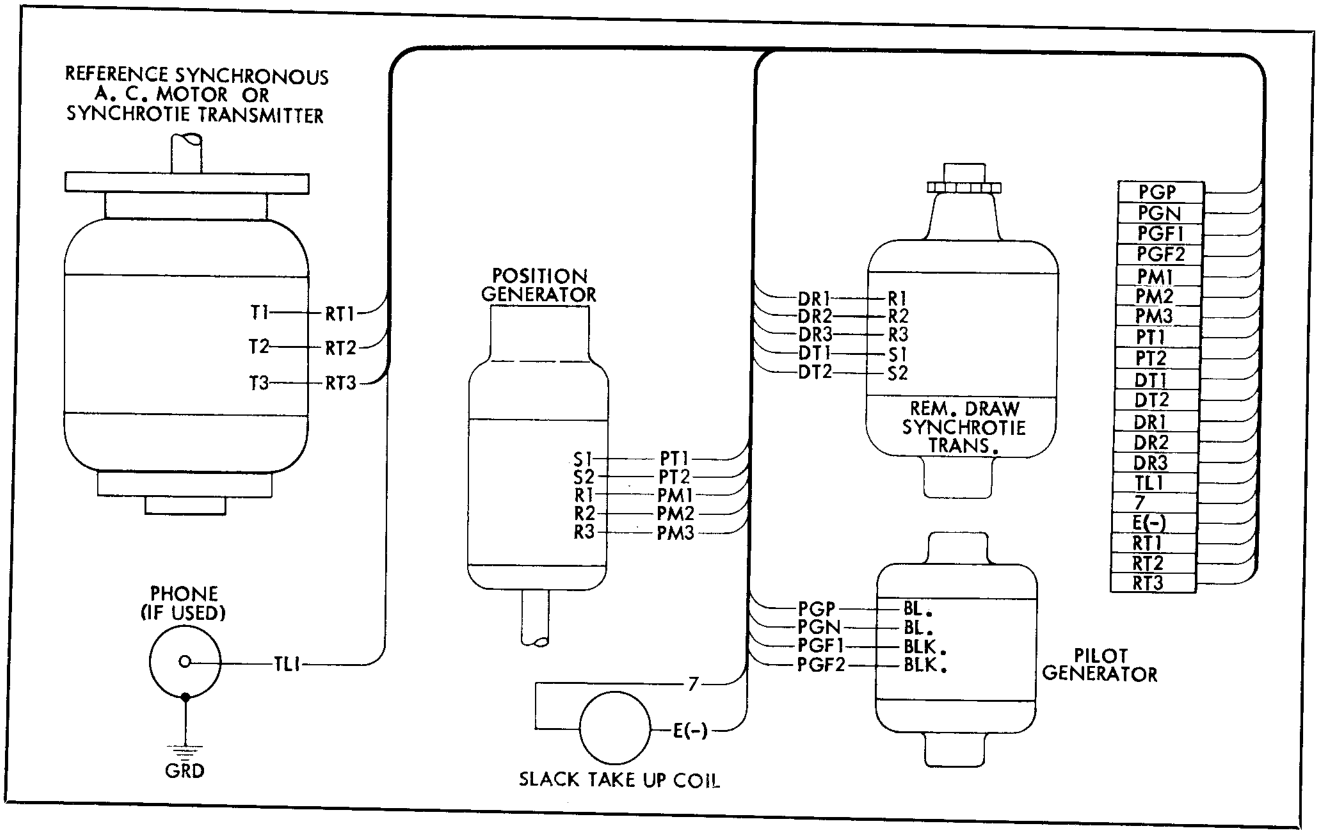


FIG. 6. Wiring Diagram for the Mechanical Differential Speed Error Detecting Unit

Reference Synchronous Motor or Synchrotie Receiver. Energize the reference bus and momentarily excite the reference motor or receiver by manually closing the transfer relay. The pointer should move to the "SLOW" position. If the rotation is wrong, interchange two of the three motor or receiver leads.

Remote Draw Control. With the motor running and the regulator in operation, check the voltage applied to the Remote Draw Control circuit. Refer to the main schematic diagram for the proper voltage. Turn the crank handle of the remote draw Synchrotie transmitter at the operator's station in the direction in which the material is flowing. This should cause the cone belt to move away from the housing of the unit and the section drive motor should increase its speed. If the resultant action is reversed, interchange two of the three stator leads.

Slack Take-up. With the motor running and the unit in operation, depress the slack takeup push-button at the operator's control station. The cone belt should move approximately 1/4 inch away from the housing of the unit and the section drive motor should increase its speed.

MAINTENANCE

Preventive Maintenance. The mechanical differential speed error detecting units have been designed and constructed to perform satisfactory service for an extended period. To insure efficient operation, it is necessary to accomplish routine mechanical and electrical inspections that will reveal unsatisfactory conditions and prevent disturbances to the control circuits.

SERVICE

Weekly	Monthly	
x	x	**Belts.** Inspect for excessively worn, cracked, or frayed belts. Check belt tension.
	x	**Sheaves.** Check condition and alignment of sheaves.
	x	**Chains.** Check for wear and cracked or broken links.
	x	**Sprockets.** Check sprockets for excessive wear, broken teeth, loose mounting and alignment.
x		**Cones.** Check cones for oil, liquids or dirt on external surfaces.
		Oil. Drain and refill when dirty or gritty.

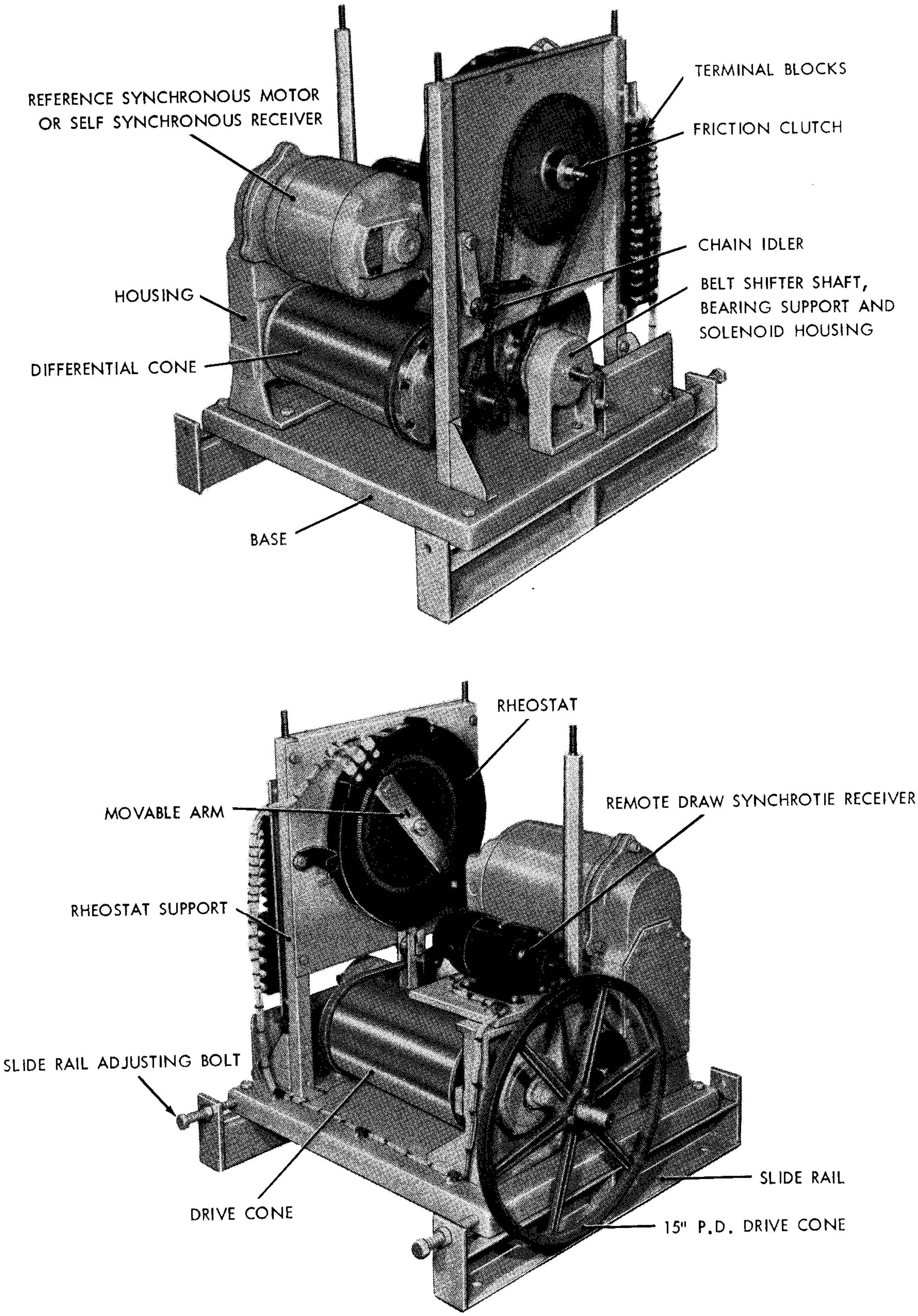


FIG. 7. Mechanical Differential Rheostatic Type Position Regulator

Replacement of Cone Belt. 1. With the drive cone turning, rotate the crank handle until the belt shifter has moved the cone belt to the ends of the cones near the crank handle.

2. Reduce the tension in the belt by turning the drive cone eccentric bearing. (Refer to step 6 under Installation.)

3. Release the chain idler and remove the output shaft drive chain.

4. Remove the belt tension bearing from the belt shifter.

5. Remove the bolts securing the belt shifter shaft bearing support to the base.

6. Remove the belt from the cones and slip the belt under the bearing support.

7. Replace the new belt in a reverse order to that given above.

VARIATION IN DESIGN AND APPLICATION

The basic mechanical differential error detecting unit (Figure 2) and the remote draw control (Figure 3) can be combined with specific equipment to form a Mechanical Differential Rheostatic Type Position Regulator as shown in Figures 7 and 8.

The required equipment is shown in Figure 8 and listed below.

1. A 26-tooth sprocket attached to the output shaft.

2. A variable rheostat whose contact arm is chain-connected to the output shaft of the differential cone.

3. The necessary frame and supports for the variable rheostat.

4. A reference synchronous motor or Synchrotie receiver to provide a mechanical reference input into the differential cone.

The chain connection between the output shaft of the differential and the rheostat provides the proper rotation of the contact arm in relation to the electrical and mechanical requirements.

The 26-tooth sprocket chain-drives a 72-tooth sprocket that is secured to the contact arm of the rheostat. A friction clutch is inserted between the sprocket and contact arm to provide protection for the rheostat and control system in case the arm is stopped at either of its extreme limits of travel.

A typical simplified control circuit (Figure 8) will be described to illustrate the operation when using the mechanical differential rheostatic type position regulator.

A mechanical drive input to the reference synchronous generator or Synchrotie transmitter provides the reference speed for the regulator. This generator or transmitter supplies power to the reference synchronous motor or Synchrotie receiver. This motor or receiver drives the sun gear of the differential cone to provide the reference.

A mechanical input to the drive cone provides the variable speed to the regulator. The drive cone imparts a rotation to the differential cone and its ring gear through the movement of the cone belt.

If the ring gear is not rotating exactly one-third the speed of the sun gear, the planetary gear will receive rotational motion and force the output shaft to rotate. The mechanical connection between the rheostat and the output shaft causes a change in position of the rheostat arm. This action results in a change of voltage across the field of the controlled motor or generator. The resultant effect will change the speed of the machine providing the mechanical drive input to the drive cone.

The above sequence will take place until the ring gear is rotating exactly one-third as fast as the sun gear. At this point, the mechanical input to the drive cone is speed matched to the mechanical input of the reference.

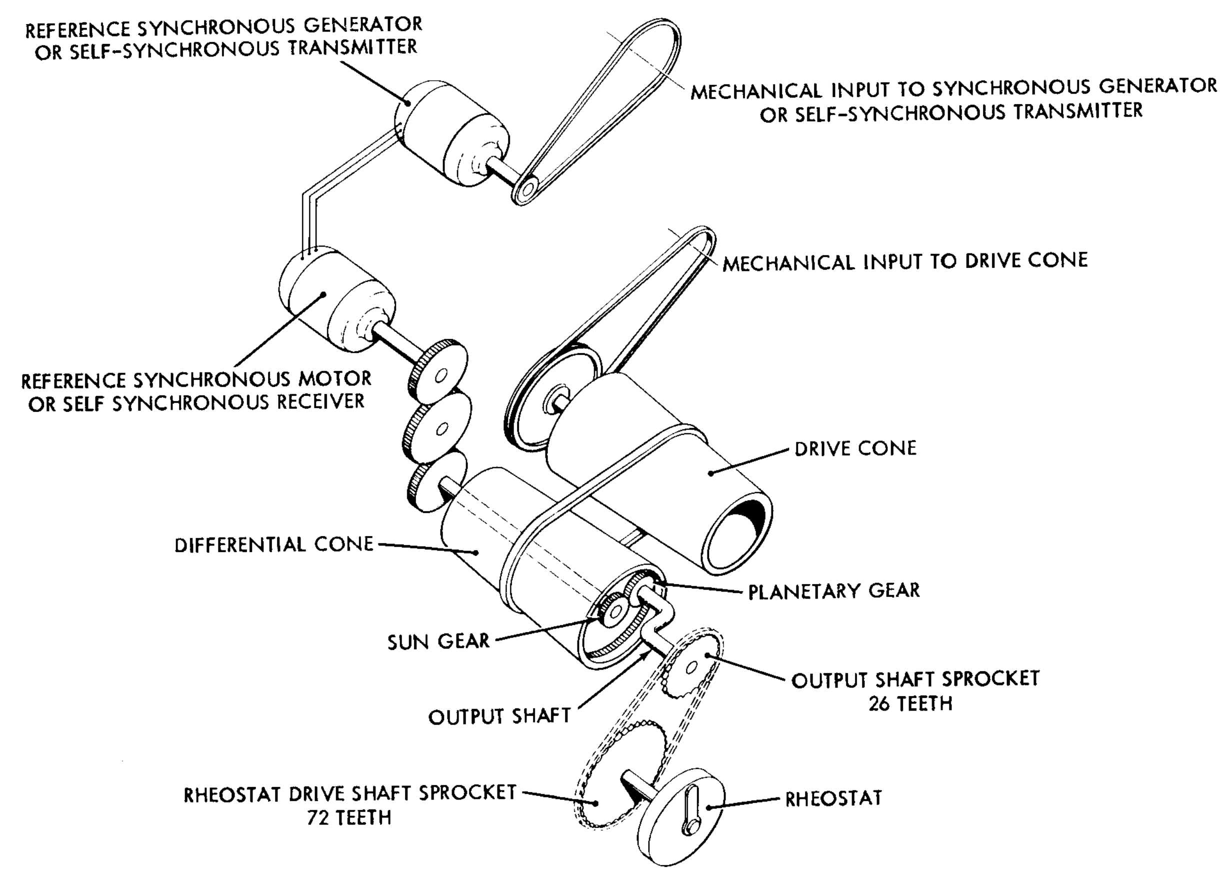


FIG. 8. Simplified Control Circuit Incorporating Mechanical Differential Rheostat Type Regulator

WESTINGHOUSE ELECTRIC CORPORATION
BUFFALO PLANT • MOTOR DIVISION • BUFFALO 5, N.Y.

Printed in U.S.A.

WESTINGHOUSE