Function Generator
Type AF

Bailey Babcock & Wilcox
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BASIC FUNCTION GENERATOR

THE BASIC MINI LINE 500 FUNCTION GENERATOR IS A PROPORTIONAL ACTION CONTROLLER WITH AN EXTERNALLY SUPPLIED GAIN CONTROL SIGNAL.

CONNECTION E2 CAN BE USED AS THE INPUT FOR REVERSE PROPORTIONAL ACTION, AS AN OPTIONAL PNEUMATIC SET POINT OR FOR APPLYING THE SECOND INPUT FOR DIFFERENTIAL CONTROL APPLICATIONS. ADDITIONAL CONTROL ACTIONS CAN BE ADDED TO THE BASIC FUNCTION GENERATOR IF REQUIRED.

SPECIAL APPLICATIONS - THE FUNCTION GENERATOR CAN BE USED IN APPLICATIONS WHERE IT IS DESIRABLE TO HAVE THE GAIN VARY AS A FUNCTION OF THE OUTPUT OR AS A FUNCTION OF ONE OF THE INPUT SIGNALS.

RATIO CONTROL - THE FUNCTION GENERATOR CAN BE USED IN CONJUNCTION WITH A TYPE AD CONTROLLER TO PROVIDE RATIO CONTROL. THE OUTPUT OF THE FUNCTION GENERATOR MODIFIED BY THE GAIN CONTROL (RATIO) SIGNAL BECOMES THE INPUT TO A PROPORTIONAL ACTION CONTROLLER REGULATING THE SECOND VARIABLE.

FIGURE 1 - Type AF Function Generator Control Actions
**FIGURE 2 - Function Generator Mounting Dimensions**

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(1) Input for adjustment, output in service
(2) Output for adjustment plugged in service
(3) Input for calibration plugged in service
(4) P for adjustment P-I in service

*Air supply is connected to S in all cases

E4 is gain control signal

**TABLE A Mounting Base Connections and Switch Settings**
INSTALLATION

1. Remove cover from Function Generator unit. Remove Function Generator from mounting base by loosening captive mounting screws (Figure 3) and pulling assembly directly from base. Remove locking knob from gain arm if fitted for shipping (red tag).

2. Attach mounting base to wall or panel in accordance with dimensions given in Figure 2. Locate Function Generator not more than 400 feet from transmitters or final control elements.

3. Make external connections to mounting base as required for particular service. Refer to Figure 1 and Table A. Connecting tubing of copper or aluminum (.028 to .032 inch wall thickness) or plastic tubing is recommended. (Connections are spaced to permit use of 1/4 inch NPT elbow connectors.)

4. Connect air supply to mounting base connection. 18 psig for 3 to 15 psig range, 30 psig for 3 to 27 psig range.

5. On applications involving integral control action, plug manifold connections E3 and E3R (E3 must be used as an input to 'C' bellows during adjustment as noted in "Placing in Service").

6. Make certain that D R disc switch on rear of Controller assembly (Figure 3) is in "D" position.

7. Check position of P P+I disc switch. Switch should be in "P" position for all applications which do not employ integral action. For integral control action, switch should be in "P+I" position.

8. Mount Function Generator unit on mounting base by pressing firmly into position with sealing plugs (Figure 3) correctly aligned with holes in Function Generator assembly casting. Tighten captive mounting screws to secure unit to mounting base.

9. Check that integral and derivative switches or plug-in units are correctly set. Integral switch or valve of integral plug-in unit must be in closed position. Derivative switch or valve of derivative plug-in unit must be in open position (Valves of plug-in units are "open or closed" when adjusting screw is turned to full clockwise or counterclockwise position respectively.)

10. Function Generator installation is complete. However, do not replace cover assembly until necessary adjustments required for particular application are made in accordance with "Placing in Service" on page 6.
PLACING IN SERVICE

SPECIAL FACTORY CALIBRATION

Function Generators which have been specially calibrated at the factory for a particular service (Type AF5000XX assemblies) can be placed directly in service after setting the integral and derivative units, if included, to the required rate of response. However, it is recommended that the calibration be verified by applying several input pressures for which the desired output pressures are known (see calibration data sheet). If incorrect output pressures result, apply minimum input pressure to the unit and set the correct output with the gain control zero adjustment. Figure 4. Repeat the application of input pressures with known outputs. If output pressures are now correct, the unit may be placed in service. If output pressures remain incorrect, the calibration has shifted and must be reset in accordance with the applicable following procedure.

CONTROLLER NULL POINT ADJUSTMENT

The standard Function Generator is nulled at the factory with the minimum range pressure (3 psig for either range) applied to E1 bellows of the Controller. If this is the desired null condition, the Function Generator can be placed in service after performing the applicable gain control mechanism adjustment outlined below.

If the service for which the Function Generator is to be used requires a different null point (and the unit has not been handled as a Special Factory Calibration), the Controller portion of the Function Generator assembly must be reset to the proper null point in accordance with the following procedure.

IMPORTANT If the Controller has had the factory calibration disturbed, it must be completely recalibrated as outlined under Complete Calibration on page 31.

3. On applications involving integral control action, make certain that manifold connection E3R is plugged. (Connection E3 will be used as an input to 'C' bellows during adjustment but must be plugged in service.)

4. Check position of P P + I disc switch. Switch should be in 'D' position for all applications which do not employ an integral control action. If an integral control action is used for particular application, switch should be in P + I position. See Figure 3.

FIGURE 4 Gain Control Zero Adjustment

FIGURE 5 Disengaging Gain Control Mechanism

1. Disengage gain control mechanism from Controller assembly by loosening set screws holding flexible coupling to Controller gain arm shaft. Figure 5.

2. Make certain that D R disc switch on rear of Controller assembly (Figure 3) is in D position.
5. Check that integral and derivative switches or plug-in units are correctly set. Integral switch or valve of integral plug-in unit must be in closed position. Derivative switch or valve of derivative plug-in unit must be in open position. (Valves of plug-in units are "open" or "closed" when adjusting screw is turned to full clockwise or counterclockwise position respectively.) See Figure 6.

6. Set Controller gain at 1.0

7. Connect separate variable input pressures to input connections required for particular service. (Connection E3 is used as an input to "C" bellows for adjustment on applications that require integral control action. On integral action units, E3 must then be plugged at manifold when unit is placed in service.)

8. Apply midrange pressure to input connections. If full range is not used in particular application, apply midrange pressure of actual input range employed, (i.e., for a range span of 3 to 11 psig, applied input pressure should be 7 psig.)

9. Connect a pressure gage or manometer to output connection "O". Apply supply air to connection "S"; 18 psig for a 3 to 15 psig range, 30 psig for a 3 to 27 psig range.

10. Turn A-B bias adjustment screw until tie plate hinges are in line with hinges on C-D beam (see upper beam alignment line, Figure 7).
NOTE: Do not turn bias screw if service involves inputs to both A and B bellows. Correct matching of A and B bellows is set at factory (If bellows match has been destroyed, see Complete Calibration on page 31.)

11. Remove indicating panel (Item 20 in Figure 32) and turn C-D sector screw until the plate hinges are in line with hinges of A-B beam (see lower beam alignment line, Figure 7).

12. Adjust output pressure to midrange with C-D bias screw.

NOTE: Do not turn bias screw if service involves pressures in both C and D bellows (such as integral control action, differential applications, etc.). Correct matching of C and D bellows is set at factory (If bellows match has been destroyed, see Complete Calibration on page 31.)

13. Apply required null pressure to input connections as dictated by particular system application.

14. Set gain at 0.2. Turn C-D sector screw to obtain output null pressure.

15. Set gain at 20. Turn A-B sector screw to obtain output null pressure.

16. Set gain at 1.0 and note output pressure. If output pressure is not equal to required null, unlock and rotate nozzle until output deviation is approximately doubled. Lock nozzle in this position.

NOTE: Large nozzle adjustments may disturb parallel relationship of vane and sector plate. To readjust vane loosen vane adjustment screw (Figure 7) and slide vane support until vane appears to be approximately parallel to sector plate.

17. Repeat steps 14 thru 16 until gain may be shifted from 0.2 to 20 without changing output pressure more than 0.5 psig.

18. Set gain at 1.0. Controller portion of Function Generator is now correctly nulled. Refer to applicable heading below for adjustment procedure required for gain control mechanism.

NOTE: If Controller portion of Function Generator assembly cannot be nulled following above procedure, basic Controller alignment has been disturbed. Reset Controller in accordance with procedures outlined under Complete Calibration on page 31.
GAIN CONTROL MECHANISM ADJUSTMENT

Linear Function, 45° Gain Arm Rotation, Direct Action.

This is the standard factory calibration for the Function Generators.

1. Turn on supply air. Apply 3 psig air pressure to gain control signal bellows (connection E4).

2. Check position of cam follower roller on cam. If cam roller is not on cam zero mark (second line), rotate gain control zero adjustment screw (Figure 8) until cam position is correct.

3. Apply air pressure to Controller "A" bellows (connection E1) 6 psig for 3 to 15 psig units, 9 psig for 3 to 27 psig units. Connect output connection "O" to a gage or manometer.

4. Output pressure should be 3.92 psig for 3 to 15 psig units; 4.84 psig for 3 to 27 psig units.

5. If output pressure is not correct, loosen flexible coupling screws on Controller gain shaft and shift gain arm until output pressure is correct. When correct output is obtained, retighten screw on flexible coupling assembly.

6. Apply maximum input, 15 psig or 27 psig, to gain control assembly bellows (connection E4) and note output pressure.

7. Output pressure should be 13.41 for 3-15 psig units and 23.82 for 3-27 psig units. If output pressure is not correct, loosen range adjustment locking screw (Figure 8) and turn range adjustment screw to provide full range output.

8. Apply 3 psig to gain control bellows (connection "E4") and reset zero adjustment screw to obtain correct output pressure. 3.92 psig for 3 to 15 psig units, 4.84 psig for 3 to 27 psig units. (Rotate zero adjustment screw counterclockwise to lower output pressure.)

9. Repeat steps 6, 7, and 8 until output pressure range is correct. Tighten range adjustment locking screw.

10. Function Generator is now ready to be placed in service after connecting inputs as required for particular service and setting integral and derivative units, if employed, to desired speed of response.

NOTE. If Function Generator cannot be adjusted as outlined above basic Controller alignment has been disturbed. Reset Controller in accordance with applicable procedure outlined under "Complete Calibration" on page 31.
Linear Function, 10° Gain Arm Rotation, Direct Action

The 10° gain arm rotation arrangement is used to provide greater accuracy on applications where the desired function is covered by 10° of gain arm rotation or less for a linear function with a minimum range null, the Controller portion of the Function Generator remains as calibrated at the factory. The gain control mechanism must be reset as follows:

1. Remove two 4-40 screws holding zero adjustment assembly in 45° position on cam follower arm. See Figure 9. Shift zero adjustment assembly to 10° position on cam follower arm (second and outside holes). Replace and tighten mounting screws.

2. Turn on supply air to Function Generator.

3. Gain control assembly position shaft will move to fully extended position. Install zero stop pin (Figure 10). Lock zero stop pin in position with two retaining rings.

4. Turn off supply air to Function Generator.

5. Remove 45° gain arm rotation cam from gain control assembly and install 10° gain arm rotation cam. Rotate cam to place position alignment line (first line on cam) to a point directly below cam follower arm roller. Lock cam in this position (see Figure 11).

6. Apply 3 psig air pressure to gain control signal bellows (connection E4).

7. Loosen range adjustment locking screw (Figure 8) and turn range screw to position range spring approximately in line with zero adjustment assembly. Tighten range adjustment locking screw.

8. Turn on supply air to Function Generator.

9. Check position of cam follower roller on cam. If cam roller is not on cam zero mark (second line), rotate gain control zero adjustment screw (Figure 8) until cam position is correct.

10. Apply air pressure to Controller A bellows (connection E1) 6 psig for 3 to 15 psig units, 9 psig for 3 to 27 psig units. Connect Function Generator output connection 'O' to a gage or manometer.

11. Output pressure should be 5.34 psig for 3 to 15 psig units, 7.68 psig for 3 to 27 psig units.
12. If output pressure is not correct, loosen flexible coupling screws on Controller gain shaft and shift Controller gain arm until output pressure is correct. When correct output is obtained, retighten screws on flexible coupling assembly. See Figure 5.

13. Apply maximum input, 15 psig or 27 psig, to gain control assembly bellows (connection E4) and note output pressure.

14. Output pressure should be 6.84 psig for 4 to 15 psig units, 10.68 psig for 3 to 27 psig units.

15. If output pressure is not correct, loosen range adjustment locking screw and turn range adjustment screw to provide correct output pressure (see Figure 6).

16. Apply 3 psig to gain control bellows (connection E4) and reset zero adjustment screw to obtain correct output pressure, 5.34 psig for 3 to 15 psig units, 7.68 psig for 3 to 27 psig units. (Rotate zero adjustment screw counterclockwise to lower output pressure.)

17. Repeat steps 13 thru 16 until output pressure range is correct. Tighten range adjustment locking screw.

18. Function Generator is now ready to be placed in service after connecting inputs as required for particular service and setting integral and derivative units, if employed, to desired speed of response.

NOTE If Function Generator cannot be adjusted as outlined above, basic Controller alignment has been disturbed. Reset Controller in accordance with applicable procedure outlined under "Complete Calibration" on page 31.

Linear Function, 45° Gain Arm Rotation, Reverse Action

1. Loosen set screw holding flexible coupling assembly to Controller Gain Arm Shaft and slide flexible coupling off shaft.

2. Remove four screws holding gain control mechanism to Controller.

3. Lift complete gain control mechanism free of Function Generator Assembly.

4. With left thumb on inner radius of driven pulley below tape tension spring, rotate driven pulley clockwise. Lower tape will slacken. Remove lower tape with right hand and hold under slight tension.

5. Rotate driven pulley about 330° counter clockwise from original position. Upper tape will now become lower as in Figure 12 Reverse Action. (This is done without disengaging upper tape and spring.)

6. Rotate original lower tape one more turn counterclockwise around driving pulley then pass up between pulleys and over top of driven pulley. Rotate driven pulley slightly to provide slack and engage tape.

7. Reinstall gain control mechanism on Function Generator assembly and tighten flexible coupling set screw.
8. Turn on supply air. Apply 3 psig air pressure to gain control signal bellows (connection E4).

9. Check position of cam follower roller on cam. If cam roller is not on cam zero mark (second line), rotate gain control zero adjustment screw (Figure 8) until cam position is correct.

10. Apply air pressure to Controller A bellows (connection E1): 6 psig (3 to 15 psig units) or 9 psig (3 to 27 psig units). Connect output connection 0 to pressure gage or manometer.

11. Output pressure should be full range Controller output, 13.41 psig or 23.82 psig.

12. To correct output pressure, loosen flexible coupling screws on Controller gain shaft and shift Controller gain arm until output pressure is correct. When correct output pressure is obtained, retighten screws on flexible coupling assembly.

13. Apply maximum input, 15 psig or 27 psig, to gain control assembly bellows (connection E4) and note output pressure.

14. Output pressure should be 3.92 psig for 3 to 15 psig units, 4.84 psig for 3 to 27 psig units. If output pressure is not correct, loosen range adjustment locking screw (Figure 8) and turn range adjustment screw to provide correct output.

15. Apply 3 psig to gain control bellows (connection E4) and reset zero adjustment screw to obtain correct output pressure, 13.41 psig for 3 to 15 psig units, 23.82 psig for 3 to 27 psig units. (Rotate zero adjustment screw counterclockwise to increase output pressure.)

16. Repeat steps 13, 14, and 15 until output pressure range is correct. Tighten range adjustment locking screw.

17. Function Generator is now ready to be placed in service after connecting required inputs for particular service and setting integral and derivative units (if employed) to desired speed of response.

NOTE: If Function Generator cannot be adjusted as outlined above, basic Controller alignment has been disturbed. Reset Controller in accordance with applicable procedure outlined under "Complete Calibration" on page 31.

Linear Function, 10° Gain Arm Rotation, Reverse Action

The 10° gain arm rotation arrangement is used to provide greater accuracy on applications where the desired function is covered by 10° of
gain arm rotation or less. For a linear function with a minimum range null, the Controller portion of the Function Generator remains as calibrated at the factory. The gain control mechanism must be reset as follows:

1. Remove two 4-40 screws holding zero adjustment assembly in 45° position on cam follower arm. See Figure 9. Shift zero adjustment assembly to 10° position on cam follower arm (second and outside holes). Replace and tighten mounting screws.

2. Turn on supply air to Function Generator.

3. Gain control assembly piston shaft will move to fully extended position. Install zero stop pin (Figure 10). Lock zero stop pin in position with two retaining rings.

4. Turn off supply air to Function Generator.

5. Remove control gain mechanism from Function Generator assembly (step 1 thru 3 on page 11).

6. With left thumb on inner radius of driven pulley below tape tension spring, rotate driven pulley clockwise. Lower tape will slacken. Remove lower tape with right hand and hold under slight tension.

7. Rotate driven pulley about 330° counter clockwise from original position. Upper tape will now become lower as in Figure 12 Reverse Action. (This is done without disengaging upper tape and spring.)

8. Rotate original lower tape one more turn counterclockwise around driving pulley then pass up between pulleys and over top of driven pulley. Rotate driven pulley slightly to provide slack and engage tape.

9. Remove 45° gain arm rotation cam from gain control assembly and install 10° gain arm rotation cam. Rotate cam to place position alignment line (first line on cam) to a point directly below cam follower arm roller. Lock cam in this position. (Refer to Figure 11.)

10. Reinstall gain control mechanism of Function Generator assembly.

11. Apply 3 psig air pressure to gain control signal bellows (connection E4).

12. Loosen range adjustment locking screw (Figure 8) and turn range screw to position range spring approximately in line with zero adjustment assembly. Tighten range adjustment locking screw.

13. Turn on supply air to Function Generator.

14. Apply 3 psig air pressure to gain control signal bellows (connection E4).

15. Check position of cam follower roller on cam. If cam roller is not on zero mark (second line), rotate gain control zero adjustment screw (Figure 8) until roller position is correct.

16. Apply air pressure to Controller A bellows (connection E1) 6 psig for 3-15 psig units, 9 psig for 3 to 27 psig units. Connect output connection 0 to a pressure gage or manometer.

17. Output pressure should be 6.84 psig for 3 to 15 psig units, 10.68 psig for 3 to 27 psig units.

18. To correct output pressure, loosen flexible coupling screws on Controller gain shaft and shift Controller gain arm until output pressure is correct. When correct output pressure is obtained, retighten screws on flexible coupling assembly.

19. Apply maximum input, 15 psig or 27 psig to gain control assembly bellows (connection E4) and note output pressure.

20. Output pressure should be 5.34 psig for 3 to 15 psig units, 7.68 psig for 3 to 27 psig units. If output pressure is not correct, loosen range adjustment locking screw (Figure 8) and turn range adjustment screw to correct output.

21. Apply 3 psig to gain control bellows (connection E4) and reset zero adjustment screw to obtain correct output pressure 6.84 psig for 3 to 15 psig units; 10.68 psig for 3 to 27 psig units. (Rotate zero adjustment screw counterclockwise to increase output pressure.)

22. Repeat steps 19, 20, and 21 until output pressure range is correct. Tighten range adjustment locking screw.

23. Function Generator is now ready to be placed in service after connecting required inputs for particular service and setting integral and derivative units, if employed, to desired speed of response.

NOTE: If Function Generator cannot be adjusted as outlined above, basic Controller alignment has been disturbed. Reset Controller in accordance with applicable procedure outlined under "Complete Calibration" on page 31.
Non-Linear Function, Direct or Reverse Action

The following procedure is intended for use where a blank cam is to be cut for a specific function. If a special calibration unit (Type AF0000000X) is involved, the cam has been cut at the factory. Refer to "Special Factory Calibration" on page 6 for information on placing the unit in service.

For service involving a specific function with a 3 psig null, the Controller portion of the Function Generator remains as calibrated at the factory. The gain control mechanism must be reset and a blank cam must be shaped in accordance with the following procedure (If the Controller null is to be other than 3 psig, the null point must be reset in accordance with "Controller Null Point Adjustment" on page 6 before proceeding.)

1 State desired function in terms of Controller input pressures and outputs desired

2 Determine required Controller gain settings in accordance with following formula

\[ \text{Gain} = \frac{\Delta D - \Delta C}{\Delta A - \Delta B} \]

Where

\[ \Delta A \] change in pressure in A Bellows
\[ \Delta B \] change in pressure in B Bellows (if employed)
\[ \Delta C \] change in pressure in C Bellows (if employed)
\[ \Delta D \] change in pressure in D Bellows (Controller output)

3. Gain control action is 'direct' if an increase in gain control signal pressure is to produce an increase in Controller gain. If desired function requires a decrease in gain on an increase in gain control signal pressure, unit must have 'reverse' gain control action. On reverse action control applications only, direction of gain arm rotation must be reversed as follows

Refer to Figure 12.

a. With left thumb on inner radius of driven pulley below tape tension spring, rotate driven pulley clockwise. Lower tape will slacken. Remove lower tape with right hand and hold under slight tension

b. Rotate driven pulley about 330° counterclockwise from original position. Upper tape will now become lower as in Figure 12 Reverse Action (This is done without disengaging upper tape and spring)

c. Rotate original lower tape one more turn counterclockwise around driving pulley then pass up between pulleys and over top of driven pulley. Rotate driven pulley slightly to provide slack and engage tape.

4. Plot gain control bellows input vs required Controller gain on Graph A.

5. Determine total gain arm rotation required for function by subtracting value on right hand scale corresponding to minimum gain from value corresponding to maximum gain of plotted function.

6. If gain value is between 10° and 45°, proceed with step 7. If gain value is 10° or less, modify gain control mechanism as follows

   a. Remove two 4-40 screws holding zero adjustment assembly in 45° position on cam follower arm. See Figure 9. Shift zero adjustment assembly to 10° position on cam follower arm (second and outside holes). Replace and tighten mounting screws

   b. Turn on supply air to Function Generator

   c. Gain Control piston shaft will move to fully extended position. Install zero stop pin (Figure 10). Lock zero stop pin in position with two retaining rings.

   d. Turn off supply air to Function Generator

7. Determine slope of plotted function at intervals of 5% of gain control signal. The slope of the plotted function is the difference between highest and lowest value from right hand scale corresponding to particular 5% input change.

8. Value determined in step 7 must not exceed 6.6 or be less than 0.21 for any 5% input change interval. If desired function is not within these limits, function cannot be performed unless it is modified so that sections of curve beyond 6.6 or less than 0.21 are eliminated. (These figures represent maximum and minimum workable cam rise limitations.)

9. Remove 45° gain arm rotation cam from gain control assembly and install blank gain arm rotation cam.

10. Loosen range adjustment locking screw (Figure 8) and turn range screw to position range
IMPORTANT: The plotted curve of the desired function must be a continuous line and may not change direction. (The sign of the slope must remain constant for any point although the value of the slope may change with the function.) An example showing the application of this graph to a typical function is given on page 16.

GRAPH A  Function Generator Gain vs Input Limits
1. State desired function in terms of gain control input (column A) and desired controller gain (column B).

2. Calculate percent of input range (column C) and plot function on graph A.

3. Determine actual gain arm rotation (column G) by subtracting minimum rotation (column E) from maximum rotation (column F) for each 5% increment of input range (column D). Gain arm rotation values are read on right hand scale of graph A.

4. Since all values in column G lie between 21 and 66, gain control cam can be shaped to provide this function.

**Example A**  Method of Checking Desired Function
spring approximately in line with zero adjustment assembly. Tighten range adjustment locking screw.

11. Connect an accurate gage or manometer to output connection "O". Connect a variable pressure input and a gage or manometer to each Controller input and to gain control input E4. Turn on supply air.

12. Supply maximum inputs to Controller and gain control mechanism for which there is a known output.

13. Scribed line on blank cam should be directly below follower arm roller. If not, set line beneath follower arm roller by turning zero adjustment screw (Figure 8).

14. Loosen set screws on flexible coupling assembly to free Controller gain arm. See Figure 5. Position gain arm to provide correct known output. Lock gain arm in this position by retightening set screws of coupling assembly.

15. Apply next lower input condition to all inputs and mark cam at point of contact with cam follower arm roller.

16. Adjust input to gain control mechanism (input to E4) until correct output pressure is obtained. Mark cam with a radial line from center to point of contact with cam follower arm roller.

17. Measure distance from cam center to point marked in step 15. Scribe this distance on radial line marked in step 16.

18. Repeat steps 15, 16 and 17 for each descending increment of inputs for which there is a known output until piston shaft hits minimum stop.

19. Remove all pressure from Function Generator and remove blank cam.

20. Connect points scribed on radial lines with a smooth continuous curve. At last radial line, continue curve parallel to remaining blank cam slope.

21. Begin shaping cam. Cut cam 1/16 inch outside of scribed curve except at highest point (maximum input). Highest point is used as reference and must not be changed. Do not attempt to complete cam shaping operation in one or two cycles of pressure applications. Remove cam material only in small amounts until desired accuracy for input-output relationship is attained.

22. Replace blank cam on gain control mechanism and tighten mounting screws.

23. Turn on supply air. Supply maximum inputs to Controller and gain control mechanism for which there is a known output.

24. If output pressure is not correct, turn zero adjustment screw (Figure 8) until correct output pressure is obtained.

25. Repeat steps 13 thru 22 until desired function is generated by shaped cam.

26. Apply maximum input to gain control connection E4 and adjust maximum stop (Figure 13) to obtain approximately 1/16-inch clearance between maximum stop screw and maximum stop bracket.

27. Function Generator is now ready to be placed in service after connecting inputs as required for particular service and setting integral and derivative units, if employed, to desired speed of responses.

NOTE: If Function Generator cannot be adjusted as outlined above, basic Controller alignment has been disturbed. Reset Controller in accordance with applicable procedure outlined under "Complete Calibration" on page 31.
MAINTENANCE

The air supply to the Function Generator must be kept free of dirt, oil, and moisture for satisfactory operation. Inspect the felt filters in the Function Generator mounting base and replace them if they are dirty. These filters are included as added protection only and are not intended to supplement the required clean air supply.

All pressure connections must be kept air tight. Periodically check all air pressure connections for leakage with a soapsuds solution.

If the Function Generator is not operating satisfactorily, refer to appl cable heading on fault correction chart below.

FAULT CORRECT ON CHART

<table>
<thead>
<tr>
<th>FAULT</th>
<th>CAUSE</th>
<th>CORRECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROLLER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller unstable</td>
<td>a. Interference of parts</td>
<td>a. Adjust clearance or replace parts as necessary.</td>
</tr>
<tr>
<td>Unit has insufficient sector plate adjustment</td>
<td>a. Hinges out of alignment</td>
<td>a. Reset hinge alignment (page 31 step 8)</td>
</tr>
<tr>
<td>Gain adjustment rough and unrepeatable</td>
<td>a. Excessive bearing end play</td>
<td>a. Replace bearing assembly.</td>
</tr>
<tr>
<td>Bellows cannot be matched</td>
<td>a. Hinges out of alignment</td>
<td>a. Reset hinge alignment (page 31 step 8).</td>
</tr>
<tr>
<td>Controller inoperable</td>
<td>a. No air supply</td>
<td>a. Check supply connection.</td>
</tr>
<tr>
<td></td>
<td>b. Booster orifices clogged</td>
<td>b. Depress orifice cleanout plungers WARNING Do not depress plunger if Type AF is used with a selector station, unless station is in manual operation</td>
</tr>
<tr>
<td></td>
<td>c. Vane not touching nozzle</td>
<td>c. Reposition vane</td>
</tr>
<tr>
<td></td>
<td>d. Dirty air supply</td>
<td>d. Replace booster and blow out lines</td>
</tr>
<tr>
<td></td>
<td>e. Derivative switch is closed</td>
<td>e. Check derivative switch</td>
</tr>
<tr>
<td></td>
<td>b. A-B bellows not matched</td>
<td>b. Match bellows (see page 31)</td>
</tr>
<tr>
<td>Poor sensitivity</td>
<td>a. C-D bellows not matched</td>
<td>a. Match bellows (see page 31)</td>
</tr>
<tr>
<td></td>
<td>b. Leak in output line</td>
<td>b. Check and repair line</td>
</tr>
<tr>
<td>Set Point changes with integral adjustment</td>
<td>a. Leak beyond integral valve (C bellows)</td>
<td>a. Check seals and repair or replace bellows.</td>
</tr>
<tr>
<td>Integral Time not equal in both directions</td>
<td>a. Leak beyond integral valve (C bellows)</td>
<td>a. Check seals and repair or replace bellows</td>
</tr>
<tr>
<td>Derivative Time not equal in both directions</td>
<td>a. Leak beyond derivative valve (D bellows)</td>
<td>a. Check seals and repair or replace bellows</td>
</tr>
<tr>
<td>FAULT</td>
<td>CAUSE</td>
<td>CORRECTION</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>GAIN CONTROL MECHANISM:</strong> Controller gain arm does not follow changes in gain control signal</td>
<td>a. Coupling assembly locking screw loose</td>
<td>a. Tighten coupling assembly screws (see Figure 5)</td>
</tr>
<tr>
<td></td>
<td>b. Broken drive tapes</td>
<td>b. Check condition of gain arm drive tapes. Replace if necessary (see page 21)</td>
</tr>
<tr>
<td></td>
<td>c. Output tape drive pulley loose on tape drum shaft</td>
<td>c. Check and tighten set screws which lock pulley on end of tape drum shaft.</td>
</tr>
<tr>
<td>Output shifts in one direction only</td>
<td>a. Broken center tape on tape drum assembly</td>
<td>a. Check for broken tape and replace tape drum assembly if required (see page 22).</td>
</tr>
<tr>
<td></td>
<td>b. Broken return spring in rolling diaphragm assembly</td>
<td>b. Disassemble rolling diaphragm assembly (see page 23) and replace spring if necessary.</td>
</tr>
<tr>
<td>Output remains at maximum while gain control signal changes</td>
<td>a. Broken return spring in zero adjustment assembly</td>
<td>a. Check return spring and replace if cracked or broken</td>
</tr>
<tr>
<td></td>
<td>b Nozzle of gain control mechanism clogged</td>
<td>b. Remove and clean nozzle. Remove and blow out connecting tube. Check condition of air supply. Change filters if necessary.</td>
</tr>
<tr>
<td>Output remains at minimum while gain control signal changes</td>
<td>a Gain control (E4) bellow ruptured</td>
<td>a. Check gain control bellows and replace if damaged (see page 23).</td>
</tr>
<tr>
<td></td>
<td>b Rolling diaphragm assembly leaking or rolling diaphragm ruptured</td>
<td>b. Disassemble rolling diaphragm unit (see page 23). Replace rolling diaphragm or realign assembly as required.</td>
</tr>
<tr>
<td>Gain control mechanism does not provide full travel for full range control signal change</td>
<td>a Gain control nozzle and vane are not correctly aligned</td>
<td>a. Inspect nozzle to make certain it is perpendicular to vane. Loosen nylon nozzle locking screw and reposition nozzle if required.</td>
</tr>
<tr>
<td>Excessive hysteresis or poor repeatability</td>
<td>a. Loose tape on tape drum assembly</td>
<td>a. Inspect tape drum assembly for a loose tape. If screw held end of tape is loose, replace and tighten screw. If tape is loose at drum end (broken weld), replace tape drum assembly.</td>
</tr>
<tr>
<td>FAULT</td>
<td>CAUSE</td>
<td>CORRECTION</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>BOOSTER RELAY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Booster unit output pressure does not immediately increase when flow of air is blocked.</td>
<td>a. Clogged nozzle orifice</td>
<td>a. Depress orifice cleanout plungers. WARNING Do not depress plunger if Type AF is used with a selector station, unless station is in manual operation.</td>
</tr>
<tr>
<td></td>
<td>b. Leakage around sections of Booster casing</td>
<td>b. Torque four screws clamping Booster sections together to 30 in lb</td>
</tr>
<tr>
<td></td>
<td>c. Dirty filters</td>
<td>c. Remove and replace filters.</td>
</tr>
<tr>
<td></td>
<td>d. Booster calibration incorrect</td>
<td>d. Check Booster calibration (see Complete Calibration on page 31).</td>
</tr>
<tr>
<td>2 Booster output sluggish or output increases then drops to zero when flow of air is blocked</td>
<td>a. Internal leakage.</td>
<td>a. Replace Booster Relay</td>
</tr>
<tr>
<td></td>
<td>b. Dirty filters</td>
<td>b. Remove and replace filters</td>
</tr>
<tr>
<td>3 Booster unit output pressure does not immediately decrease when vane is pulled away from nozzle.</td>
<td>a. Blocked air line from Booster unit to nozzle.</td>
<td>a. Remove line and clean</td>
</tr>
<tr>
<td></td>
<td>b. Booster calibration incorrect.</td>
<td>b. Check Booster Calibration (see &quot;Complete Calibration&quot; on page 31)</td>
</tr>
<tr>
<td></td>
<td>c. Internal leakage.</td>
<td>c. Replace Booster Relay.</td>
</tr>
</tbody>
</table>

CONTROLLER ASSEMBLY

The following disassembly procedures require that the controller portion of the Function Generator assembly be removed from the mounting manifold.

NOTE: Before attempting to remove the Controller from the mounting manifold, make certain that the three captive mounting screws (refer to Figure 3 on page 5) are completely unscrewed from the base. The Controller, with gain mechanism attached, can then be pulled free. (Some resistance will be evident due to the O ring seals on the manifold.)

Removal of Bellows, Sector Plate, or Tie Plate

1. Remove screws (10) attaching balance beam (25) to castings (Figure 32).

2. Unlock bellows set screws (26).

3. Remove range spring nuts (45) Remove spring supports (8 or 9) with springs attached.

4. Remove gain assembly vane (41) and vane adjustment (24) by removing screw (48).

5. Remove bolts (23) attaching side castings (30 and 31) to rear manifold (22) Remove screw (18) holding side casting together. Pull castings forward slightly and remove castings with bellows attached.
6. Remove retaining ring (12) and push bellows (13) out of casting.

7. Disassemble center structure only if sector (29) or tie plate (15) replacement is necessary.

8. Reassemble unit following steps 1 thru 7 in reverse order. Coat all O-rings lightly with silicone grease.

**Bearing Adjustment** (refer to Figure 32)

Normally, the bearing adjustment of the Controller portion of the Function Generator assembly should not have to be disturbed. If, however, the Controller gain adjustment arm appears loose and the Controller cannot be properly nulled, the gain adjustment arm can be removed and the bearing adjusted as follows:

1. Remove vane (41) and nozzle (52) from Controller assembly.

2. Remove Booster Relay unit (2) from rear of Controller manifold (22).

3. Remove rear Controller manifold (22).

**NOTE:** Be sure to remove bolts attaching nozzle arm assembly from between bellows (13)

4. Rotate nozzle arm assembly (38) and withdraw arm from between bellows (13).

5. Remove nozzle arm assembly (38) from pivot support

6. Clean bearings in upper (35) and lower (37) bearing plates with solvent. Both bearings must turn freely and without excessive free play. Add a light grease to bearings. Lubricate all O-rings lightly with silicone grease.

7. Install nozzle arm assembly (38) in upper bearing plate (35). Add lower bearing plate (37) with two screws. Do not fully tighten screws.

8. Place entire pivot support assembly in a vise. Rotate nozzle arm 90 degrees. If nozzle arm turns smoothly, tighten screws (18). If nozzle arm rotation discloses a tight spot, tap lower bearing plate (37) lightly with a hammer. Direction of tapping should be perpendicular to nozzle pivot shaft and such that axis of this shaft is shifted.

9. Repeat bearing plate adjustment until nozzle arm turns freely. When proper alignment is obtained, tighten screws (18).

**Integral Valve Dial Range**

The integral valve setting is adjusted by turning the adjustment screw beneath the dial indicator on the integral plug-in unit attached to the Controller. The dial is graduated on one side for a range of 0.5 to 24 repeats per minute. The other side is calibrated for 15 to 100 repeats per minute. To change the scale range:

1. Set indicating dial to 15 repeats per minute by turning integral adjustment screw.

2. Remove "E" type retaining ring which holds indicating dial in position.

3. Remove indicating dial, turn over and replace in position to read 15 repeats per minute on reverse side. Replace "E" type retaining ring to hold dial in position.

**GAIN CONTROL MECHANISM**

Before attempting maintenance on the gain control mechanism separate it from the Control assembly as follows.

1. Loosen set screw holding flexible coupling assembly to Controller Gain Arm Shaft and slide flexible coupling off shaft.

2. Remove four screws holding gain control mechanism to Controller Assembly.

**CAUTION:** The steel tapes used in the gain control mechanism are .0015 inch thick. They must be handled properly. Take extreme care during any assembly or adjustment that involves the tapes to avoid any sharp bends, nicks or other damage. Nicked or bent tapes will function properly, but service life will be considerably shortened.

**Drive Pulley and Tapes** (refer to Figure 33)

The tapes of the drive pulley assembly are welded to the output pulley. If the tapes have been damaged, the drive pulley and tapes must be replaced as a unit, as follows.

1. Release tapes from drive pulley by sliding tape off tab on driven pulley and unhooking second tape from spring (see Figure 12).

2. Loosen two set screws (23) holding drive pulley assembly (25) to output shaft assembly (16) and slide drive pulley assembly off end of output shaft.

3. Mount replacement drive assembly on output shaft. Make certain that set screws (23)
are correctly aligned with holes drilled in output shaft.

4. **Direct Action Units Only** Wrap tape with hole for spring twice around drive pulley and hook spring (32) into end of tape. Place other end of spring over tab provided on driven pulley as shown in Figure 15. Wrap remaining tape once around drive pulley in opposite direction. Slip end of tape over tab provided on driven pulley. Make certain that tapes are tight.

**Reverse Action Units Only** Wrap tape which was connected to spring. 3/4 of a turn around drive pulley and reconnect spring (32) by passing one end thru end of tape and hooking other end in reverse direction over spring tab provided on driven pulley. Remaining (outside) tape is wound 3 turns around output pulley and slide in reverse direction over tab on driven pulley (Figure 15). Make certain that tapes are tight.

**Zero Adjustment Tape**

The tape of the zero adjustment assembly is welded to the zero adjustment drum (50). If necessary to replace the tape, the complete zero adjustment assembly must be replaced as follows. Refer to Figure 33.

1. Tip gain control mechanism bellows beam (38) towards zero adjustment assembly to relieve tension on zero adjustment tape. Unhook tape from range spring (51).

2. Note position of zero adjustment assembly on cam follower arm assembly (first and third holes from pivot for 45° gain arm rotation units, second and fourth holes for 10° gain arm rotation units). Remove screws (24) holding zero adjustment assembly to cam follower arm and remove zero adjustment assembly.

3. Install new zero adjustment assembly in correct holes for desired gain arm rotation. Replace and tighten mounting screws.

4. Tip bellows beam towards zero adjustment assembly and reconnect range spring to zero adjustment tape.

5. Refer to applicable procedure listed under "Placing in Service" on page 6 for required readjustment.

**Piston Shaft Tapes**

The piston shaft tapes are welded to the drum assembly. If a tape is damaged or broken, the complete tape drum assembly must be replaced as follows. Refer to Figure 33.

1. Release drive pulley tapes from driven pulley by sliding tape off tab on driven pulley and unhooking tape from spring (see Figure 12).

2. Loosen two set screws (23) holding drive pulley assembly (25) to output shaft assembly (16).

3. Slide drive pulley assembly off end of output shaft.

4. Remove upper cylinder housing (12) from gain control mechanism by loosening screws (36). Remove two screws (24) to release top piston shaft tapes from extended bracket of piston shaft.

5. Lift piston shaft to extended position to reach screw (13) holding bottom piston shaft tape to piston shaft and release bottom tape.

**NOTE** Move piston shaft carefully to avoid damaging tapes. Do not allow piston shaft to slip back to retracted position after tapes are loose.

6. Release two set screws (23) locking tape drum assembly (14) on output shaft assembly (16). Withdraw output shaft assembly (with cam attached) from upper cylinder housing assembly (12).

7. Tape drum assembly is now free and can be removed from upper cylinder housing assembly. Take care not to damage tapes.

8. Place new tape drum assembly in position and retain by sliding output shaft assembly thru bearing of upper cylinder housing, thru drum assembly, and thru bearing on opposite side of upper cylinder housing.

9. Lock tape drum assembly in place on output shaft with set screws (23). Make certain both set screws are correctly aligned with holes drilled in output shaft.

10. Wrap two outside tapes one turn around tape drum and attach to piston shaft with screws (24). Take care not to damage tapes.

11. Fasten center tape from drum assembly to bottom piston shaft using shoulder screw (13).

12. Carefully lower piston shaft from extended position while observing tapes to make certain that they are winding properly.

13. Mount drive pulley assembly on output shaft. Make certain that screws (23) are correctly aligned with holes drilled in output shaft before tightening set screws.
14 Direct Action Units Only
Wrap tape with hole for spring twice around drive pulley and hook spring (32) into end of tape. Place other end of spring over tab provided on driven pulley as shown in Figure 14. Wrap remaining tape once around drive pulley in opposite direction. Slip end of tape over tab provided on driven pulley. Make certain that tapes are tight.

Reverse Action Units Only
Wrap tape which was connected to spring. 3/4 of a turn around drive pulley and reconnect spring (32) by passing one end thru end of tape and hooking other end in reverse direction over spring tab provided on driven pulley. Remaining (outside) tape is wound 3 turns around output pulley and slid in reverse direction over tab on driven pulley (see Figure 15). Make certain that tapes are tight.

15 Refer to applicable procedure listed under "Placing in Service" on page 6 for required readjustment.

Rolling Diaphragm (refer to Figure 33)

1. Loosen set screw (26) holding bellows coupling assembly to Controller gain arm shaft. Slide sleeve of bellows coupling off gain arm shaft.

2. Remove four screws (35) which hold gain control mechanism to Controller.

3. Lift complete gain control mechanism free of Function Generator assembly.

4. Remove four screws (36) which hold upper cylinder housing assembly (12) to lower cylinder housing base (6).

5. Upper cylinder housing assembly with piston and shaft attached can now be lifted from lower cylinder base, releasing rolling diaphragm (8).

NOTE: Lift upper cylinder housing carefully while holding cam follower arm. Since gain control cam will be removed, it is desirable to release tension on cam follower arm, caused by range spring, gradually to prevent damage to flexible tape of zero adjustment assembly.

6. With shaft held in 10° position, cover sealing lip of new rolling diaphragm (8) with a light coating of O ring lubricant and install over piston (10). (Make certain correct side of diaphragm is against piston.) Place diaphragm sealing lip in groove of upper cylinder housing.

7. Carefully fasten upper cylinder housing to lower cylinder base with four screws (36). Check, while tightening screws, that diaphragm remains in place and is seating properly.

8. Return gain control mechanism to position in Function Generator assembly. Lock gain control mechanism to Controller with four screws (35).

9. Place flexible coupling assembly in position over Controller gain arm shaft. DO NOT TIGHTEN SET SCREW (26).
10. Refer to applicable section under "Placing in Service" on page 6 for correct method of realigning gain control mechanism with gain arm shaft of Controller portion of Function Generator.

Feedback Bellows Replacement
(refer to Figure 33)

1. Loosen set screw (26) holding flexible coupling assembly to Controller gain arm shaft. Slide sleeve of flexible coupling off gain arm shaft.

2. Remove four screws (35) which hold gain control mechanism to Controller.

3. Lift complete gain control mechanism free of Function Generator Assembly.

4. Remove three screws (36) which hold transmitter casting (48) to lower cylinder housing base (6). Disconnect flexible air line (44) from nozzle (58). Lift transmitter casting from base with bellows beam assembly attached.

NOTE: Support cam follower arm when lifting assembly clear of base. It is desirable to release tension on cam follower arm, caused by range spring, gradually to prevent damage to flexible tape of zero adjustment assembly.

5. Remove screw (34) which holds bellows beam (38) to bellows assembly (47). Unscrew and remove bellows taking care not to place excessive strain on hinges of bellows beam. Remove O-ring (37) from bellows assembly.

6. Lubricate O-ring (37) and place over end of new bellows assembly. Thread bellows assembly into transmitter casting. Tighten firmly. Reattach bellows beam to bellows assembly with screw (34).

7. Remount transmitter casting on lower cylinder housing base with three screws (36). Reconnect flexible air line to nozzle.

8. Return gain control mechanism to position in Function Generator assembly. Lock gain control mechanism to Controller with four screws (35).

9. Place flexible coupling assembly in position over Controller gain arm shaft. DO NOT TIGHTEN SET SCREW (26).

10. Refer to applicable section under "Placing in Service" on page 6 for correct method of realigning gain control mechanism with gain arm shaft of Controller portion of Function Generator.

BOOSTER RELAY

It is recommended that the Booster Relay portion of the Function Generator be returned to the factory for repair, since realignment of the diaphragm clamping assembly and the required recalibration is extremely critical.
DESCRIPTION OF OPERATION

The MINI-LINE 500 Function Generator is essentially a pneumatic Controller to which a pneumatic gain control mechanism has been added. The gain control mechanism is sensitive to an air pressure signal and acts to reposition the gain arm of the Controller whenever a change in this signal occurs. Refer to Figure 16.

The gain control mechanism includes a cam which controls the vane to nozzle distance for any given signal pressure applied. The shape of the cam determines the amount of gain change that will occur in the Controller. It is this cam that enables the unit to generate any given function within its range.

FIGURE 16 - Schematic of Pneumatic Function Generator
In addition, the Function Generator has a Booster Relay connected directly to the Controller. The Booster Relay operates in conjunction with the nozzle and vane assembly of the Controller to provide an output pressure signal proportional to the variable influencing the Controller.

The operation of the Controller, the pneumatic gain control mechanism, and the Booster Relay are discussed separately below.

**PNEUMATIC CONTROLLER**

Refer to Figure 17. A change in input pressure to the bellows units repositions the two balance beams. The resultant shift in balance beam alignment causes a change in the angle of the tie plate connecting the free ends of the balance beams. The tie plate supports a sector plate on which position the vane of the Controller gain mechanism. The shift in vane and nozzle distance produces a nozzle pressure change that is amplified and transmitted by the Booster Relay as the output pressure.

The Booster Relay also supplies the amplified pressure to the D bellows to eliminate the unbalance caused by the input pressure change and restore the vane and nozzle to the "at balance" distance.

The effect a given input pressure change has upon the output pressure depends upon the function for which the Controller is set, the gain setting of the unit at that point, and the control actions employed.

**Controller Functions**

With input pressure applied only to the A bellows, the Controller transmits an output pressure proportional to the input pressure. The amplification of the output pressure is dependent upon the gain setting of the unit at that point.

With the input pressure applied only to the B bellows (either directly thru connection E2 or thru connection E1 with the direct reverse switch in the "R" position), the Controller transmits an output pressure proportional to the input pressure, but acting in the opposite direction. The amplification of the output pressure is dependent upon the gain setting at that point.

Inputs directly to the C bellows are used only for subtracting or averaging functions. There is a C bellows pressure on all applications which involve integral control action. However, this pressure is received from the D bellows thru a throttling valve and not from a separate manifold connection. Pressure in the C bellows is unaffected by the gain setting.

The D bellows does not have an individual input signal, but is connected directly to the Booster Relay output pressure (feedback).

With input pressures applied to more than one bellows of the Controller (as in differential pressure applications), the output pressure is the algebraic sum of the resultant forces on the A, B, and C D balance beams. Pressures applied to the A and C bellows act in the same direction and a totaling function is obtained. Pressures applied to the A and B bellows (or the C and D bellows) are in opposition (differential function) and the output pressure is proportional to their difference. The change in output pressure from the Function Generator for given input pressure changes is determined as follows:

\[ \Delta D = (\Delta A \Delta B) + \Delta C \]

where:

- \( \Delta D \) output pressure change
- \( \Delta A \) input pressure change to A bellows
- \( \Delta B \) input pressure change to B bellows
- \( \Delta C \) input pressure change to C bellows
FIGURE 18 Schematic of Controller Gain Mechanism

Gain Setting

Gain is the ratio of the resulting output pressure change for a given change in input pressure.

\[ \text{Gain} = \frac{\text{change in output pressure}}{\text{change in input pressure}} \]

The gain mechanism of the Controller is shown schematically in Figure 18. The amount of gain for any given position of the gain adjustment arm is the ratio of distance \( L_1 \) to \( L_2 \). If the nozzle and vane assembly is positioned near the A-B bellows end of the sector plate, a small change in A-B bellows pressure will require a large change in output pressure to rebalance the Controller. With the nozzle and vane positioned near the C-D bellows end of the sector plate, the same input pressure change to the A-B bellows will produce a smaller output pressure change.

The gain of the Controller can be varied from 0.2 to 20. This represents a Controller gain arm rotation of approximately 90°. (The gain control mechanism, when the Controller is used as part of a Function Generator, can provide 45° of Controller gain arm rotation. This 45°, however, can be taken at any point within the 90° span of the Controller.) The gain in a standard factory calibrated unit is set to range from 3 to 3. A 10 psi change in the input pressure will produce a 2 psig change in the output pressure at the lowest gain setting. At the highest gain setting, a 1 psig change in input pressure will produce a 20 psig change in the output pressure.

Null Balance

The Controller portion of the Function Generator is 'nulled' when the sector plate is made parallel to the balance beams with the 'null pressures' required for the particular application applied to the Controller. This is accomplished by proper adjustment of the Controller as outlined under 'Placing in Service' on page 6.

At null balance, the gain adjustment arm can be positioned at any point thru the full gain range without causing a change in the output pressure since, as a result of the parallel alignment with 'null pressures' applied, no change in the nozzle to vane distance occurs during full travel of the gain mechanism.

The required 'null pressures' for any particular installation depend upon the conditions of the individual control system and the range of input pressures which will be applied to the Function Generator.

Integral Control Action

Integral control action of the Controller portion of the Function Generator is accomplished by means of a volume chamber and adjustable throttle valve assembly plugged into the air line between the C and D bellows. Refer to Figure 19.
The speed at which the integral action takes place is determined by the throttle valve setting and is expressed as the integral rate in repeats per minute. The plug in integral unit provides an integral rate from 0.5 to 100 repeats per minute.

**Derivative Control Action**

Derivative action in the Controller portion of the Function Generator is accomplished by a unit containing a spring-loaded bellows inclosed in a volume chamber. Refer to Figure 20. The unit is plugged into the air line between the Booster Relay assembly and the D bellows.

The restriction, controlled by an adjustable throttle valve, between the Booster Relay and the D bellows causes an initially amplified output pressure change. The amplified output pressure returns to normal as the volume chamber pressure bleeds to the D bellows.

The throttle valve assembly setting determines the time interval required for the accelerated output signal to return to normal. The plug in derivative unit provides a derivative time of from 1 to 10 minutes.

**GAIN CONTROL MECHANISM**

The gain control mechanism is shown in Figure 21. The unit utilizes a piston and rolling diaphragm (bellofram) assembly to provide the force required to shift the Controller gain arm. The pressure in the diaphragm chamber depends upon the pressure applied to the E4 connection (gain control signal pressure). A pressure increase at connection E4 moves the vane towards the nozzle. The resultant back pressure in increase causes movement of the piston of the diaphragm assembly. This movement is transmitted by the tape drum shaft, thru a pulley arrangement, to the gain arm of the Controller. In addition, the tape drum shaft repositions the vane of the vane and nozzle assembly by means of a cam. The shape of this cam determines the amount of Controller gain arm rotation which will take place for any given change in the gain control signal pressure to connection E4.

Two sets of steel tapes are used in each gain control mechanism. One set is used to transmit the bellofram piston movement to tape drum shaft rotation and the second is used in turn to transmit the tape drum shaft rotation to the rotation of the Controller gain arm assembly. Refer to Figure 16.

The piston of the bellofram assembly is rigidly connected to a piston shaft that transmits the linear motion of the piston to three steel tapes. One end of the tapes is fastened to the tape drum shaft and wrapped around its circumference. The tapes are wrapped in opposite directions (see Figure 12) and attached to the piston shaft so that during motion of the shaft at least one tape is wrapping and one unwrapping from the tape drum shaft. The tapes convert linear motion to rotational motion with a minimum of backlash.

Full travel of the bellofram piston produces 270 degrees of rotation of the tape drum shaft and the feedback cam which is mounted on the end of the shaft. (This rotation is reduced to 45 degrees when the tape drum shaft motion is transmitted to the Controller gain arm shaft.)
The second set of tapes have one end fixed to the tape drum shaft and are wound in opposite directions around its circumference. The other end of each tape is attached to the circumference of the output pulley which is coupled to the gain arm of the Controller. Refer to Figure 16. Rotation of the tape drum shaft is transmitted to the output pulley. However, since the output pulley is larger than the tape drum shaft the amount of angular rotation is considerably reduced.

The gain control mechanism cam is mounted on the end of the tape drum shaft and is used for feedback control to the gain unit vane and nozzle assembly.

Any rotational motion of the tape drum shaft also rotates the feedback cam. This motion is picked up by the cam follower connected to the cam follower arm of the pivot shaft. The motion of the pivot shaft exerts a force proportional to the cam rise on the range spring. The spring is connected to the bellows beam which acts as the vane of the gain unit vane and nozzle assembly. The movement is in the direction required to oppose the motion of the bellows beam caused by the input pressure change in the gain control signal pressure applied to connection E4. At balance conditions, the forces acting on the bellows beam from the range spring and from the gain control signal pressure are equal.

Three cams are supplied with the Function Generator. The 45° cam provides a full range linear function. The 10° cam provides a more accurate linear function when the total required Controller gain arm rotation is 10° or less. In addition, a blank cam is supplied which must be shaped to provide a desired non-linear function (For cam shaping procedure refer to "Placing in Service").

Figure 22 shows the relationship between degrees of gain arm rotation and the actual gain of the Controller. The 45° or 10° span can be taken over any portion of the gain scale. The gain change for any given gain control input signal change depends upon the section of the Controller gain range selected.

FIGURE 21 Gain Control Mechanism

FIGURE 22 - Gain Arm Rotation Relationship to Gain Scale
BOOSTER RELAY

The Booster Relay amplifies the D bellows pressure of the Function Generator in order to re-establish the vane and nozzle distance. Thus amplified pressure is also the output pressure of the Function Generator.

Figure 23 is a schematic operating diagram of the Booster Relay assembly.

Three diaphragms divide the inside of the unit into four air pressure chambers. The diaphragms move together since they are clamped at their centers by the diaphragm clamp assembly. Since chambers 1 and 4 are connected and are equal in effective diaphragm area, their opposing forces on the diaphragm assembly are balanced out. Chamber 2 is open to atmosphere. The operator spring exerts a downward force on the diaphragm assembly. Thus, since chamber 3 pressure exerts an upward force, the position of the diaphragm assembly is a direct function of chamber 3 pressure.

Supply air enters chamber 3, and the nozzle of the Controller portion of the Function Generator, thru a pressure-reducing orifice. The rate of air flow from the Controller nozzle determines the magnitude of the pressure in chamber 3. At balance, this pressure is approximately 2 psig, which is the pressure required to balance the downward force of the operator spring.

When the measured input to the Function Generator increases, the sector plate of the Controller assembly shifts to position the vane closer to the nozzle tip. This retards the flow of air from the nozzle and increases the pressure in chamber 3. The pressure increase moves the diaphragm assembly upward, opening the inlet valve and closing the exhaust valve. Supply air enters chamber 1 thru the inlet valve, causing the output pressure of the Function Generator to begin to increase.

Chamber 1 pressure is also applied to the D bellows. As the pressure increases, the D bellows extends, tipping the sector plate to move the vane away from the nozzle. The resulting increased rate of air flow from the nozzle causes the pressure in chamber 3 to begin to decrease.

Chamber 1 pressure will continue to increase until the vane is restored to the position with respect to the nozzle which produces a pressure of approximately 2 psig in chamber 3. The operator spring then has moved the diaphragm assembly downward to its original position, closing the inlet valve and causing the Function Generator output pressure to stabilize at the new increased value.

When the measured input to the Function Generator decreases, the operation of the Booster Relay as described above is reversed.
COMPLETE CALIBRATION

The Function Generator consists of three basic assemblies, the Controller, the gain control mechanism, and the Booster Relay. Each of these assemblies can be separately calibrated for basic alignment. If it has been necessary to replace or repair parts in any of the separate assemblies, the basic alignment of the unit can be reestablished following the applicable procedure outlined below. After the individual unit has been realigned, it will be necessary to repeat the steps outlined under "Placing in Service" to adjust the complete Function Generator for the required service.

Controller Assembly

If the Controller has been disassembled for replacement or repair of parts, or if the Function Generator could not be correctly adjusted for service as outlined under "Placing in Service", the basic Controller alignment must be reestablished as follows:

1. Release gain control mechanism from Controller by loosening setscrews holding flexible coupling assembly to Controller gain arm shaft. See Figure 24.

2. With Controller in place on mounting manifold, connect output connection "O" to a gage or manometer.

3. Connect supply pressure to manifold connection "S", 18 psig for 3 to 15 psig range, 30 psig for 3 to 27 psig range.

4. Open derivative switch or valve of derivative plug-in unit. Close integral switch or valve of integral plug-in unit. Refer to Figure 25.

NOTE: If integral or derivative plug-in units are employed, valve will be "open" or "closed" when adjusting screw is turned to full clockwise or counterclockwise position respectively.

5. Make certain that direct-reverse switch is in "D" position. Place proportional-proportional plus integral switch in "P" + I" position (see Figure 3). Plug connection E3R at manifold.

6. Apply midrange pressures to "E1", "E2" and "E3" connections, 9 psig for 3 to 15 psig range, 15 psig for 3 to 27 psig range. Turn on supply air.

7. Position gain arm at 1.0. Lock with knob mounted on base (item 70 Figure 32). Adjust A B and/or C-D sector screws (see Figure 26) to obtain an output equal to midrange pressure.

8. Beam hinges should be aligned with hinges on tie plate (refer to upper and lower beam alignment lines in Figure 26). If not, adjust beam position with A B and/or C-D sector bias screws until proper alignment is obtained. (This will necessitate readjusting A-B and/or C-D sector screws to regain midrange output pressure.)

9. Connect output "O" to connection E2 (in addition to gage or manometer). Connect separate variable inputs to E1 and E3. Tee connection.

FIGURE 25 - Integral and Derivative Switches
FIGURE 26 Controller Adjustments

E3R to E3 if recalibration is being performed on a Controller with an integral plug in unit in place.

10 Open integral switch or valve of integral plug in unit. Close derivative switch or valve of derivative plug-in unit.

11 Remove pressure from connection E3. Unlock set screws retaining C and D bellows (see Figure 26) and rotate bellows with bellows matching screws until eccentricity marks are located toward front of Controller.

12 Lock pointer of gain adjustment arm at line across scale below gain of 0.1. Adjust pressure to connection E3 to midrange value. Adjust C-D sector to provide midrange output pressure.

13 Apply pressure from minimum to maximum range to connection E3 while noting output pressure. Remove pressure from connection E3.

14 If output pressure increased, rotate C and D bellows clockwise by equal amounts (as viewed from their respective sides of Controller). If output decreased, rotate bellows counterclockwise by equal amounts. Do not exceed 90 degrees of rotation of either bellows.

15 Repeat steps 13 and 14 until output pressure change is less than 1.0 psig. Apply pressure to connection E3 and lock bellows with set screws.

16 Repeat step 13 If output pressure increases, rotate C-D bias screw clockwise. If output pressure decreases, rotate screw counterclockwise.

17 Repeat step 13 and step 16 until output pressure change is less than 0.5 psig. If more than 1.2 turn of C-D bias screw is required, return screw to original position, unlock C and D bellows and repeat steps 13 thru 17.

18 Tee connection E1 to E2 and connect a separate variable input pressure and gage. Connect a variable input pressure and gage to connection E3R.
19. Open derivative switch or valve of derivative plug-in unit. Close integral switch or valve of integral plug-in unit.

20. Unlock set screws retaining A and B bellows (see Figure 26) and rotate bellows until eccentricity marks are towards front of Controller.

21. Lock gain arm at line across gain scale above 20. Adjust pressure to connection E3 to midrange value. Adjust A B sector screw to provide a midrange output pressure.

22. Apply pressure from minimum to maximum range to connection E1 while noting output pressure. Remove pressure from connections E1 and E2.

23. If output increased, rotate A and B bellows counterclockwise by equal amounts (as viewed from their respective side of Controller). If output pressure decreased, rotate bellows clockwise by equal amounts. Do not exceed 90 degrees of rotation of either bellows.

24. Repeat steps 22 and 23 until output pressure change is less than 0.5 psig. Apply pressure to connections E1 and E2 and lock bellows.

25. Repeat step 22. If output in creases, rotate A B bias screw clockwise. If pressure decreases rotate screw counterclockwise.

26. Repeat steps 22 and 25 until output pressure change is less than 0.5 psig (If more than 1/2 turn of A-B bias screw is required, return screw to original position, unlock A and B bellows and repeat steps 22 thru 26.)

27. Remove locking knob. Controller portion of Function Generator assembly is now ready to be adjusted as outlined under applicable section of "Placing in Service."

IMPORTANT: Do not reconnect flexible coupling between Controller and gain control mechanism. This connection must be made only after determining that full 45° rotation of Controller gain arm is possible without exceeding maximum or minimum gain arm position limits.

Gain Control Mechanism

The actual calibration of the gain control mechanism is accomplished during the procedure outlined under "Placing in Service". However, if the gain control mechanism is disassembled for repair or replacement of parts, the basic alignment of the components can be established after reassembly as follows.

1. Place zero adjustment assembly (see Figure 27) in either 45 degree or 10 degree position on cam follower arm assembly.

2. Place end of range spring thru hole in lower pivot assembly. Slip other end of range spring thru hole in end of flexible tape (see

FIGURE 27 - Positioning of Zero Adjustment Assembly
FIGURE 28 - Gain Control Mechanism Adjustments

3. Loosen gain control mechanism nozzle locking screw to release nozzle. Adjust bellows beam, by positioning free end, until signal bellows convolutions are approximately parallel. Hold bellows beam in this position and slide nozzle in until it contacts vane. Lock nozzle in this position.

4. Install cam (45°, 10°, or blank, depending on service requirements) and rotate cam until position alignment line (first line on cam) is directly below cam follower arm roller. Tighten screws to lock cam in this position.

5. Apply 3 psig air pressure to gain control signal bellows (manifold connection "E4").

6. Adjust range screw (see Figure 28) to place range spring assembly approximately in line with zero adjustment assembly.

7. Turn zero adjustment screw to raise gain control nozzle approximately .005 inch off of vane.

8. Turn on supply air to gain control thru common supply connection "S" on Function Generator mounting manifold.

9. Turn zero adjustment screw until cam follower arm roller is directly above cam zero line (second line on cam).

10. If unit is to be used for an application requiring only 10° of Controller gain arm movement, install zero stop pin in extended piston shaft. Lock stop pin in position with two retaining rings. (See Figure 10).

11. Gain control mechanism of Function Generator assembly can now be calibrated for particular service application in accordance with procedures outlined under "Placing in Service" on page 6.

Booster Relay

The Booster Relay portion of the Function Generator assembly has only one adjustment. The valve adjustment, shown in Figure 29, adjusts the inlet valve seat to balance the effective areas of the chamber 1 and chamber 5 diaphragms to obtain an even rate of output pressure change.
psig for 3 to 15 psig units, 30 psig for 3 to 27 psig units.

5. Gradually apply about 2 psi air pressure to calibration block input connection to simulate nozzle back pressure from Controller portion of Function Generator. Note value of pressure (on nozzle back pressure manometer) at which output pressure increases at a constant rate. Gradually reduce nozzle back pressure and note nozzle pressure at which output pressure decreases at a constant rate.

a. If rate of output pressure rise slows down (decelerates), turn valve adjustment screw clockwise a small amount.

b. If rate of output pressure rise speeds up (accelerates), turn valve adjustment screw counterclockwise a small amount.

6. Repeat step 5 above until output pressure changes at a constant rate. The difference between the nozzle back pressure which causes a constant rise and that which causes a constant drop should be less than 0.1 psi and should occur between 1.6 psi and 2.5 psi.

7. If Booster Relay cannot be calibrated as described above, difficulty may be caused by leakage. Refer to 'Booster Relay' under "Maintenance" for correct method of assembling and proper alignment.

FIGURE 29 - Booster Relay Valve Adjustment

This adjustment normally does not require attention and is not part of the calibration procedure. The adjustment is sealed after calibration with a drop of Loctite cement (Grade C) at the factory. Do not change the setting of this adjustment unless absolutely necessary.

If the Booster Relay has been disassembled, or if the setting of the valve adjustment has been changed for any reason, check the calibration of the unit as outlined below.

1. Remove Booster Relay from Controller portion of Function Generator by removing mounting screws.

2. Attach calibration block (Bailey Part Number 5320549-2) to Relay using screws which held Relay to Controller. Connect unit in calibration set-up as shown in Figure 30.

3. Connect a mercury manometer to output pressure connection (on calibration block). Connect a second mercury manometer to tee fitting in piping to input connection of calibration block.

4. Apply supply air to Booster Relay supply pressure connection on calibration block; 18
An "X" in any Nomenclature position indicates that in this respect the unit is special. An "X" as a suffix to the Type Nomenclature indicates that the unit has been calibrated for a special function at the factory.
### TABLE B  Type AF Function Generator Specifications

#### A. Performance Characteristics (% Range Span, 75°F)

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#### B. Operating Conditions

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<td>28 to 35 psig</td>
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<td>16 to 20 psig</td>
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#### C. General

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REPLACEMENT PARTS

Spare Parts Kit

The Spare Parts Kits shown in Figures 31 thru 35 should be carried in stock. Specify the Spare Parts Kit part number to order a complete kit.

Ordering Individual Parts

Parts Drawing for the Type AF Function Generator are shown in Figures 31 thru 35. Normally these drawings will apply to the units furnished. However, there may be individual differences in specific units because of

a. Design changes made since the printing of this Instruction Section.

b. Special design of the Type AF Function Generator furnished to make it suitable for special applications

Therefore, when ordering parts, assure the receipt of correct replacements for the Function Generator by specifying on the order

1. The complete nomenclature (stamped on instrument nameplate) of the Function Generator for which parts are desired

2. The Parts Drawing on which each part is illustrated. (The Parts Drawing Number is given in the title for the Figure.)
FIGURE 31  Parts Drawing P92 2. Type AF Function Generator Assembly
FIGURE 32  Parts Drawing P92-4,
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### TABLE

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**NOTE** Specify number on label when ordering parts.
FIGURE 34  Parts Drawing P92 15, Booster Relay Assembly, Pt No 5319700 5
FIGURE 35  Parts Drawing P92 6, Mounting Base Assembly  Pt No 5323944-1
Product Warranty

Bailey Meter Company warrants the products manufactured by it to be free from defects in material and workmanship and will repair or replace, at its option, free of charge, f.o.b. its factory, such part or parts which prove defective within one year from date of shipment. In respect to any products which are not an integral part of a product manufactured by the Company, the warranty given by the manufacturer thereof shall apply.

Shipping Damage

We strongly recommend that you inspect and test your instrument as soon as you receive it. If the instrument is damaged or operates improperly, notify the carrier for inspection of the shipment. The carrier’s claim agent will prepare a report of damage, a copy of which should be forwarded to your nearest Bailey District Office (see back cover for location). The District Office will then tell you how to have the instrument repaired or replaced.

Service

The Bailey Meter Company is vitally concerned that your Bailey instrument provides continued, fine performance. This instruction manual is designed to fully describe the correct installation, operation, and maintenance of your instrument under recommended conditions. If the need arises, factory-trained Service Engineers are on call for prompt, in-plant maintenance. Telephone or wire your nearby Bailey District Office to make arrangements for this service.

Replacement Parts and Supplies

Complete parts drawings and recommended spare parts kit information are included in this instruction manual. When replacement parts or supplies are required for maintenance of your Bailey instrument, contact your nearest Bailey District Office (see back cover for location). Always specify complete data on the instrument nameplate on your inquiry or order for parts. Common parts are available for shipment with a 48-hour lead on a speed order basis.