NORTHERN ALBERTA INSTITUTE OF TECHNOLOGY
EDMONTON ALBERTA

INSTRUMENTATION TECHNOLOGY

MAGNETIC FLOW TRANSMITTER

General

The Foxboro Magnetic Flow Meter System measures the flow rate of most liquids and semi-liquids with freedom from many of the limitations of conventional flow meters of the differential pressure or variable area type. The meter reads volume flow rate at the flowing temperature; the calibration is unaffected by changes in pressure, temperature, viscosity, or density of the flowing fluid. There is no restriction in the flow line. Corrosive liquids or slurries are measured with ease.

The Magnetic Flow Meter System consists of a flow transmitter connected by electric cable to a Dynalog receiver or Model 696 Converter. The flow transmitter consists simply of a non-magnetic tube through which the liquid flows, an electrically insulating liner on the inside of the tube, an electromagnet which induces a magnetic field through the tube, and two metallic electrodes which are essentially flush with the inside surface of the tube and which contact the flowing liquid. The electromagnet is enclosed in a gasketed housing with provision for electrical connections. See Fig. B3573.

Specifications

Calibrated Accuracy: ±1% of full scale throughout the entire scale for the entire system (includes transmitter, connecting cable, and receiver). For example, if the system is calibrated for a range of 0-100 GPM, the reading will be correct to within 1 GPM at any point on the scale.

Repeatability: ±½ of 1% of full scale; not affected by line voltage changes of ±10%.

Temperature Limits: The temperature limitation of a transmitter depends on the type of lining, and the type of insulation on the magnet coils. Temperature limits of the measured liquid for the different types of transmitters are given on the "Installation" sheets. Maximum ambient temperature for any transmitter is 135°F. Changes in liquid or ambient temperature do not affect the transmitter calibration.

Conductivity and Lead Length: The fluid conductivity, lead length, transmitter size, and accuracy are all interdependent. For standard system accuracy of ±1%, the relation between conductivity, lead length, and transmitter size is given in the graphs on Pages 3 and 4 of this sheet.

Position Influence: The transmitter will operate in any position as long as the line is completely filled.

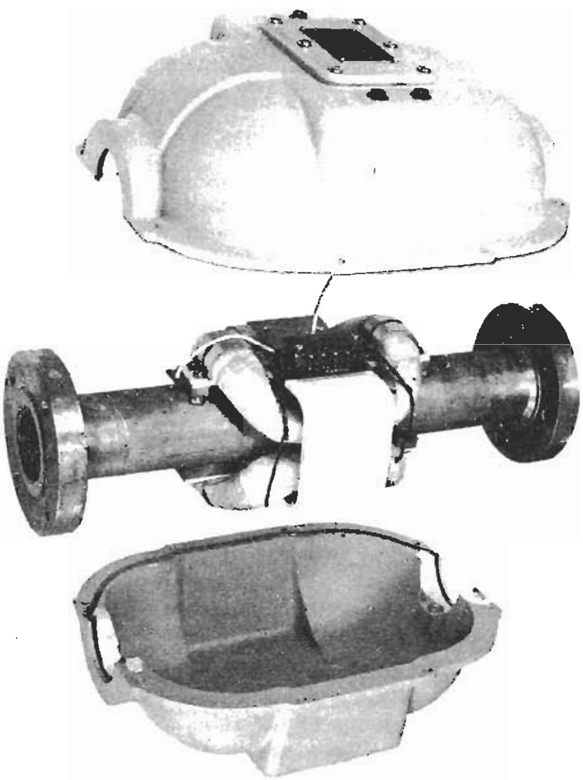

Fig. B3573

Effect of Vibration: The calibration is unaffected by vibration of the pipeline.

Effect of Entrainment: If air bubbles or other matter are entrained in the liquid, the meter will read the volume flow rate of the *total* mixture. It is only necessary to have the tube completely filled with a homogeneous mixture at all times. For example, if 75 gallons of water and 25 gallons of sand pass through the meter in a one-minute period, the meter will read 100 gallons per minute.

Effect of Deposits: The calibration will not be affected by a concentric deposit of residue or slime on the walls of the transmitter, provided that the deposit has the same conductivity as the flowing liquid. Removal of the deposit is necessary only when the pressure drop through the transmitter becomes prohibitive. If, however, the conductivity of the deposit differs from that of the liquid, incorrect readings will be obtained. (For more details, refer to Technical Information 27-71a.)

Principle of Operation

Operation of the magnetic transmitter is based on Faraday's well-known law of electromagnetic induction: the voltage E induced in a conductor of length d moving through a magnetic field h is proportional to the velocity v of the conductor. Stated in mathematical form:

$$E = Chdv \qquad (1)$$

(C is a dimensional constant).

The voltage is generated in a plane which is mutually perpendicular to both the velocity of the conductor and the magnetic field. A graphic representation of this formula is shown in Fig. B899. Since the transmitter's magnetic field h alternates at 60 cycles per second, the generated voltage E also alternates at the same frequency, as shown by the dotted lines.

This same principle makes possible the operation of power generators, tachometer generators, and similar electrical equipment.

Fig. B900 graphically relates this law to the operation of the transmitter. A magnetic field is produced by two saddle-shaped coils, and focused by a core. The fluid to be measured is the moving conductor. It passes through the tube and the alternating magnetic field h.

The conductive fluid is analogous to a continuous series of fluid discs whose diameter equals the inside diameter of the tube. The discs flowing through the tube are "conductors of length d" (d is equal to the diameter of the disc).

An EMF is generated across the discs as it would be in any conductor passing through the field. This EMF is sensed by two "point" electrodes and conducted to a Foxboro Dynalog receiver or Model 696 Converter. The faster the discs move through the magnetic field, the greater the voltage generated. A direct, linear measurement of fluid flow is thus provided.

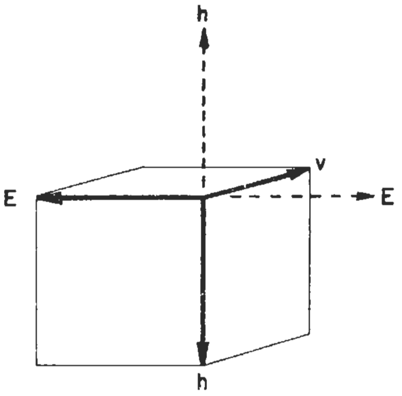

Fig. B899

Since d and h are constant, voltage E is proportional to v. Because the magnetic field is uniform, the voltage generated is proportional to *average* velocity, thus changes in "velocity profile" due to viscosity or turbulent variations do not affect the generated voltage. Any change in average velocity must result in a proportional change of voltage E.

Since average velocity is directly proportional to volume rate of flow, the magnetic flow meter measures volume rate of flow at the existing temperature.

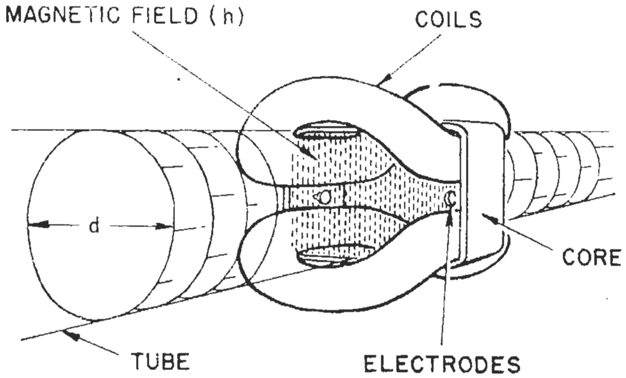

Fig. B900

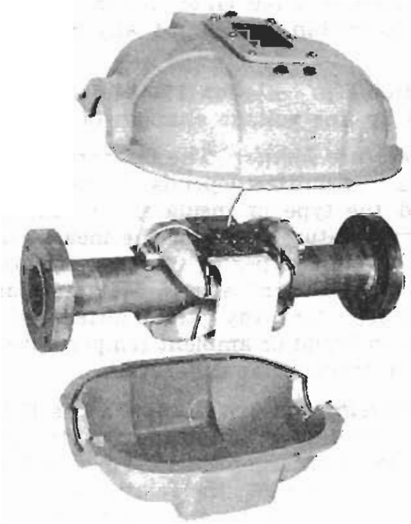

Fig. B3574

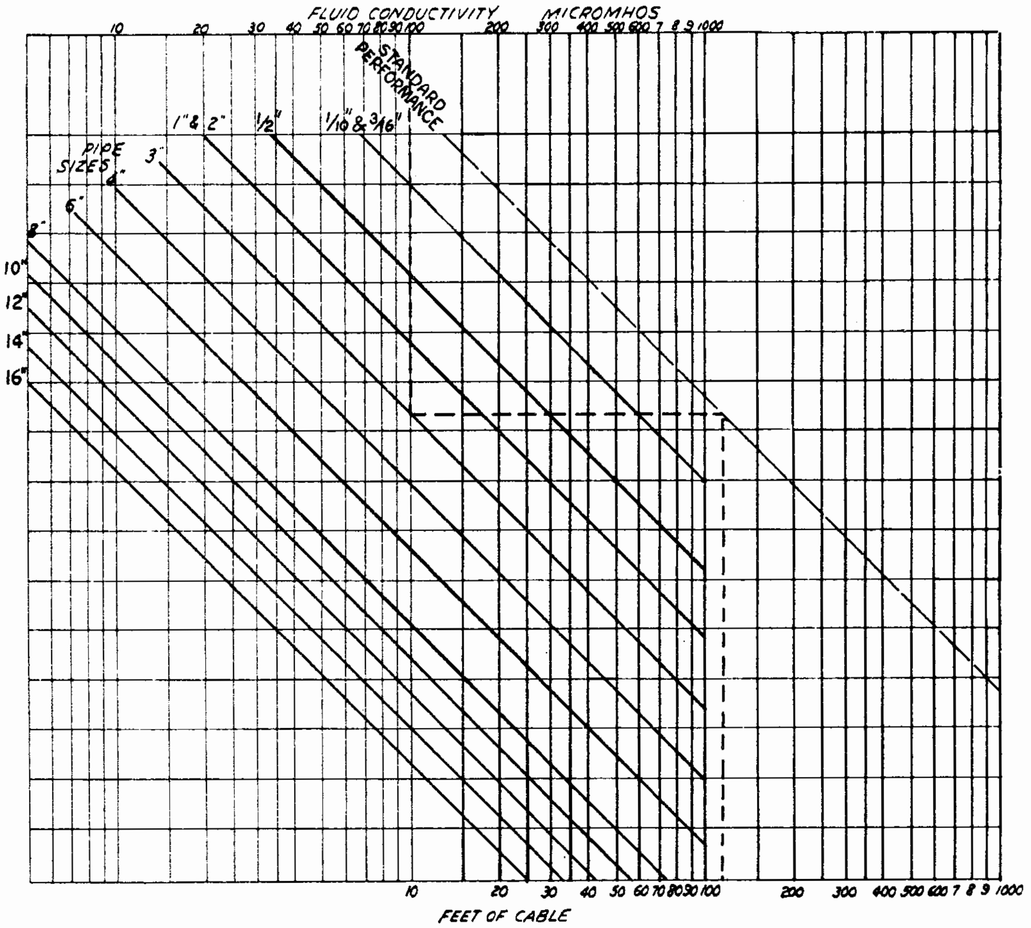

Fig. B3575. Transmitter Connected to Dynalog Receiver

Relation of Fluid Conductivity and Lead Length for Dynalog Receiver

General

The above graph relates fluid conductivity, transmitter size, and lead length to standard system accuracy. It can be used to determine:

(1) the maximum lead length for standard accuracy with a given transmitter size and liquid conductivity;

(2) the minimum conductivity for standard accuracy with a given transmitter size and lead length.

This graph is valid for Foxboro-supplied cables. The cable which is used with Model 9600B Dynalog instruments is Foxboro Part Number R-101-PZ (Belden 8422). The cable assembly which is used with Model 9600C Dynalog instruments is Foxboro Part Number A68007 and consists of both cable and connector. Be sure to specify cable length when ordering either part number.

If signal lead lengths longer than those allowed by the above graph are required, refer to The Foxboro Company.

How to Use the Graph

Example (1): Assume a 3″ transmitter measuring a liquid with a conductivity of 100 micromhos per centimeter cube. To maintain the standard system accuracy of ±1%, what is the maximum lead length that can be used?

At top of graph, locate the 100-micromhos vertical line. Follow this line downward (as shown by the dotted line) until it intersects the 3″ transmitter line. Move horizontally to the right until intersection is made with the Standard Performance line. Next, move vertically downward and read the maximum length of cable from the bottom scale. In this example, the length can be approximately 120 feet.

Note that with a 3″ transmitter and 120 feet of cable, any conductivity *greater* than 100 micromhos results in standard accuracy.

Example (2): For standard accuracy, what minimum conductivity can be used for an 8″ transmitter with 200-foot lead length?

Find the 200-foot line at bottom of graph and follow this line vertically upward until it intersects the Standard Performance line. Now move horizontally to the left until intersection is made with the 8″ transmitter line. Next, move vertically upward and read the conductivity value from the top scale. In this example, standard accuracy can be obtained with any conductivity greater than 35 micromhos.

Relation of Fluid Conductivity and Lead Length for Model 696 Converter

General

The graph below relates fluid conductivity, transmitter size, and lead length to standard system accuracy. It can be used to determine:

(1) the maximum lead length for standard accuracy with a given transmitter size and liquid conductivity;

(2) the minimum conductivity for standard accuracy with a given transmitter size and lead length.

This graph is valid for Foxboro-supplied driven-shield cable. With Style C Converters, use Connector and Cable Assembly, Part W-195-PT, which consists of Cable (Part R-101-ZS) and Connector (Part W-195-FA). With Style A or B Converters, use Plug and Cable Assembly, Part N-131-ZS. Be sure to specify cable length when ordering cable or assemblies.

If signal lead lengths longer than those allowed by the graph are required, refer to The Foxboro Company.

How to Use the Graph

Example (1): Assume a 3" transmitter measuring a liquid with a conductivity of 55 micromhos per centimeter cube. To maintain the standard system accuracy of ±1%, what is the maximum lead length that can be used?

From 55 micromhos on conductivity scale, drop vertically to intersect with the 3" transmitter line. Move horizontally to the right until intersection is made with the Standard Performance line. Next, drop vertically to "Feet of Cable" scale. Maximum permissible cable length is 185 feet.

Note that with a 3" transmitter and 185 feet of cable, any conductivity *greater* than 55 micromhos results in standard accuracy.

Example (2): For standard accuracy, what minimum conductivity can be used for a 6" transmitter with 250-foot lead length?

Find the 250-foot line at bottom of graph and follow this line vertically upward until it intersects the Standard Performance line. Now move horizontally to the left until intersection is made with the 6" transmitter line. Next, move vertically upward and read the conductivity value from the top scale. In this example, standard accuracy can be obtained with any conductivity greater than 25 micromhos.

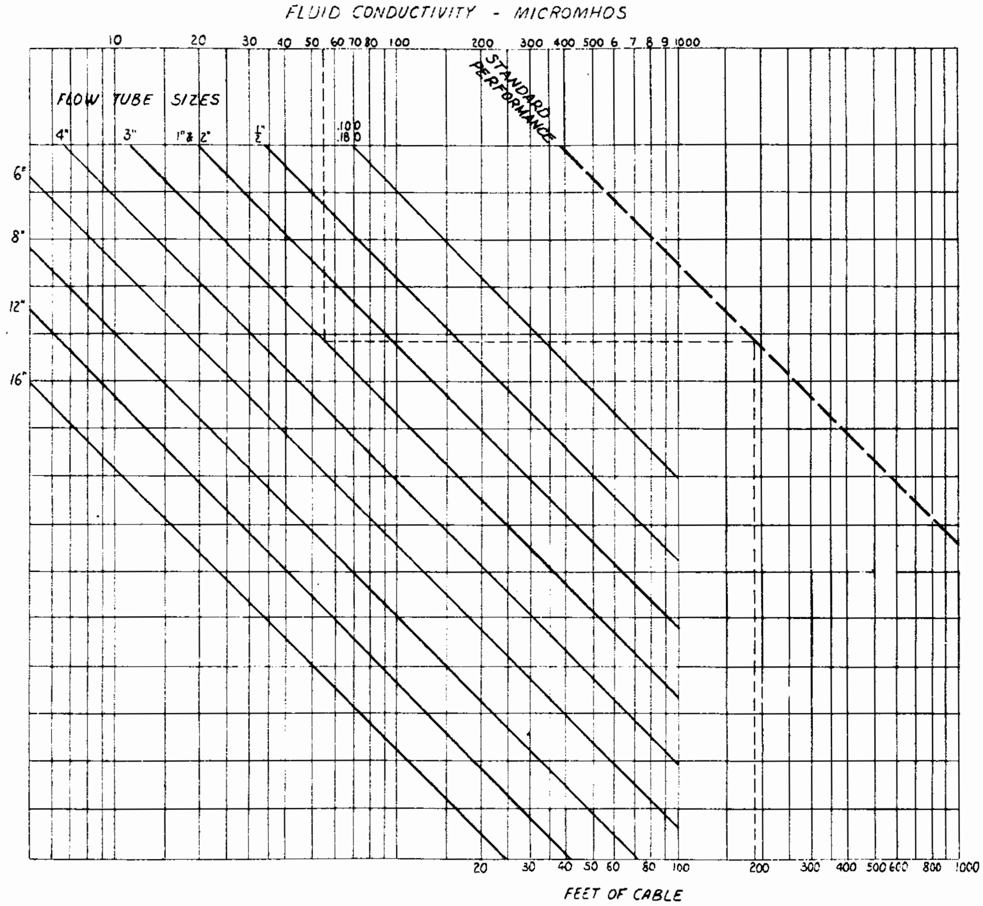

Fig. B8432. Transmitter Connected to Model 696 Converter

PRINCIPLE OF OPERATION
Model 696 Magnetic Flow-To-Current Converter

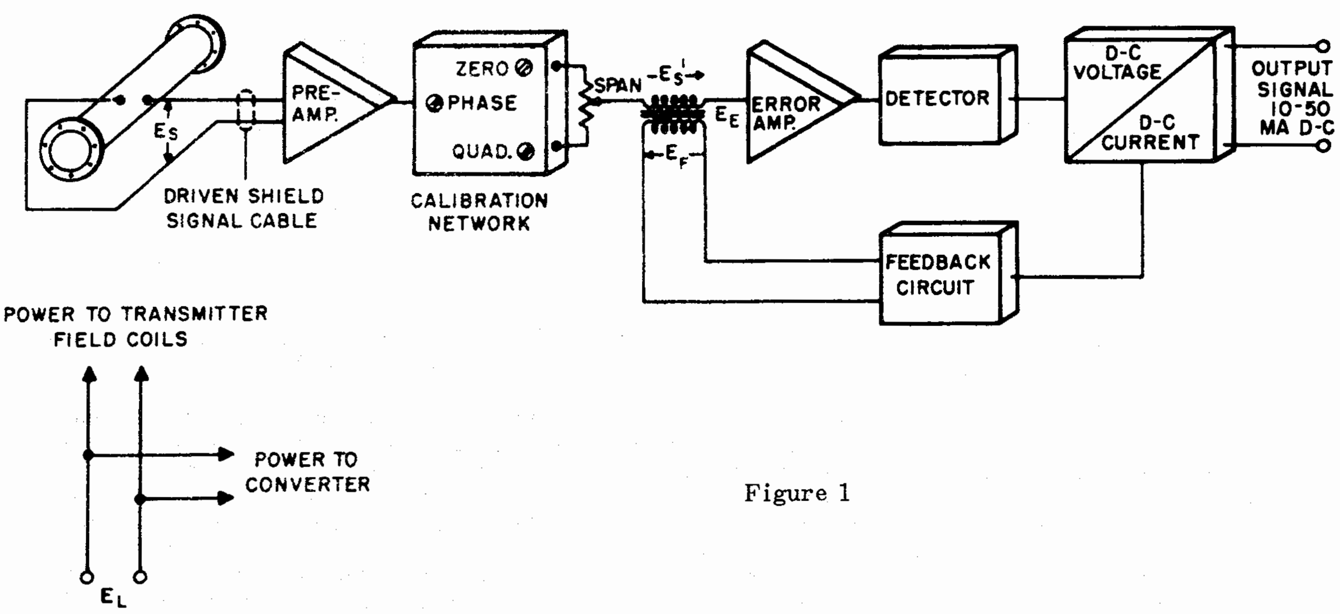

Figure 1

Figure 1 is a simplified block diagram showing the functional parts of the Model 696 Converter. The converter produces a linear output signal, 10-50 milliamperes d-c, proportional to flow rate through a Foxboro Magnetic Flow Transmitter.

The field coils of the transmitter are excited from a 115 or 230 volt, 50 or 60 cps power source. This same power source supplies power to the converter. In addition, a special two-wire driven shield signal cable carries the generated signal voltage E_S from the transmitter to the converter, (Fig. 2). The generated signal voltage E_S will lag the line voltage E_L by approximately 90 degrees. Along with the generated signal voltages E_S proportional to flow rate in the transmitter, ther may be additional extraneous voltages E_X present, which can be compensated for.

The generated signal voltage E_S is first fed through the converter pre-amp, a 1:1 amplifier employing high impedance input (1500 megohms) for minimum loading of the transmitter signal. The generated signal voltage E_S is phase shifted (Fig. 3) in the calibration network. The phase adjustment will simultaneously rotate forward the signal voltage E_S, and any extraneous voltage E_X, until the signal voltage E_S is inphase with the system line voltage E_L.

At zero flow conditions E_S' (phase rotated) = 0. Any extraneous voltage E_X' is removed from the measuring circuit (Fig. 4) by inducing a real voltage (zero adjustment) and a quadrature voltage (quadrature adjustment), until the vector sum of both induced voltages (90 degrees to each other) cancels the effect of any extraneous voltage E_X'. Regardless of the phase angle of any extraneous voltage E_X', its effect may be removed from the signal circuit as both the zero and quadrature adjustments are capable of inducing positive or negative voltages on their respective axes. Once the zero and quadrature adjustments are properly set, the converter will automatically put out 10 ma at zero flow.

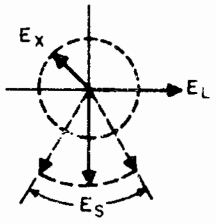

Figure 2

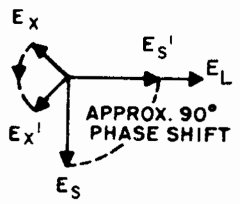

Figure 3

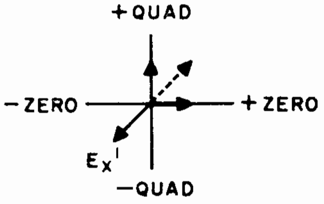

Figure 4

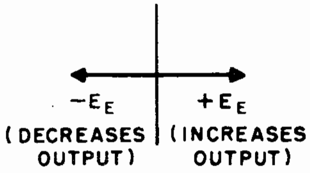

Figure 5

The span adjustment is made at the output of the calibration network and is adjusted for any millivolt signal span between the ranges of 0-1.5 and 0-30 mv for full scale output.

After span adjustment, the signal voltage is now connected in series opposition to the output voltage E_F of the solid state feedback circuit employing a Hall crystal. Approximately 98% of the signal voltage E_S' is balanced by the feedback voltage E_F with the remaining 2% fed to the input of the error amplifier. If a change in flow rate occurs, signal voltage E_S' produced by the transmitter will be different from the output voltage E_F produced by the feedback circuit. This difference or error voltage E_E ($E_E = E_S' - E_F$) will be amplified by the error amplifier and then phase detected (Fig. 5) to see if flow has increased ($+E_E$) or decreased ($-E_E$). The output of the phase detector is a d-c voltage. The d-c voltage to d-c current converter receives the signal output of the phase detector and responds by increasing or decreasing the converter output signal accordingly.

The Hall crystal employed in the solid state feedback circuit is connected in series with the output current of the converter thereby obtaining a feedback voltage E_F proportional to the 10-50 ma d-c output signal of the converter. Any change in the converter output signal will result in a corresponding change in the feedback voltage E_F until the system is in balance.

By utilizing the above circuit design, line voltage fluctuations of ±10 % or frequency varations of ±2 cps from rated value will have negligible effect on measurement since the generated voltage E_S and the feedback voltage E_F will change in unison with line voltage and frequency fluctuations.

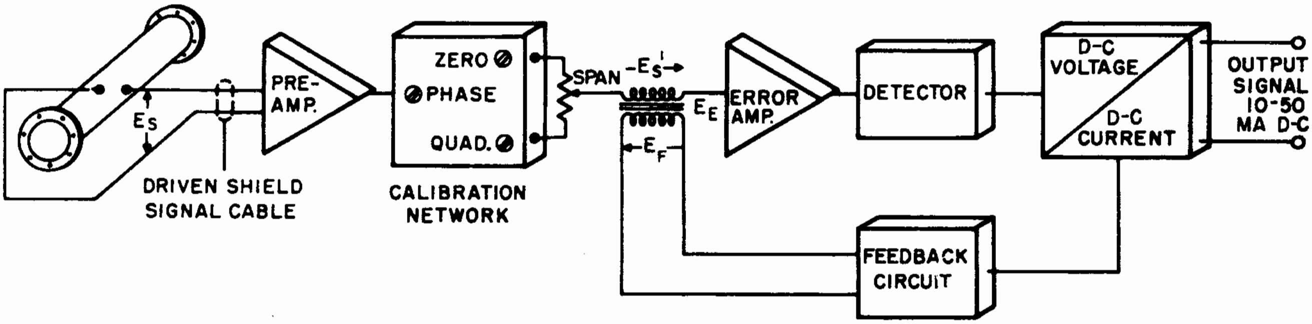

Figure 6