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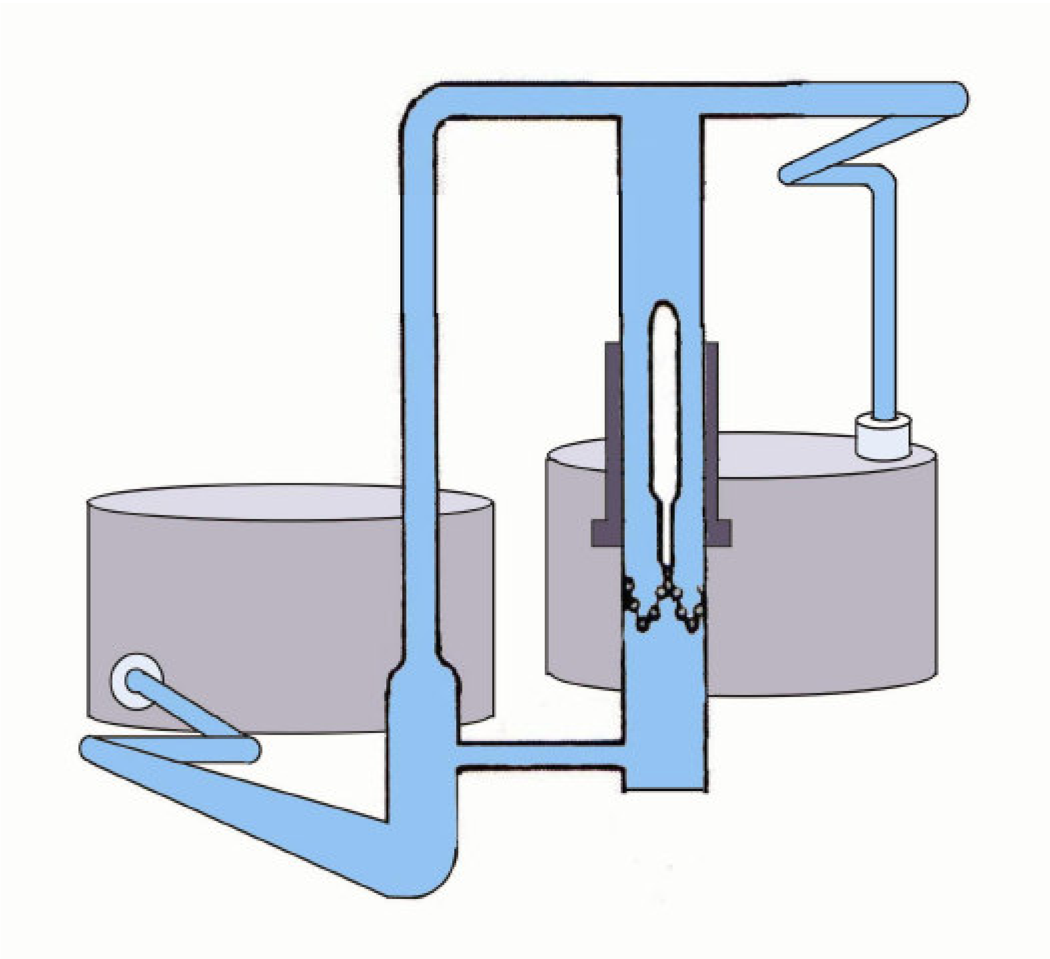
The Princo Densitrol™ Specific Gravity Monitor

Installation and Operating Instructions

Rev 1, 23 Sep 04



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Section 1. DENSITROL SPECIFICATION and CUSTOMER DATA SHEET

MODEL NO.:

SERIAL NO.:

SUPPLIED FOR:

PURCHASE ORDER NO.:

DENSITY RANGE:

ACCURACY:

MAXIMUM TEMPERATURE:

MAXIMUM PRESSURE:

TEMPERATURE DENSITY COEFFICIENT:

AUTOMATIC TEMPERATURE COMPENSATION SPAN:

PLUMMET TRAVEL:

OUTPUT SIGNAL:

POWER REQUIREMENT:

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Section 2. PRINCIPLES OF OPERATION

The Densitrol measures continuous liquid density in three concurrent operations:

1. It senses the liquid density.

2. It senses the liquid temperature.

3. It combines and conditions the density and temperature signals to provide a temperature-corrected density signal suitable for indication, recording or control.

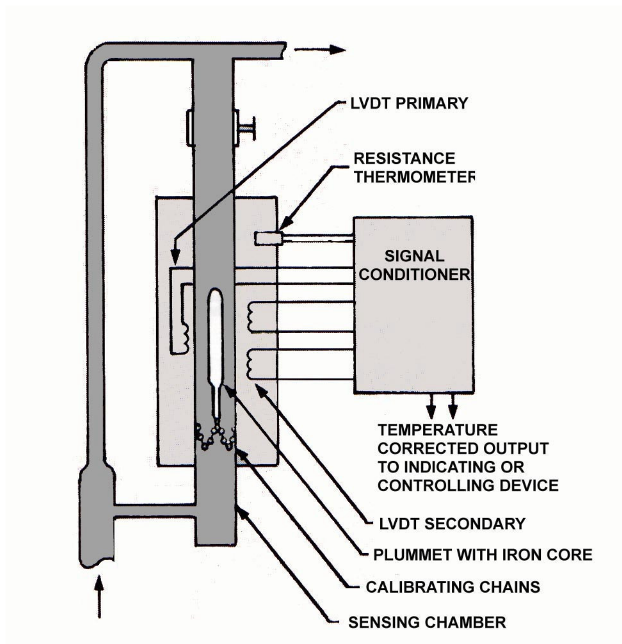

Figure 1. Densitrol Pictorial

1. Density Detection:

   The density of a liquid may be determined by formula as follows:

$$\textbf{Density} = \frac{\textbf{Weight}}{\textbf{Volume}}$$

   The Densitrol operates according to this formula and determines density by the constant volume, variable weight method. In the Densitrol the volume of a submerged body is constant and the buoyant force acting on the body will vary with the liquid density.

   A totally submerged plummet of constant volume is the density sensor for the Densitrol. The plummet is fastened by chains to a reference base and the whole assembly (plummet, chains and reference base) is housed within a chamber through which the liquid flows. The plummet is weighted so that it assumes an equilibrium position at mid range with the weight of the chains equally supported by the plummet and reference base. The weight acting on the plummet will change as the plummet moves up or down in response to a change in liquid density. For each liquid density the plummet will assume a definite position corresponding to that density.

A Linear Variable Differential Transformer (LVDT) is mounted on the outside of the sensor chamber and monitors the plummet inside. The plummet includes a magnetic iron core. When the density changes, the plummet moves to a new position which is sensed by the LVDT. The voltage signal from the LVDT is a function of the plummet position and corresponds to the existing liquid density.

2. Temperature Detection:

   A platinum resistance temperature detector (RTD) is mounted in a well in the sensor chamber. As the sample stream temperature varies, the resistance of the RTD varies. This resistance is part of a bridge circuit which produces an adjustable signal in response to temperature changes.

3. Temperature - Density Effects and Signal Conditioning:

   The signals from the LVDT and the platinum RTD are separately measured, modified and then combined. Temperature changes expand or contract the liquid sample, changing its density. This density change causes the plummet to move to a different position, changing the density signal. To compensate for this change in density, caused only by the change in temperature, the RTD bridge develops a signal equal and opposite to the change of signal generated by change in plummet position.

   Example: The Densitrol monitors a 20% concentration of solution at 25 ºC (Density = 1.030 g/cc). When the process temperature changes to 35 ºC, the plummet moves to indicate the new density, 1.028 gm/cc. The temperature correction circuit detects the change of temperature and produces an additive signal to maintain the output indication 20% concentration.

   Automatic temperature compensation is possible through a temperature range, equivalent in density change, to at least, twice the density range of the Densitrol: e.g. if the density change is 0.0005 per ºC (temperature density coefficient), and Densitrol range is 0.01 density, compensation can be furnished for a total temperature change of 40 ºC, or ± 20 ºC around a specified operating temperature. (.0005 x 40=.02, or 2 X .01 range). Maximum temperature compensation can be computed by formula as follows:

   Let R = Range

   TDC = Temperature density coefficient

   ATC = Automatic temperature compensation span

$$\boxed{\mathbf{ATC} = \frac{\mathbf{2 \times R}}{\mathbf{TDC}}}$$

The span of compensation is determined partly by the plummet travel used and in some cases can be greater than the example above.

Section 3. INSTALLATION

Actual installation will vary according to use. In general however, these steps should be followed:

1. Determine type of installation - direct or by-pass.

CAUTION: Maximum flow through the Densitrol should be 0.5 gallons per minute.

   The Densitrol may be installed directly into the flow line or into a by-pass line. By-pass flow may be obtained by gravity feed, pressure drop across an orifice plate (or other restriction), or by pump. The by-pass line may return to the main line or flow to drain. A steady flow without surges or bubbles is desirable.

2. Prepare lines for installation.

   Refer to Densitrol prints for measurements, then lay out flow lines according to the type of installation, leaving a measured gap for the Densitrol. Provide for suitable valving to isolate the Densitrol from the flow line. A bleed valve on outlet side, in addition to other valves, is suggested. For recommended layouts, refer to the suggested installations (Appendix A).

3. Unpack Densirol unit and check parts against the packing list. The Densitrol consists of:

   a. Sensor chamber assembly

   b. Plummet assembly with gasket

   c. An integrator assembly (signal conditioner)

   d. Interconnecting cable with lugs

4. Assemble sensor chamber in flow line.

   a. Mount the Densitrol vertically so that liquid will flow up through the reference base, past chains and plummet.

   b. Connect the sample lines to the inlet and outlet connections, with suitable valving.

5. Install the plummet assembly in the sensor chamber by opening the flange connection where the reference base mounts.

   a. Slide gasket over plummet, past chains, and seat on reference base lip.

   b. Insert plummet and gasket assembly into sensor chamber.

   c. Re-assemble flange joint.

   Note: On some models it is advisable to install the plummet after the sensor chamber is mounted. If piping connections will interfere with plummet installation, install the plummet in the chamber before mounting the chamber in the lines.

6. Install Integrator (signal conditioner) as follows:
   a. Mount integrator on suitable panel.
   b. Run cable from the integrator to sensor chamber and connect as indicated on the wiring diagram.
   c. Connect signal output to receiving instruments.
   d. Connect power line to integrator.

Section 4. START-UP

With all piping and wiring completed, initial flow through the Densitrol can now begin. Turn on the power and start operation, as follows:

1. Open the valve on outlet side.
2. The valve on the inlet side should now be opened slowly.

CAUTION: Surges of compressed air, released when valves are opened, can damage plummet assembly. Open inlet valve slowly, gradually filling the Densitrol. Check all points for leaks and adjust as necessary.

3. Continue to open inlet valve gradually to obtain adequate flow through the chamber. Control rate of flow by adjusting valve on outlet side. Once proper rate of flow has been established, mark point on valve so that in the future the valve can always be opened to this point.

Section 5. ADJUSTMENT PROCEDURE

With the rate of flow established, the Densitrol is ready for operation. At this point, certain adjustments must be made. (If automatic temperature compensation was not included, go on to paragraph 3, Zero Setting).

1. Refer to the calibration curves (Appendix B).

   Two curves have been supplied for your Densitrol for determining the settings of the average operating temperature and temperature-density coefficient values. One curve shows average operating temperature; the other shows the average temperature-density coefficient, expressed as a percentage of range.

2. Dial setting instructions.
   a. AVERAGE OPERATING TEMPERATURE (AOT).
      1) Find the temperature corresponding to normal conditions on the AOT curve and adjust the knob accordingly.
   b. TEMPERATURE DENSITY COEFFICIENT (TDC).

1) Temperature-density coefficient is the change in density of a liquid per degree of temperature change and must be known before the plummet can be designed. (See Section 1.)
2) Since each instrument is designed for a specific application, the knob is simply calibrated 0 to 100. To find the correct setting, the temperature-density coefficient is expressed as a percentage of range. To do this, divide the temperature-density coefficient by the plummet range and multiply by 100.

   R = Maximum density minus minimum density.

   TDC = Temperature-density coefficient.

   Thus:

$$\boxed{\frac{\mathbf{TDC\ x\ 100}}{\mathbf{R}} = \%}$$

3) Refer the figure thus obtained to the temperature-density coefficient curve and set the knob accordingly.

   NOTE: The calibration curve sent from the factory is marked with the correct setting based on the temperature-density data supplied by the customer. Any subsequent changes in range or TDC can be accomodated by finding the new setting on the curve.

3. Zero Setting

Your Densitrol has been calibrated for range. Now it must be zero set. Allow the Densitrol to run until the temperature of all parts stabilizes. After this has been done and the normal liquid flow through the Densitrol has been established, the zero setting may be made. A liquid of any density within the range may be used.

a. If unit has a front panel ZERO SET dial, set it at mid-point (50).
b. Take a sample of product as it leaves the sensor chamber and determine its density with a hydrometer or other means.
c. Note indicated output reading and correct as needed by turning the LVDT adjustment screw on the sensor chamber until the indicator shows the proper density.
d. After adjusting, allow to run for a while and then recheck and re-adjust if necessary.

NOTE: Some models are equipped with a third calibration knob, labeled "ZERO SET" which provides a remote adjustment in addition to that on the sensor chamber. Set this knob at its midpoint and use it to trim the value obtained by the setting of the sensor chamber adjustment. Best results are obtained by setting the LVDT adjustment as closely as possible and using this trim setting only if necessary.

Instruments having a screw driver adjustable trimmer for resistor M are pre-set before shipping.

The Densitrol is now in operation. Since the final adjustments were made with normal flow and viscosity, no further compensation is required. Should these conditions change, a new setting may be made. A sudden change in liquid flow will cause a momentary pulsation of plummet position which should not extend beyond five seconds.

Section 6. SYSTEM MAINTENANCE

The Densitrol is inherently trouble free and does not require periodic calibration, lubrication, or adjustment. If the process liquid does have a tendency to coat the plummet or to deposit solids in the chamber, a periodic schedule of cleaning and examination of the plummet and chains may be established. No parts require lubrication and calibration is performed only at start-up. If a signal converter is included, calibration may be checked periodically if ambient temperature changes significantly (50 ºF = 1% drift) .

The formation of bubbles on the plummet and chain assembly can be a cause of trouble. If the bubbles are a natural condition of the solution they must be removed for the Densitrol to give proper readings.

Bubbles can also occur when the pressure in the sensor chamber is lower than inlet supply pressure. To avoid this, regulate the rate of flow on the outlet side of the Densitrol rather than on the inlet side.

Air, brought into the fluid stream by leaks in pump packings, etc. is another cause of bubbles. If this condition exists, use a small chamber such as an expansion tank or a "Constant Head" tank to cause a short holdup in the stream so that the bubbles can separate.

Little maintenance is required. However, the plummet and chains should be checked periodically for corrosion or deposits, and cleaned. Do not subject the plummet assembly to excess pressures when cleaning the pipe lines of the system. Do not use steam purging.

Section 7. RESPONSE TO OPERATING CONDITIONS

The Densitrol will measure the average density of all materials in the sensor chamber. This includes solids and gas bubbles as well as the liquid. Thus the liquid supplied to the sensor chamber must be in the physical condition for which the density measurement is desired. If density of the liquid is desired, then the solids and gases must be removed. Density of slurries can be measured, but the solids in the liquid stream should be less than 1/32” mean diameter to be passed, and should not readily drop out of suspension.

Section 8. PARTS DESCRIPTION

The Densitrol consists of the mechanical plummet assembly in the sensor chamber housing, and one or more electrical circuits. These circuits are the density signal circuit, the temperature compensation circuit, and a signal converter circuit. The temperature and converter circuits are optional.

1. Mechanical Parts:

   Refer to Assembly Drawing in Appendix A.

   a. Plummet: Each plummet assembly is built for a specific range of density. The chains are long enough to permit small shifts of reading by coil adjustment, but the span of density indicated cannot be expanded or reduced mechanically.

   b. Gaskets: The gaskets supplied for the reference base flange are specifically selected for corrosion resistant properties. In replacement, care must be taken to order the same material.

2. Electrical Parts:

   Refer to Assembly Schematic and Pictorial Diagram in Appendix A.

   a. Power Supply:

      Constant voltage transformer and associated capacitor.

      Converts line power input to constant voltage source for density and temperature circuits. Supplies 110 volts AC and 12.6 volts AC despite line voltage variation of 15%. This transformer is matched to its capacitor in a tuned AC circuit. Any replacement is made by replacing both transformer and capacitor.

      CAUTION: The matching capacitor, located next to the transformer, can develop surges of 650 volts. Exercise care in working near the terminals.

   b. Density Measuring Circuit

      1) Linear Variable Differential Transformer (LVDT)

         The plummet position sensing LVDT is located in the sensor chamber. This sensor surrounding the sampling pipe is made up of three coil windings in the following order: Secondary, Primary, and Secondary. The position of the plummet (which contains a ferrous-alloy core) determines the voltage induced in the two secondary coils. The plummet position determines the flux linkage and therefore the value of the voltages of the two secondary coils. These voltages are then rectified.

      2) Rectifiers:

         Contained in plug-in assemblies inside the integrator, the two rectifiers are somewhat affected by ambient changes. The case should be kept closed to reduce temperature variations. The rectifiers have keyed bases to assure proper insertion.

3) "J" Resistor:

The voltages from the LVDT, after rectification, are placed in opposition to each other across the "J" resistor. The resulting voltage corresponds to the existing density. The “J” resistor is individually calibrated to match the core of each plummet, and usually consists of a fixed resistor in series with a trimmer. The value is factory set so that the plummet displacement over the full density range produces the full range of output signal.

4) Output capacitor and resistor:

This capacitor and matching resistor “K” are the filter circuit for the mV output signal.

c. Temperature Compensation Circuit (for those instruments with this option):

1) Rectifier:

This rectifier bridge converts the 12.6AC volt input from the constant voltage transformer to DC for the temperature compensation circuit.

2) Bridge:

This is a Wheatstone, resistance type, DC bridge, one leg of which includes the resistance thermometer.

3) Resistance Thermometer:

A tip-sensitive thermometer is located in a well protruding into the liquid flow in the sensor chamber. A change of temperature causes a change in resistance and an unbalanced bridge. The unbalance develops a voltage across the “L” resistor which is equal and opposite to the change on the “J” resistor caused by the plummet displacement due to a density change caused only by temperature-density change. The combined density and temperature signals provide a temperature corrected value.

4) Zero-set:

The zero set is a variable resistor, (“M” in the circuit) which changes the input point of voltage fed to the bridge and does not require calibration. It is set at the time of manufacture to eliminate imbalances caused by resistor tolerances. It can be used to make fine corrections to the output signal, but these are preferably made by repositioning the LVDT. In some models, “M" is located on the resistor board; on others it is on the front panel and labeled “ZERO SET”.

5) Average operating temperature:

   This variable resistor ("N" in the circuit) is in series with the resistance thermometer in one leg of the bridge, and is used to adjust the resistance thermometer bridge for a given working temperature. It is located on the front panel and labeled "AVERAGE OPERATING TEMPERATURE". A calibration chart (Appendix B) is supplied that relates the dial setting, 0 to 100, of "N" to the operating temperature of the process liquid.

6) Temperature-density coefficient:

   This resistor ("L" in the circuit) determines how much voltage correction from the bridge is added to the output signal. In effect, it is an electrical expression of how much density change occurs in the liquid for a given deviation from operating temperature. It is located on the front panel and labeled "TEMPERATURE DENSITY COEFFICIENT". A calibration chart is supplied to allow proper setting of "L" (Appendix B).

   NOTE: Some Densitrols are not equipped with automatic temperature compensation. In this case, the previous six paragraphs do not apply. In addition, that portion of the schematic and wiring diagrams which includes the temperature compensation components may be disregarded. The front panel will of course, have no adjustments for zero set, operating temperature or temperature-density coefficient, when the instrument is supplied without automatic temperature compensation.

d. Signal Converter:

   The two sensing circuits described above produce low level millivolt outputs. The combined signals are calibrated to produce an output of -5mV to +5mV corresponding to the range of density selected. The –5mV to +5mV signal can be used as a final output, but is normally fed to the input of a signal converter, Princo part number CRI-30. Signal conversion circuitry is arranged on a printed circuit board with a 4 to 20 mA output standard. Optional outputs are available. There are coarse and fine, zero and span adjustments on this assembly. These controls are set during factory calibration and no field adjustments are normally required.

   For a more detailed description of the CRI-30, refer to Section 11.

Section 9. TROUBLE SHOOTING

When a problem occurs in a Densitrol installation, it is helpful to examine separate sections of the installation. Refer to Pictorial Diagram, Appendix A, for location of resistors and circuit junctions. (Specific values are shown in paragraph 4 below.)

1. Process flow components:
    a. Check to see that the sample stream is normal:
        - Flow rate of 0 to 0.5 GPM.
        - Absence of bubbles
        - Viscosity less than 50cp
    b. Visually examine the plummet for leaks, broken chains or deposits.
    c. With power on, and “L” set to zero, move the LVDT adjustment to simulate plummet motion and check for corresponding output change. With chamber empty, manually move the plummet and check for corresponding output change. For plummet design travel, see page 1.

NOTE: The foregoing (a,b,c) are used to determine if the problem relates to the process stream and physical response. If these checks do not indicate the problem, look for electrical problems.

2. Density circuit:

With power on, set the TDC knob (Resistor “L”) to zero to eliminate the temperature circuit. Disconnect leads from terminals 6 and 7 on CRI-30. Measure the voltage between these two wires (negative lead to terminal 7, positive to terminal 6). Moving the plummet up and down in the chamber (see c. above) should yield a millivolt signal of -5mVdc corresponding to minimum density and +5mVdc corresponding to maximum density. Incorrect results indicate a problem in the density circuitry.

3. Temperature Compensation Circuit:

With power on and TDC (“L”) and AOT (“N”) set to proper values, short circuit resistor “J” to eliminate the effects of the density circuit. Check the resistance thermometer value. Substitute a variable resistor (decade box) for the RTD and simulate temperature changes. Set the simulated RTD value to produce 0 mV across resistor “L” (TDC resistor). A change of 0.1Ω at the simulated RTD corresponds to a 1.0 ºF change in temperature. (0.18 Ω per 1ºC). Increasing the resistance produces positive mV readings at “L” (junction DE [+] to junction BA [-]).

Decreasing resistance produces negative mV readings. The TDC calibration curve shows the percentage change of output (-5 to +5mV) per degree of temperature change.

4. Circuit values and checks for 1-3 above.

Look for open circuits, including interconnecting wiring, absence of power, or missing signal. Slight variations from the following values are not important.

    a. Constant voltage Transformer:

1) 110 Volt, 60 HZ:

Leads	Voltages (Vac)	Winding	Resistance (Ω) (Disconnect to read)
Red & Red	115	Primary	90
White & White/Black	125	Density Secondary	120
Blue & Blue	12	Temperature Secondary	14
Black & White/Black	225	Capacitor	200

2) 220 or 110 Volt, 50HZ:

Leads	Voltages (Vac)	Winding	Resistance (Ω) (Disconnect to read)
Red & Green (110V)	110	Primary	200
or Red & Green/Yellow (220V)	220	Primary	480
White & White/Black	125	Density Secondary	118
Blue & Blue	12	Temperature Secondary	8
Black & White/Black	225	Capacitor	150

b. Pick-up Coil (LVDT) Terminals.

Located on sensor chamber terminal strip (refer to wiring diagram).
Disconnect 9-conductor cable leads when tests are made for resistance.

Terminals	Voltage (Vac)	Winding	Resistance (Ω)
1 TO 2	1.2 TO 4.0	Primary	270 TO 330
3 TO 4	0.15 To 0.5	Secondary	4500 TO 5500
5 TO 6	0.15 TO 0.5	Secondary	4500 TO 5500

c. Resistance Thermometer

Approximate resistance 50Ω at 20 ºC with an approximate increase of resistance of 0.18Ω per ºC increase.

Measure at the integrator (signal conditioner) leads to terminals 7 and 8 on sensor chamber terminal strip. Disconnect the leads so that only the resistance thermometer and leads to terminals 7 and 8 are included.

d. Temperature Correction Circuit:

1) 8 to 12 Vdc at rectifier bridge output.

2) Resistors and DC Bridge: Refer to Densitrol Schematic Wiring Diagrams for resistance values.

NOTE: All resistors are accurate within +/- 1%. Disconnect one side to read.

> CAUTION: The values given above are **typical**, not specific. Trouble in the Densitrol circuit is generally reflected by great changes from these values given above, open circuits where a reading should be obtained, etc., rather than small variations.

5. Signal Converter (mV to mA, CRI-30):

If it is suspected that the signal converter is not functioning properly, several basic checks may be made:

a. Power Failure:

If red pilot light (CR8) in upper corner of circuit board is not illuminated, check fuse F-1 and replace if necessary.

b. Basic Output Current Check:

Remove input signal wires from terminals 6 and 7 on terminal strip TB-l.

> WARNING: 115 VAC is connected to terminals 1 and 2.

Connect jumper wire between terminals 6 and 7. Output current at terminals 9 and 10 should be approximately 12 milliamps. (4-20mA range).

c. Precise Output Current Check:

Remove input signal wires as noted in paragraph b above. Connect millivolt signal source to input terminals 6 and 7. Vary input between -5 mV and +5 mV. Current output should vary between 4 mA and 20 mA respectively (or 1 to 5 mA etc).

If an electrical problem was indicated in test a or b, it is recommended that the entire PC board assembly be replaced. An outline drawing and schematic are included in Appendix A to help in attempting to repair the assembly.

Section 10. TYPES OF TROUBLE

1. Electrical Checks:

   The following are three types of errors and checks for each.

   a. Instrument reads on scale but does not respond to change of density.

      1) Check power to Densitrol.

      2) Check output filter capacitor (may be shorted).

   b. Instrument reading remains at top or bottom of scale:

      Turn temperature-density coefficient dial to zero to temporarily eliminate temperature compensation. If reading remains off scale:

      1) Remove one density circuit rectifier. If no change, replace.

      2) Remove other density circuit rectifier. If no response, replace and check constant voltage transformer and pick-up coil for open windings. With both rectifiers removed, the instrument should read approximately mid-scale. If instrument does not read mid-scale, short circuit millivolt signal leads (terminals 6 and 7 on the ten terminal strip of the CRI-30 mV to mA converter). Indication should go to mid-scale. If not, check circuit board of signal converter. See voltage to current converter instructions in Section 11.

      3) Move pick-up coil up and down. If this produces response, check plummet and chains for breakage or blockage.

      4) Plummet Motion: Remove process liquid and manually move within field of pick-up coil. A lack of response means that the trouble is in electrical circuits or the indicator itself. A few centimeters (depending on calibration of plummet travel) should cause full scale indicator change.

      5) Inter-wiring continuity: Check for breaks in leads, or disconnected wires. Check for incorrect wiring connections.

   c. Erratic Reading:

      1) Reheat soldered connection to see that none have loosened.

      2) Check both capacitors.

CAUTION: High voltage on CVT capacitor.

      3) Check calibration resistors “N” and “L” for good electrical contacts.

      4) Check plummet - may be broken or wrong range.

2. Mechanical Checks:

   If the electrical circuit is found to be functioning normally, the system should be checked as follows.

   a. Plummet Assembly:

A symptom of plummet error can be a gradual shift in the output indication.

1) Remove plummet assembly and look for excessive signs of corrosion or deposits on chains and plummet.
2) With plummet removed, check plummet for leaks. No liquid should be present in the plummet.

b. Process Changes:

A shift in output indication can be caused by process changes beyond those compensated for by the Densitrol specifications (liquid composition, flow, temperature, etc.). The Densitrol must be modified to accommodate any process changes beyond those compensated for in the original purchase specifications.

The density range may be shifted up or down by repositioning the LVDT and re-calibrating. Consult the factory.

Section 11. VOLTAGE TO CURRENT CONVERTER (PART NO. CRI-30)

1. Specifications

Input Signal	5 mVdc to 50Vdc spans in four decade ranges of either polarity.
Zero Offset	Zero volt may be adjusted anywhere in span range noted above.
Output Signals	1) 1 to 5 mAdc into 2K ohms. 2) 4 to 20 mAdc into 500 ohms. 3) 10 to 50 mAdc into 200 ohms.
Linearity	Within 0.3% of span (max.), typically +/-0.15%.
Repeatability	Typically within 0.1%.
Input Impedance	1.0 megohm.
Stability	Typically 0.5% change over temperature range of 50º F.
Ambient Temperature Range	0 to 150ºF
Power Line Effect	+/-0.1% calibration change for +/-10% change in line voltage with output current of 4 to 20 millamps.
Power Requirements	115 Vac or 230 Vac +/-10%, 50 to 60 Hz, 5 watts
Mechanical	6 ½ " L x 4" W x 1 ½ "H (1 ½ " max. protrusion).

2. Most Densitrols include an additional PC board mounted on their chassis. The function performed by this PC board is a voltage to current conversion.

Specifically, it converts the -5 to +5 millivolts dc output of the Densitrol to 4 to 20 milliamps dc (or other standard signal current range output). This signal current, in turn, may be used to drive indicators, recorders, control systems, etc. for various monitoring and process control applications.

3. Operation/Adjustments

   No field adjustments are required for normal operation of the CRI-30. Factory adjustments should remain accurate and stable over years of usage.

4. Repair Notes

   If it is suspected that the CRI-30 is not functioning properly, refer to Section 9.5.

Appendix A. Prints and Diagrams

Appendix B. Calibration Curves

Appendix C. Spare Parts List