EL-FLO CONTROLLER INSTALLATION AND MAINTENANCE MANUAL

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The Electronic Filter Level Offset (EL-FLO) Controller is a downstream open canal water level controller that operates the canal gates. This manual provides information and procedures on installation, operation, maintenance, and repair of the EL-FLO Controller.

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by
D. G. Ehler
A. C. Matthaei
G. W. McDermott

Hydraulics Branch
Division of General Research
Engineering and Research Center
Denver, Colorado
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SECTION I. - GENERAL INFORMATION

1-1 General Description

Introduction. - The EL-FLO controller is a downstream canal water level controller. A normal installation would provide a controller at each gate and the filter portion installed at the end of the canal.

The controller requires a direct-current communications circuit between each controller and an alternating-current circuit to a central alarm point if the alarm system is used. Power requirement is 115-volt alternating current. Communications circuits should be protected from lightning and preferably buried. The alternating-current circuit should be provided with lightning arresters.

The controller makes extensive use of integrated circuits and is entirely solid state.

Proportional mode of control. - The longitudinally compressed figure 1-1 is an example of an enlarged system which includes a check gate and the canal reach downstream from it. By moving the water level sensor to the lower end of the downstream canal reach and by adding transmitter, communication channel, and receiver elements between the sensor and the controlling gate upstream (a distance of perhaps several miles), a response to a disturbance at the lower end of the canal reach can be instantaneous at the upper end.

In reference to figure 1-1, the downstream canal side turnout demand, or its equivalent canal flow, is related to the "offset" (the drop in the canal water surface as flow increases, broken line represents water profile). The "offset," or the controlled variable, is measured from the selected REFERENCED INPUT which is the water level desired at zero flow. The upstream gate opening is then made directly proportional to the offset that will produce a flow INPUT that matches the flow OUTPUT. The feedback system is basically a proportional mode of control. A special filter is a required element in the feedback path and provides the necessary time lag to compensate for the long dead time in the SYSTEM. The analog computer develops the desired gate opening on a continuous basis.

Central to the stable operation of the expanded SYSTEM is the selection of three primary control parameters, (1) the filter "time constant," (2) the water level "offset," and (3) the proportionality factor or "gain." These control parameters are carefully selected through mathematical model simulation studies to eliminate instability inherent in automatic feedback control systems and to give a high degree of self regulation; i.e., the fastest response and recovery of the system to a new steady state without excessive overshooting of the flow INPUT.

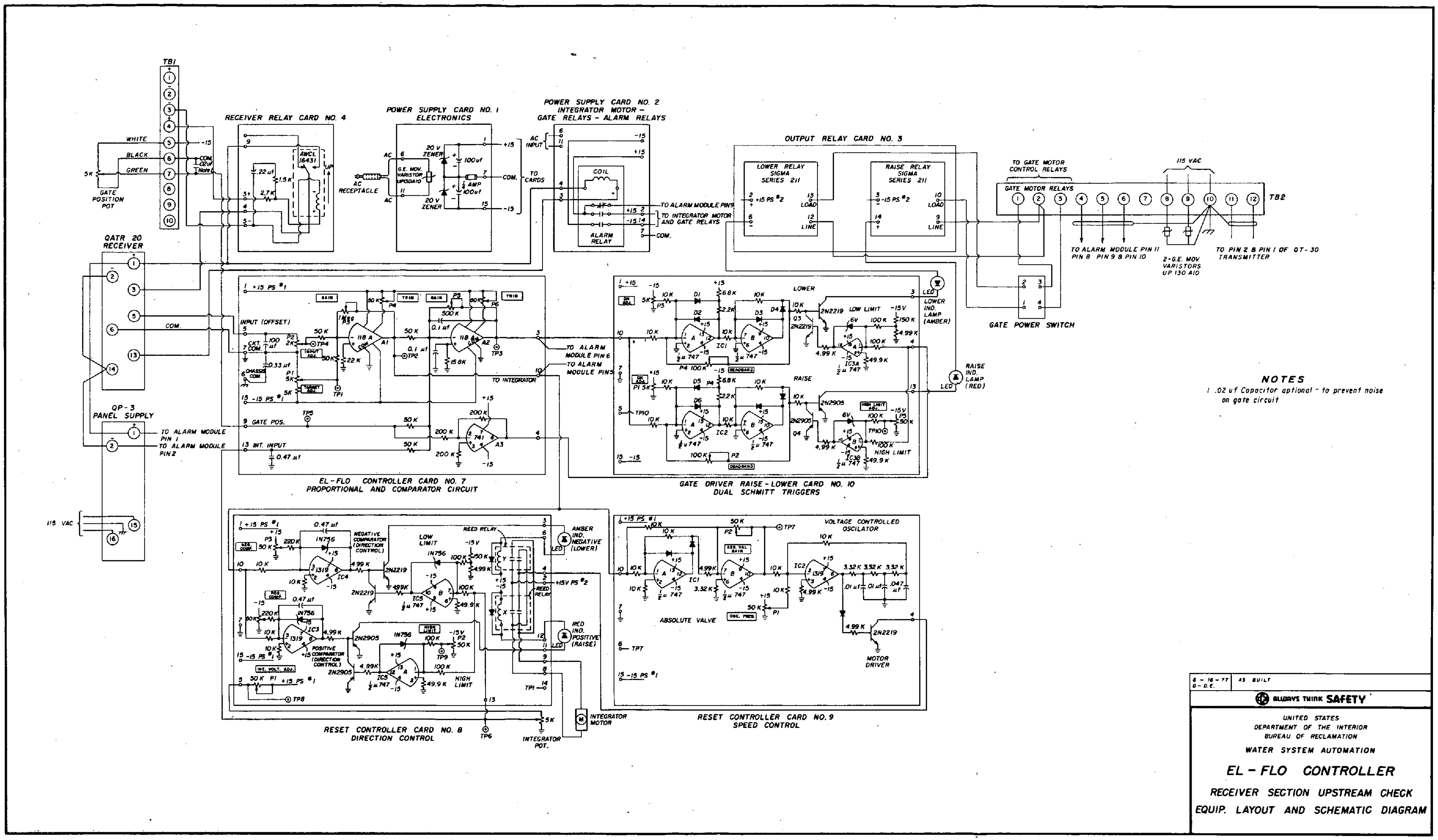


Figure 1-1. - Receiver section upstream check, equipment layout, and schematic diagram.

Proportional plus reset mode of control. - If a RESET controller is added as an element in the feedback path, the residual "offset" characteristic to the proportional mode of control can be eliminated.

The elimination of the offset has certain advantages. The water level deviations are reduced and the maximum channel flow capacity is maintained. Even though the "offset" is physically eliminated in the water level, the RESET controller electronically stores an "offset" so that the automatic coupling of the INPUT to OUTPUT of the SYSTEM is still maintained.

Figure 1-2, solid line parallel to broken line, illustrates the characteristic response of canal reach by the proportional plus reset mode of automatic downstream control.

The controller is a completely solid state unit with one motor-driven potentiometer.

The controller consists of 10 controller cards, 1 analog telemetry transmitter, 1 analog telemetry receiver, 1 alarm module, 1 alarm transmitter, and 1 telemetry power supply. The alarm receiver is located at a central monitoring location.

The EL-FLO controller computes an analog approximation of the following control algorithm:

$$\text{Gate opening} = K_3\,(K_1 e + K_2 \int_0^T e\,dT)$$

where K_1, K_2, and K_3 = real numbers representing the parameters for a particular canal reach

e = filtered voltage representing deviation of the water level from the target elevation

dT = increments of time

$K_1 e$ = the proportional control gate opening function

$K_2 \int_0^T e\,dT$ = the reset control gate opening function

The controller utilizes operational amplifiers with various feedback techniques, an RC filter network, and a direct-current variable speed motor/potentiometer integrator to simulate the above control algorithm.

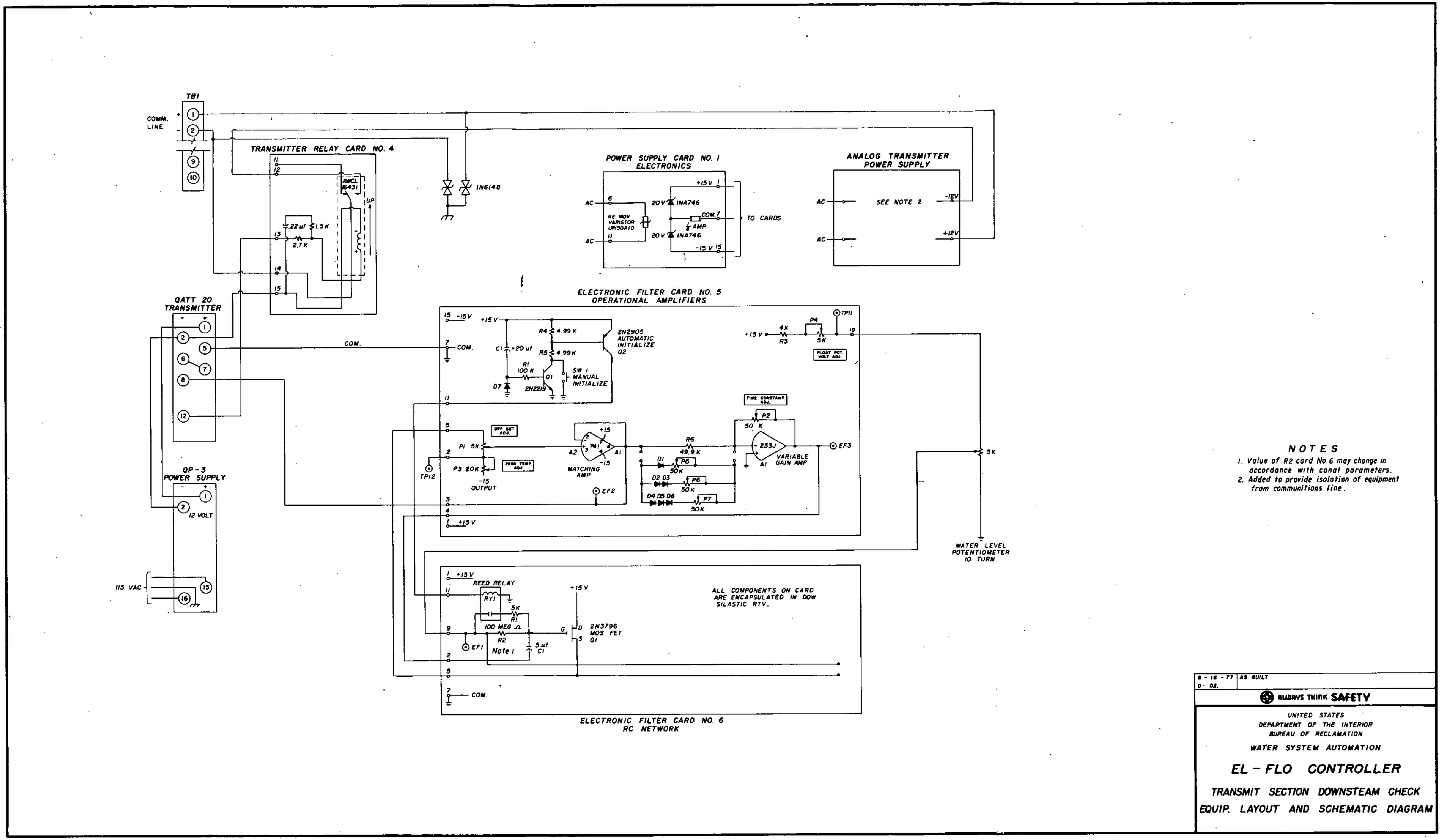


Figure 1-2. - Transmit section downstream check, equipment layout, and schematic diagram.

The controller has two ±15-volt and one +12-volt regulated direct-current power supplies. The +12-volt power supply furnishes power for the alarm and analog telemetering equipment. One of the ±15-volt power supplies furnishes power for all the electronic circuits; the other ±15-volt power supply is used for the integrator motor, gate relay, and to provide the alarm module a signal to indicate receiver alarm condition. Each power supply is a plug-in type and may be replaced as a unit. Figures 1-1 and 1-2 are the schematic diagrams for the controller. Refer to figure 1-1 for all cards except for cards No. 5 and 6 and the analog transmitter.

1-2 Card No. 1

Card No. 1 contains a ±15-volt direct-current power supply complete with surge protection, filter, and fuse and provides the power for all the electronics on the other cards.

1-3 Card No. 2

Card No. 2 contains a ±15-volt direct-current power supply with surge protection and cutoff relay with two normally open contacts and two normally closed contacts of which only one is shown on figure 1-1. All relay contacts are in series with the output of the power supply. The relay control circuit (coil) is driven by the alarm relay of the analog receiver QATR-20. Whenever the power or the input signal to the analog receiver is lost, the control signal for the cutoff relay is lost which in turn interrupts power to the gate relay circuit and the integrator motor. Also, a normally closed contact supplies voltage to the alarm module pin No. 9 which will cause a receiver alarm when open.

1-4 Card No. 3

Card No. 3 contains the gate raise and lower output relays. These relays have a reed relay coil at the input and the reed relay contacts operate a 10-ampere triac. The reed relay coils are connected to the output of the Schmitt triggers on card No. 10 via the raise and lower LED (light emitting diode) indicators.

1-5 Card No. 4

Card No. 4 contains the high-speed mercury transmit and receive relays. The receive relay coil is connected in series with the downstream transmit relay contact, communication line, and the QP3 power supply. The receive relay contacts are in series with the input of the receiver which isolates the output of the transmitter from the communication line.

1-6 Card No. 5

Card No. 5 contains two amplifiers. Amplifier (A2) is an impedance matching amplifier that matches the high impedance output of the (RC) network of card No. 6 to the low impedance amplifier (A1). Amplifier (A1) is an adjustable gain amplifier which determines the time constant (T) of the electronic filter. The larger the gain of (A1), the longer the time constant (T). The gain of the amplifier is the ratio of the output voltage to the input voltage. The output voltage is the voltage at test point (EF3) and the input voltage is the voltage at test point (EF2). The gain of the amplifier is adjusted by adjusting potentiometer (P2) of card No. 5 while holding the initializing pushbutton of card No. 5 down and making voltage measurements at test point (EF2) and (EF3). Card No. 5 also contains manual and automatic initializing circuits. When activated, these circuits initialize the filter output (EF2) to the present value of the input voltage at (EF1). Manual initializing is accomplished by pushing the initialize pushbutton on card No. 5. Automatic initializing is provided whenever the alternating-current power to the controller is turned on. Potentiometer (P4) on card No. 5 is used to adjust the volt/foot ratio for the water level sensing potentiometer. The voltage across the potentiometer is measured at test point (TP11).

1-7 Card No. 6

Card No. 6 contains the (RC) network for the filter, the initializing reed relay, and an insulated gate field effect transistor (MOS-FET). The entire card is encapsulated to prevent humidity contamination of the 100-megohm resistor (50-megohm or 20-megohm resistors are used on some cards) and to protect the MOS-FET from physical contact when the card is removed from chassis. The 100-megohm resistor and the 5-µF capacitor form an (RC) filter network. The 100-megohm resistor is shunted by the normally open (NO) contacts of the reed relay in series with a 5-kilohm resistor. When the reed relay contacts close, the 5-µF capacitor charges to the value of the water level input (EF1) in approximately 25 milliseconds. The MOS-FET transistor connected to the (RC) network provides an extremely high input impedance to the capacitor to prevent it from discharging through the MOS-FET. Special precautions must be taken whenever card No. 6 is removed from the controller to prevent damage to the MOS-FET. (See section IV, Troubleshooting for handling instructions for card No. 6.)

1-8 Card No. 7

Card No. 7 contains three amplifiers. Amplifier (A1) and its input summing junction determines the error of the water level from the desired target level. The value is (e) in the control equation. The gain of (A1) is the constant (K_1) in the control equation. Amplifier

(A2) and its associated summing junction determines the value of the sum of the proportional gate opening and the reset gate opening. This is the value ($K_1e + K_2 \int edT$) in the control equation. Amplifier (A3) is an inverter amplifier that inverts the gate position voltage. This voltage is used in the Schmitt trigger circuit. Amplifiers (A1) and (A2) are provided with trim potentiometers to zero any offset across the amplifiers. To adjust the offset for (A1) amplifier, adjust potentiometer (P1) until test point (TP4) is as close to zero as possible. Adjust potentiometer (P2) until test point (TP1) is as close to zero as possible. Using clip leads, connect test points (TP1) and (TP4) to common. Measure the voltage at test point (TP2) and adjust potentiometer (P4) until the voltage at test point (TP2) is zero. Adjust the voltage to test point (TP8) to 2 volts using potentiometer (P1) on card No. 8. Using a clip lead, connect test point (TP6) to common. Disconnect the gate potentiometer lead on terminal block (TB1-7) and reconnect to common. Measure the voltage at test point (TP3) and adjust potentiometer (P6) until the voltage at (TP3) is zero. The offset of amplifiers (A1) and (A2) is now zero and all connections from the test points to common should be removed. The gate potentiometer should be reconnected to (TB1-7). The test points (TP4), (TP1), and (TP8) should be adjusted to their previous values. The output current of the analog receiver is converted to a voltage by potentiometer (P1). This voltage then goes into the summing junction along with the target voltage. The algebraic sum of these two voltages represents the canal water level error (e); the error voltage is then multiplied by the gain of amplifier (A1) which is the constant (K_1). The target voltage is adjusted by potentiometer (P2) and is measured at test point (TP1). The input voltage is adjusted by (P1) and measured at test point (TP4). The gain of amplifier (A1) is adjusted by potentiometer (P3). The gain is the output voltage at test point (TP2) divided by the input voltage [the algebraic sum of test points (TP1) and (TP4)]. (TP1) will always be negative. The (A1) output goes into the summing junction of amplifier (A2); also the gate position potentiometer slider and the integrator potentiometer slider are summed together and are also input voltages of (A2) amplifier; this sum is then multiplied by the gain of (A2) amplifier which is the constant (K3). The amplifier gain is adjusted by potentiometer (P5). The gain of (A2) amplifier is the ouput voltage at test point (TP3) divided by the sum of the voltage at (TP2), (TP5), and (TP6). Amplifier (A3) is connected as an inverting amplifier with a gain of 1. It is used to invert the gate position polarity and is fed to the summing junction in the Schmitt trigger circuit.

1-9 <u>Card No. 8</u>

Card No. 8 contains the direction control and voltage limit circuits for the reset controller. The card has two circuits that are basically identical. One is for the clockwise operation of the integrator motor; the other is for counterclockwise operation. The input to the direction control circuit is the output of the amplifier (A1) which is the same as test point (TP2). If the input voltage is negative, the negative comparator circuit will operate; if it is positive, the positive comparator will operate. The two circuits are identical except that the positive comparator circuit has an adjustable high limit while the negative comparator has a fixed low limit. Only the positive comparator circuit will be discussed since the negative comparator is identical except that it compares the negative input voltage. Amplifier (IC3) and transistor (Q3) act as an adjustable turn-on switch. The turn-on voltage of the switch is set using potentiometer (P4). As the input voltage goes from zero to some positive voltage, the output of amplifier (IC3) is zero. When the input voltage reaches the turn-on set point, the output of the amplifier goes to 8 volts which turns on transistor (Q3). Transistor (Q3) turns on the red LED, and the relay will pick up causing the integrator motor to run in a direction that will cause the integrator potentiometer slider voltage to increase. To adjust the turn-on voltage, adjust the voltage at test point (TP2) to zero using potentiometer (P2) and card No. 7. The red LED should be off; if not, adjust potentiometer (P4) on card No. 8 until it goes off. Continue turning potentiometer (P4) in the same direction five turns. Using potentiometer (P2) on card No. 7, adjust the voltage at test point (TP2) to the desired turn-on voltage. The red LED should be off; if not adjust potentiometer (P4) of card No. 8 until it goes off. Then adjust potentiometer (P4) of card No. 8 until the LED comes on. The switch will now turn on at the value of test point (TP2). Readjust potentiometer (P2) of card No. 7 so that test point (TP2) is at its proper value. The same procedure is used to adjust the turn-on point of the negative comparator, except voltage at test point (TP2) will now be negative. Amplifier (IC5A) and transistor (Q4) are used as a limit switch that prevents the integrator motor from moving the potentiometer past a calculated maximum voltage or its end stop. The limit point of the limit switch is the voltage at test point (TP9). The voltage is set by adjusting potentiometer (P2) of card No. 8 until the voltage at test point (TP9) is the desired limit voltage. Any time the integrator potentiometer voltage at test point (TP6) is equal to or greater than the voltage at test point (TP9), the raise reed relay of card No. 8 will be deenergized and the motor will not run. The negative comparator circuit has a limit switch feature except that it is fixed at approximately 0.5 volt. Potentiometer (P1) of card No. 8 is used to adjust the volts/revolution of the integrator potentiometer. The volts/revolution value is the voltage at test point (TP8) divided by 10 and can be adjusted with potentiometer (P1) of card No. 8.

1-10 Card No. 9

Card No. 9 contains three amplifiers and a motor drive transistor. Amplifiers (IC1A) and (IC1B) are used in an absolute value circuit which has an output that is proportional to the input but always negative. The gain of the absolute value circuit is the constant K_2 in the control equation. Its gain is adjusted by potentiometer (P2). The gain of the circuit is the output voltage at test point (TP7) divided by the input voltage at test point (TP2). The third amplifier (IC2) is used as a voltage-controlled phase shift oscillator. The oscillator drives the integrator motor through the drive transistor. The speed of the motor is proportional to the positive shift of the oscillator and the shift of the oscillator is proportional to the input voltage. The input voltage to the absolute value circuit is the output of (A1) of card No. 7 (TP2). If the input voltage is positive, diode (D1) conducts causing the gain of amplifier (IC1A) to be zero. Therefore, the output of the absolute value circuit is the input multiplied by the gain of amplifier (IC1B). The output is inverted by amplifier (IC1B). The gain of amplifier (IC1B) is the output voltage at test point (TP7) divided by the voltage at test point (TP2) and is adjusted by potentiometer (P2). If the input voltage is negative, amplifier (IC1A) has a gain of one; it also inverts the signal. The output voltage of (IC1A) is summed with the output of amplifier (IC1B) which has a gain greater than one. Amplifier (IC1B's) output is also inverted; therefore, the output is still negative. The negative output voltage of the absolute value circuit drives the voltage-controlled oscillator. The varying voltage input to the oscillator causes the oscillator to change the positive period of its output. The positive shift of the oscillator determines the on-time to off-time ratio of the motor drive transistor. This controls the average direct-current voltage to the integrator motor and the motor speed varies with this applied voltage. Thus, the circuit controls the speed of integration in direct proportion to the error voltage at test point (TP2).

1-11 Card No. 10

Card No. 10 contains the raise-lower Schmitt triggers and the gate high and low electronic limit switches. Amplifiers (IC1A) and (IC1B) and transistor (Q1) comprise the lower Schmitt trigger. Amplifier (IC3A) and transistor (Q3) comprise the lower electronic limit switch. Amplifiers (IC2A) and (IC2B) and transistor (Q2) comprise the raise Schmitt trigger. Amplifier (IC3B) and transistor (Q4) comprise the raise electronic limit switch. The input to the Schmitt trigger circuit is the output of amplifier (A2) of card No. 7 (TP3). As the output of amplifier (A2) varies plus and minus the lower and raise Schmitt triggers turn on to adjust the canal gate. When one of the triggers operates, the gate moves until the gate position potentiometer output fed to (A2) corrects the output voltage of amplifier (A2) to zero where the energized Schmitt trigger turns off. The Schmitt triggers are set to turn on at ±1.0 volt and to turn off at zero volt (turn-on voltage of some units may be set at voltages other than ±1.0). The turn-on voltages of the triggers are set using potentiometers (P1) and (P3) on card No. 10. The turn-off voltages are set using potentiometers (P2) and (P4). If the output of amplifier (A2) is positive, the lower Schmitt trigger will fire when the output reaches +1.0 volt; if the amplifiers's output is negative, the raise Schmitt trigger will operate when the output reaches -1.0 volt. When the trigger turns on, transistor (Q1) or (Q2) turns on and energizes the proper raise or lower relay. The lower Schmitt trigger has a limit switch that has a fixed-limit voltage of 0.5 volt. This means that when the voltage from the gate potentiometer is equal to or less than 0.5 volt, the Schmitt trigger is prohibited from lowering the gate any further. The input voltage to the limit switch is the gate position voltage from the inverting amplifier (A3) of card No. 7. The high limit switch for the raise Schmitt trigger has an adjustable limit point. It is usually set to limit when the gate is just above the maximum flow gate opening. The high limit trip voltage is the voltage at test point (TP10) and is adjusted by potentiometer (P5) on card No. 10.

1-12 QATR 20 and QATT-20

QATR-20 and QATT-20 comprise an analog telemetry system used for the remote measurement of quantities which have been converted to proportional direct-current currents or voltages. The system consists of a telemetry transmitter QATT-20 and companion receiver QATR-20.

The transmitter emits a signal whose frequency varies within the range of 5 to 25 pulses per second and is controlled by the input direct-current current or voltage. The receiver converts the pulses into direct-current current that is proportional to the input of the QATT-20 at the transmit location.

1-13 QR-30 and QT-30

QR-30 and QT-30 comprise a tone telemetry system for centralized indication of system alarms. The QR-30 is located at a centralized loction for monitoring.

Note: See Quindar Equipment Manuals for operation and maintenance instruction for the above equipment.

1-14 Alarm Module

The alarm module monitors (TP-2), (TP-3), and the relay on power supply No. 2 and the high and low water alarm relays. An abnormal condition causes the output relay to key the QT-30 tone transmitter and signal an alarm. (See figure 1-3.)

1-15 Additional Equipment

Additional equipment includes a water level float assembly that drives a 10-turn 5-kilohm potentiometer to provide the canal water level, a 10-turn or 5-turn 5-kilohm potentiometer attached to the gate hoist to provide gate position, and the necessary relays and timers to interface the gate hoist controller.

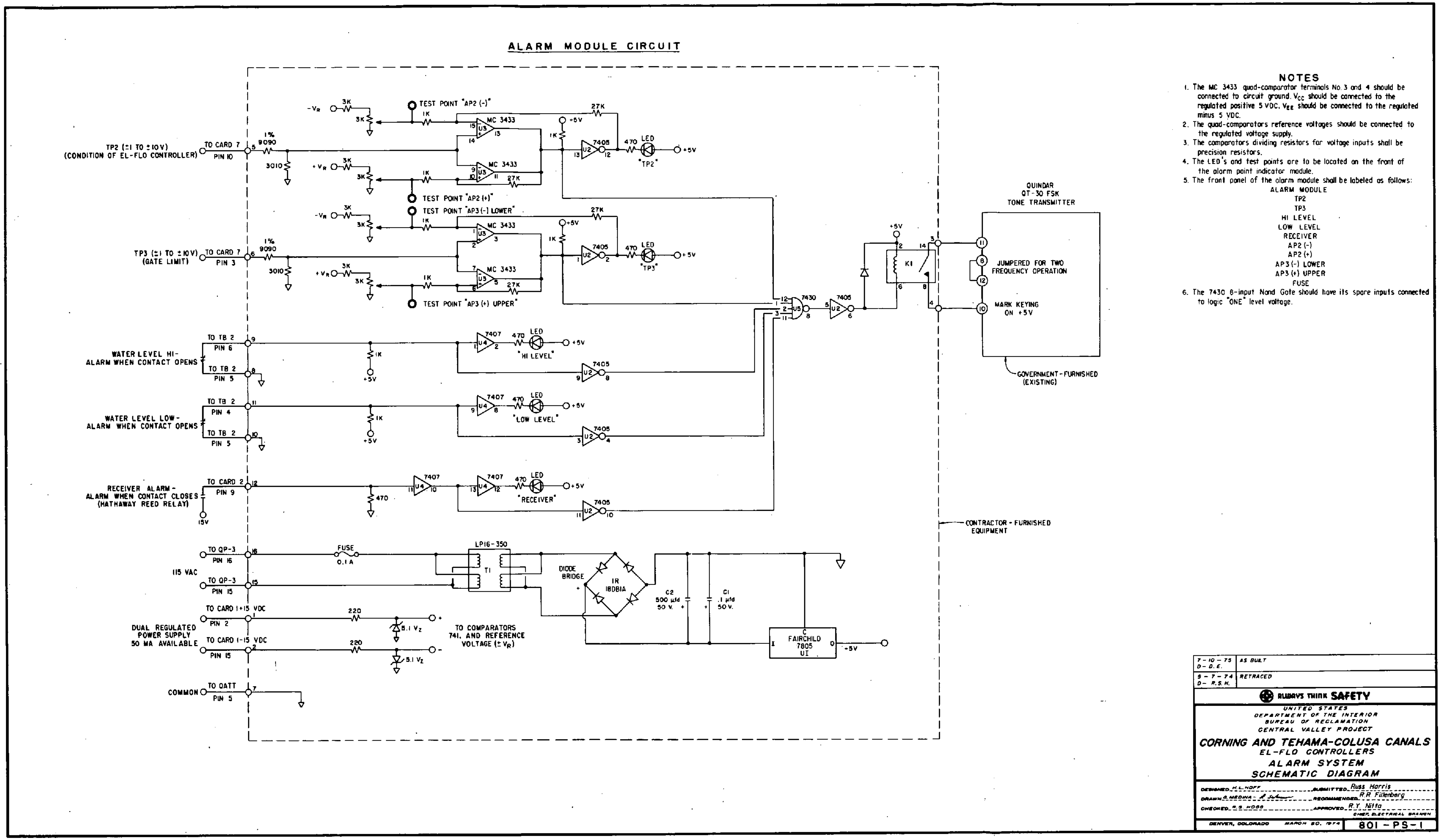


Figure 1-3. - Alarm system, schematic diagram.

SECTION II. - THEORY OF OPERATION

2-1 Water Level Sensor, RC Network, and Test Point (EF1)

The water level sensor (potentiometer) at the downstream check point applies voltage to the RC network (R2 and C5) of card No. 6 and is monitored at test point (EF1). This voltage applied to amplifier (A1) of card No. 5 will simulate the time it takes for a change in water level to reach the upstream checkpoint. (The longer the canal reach, the longer the time constant needed.)

By changing (R2) of card No. 6 and by adjusting (P2) of card No. 5, the time constant can be adjusted to match most any canal reach.

2-2 MOS-FET Transistor (Q1) of Card No. 6 (A1) and (A2) of Card No. 5

(Note: See section IV, maintenance for handling instructions for card No. 6.)

The gate of the MOS-FET transistor (Q1) of card No. 6 is connected to the R-C (Resistor-capacitor) circuit consisting of (R2 and C5) of card No. 6. The gate of (Q1) has a very high input impedance that will prevent loading of the R-C circuit, but will allow any change in voltage developed across (C5) of card No. 6 to affect the source follower circuit of (Q1) of card No. 6. The source voltage of (Q1) is the input voltage for amplifier (A2) of card No. 5 via potentiometer (P1) of card No. 5.

Amplifier (A2) of card No. 5 has unity gain and is a noninverting amplifier whose output at (EF2) provides the input voltage for the QATT-20 telemeter transmitter and the variable time constant amplifier (A1) of card No. 5. Amplifier (A1) of card No. 5 is an inverting amplifier with a monitoring test point at (EF3). The voltage at test point (EF3) is also applied to (C5) of card No. 6. This negative voltage is proportional to the gain of amplifier (A1) of card No. 5 and the source voltage of the MOS-FET transistor (Q1).

2-3 Automatic and Manual Initialize Circuit, Cards No. 5 and 6

Cards No. 5 and 6 also have an automatic and manual initialize circuit. When the alternating-current power is first turned on, transistor (Q1) of card NO. 5 will saturate due to the charging of (C1) of card No. 5. When transistor (Q1) saturates, it will force transistor (Q2) of card No. 5 to saturate which will in turn cause relay (RY1) of card No. 6 to operate. When (RY1) relay operates, its normally open contact closes and a 5-kilohm resistor (R1) of card No. 6 shunts (R2) of card No. 6

which allows (C5) of card No. 6 to charge in approximately 25 milliseconds to the voltage present at the slider of the water sensor potentiometer.

Switch No. 1 of card No. 5 is the manual initializing switch. When switch No. 1 is pressed, it will force transistor (Q2) of card No. 5 to saturate which will again operate relay (RY1).

2-4 Test Point (EF2), QATT-20 Telemeter Transmitter, and Card No. 4

Test point (EF2) provides positive voltage in proportion to the voltage applied to the gate of transistor (Q1) of card No. 6. The voltage at test point (EF2) is the input voltage for the QATT-20 telemeter transmitter pin No. 8. The QATT-20 telemeter transmitter converts the slow-changing positive voltage from test point (EF2) to pulsating direct-current voltage of from 5 to 25 Hz at the output of the QATT-20 telemeter transmitter pin No. 12. The rate of pulsation is proportional to the direct-current voltage at test point (EF2). The greater the voltage at test point (EF2), the faster the rate. The output at pin No. 12 of the QATT-20 telemeter transmitter is connected to (TB1-1 and 2) via the transmitter relay on card No. 4. This pulsating direct-current voltage is transmitted upstream to (TB1-3 and 4) at the next check controller via a communication cable.

2-5 QATR-20 Telemeter Receiver, Cards No. 2 and 4

QATR-20 telemeter receiver, cards No. 2 and 4 (TB1-3 and 4) at the upstream checkpoint, the transmitted pulsating direct-current voltage is applied via the receiver relay of card No. 4 to pin No. 3 of the QATR-20 telemeter receiver. The pulsating direct-current voltage that is received by the QATR-20 telemeter receiver is converted to a slow-changing direct-current current level and is applied across potentiometer (P1) of card No. 7. Also inside the QATR-20 telemeter receiver is a relay that operates whenever the pulsating direct-current voltage is received from the downstream QATT-20 telemeter transmitter. Negative voltage from the QP3 power supply pin No. 2 is connected to pin No. 14 of the QATR-20 telemeter receiver through the normally closed contacts of the QATR-20 telemeter receiver. This negative voltage is then applied across the coil of the relay of card No. 2 and then back to pin No. 1 of the QP3 power supply positive terminal via pin No. 1 of the QATR-20 telemeter receiver. So whenever a pulsating direct-current voltage is received, the relay of card No. 2 will be energized.

The operation of the relay of card No. 2 will close a circuit to supply a positive 15 volts to the intergrator motor via contacts of the (Y) or (X) relays of card No. 8. Also $\pm$15 volts is applied to the gate relays via the relay contacts of card No. 2. The relay of card No. 2 has a set of normally closed contacts that will open when the receiver signal is present. When these contacts are closed the alarm receiver at the central alarm panel signals an alarm via the alarm tone transmitter and alarm module.

2-6 Test Point (TP4) "Water Input Voltage," Test Point (TP1) "Target Voltage," and Error Voltage and Amplifier (A1) of Card No. 7

The output current level provided by the QATR-20 telemeter receiver is applied across potentiometer (P1) of card No. 7. This current will develop a voltage at test point (TP4) in proportion to the output current of the QATR-20 telemeter receiver. The voltage at test point (TP4) is adjustable via the slider of potentiometer (P1) of card No. 7. (The voltage at (TP4) is proportional to the water level sensor at the downstream checkpoint.) Refer to paragraphs 2-1 through 2-4 for downstream checkpoint operation. The sum of test point (TP4) a positive voltage representing the downstream water level and test point (TP1) negative voltage representing the target water level, provides the input for (A1) of card No. 7. The input voltage to (A1) of card No. 7 may either be positive or negative due to the fact that the target voltage (TP1) is always negative and of some adjusted fixed voltage, while the input water level voltage (TP4) is always positive, but will vary in accordance with the water at the downstream checkpoint.

If the water at the downstream checkpoint is high, then the positive voltage at test point (TP4) will be more positive than the negative target voltage at test point (TP1). The error voltage (e) will be positive. If water level at the downstream checkpoint be low, water level voltage at test point (TP4) will be less positive than the negative target voltage at test point (TP1). Therefore, the error voltage (e) will be a negative voltage.

(A1) card No. 7 is an inverting amplifier - if the error voltage is negative, the output of (A1) of card No. 7 will be a positive voltage; and if the error voltage is positive, the output of (A1) of card No. 7 will be a negative voltage.

2-7 Test Point (TP2) Output Voltage and Adjustments of Amplifier (A1) of Card No. 7

(A1) of card No. 7 has two adjustments; potentiometer (P4) is the input adjusting potentiometer and potentiometer (P3) is the variable gain adjusting potentiometer. The output of (A1) card No. 7 supplies voltage to four circuits and can be monitored at test point (TP2). The four input circuits supplied by the output of (A1) card No. 7 are as follows:

Pin No. 5 of the alarm module (to be covered later).

Pin No. 10 of card No. 8 reset controller (to be covered in paragraph 2-12).

Pin No. 10 of card No. 9 reset speed control (covered in paragraph 2-14).

The input summing junction of amplifier (A2) card No. 7 (covered in paragraph 2-8).

2-8 Test Point (TP2), Test Point (TP5), and Test Point (TP6)

The summing junction of amplifier (A2) card No. 7 has three inputs:

a. The output of amplifier (A1) card No. 7, test point (TP2) (which can be either negative or positive voltage)
b. The voltage at the slider of the integrator potentiometer, test point (TP6) (which is always a positive voltage)
c. The voltage at the slider of the gate position potentiometer, test point (TP5) (which is always a negative voltage)

These three test point voltages, (TP2), (TP5), and (TP6), are summed via the (50-K) resistors and applied to the input of amplifier (A2) of card No. 7. That is, the algebraic sum of test points (TP2), (TP5), and (TP6) comprises the input for amplifier A2 of card No. 7.

2-9 Test Point (TP3) and Amplifier (A2) of Card No. 7

Amplifier (A2) of card No. 7 is a variable gain amplifier whose gain is adjustable by potentiometer (P5) of card No. 7. Potentiometer (P6) of card No. 7 is the trim potentiometer for amplifier (A2) of card No. 7. Amplifier (A2) of card No. 7 is an inverting amplifier whose output is monitored at test point (TP3). For example, if the water level is high at the downstream checkpoint, this will make the voltage at test point (TP4) a higher positive voltage than the negative voltage at test point (TP1). This means that the input voltage applied to amplifier (A1) of card No. 7 will be a positive voltage. The amount of positive voltage at test point (TP4) is dependent on how high the water level is at the downstream checkpoint. Amplifier (A1) of card No. 7 is an inverting amplifier; therefore, the output of amplifier (A1) of card No. 7 monitored at test point (TP2) will be some negative voltage determined by the amount of (A1's) input voltage times the gain of amplifier (A1) of card No. 7. This negative voltage at (TP2) is then summed with the integrator potentiometer (positive voltage) test point (TP6) and the gate position potentiometer (negative voltage) test point (TP5) plus the output of amplifier (A1) of card No. 7 (negative voltage for this example) at test point (TP2).

Amplifier (A2) of card No. 7 is an inverting amplifier which will invert the negative voltage (the input) to obtain a positive voltage at the output of amplifier (A2) of card No. 7 test point (TP3). The output of amplifier (A2) card No. 7 test point (TP3) supplies inputs for two circuits:

a. Pin No. 6 of the alarm module (to be covered later)
b. Pin No. 10 of card No. 10 which will be covered in paragraph 2-10

2-10 Lower Schmitt Trigger Circuit of Card No. 10

When the output of (A2) of card No. 7 is positive, (IC1A) and (IC1B) plus transistor (Q1) of card No. 10 are affected.

When the output of (A2) of card No. 7 is negative, (IC2A) and (IC2B) plus transistor (Q2) of card No. 10 are affected. Keep in mind that the output of amplifier (A2) of card No. 7 is the composite of the target voltage test point (TP1) (always a negative voltage) and downstream water level test point (TP4) (a variable positive voltage determined by the downstream water level) combined with the gate position voltage test point (TP5) (a variable negative voltage) and the integrator position voltage, "a variable positive voltage." If the water level downstream is high, the error voltage at the input of (A1) card No. 7 will be positive; and the output of (A1) of card No. 7 will be negative as monitored at test point (TP2). The summing junction at the input of (A2) of card No. 7 will combine the negative voltage at test point (TP2) with the positive voltage of test point (TP6) and the negative voltage at (TP5). Then the algebraic sum of (TP2), (TP5), and (TP6) will be amplified by (A2) of card No. 7 which is the input of the Schmitt trigger card No. 10. As was stated, the water level at the downstream checkpoint is high. This will in turn make the input of (A1) card No. 7 positive and its output negative. From this we can assume that the negative at the output of (A1) card No. 7 will have the greatest influence on the input of (A2) of card No. 7. With a negative voltage at the input of (A2) of card No. 7, we will have a positive voltage at the output of (A2) of card No. 7. This positive voltage will affect the Schmitt trigger (IC1A) and (IC1B) plus transistor Q1 of card No. 10. The normal turn-on point of both Schmitt triggers is 1 volt, but this point can be varied by potentiometer (P3) for the lower Schmitt trigger and by potentiometer (P1) for the raise Schmitt trigger. The normal turn-off point of the Schmitt triggers, both raise and lower, is 0 volt. A 1.0-volt positive at (TP3), the output of (A2) of card No. 7, will cause the lower Schmitt trigger to operate. This in turn will cause transistor (Q1) to saturate. When (Q1) saturates, it will cause the lower relay of card No. 3 to operate via the lower amber LED. When the lower relay operates, it will, via 10-ampere triac solid-state relay, cause the gate motor to operate and in turn cause the gate position potentiometer to change the voltge at (TP5). This change in voltage at TP5 will change the output of (A2) of card No. 7. As was stated, the Schmitt trigger will turn on at 1.0 volt and off at 0 volt. As the gate motor drives the gate position potentiometer less negative, this will cause the output of (A2) of card No. 7 to become 0. When this happens, the Schmitt trigger will turn off and (Q1) will come out of saturation which will release the lower relay via the amber LED, and the gate motor will stop. This condition will be maintained until test point (TP3) again becomes 1.0 volt positive or negative, at which time either the lower or the raise Schmitt trigger will again operate to satisfy the demands downstream.

2-11 Raise Schmitt Trigger Circuit of Card No. 10

The raise Schmitt trigger circuit operates the same as the lower Schmitt trigger but will operate when the output of (A2) card No. 7 at test point (TP3) is 1.0 volt negative and turn off when the voltage at test point (TP3) reaches 0 volt. The lower and raise electronic limit switches receive their input from the same source (A3) of card No. 7. (A3) of card No. 7 is an inverter amplifier that inverts the negative voltage from the slider of the gate position potentiometer via test point (TP5).

The lower limit switch consists of (IC3A) and transistor (A3) of card No. 10. When the voltage at test point (TP5) reaches 0.5 volt, (IC3A) of card No. 10 will turn on causing (Q3) to saturate which will, in turn, prevent (Q1) from saturating. This action is needed to prevent the gate from closing beyond the point where the gate cables would become loose. Also, to prevent the gate position potentiometer from being forced past its stop, the lower limit is a nonadjustable limit .

The raise limit consists of (A3) of card No. 7. (IC3B) and transistor (Q4) of card No. 10, and (IC3B) and potentiometer (P5) of card No. 10 determine the upper limit to which the gate will raise. When this limit is reached, (Q4) will saturate preventing (Q2) from operating the raise relay via the red LED which will prevent the gate from raising past the upper adjustable limit. [Refer to the table on the front door of controller for the adjustment of test point (TP10)].

2-12 Positive and Negative Comparator of Card No. 8

Both the positive and the negative comparators receive their input from the output of amplifier (A1) of card No. 7 monitored at test point (TP2). Also, both the negative and positive comparators have a variable input. Potentiometer (P4) is the adjustable input for the positive comparator and potentiometer (P3) is the adjustable input for the negative comparator. By way of the above two potentiometers, the turn-on points of each of the comparators can be varied to meet the reset needs.

Let us take a close look at the input to the positive comparator as the water level at the downstream checkpoint decreases (due to a greater demand). This drop in water level will be reflected upstream via the QATT-20 telemeter transmitter and the QATR-20 telemeter receiver. The output of the QATR-20 telemeter receiver is monitored at test point (TP4). Now as the water level has decreased at the downstream checkpoint, this will mean that the voltage at test point (TP4) will now become less positive than the negative target voltage at test point (TP1). This in turn will cause the voltage at amplifier (A1's) summing junction to become some negative voltage (determined by how low the downstream water level is). This negative voltage will be inverted and amplified by amplifier (A1) of card No. 7. With this negative input at (A1) we will have a large positive at the output of (A1) test point (TP2). As the positive voltage at test point (TP2) reaches some positive potential determined by the setting of potentiometer (P4), it will cause the output of (IC3) of card No. 8 to switch from 0 volt to about 8 volts positive. This positive 8 volts at the output of (IC3) will cause transistor (Q3) to saturate. When transistor (Q3) saturates, it will operate the (X) relay of card No. 8 via the red indicator LED. The operation of the (X) relay will cause the integrator motor to run in a direction that will cause the positive voltage at the slider of the integrator potentiometer to raise or become more positive. The slider of the integrator potentiometer is monitored at test point (TP6) and is one of the inputs of the (A2) summing junction of card No. 7. This increase in positive voltage will cause the input of amplifier (A2) of card No. 7 to become more positive. This positive at the input of (A2) of card No. 7 will cause the output of (A2) card No. 7 to become more negative which will aid the positive voltage at test point (TP2) in causing the raise Schmitt trigger circuit in operating the raise relay of card No. 3.

As we have seen, the direction of the integrator motor is under the control of the downstream water level via (A1) of card No. 7. Now if the water level at the downstream checkpoint increases (due to a lesser demand), this will cause test point (TP4) to become more positive. This positive will now be greater than the negative at test point (TP1) and will cause the input of amplifier (A1) of card No. 7 to become positive and the output of (A1) card No. 7 to become more negative as monitored at test point (TP2). This negative voltage will now effect the negative comparator circuit (IC4) and transistor (Q1) of card No. 8. The turn-on point of the negative comparator (IC4) of card

No. 8 can be adjusted via potentiometer (P3). When the negative voltage at test point (TP2) reaches some negative voltage determined by the set of potentiometer (P3), (IC4) will switch from 0 volt to about 8 volts. The 8 volts at the output of (IC4) of card No. 8 will cause transistor (Q1) to saturate which will cause the (Y) relay of card No. 8 to operate via the amber indicator LED. The operation of the (Y) relay of card No. 8 will cause the integrator motor to run in a direction that will cause the voltage at the slider of the integrator potentiometer to become less positive. This voltage is monitored at test point (TP6) which is again one of the (A2) inputs. As the input of (A2) card No. 7 is caused to become less positive (or more negative) by the voltage at the slider of the integrator potentiometer, this less positive voltage will aid the negative voltage at test point (TP2) and will cause lower Schmitt trigger to operate the lower relay of card No. 10 which will close the gate to satisfy the downstream demands.

2-13 High and Low Electronic Limit Switch of Card No. 8

Amplifier (IC5A) and transistor (Q4) make up the high electronic limit switch. This circuit limits the operational range of integrator motor potentiometer and prevents it from going past its end stop. The turn-on point of the high limit switch is the voltage at test point (TP9). The limit voltage is adjusted by potentiometer (P2) of card No. 8 until the voltage at test point (TP9) is at the desired limit voltage. Any time the integrator potentiometer voltage at test point (TP6) is equal to or greater than the voltage at test point (TP9), (IC5A) of card No. 8 will switch causing transistor (Q4) of card No. 8 to saturate which grounds the base of (Q3) preventing operation of the (X) relay of card No. 8. Thus, any operation of the integrator motor is prevented.

The low electronic limit circuit operates the same as the high electronic limit switch but has a fixed electronic limit of 0.5 volt. This means that whenever the voltage at the slider of the integrator potentiometer test point (TP6) reaches 0.5 volt, (IC5A) will switch and cause transistor (Q2) of card No. 8 to saturate which will ground the base of transistor (Q1). This prevents transistor (Q3) from saturating and operating the (Y) lower relay, and preventing the integrator motor from forcing the integrator potentiometer against the end stop.

2-14 Absolute Value Amplifier of Card No. 9

As was stated in paragraph 2-8a , the output of amplifier (A1) of card No. 7, monitored at test point (TP2), can either be a negative or a positive voltage depending on the downstream water conditions. As the voltage at test point (TP2) becomes negative, diode (D1) of card No. 9 will block the negative voltage and will cause amplifier (IC1A) of card No. 9 to invert this negative voltage thus applying a positive voltage to the input to amplifier (IC1B) of card No. 9.

As the voltage test point (TP2) becomes positive, diode (D1) of card No. 9 will shut amplifier (IC1A) of card No. 9 thereby again applying a positive voltage to the input of amplifier (IC1B). Thus, whether the voltage at test point (TP2) is negative or positive, the voltage at the input of amplifier (IC1B) of card No. 9 and at test point (TP12) will always be positive. The positive voltage at the input of (IC1B) card No. 9 will be amplified and inverted by amplifier (IC1B). The gain of amplifier (IC1B) is controlled by potentiometer (P2) of card No. 9. The output of (IC1B) of card No. 9 will always be a negative voltage and is monitored at test point (TP7). (IC1A) and (IC1B) comprise an absolute value amplifier.

2-15 Voltage Controlled Oscillator (IC2) and Motor Drive Transistor (Q1) of Card No. 9

As we saw in paragraph 2-15, the output of the absolute value amplifier (IC1A) and (IC1B) has its output monitored at test point (TP7) and is always a negative voltage. This negative voltage is the input of the voltage controlled oscillator (IC2) of card No. 9 and will determine the positive shift at which the oscillator will operate. The higher the input voltage, the higher the shift. Also, at the input of (IC2) of card No. 9, we have a potentiometer (P1) which is used to calibrate the amount of voltage that will be developed across the integrator motor. The voltage-controlled oscillator determines the on-time to off-time ratio of the motor drive transistor of card No. 9. The voltage-controlled oscillator will determine the average current applied to the base of the motor drive transistor (Q1) of card No. 9 which will in turn control the average direct current applied to the integrator motor. Thus, we are using the error voltage at test point (TP2) of card No. 7 via the absolute value amplifier (IC1A and IC1B), the voltage-controlled oscillator, and the motor drive transistor to control the speed of the integrator motor. Therefore, the speed of the integrator motor is in direct proportion to the voltage negative or positive at test point (TP2). The collector of the motor drive transistor (Q1) of card No. 9 is connected via the direction control relays (X) or (Y) of card No. 8 to the integrator motor. The direction of the integrator motor is controlled by the negative or positive error voltage at test point (TP2) and the speed of the integrator motor is controlled by the amount of negative or positive voltage at test point (TP2).

2-16 Alarm Module

The alarm module monitors the voltage at (TP2) and (TP3), two normally closed contacts and one normally open contact. Any change in the monitored contacts or a voltage change in (TP2) or (TP3) out of the reference limits set will cause the output relay of the module to close. This output relay usually controls a Quindar QT-30 FSK tone transmitter.

(TP2) is input through a voltage divider to two Motorola MC3433 voltage comparators. Positive and negative reference voltages are also input to the comparators. These voltages are set by trim potentiometers. When (TP2) exceeds the negative or positive reference, the output of the comparator changes state causing the output relay to close. The circuit for (TP3) is identical to (TP2). The contact inputs are monitored by TTL logic gates. All these signals are input to a five input "or" gate to drive the output relay.

A 5-volt logic power supply is provided on the card; however, the comparator reference voltage is derived from the EL-FLO card No. 1 power supply.

TABLE OF TEST POINT VOLTAGES AND AMPLIFIER GAINS FOR EL-FLO CONTROLLER CHECK NO. STA. NO.

(1) Volts @ TP11 = Volts/foot water level sensor.

(2) Gain of Amp. A1 card No. 5 =

(3) Gain of Amp. A1 card No. 7 =

(4) Gain of Amp. A2 card No. 7 =

(5) Volts @ TP8 =

(6) Turn-on volts for red reset indicating light =

(7) Turn-on volts for amber reset indicating light =

(8) Integrator high limit volts @ TP9 =

(9) Schmitt Trigger turn-on Lower = + volts
Raise = − volts

(10) Gain of Absolute Value Amp. card No. 9 =

(11) Water Surface target Elevation =

(12) Voltage between TP12 and Source lead of MOS - FET =

(13) Gate high limit volts @ TP10 =

(14) Target volts @ TP1 =

(15) Input volts @ TP4 =

(16) Alarm volts @ AP2 Pos. limit = Neg. limit =

(17) Alarm volts @ AP3 Pos. limit = Neg. limit =

Figure 3-1. - Table of test point voltages and amplifier gains.

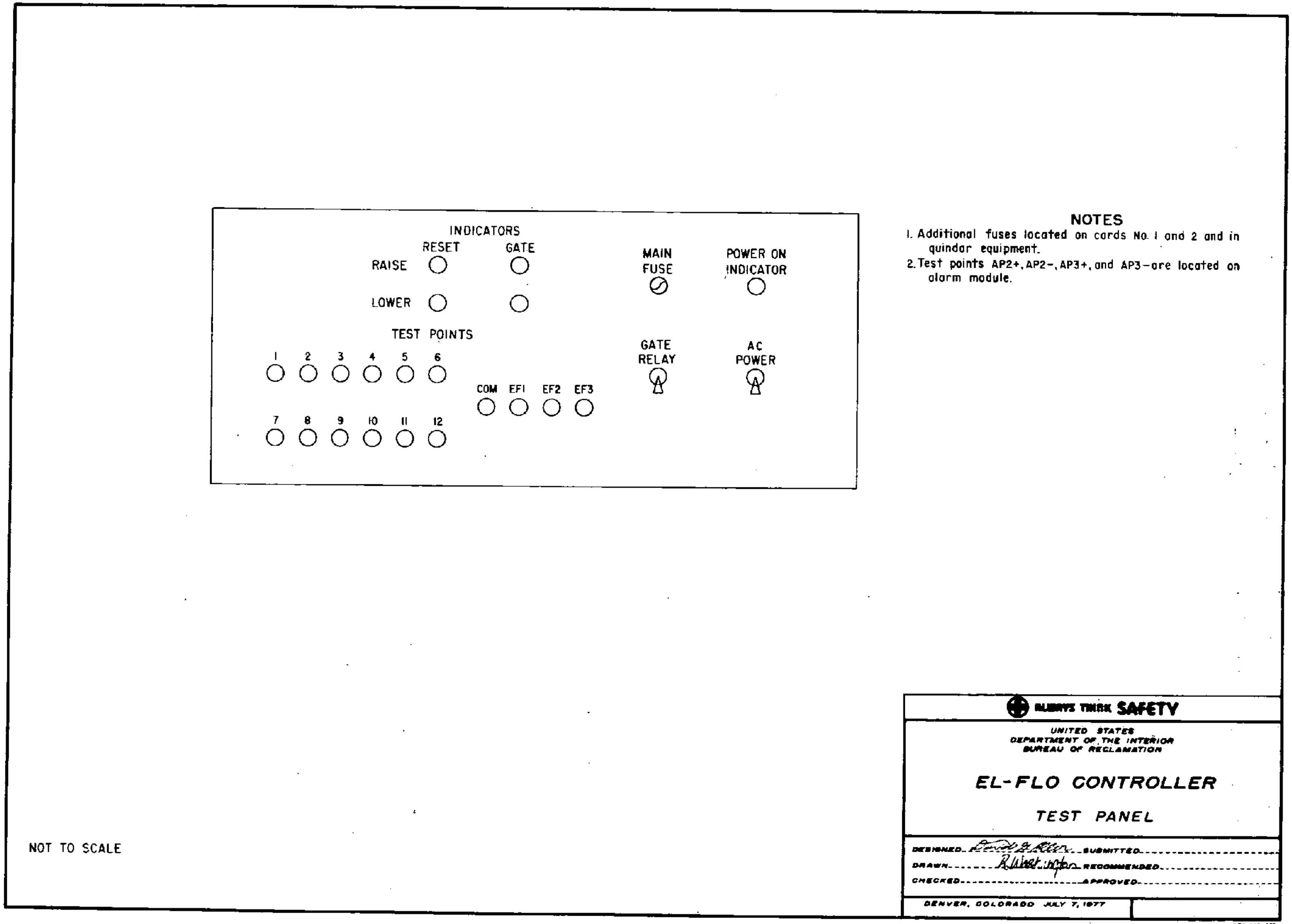


Figure 3-2. - Controller test panel.

SECTION III - STARTUP AND RECALIBRATION PROCEDURE

3-1 General Information

The following procedure is to be used whenever a new controller is placed into operation for the first time or when a printed circuit card is replaced in an operating controller. If the controller has been in operation and a card is replaced, it is important to follow the complete procedure even though many of the adjustments may not have changed. Many of the amplifier gain settings and voltage adjustments vary from canal reach to canal reach depending on the various parameters of the canal; therefore, on the inside door of each controller is a table listing the specific values to be set while going through the setup procedure. A sample table is provided as figure 3-1. It is important to note that each cabinet contains a complete controller consisting of a transmitter section and a receiver section. However, only the receiver section is used to control the gate at the cabinet location. The transmitter section is used by the controller at the next gate upstream. The receiver section receives information from the transmitter section of the controller at the next downstream location.

If problems are enountered in following this procedure and obtaining the proper results it may be the result of a defective controller card. If a defective card is suspected refer to the appropriate parts of section IV of this manual "Trouble Shooting."

This calibration procedure should be carried out from start to finish. However, during the operating season, to minimize downtime, parts of the calibration procedure may be deleted. This is particularly useful when replacing a card, changing gain factors, or changing limits. An outline of these shortcut procedures is provided in section 4-3 of this manual.

When these are used, the target (TP2), and Op Amp 2 and Op Amp 3 gains (TP2) and (TP3) should always be verified before placing the controller back in service. Do not attempt to adjust Op Amp 2 or 3 offset without going through the entire procedure.

All voltage measurements are to be made with a digital voltmeter. The common of the voltmeter should be plugged into test point common (COM), and the positive voltmeter lead is plugged into the appropriate test points unless specifically directed otherwise. The polarity of the voltage to be measured is important only when noted. Test points, indicators, and switches are identified on figure 3-2 and listed in table 3-3.

Figure 3-3. - Table of test points.

No.	Description	Adjustment	Test point table figure 3-1
*TP1	Target voltage	Card No. 7 - P1	14
*TP2	Op Amp No. 1 - Output	Card No. 7 - P3	**3
*TP3	Op Amp No. 2 - Output	Card No. 7 - P5	**4
*TP4	Water level input	Card No. 7 - P2	N/A
TP5	Gate potentiometer voltage	Gate position	N/A
*TP6	Reset output	Integrator potentiometer	N/A
TP7	Absolute value output	Card No. 9 - P2	**10
TP8	Integrator potentiometer voltage	Card No. 8 - P1	5
TP9	Integrator high limit	Card No. 8 - P2	8
TP10	Gate high limit	Card No. 10 - P5	13
TP11	Water level potentiometer voltage	Card No. 5 - P4	1
TP12			
COM	Circuit common	N/A	N/A
*EF1	Electronic filter input	Water level potentiometer	
*EF2	Electronic filter output	Card No. 5 - P1 and P3	
EF3	Electronic filter calibration	Card No. 5 - P2	**2

* Most useful in equipment checking.
** Amplifier gain.

3-2 External Connections

a. Turn alternating-current power on-off switch to the off position.

b. Turn the gate relay on-off switch to the off position.

c. Connect alternating-current power and ground to terminal block (TB2) as shown on schematic wiring diagram (fig. 3-4).

d. Connect the gate control circuit to terminal block (TB2) as shown on schematic wiring diagram (fig. 3-4), being careful to observe polarity.

e. Connect the gate potentiometer to terminal block (TB1) (as shown on schematic wiring diagram (fig. 3-4), making sure that the slider is connected to the terminal marked (GPSLD).

Note: If the controller is or has been in service, the above connections will have already been made.

3-3 Telemeter Receiver Calibration

The receiver should be calibrated using the following procedure:

a. With the communication line cable pair disconnected (see schematic wiring diagram fig. 3-4), connect the +XMIT to the +REC terminal and the -XMIT to the -REC terminal with a short jumper wire.

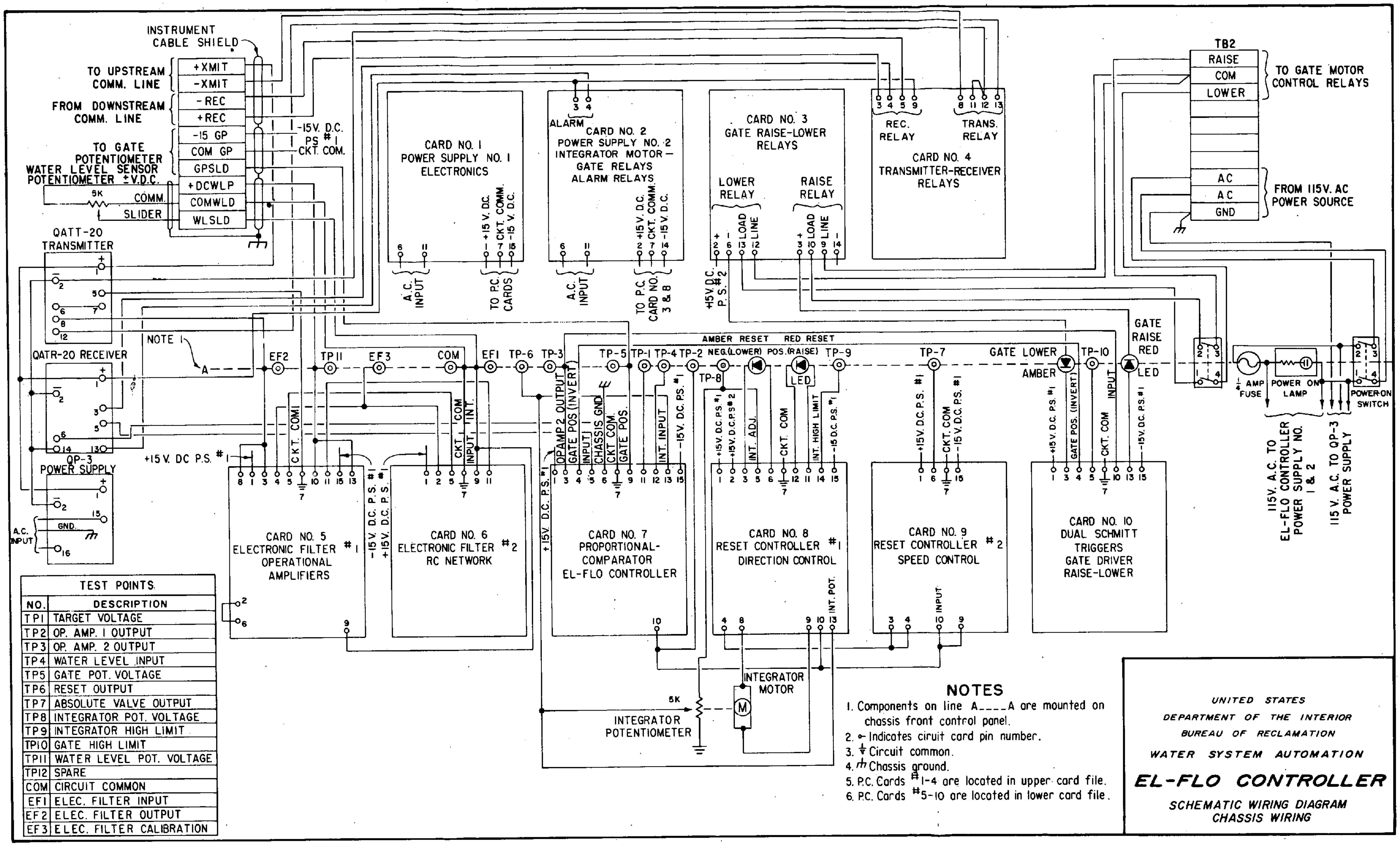
b. Turn the alternating-current power on-off switch to the on position. (DO NOT TURN ON THE ON-OFF GATE RELAY SWITCH TO THE ON POSITION.)

c. Place the transmitter selector switch to the MC position. The red indicating lamp on the receiver should be lit.

d. If red indicating lamp does not light, remove the negative test lead from common test point.

e. Connect the negative test lead to terminal No. 2 of the QP3 Quindar power supply.

f. Connect the positive test lead of the voltmeter to terminal No. 1 of the QP3 power supply.



TEST POINTS

NO.	DESCRIPTION
TP1	TARGET VOLTAGE
TP2	OP. AMP. 1 OUTPUT
TP3	OP. AMP. 2 OUTPUT
TP4	WATER LEVEL INPUT
TP5	GATE POT. VOLTAGE
TP6	RESET OUTPUT
TP7	ABSOLUTE VALVE OUTPUT
TP8	INTEGRATOR POT. VOLTAGE
TP9	INTEGRATOR HIGH LIMIT
TP10	GATE HIGH LIMIT
TP11	WATER LEVEL POT. VOLTAGE
TP12	SPARE
COM	CIRCUIT COMMON
EF1	ELEC. FILTER INPUT
EF2	ELEC. FILTER OUTPUT
EF3	ELEC. FILTER CALIBRATION

NOTES

1. Components on line A----A are mounted on chassis front control panel.
2. ⊸ Indicates ciruit card pin number.
3. ⏚ Circuit common.
4. ⏚ Chassis ground.
5. P.C. Cards #1-4 are located in upper card file.
6. P.C. Cards #5-10 are located in lower card file.

Figure 3-4. - Controller schematic wiring diagram.

g. The voltage at terminals No. 1 and 2 of the Quindar power supply should read approximately +12 volts.

h. If voltage is not present, refer to Quindar manuals and check QP3 power supply.

i. If 12-volt direct current is present, check QATT-20 and QATR-20 fuses; if trouble is still not found, refer to Quindar manuals.

j. Insert voltmeter positive test lead in the test point (TP4) and adjust potentiometer (P1) of card No. 7 until the voltage at test point (TP4) is at its maximum voltage (approximately +5 volts with transmitter in MC position).

k. Move selector switch of the transmitter to the ML position.

l. Adjust "0" potentiometer on receiver until test point (TP4) reads approximately 0.0 volt.

m. Move selector switch of the transmitter to the MR position.

n. Adjust "FS ADJ" potentiometer on receiver until test point (TP4) reads approximately 10.0 volts.

o. Move selector switch of the transmitter to the ML position and readjust "0" potentiometer until test point (TP4) equals 0.0 volt.

p. Move the selector switch of the transmitter to the MR position and readjust "FS ADJ" potentiometer until test point (TP4) equals +10.0 volts.

q. Repeat (i) and (j) until test point (TP4) is 0 volt in the ML position and +10.0 volts in the MR position.

r. When the conditions of step (k) have been satisfied, turn the alternating-current power on-off switch to the off position. Disconnect the jumper wires from the transmitter and receiver terminals of (TB1) and reconnect the transmitter and receiver communication cable (refer to schematic wiring diagram B/A02S011, figure 3-1) being careful to observe proper polarity.

3-4 Power Supply Checkout

a. Turn the alternating-current power on-off switch to the on position.

b. Check to see that the "power on" lamp is lit. If not, check fuse, source, and indicator lamp.

c. Tilt out the swing rack.

d. Plug the negative voltmeter lead into the common test point. Connect the positive test lead to the terminal numbers to be measured.

e. To test power supply No. 1 card No. 1 connect the positive test lead of the voltmeter to terminal No. 1 of card No. 8. The voltage at terminal No. 1 should read approximately +15.0 volts. Connect the positive test lead of the voltmeter to terminal No. 15 of card No. 8. The voltage at terminal No. 15 should read approximately -15.0 volts. If both +15.0 and -15.0 volts are not measured in steps (e) and (f), card No. 1 may be defective and should be checked by substitution.

f. To test power supply No. 2 card No. 2 connect the positive test lead of the voltmeter to terminal No. 2 of card No. 8. The voltage at terminal No. 2 should read approximately +15.0 volts. Connect the positive test lead of the voltmeter to terminal No. 14 of card No. 2. The voltage at terminal No. 14 should read approximately -15.0 volts. If no voltage in steps (g) and (h) check terminals No. 3 and 4 for 12 volts. If 12 volts are not present, check the Quindar QTAR-20 receiver alarm operation. If 12 volts are present, substitute card No. 2.

g. If trouble persists, refer to section IV, "Trouble shooting"

Note: Steps 3-2 through 3-4 must be repeated downstream since the following adjustments require working with two controllers at different locations. Controller No. 1 will be designated as the upstream controller and controller No. 2 will be known as the downstream controller. The receiver section of controller No. 1 and the transmitter section of controller No. 2 will have to be adjusted to control one canal reach. This procedure will have to be repeated for each controller on the remaining canal reaches.

3-5 Checkout of Telemeter Transmitter

a. Turn the alternating-current power on-off switch for controllers No. 1 and 2 to the on position.

b. At controller No. 2, turn the transmitter selector switch to the MC position.

c. A distinct clicking noise should be heard near the transmit relay of card No. 4.

3-6 Adjustment of Electronic Filter Cards No. 5 and 6 (Downstream Controller)

(See Section IV, Troubleshooting, paragraph 4-4, before removing card No. 6.) If cards No. 5 and 6 are not installed in controller as in the most upstream controller, go to paragraph 3-7.

a. Turn the transmitter selector switch to the operate position.

b. Connect the negative test lead of the voltmeter to the common test point.

c. Connect the positive test lead of the voltmeter to test point (TP11).

d. Adjust potentiometer (P4) of card No. 5 until the voltage at test point (TP11) is the same as that listed in item 1 of the data sheet on the door.

e. Move the positive test lead to test point (EF1).

f. Adjust the pulley that is connected to the water level potentiometer until the voltage at test point (EF1) is equal to +1.0 volt. (Remove float tape from pulley.)

g. Move the positive test lead to test point (EF2).

h. Depress and hold the manual initialize pushbutton on card No. 5 while adjusting potentiometer (P1) (CCW) on card No. 5 for maximum voltage at test point (EF2).

i. Again with the manual initialize pushbutton depressed, adjust potentiometer (P3) (CW) on card No. 5 for +1.0 volt at test point (EF2).

Note: Check the voltage at (EF1) and (EF2). Both readings should be +1.00 volt ±0.02 volt. If (EF2) is not equal to (EF1) within ±0.02 volt of the +1.00 volt setting, repeat (i) above.

j. Move the positive test lead from test point (EF2) to test point (EF3).

k. Depress the initialize pushbutton and adjust potentiometer (P2) of Card No. 5 until the reading at test point (EF3) is equal to that determined by item 2 of the data sheet on the door, (EF3) = (EF2) x [gain of (A1) card No. 5].

Note: When the voltage at test point (EF2) is equal to +1.0 volt, the gain of amplifier (A1) is equal to the voltage at (EF3).

In order to facilitate making adjustments at controller No. 1, a specific set of conditions must be left at controller No. 2:

(1) Controller No. 2 alternating-current power must be on.

(2) Controller No. 2 transmitter selector switch must be in the operate position.

(3) The voltage at test point (EF1) must be +1.00 volt ±0.03 volt.

(4) The manual initialize pushbutton should be pressed momentarily before leaving the downstream check.

(5) After the initialize pushbutton is released, the voltage at test point (EF2) should be checked to see that it is approximately equal to the voltage at test point (EF1). If a voltage drift is noted at (EF2) and does not stabilize or if the offset voltage between test points (EF1) and (EF2) is greater than 20 millivolts and cannot be adjusted out with potentiometer (P1), there is possible trouble with the filter circuit of card No. 6. If either of the above conditions exists, see the trouble-shooting section for additional information.

(6) The float tape is left off of the water level sensor pulley. Upon completion of the adjustments at controller No. 1, but before turning on the gate switch, the float tape must be placed back on the pulley in the correct position at controller No. 2.

3.7 Amplifiers (A1) and (A2) Offset Adjustment, Card No. 7

a. To determine that the receiver is receiving a signal from the downstream transmitter, check for an audible buzzing noise near the receiver relay of card No. 4 and check that the red indicating lamp on the front panel of the receiver is lit. Refer to trouble shooting section if either condition does not exist.

b. Remove the wire from terminal block (TB1-7) that connects to the controller. Connect a jumper wire from the disconnected wire to (COM).

c. Adjust potentiometer (P1) of card No. 8 (CW) until the voltage at test point (TP8) equals +2.0 volts.

Note: Omit step c. if card No. 8 is not installed.

d. Adjust potentiometer (P1) of card No. 7 until the voltage at test point (TP4) equals 0.

e. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP1) equals 0.

f. Connect test points (TP1), (TP4), and (TP6) with a jumper to test point (COM).

g. Adjust potentiometer (P4) of card No. 7 until the voltage at test point (TP2) is equal to 0.

h. Adjust potentiometer (P6) on card No. 7 until the voltage at test point (TP3) is equal to 0.

i. Remove only jumper connection from test points (TP4) and (COM).

3-8 Gain Adjustment of Amplifiers (A1) and (A2), Card No. 7

a. With the remaining jumpers from step 7 still in place, adjust potentiometer (P1) of card No. 7 until the voltage at test point (TP4) is equal to +1.0 volt.

b. The gain of amplifier (A1) is determined by the following equation:

$$\text{Gain of (A1)} = \frac{\text{Voltage at test point (TP2)}}{\text{Voltage at test point (TP4)}}$$

This equation will be true only if test point (TP1) is 0.

Adjust potentiometer (P3) of card No. 7 until the voltage at test point (TP2) is equal to the gain for A1 card 7, on the data sheet on the front door of the controller.

c. Adjust potentiometer (P1) of card No. 7 until the voltage at test point (TP2) is equal to -1.0 volt.

d. The gain of amplifier (A2) is determined by the following equation:

$$\text{Gain of (A2)} = \frac{\text{Voltage at test point (TP3)}}{\text{Voltage at test point (TP2)}}$$

This equation is true only if test points (TP5) and (TP6) are 0.

Adjust potentiometer (P5) of card No. 7 until the voltage at test point (TP3) is equal to the gain of A2 card 7, item 4 on the data sheet on the front door of the controller.

e. Repeat this procedure starting at step 7a through 8d.

f. Remove the jumper wires from (TP1) and (TP6) to test point (COM). Also, remove the jumper wire connecting the wire removed from terminal block (TB1-7) to test point (COM) and reconnect the wire to terminal block (TB1-7).

g. Adjust potentiometer (P1) of card No. 7 until the voltage at test point (TP4) is equal to the voltage listed on item 15 of the data sheet on the front door of the controller. If test point (TP4) is negative, amplifier (A1) on card No. 7 is probably defective. See section IV.

h. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP1) negative equals that of test point (TP4) positive.

Note: If card No. 8 is not provided, (TP1) must be adjusted to (TP4) and (TP5) 1 gain of (A1). (The target must include the gate low limit.)

3-9 Adjustment of Limit Switches, Direction Control,and Deadband Circuit, Card No. 8

Go to section 3-10 if card No. 8 is not installed.

a. Adjust potentiometer (P1) of card No. 8 until the voltage at test point (TP8) is equal to item 5 of the data sheet on the front door of the controller.

b. Adjust potentiometer (P2) of card No. 8 until the voltage at test point (TP9) is 2 volts greater than the voltage at test point (TP6) [test point (TP6) must be at least 0.5 volt, if (TP6) is less than 0.5 volt, see note below].

c. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP2) is equal to item 6 of the data sheet on the front door of the controller (observe polarity).

d. Adjust potentiometer (P4) of card No. 8 until the red reset indicator lamp just turns on. Adjust (P4) (CCW) to turn indicator lamp off and (CW) for on.

e. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP2) equals item 7 of the data sheet on the front door of the controller (observe polarity).

f. Adjust potentiometer (P3) of card No. 8 until the amber reset indicator lamp just turns on. Adjust (P3) (CCW) to turn the lamp on and (CW) to turn the lamp off.

Note: The voltage at test point (TP6) must be greater than +0.5 volt or the amber reset indicator lamp will not turn on. If the voltage is below +0.5 volt, adjust voltage at test point (TP2) to its maximum positive value using potentiometer (P2) of card No. 7 and let the integrator motor run until the voltage at test point (TP6) is at least +1.0 volt. Then repeat steps 9c through 9f.

g. Adjust potentiometer (P2) of card No. 8 until the voltage at test point (TP9) equals that listed in item 8 of the data sheet on the front door of the controller.

h. If Schmitt triggers, card No. 10, are not being adjusted, adjust potentiometer (P2) of card No. 7 to item 14 of the data sheet on the front door of the controller.

3-10 Adjustment of the Dual Schmitt Triggers, Card No. 10

a. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP3) equals 0.

b. Turn potentiometers (P1), (P3), and (P4), on card No. 10, 22 turns counterclockwise and then one-half turn clockwise.

c. Turn potentiometer (P2), of card No. 10, 22 turns clockwise and then one-half turn counterclockwise.

d. Adjust potentiometer (P5) of card No. 10 until the voltage at test point (TP10) equals 14.0 volts.

e. If the gate raise red indicator lamp is off, continue to step 10f. If the gate raise red indicator lamp is on, see trouble shooting section.

f. If the gate lower amber indicator lamp is off, continue to step 10g. If the gate lower amber indicator lamp is on, see troubleshooting section for instructions.

g. Adjust potentiometer (P2) of card No. 7 until the voltage at test (TP3) equals that listed in item 9 of the data sheet on the front door of the controller (lower). Observe polarity.

h. Adjust potentiometer (P3) of card No. 10 (CW) about 18 turns until the amber gate lower indicator lamp just comes on.

i. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP3) equals 0.

j. Adjust potentiometer (P4) of card No. 10 until the amber lower lamp just turns off (about 18 turns clockwise).

k. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP3) equals that listed in item 9 of the data sheet on the front door of the controller (raise). Observe polarity.

l. Adjust potentiometer (P1) of card No. 10 until the red gate raise lamp just turns on (about 18 turns clockwise).

m. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP3) equals 0.

n. Adjust potentiometer (P2) of card No. 10 until the red gate raise lamp just turns off (about 18 turns counterclockwise).

o. Adjust potentiometer (P5) of card No. 10 until the voltage at test point (TP10) equals item 13 of the data sheet on the front door of the controller.

p. Recheck the on and off voltage value set into each Schmitt trigger by adjusting potentiometer (P2) of card No. 7 and observing the voltage at test point (TP3) plus the red and amber indicator lamps. The lamp should light at the on voltage value and turn off at 0 volts [test point (TP10) must have a higher negative voltage than test point (TP5) in order to operate the Schmitt trigger circuits].

3-11 Adjustment of the Integrator Motor Speed Control Circuit, Card No. 9

Go to section 3-12 if card No. 9 is not installed.

a. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP2) equals +1.0 volt.

b. The gain of the speed control circuit (absolute value amplifier) is given in the following equation:

$$\text{Gain of absolute value circuit} = \frac{\text{Voltage at (TP7)}}{\text{Voltage at (TP2)}}$$

Adjust potentiometer (P2) of card No. 9 until the voltage at test point (TP7) equals that listed in item 10 of the data sheet on the front door of the controller.

c. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP7) equals -5.30 volts.

d. For this measurement only, connect the two test leads of the voltmeter to the two terminals of the integrator motor.

Caution: Be sure the voltmeter leads do not touch the motor! Adjust potentiometer (P1) of card No. 9 until the voltage across the motor terminals reads 7.80 volts (neglect polarity).

e. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP1) equals that listed in item 14 of the data sheet on the front door of the controller.

3-12 <u>Adjustment of Float at the Downstream Controller No. 2</u>

Do not turn the gate relay switch on.

a. The transmit and receive sections have now been adjusted for proper operation on one reach of the canal. The only remaining adjustment is to set the float level at controller No. 2 so that the water level sensor represents the correct canal elevation. Adjust potentiometer (P4) of card No. 5 of controller No. 2 until the voltage at test point (TP11) equals +6.0 volts.

b. Install float, float tape, and counterweight assembly being certain to loosen the clutch on the pulley assembly to prevent damage to the water level potentiometer.

c. The target elevation for the check water level is listed on the data sheet on the front door of the controller. Determine the actual water surface elevation from the staff gage. If the staff gage reading is within ±1/2 foot of the listed target elevation, proceed with step d. If not, canal water surface must be manually adjusted until it is within ±1/2 foot of the target elevation.

d. The following equation should be used to calculate the voltage value to be set at test point (EF1). The voltage is set by loosening the float pulley clutch and turning the shaft that connects the water level potentiometer until the voltage at test point (EF1) equals the calculated voltage value. The voltage calculation is presented in three parts depending upon the actual canal water surface elevation.

Part No. 1. - Measured water surface elevation is equal to the target elevation. In this case, set (EF1) to equal +1.0 volt.

Part No. 2. - Measured water surface elevation is lower than target elevation. Determine the difference between the actual and target elevation in hundredths of a foot. Multiply the difference by the quantity (2 volts/foot). Subtract the result from +1.0 volt. The calculated value is the voltage to be set at test point (EF1).

Example: Target elevation = 6.82 feet
Actual water elevation = 6.46 feet

Target	6.82 feet
Actual	6.46 feet
Difference	0.36 foot

1 volt - (2 volts/foot x 0.36 foot) -
1 volt - 0.72 volt = 0.280 volt

Part No. 3. - Measured surface is higher than the target elevation. Determine the difference between the actual and target elevations in hundredths of a foot. Multiply the difference by the quantity (2 volts/foot), and add the results to 1.0 volt. This then would be the calculated voltage value to be set at test point (EF1).

Example: Target elevation = 6.82 feet
Actual elevation = 7.18 feet

Actual	7.18 feet
Target	6.82 feet
	0.36 foot

1 volt + (0.36 foot x 2 volts/foot) +
1 volt + 0.72 volt = 1.72 volts

Therefore, test point (EF1) would be set at +1.72 volts.

3-13 Gate Relay Switch Operation at the Upstream Controller No. 1

During the setup procedure, the gate relay switch has been in the off position to prevent operation of the gate during adjustment. Before the gate switch is turned on, the downstream canal water surface should be manually adjusted until it is within three-hundredths of a foot of the target elevation. The voltage at test point (TP3) indicates the amount the gate will move when the gate relay switch is turned on. The voltage at test point (TP3) indicates a gate movement up or down depending on polarity. Before the gate switch is turned on, the voltage at test point (TP3) should be between +1.5 and -1.5 volts. In order to achieve this voltage, it is necessary to manually regulate the canal toward the target elevation. The voltage at test point (TP3) should be monitored and when the voltage is between +1.5 and -1.5

volts, the gate operate switch can be turned on. The gate should operate and the voltage at test point (TP3) should null to 0 volt.

3-14 Special Configurations

a. End of canal unit. - The end of canal unit only provides the filtered water level for the next unit upstream. This unit needs only cards No. 1, 4, 5, and 6, Quindar modules QP3 power supply, and QATT-20 transmitter (also alarm module and Quindar QT-30 transmitter if alarm system provided). Any other cards if provided may be used as spares.

b. Canal reach not requiring reset. - A reach that does not require reset does not require cards No. 8 and 9. Note that the low gate limit must be added to value of target; this is normally offset by a potential on the reset potentiometer. Calibration procedures outlined in sections 3-9 and 3-11 are deleted.

c. Most upstream unit. - The beginning of canal unit does not require the water level sensor and filter unless it is required for a pump controller. If the water level sensor and filter are not required, cards No. 5 and 6 can be removed and used for spaces. Note removal procedure for card No. 5 in section 4. Calibration procedures outlines in sections 3-5, 3-6, and 3-12 are deleted.

d. Voltage divider used in downstream water level sensor and filter.

3-15 Alarm Module

a. Alarm limit calculations:

AP3'+ = +10 volts
AP3'- = +10 volts
AP2'+ = [-Target volts + 0.05] * Gain (A1), card No. 7
(Item 14, figure 3.1) (Item 2, figure 3.1)
AP2'- = [(1.2 feet * H_2O volts/foot) + -(target volts)]* Gain (A1), card No. 7 + 0.1 volt

b. Adjustment of comparator reference voltages. - Since voltage dividers are used in the comparator circuits one cannot just set the references to the values calculated in a. above.

To set (AP3), set (TP3) to +10 volts using (P1) and (P2) on card No. 7. Assure (AP3) lamp is on. If not, adjust potentiometer (AP3+) until light is on then readjust (TP3) to +10 volts using (P1) and (P2) then adjust potentiomater (AP3+) until (AP3) indicator lamp just goes out. Repeat procedure for (AP3-) using

-10 volt at (TP3) and adjusting (AP3-). Vary (TP3) from +10 volts to -10 volts to assure that the limits are correct. Readjust if necessary. Occasionally, a comparator will not adjust to the 10-volt setting. For these alarm modules, set the potentiometer fully clockwise then back one-half turn.

(AP2+) and (AP2-) are set in a similar manner except (TP2) is adjusted to (AP2'+) and (AP2'-) for (AP2+) and (AP2-), respectively.

Assure that indicator lamps (TP3) and (TP2) on the alarm module are on. Measure and record in items 16 and 17 on the data sheet on the door of the controller.

Subsequent adjustments on the same module can be made by assuring the indicator lamps are on and adjusting the (AP3+), (AP3-), (AP2+), and (AP2-) to their respective values in the table.

Note: A new module should be recalibrated as there is some variance between alarm modules for the same AP' value.

SECTION IV - TROUBLESHOOTING

4-1 Introduction

The troubleshooting section is divided into four parts:

a. Downstream water level cards, 4-3. - This includes test points (TP11), (EF1), (EF2), (EF3), and cards No. 1, 5, and 6.

b. Water level communications, 4-5. - This includes test point (TP4) at the upstream controller, terminal strips, receiver lamp in upstream controller, card No. 4 at both controllers, the Quindar QP3 power supply, QATT-20 transmitter, QATR-20 receiver, and the communications line.

c. Controller cards, 4-6 (that portion of the whole controller associated with the controlled gate and located in the controller at the gate site). - This includes reference voltage test points (TP1), (TP8), (TP9), and (TP10); test points (TP2) through (TP7); and cards No. 1, 2, 3, 7, 8, 9, and 10.

d. Power supply problems, 4-7.

EL-FLO troubleshooting chart. -

The alarm system will usually indicate the canal check which is experiencing difficulties. If the alarm system is not installed, abnormal operation or inability of the controller to maintain proper water elevations downstream would indicate trouble. The controller is made up of three parts: (1) the actual controller and (2) the water level sensor and filter connected by (3) an analog communications link from water level sensor to the upstream controller. A determination of which location is the source of trouble should be made at the upstream controller causing the alarm.

This troubleshooting procedure utilizes card substitution for many of the test procedures. Maintenance is only carried to the card level in this manual. Before attempting to repair a controller, a full set of good cards including the Quindar communications cards should be available.

4-2 Alarm Analysis

Annunciator Alarm

Without carrier alarm

High or low water alarm loss of direct-current power to controller.

High water or
Low water

Normally not an equipment failure - look for abrupt flow change - incorrect pump base load - obstruction in float wall (controller parameters do not match canal)

Receiver alarm [may include (TP2) and (TP3) alarms]

Loss of downstream analog telemetering - check transmitter (downstream) communications cable and receiver Part II Quindar Manuals.

(TP2) alarm - check (TP4), downstream (EF1), (EF2), and (EF3) Part I, target (TP1) (Part III, and Op Amp (A), card No. 7.

(TP3) alarm - check gate potentiometer (TP5) integrator potentiometer (TP6), and Op AmP (A), card No. 7.

(TP2) and (TP3) alarms - check and correct (TP2) conditions, then proceed to (TP3) if problem still persists.

With carrier alarm

Loss of alternating current at controller.

Carrier alarm and one check alarm - problem with alarm transmitter and/or receiver check Quindar manuals.

Carrier alarm and two or more check alarms (carrier alarm may apply to one, two, or all alarms).

1. Determine which alarms are equipment and which are alarm communications. Remove all alarm receivers and replace one at a time to determine which remotes have carrier alarm.
2. Proceed for equipment alarm as in (without carrier alarm).
3. Proceed for alarm communications as above.

4-3 Card Replacement and Calibration Guide

In emergencies, portions of the calibration may be deleted when replacing a defective card so the controller may be placed back in service with a minimum delay.

Card replaced	Calibration steps required	Other cards affected
No. 1	None	None
No. 2	None	None
No. 3	None	None
No. 4	None	None
No. 5	Complete procedure outlined in paragraph 3-6 of this manual	No. 6
No. 6	Complete procedure outlined in paragraph 3-6 of this manual	No. 5
No. 7	Complete procedure outlined in paragraphs 3-7 and 3-8 of this manual	None
No. 8	Complete procedure outlined in paragraph 3-9 of this manual	No. 7, paragraph 3-8
No. 9	Complete procedure outlined in paragraph 3-11 of this manual	No. 7, paragraph 3-8
No. 10	Complete procedure outlined in paragraph 3-10 of this manual	No. 7, paragraph 3-8

4-4 Downstream Water Level Cards

Water level transmitter check of the downstream controller of troubled controller (downstream water level check).

Test point and card or component or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(TP11) Cards No. 5 and 1	A. The voltage at test point (TP11) should be that listed in item 1 of the table of test point voltages amd amplifier gains on the front door of the controller; (TP11) is the supply voltage for the gate potentiometer.	
	1. Adjust potentiometer (P4) of card No. 5. 2. Check water level potentiometer for a short or open, replace if necessary. 3. Check test point (TP11) and water level potentiometer circuit and power supply No. 1, card No. 1 - replace card No. 1 if no voltage. 4. If problem still persists replace card No. 5 and recalibrate.	Too high or too low.
(EF1)	A. The voltage at test point (EF1) is the voltage present at the slider of the water level sensor potentiometer (this voltage is always positive). To determine the correct voltage for test point (EF1) refer to paragraph 3-12, [1 volt ± deviation from target x 2 volts/foot (+ if above, - if below)].	
	1. Make checks for (TP11) above. 2. Check water level sensor potentiometer and connecting cable.	No voltage.
	3. Check for obstruction in floatwell and the intake to the floatwell. 4. Check for slippage of water level potentiometer (mounting and shaft) on its mechanical mounting or slippage due to loose thumb screws on the float adjustment mechanism.	Voltage too high or too low.

Test point and card or component or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(EF2) Card No. 6	A. The voltage at test point (EF1) should be equal to the voltage of test point (EF2) (within ± 0.02 volt).	
	1. A recent large flow change downstream from controller can cause a differential voltage. 2. Press the initialize pushbutton and recheck test points (EF1) and (EF2). If test points (EF1) and (EF2) still are not equal, proceed as follows (within ± 0.02 volt):	Voltage at (EF1) is considerably different from the voltage at (EF2), unstable or 0.
	a. Recalibrate card No. 5 in accordance with paragraph 3-6. If problem persists, then b. Replace card No. 5, recalibrate in accordance with paragraph 3-6, and recheck test points (EF1) and (EF2). If test points (EF1) and (EF2) are still not approximately equal, c. Replace card No. 6 in accordance with instructions below; the MOS-FET is damaged or leaky and recalibrate as above should solve the problem.	Voltage at (EF2) drifts after being initialized.
(EF3)	A. The voltage at test point (EF3) is equal to the gain of (A1) card No. 5 times the voltage at (EF2). Note: The gain of amplifier (A1) is item No. 2 on the table of test point voltages and amplifier gains on the front door of the controller.	

Test point and card or component or condition	Normal indication, possible trouble, and/or information	Abnormal indication
	1. Adjust potentiometer (P2) of card No. 5 while holding initialize button. 2. Replace card No. 5 and recalibrate if step 1 does not correct problem.	Too high or too low.

The following precautions apply to the installation and removal of card No. 6:

1. Before removing card No. 6 from chassis:

   a. Turn off power to controller.

   b. Install alligator clips with jumper leads between the two solder posts. The top post must be connected first and the bottom post last.

   c. Remove the card from the chassis being careful not to touch the printed circuits or connectors.

   d. The jumper leads must remain in place until card No. 6 is returned to the controller or a jumper wire is soldered in place.

2. Installing new card No. 6:

   a. Make sure the power to the chassis is off.

   b. Insert new card in chassis.

c. Remove jumper leads from solder posts, removing bottom lead first then the top lead.

Note: If the card is a new one, it will have a piece of bare wire soldered between the two solder posts. To remove this wire, follow steps 1a and 1b above. Then, using a pair of wirecutters, cut the bare wire. Then follow steps 2a. 2b. and 2c.above.

d. Turn power back on.

3. Transporting card No. 6:

a. Before transporting card No. 6 in any manner (car, mail, etc.), it must be wrapped carefully and tightly in several layers of aluminum foil to prevent the MOS-FET from being damaged by static charges from things like seat covers, clothing, etc.

b. If the card is to be mailed, the foil-wrapped card should be packed only in paper - no plastic material should be used.

c. If desired, a bare wire jumper as described in paragraph 2 can be replaced. Only after the bare wire is soldered between the two solder posts should the jumper leads be removed.

4-5 Water Level Communications

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
Transmitter QATT-20 operation check	A. An audible sound should be heard near the transmit relay of card No. 4. B. If no clicking sound is coming from the transmit relay of card No. 4, proceed as follows:	
	1. Change the "Cal. Sw." on the front of the (QATT-20) transmitter from operate to the ML, MC, and MR positions and listen at the transmit relay	No sound.

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
Qatt-20 - continued	card No. 4; the relay should operate at 5 Hz, 12.5 Hz, and 25 Hz, respectively. If no relay operation can be detected at card No. 4, proceed as follows: a. Set an analog volt-ohm-meter (VOM) function switch to direct-current volts and the selector of the (VOM) to 10 volts or higher. b. Connect the (VOM) positive test lead to the (QATT-20) transmitter terminal No. 12 and the negative test lead of the (VOM) to terminal No. 2. c. Set the "Cal. Sw." of the QATT-20 transmitter to the ML, MC, and MR positions. The (VOM) movement should move back and forth at a 5-Hz, 12.5-Hz, and 25-Hz rate. d. If no meter movement is detected above, remove the QATT-20 transmitter and check the fuse. If meter movement is detected, go to (h). e. If the fuse is good, then check the QP3 power supply at terminals No. 1 and 2 of the QATT-20 transmitter. The voltage at terminals No. 1 and 2 of the (QATT-20) transmitter should read 12 volts. f. If 12 volts are not present at terminals No. 1 and 2 of the (QATT-20) transmitter, pull the QP3 power supply and check the fuse and/or replace the QP3 power supply.	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
QATT-20 - continued	g. Replace the transmitter and recheck c. above. If the transmitter is not operating, replace with a spare and consult the Quindar instruction manual for the repair of the inoperative receiver. h. There should now be meter movement at terminals No. 12 and 2 of the (QATT-20) transmitter. If there is no sound of relay operation at card No. 4, check the following: (1) Check (TB1) terminals No. 1 and 2 with the (VOM) with the "Cal. Sw." in the ML, MC, and MR position; should have the same indications as in c. above. (2) If there is still no meter movement, replace card No. 4 and check wiring. (3) If there is a meter movement at (TB1) terminals No. 1 and 2, this means that the transmit relay of card No. 4 is all right and the downstream unit is sending a water level signal upstream.	

Upstream check controller No. 1. - If the downstream controller checks out all right and the trouble is still not cleared, then proceed to the upstream controller.

Note: Before leaving the downstream controller, make sure that the "Cal. Sw." of the QATT-20 is in the MC position.

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
Visually check QATR-20 receiver lamp	A. The normal condition of the QATR-20 receiver lamp is on - go to (TP4). If lamp is off - continue below.	Receiver lamp on.
	1. Check lamp and replace if defective.	
	2. Check the input voltage of the QATR-20 receiver by listening at the receiver relay of card No. 4. The receiver relay should operate at 12.5 Hz with the downstream QATT-20 transmitter "Cal. Sw." in the MC position.	Receiver lamp off.
	3. If no receiver relay operation can be detected at card No. 4, use a (VOM) and check (TB1) terminals No. 3 and 4. The meter should move back and forth at a 12.5-Hz ratio to indicate signal from downstream. If no voltage is present at (TB1) terminals No. 3 and 4, the communication cable is open because there was voltage at (TB1) terminals No. 1 and 2 at the downstream check.	
	4. With voltage at (TB1) terminals No. 3 and 4 check for voltage at terminals No. 1 and 3 of the QATR-20 receiver. The meter should flicker at a 12.5-Hz rate. If there is no meter movement, change card No. 4 and check the connecting wires from (TB1) to card No. 4 and to QATR-20.	
	5. If there is voltage at terminals No. 1 and 3 of the QATR-20, pull out the QATR-20 and check the fuse. Also check at terminals No. 1 and 2 for 12 volts direct current. If the fuse is good and there is 12 volts at terminals No. 1 and 3, replace the QATR-20 receiver	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
QATR-20 - continued	with a spare and consult the Quindar manual for repair of inoperative receiver. 6. If 12 volts are not present at terminals No. 1 and 2, pull the QP3 power supply and check fuse. Replace fuse if blown and install QP3 power supply. If fuse again blows, replace QP3 with a spare. 7. If the fuse is good in the QP3 power supply, replace the QP3 with a spare. Consult the Quindar manual for repair of inoperative power supply.	
	B. Check the main power fuse at the next downstream controller and filter cards.	Receiver lamp of the QATR-20 flashes off and on.
4-6 Controller Cards		
(TP4)	A. Test point (TP4) is the filtered downstream water level and with the downstream QATT-20 transmitter "Cal. Sw." in the MC position, there should be 1.2 volts at test point (TP4), the output of QATR-20. If (TP4) is correct go to (TP1).	
	1. Adjust potentiometer (P2) of card No. 7. If this does not solve problem, replace card No. 7 and/or check circuit wiring (recalibrate card No. 7).	Too high or too low.

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(TP4) - continued	2. If (TP4) is not correct, return to parts I and II.	
(TP1)	A. This is the target voltage and should equal item 14 of the table on the front door of the controller. If correct, go on to (TP2).	
	1. Adjust potentiometer (P1) of card No. 7 for correct voltage. If this does not correct the problem, check power supply, potentiometer (P1's) circuitry, and/or replace card No. 7. (Recalibrate card No. 7 if replaced).	Too high or too low.
(TP2)	A. The normal voltage reading for test point (TP2) is the difference between test point (TP4) and test point (TP1) times the gain of amplifier (A1) of card No. 7. Test point (TP4) is always a positive voltage and test point (TP1) is always a negative voltate. Test point (TP2) is equal to the algebraic sum of test point (TP4) and test point (TP1) times the gain of amplifier (A1) of card No. 7 times (-1). The gain of amplifier (A1) is item 3 on the table of test point voltages and amplifier gains on the front door of the controller.	
	Note: Before deciding if the voltage at test point (TP2) is too high or too low, the voltage at test point (TP4) should be measured and recorded. Then through the use of potentiometer (P2) of card No. 7, test point (TP1) should be measured and potentiometer (P2) adjusted until test point (TP1) is approximately 1 volt	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(TP2) - continued	greater than test point (TP4) (disregard sign). This is done to insure that the offset of A1 has a negligible effect on the voltage at test point (TP2). With the difference between test points (TP4) and (TP1) adjusted to 1 volt, the gain of amplifier (A1) on card No. 7 can be determined by measuring the voltage at test point (TP2). The gain at test point (TP2) should be equal to that of item 3 of the table (of test point voltages) on the front door of the controller.	
	Note: With (TP4) minus (TP1) equal to 1, (TP2) equal gain.	
	1. If the gain at test point (TP2) does not equal that listed in item 3 of the data sheet, adjust potentiometer (P3) of card No. 7 until the gain is correct. Amplifier (A1) of card No. 7 is an inverting amplifier; therefore, the output at test point (TP2) should be of opposite polarity to that at the summed input of amplifier (A1).	Too high or too low.
	2. If the gain at test point (TP2) cannot be made equal to that of item 3 of the data sheet through the adjustment of potentiometer (P3), replace card No. 7 and recalibrate. Amplifier (A1) is defective or overloaded.	
	Note: Readjust potentiometer (P2) (target) of card No. 7 to item 14 of the data sheet, after completing, check.	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(TP5)	A. Test point (TP5) is the voltage at the slider of the gate position potentiometer and is always a negative voltage. To verify the correct voltage at test point (TP5), proceed as follows:	
	1. Check the gate opening in feet. 2. Multiply the gate opening in feet by the volt/foot calculation (normally at the bottom of the data sheet on the front door of the controller). 3. After computing 2. above, add the offset (normally 0.75 volt) which equals one-half turn of the gate potentiometer. 4. Example:	
	Gate opening = 3.70 feet Volt/foot = 0.805 One-half turn of gate potentiometer = 0.75 volt (3.7) x (0.805) + 0.75 volt = 3.728 volts	
	Test point (TP5) should equal 3.728. 5. If the voltage at test point (TP5) does not measure 3.728 volts (accuracy) ± 0.1:	Too high or too low.
	a. The voltage at (TB1) terminal No. 5 should measure a negative 15 volts; if not check the wiring bus to power supply card No. 1 and check power supply card No. 1. b. Measure the voltage at (TB1) terminal No. 6. It should measure 0 volt; if not, check for an open ground connection.	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(TP5) - continued	c. Measure the voltage at (TB1) terminal No. 7. It should read the same as test point (TP5); if not, check the wiring from (TB1) terminal No. 7 to test point (TP5). d. The most probable trouble will be when the gate position potentiometer coupling and/or lock nut slips, which will allow a change in voltage at test point (TP5). In this case, calculate the voltage that should be present at test point (TP5) and reposition the gate position potentiometer to the calculated value. Note: If the voltage at test point (TP5) is either 0 or 15 volts, this is an indication that the gate position potentiometer is broken or that there is a loss of a ground or -15 volts at the gate position potentiometer connections. If test point (TP5) measures a -15 volts, the gate will close to its mechanical limit and if test point (TP5) is 0 volt, the gate will open to its limit.	
(TP8)	Check test point (TP8). It should be equal to item 5 of the data sheet on the front door of the controller. Also check out the circuitry of test point (TP8).	Not equal to item 5 of data sheet.
(TP6)	A. Test point (TP6) is the voltage at the slider of the integrator potentiometer and is always a positive voltage determined by the integrator motor. B. The voltage at test point (TP6) in a normal working system should be approximately equal to the voltage at test point (TP5) but of opposite polarity.	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(TP6) - continued	C. The most probable trouble with the integrator potentiometer will be intermittent loss of contact between the slider and the resistance element of the potentiometer. This is due to the very slow speed at which the integrator motor turns the integrator potentiometer. When the slider of the integrator loses contact, this will cause the voltage at test point (TP6) to drop to 0 volt which will cause the gate to lower. This condition is normally momentary, but if it persists, the only solution is to replace the integrator potentiometer. For other problems with incorrect voltage at (TP6), check procedures under (TP7) and (TP8).	Too high or too low.
	D. To check the integrator motor operation, adjust potentiometer (P2) of card No. 7 until the red or amber reset lamp turns on, then listen at or near the integrator motor. A high frequency audible sound should be heard. This will indicate that the integrator motor has a variable direct-current voltage applied. Next monitor test point (TP6) for a few minutes. There should be a small change in voltage. This will indicate that the integrator motor is turning the integrator potentiometer. If the above conditions can be observed, it can be assumed that the reset portion of the controller is all right. If not proceed as follows:	Voltage does not change.
	E. Connect a (VOM) across the integrator motor terminals, adjust potentiometer (P2) of card No. 7 (CW) until the amber reset lamp just comes on. There should be 0 volt or some low value voltage at this time. As potentiometer (P2) is turned further (CW), this voltage should increase.	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(TP6) - continued	1. If the amber reset lamp will not come on, replace card No. 8 and recalibrate. 2. If the amber reset lamp comes on but there is no voltage indication on the (VOM) as potentiometer (P2) of card No. 7 is turned further (CW), replace card No. 8 first and recalibrate (the Y relay may have bad contacts). If this does not clear the trouble, replace card No. 9 and recalibrate (either the driver transistor is open or the oscillator is not operating). If replacing card No. 9 cures the problem, replace the old card No. 8 and leave in if it now operates; otherwise, both cards No. 8 and 9 are defective and should be replaced. 3. If when the amber reset lamp comes on and there is a high voltage of about 15 volts across the motor, this indicates a bad card No. 9 or an open integrator motor. Replace card No. 9 and recalibrate. Ths integrator motor could be open (but replace card No. 9 first). F. The same procedure is then used to check out the red reset circuit.	
(TP7)	A. Connect a digital voltmeter from test point (TP2) to (COM) and adjust potentiometer (P2) of card No. 7 until the digital voltmeter reads 1.0 volt positive. B. Move the red lead of the digital voltmeter to test point (TP7). The digital voltmeter should read the same value as that listed in item 10 on the front door of the controller.	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(TP7) - continued	C. If not, adjust potentiometer (P2) of card No. 9. If the correct value cannot be obtained, replace card No. 9 and recalibrate. D. Do the same as in A., B., and C. above, but this time adjust potentiometer (P2) of card No. 7 until the digital voltmeter connected to test point (TP2) reads 1.0 volt <u>negative</u>. Note: It makes no difference if the voltage at (TP2) is negative or positive. The voltage at test point (TP7) should always be positive.	
(TP3)	A. The normal voltage at test point (TP3) is the algebraic sum of test points (TP5), (TP6), and (TP2) times the gain of amplifier (A2) of card No. 7 (the gain of amplifier (A2) is listed in item 4 of the data sheet). Note: Before the gain at test point (TP3) can be determined as being too high or too low: 1. Measure and record the voltage at test points (TP5), (TP6), and (TP2). (TP3) = [(TP2) and (TP5) and (TP6)] times gain of amplifier (A2), card No. 7 (item 4 of data sheet). 2. Calculate the algebraic sum of test points (TP5), (TP6), and (TP2). If not approximately $\pm$1.0, adjust potentiometer (P2) of card No. 7 until the algebraic sum of the test points (TP5), (TP6), and (TP2) equals 1.0 volt positive or negative.	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
(TP3) - continued	3. With the input of amplifier (A2) equal to 1.0 volt, the voltage at test point (TP3) should equal the gain listed in item 4 of the table on the front door of the controller.	
	B. If the voltage at test point (TP3) does not equal the gain listed in item 4 of the data sheet, adjust potentiometer (P5) of card No. 7. Not only should the voltage be equal, but also the polarity of the output of amplifier (A2) at (TP3) must be opposite that of the input.	Too high or too low. Wrong polarity.
	C. If there is no polarity shift or if the voltage at test point (TP3) cannot match the gain listed in item 4 of the data sheet, replace card No. 7 and recalibrate.	
Gate Driver Raise and lower Card No. 7	A. Turn the gate relay switch to the off position and connect a digital voltmeter from test point (TP3) to (COM).	
	B. Adjust potentiometer (P2) of card No. 7 until the voltage at test point (TP3) is equal to that listed in item 9 (lower of the data sheet on the front door of the controller). At this time the amber lower lamp should turn on.	
	1. If it takes more voltage than that listed in item 9 to turn the amber indicator lamp on or it does not come on, then recalibrate card No. 10 in accordance with paragraph 3-10.	
	2. If the amber indicator lamp still does not come on, then replace card No. 10 and recalibrate.	

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
Gate Driver - continued	3. If after replacing and recalibrating card No. 10 the amber indicator lamp still will not turn on, then replace card No. 3. C. The raise red indicator lamp can be checked out the same way but this time the potentiometer (P2) of card No. 7 must be adjusted to equal item 9 raise. Proceed the same way; check out the raise indicator lamp as you lower indicator lamp. D. If the gate motor will not operate when the amber or red indicator lamp is on, check the gate switch and all wiring to and from the gate motor and card No. 3 of the controller.	

4-7 Power Supply Problems

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
Power supply No. 1 Card No. 1	Place the common test probe of a digital voltmeter on connector pin No. 7 and the other probe on connector pin No. 1 on the back of power supply No. 1 card. Reading should be +15.0 volts $\pm$5 percent. Then move second probe from pin No. 1 to pin No. 15. Reading should be -15.0 volts $\pm$ 5 percent.	
	If either reading is lower than 15 volts, proceed as follows; if readings are all right, power supply No. 1 card is all right.	Lower than 15 volts.

Test point or condition	Normal indication, possible trouble, and/or information	Abnormal indication
Power supply No. 1 - continued	A. Turn off alternating-current power and gate relay switch. B. Substitute power supply No. 1 card. Turn power on and repeat above test. If readings are now 15 volts, power supply No. 1 is now all right. Mark removed No. 1 card as defective. If readings are still low continue to C. C. Remove all other cards <u>except</u> card No. 6. D. Turn on alternating-current power switch and repeat above test. If readings are 15 volts, replace old power supply No. 1 card and repeat test (substitute card from step B. is still in controller). If all right, continue below; if defective, mark card and replace with substitute card. E. If 15 volts is still not obtained, check all associated wiring for opens and/or shorts. F. If the correct voltages are obtained in step D. above, a controller card is shorted. Replace each card one at a time and make the above test. When the voltage drops, the last card replaced is defective and must be replaced.	
Power supply No. 2 Card No. 2	Same procedure as above is used except with the following changes. Voltage is measured between pins No. 2 and 7 and 7 and 14 on the back of power supply No. 2. Only cards No. 3 and 8 need be removed in step C. Be sure to make relay check outlined in part C.	

4.8 Card Maintenance

It is not the intent of this manual to cover card maintenance; however, many components can be replaced simply by pulling the old component out of its socket and replacing it. Several cards contain few items with one being the common failure item; where this item can be replaced by a simple soldering task it will be mentioned. These procedures will repair over 90 percent of the card failures. When a card is identified as defective from parts A. through D, this table can be consulted for repair. Table 4-1 is a list of cards and the replaceable parts. Table 4-2 is a list of spare parts.

Table 4-1. - Card component replacement guide

Card No.	Replaceable component
1	Check and replace fuse. Replace calex modular power supply.
2	Check and replace relay. Replace calex modular power supply.
3	Replace defective solid state raise and/or lower relay as determined from part 4-6.
4	Replace defective send and/or receive relay as determined from part 4-5.
5	Replace 741 operational amplifier. The 741 is mounted in socket on most boards. Note: Common failure item in electrical storms.
6	Replace 2N3796 MOS-FET. Note: This procedure requires special procedure and silicone potting compound.
7	Repair not recommended. Requires complicated component analysis.
8, 9, 10	Replace 747 operational amplifiers. The 747's are mounted in sockets on all cards. Replace one at a time and test to determine defective amplifier.
Mainframe	Replace damaged Bourns 10-turn potentiometer.

Table 4-2. - Spare parts

1.	Calex -	Model No. 22-100, Dual 15-V Power Supply California Electronic Manufacturing Company P.O. Box 555 Alamo, California 94507
2.	Sigma -	Catalog No. 221A-4-12D, Solid State Relay Sigma Instruments, Inc. Braintree, Massachusetts 02148
3.	Adams and Westlake -	No. AWCL16931-S, Mercury Whetted Relay Adams and Westlake Company 1000 G North Michigan Street Elkhart, Indiana 46514
4.	Fairchild -	741EHC Frequency Compensated Op Amplifier or equal (Any electronics supplier)
5.	Raytheon -	RM747D Dual Frequency Compensated Op Amplifier or equal (Any electronics supplier)
6.	Bourns -	Precision Potentiometer 10-turn 5-K ohms, No. 3500S-1-502 Bourns, Inc. Trimpot Products Division 1200 Columbia Avenue Riverside, California 92507

GPO 843-342