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AN AUTOMATED INSTRUMENT FOR CONTROLLED-POTENTIAL COULOMETRY: SYSTEM DOCUMENTATION

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DISCLAIMER

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ABSTRACT

An automated controlled-potential coulometer has been developed at the Savannah River Plant for the determination of plutonium. Two such coulometers have been assembled, evaluated, and applied. The software is based upon the methodology used at the Savannah River Plant, however the system is applicable with minimal software modifications to any of the methodologies used throughout the nuclear industry.

These state-of-the-art coulometers feature electrical calibration of the integration system, background current corrections, and control-potential adjustment capabilities. Measurement precision within 0.1% has been demonstrated. The systems have also been successfully applied to the determination of pure neptunium solutions.

The design and documentation of the automated instrument are described herein. Each individual module's operation, wiring layout, and alignment are described. Interconnection of the modules and system calibration are discussed. A complete set of system prints and a list of associated parts are included.

Key words: Controlled-potential coulometer, plutonium, neptunium, automated, and electrical calibration.

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INTRODUCTION

Reliable controlled-potential coulometric determination of plutonium requires accurate electrolysis current integration, stable/low noise potential control, and easily operated instrumentation.

Commercially-available coulometers are capable of excellent potential control. These same coulometers have been interfaced to computer systems for instrument control, although the coulometers were not designed with automation as the primary intent. However, these systems are deficient in their ability to accurately integrate the electrolysis current. An analog integrator accumulates a charge on the integrating capacitor that is proportional to the quantity of material electrolyzed. This type of integrator deviates inherently from the ideal response by as much as -0.1% because of its inability to retain the accumulated charge quantitatively. The cause of this non-ideal response (integrating capacitor leakage and dielectric absorption) has been identified and mathematical corrections and procedural modifications have been developed to reduce the systematic errors.[1] However, a simpler solution is the use of a digital integrator. A digital integrator does not suffer from deviations associated with analog integrators. A digital integrator consists of a voltage-to-frequency converter to generate pulses (the sum of which is proportional to the quantity of material electrolyzed), a counter to accumulate these pulses (minimizing integrating capacitor losses), and a display which allows the value of the counter to be read. Although digital integrators have been incorporated in commercially-available coulometers, manufacturers' specifications on the integrating components preclude insuring the accuracy of such instruments beyond that obtained with analog integrators. Plutonium measurements obtained using the EG&G Princeton Applied Research digital coulometer at SRP were consistent with expectations based upon the manufacturer's specifications.

Thomas L. Frazzini and Michael K. Holland, while employed at the Department of Energy's New Brunswick Laboratory, NBL, developed a digital integrator using state-of-the-art electronic components in a patented circuit design,[2,3] and incorporated the integrator into the second and third generation automated coulometric measurement systems.[4]

The objective at SRP was to utilize documentation supplied by NBL to fabricate two systems comparable to the third generation NBL system and to ensure that the documentation would meet SRP QA requirements.

SUMMARY

Two automated coulometers have been fabricated and installed at SRP. One of the systems is located in 772-F for routine sample measurements and the other system is in 772-1F to support development/evaluation activities and to provide backup for routine operations. During the course of construction and testing of these two systems, significant improvements in system operation were achieved. Both previously observed and unidentified anomalous system behaviors were identified and corrected. Documentation deficiencies were also identified and corrected.

Assembly, testing, evaluation, and documentation of these fourth-generation, state-of-the-art systems are described herein.

DESCRIPTION

The SRP controlled-potential coulometer units are each composed of two potentiostat modules, an integrator module, a counter module, and an automation module. The units are controlled by a Hewlett-Packard computer. The computer, associated peripherals, and cell assembly are described in detail in a subsequent section of the report.

The potentiostat modules are based on the design of J. E. Harrar et al. using the best available electronic components. The units supply a stable control potential to the cell assembly where the species of interest is electrolyzed. Two potentiostats are used to separate the oxidation and reduction functions although the units are of identical design and are interchangeable. In both units, all of the electrolysis current passes thru a 50-ohm load resistor in series with the measurement cell. The voltage drop across the load resistor is thus proportional to the electrolysis current. When the voltage signal across the load resistor is integrated, the quantity of material electrolyzed may be determined from Faraday's Law.[6] Potentiostat #1, used for sample oxidation, is connected to the integrator module.

A programmable digital-to-analog-converter power supply is connected through a precision voltage divider to both of the potentiostat modules. The signal from the power supply is routed to the non-inverting input of the driver amplifier. Connection of the signal to this reference point of the driver amplifier allows programmable incrementing of the control potential voltage supplied to the measurement cell. The selection of signal polarity in this system causes addition of the voltage to the control potential supplied by the reference supply. Addition of a signal to the control potential is a somewhat more convenient approach than a subtraction for automating the control potential adjustment[6] and the formal potential determination.

The integrator module is composed of two voltage-to-frequency converters (VFC's) and a quartz crystal oscillator. The signal from the potentiostat to be integrated and a small offset signal are supplied to VFC #1. Only the offset signal is supplied to VFC #2. The frequency signal from the two VFC's and the crystal oscillator are supplied to the counter module for accumulation on counters #1, #2, and #3, respectively. The signal to be integrated would be exponentially decaying DC were it not for AC noise and the adjustment of the control potential which cause changes in the polarity. The offset signal is supplied to ensure that the polarity of the net signal to be integrated is always positive. Supplying only the offset signal to VFC #2 allows accurate correction for the contribution of the offset signal to the total integrated counts from VFC #1. The integral of the signal from potentiostat #1, V_i is calculated as follows:

$$V_i = V_{i+o} - V_o \times K_o \qquad (1)$$

where V_{i+o} is the signal plus offset counts (counter #1), V_o is the offset counts (counter #2) and K_o is the ratio of the responses (count/sec/V) of VFC #1 to VFC #2. This ratio, although near unity, is sufficiently different from one to be important to the accurate calculation of the integral. The value of K_o is easily and accurately determined when no current is flowing thru potentiostat #1 (standby mode). When the signal to be integrated is zero then, VFC #1 and VFC #2 both integrate only the offset signal. Thus, $K_o = V_{i+o}/V_o$ when the signal is zero.

The potentiostat/integrator combination can be calibrated electrically using a precision resistor to replace the measurement cell. By using the potentiostat to apply a potential across the precision resistor and integrating for a known period of time, the coulombs and counts are obtained and their ratio may be determined as follows:

$$C = \frac{V_{Pr} \times T}{R \times V_i} \qquad (2)$$

where Vp_r is the voltage drop across the precision resistor of value R in ohms, T is the calibration time in seconds, and V_i is the net counts calculated using Equation 1.

The theoritical value for the electrical calibration factor, C(theoretical), may be calculated from the design and component selection of the potentionstat and integrator.

$$C\ (\text{theoretical}) = \frac{1}{(R_x)(r)}$$

where R_x is the potentiostat #1 load resistance in ohms and r is the response of VFC #1 in counts/sec per volt of signal to be integrated.

For convenience, the value of the electrical calibration factor is expressed in coulombs per million counts.

The automation module allows interconnection/interfacing, data acquisition, and computer control for the peripherals, the cell assembly, and the coulometer modules. An overall system block diagram is shown in Fig. 1.

INSTRUMENTATION

Computer and Accessories

The computer and all accessories used were made by Hewlett Packard. The computer is a Series 200, Model 226. It comes with a 5 1/4 inch disk drive, 7 inch monochrome screen, 512 kbytes of internal RAM, and a HP-IB (IEEE-488) interface. In addition, the following accessories were installed;

- BCD (Binary Coded Decimal) Interface
- GPIO (General Purpose Input/Output) Interface
- additional 512 kbytes RAM

BCD Interface

The BCD interface is used to read the value from the seven digit Counter module in binary coded decimal format. The BCD interface attaches to the Counter module through a customized cable (Ref print S5-2-15969). This interface inputs data only.

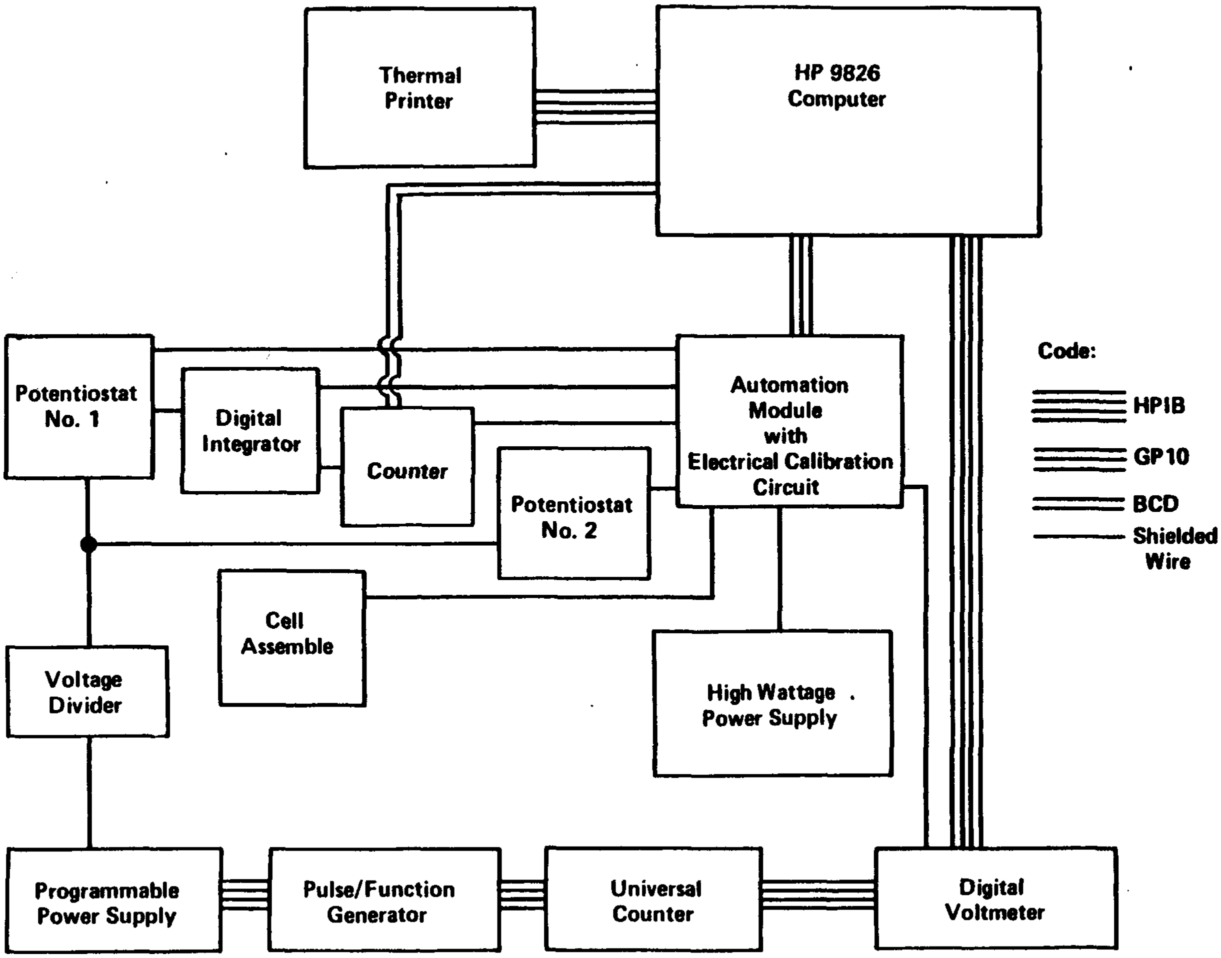

FIGURE 1. System Block Diagram

The switch settings on the BCD interface are as follows;

OF=ON	CTLB=OFF	SELECT CODE=01011 (ELEVEN)
DATA=ON	CTLB-2=OFF	INT=00
SIGN1=ON	DFLGB=OFF	
SIGN2=ON	CTLA=OFF	
OVLD=OFF	CTLA-2=OFF	
	DFLGA=OFF	

GPIO Interface

The GPIO interface allows the computer to control the automation module which selects the coulometer operating mode and interconnects the coulometer, measurement cell assembly and peripheral devices via a series of mercury-wetted relays. For example, the computer can put the oxidation potentiostat in the standby mode while operating the reduction potentiostat and connecting it to the cell. The details of the capabilities of the GPIO interface are discussed fully in the automation module description. The GPIO interface connects to the automation module through a customized cable (Ref print S5-2-15969).

The switch settings on the GPIO interface are as follows;

PCTL=1	RD=1	SELECT CODE=01100 (TWELVE)
PFLG=0	BSY=1	INT=00
PSTS=1	RDY=0	
HSHK=1	RD=1	
DIN=1	BSY=1	
DOUT=0	RDY=0	

Peripherals

The following peripherals, all manufactured by Hewlett Packard, are connected to the computer through the HPIB interface:

- 3456A Digital Voltmeter
- 59501B Digital-to-Analog Converter/Power Supply
- 5316A Electronic Counter
- 8116A Pulse Function Generator
- 2673A Printer

3456A Digital Voltmeter

The 3456A is a highly accurate 6 1/2 digit voltmeter. Full programmability over the HPIB (address 705) is standard. The 3456A connects to the automation module output labeled DVM. Through the

GPIO interface, the computer connects the voltmeter to various points in the system. These points are detailed in the automation module description. All the settings on the voltmeter are made through software except for a front panel button which selects the rear terminals as the input.

59501B Digital-To-Analog Converter (DAC)

The 59501B is a fully HPIB (address 707) programmable signal channel digital-to-analog converter, capable of supplying a 0-1 and 0-10 VDC in a unipolar mode. In the bipolar mode it is capable of supplying a -1 to +1 and a -10 to +10 VDC signal. The DAC is used in the 0-1 and 0-10 VDC range to automatically adjust the control potential on the potentiostat modules.

To reduce the DAC signal, the voltage is scaled down by a precision voltage divider (Ref print S5-2-15952D). The divider circuit reduces the input signal by a factor of five. The output of the divider network connects to the external potential input on both potentiostat modules (Ref print S5-2-15953) and from there directly to the non-inverting input of the driver amp AR2 (Ref print S5-2-15956). Note that the polarity of the DAC signal is positive at the non-inverting input of AR2 with respect to the amplifier common. When the output from the DAC is increased from zero, the control potential VCP, will increase (Ref Fig 2).

5316A Electronic Counter

The 5316A is a highly accurate 7 digit counter which is fully programmable through the HPIB (address 708) interface. The counter was used in conjunction with the 8116A pulse generator for general timing of events. The counter provides accurate timing during electrical calibration and sample electrolysis. An additional application of the counter is realized during periodic alignment described in the digital integrator description.

The mode of operation of the counter is software controlled but the following front panel controls must be set:

Input=Channel A
Trigger/Sensitivity Button=Trigger Position
AC/DC button=DC position
Filter/Norm button=Filter position
Gate Time Delay Dial=Midpoint
Level/Sense Dial=Midpoint
Slope=positive
Attn=x1 position
SEP/COM A button=Sep position

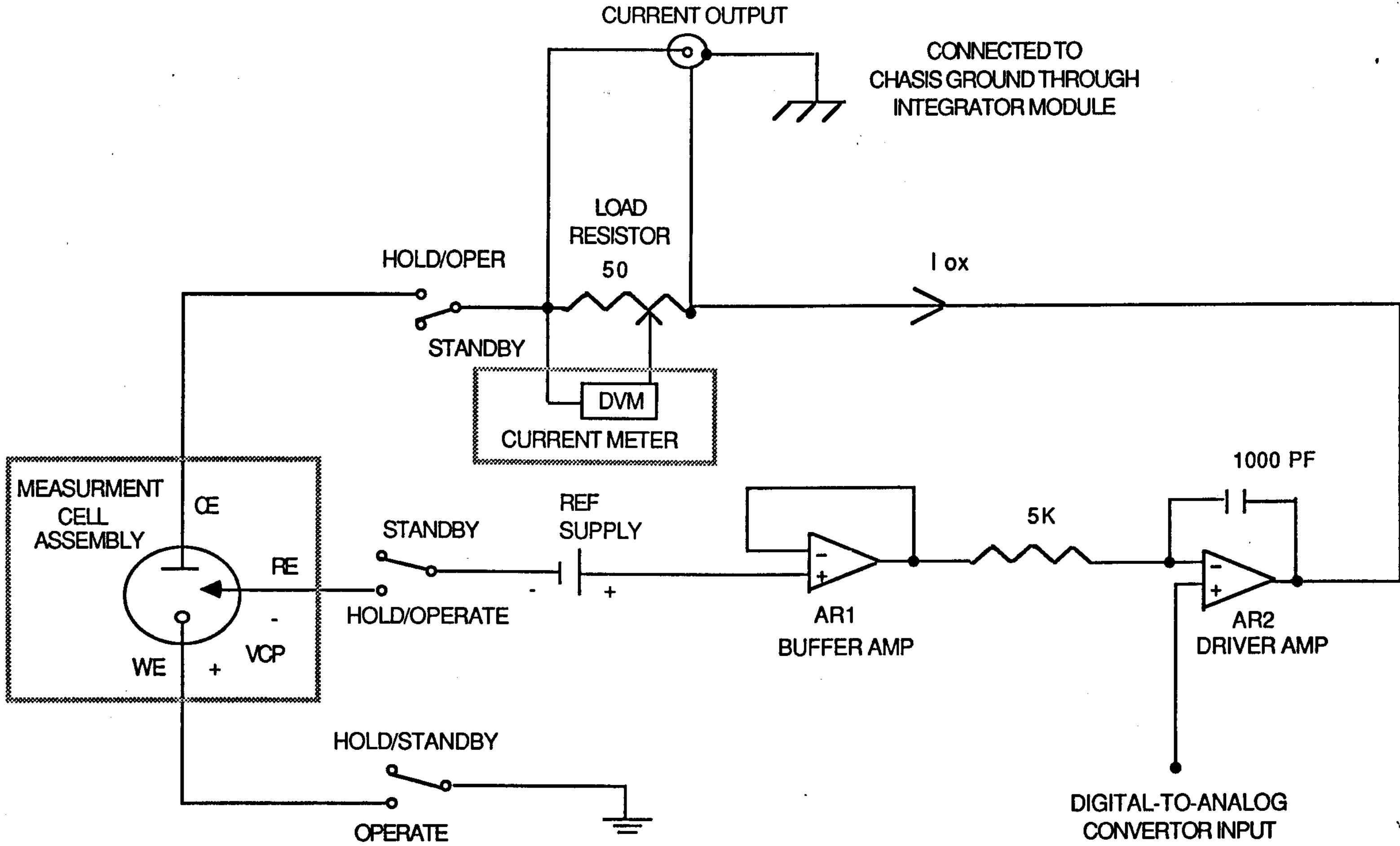

FIGURE 2. Potentiostat Circuit

8116A Pulse Function Generator

The 8116A generates pulses and waves with various duty cycles and frequencies. It is fully programmable through the HPIB (address 709). The pulse generator was used with the 5316A counter for general timing purposes. All controls are programmed except for two buttons. The COMPL and the DISABLE LED's buttons must be manually deactivated.

2673A Graphics Printer

The 2673A is fully programmable through the HPIB (address 710). It is used to print all relevant data for a process.

MEASUREMENT CELL ASSEMBLY

1.0 Princeton Applied Research Measurement Cell Assembly, Model 377A. The unit is composed of a platinum working and counter electrode, counter and reference bridge tubes with porous glass frits, a Teflon cell head, a Teflon cell retainer ring, a synchronous stirring motor, and a support stand. Sulfuric Acid (1.0N) is used in conjunction with the platinum working electrode.

2.0 A custom-made gold working electrode has been fabricated from gold mesh (punched/expanded metal ribbon) on a 16 gauge gold wire frame. The gold working electrode has also been used in the cell assembly. The supporting electrolyte used in conjunction with the gold electrode was 0.8N HNO_3.

3.0 Reference Electrode. A miniature saturated calomel reference electrode is used. The Fisher Scientific catalog #13-639-79 has been found to be satisfactory.

4.0 Reverse-S Shaped Stirrer.[7] The PAR paddle stirrer was replaced with a comparable sized reverse-S shaped stirrer to prevent mechanical losses of the sample solution by splashing.

5.0 A Kel-F coated support rod replaces the manufacturer's support rod to prevent electrical paths from the cell to ground thru the support stand.

POTENTIOSTAT MODULE

Description

The potentiostat module's main purpose is to supply a constant potential to the cell through the working and reference electrodes. The potential is supplied by a 6.2 VDC floating supply. A 20 K ohm potentiometer is used to set the full scale span of the control potential. The voltage can then be adjusted over the span with the 2 K ohm Helipot (Ref print S5-2-15955). Two banana plugs on the rear panel allow the full-scale span voltage to be measured.

A three position front panel switch selects the three modes of operation through 5VDC relays. The three modes are; standby, hold, and operate. In the standby mode, the relays which connect the control circuit are disconnected from the 5 VDC supply leaving them in a de-energized state (Ref prints S5-2-15955, S5-2-15956). Note that when the computer is controlling the operation of the potentiostat, the mode switch is in the standby position and the relays can be energized by the automation module through the potentiostat connector J3. In the hold mode (see Fig 2), the counter and reference electrodes are connected to the circuit but the working electrode is still disconnected. Finally, in the operate mode the circuit is completed and the working electrode connects to the power supply common.

There are three remaining switches on the front panel which control the cell current monitor. The charge/normal switch supplies 4.8 VDC to the current monitor in the normal position. The 4.8 VDC is supplied by four 1.2 V Duracell batteries. In the charge position the monitor is off. The 200 mA/20 mA switch in the 20 mA position displays the cell current from 0 to 19.999 mA and the 200 mA position displays the current from 0 to 199.0 mA. The polarity shown on the current monitor for oxidation is negative while for reduction, positive. The display test switch illuminates the entire display.

On the rear of the potentiostat module are three coax connectors. The external potential input allows the user to input a voltage to the non-inverting input on the power amplifier to offset the reference supply (see Fig 2). The output current connector provides a voltage proportional the the cell current for use by the integrator. Note in Fig 2 the direction of I_{OX} (oxidation current). The voltage drop across the 50 ohm resistor is positive which is necessary since the integrator can only accept a positive voltage. The control potential output, used only during instrument alignment and troubleshooting, allows the user to measure the voltage between the working and reference electrodes.

The working, reference, and counter electrodes are connected directly to a three-pin Amphenol connector on the rear panel. The cell connections are also tied to the automation module through the NIM (Nuclear Instrument Module) connector for use in the computer controlled mode.

Alignment

Alignment of the potentiostat module includes the internal null adjustments of both amplifier circuits and the span adjustment on the control potential circuit. Equipment needed for calibration includes:

- Hewlett Packard 3456 Voltmeter.
- BNC shorting plug.
- NIM Extender Cable with pins 34 and 42 not shorted.
- Reference prints S5-2-15956, S5-2-15955

1.0 <u>Initial Null Adjustments</u>

1.1 Turn the power switch on the automation Module off and switch the potentiostat to standby.

1.2 Remove the potentiostat to be calibrated from the NIM bin and remove the switching and load card.

1.3 Connect the NIM extender cable from J3 on the NIM bin to the NIM connector on the potentiostat module. Apply power to the system and allow for a 30 minute warmup.

1.4 Connect a short jumper from TP1 on the control amplifier board (Ref print S5-2-15956) to the ground plane of the board. Note: do not connect the jumper to the chasis ground; the control amplifier board ground floats.

1.5 Connect the negative lead from the 3456A Voltmeter to the ground plane and the positive lead to the output of amplifier AR1 (TP2).

1.6 Adjust R4 until the DVM reads less than .003 mvolts. Note: turn the potentiometer in a counter-clockwise direction to decrease the voltage.

1.7 Leave the non-inverting input of AR1 and the negative lead of the DVM grounded.

1.8 Attach the BNC shorting plug to the external potential connector on the rear panel.

1.9 Connect the positive lead of the DVM to the output of AR2 (TP3).

1.10 Short capacitor C1 with as short a wire as possible.

1.11 Adjust R5 until the DVM reads less than 1.0 mVolts.

1.12 This completes the initial offset adjustments for the Potentiostat module. Turn off the power to the system and remove all jumpers.

1.13 Re-assemble the Potentiostat Module.

2.0 <u>Span Adjustment of the Control Potential</u>

2.1 Connect a coax cable from the rear control potential jack on the Potentiostat module to the 3456A voltmeter.

2.2 Adjust the control potential dial on the front panel until it reads 0.

2.3 Adjust the span potentiometer on the rear panel until the voltmeter reads less than 0.10 volts.

2.4 Verify that when the front panel dial is reading full scale, the control potential output is 1 volt.

The accuracy of this adjustment is not crucial to the system's performance since the control potential is adjusted automatically by the computer during measurements.

DIGITAL INTEGRATOR MODULE

Description

The digital integrator module converts a voltage signal from the load resistor of the potentiostat module to a frequency. The voltage signal is proportional to the current passing through the cell. It is unique with respect to other integrators since it has two voltage-to-frequency convertors.

When the test/normal switch is in the normal position, the input potential from the potentiostat is sensed by the detection circuit (see Fig 3). Under normal conditions, the input will range from 0 to 3 VDC. If the voltage is negative, the sensing circuit will energize relay K1, disengaging the input from VFC #1, protecting it. The readout circuit accepts the 0-3 VDC input and converts it to a 1200 Hz to 31.200 kHz frequency signal. A 1.35 volt mercury battery in the automation module provides the 1200 Hz

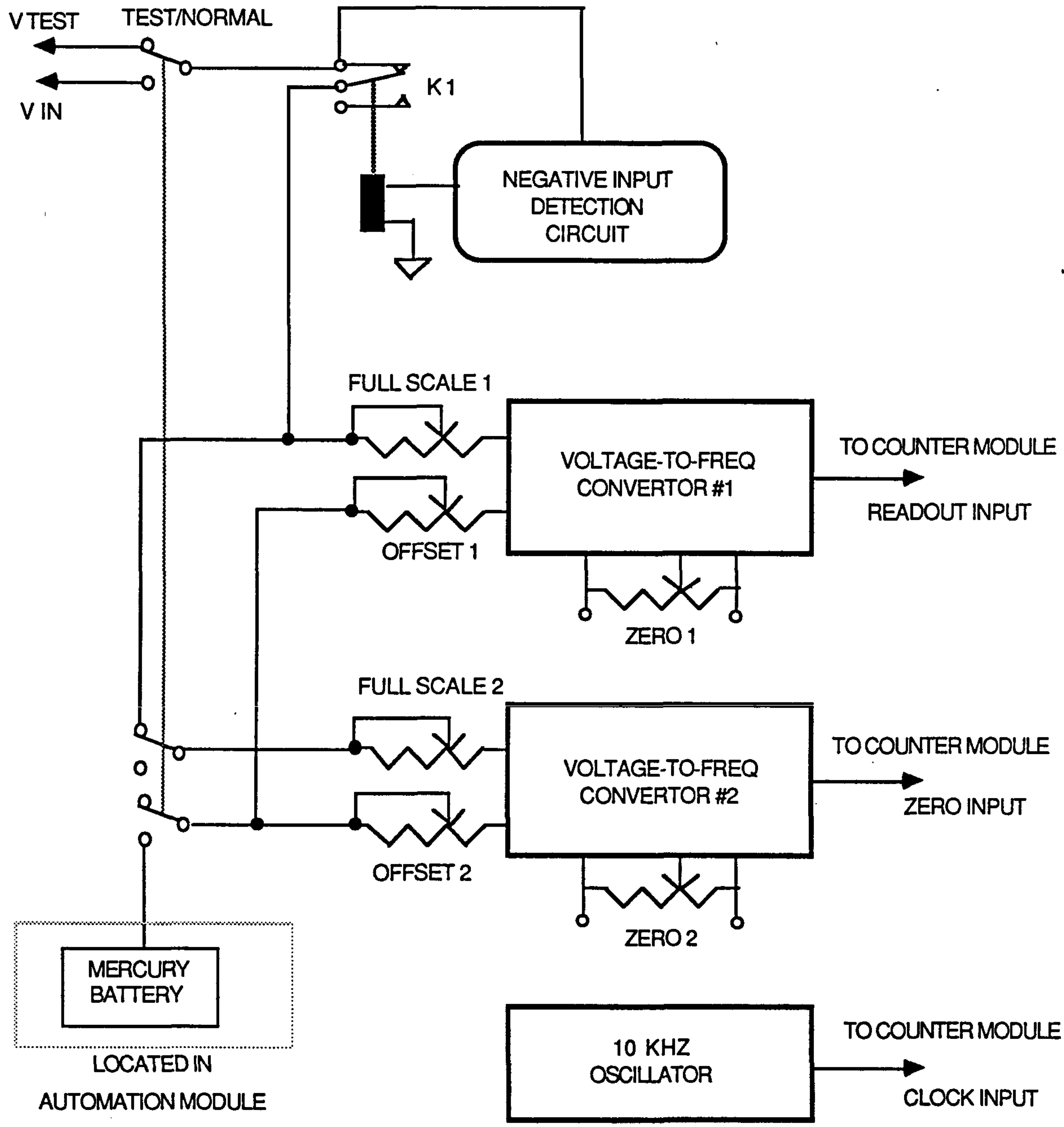

FIGURE 3. Digital Integrator Module

offset. The zero circuit receives the same 1.35 volt signal from the automation module and converts it to a constant 1200 Hz offset. The benefit of the two VFC's and the offset voltage is discussed in the description.

The test/normal switch is put in the test position when calibrating and aligning the VFC's. In this position, the same voltage can be applied to both VFC's simultaneously.

Under normal operation, the outputs of VFC #1 and #2 connect to the counter module inputs, readout, and zero, respectively. The counter then converts the signals to a binary coded decimal format for display and input to the computer.

The 10 kHz crystal oscillator circuit is described in the Counter module description.

Alignment

Alignment of the digital integrator includes setting the zero, span, and offset of the two VFC's. In addition, an internal protection circuit which protects the VFC's and a 10.000 kHz clock must be initially set. Equipment needed for calibration includes:

- Fluke 343A DC Calibrator.
- Hewlett Packard 5316A Electronic Counter.
- Hewlett Packard 3456A Voltmeter.
- Prints S5-2-15958, S5-2-15959.

1.0 <u>Alignment Procedure - READOUT</u>

1.1 Allow a 30-minute warmup before making adjustments.

1.2 Set the TEST/NORMAL switch to TEST.

1.3 Apply an input voltage of 10 mVolts to the rear panel BNC labeled CURRENT on the digital integrator module.

1.4 Monitor the front panel output BNC labeled READOUT with the Hewlett Packard Counter.

1.5 Adjust the front panel trimpot labeled Z1 for a reading of 100 Hz on the frequency counter (Note: a clockwise rotation of the trimpot will cause a decrease in frequency).

1.6 Apply an input voltage of 3.000 volts.

1.7 Adjust the front panel trimpot labeled FS1 for a reading of 30.000 kHz on the frequency counter.

1.8 Repeat steps 1.3 to 1.7 to determine repeatability and accuracy of adjustments made previously. Repeatability should be +/- 1 count.

1.9 Set the TEST/NORMAL switch to NORMAL.

1.10 Attach a cable from the rear panel BNC labeled OFFSET VOLTAGE on the automation module to the rear panel BNC labeled OFFSET on the digital integrator module.

1.11 Adjust the input voltage to 3.000 Volts.

1.12 While monitoring the READOUT output BNC with the frequency counter, adjust the front panel trimpot labeled O1 for a display of 31.200 kHz on the counter. this supplies an offset voltage of 1.200 volts to the input of VFC1.

2.0 Alignment Procedure - ZERO

2.1 Set the TEST/NORMAL switch to TEST.

2.2 Attach a cable from the rear panel BNC labeled OFFSET VOLTAGE on the automation module to the rear panel BNC labeled OFFSET on the digital integrator module.

2.3 Apply an input voltage of 10.00 mVolts to the rear panel BNC labeled CURRENT on the Digital Integrator module.

2.4 Monitor the front panel output BNC labeled ZERO with the frequency counter.

2.5 Adjust the front panel trimpot labeled Z2 for a reading of 100 Hz on the frequency counter.

2.6 Adjust the input voltage supply for an output of 3.000 volts.

2.7 Adjust the front panel trimpot labeled FS2 for a reading of 30.000 kHz on the frequency counter.

2.8 Repeat steps 2.3 to 2.7 to determine repeatability and accuracy of adjustments made previously. Repeatability should be +/- 1 count.

2.9 Set the TEST/NORMAL switch to NORMAL.

2.10 Continue monitoring the front panel output BNC labeled ZERO with the frequency counter.

2.11 Adjust the front panel trimpot labeled 02 for a reading of 1200 Hz on the frequency counter.

3.0 <u>Alignment Procedure - Oscillator</u>

3.1 Monitor the rear panel BNC labeled CLOCK on the digital integrator with the frequency counter.

3.2 Adjust the front panel trimpot labeled CLOCK for a frequency of 10.000 kHz.

4.0 <u>Calibration Procedure - Internal Protection Circuit</u>

The internal protection circuit senses the CURRENT input and isolates this input from the VFC's if the input is driven more than 300 mVolts negative.

4.1 Remove any external connections from the rear panel CURRENT BNC.

4.2 Measure the voltage at pin 3 of U2 with a DVM and set the front panel trimpot labeled NCO for a reading of -300 mV on the DVM.

4.3 Short pin 2 and pin 6 of U2 together and monitor the output voltage on pin 6 of U2.

4.4 Adjust the front panel trimpot labeled A2 for a reading of -300 mV on the DVM.

4.5 Remove the jumper between pins 2 and 6 on U2.

4.6 Jumper pins 2 and 3 of U1 to ground.

4.7 Monitor pin 6 of U1 with a DVM and adjust the front panel trimpot A1 clockwise until the DVM reads +15 volts. Next, adjust the trimpot slowly counter-clockwise until the DVM reads a negative voltage.

4.8 Remove all jumpers from the circuit. This completes the protection circuit adjustments. The following steps outline testing of the calibration.

4.9 Set the TEST/NORMAL switch to NORMAL.

4.10 Connect the Fluke Voltage Supply to the Current Input on the Digital Integrator module. Input 0.00 Volts.

4.11 Remove the shorting bar connecting the negative terminal on the 343A to the ground terminal.

4.12 Monitor pin 2 and 4 on U3 with the DVM. The voltage should be approximately 4 Volts (logic "1"). Slowly decrease the voltage from 0.00 Volts to -500 mVolts. At approximately -300 mVolts pin 2 and 4 on U3 should read less than 1 Volt (logic "0") causing K1 to energize, isolating the CURRENT input from the VFC's.

NOTE: To obtain the negative voltage from the 343A calibrator, reverse the leads.

COUNTER MODULE

Description

The counter module is a multiplexed seven digit, three counter scaler with a rear panel BCD output. There are no calibrations or internal adjustments.

The three counter inputs are clock, readout, and zero. They accept the frequency outputs of the digital integrator module. All three counter circuits are identical. Their outputs can be selected through a front panel switch or through the rear NIM connector. Details of how each counter is selected is presented in the automation module description.

The readout and zero signal are described in the digital integrator description and are not discussed here. The clock signal is a precise 10 kHz signal generated by a crystal oscillator in the digital integrator. This signal provides the timing signal used to multiplex the eight digit LED display (Note: the eighth digit is not used). In addition, the clock signal provides accurate timing for the computer to use when timing oxidation reactions.

1.0 <u>Controls</u>

1.1 MANUAL/AUTO - Local operation of the counter module is provided when this switch is in the MANUAL position. It enables all front panel switches. When the switch is in the AUTOMATIC position, all controlling is done by the computer through the automation module and the front panel switches are disabled except the LAMP TEST button.

1.2 CLEAR - When the MANUAL/AUTO switch is in the MANUAL position, the pushbutton clears all three circuits to zero.

1.3 LAMP TEST - When pressed, all the digits in the LED display are illuminated.

1.4 ZERO/READOUT/CLOCK - When the MANUAL/AUTO switch is in the MANUAL position, this switch selects any of the three internal counters for display on the front panel LED display.

1.5 HOLD - When the MANUAL/AUTO switch is in the MANUAL position, this pushbutton latches the display; however, the internal counters continue to increment. If the CLEAR pushbutton is pressed while the display is latched, the display will not clear but the counters will. Once the hold is removed, the display will represent the value in the counters.

AUTOMATION MODULE

Description

The automation module contains two circuit boards, a +/- 15 VDC supply, a 1.35 V mercury battery, and 120 VAC power switch with a neon lamp. The automation module's main function is to act as an interface between the computer and the rest of the system. The computer sends signals to the GPIO interface, which directly connects to the driver/interface card (Ref print S5-2-15965). The driver/interface card amplifies the signals to a level that can drive the relays located on the automation card and on the switching and load card. The driver/interface card also drives the signals that control the counter module operation.

The list below describes computer controlled functions performed by the automation module. Each operation references to the pin on the driver/interface board which executes it. Note for these functions to be enabled, the mode switch on the potentiostats must be in the standby position and the manual/auto switch on the counter module must be in the auto position. A logic one is defined as 3 to 5 volts and a logic zero as less than .7 volts.

- A logic one signal applied to pins H and J energize K1 and K2 respectively on the switching and load card which puts the oxidation potentiostat in the operate mode.

- Pin E and F operate identical to H and J except the reduction potentiostat replaces the oxidation potentiostat.

- A logic zero signal applied to pin U energizes K1 and K2 on the automation card. When energized, the oxidation potentiostat is connected to the cell and when de-energized, it is connected to a calibration resistor.

- Pin T operates identical to Pin U except the reduction potentiostat replaces the oxidation potentiostat.

- A logic zero signal applied to pin S energizes K5 and K6 on the automation card. When energized, the external potential input is connected to external potential #1. When de-energized, the external potential input is connected to external potential #2. This feature is not presently used due to noise problems. Instead, the external potential signal is supplied to both potentiostats at the same time. This does not cause a problem since only one potentiostat is operated at a time.

- A logic zero signal applied to pins R, M, or L, will energize K7, K8, and K9, respectively. These three relays combined allow the digital volt meter to measure the voltage at various points in the system. Table 1 below details the operation. Note "X" indicates a don't care state.

TABLE 1

Logic Table for Controlling DVM Monitor Point

K7	K8	K9	DVM Monitors
X	De-energized	De-energized	Calibration resistor
De-energized	X	Energized	Load #1
X	Energized	De-energized	Ox/red potential
Energized	X	Energized	Load #2

- Pin D and C control "select A" and "select B", respectively. Their outputs do not drive relays but directly connect to the counter/multiplexer board in the counter module. When the manual/auto switch on the counter module is in the auto position, Pins D and C choose which counter circuit, readout, zero or clock is to be displayed. Table 2 shows how select A and select B operate.

TABLE 2

Logic Table for Controlling Counter Module Data Multiplexer

Select A	Select B	Counter Circuit Selected
Logic zero	Logic zero	READOUT
Logic zero	Logic one	CLOCK
Logic one	Logic zero	ZERO
Logic one	Logic one	Not Used

For explanation of each circuit, see the digital integrator description.

SYSTEM SOFTWARE

The Hewlett-Packard series 200 model 226 utilizes RAM based Basic language version 3.0. The software developed for the instrument control is a user-friendly menu driven system. Two main menus, each having a version for the type of supporting electrolyte, which allow access to the various system capabilities are reproduced in Figures 4-7. Password control of selected system capabilities prevent unintentional access to these capabilities by the technician performing routine measurements.

The software package for plutonium measurement permits the determination of pure plutonium in both a sulfuric acid supporting electrolyte at a platinum working electrode and a nitric acid supporting electrolyte at a gold working electrode. In both method variations, measurement of the supporting electrolyte blank precedes sample determination. The formal potential of the pure plutonium can be measured for either supporting electrolyte following sample measurement. Concurrent measurement of plutonium and small amounts of neptunium or iron [8] in nitric acid supporting electrolyte has been fully automated. Electrical calibrations are performed with each plutonium measurement and continuously when the system is not being used for plutonium measurements. To comply with SRP measurement and test equipment (MTE) requirements, the system automatically monitors parameters of key components to ensure that no significant shifts have occurred which would adversely affect the reliability of the system calibration.

All measurement results and related information are logged to a data disc in serially numbered data files. The same data disc also contains the results of the last ten electrical calibrations to be used in subsequent measurement calculations, and the data from the last blank measurement.

```
-----------------------------------+
                                   |
          MENU 1                   |
 1 = MEASURE SULFURIC BLANK        |
 2 = CONDITION/MEASURE BLANK       |
 3 = MEASURE CALIBRATION FACTOR    |
 4 = CHANGE TYPE OF ELECTROLYTE    |
 5 = CHANGE CALIBRATION FACTOR     |
 6 = CHANGE CALIBRATION TIMING     |
 7 = CHANGE MEASUREMENT TIMING     |
 8 = MANUAL OPERATION/TESTING      |
 9 = SKIP TO MENU_2                |
10 = MINI-PROCEDURE                |
11 = MTE LINEARITY TEST            |
99 = STOP                          |
 ENTER # OF THE DESIRED OPTION     |
                                   |
-----------------------------------+
```

FIGURE 4. Menu 1 for Sulfuric Acid Supporting Electrolyte

```
-----------------------------------+
                                   |
          MENU 2                   |
                                   |
 10 = MEASURE NEXT BLANK           |
 20 = MEASURE THE SAMPLE           |
 30 = RE-MEASURE THE SAMPLE        |
 60 = MEASURE FORMAL POTENTIAL     |
      OF Pu(IV)/Pu(III) COUPLE     |
 70 = PRINT/DISPLAY LOGBOOK        |
 80 = PRINT PROGRAM LIST           |
 99 = LAST MEASUREMENT DONE        |
                                   |
 ENTER # OF THE DESIRED OPTION     |
                                   |
-----------------------------------+
```

FIGURE 5. Menu 2 for Sulfuric Acid Supporting Electrolyte

```
+--------------------------------+
|                                |
|          MENU 1                |
| 1 = MEASURE THE NITRIC BLANK   |
| 3 = MEASURE CALIBRATION FACTOR |
| 4 = CHANGE TYPE OF ELECTROLYTE |
| 5 = CHANGE CALIBRATION FACTOR  |
| 6 = CHANGE CALIBRATION TIMING  |
| 7 = CHANGE MEASUREMENT TIMING  |
| 8 = MANUAL OPERATION/TESTING   |
| 9 = SKIP TO MENU_2             |
|10 = MINI-PROCEDURE             |
|11 = MTE LINEARITY TEST         |
|99 = STOP                       |
| ENTER # OF THE DESIRED OPTION  |
|                                |
+--------------------------------+
```

FIGURE 6. Menu 1 for Nitric Acid Supporting Electrolyte

```
+--------------------------------+
|                                |
|          MENU 2                |
|                                |
| 10 = MEASURE NEXT BLANK        |
| 20 = MEASURE THE SAMPLE        |
| 30 = RE-MEASURE THE SAMPLE     |
| 40 = CONCURRENT ELECTROLYSIS   |
|      OF Pu/Np SAMPLE           |
| 50 = CONCURRENT ELECTROLYSIS   |
|      OF Pu/Fe SAMPLE           |
| 60 = MEASURE FORMAL POTENTIAL  |
|      OF Pu(IV)/Pu(III) COUPLE  |
| 70 = PRINT/DISPLAY LOGBOOK     |
| 80 = PRINT PROGRAM LIST        |
| 99 = LAST MEASUREMENT DONE     |
|                                |
| ENTER # OF THE DESIRED OPTION  |
|                                |
+--------------------------------+
```

FIGURE 7. Menu 2 for Nitric Acid Supporting Electrolyte

The program listings for plutonium and neptunium measurement with cross reference listings (XREF) are available from the National Energy Software Center.[9]

OPERATION

Startup/Shutdown

The system startup and shutdown procedures are outlined below. The startup procedure utilizes the Hewlett-Packard AUTOSTART capability. The autostart program written for this system ensures loading of all of the desired features of Basic 3.0 Language, the loading of the plutonium measurement software, and returning of the log disc to the disc driver. The autostart program is included in the appendixes.

1.0 Instrument Startup Procedure

1.1 Turn on the following items in order listed below:

- Power strips in rear of cabinet
- HP2673A Graphics Printer
- HP8116A Pulse/Function Generator
- HP5316A Universal Counter
- HP3456A Digital Voltmeter
- NIM Bin POWER switch
- Automation Module-AC POWER switch
- 5V supply on bottom panel

1.2 Press "DISABLE" button on HP8116A so as to turn off the RED light.

1.3 Ensure that the Coulometer Counter/Timer switch is in AUTO position.

1.4 Ensure that the DVM terminal button is in the REAR position.

1.5 With computer power off, insert disk labeled "AUTOSTART" and press AC LINE switch to turn power on. Wait for "READ" light on disc drive to turn off.

1.6 Follow instructions on the CRT.

1.7 Insert LOGBOOK disc.

1.8 Press RUN key and the program should begin. If program does not display a safety message, then hold down SHIFT key while pressing PAUSE key (RESET), then press RUN key.

1.9 Answer the safety and time and date questions.

NOTE: The ENTER, CONTINUE, OR EXECUTE keys may be used interchangeably to input answers to questions but the CONTINUE key is required when requested.

2.0 Instrument Shutdown Procedures

Coulometer shutdown procedure, used for emergency generator load test and instrument maintenance.

2.1 Remove disc from drive

2.2 Reset computer (SHIFT/PAUSE)

2.3 Turn the following to OFF position in order:

- 5V supply on bottom panel
- Automation module - AC POWER
- NIM Bin POWER
- Voltmeter
- Counter
- Pulse/Function Generator
- Printer

2.4 Turn off the computer - AC line button

2.5 Turn off power strips in rear of cabinet

3.0 Loading the Neptunium Measurement Software

3.1 Remove the log disc from the internal disc driver

3.2 Insert the neptunium program disc into the driver

3.3 Type 'SCRATCH' then press the 'EXECUTE' key

3.4 Type 'SCRATCH A' then press the 'EXECUTE' key

3.5 Type 'LOAD "NP_CPC"' then press the 'EXECUTE' key

3.6 Allow the program to load, then remove the neptunium program disc

3.7 Return the Log disc to the driver

3.8 Press the 'RUN' key

4.0 Initiating Sample Measurements -- Daily: The startup procedure to go from continuous, electrical calibration to sample measurement, is outlined in the mini-procedure reproduced below from the software.

4.1 Inspect CAL RESULTS/PRINTOUT

a. AVE CAL Factor Near 2.000

b. RSD less than .0010%

4.2 Press 'RESET' (SHIFT/PAUSE)

4.3 Press 'RUN'

4.4 Answer questions

4.5 When the electrode starts to reduce the blank, switch the two toggle switches on Pot #2 to 'NORMAL' & '20mA' then disconnect counter electrode. The meter reading should decrease to <.004 V. Reconnect counter electrode. Return switch on Pot #2 to 'CHARGE' and '200mA'.

4.6 If blank run is excessively slow, then repeat steps 2, 3, & 4.

NOTE: When Menu 2 is used to start sample: If '10' is entered mistakenly, repeat steps 2-4 then select Option 9 when Menu 1 appears. Option 9 reloads last blank data and returns to Menu 2. If system fails any of these tests, do not proceed. Contact M. K. Holland or your supervisor.

5.0 Software Menu Usage

The software menu #1 is obtained after a reminder about safety and quality, a check of the system clock setting, and the type of electrolyte to be used is specified. The type of electrolyte must be specified first because both menus have two versions depending upon the type of electrolyte.

For routine measurements, the supporting electrolyte blank is measured before each sample is determined. Following blank measurements, the sample is dissolved in the electrolyte upon which the blank was determined. After sample measurement is completed, the next blank is routinely determined; however, the sample may be remeasured to verify the result or the formal potential may be determined.

The formal potential and the complete MTE test are performed periodically as dictated by SRP quality assurance requirements and when considered appropriate by the technical staff.

Other menu accessible capabilities are sufficiently self explanatory.

6.0 Completion of sample measurements -- daily: When measurements are completed, the system is advised from the Menu #2 Option 99. The system reminds the analyst of the items listed below, performs a short MTE linearity test, and initiates continuous electrical calibration until the next time the system is used for measurements.

REMINDERS TO THE ANALYST:

- Turn off the argon gas
- Flame the electrodes
- Enter assay results log book
- Enter assay results in LASSO if appropriate
- Do not turn 9826 computer off
- Hit 'CONTINUE' when ready

RESULTS AND DISCUSSION

Significant improvements in the system design were achieved. Noise in the control potential circuit caused by the automation module was identified and corrected. Further reduction of noise in the voltage signal to be integrated was accomplished by addition of a 100 nF capacitor AC shunt. Problems with the isolation of the manual potentiostat mode switch from the automation module, the isolation of the charging system for the potentiostat current meter, stability of the control amplifier circuit, and the operation of the polarity protection circuit for the digital integrator VFC circuit were also identified and corrected. The peripheral units were upgraded by the selection of more recently introduced Hewlett-Packard devices.

The system capabilities have been improved by upgrading the system control software. The capability to measure plutonium in dilute sulfuric acid at a platinum electrode has been added to the previous plutonium method variation in dilute nitric acid at a gold electrode. The capacity of the system to electrolyze large samples (>35 mg Pu or Np) by monitoring the integrator for overflow was added. The control potential stability at high current levels was improved by software adjustments of the programmable digital-to-analog converter to compensate for loading of the driver amplifier in the potentiostat. The software was later modified to measure neptunium. Quality assurance tests were added to ensure the stability of components critical to accurate system calibrations.

The control potential of the potentiostat is controlled by adjusting the voltage on the non-inverting input of AR2 (Ref print S5-2-15956). In the original design, the signal from the digital-to-analog converter was connected to the automation module at the external potential input. The computer selected which potentiostat would receive the signal. The problem with routing the signal through the relays in the automation module was noticed during linearity checks of the calibration factor. The value of the calibration factor varied with the control potential. The cause of the non-linearity was traced to the noise level at the non-inverting input of AR2. The problem was corrected by connecting the digital-to-analog converter signal directly to the external potential inputs on both potentiostats. This did not cause a problem since only one potentiostat is operated at a time.

The signal generated by the potentiostat for integration is an exponentially decaying DC voltage. Accompanying the DC signal of interest is AC noise (see Figures 8-10) contributed from many sources (e.g., measurement cell stirring system, cell capacitance, potentiostat control circuit oscillation, pickup from 120V 60Hz supply, and from fluorescent lighting). The offset voltage produced by the digital integrator handles peak AC noise up to 0.1V and is most effective on low frequency noise. Several approaches have been used to ensure that AC noise is reduced. At the New Brunswick laboratory, the major source of AC noise on the signal to be integrated was from the AC noise on the power supply to the DC stirrer system of the measurement cell. Power supply noise was eliminated by a capacitor shunt across the power supply outputs. The other sources of noise in the NBL system were ignored since their combined contribution was less than 0.1V peak. Princeton Applied Research sells a noise filter accessory for the PAR cell assembly which utilizes a 100 nF capacitive shunt between the counter and reference electrode. The 100 nF capacitive shunt feature was incorporated into the potentiostat module between the counter and reference electrode output to the cell assembly which reduces AC noise (above 1 kHz) beyond that obtained by the 1000 nF

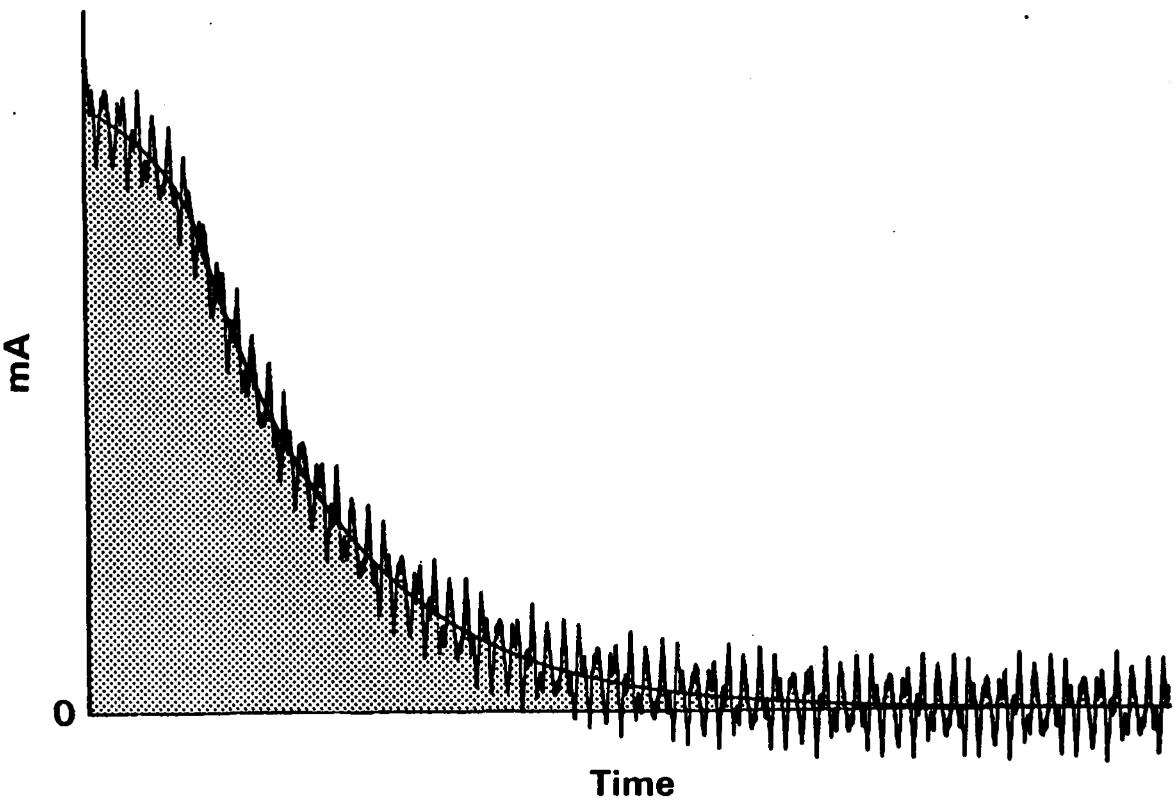

FIGURE 8. Electrolysis Current Signal

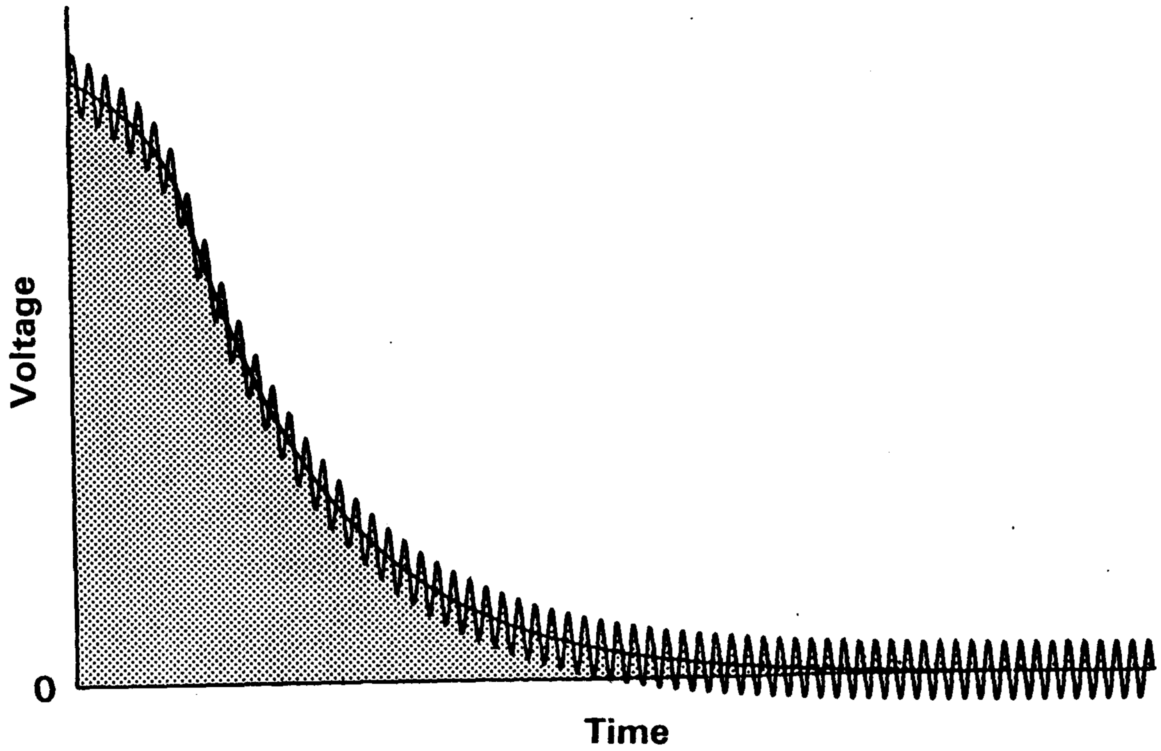

FIGURE 9. Filtered Signal to be Integrated

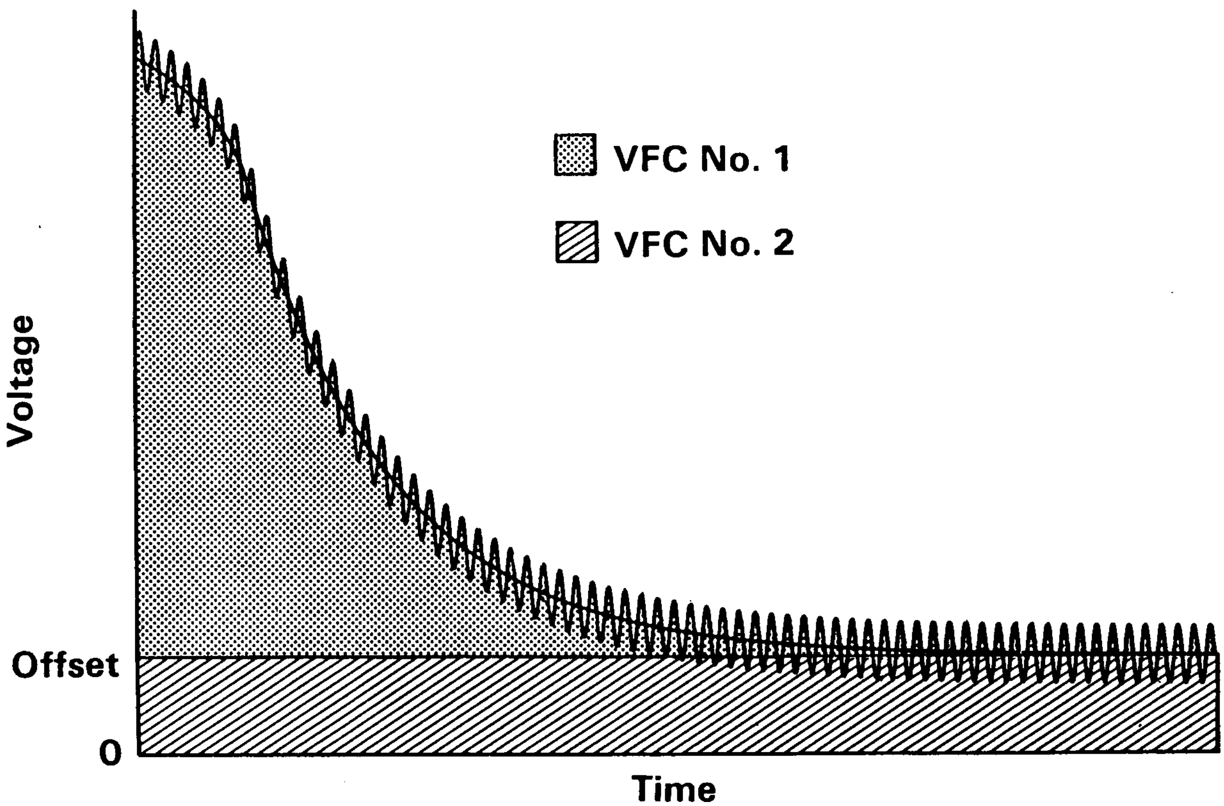

FIGURE 10. Signal Integrated by State of the Art Coulometer

shunt located on the cell assembly. Examination with oscilloscope showed <0.03 V peak 60 cycle noise. It should be noted that an oscilloscope must be used for this measurement, not an AC voltmeter which measures RMS voltage and is not sensitive to high frequency noise which will adversely affect integration performance.

The mode switch on the potentiostat module allows for manual operation. The switch has three positions: standby, hold, and operate. These modes of operation are discussed in detail in the potentiostat module description. If the system is to be operated by the computer, the mode switch must be in the standby position. In this position, the relays can be driven by 74128 line drivers located in the automation module. In the original design, the outputs of the drivers were not isolated from the mode switch. Therefore, if the mode switch was switched to the hold or operate position, 5 volts would be applied to the outputs of the drivers (Ref print S5-2-15955). This caused the output stage of the driver to sink more than its rated current. The problem was corrected by isolating the drivers from the mode switch when in the hold or operate position.

The current meter in the potentiostat module monitors the cell current by measuring the voltage across a 1 ohm resistor in the 20 mA position and a 10 ohm resistor in the 200 mA position. Since the control amplifier board floats with respect to chasis ground, the system 5 volt power supply could not be used to power the current meter. Therefore, in the initial design, four nicad rechargeable batteries were used to supply power to the meter. However, if the display/charge switch was left in the charge position when the system power was off, the batteries would discharge. The nicad batteries were replaced by four Duracell AA batteries and isolated from the power supply. The current meter has a LCD display which draws little current and is only used when manually operating the system; therefore, the batteries will last for about two years under normal use.

The current amplifier on the control amplifier board (Ref print S5-2-15956) is a Teledyne 1461. The 1461 requires a compensation capacitor between pins 11 and 12. Initial design called for a 39 pF compensation capacitor. A problem was encountered with the amplifier circuit when attempting to zero the offset voltage. A 3 mV peak to peak ripple was present across the inputs of the amplifier that could not be nulled out with the trimpot. The value of the compensation capacitor was changed to 100 pF and the ripple was eliminated.

The polarity protection circuit senses the input voltage to the digital integrator. If the input is less than -300 mV, the circuit will isolate the input voltage from voltage-to-frequency converter #1 (VFC #1). The initial design of the circuit did not work due to the placement of a feedback diode in the amplifier stage.

More recently introduced Hewlett-Packard peripheral devices were incorporated in the SRP systems. Precision timing in the software system is accomplished with an HP8116A Pulse/Function Generator and an HPS318A Universal Counter. The counter is also used during digital integration alignment. All voltage measurements are made with an HP3456A digital voltmeter. An HP2673A graphics printer was selected for hard copy output. No change from the NBL prototype was made when the HP59501B DAC/power supply was selected. Appropriate changes in software were made to accommodate these devices.

The modification to the software to allow for a second method variation involving a change in the type of supporting-electrolyte and working-electrode was accomplished by the addition of a variable flag (Electro-flag) set for the method variation selected. The integer variable So4 and No3 were assigned the numerical value of 1 and 2, respectively, at program startup. When the 1N H_2SO_4 or N HNO_3 electrolyte selection is made, the variable Electro-flag is set to So4 or No3, as appropriate. When a program line or series of programs are dependent upon the method variation being applied, an IF......THEN or IF......THEN......ELSE construction with Electro-flag=So4 or Electro-flag=No3 in the argument is used to direct program execution.

The counters in the integration module are capable of accumulating up to 9,999,999 counts, at which point the most significant bit is lost and the counter continues from zero. Ten million counts correspond to the integration of 20.0 Coulombs of electricity. When the counts due to the offset are considered, the integrator has the capacity to electrolyze up to 35 mg of plutonium or neptunium. The software has been modified to monitor the counters when the intergrator is operating. A variable flag is set for each counter when it exceeds five million counts. Should the counter accumulate ten million counts and reset to zero, the software will increment a second variable flag which counts the number of times the counter overflows and resets the five million count flag for the appropriate counter.

At the beginning of the sample reduction and oxidations, the electrolysis current is sufficient to load down the driver amplifier in the potentiostat. The software monitors the control potential supplied to the cell assembly and reduces or increases the signal from the digital-to-analog-converter power supply to maintain the control potential at the desired voltage.

The system/software was later applied to the measurement of pure neptunium solutions. The number of differences between plutonium and neptunium measurement where sufficiently numerous and complex to make the use of variable flag(s) for the element being analyzed to be undesirable. A copy of the plutonium software was obtained from the plutonium controlled-potential coulometry program file (Pu_CPC), modified to measure neptunium, and then stored in a different program file (Np_CPC). Appropriate program upgrades are then made to both programs. The neptunium program is always removed from RAM when measurements are completed to avoid inadvertent usage.

The continuous electrical calibration is dependent upon the accurate measurement/alignment and the stability of the calibration resistor, the quartz crystal oscillator, and the digital voltmeter, and upon the stability of the load resistor and the voltage-to-frequency converters. A series of quality assurance tests were added to the plutonium measurement software to ensure the stability of each of these critical components once they have been aligned/-measured.

The routine electrical calibration precision (2-sigma) is less than 0.001% at the current levels of major importance and only slightly poorer at a lower level. By using electrical calibration, shifts in components can be detected before they impact upon the measurement reliability of the system. The periodic use of the quality assurance tests ensures that the system is accurately calibrated.

Four test subroutines have been developed. The first is a load vs. calibration resistors check, performed over the range of current levels important to sample measurement. This test ensures the relative stability of the resistors and the performance of the voltmeter. The second test is a measurement of the response of voltage-to-frequency converter #1 over the range of current levels important to sample measurement. The third and fourth tests utilize electrical calibrations to evaluate the linearity of the integrator response (count/sec per volt) over the ranges of interest. Calibrations are performed at selected input values encountered in sample measurement both above and below the input value used for electrical calibration. The results of tests three and four are expressed as the percent error caused by the integrator nonlinearity on the measurement of the exponentially decaying input signal obtained during sample measurement at high and low current levels, respectively. The algebraic sum of the two nonlinearity test results quantifies the total effect of integrator nonlinearity upon sample measurement. A summary of the data/results for the four tests on both measurement systems are shown in Table 3.

TABLE 3

Quality Assurance Test Results

Test #1: Load Resistance

System 1 / Potentiostat 1

Current Level, mA	Ohms
0.5	50.014
3.0	49.997
5.5	49.998
8.0	49.998
10.5	49.998
13.0	49.998
15.5	49.998
18.0	49.998

System 2 / Potentiostat 1

Current Level, mA	Ohms
0.5	50.040
3.0	50.064
5.5	50.066
8.0	50.066
10.5	50.067
13.0	50.066
15.5	50.067
18.0	50.067

TABLE 3, contd

Test #2: Integrator Response

System 1

Current Level, mA	Response - Counts/Sec/Volt
0.5	10000.50
3.0	10000.08
5.5	10000.19
8.0	10000.27
10.5	10000.21
13.0	10000.17
15.5	10000.14
18.0	10000.10

System 2

Current Level, mA	Response - Counts/Sec/Volt
0.5	10005.09
3.0	10001.58
5.5	10001.33
8.0	10001.24
10.5	10000.98
13.0	10001.02
15.5	10001.28
18.0	10000.84

TABLE 3, contd

Theoretical Electrical Calibration -- Calculated from Test 1 and 2 Results Using Equation 3.

System 1	Current	C (Theoretical)	C(Measured)	RD %
	0.5	1.99932	1.99964	+0.06
	3.0	2.00009	2.00004	+0.003
	5.5	2.00001	2.00004	-0.002
	8.0	2.00003	2.00002	+0.001
	10.5	2.00001	2.00002	-0.001
	13.0	2.00005	2.00003	+0.001
	15.5	2.00006	2.00004	+0.001
	18.0	2.00005	2.00005	0.000
	20.0	-	2.00006	-
	30.0	-	2.00005	-

System 2	Current	C (Theoretical)	C(Measured)	RD %
	0.5	1.99738	1.99710	+0.014
	3.0	1.99713	1.99708	+0.003
	5.5	1.99710	1.99710	0.000
	8.0	1.99712	1.99718	-0.003
	10.5	1.99713	1.99720	-0.004
	13.0	1.99716	1.99722	-0.003
	15.5	1.99707	1.99723	-0.008
	18.0	1.99716	1.99725	-0.005
	20.0	-	1.99726	-
	30.0	-	1.99729	-

"-" No Data Point

TABLE 3, contd

Test #3: Integrator Non Linearity at High Current Levels

System 1

Current Level, mA	Calibration Coulombs/Million Counts	Precision of 10 Replicates (2-Sigma) %
10	2.00002	0.002
20	2.00006	0.001
30	2.00005	0.001

Non Linearity -0.0012%

System 2

10	1.99720	0.001
20	1.99726	0.001
30	1.99729	0.000

Non Linearity -0.0033%

Test #4: Integrator Non Linearity at Low Current Levels

System 1

Current Level	Coulombs/Million Counts	10 Replicates (2-Sigma) %
0.1	1.99779	0.028
0.5	1.99964	0.015
1.0	1.99980	0.004
3.0	2.00004	0.003
5.0	2.00004	0.002
10.0	2.00002	0.002

Non Linearity +0.0004

System 2

0.1	1.99695	0.047
0.5	1.99721	0.017
1.0	1.99717	0.009
3.0	1.99719	0.002
5.0	1.99721	0.001
10.0	1.99720	0.001

Non Linearity -0.0001

The Combined effect of non linearity upon electrical calibration:

System #1 -0.0008%
System #2 -0.0034%

Excellent system reliability was demonstrated using plutonium standard reference material SRM949f, traceable secondary standards, and Plutonium Metal Exchange Samples. The data are shown in Tables 4 through 6.

TABLE 4

Coulometric Measurements of Plutonium Standards using Nitric Acid Supporting Electrolyte and a Gold Working Electrode

Primary Standards	Preparation 1	Preparation 2	Preparation 3	Preparation 4
Recovery	99.96	99.98	100.02	100.02
% vs.	100.04	99.98	100.01	100.11
Reference			100.03	100.02
Values			100.00	100.08
			99.95	99.86
			99.99	-
Mean	100.00	99.98	100.00	100.02
Precision (2-Sigma)%	0.11	0.00	0.006	0.19

Secondary Standards Preparation	n	Precision (2-Sigma)%	Mean Recovery, %
A	5	0.09	100.05
B	5	0.16	99.98
C	3	0.19	99.95

TABLE 5

Coulometric Measurements of Plutonium Standards Using Sulfuric Acid Supporting Electrolyte and a Plutonium Working Electrode

Primary Standard	Preparation 3	Preparation 4
	99.98	100.17

Secondary Standards

Preparation	n	Precision (2-Sigma),%	Mean Recovery, %
D	15	0.16	100.06
E	12	0.18	100.05

TABLE 6

Plutonium Measurements - System #1. Rocky Flats Metal Exchange Program

Exchange	Measurement Period	Measurement Bias	Precision (2-Sigma)	Metal
0387	Mar 87 - May 87	0.0%, 0.0%	0.1%, 0.2%	A84, B84
1286	Dec 86 - Feb 87	0.0%, 0.0%	0.1%, 0.1%	A84, C84
0986	Oct 86 - Nov 86	0.0%, -0.1%	0.1%, 0.2%	B84, C84
1285	Jul 86 - Sep 86	0.1%, -0.1%	0.1%, 0.2%	B84, C84
0985	May 86 - Jun 86	0.0%, 0.0%	0.1%, 0.2%	A84, B84
0685	Jan 86 - Mar 86	0.0%, -0.1%	0.1%, 0.3%	A84, C84

The ease of operation and the self-monitoring features of the system have contributed to its success at SRP. In addition to improving reliability thru the improved repeatability of automated instruction and enhanced quality assurance in data reduction, the system permits focusing of the analysts training upon the critical aspects of sample preparation.

Future plans include:

- Interfacing a programmable quartz thermometer to the system to improve the measurement of the solution temperature and to allow automatic monitoring of the instrument's environment.
- Continuing refinement of the system and related preparation reliability and efficiency.
- Interfacing of the system to the laboratory data base management system.
- Continuing application of the system to critical measurement needs in the support of other development/evaluation programs.

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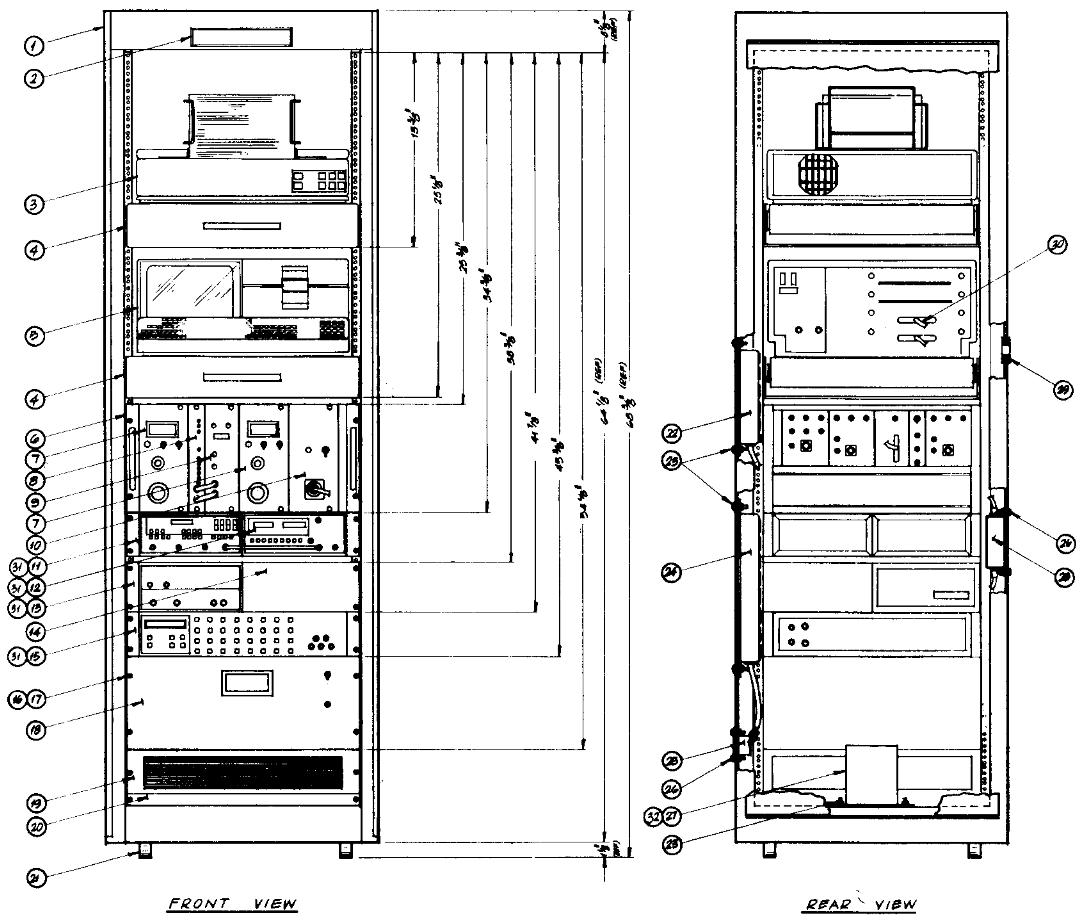
APPENDIX A

DRAWING LIST

1.	S5-2-15950	System No. 1 Assembly
2.	S5-2-15951	System No. 2 Assembly
3.	S5-2-15952	System No. 1 Schematic Assemblies and Details
4.	S5-2-15953	Interconnection Diagram System 1 & 2
5.	S5-2-15954	NIM Power Supply Arrangement Detail and Connector Function Table
6.	S5-2-15955	Potentiostat Module Assembly, Connection Diagram and Parts Lists
7.	S5-2-15956	Switching and Load and Control Amplifier Printed Circuit Boards, Schematic and Component Layout
8.	S5-2-15957	Potentiostat Module Details
9.	S5-2-15958	Integrator Module Assembly, Connection Diagram and Parts Lists
10.	S5-2-15959	Voltage-To-Frequency Printed Circuit Board, Schematic and Component Layout
11.	S5-2-15960	Integrator Module Details
12.	S5-2-15961	Counter/Timer Module, Assembly Connection Diagram and Parts List
13.	S5-2-15962	Display/Driver Printed Circuit Board, Schematic and Component Layout
14.	S5-2-15963	Counter/Multiplexer Board, Schematic and Component Layout
15.	S5-2-15964	Counter-Timer Details
16.	S5-2-15965	Automation Module, Assembly Connection Diagram and Parts List
17.	S5-2-15966	Automation Printed Circuit Board, Schematic and Component Layout
18.	S5-2-15967	Driver/Interface Printed Circuit Board, Schematic and Component Layout
19.	S5-2-15968	Automation Module Details
20.	S5-2-15969	Cable Details

Analyze this print for
SAFETY CONSIDERATIONS



REPRODUCED FROM
BEST AVAILABLE COPY

ITEM	PART DESIG	PART AND DRAWING NO	REQ'D PER ASS'Y	DESCRIPTION
32	F2	C O M L	1	FUSE, 3AG, SLO-BLO, 3 AMP, LITTLEFUSE, #313003W/FUSE HOLDER, BUSSMAN, #HHI
31	W19-W23	(S5-2-15953)	5	CABLES, HEWLETT-PACKARD, HPIB, (SEE INTERCONNECTION DIAGRAM)
30	W1-W18	(S5-2-15953)	18	CABLES, (SEE INTERCONNECTION DIAGRAM)
29		C O M L	AS REQ'D	GROMMET, STRIP, FOR 14-12 GA METAL, ELECTRO-VERT, #05-B-CP
28		S5-2-15952D	1	VOLTAGE DIVIDER NETWORK (SEE DETAIL)
27	PS1	(S5-2-15952A	1	POWER SUPPLY, ASSEMBLY (SEE DETAIL)
26		C O M L	6	#4-40UNC-2A × 1/2" LONG BINDER HEAD MACH SCREW W/HEX NUT
25	J1		1	PLUG, MALE, 2 POLE, 3 WIRE, STRAIGHT, U-GND, RECESSED, 15A, 125V, HUBBELL, #5278
24			1	POWER LINE CONDITIONER S.L. WEBER, #UL1300SSBN
23			8	#6-32UNC-2A × 1/2" LONG BINDER HEAD MACH SCR W/HEX NUT
22			1	POWER OUTLET STRIP S.L. WEBER, #602
21		C O M L	4	CASTER, TRIMLINE, #CA-7
20		S5-2-15952E	1	PANEL, BLANK, BUD RADIO, #PS-1250, (MODIFIED)
19		C O M L	1	COOLING FAN, MCLEAN ENGINEERING, #2EB3501A3T
18		S5-2-15952B	1	5VDC POWER SUPPLY CONTROL PANEL, (SEE DETAIL)
17		C O M L	12	SPEED NUTS, CHALLENGER, #80-0401-08
16			12	MAR-PROOF SCREWS, CHALLENGER, #80-0101-05
15			1	DVM HEWLETT-PACKARD #3456A
14			1	RACK MOUNT KIT HEWLETT-PACKARD, #HP5060-0173
13			1	DAC/SUPPLY HEWLETT-PACKARD, #59501B
12			1	COUNTER, HEWLETT-PACKARD, #5316A
11		C O M L	1	PULSE GENERATOR, HEWLETT-PACKARD, #8116A
10		S5-2-15965	1	AUTOMATION MODULE (SEE DETAIL)
9		S5-2-15961	1	COUNTER-TIMER MODULE (SEE DETAIL)
8		S5-2-15958	1	INTEGRATOR MODULE (SEE DETAIL)
7		S5-2-15955	2	POTENTIOSTAT MODULE, (SEE DETAIL)
6		C O M L	1	NIM BIN, TENNELOC, #TB5
5			1	COMPUTER, HEWLETT-PACKARD, #98266
4			2	SLIDING SHELVES, TRIMLINE, #TWS-319
3		C O M L	1	GRAPHICS PRINTER, HEWLETT-PACKARD, #2673A
2		S5-2-15952F	1	SYSTEM IDENTIFICATION PLATE (SEE DETAIL)
1		S5-2-15952C	1	CABINET, VERTICLE, TVA SERIES TRIMLINE, #TVA-6119-26 (MODIFIED)

FINISH √ ALL MACHINED SURFACES U.O.S.

BREAK ALL SHARP EDGES U.O.S.

THE NUMBER IN THIS FINISH SYMBOL √ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE IN A.A. MICRO-INCHES.

TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE
ONE PLACE DECIMAL ± 0.05
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005
FRACTIONAL ±
ANGULAR ±

REFERENCE DRAWINGS

S5-2-15951	ASSEMBLY, SYSTEM Nº2
S5-2-15952	CABINET, 5V POWER, & VOLTAGE DIVIDER
S5-2-15953	INTERCONNECTION DIAGRAM
S5-2-15954	NIM BIN WIRING DIAGRAM
S5-2-15955	POTENTIOSTAT MODULE
S5-2-15958	INTEGRATOR MODULE
S5-2-15961	COUNTER TIMER MODULE
S5-2-15965	AUTOMATION MODULE
S5-2-15969	CABLE DETAILS

REFERENCE STANDARDS

S5-2-15950

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772-F — PROBLEM NO. 2-3588 — E.O.P. CODE — PROJECT NO.

TITLE: COULOMETER SYSTEM
SYSTEM Nº1
ASSEMBLY

DESIGNED BY: J.V. CORDARO — DRAWN BY: L.E. FEUTRAL
ENGINEER: J.V. CORDARO — CHECKED BY: [illegible]

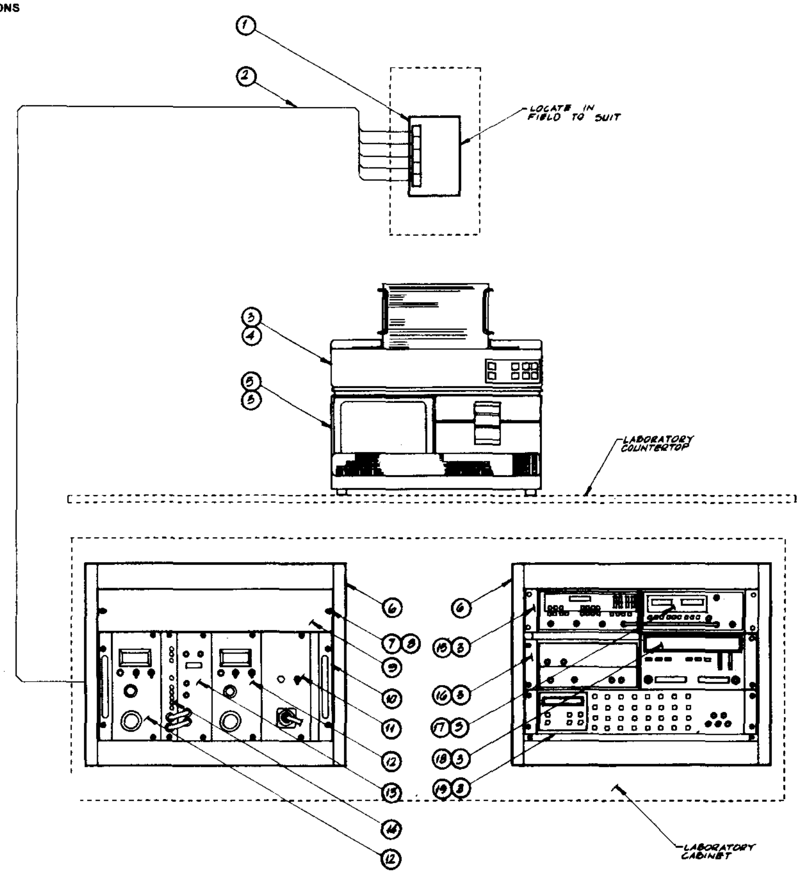
WORKS ENGRG APPROVALS
J.V. Cordaro
M.K. HOLLAND 6-10-
W.F. AYRES 6-10-
D.J. FAUTH 6-10-
W.R. JACOBSEN 6-11-
W.E. Cowell 6-30-

OTHER APPROVALS
K.E. SCHEFFTER 6-10-

DATE 7-1-87 — SCALE 3" = 1'-0" — FILE 20 MECH / 60 ELEC — S5-2-15950

Drawing 1

Analyze this print for
SAFETY CONSIDERATIONS



FRONT VIEW

Drawing 2

ITEM	PART DESIG	PART AND DRAWING NO	REQ'D PER ASS'Y	DESCRIPTION
19		COML	1	DVM HEWLETT-PACKARD, #3456A
18			1	QUARTZ THERMOMETER, HEWLETT-PACKARD, #2804A
17			1	COUNTER, HEWLETT-PACKARD, #5316A
16			1	DC/SUPPLY, HEWLETT-PACKARD, #59501B
15		COML	1	PULSE GENERATOR, HEWLETT-PACKARD, #8116A
14		S5-2-15958	1	INTEGRATOR MODULE (SEE DETAIL)
13		S5-2-15961	1	COUNTER-TIMER MODULE (SEE DETAIL)
12		S5-2-15955	1	POTENTIOSTAT MODULE (SEE DETAIL)
11		S5-2-15965	1	AUTOMATION MODULE (SEE DETAIL)
10		COML	1	NIM BIN TENNELOC, #TB5
9			1	PANEL, RACK, BLANK, 3 1/2" x 19", BUD RADIO, #PA-1102-LG
8			18	SPEED NUTS CHALLENGER, #80-0401-08
7			18	MAR-PROOF SCREWS CHALLENGER, #80-0101-08
6			2	RACK, EQUIPTO, #43-1220-05 EQUIPTO ELECTRONICS CORP
5			1	COMPUTER, HEWLETT-PACKARD, #98265
4			1	GRAPHICS, PRINTER, HEWLETT-PACKARD, #2673A
3	W10-W23	COML	5	CABLES, HEWLETT PACKARD, HPIB (SEE INTERCONNECTION, S5-2-15953)
2	W1-W18	(S5-2-15969)	18	CABLES (SEE INTERCONNECTION, S5-2-15953)
1	PS1	COML	1	POWER SUPPLY, SORENSEN, MODEL PTM5-11

FINISH √ ALL MACHINED SURFACES U.O.S.
BREAK ALL SHARP EDGES U.O.S.
THE NUMBER IN THE FINISH SYMBOL √ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE IN A.A. MICRO INCHES.

TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE
ONE PLACE DECIMAL ± 0.05
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005
FRACTIONAL ±
ANGULAR ±

REFERENCE DRAWINGS

S5-2-15950	ASSEMBLY, SYSTEM Nº1
S5-2-15953	INTERCONNECTION DIAGRAM
S5-2-15954	NIM BIN WIRING DIAGRAM
S5-2-15955	POTENTIOSTAT MODULE
S5-2-15958	INTEGRATOR MODULE
S5-2-15961	COUNTER-TIMER MODULE
S5-2-15965	AUTOMATION MODULE
S5-2-15969	CABLE DETAILS

REFERENCE STANDARDS

S5-2-15951

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772F — PROBLEM NO 2-5588 — E.D.P. CODE — PROJECT NO

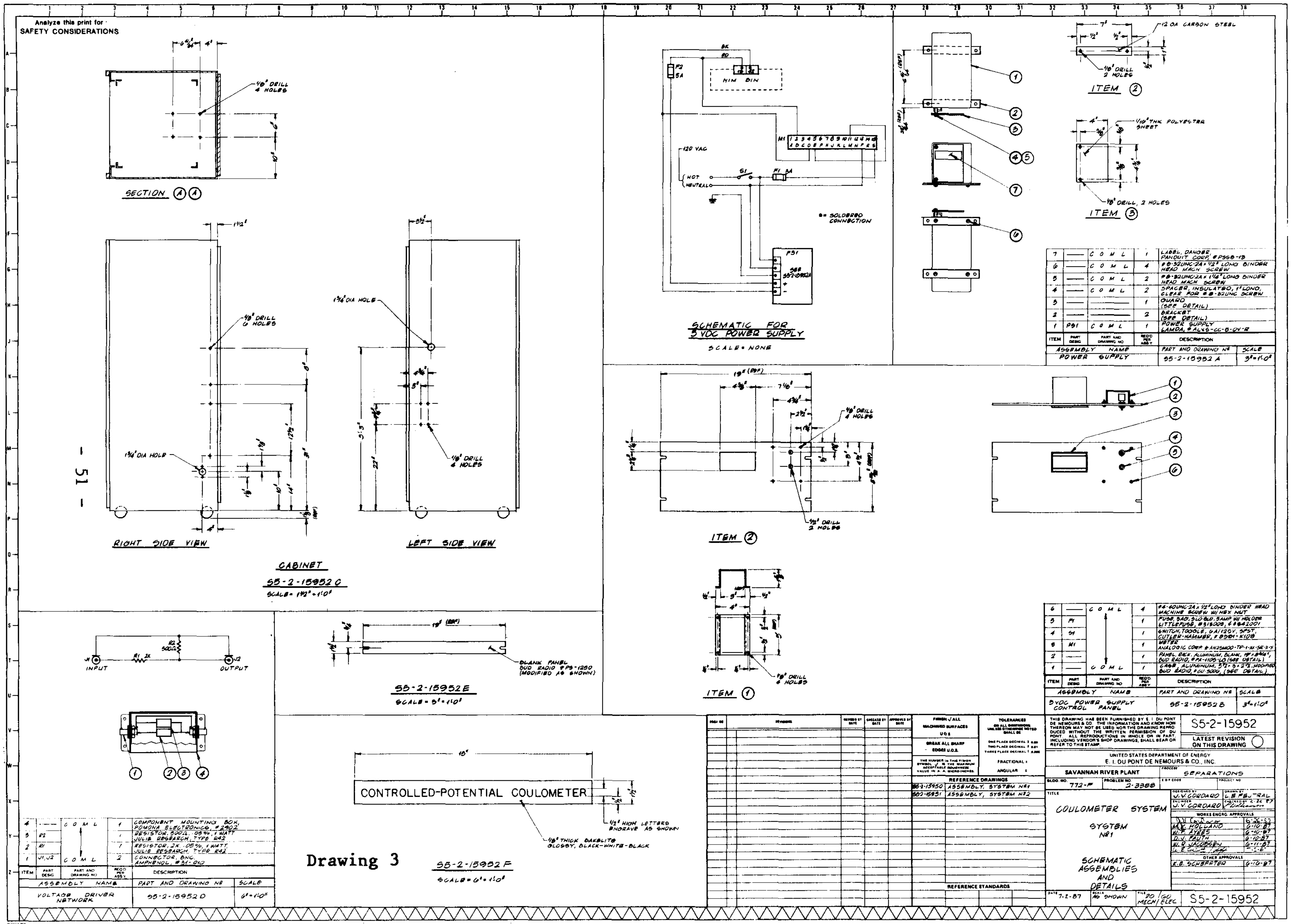
TITLE: COULOMETER SYSTEM
SYSTEM Nº 2
ASSEMBLY

DESIGNED BY J.V. CORDARO — DRAWN BY L E FE…
ENGINEER J.V. CORDARO — CHECKED BY

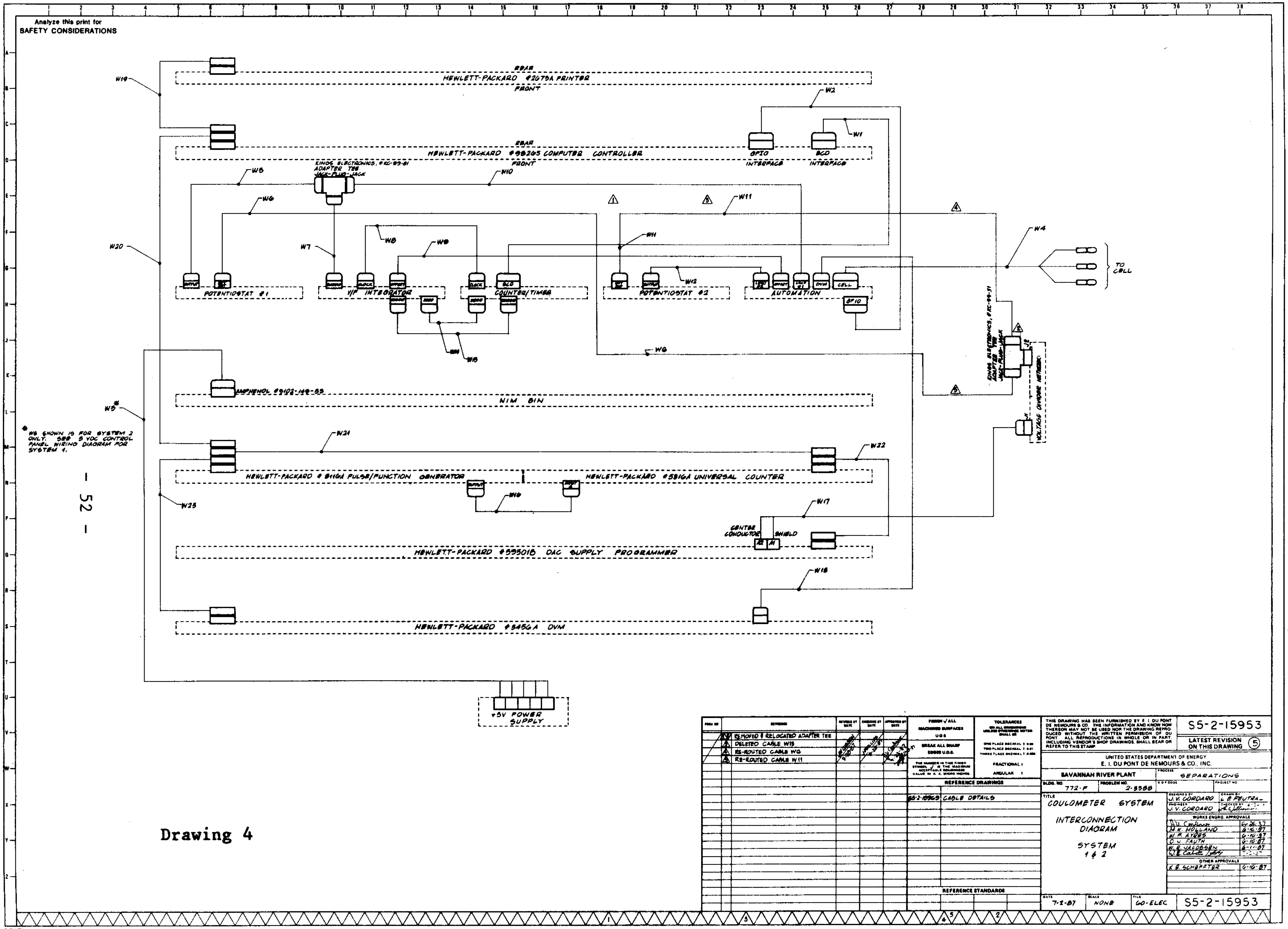
WORKS ENGRG. APPROVALS
M.K. HOLLAND
W. F. AYRES
O. J. FAUTH
W R JACOBSEN
W.S. Corbett

OTHER APPROVALS
J. E. SCHUBERT

DATE 7-2-87 — SCALE 3"=1'-0" — FILE 20 MECH / 60 ELEC — S5-2-1595

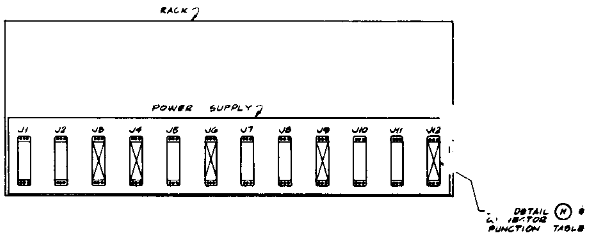

Analyze this print for
SAFETY CONSIDERATIONS
SECTION A-A
RIGHT SIDE VIEW
LEFT SIDE VIEW
CABINET
S5-2-15952 C
SCHEMATIC FOR
5 VDC POWER SUPPLY
SCALE = NONE
ITEM 1
ITEM 2
ITEM 3
POWER SUPPLY
S5-2-15952 A
5 VDC POWER SUPPLY CONTROL PANEL
S5-2-15952 B
VOLTAGE DRIVER NETWORK
S5-2-15952 D
S5-2-15952 E
CONTROLLED-POTENTIAL COULOMETER
S5-2-15952 F
UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.
SAVANNAH RIVER PLANT
SEPARATIONS
COULOMETER SYSTEM
SYSTEM N°1
SCHEMATIC ASSEMBLIES AND DETAILS
S5-2-15952

Drawing 3

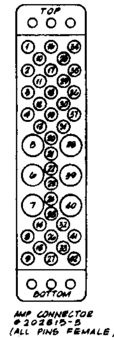

Analyze this print for
SAFETY CONSIDERATIONS
REAR
HEWLETT-PACKARD #2673A PRINTER
FRONT
REAR
HEWLETT-PACKARD #98265 COMPUTER CONTROLLER
FRONT
GPIO INTERFACE
BCD INTERFACE
KINGS ELECTRONICS, #KC-99-51 ADAPTER TEE JACK-PLUG-JACK
POTENTIOSTAT #1
V/F INTEGRATOR
COUNTER/TIMER
POTENTIOSTAT #2
AUTOMATION
DVM
CELL
GPIO
TO CELL
NIM BIN
AMPHENOL #9102-149-83
W8 SHOWN IS FOR SYSTEM 2 ONLY. SEE 5 VDC CONTROL PANEL WIRING DIAGRAM FOR SYSTEM 1.
HEWLETT-PACKARD # 8116A PULSE/FUNCTION GENERATOR
HEWLETT-PACKARD #5316A UNIVERSAL COUNTER
CENTER CONDUCTOR
SHIELD
HEWLETT-PACKARD #59501B DAC SUPPLY PROGRAMMER
HEWLETT-PACKARD #3456A DVM
+5V POWER SUPPLY
VOLTAGE DIVIDER NETWORK
W1 W2 W4 W5 W6 W7 W8 W9 W10 W11 W12 W14 W16 W17 W18 W19 W20 W21 W22 W23
REVISIONS
REMOVED & RELOCATED ADAPTER TEE
DELETED CABLE W15
RE-ROUTED CABLE W9
RE-ROUTED CABLE W11
REFERENCE DRAWINGS
S5-2-10969 CABLE DETAILS
REFERENCE STANDARDS
THIS DRAWING HAS BEEN FURNISHED BY E. I. DU PONT DE NEMOURS & CO. THE INFORMATION AND KNOW HOW THEREON MAY NOT BE USED NOR THE DRAWING REPRODUCED WITHOUT THE WRITTEN PERMISSION OF DU PONT. ALL REPRODUCTIONS IN WHOLE OR IN PART, INCLUDING VENDOR'S SHOP DRAWINGS, SHALL BEAR OR REFER TO THIS STAMP.
S5-2-15953
LATEST REVISION ON THIS DRAWING 5
UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.
SAVANNAH RIVER PLANT
PROCESS SEPARATIONS
BLDG. NO. 772-F
PROBLEM NO. 2-3588
TITLE
COULOMETER SYSTEM
INTERCONNECTION DIAGRAM
SYSTEM 1 & 2
DESIGNED BY J.V. CORDARO
DRAWN BY L E FEUTRAL
ENGINEER J.V. CORDARO
WORKS ENGRG. APPROVALS
M.K. HOLLAND 6-16-87
W.F. AYRES 6-10-87
D.V. FAUTH 6-10-87
W.E. JACOBSEN 6-11-87
OTHER APPROVALS
K.E. SCHEFFTER 6-16-87
DATE 7-2-87
SCALE NONE
FILE 60-ELEC
S5-2-15953

Drawing 4

Analyze this print for
SAFETY CONSIDERATIONS



ARRANGEMENT
(NIM BIN RACK & POWER SUPPLY)



DETAIL (H)

CONNECTOR FUNCTION TABLE
TENNELEC TB3 N.I.M. POWER SUPPLY

	POTENTIOSTAT #1 MODULE	INTEGRATOR MODULE	COUNTER/TIMER MODULE	POTENTIOSTAT #2 MODULE	AUTOMATION MODULE
PIN NUMBER	J3	J4	J6	J9	J12
1					
2					
3					**115 HOT (OUT)
4					
5					
6					
7					
8	HOLD #1				HOLD #1
9	OPERATE #1				OPERATE #1
10					
11			HOLD DISPLAY		HOLD DISPLAY
12			CLEAR DISPLAY		CLEAR DISPLAY
13	*5V (IN)			*5V (IN)	
14				HOLD #2	HOLD #2
15				OPERATE #2	OPERATE #2
16	12 V (IN) →	———	———	———	← 12 V (IN)
17	-12V (IN) →	———	———	———	← -12 V (IN)
18	5 V (IN)		5V (IN)	5 V (IN)	5V (IN)
19	5V (RETURN)		5V (RETURN)	5V (RETURN)	5V (RETURN-IN)
20					
21	COUNTER #1				COUNTER #1
22	REFERENCE #1				REFERENCE #1
23	WORKING #1				WORKING #1
24				COUNTER #2	COUNTER #2
25				REFERENCE #2	REFERENCE #2
26				WORKING #2	WORKING #2
27					
28	24V (IN) →	———	———	———	← 24V (IN)
29	-24V (IN) →	———	———	———	← -24V (IN)
30			SELECT A		SELECT A
31			SELECT B		SELECT B
32					
33	115 VAC (H) IN →	———	———	———	← 115 VAC (H) IN
34	COMMON			COMMON	
35		+15 V (IN)			+15 V (OUT)
36		15 V RETURN (IN)			15V RETURN (OUT)
37		-15V (IN)			-15V (OUT)
38					
39					
40					
41	115 VAC (N) IN →	———	———	———	← 115 VAC (N) IN
42	CHASSIS GND →	———	———	———	← CHASSIS GND

*NOTE: 5V (IN) IS NOT CONNECTED TO PIN #13 ON SYSTEM 1

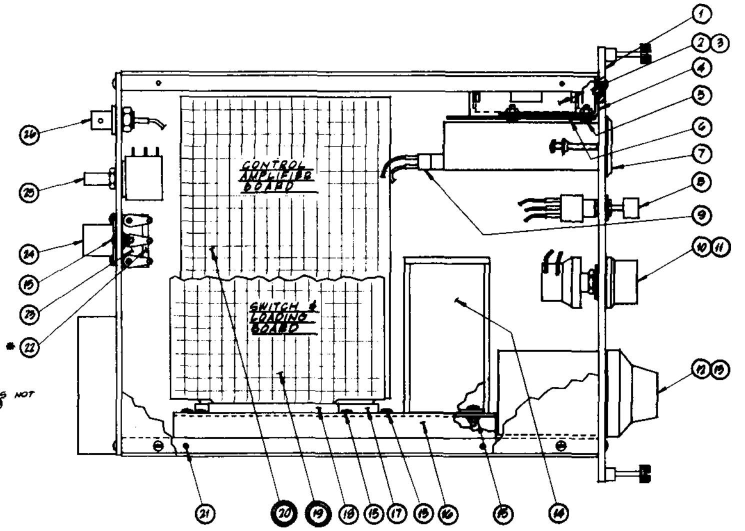
**NOTE: 115 HOT IS NOT CONNECTED TO PIN #3 ON SYSTEM 1

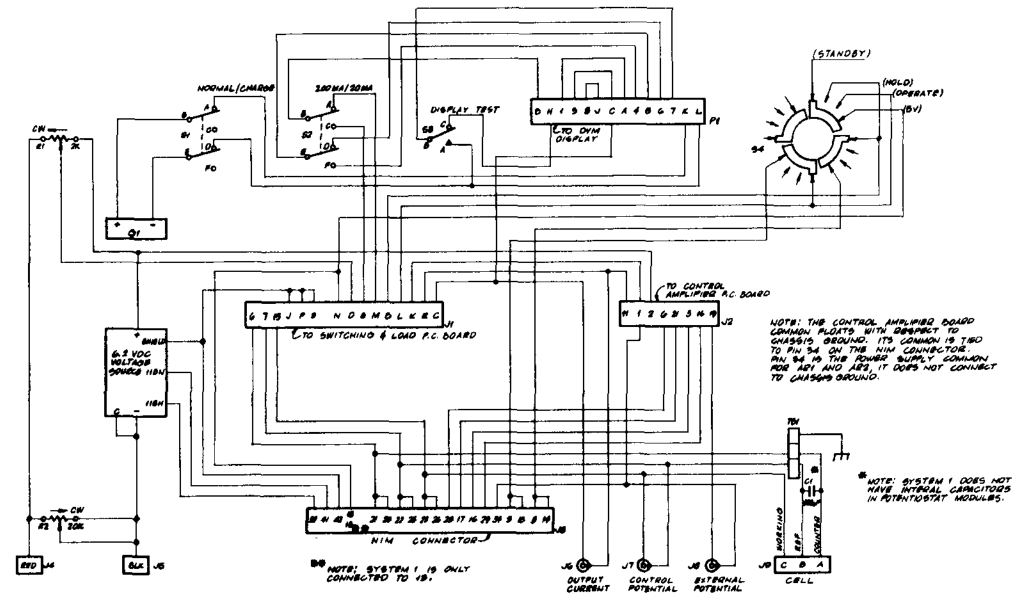
Drawing 5

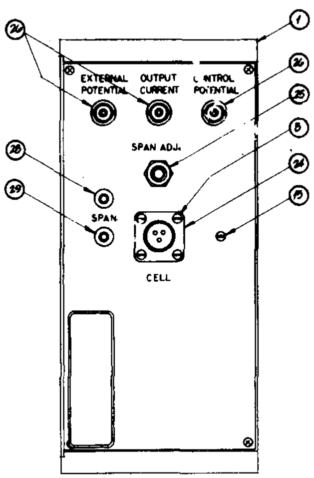
DRAWING NO.	S5-2-15954
LATEST REVISION ON THIS DRAWING	○
	UNITED STATES DEPARTMENT OF ENERGY E. I. DU PONT DE NEMOURS & CO., INC.
	SAVANNAH RIVER PLANT
PROCESS	SEPARATIONS
BLDG NO.	772-F
PROBLEM NO.	2-3386
TITLE	COULOMETER SYSTEM NIM POWER SUPPLY ARRANGEMENT, DETAIL AND CONNECTOR FUNCTION TABLE
DESIGNED BY	V.V. CORDARO
DRAWN BY	L E FEUTRA
ENGINEER	V.V. CORDARO
WORKS ENGRG APPROVALS	M K HOLLAND 6-16 W F AYRES 6-16 D J FAUTH 6-16 W R JACOBSEN
OTHER APPROVALS	K E SCHEFFTER 6-16-87
DATE	7-2-87
SCALE	NONE
FILE	GO ELEC

S5-2-15954

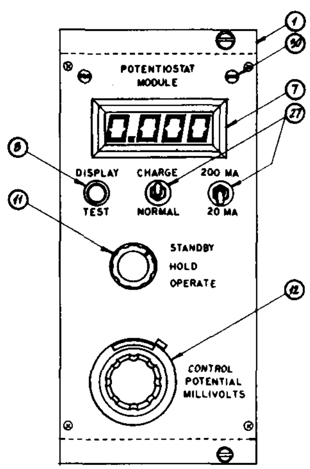
Analyze this print for SAFETY CONSIDERATIONS







REAR VIEW



FRONT VIEW

Drawing 6

(PARTS LIST CONTINUED BELOW)

ITEM	PART DESIG.	PART AND DRAWING NO.	REQ'D PER ASS'Y.	DESCRIPTION
18	J1	COML	1	CONNECTOR, EDGE BOARD, TEW/CINCH, #50-30A-30
17	J2	COML	1	CONNECTOR, EDGE-BOARD, TEW/CINCH, #50-22A-20
16		(S5-2-15957)	1	COMPONENT MOUNT PLATE, MODIFIED, (SEE DETAIL)
15		COML	8	#4-40UNC-2A x 1/2" LONG BINDER HEAD MACHINE SCREW W/HEX NUT & WASHER
14			1	VOLTAGE SOURCE, 6.2V, ELCOR # ARC 2-10
13			1	DIAL, FOR HELIPOT, SERIES A
12	R1		1	POTENTIOMETER, 2K, SERIES A, 10 TURN, WIRE WOUND, LINEARITY .25
11			1	KNOB, FOR 1/4" DIA SHAFT, RADIO SHACK, # 274-407
10	S4		1	SWITCH, ROTARY, 5 POSITION, GRAYHILL, # 4403001-4-MN
9	P1		1	CONNECTOR, EDGE BOARD, TEW/CINCH, # 50-20A-30M-1
8	S3		1	SWITCH, PUSHBUTTON ALCO, # MPA106F
7	DVM DISPLAY	COML	1	VOLTAGE, METER, 200 MV RANGE TEXMATE, # PM-45X
6		(S5-2-15957)	1	VECTOR BOARD, MODIFIED (SEE DETAIL)
5		COML	9	#4-40UNC-2A x 1/4" LONG BINDER HEAD MACHINE SCREW W/HEX NUT & WASHER
4		(S5-2-15957)	2	BRACKET, (SEE DETAIL)
3	G1	COML	4	BATTERY, 1.5V, ALKALINE, SIZE AA, DURACELL
2		COML	1	HOLDER, BATTERY, FOUR BATTERY CAPACITY, RADIO SHACK, # 270-397
1		(S5-2-15957)	1	NIM BIN, 4" WIDE, MODIFIED (SEE DETAIL)

ITEM	PART DESIG.	PART AND DRAWING NO.	REQ'D PER ASS'Y.	DESCRIPTION
30		COML	7	#4-40UNC-2A x 1/4" LONG FLAT HEAD MACHINE SCREW
29	J5		1	JACK, BANANA, CHASSIS OR PANEL, BLACK, MOLDED NYLON
28	J4		1	JACK, BANANA, CHASSIS OR PANEL, RED, MOLDED NYLON
27	S1, S2		2	SWITCH, TOGGLE, BAT LEVER, ALCO, # MTA206N
26	J6, J7, J8		3	CONNECTOR, BNC, INSULATED MOUNT AMPHENOL, # 31-010
25	R2		1	POTENTIOMETER, 20K, 10 TURN, SPECTROL, # 536-1-1-203
24	J9		1	CONNECTOR AMPHENOL, # 3102A-10SL-3P
23	TB1		1	TERMINAL STRIP, LUG TYPE, 5 LUGS; 1 GND. TEW/CINCH # 52A
22	C1		1	CAPACITOR, 100nF, POLYSTYRENE, MALLORY, # 5XK010
21		COML	4	#4-40UNC-2A x 1/4" LONG SET SCREW. FULL DOG POINT
20		(S5-2-15956)	1	CONTROL AMPLIFIER BOARD SUBASSEMBLY
19		(S5-2-15956)	1	SWITCH & LOADING BOARD SUBASSEMBLY

(PARTS LIST CONTINUED)

REFERENCE DRAWINGS	
S5-2-15956	SWITCH & LD., & CONT. AMP BOARD
S5-2-15957	ENGRAVING DETAILS

REFERENCE STANDARDS

FINISH √ ALL MACHINED SURFACES U.O.S.

BREAK ALL SHARP EDGES U.O.S.

THE NUMBER IN THIS FINISH SYMBOL √ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE IN A. A. MICRO-INCHES.

TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE: ONE PLACE DECIMAL ± .00 TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005 FRACTIONAL ± ANGULAR ±

S5-2-15955

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772-F — PROBLEM NO. 2-5588

TITLE: COULOMETER POTENTIOSTAT MODULE ASSEMBLY, CONNECTION DIAGRAM AND PARTS LIST

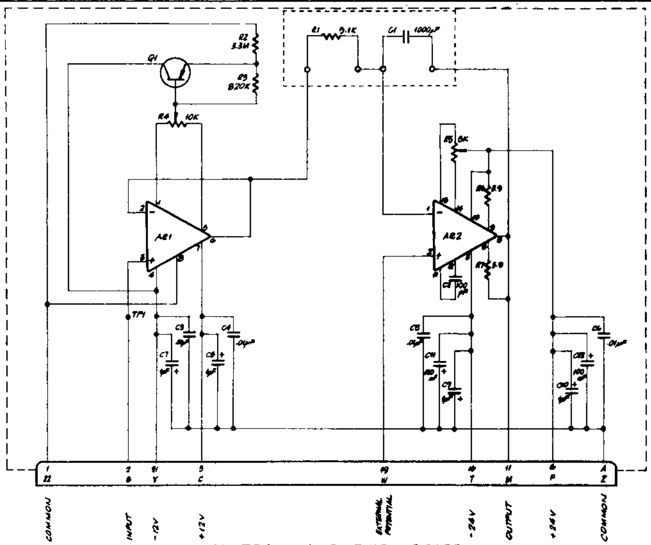
DESIGNED BY J.V. CORDARO — DRAWN BY L.E. FEUTRA
ENGINEER J.V. CORDARO — CHECKED BY J. Williams

WORKS ENGRG APPROVALS
D.V. Cordaro	6-26-87
M.K. HOLLAND	6-10-87
W.F. AYRES	6-10-87
D.W. FAUTH	6-10-87
W.R. JACOBSEN	6-11-87
W.E. Colina	7-1-87

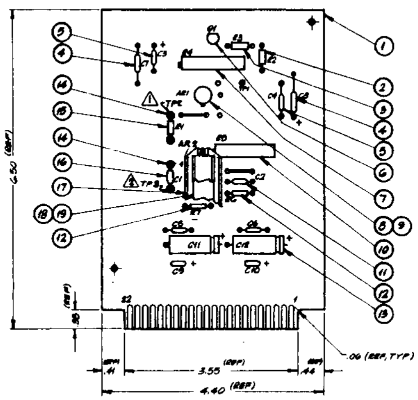
OTHER APPROVALS
K.E. SCHEFFTER	6-16-87

DATE 7-2-87 — SCALE NONE — FILE 20/60 MECH/ELEC — S5-2-15955

Analyze this print for SAFETY CONSIDERATIONS



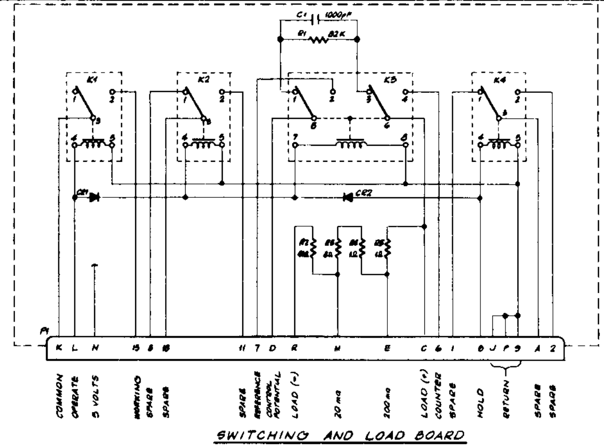
CONTROL AMPLIFIER BOARD
SCHEMATIC



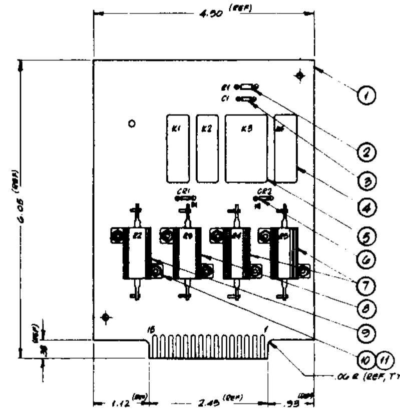
COMPONENT LAYOUT

ITEM	PART DESIG	PART AND DRAWING NO	REQ'D PER ASSY	DESCRIPTION
19	XAR2	COML	1	SOCKET, I.C., 14 PIN, TEXAS INSTRUMENTS, # C2714-09
18	AR2		1	AMPLIFIER, TELEDYNE PHILBRICK, # 1461
17	——		1	HEAT SINK, THERMALOY, # 6007A
16	C1		1	CAPACITOR, 1000 pF, MICA SANGAMO, # CM05FA102J03
15	R1		1	RESISTOR, 5.1 KΩ, 1/2 WATT, 1% TOL.
14	——		4	TERMINAL, TURRET, HOLLOW LUG, H.H. SMITH, STOCK # 2000A
13	C11 C12		2	CAPACITOR, 100 µF, ELECTROLYTIC, PANASONIC, # ECE-B1HV101S
12	R6 R7		2	RESISTOR, 3.9 Ω, 1/4 WATT, 5% TOL SANGAMO, # CM04ED390J03
11	C2		1	CAPACITOR, 100 pF, MICA, ±5% TOL
10	R5		1	RESISTOR, POTENTIOMETER, 5 KΩ, SPECTROL, # 70Y502
9	AR1		1	AMPLIFIER, BURR-BROWN, # 3521L
8	XAR1		1	SOCKET, I.C. ROUND, 8 PIN, AUGAT, # 8059-2G5
7	R4		1	RESISTOR, POTENTIOMETER, 10 KΩ, SPECTROL, # 70Y103
6	Q1		1	TRANSISTOR, 2N3906 MOTOROLA, EBCK, OR EQUIV.
5	C3, C4, C5, C6		4	CAPACITOR, .01 µF CERAMIC, SPRAGUE, # 1C10Z5U103M050B
4	C7, C8, C9, C10		4	CAPACITOR, 1 µF, ELECTROLYTIC, 50WV PANASONIC, # ECE-B1HV010S
3	R3		1	RESISTOR, 820 KΩ, 1/4 WATT, 5% TOL
2	R2		1	RESISTOR, 3.3 MΩ, 1/4 WATT, 5% TOL.
1	——	COML	1	BOARD, PRINTED CIRCUIT, POTENTIOSTAT, REF. BLONSW LAB MODEL # F1

Drawing 7



SWITCHING AND LOAD BOARD
SCHEMATIC



COMPONENT LAYOUT

ITEM	PART DESIG	REQ'D PER ASSY	DESCRIPTION
11	COML	8	BUSHING, STANDOFF, BRASS, I.D. CLEAR. FOR #4 MACHINE SCREW × 1/4" LONG
10	COML	8	#4-40 UNC-2A × 1/2" LG BINDER HEAD MACH SCREW W/ HEX NUT
9	R3	1	RESISTOR, 40 Ω, 25 WATTS, DALE, # RH-25
8	R5	1	RESISTOR, 8 Ω, 25 WATTS, DALE, # RH-25
7	R4, R5	2	RESISTOR, 1 Ω, 25 WATTS, DALE, # RH-25
6	CR1, CR2	2	DIODE, SWITCHING, SI, PIV 75V, 10mA, 1N4151, OR EQUIV.
5	K3	1	RELAY, 2 FORM C, 5 VOLTS, C.P. CLARE, # HGW 2MT54111000
4	K1, K2, K4	3	RELAY, FORM C, 5 VOLTS C.P. CLARE, # HGWM51111K00
3	C1	1	CAPACITOR, 1000 PF, MICA, SANGAMO, # CM05FA102J03
2	R1	1	RESISTOR, 82 KΩ, 1/4 WATT, 5% TOL
1	COML	1	BOARD, PRINTED CIRCUIT, POTENTIOSTAT, PRINTED WIRING SERVICES

REVISIONS	REVISED BY DATE	CHECKED BY DATE	APPROVED BY DATE
2 ADDED TP2, TP3			

FINISH √ ALL MACHINED SURFACES

REFERENCE DRAWINGS: S5-2-15955 POTENTIOMETER MODULE

REFERENCE STANDARDS

S5-2-15956

LATEST REVISION ON THIS DRAWING (2)

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG NO 772-F — PROBLEM NO. 2-3566

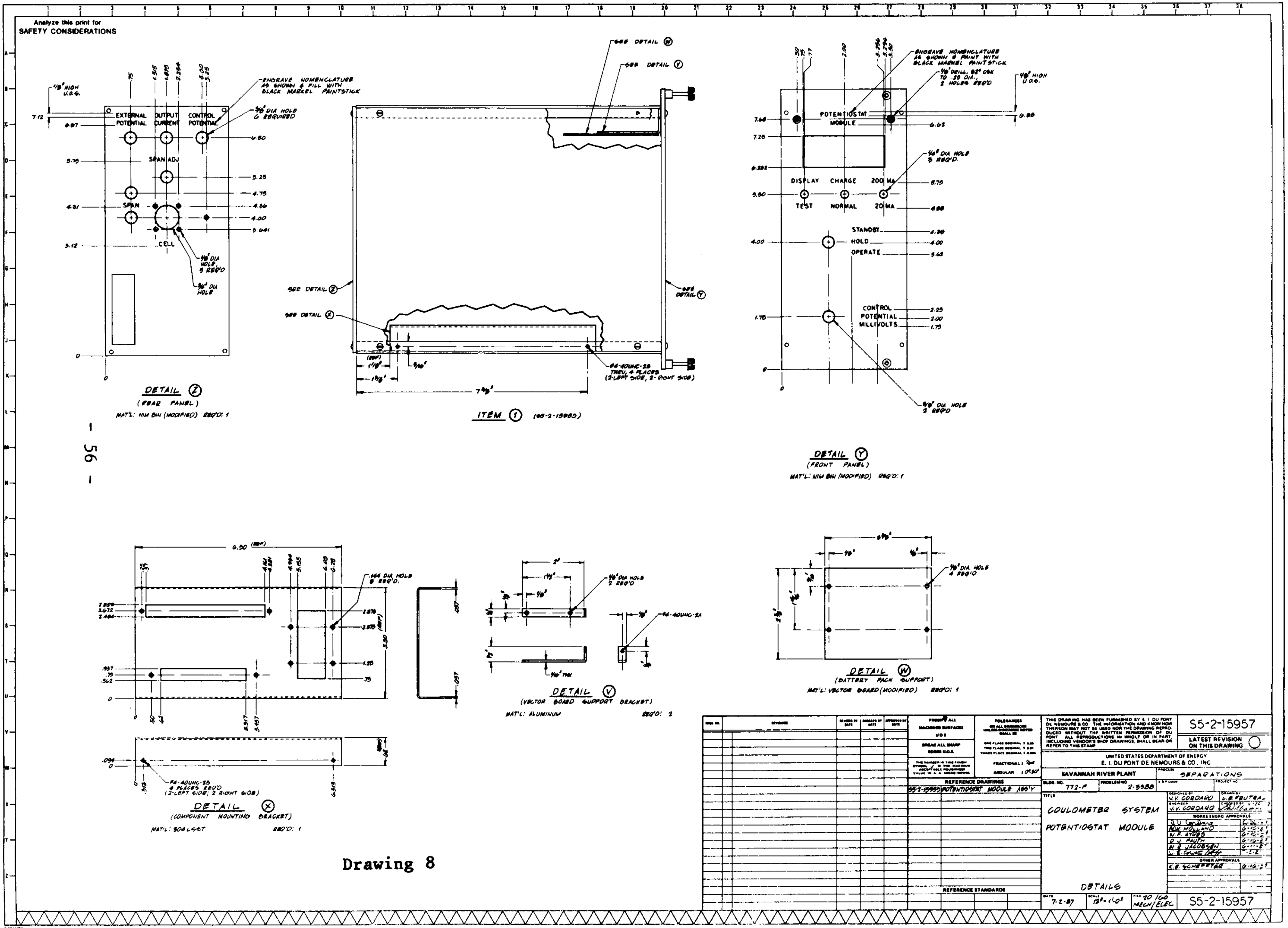
TITLE: COULOMETER SYSTEM
SWITCHING AND LOAD AND CONTROL AMPLIFIER PRINTED CIRCUIT BOARDS
SCHEMATIC AND COMPONENT LAYOUT

DESIGNED BY: J V CORDARO — DRAWN BY: L E FEUTHAL
ENGINEER: J V CORDARO

WORKS ENGRG APPROVALS: M K HOLLAND, W F AYRES, C J FAUTH, W R JACOBSEN
OTHER APPROVALS: K E SCHEFFTER

DATE 7-2-87 — SCALE NONE — FILE GO-ELEC

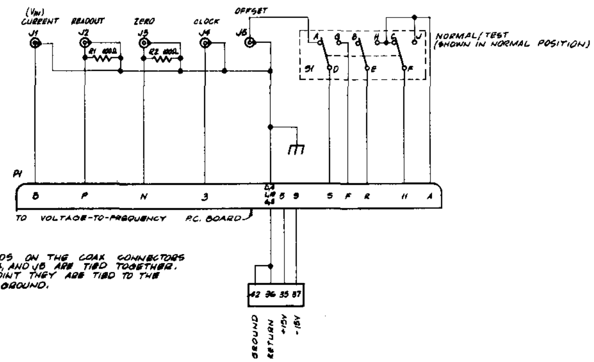
S5-2-15956



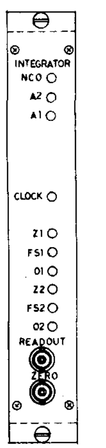
Analyze this print for
SAFETY CONSIDERATIONS
EXTERNAL POTENTIAL
OUTPUT CURRENT
CONTROL POTENTIAL
SPAN ADJ
SPAN
CELL
DETAIL Z
(REAR PANEL)
ITEM 1
POTENTIOSTAT MODULE
DISPLAY
CHARGE
200 MA
TEST
NORMAL
20 MA
STANDBY
HOLD
OPERATE
CONTROL
POTENTIAL
MILLIVOLTS
DETAIL Y
(FRONT PANEL)
DETAIL X
(COMPONENT MOUNTING BRACKET)
DETAIL V
(VECTOR BOARD SUPPORT BRACKET)
MAT'L: ALUMINUM
DETAIL W
(BATTERY PACK SUPPORT)
S5-2-15957
LATEST REVISION ON THIS DRAWING
UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC
SAVANNAH RIVER PLANT
SEPARATIONS
REFERENCE DRAWINGS
REFERENCE STANDARDS
COULOMETER SYSTEM
POTENTIOSTAT MODULE
DETAILS
S5-2-15957

Drawing 8

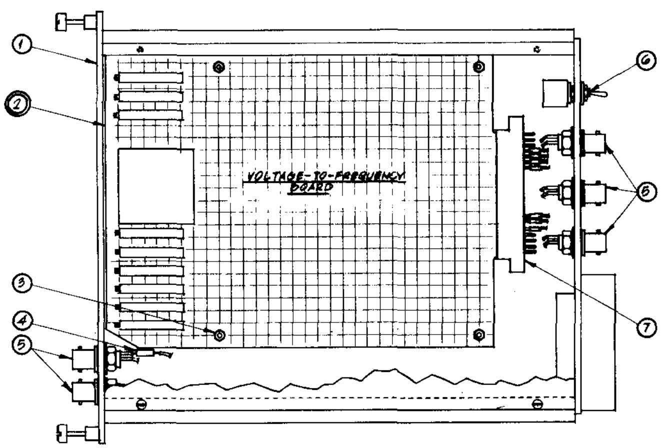
Analyze this print for
SAFETY CONSIDERATIONS

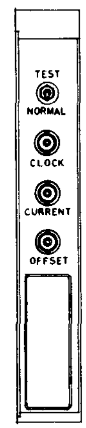


THE SHIELDS ON THE COAX CONNECTORS J1, J2, J3, J4, AND J5 ARE TIED TOGETHER. AT ONE POINT THEY ARE TIED TO THE CHASSIS GROUND.



FRONT VIEW





REAR VIEW

ITEM	PART DESIG	PART AND DRAWING NO	REQ'D PER ASS'Y	DESCRIPTION
7	P1	C O M L	1	CONNECTOR, EDGE BOARD, TRW/CINCH, #50-30A-30
6	S1		1	SWITCH, TOGGLE, BAT LEVER ALCO, # MTA-306D
5	J1 THRU J5		5	CONNECTOR, BNC, INSULATED MOUNT AMPHENOL, #31-010
4	R1, R2		2	RESISTOR, 100Ω, 1/4 WATT, 5% TOL
3		C O M L	4	#4-40UNC-2A x 3/4" LONG FLAT HEAD MACH SCR W/HEX NUT
2		(S5-2-15959)	1	VOLTAGE-TO-FREQENCY P.C. BOARD SUBASSEMBLY
1		(S5-2-15960)	1	NIM BIN, 1 3/8" WIDE, MODIFIED (SEE DETAIL)

Drawing 9

REFERENCE DRAWINGS

S5-2-15959	VOLTAGE-TO-FREQUENCY P.C. BOARD

REFERENCE STANDARDS

S5-2-15958

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772-F — PROBLEM NO. 2-3388

TITLE: COULOMETER SYSTEM INTEGRATOR MODULE ASSEMBLY CONNECTION DIAGRAM AND PARTS LIST

DESIGNED BY: J.V. CORDARO — DRAWN BY: [illegible]
ENGINEER: J.V. CORDARO

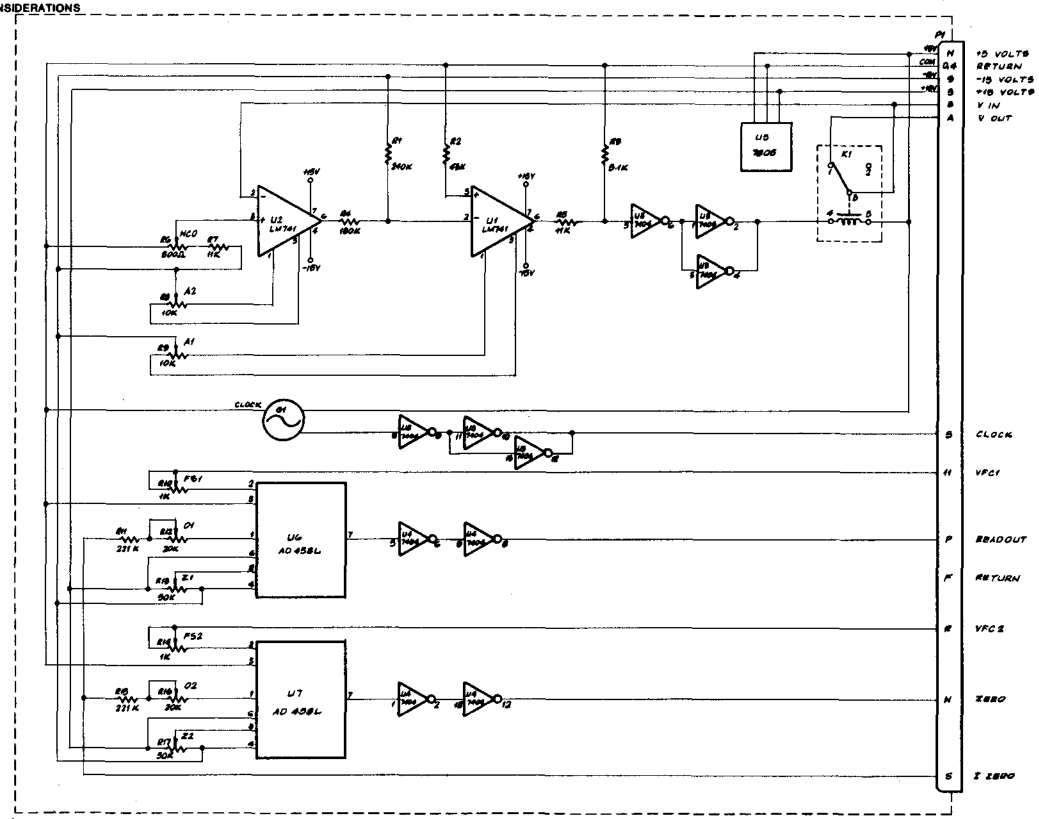
WORKS ENGRG. APPROVALS
[illegible]
M.K. HOLLAND
W.F. AYRES
D.J. FAJTH
W.E. JACOBSEN
[illegible]

OTHER APPROVALS
K.E. SCHEFFTER

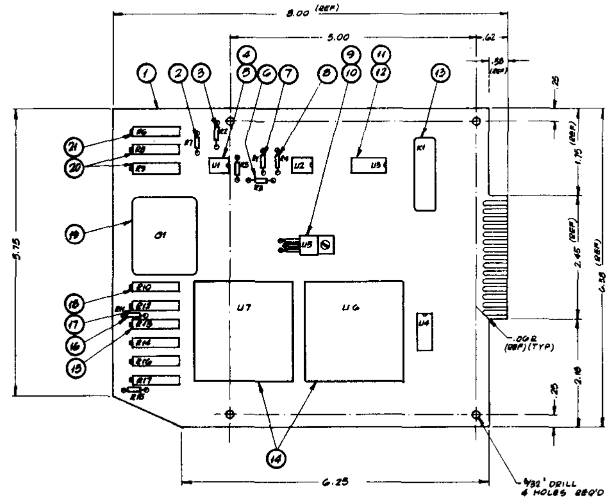
DATE 7-2-87 — SCALE NONE — FILE 20 160 MECH/ELEC

S5-2-15958

Analyze this print for
SAFETY CONSIDERATIONS



VOLTAGE - TO - FREQUENCY BOARD
SCHEMATIC



COMPONENT LAYOUT

ITEM	PART DESIG.	PART AND DRAWING NO.	REQ'D PER ASSY.	DESCRIPTION
21	R6	COML	1	POTENTIOMETER, 500Ω SPECTROL, #70Y501
20	R8, R9		2	POTENTIOMETER, 10KΩ, SPECTROL, #70Y103
19	G1		1	CRYSTAL OSCILLATOR, 10KHZ VECTRAN #CO233-T-3
18	R10, R14		2	POTENTIOMETER, 1K SPECTROL, #70Y102
17	R12, R16		2	POTENTIOMETER, 20K SPECTROL, #70Y203
16	R11, R15		2	RESISTOR, 221 KΩ, 1/4 WATT, 1% TOL
15	R13, R17		2	POTENTIOMETER, 50K SPECTROL, #70Y503
14	U6, U7		2	CONVERTOR, VOLTAGE-TO-FREQUENCY, ANALOG DEVICES #458L
13	K1		1	RELAY, FORM C, 5 VOLTS, C.P. CLARE, #HGWS1111K00
12	XU3, XU4		2	SOCKET, INTEGRATED CIRCUIT, 16 PIN DIP, TEXAS INSTRUMENTS, #C7216-09
11	U3, U4		2	INTEGRATED CIRCUIT, QUAD INVERTOR, #SN7404N
10			1	#4-40UNC-2A x .50 LG BINDER HEAD MACH SCR WITH HEX NUT
9	U5		1	VOLTAGE REGULATOR, NATIONAL SEMICONDUCTOR, #UA7805 CKC
8	R4		1	RESISTOR, 180KΩ, 1/4 WATT, 5% TOL
7	R1		1	RESISTOR, 240KΩ, 1/4 WATT, 5% TOL
6	R3		1	RESISTOR, 5.1KΩ, 1/4 WATT, 5% TOL
5	XU1, XU2		2	SOCKET, INTEGRATED CIRCUIT, 8 PIN DIP TEXAS INSTRUMENTS, #C7208-09
4	U1, U2		2	INTEGRATED CIRCUIT, OPERATIONAL AMPLIFIER, #741,
3	R2		1	RESISTOR, 49KΩ, 1/4 WATT, 5% TOL
2	R5, R7		2	RESISTOR, 11KΩ, 1/4 WATT, 5% TOL
1		COML	1	BOARD, PRINTED CIRCUIT, PRINTED WIRING SERVICE

FINISH √ ALL MACHINED SURFACES U.O.S.

BREAK ALL SHARP EDGES U.O.S.

THE NUMBER IN THE FINISH SYMBOL √ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE IN A.A. MICRO-INCHES.

TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE
ONE PLACE DECIMAL ± 0.03
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005
FRACTIONAL ±
ANGULAR ±

REFERENCE DRAWINGS

S5-2-15958 INTEGRATOR MODULE

REFERENCE STANDARDS

S5-2-15959

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772-F — PROBLEM NO. 2-3388

TITLE: COULOMETER SYSTEM
VOLTAGE - TO - FREQUENCY PRINTED CIRCUIT BOARD
SCHEMATIC AND COMPONENT LAYOUT

DESIGNED BY J. V. CORDARO — DRAWN BY L. E. FEUTRA
ENGINEER J. V. CORDARO — CHECKED BY

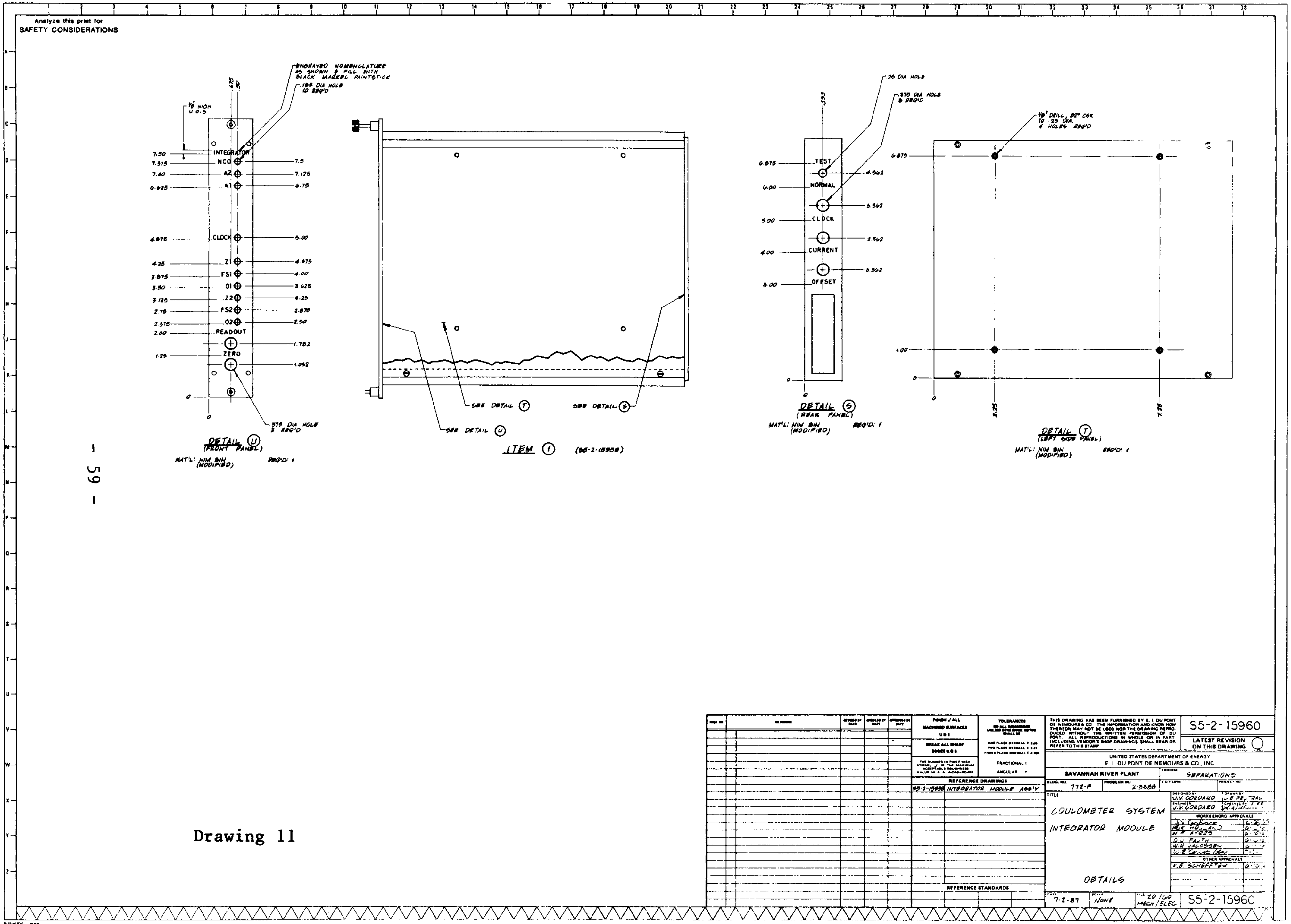
WORKS ENGRG. APPROVALS
M.K. HOLLAND 6-10-87
W.F. AYRES 6-10-87
D.J. FAUTH 6-10-87
W.R. JACOBSEN 6-11-87

OTHER APPROVALS
K.B. SCHEFFTER 6-12-87

DATE 7-2-87 — SCALE NONE — FILE 60-ELEC

S5-2-15959

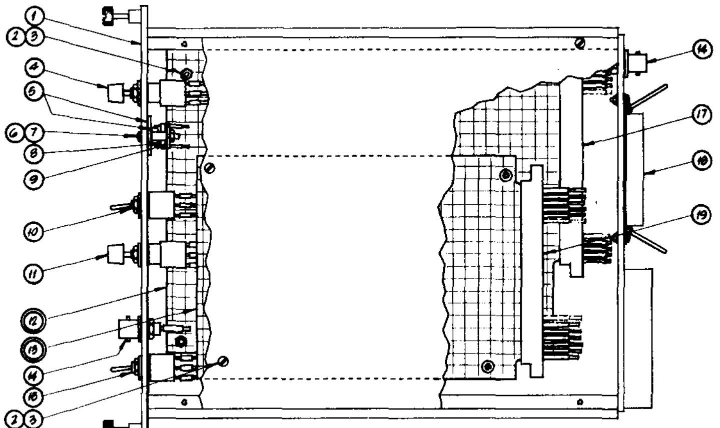
Drawing 10

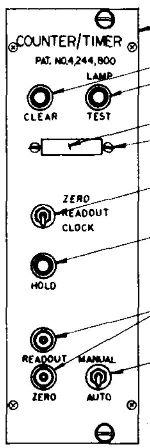


Analyze this print for
SAFETY CONSIDERATIONS
ENGRAVED NOMENCLATURE AS SHOWN & FILL WITH BLACK MARKEL PAINTSTICK
INTEGRATOR
NCO
A2
A1
CLOCK
Z1
FS1
01
Z2
FS2
02
READOUT
ZERO
DETAIL (U)
(FRONT PANEL)
SEE DETAIL (T)
SEE DETAIL (S)
SEE DETAIL (U)
ITEM (1)
TEST
NORMAL
CLOCK
CURRENT
OFFSET
DETAIL (S)
(REAR PANEL)
DETAIL (T)
(LEFT SIDE PANEL)
REFERENCE DRAWINGS
INTEGRATOR MODULE ASS'Y
REFERENCE STANDARDS
THIS DRAWING HAS BEEN FURNISHED BY E. I. DU PONT DE NEMOURS & CO. THE INFORMATION AND KNOW HOW THEREON MAY NOT BE USED NOR THE DRAWING REPRODUCED WITHOUT THE WRITTEN PERMISSION OF DU PONT. ALL REPRODUCTIONS IN WHOLE OR IN PART, INCLUDING VENDOR'S SHOP DRAWINGS, SHALL BEAR OR REFER TO THIS STAMP.
S5-2-15960
LATEST REVISION ON THIS DRAWING
UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.
SAVANNAH RIVER PLANT
PROCESS SEPARATIONS
BLDG. NO. 772-F
PROBLEM NO 2-3388
TITLE
COULOMETER SYSTEM
INTEGRATOR MODULE
DETAILS
DESIGNED BY J.V. CORDARO
ENGINEER J.V. CORDARO
WORKS ENGRG APPROVALS
OTHER APPROVALS
DATE 7-2-87
SCALE NONE
FILE 20/60 MECH/ELEC
S5-2-15960

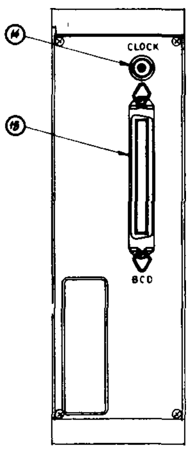
Drawing 11

Analyze this print for
SAFETY CONSIDERATIONS

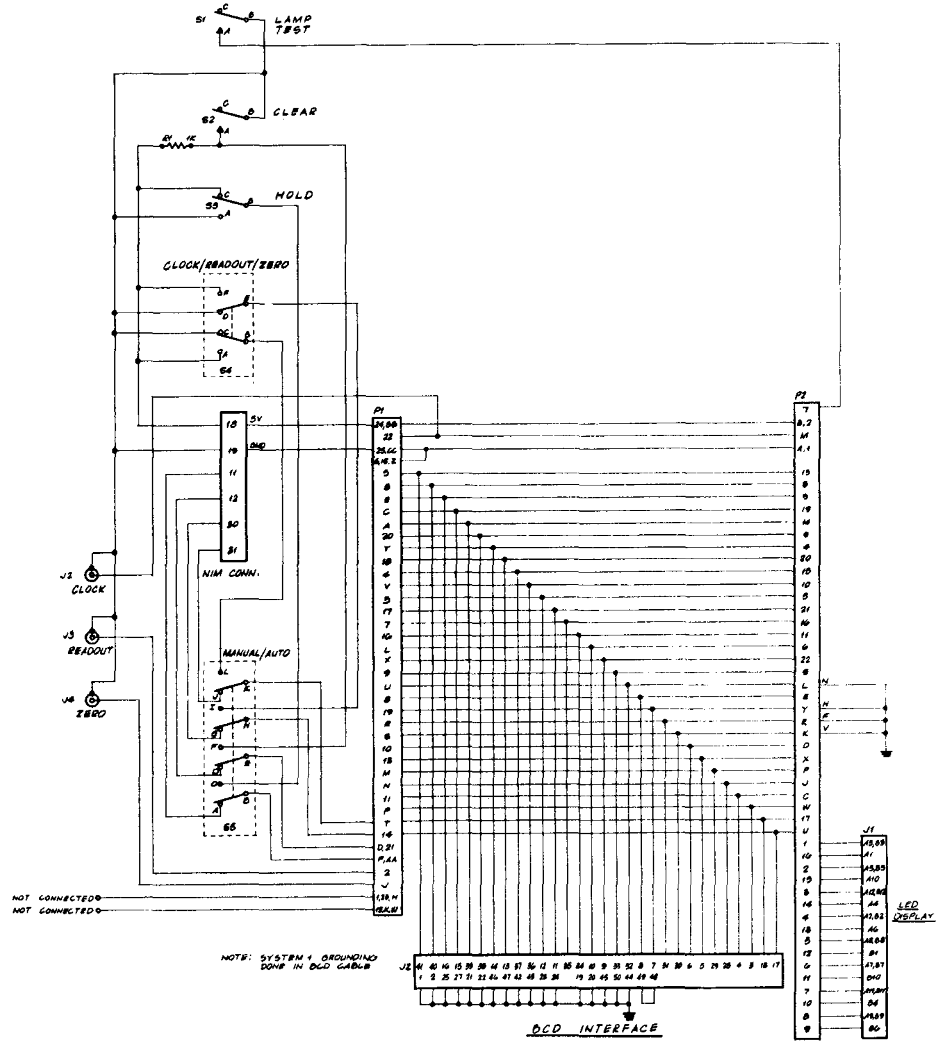




FRONT VIEW



REAR VIEW



BCD INTERFACE

ITEM	PART DESIG.	PART ENG DRAWING NO	REQD PER ASSY	DESCRIPTION
19	P1	C O M L	1	CONNECTOR, EDGE BOARD, TRW/CINCH, #50-44A-30
18	J2		1	CONNECTOR, MICRO-RIBBON, AMPHENOL, #57-40500
17	P2		1	CONNECTOR, EDGE BOARD, TRW/CINCH, #50-50A-30
16	S2		1	SWITCH, PUSHBUTTON, ALCO, #MPA-106F, W/WHITE BUTTON, #C-22
15	S5		1	SWITCH, TOGGLE, BATT LEVER, ALCO, #MGT405N
14	J1, J3, J4	C O M L	3	CONNECTOR, BNC, INSULATED MOUNT AMPHENOL, #31-010
13	——	(S5-2-15963)	1	COUNTER/MULTIPLEXER P.C. BOARD SUBASSEMBLY
12	——	(S5-2-15962)	1	DISPLAY/DRIVER, P.C. BOARD SUBASSEMBLY
11	S3	C O M L	1	SWITCH, PUSHBUTTON, ALCO, #MPA-106D, W/RED BUTTON, #C-22
10	S4	C O M L	1	SWITCH, TOGGLE, BATT LEVER, ALCO, #MTA-206TA
9	——	(S5-2-15964)	1	VECTOR BOARD, MODIFIED, (SEE DETAIL)
8	——	C O M L	1	SOCKET, IC, DUAL-IN-LINE, SOLDER TAIL, 14 PIN, AUGAT, #514-A0100 (MODIFIED TO 12 PIN)
7	——		2	SPACER, 1/4" O.D. x 3/8" LONG, ALUMINUM, CLEARANCE FOR #4 SCR, H.H.SMITH, #8482
6	——		2	#4-40UNC-2A x 1/4" LONG BINDER HEAD MACH SCR W/HEX NUT
5	DS1		1	LED DISPLAY, 4 DIGIT, W/COVER HEWLETT-PACKARD, #HP-5082-7414
4	S1		1	SWITCH, PUSHBUTTON, ALCO, #MPA-106F, W/YELLOW BUTTON, #C-22
3	——		8	SPACER, 1/4" O.D. x 1/4" LONG CLEARANCE FOR #4 SCREW, H.H.SMITH, #2340
2	——	C O M L	8	#4-40UNC-2A x 1/2" LONG FLAT HEAD MACH SCR W/HEX NUT
1	——	(S5-2-15964)	1	NIM BIN, 2 3/4" WIDE, MODIFIED, TENNELEC, # NIM-32W, (SEE DETAIL)

Drawing 12

REFERENCE DRAWINGS	
S5-2-15962	DISPLAY/DRIVER P.C. BOARD
S5-2-15963	COUNTER/MULTIPLEXER P.C. BOARD

REFERENCE STANDARDS

FINISH √ ALL MACHINED SURFACES U.O.S.
BREAK ALL SHARP EDGES U.O.S.
THE NUMBER IN THE FINISH SYMBOL √ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE IN A. A. MICRO-INCHES

TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE
ONE PLACE DECIMAL ± 0.05
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005
FRACTIONAL ±
ANGULAR ±

S5-2-15961

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772-F — PROBLEM NO. 2-5388

TITLE: COULOMETER SYSTEM
COUNTER/TIMER MODULE
ASSEMBLY, CONNECTION DIAGRAM AND PARTS LIST

DESIGNED BY: J.V. CORDARO — DRAWN BY: L.E. FEJTEAL
ENGINEER: J.V. CORDARO

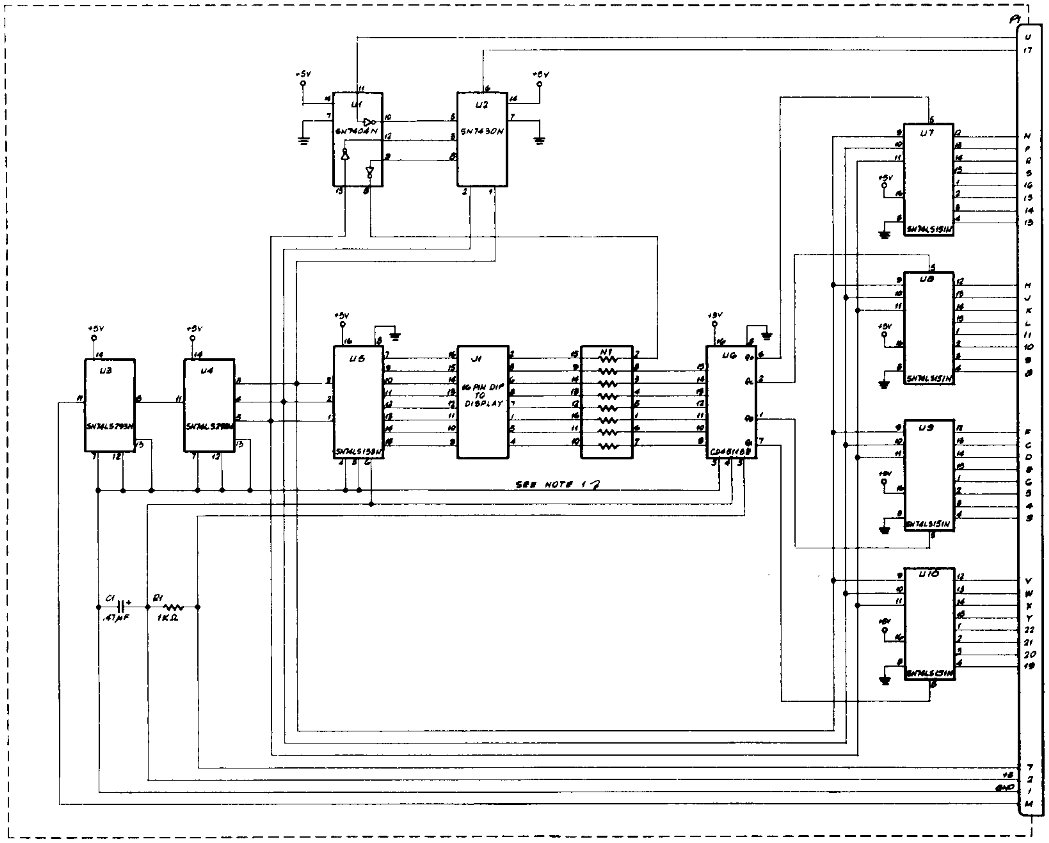
WORKS ENGRG APPROVALS
D.V. Cordaro
M.K. HOLLAND
W.F. AYRES
D.J. FAUTH 6-10-87
W.R. JACOBSEN 6-11-87

OTHER APPROVALS
K.E. SCHEFFTER 6-16-87

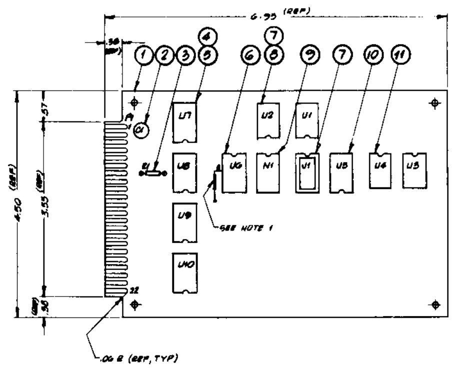
DATE 7-2-87 — SCALE NONE — FILE 20100 MECH/ELEC

S5-2-15961

Analyze this print for
SAFETY CONSIDERATIONS



DISPLAY/DRIVER BOARD SCHEMATIC



COMPONENT LAYOUT

NOTE:
1. JUMPER 16 TO BE ADDED TO THE PRINTED CIRCUIT BOARD FROM PIN 5 ON U6 TO GROUND.

ITEM	PART DESIG	PART AND DRAWING NO	REQ'D PER ASS'Y	DESCRIPTION
12	U2	COML	1	INTEGRATED CIRCUIT, #SN7430N
11	U3, U4		2	INTEGRATED CIRCUIT, DATA SELECTOR/MULTIPLEXER, #SN74LS298N
10	U5		1	INTEGRATED CIRCUIT, DECODER/DEMULTIPLEXER, #SN74LS138N
9	N1		1	RESISTOR NETWORK, 100Ω, ALLEN-BRADLEY, MODEL 316B
8	XU1 THRU XU4		4	SOCKET, INTEGRATED CIRCUIT, 14 PINS, TEXAS INSTRUMENTS, C7-214-09
7	U1		1	INTEGRATED CIRCUIT, QUAD INVERTER, #SN7404N
6	U6		1	INTEGRATED CIRCUIT, BCD TO 7 SEGMENT DECODER/DRIVER, #CD4511BE
5	XU5 THRU XU10, J1		7	SOCKET, INTEGRATED CIRCUIT, 16 PINS, TEXAS INSTRUMENTS, C7-216-09
4	U7 THRU U10		4	INTEGRATED CIRCUIT, DATA SELECTOR/MULTIPLEXER, #SN74LS151N
3	R1		1	RESISTOR, 1KΩ, 1/4 WATT, 5% TOL
2	C1		1	CAPACITOR, 47µF, ELECTROLYTIC 50WV
1		COML	1	BOARD, PRINTED CIRCUIT, MULTIPLEXER, DECODER/DRIVER, PRINTED WIRING SERVICES

- 61 -

Drawing 13

FINISH √ ALL MACHINED SURFACES UOS
BREAK ALL SHARP EDGES U.O.S.
THE NUMBER IN THIS FINISH SYMBOL √ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE IN A A MICRO-INCHES

TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE
ONE PLACE DECIMAL ± 0.05
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005
FRACTIONAL ±
ANGULAR ±

REFERENCE DRAWINGS

S5-2-15961	COUNTER/TIMER MODULE

REFERENCE STANDARDS

S5-2-15962

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT

PROCESS: SEPARATIONS

BLDG NO.: 772-F | PROBLEM NO.: 2-3368 | EDP CODE | PROJECT NO

TITLE: COULOMETER SYSTEM DISPLAY/DRIVER PRINTED CIRCUIT BOARD SCHEMATIC AND COMPONENT LAYOUT

DESIGNED BY: U.V. CORDARO
DRAWN BY: L.E. FEUTRA
ENGINEER: U.V. CORDARO
CHECKED BY: [illegible]

WORKS ENGRG APPROVALS

[illegible signature]	6-26-87
M.K. HOLLAND	6-10-87
W.F. AYRES	6-10-87
D.J. FAUTH	6-10-87
W.R. JACOBSEN	6-11-87
[illegible]	[illegible]

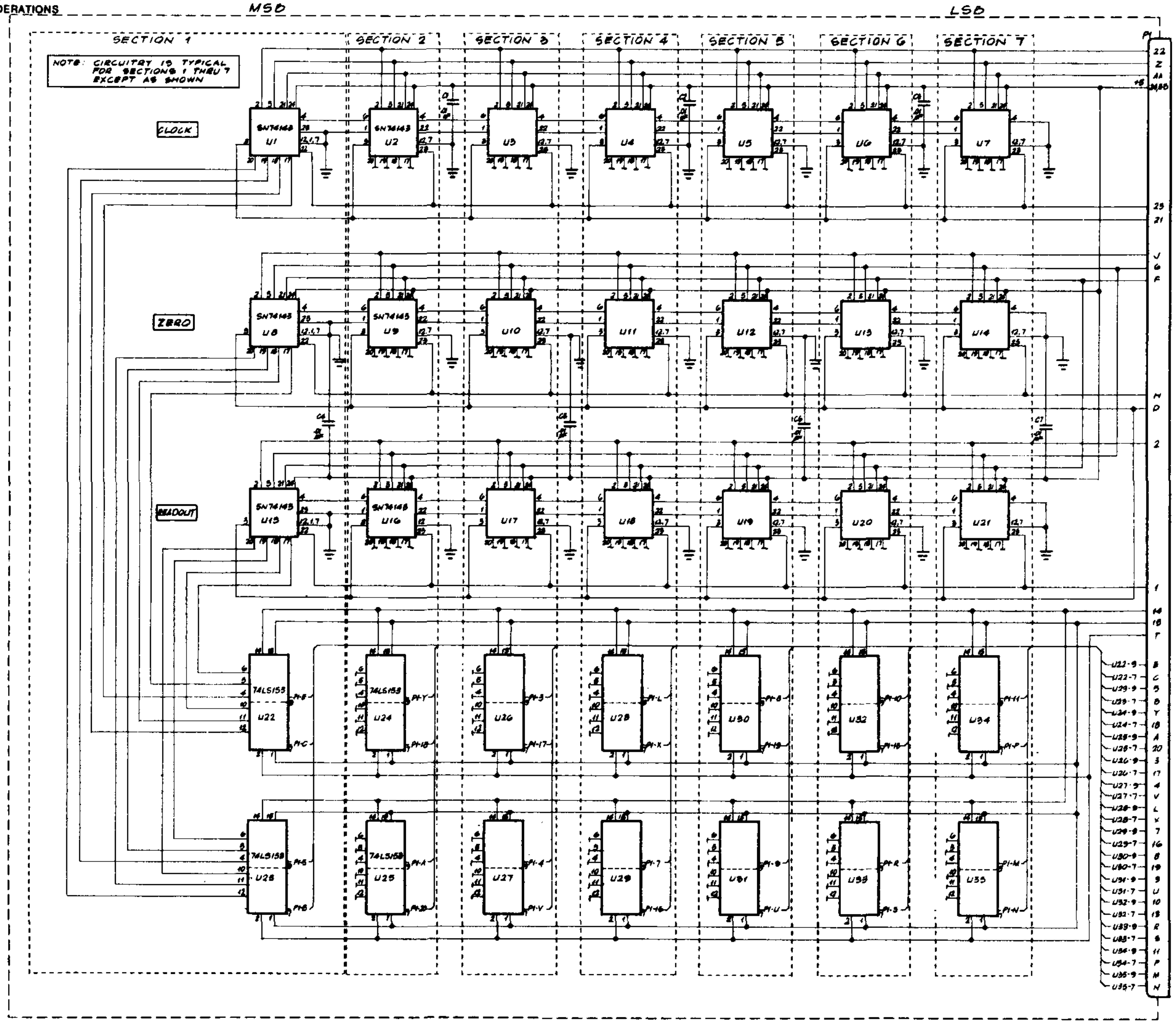
OTHER APPROVALS

K.E. SCHEFFTER	6-16-87

DATE: 7-2-87 | SCALE: NONE | FILE: 20-MECH 60-ELEC

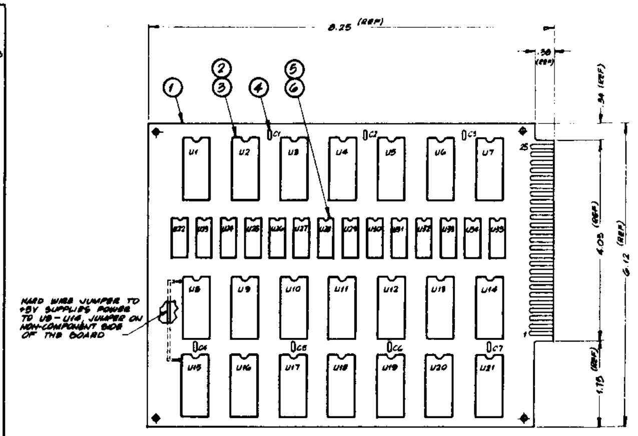
S5-2-15962

Analyze this print for SAFETY CONSIDERATIONS



COUNTER/MULTIPLEXER BOARD

SCHEMATIC



COMPONENT LAYOUT

ITEM	PART DESIG	PART AND DRAWING NO	REQ'D PER ASS'Y	DESCRIPTION
6	U22 THRU U35	COML	14	INTEGRATED CIRCUIT, DUAL 4 TO 1 LINE SELECTOR, #SN74LS153N
5			14	SOCKETS, I.C., 16 PINS, NEWARK STOCK #76F1044
4	C1 THRU C7		7	CAPACITOR, .01µF, CERAMIC, NEWARK STOCK #81F2060
3	U1 THRU U21		21	INTEGRATED CIRCUIT, 4 BIT COUNTER/LATCH 7 SEG-DRIVER, #SN74143
2			21	SOCKETS, I.C., 24 PINS, NEWARK STOCK #76F1048
1		COML	1	BOARD, PRINTED CIRCUIT, PRINTED WIRING SERVICE

Drawing 14

REFERENCE DRAWINGS	S5-2-15961 COUNTER-TIMER MODULE

THIS DRAWING HAS BEEN FURNISHED BY E. I. DU PONT DE NEMOURS & CO. THE INFORMATION AND KNOW HOW THEREON MAY NOT BE USED NOR THE DRAWING REPRODUCED WITHOUT THE WRITTEN PERMISSION OF DU PONT. ALL REPRODUCTIONS IN WHOLE OR IN PART, INCLUDING VENDOR'S SHOP DRAWINGS, SHALL BEAR OR REFER TO THIS STAMP

S5-2-15963

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772-F — PROBLEM NO. 2-3388

TITLE: COULOMETER SYSTEM
COUNTER/MULTIPLEXER BOARD
SCHEMATIC AND COMPONENT LAYOUT

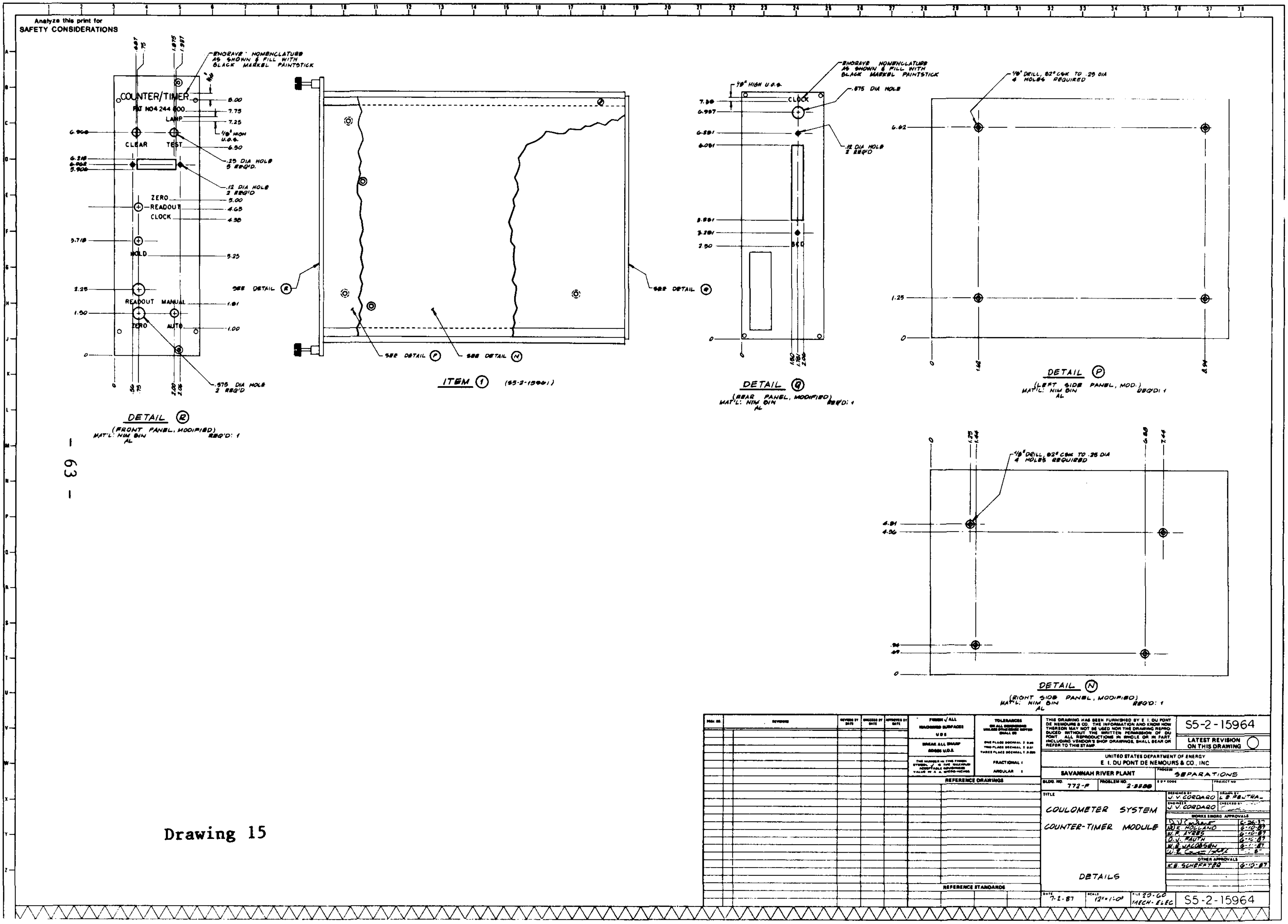
DESIGNED BY: V. V. CORDARO — DRAWN BY: L E FEU
ENGINEER: V. V. CORDARO

WORKS ENGRG APPROVALS: K. HOLLAND 6-10-87; W. P. AYERS 6-10-87; O. J. FAUTH 6-10-87; W. R. JACOBSEN 6-11-87

OTHER APPROVALS: K E SHEFFER 6-16-87

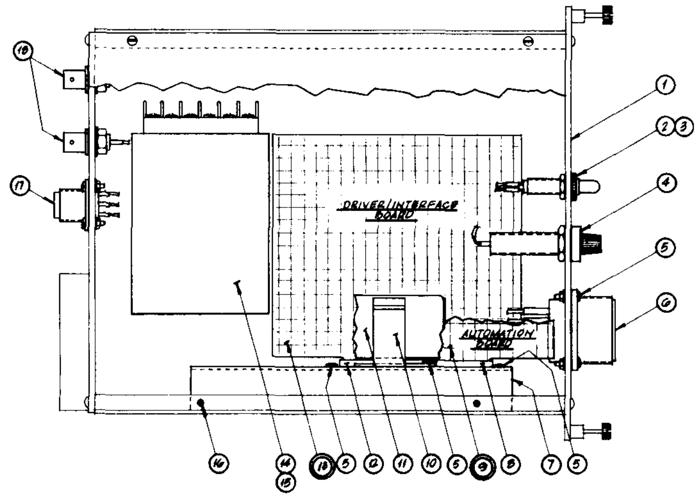
DATE 7-2-87 — SCALE NONE — FILE 20-60 MECH-ELEC

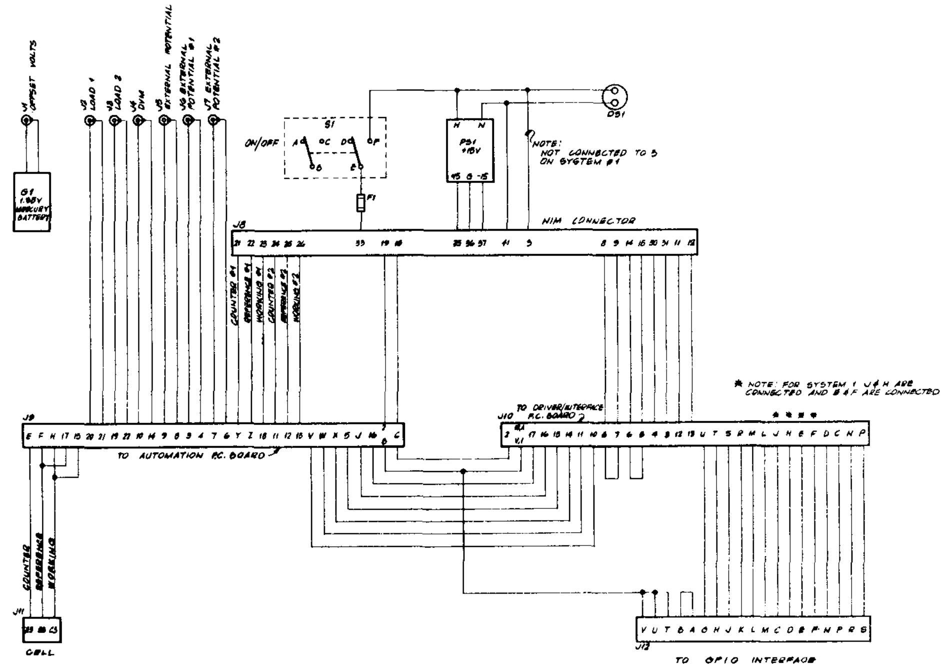
S5-2-15963

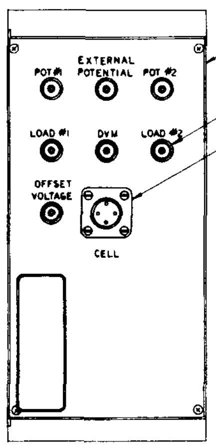

Analyze this print for SAFETY CONSIDERATIONS
ENGRAVE NOMENCLATURE AS SHOWN & FILL WITH BLACK MARKEL PAINTSTICK
COUNTER/TIMER
PAT NO4 244 800
LAMP
CLEAR
TEST
.25 DIA HOLE 5 REQ'D.
.12 DIA HOLE 2 REQ'D
ZERO
READOUT
CLOCK
HOLD
READOUT
MANUAL
ZERO
AUTO
.575 DIA HOLE 2 REQ'D
DETAIL (R)
(FRONT PANEL, MODIFIED)
MAT'L: NIM BIN AL
REQ'D: 1
SEE DETAIL (R)
SEE DETAIL (P)
SEE DETAIL (N)
SEE DETAIL (Q)
ITEM (1)
1/8" HIGH U.O.S.
CLOCK
.575 DIA HOLE
.12 DIA HOLE 2 REQ'D
BCD
DETAIL (Q)
(REAR PANEL, MODIFIED)
MAT'L: NIM BIN AL
REQ'D: 1
1/8" DRILL, 82° CSK TO .25 DIA 4 HOLES REQUIRED
DETAIL (P)
(LEFT SIDE PANEL, MOD.)
MAT'L: NIM BIN AL
REQ'D: 1
DETAIL (N)
(RIGHT SIDE PANEL, MODIFIED)
MAT'L: NIM BIN AL
REQ'D: 1
THIS DRAWING HAS BEEN FURNISHED BY E. I. DU PONT DE NEMOURS & CO. THE INFORMATION AND KNOW HOW THEREON MAY NOT BE USED NOR THE DRAWING REPRODUCED WITHOUT THE WRITTEN PERMISSION OF DU PONT. ALL REPRODUCTIONS IN WHOLE OR IN PART, INCLUDING VENDOR'S SHOP DRAWINGS, SHALL BEAR OR REFER TO THIS STAMP.
S5-2-15964
LATEST REVISION ON THIS DRAWING
UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC
SAVANNAH RIVER PLANT
PROCESS SEPARATIONS
BLDG. NO. 772-F
PROBLEM NO. 2-3588
TITLE
COULOMETER SYSTEM
COUNTER-TIMER MODULE
DETAILS
DESIGNED BY J. V. CORDARO
DRAWN BY L. E. FEUTRA
ENGINEER J. V. CORDARO
WORKS ENGRG APPROVALS
K. HOLLAND 6-10-87
W. F. AYRES 6-10-87
O. J. FAUTH 6-15-87
W. R. JACOBSEN
OTHER APPROVALS
K. E. SCHEFFTER 6-15-87
DATE 7-2-87
SCALE 12"=1'-0"
FILE 20-60 MECH-ELEC
S5-2-15964
REFERENCE DRAWINGS
REFERENCE STANDARDS

Drawing 15

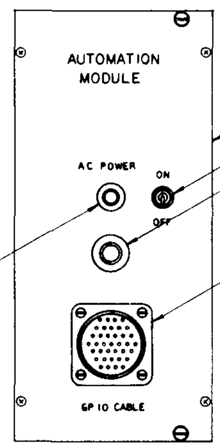
Analyze this print for SAFETY CONSIDERATIONS







REAR VIEW



FRONT VIEW

(PARTS LIST CONTINUED BELOW)

ITEM	PART DESIG.	PART AND DRAWING NO	REQ'D PER ASS'Y	DESCRIPTION
15	——	COML	4	#4-40UNC-2A x 1/2" LONG FLAT HEAD MACH SCREW
14	PS1	COML	1	POWER SUPPLY, ±15VDC, SOLA, #85-15-2150
13	——	(S5-2-15967)	1	DRIVER/INTERFACE PC BOARD SUBASSEMBLY
12	J10	COML	1	CONNECTOR, EDGE BOARD, TRW/CINCH, #50-36A-30
11	G1	COML	1	BATTERY, MERCURY, D-SIZE, 1.35V
10	——	COML	1	HOLDER, BATTERY, FOR D-SIZE BATTERY, KEYSTONE, #175
9	——	(S5-2-15966)	1	AUTOMATION P.C. BOARD SUBASSEMBLY
8	J9	COML	1	CONNECTOR, EDGE BOARD, TRW/CINCH, #50-44A-30
7	——	(S5-2-15968)	1	COMPONENT MOUNT PLATE, MODIFIED, (SEE DETAIL)
6	J12	COML	1	CONNECTOR, AMPHENOL, #MS3102A22-14P
5	——	↓	14	#4-40UNC-2A x 1/2" LONG BINDER HEAD MACH SCR W/HEX NUT
4	F1	↓	1	FUSE, FUSETRON, BUSSMAN, 3A, 120 V W/HOLDER, LITTLEFUSE, #342001
3	——	↓	1	HOLDER, LAMP, TURRET TERMINAL, W/O COLLAR, DIALIGHT, #350-8745-44-504
2	DS1	COML	1	LAMP, NEON CARTRIDGE, STOVEPIPE LENS, RED, DIALIGHT, #607-4538-093-610
1	——	(S5-2-15968)	1	NIM BIN, 4" WIDE, MODIFIED, TENNELEC, # NIM-B3W

ITEM	PART DESIG.	PART AND DRAWING NO	REQ'D PER ASS'Y	DESCRIPTION
19	S1	COML	1	SWITCH, TOGGLE, BAT LEVER ALCO, #MTA206N
18	J1 THRU J7	↓	7	CONNECTOR, BNC, AMPHENOL, #31-010, INSULATED MOUNT
17	J11	↓	1	CONNECTOR, AMPHENOL, #MS3102A10SL-3P
16	——	COML	4	#4-40UNC-2A x 1/4" LONG SET SCREW, FULL DOG POINT

(PARTS LIST CONTINUED)

Drawing 16

FINISH √ ALL MACHINED SURFACES U.O.S.

BREAK ALL SHARP EDGES U.O.S.

THE NUMBER IN THE FINISH SYMBOL √ IS THE MAXIMUM ACCEPTABLE ROUGHNESS VALUE IN A.A. MICRO-INCHES

TOLERANCES ON ALL DIMENSIONS UNLESS OTHERWISE NOTED SHALL BE: ONE PLACE DECIMAL ± 0.06; TWO PLACE DECIMAL ± 0.01; THREE PLACE DECIMAL ± 0.005; FRACTIONAL ±; ANGULAR ±

REFERENCE DRAWINGS

S5-2-15966	AUTOMATION P.C. BOARD
S5-2-15967	DRIVER/INTERFACE P.C. BD.

REFERENCE STANDARDS

S5-2-15965

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772-F — PROBLEM NO. 2-3588

TITLE: COULOMETER SYSTEM AUTOMATION MODULE ASSEMBLY CONNECTION DIAGRAM AND PARTS LIST

DESIGNED BY: J.V. CORDARO — DRAWN BY: L.E. FEUTRAL
ENGINEER: J.V. CORDARO — CHECKED BY: [illegible]

WORKS ENGRG APPROVALS

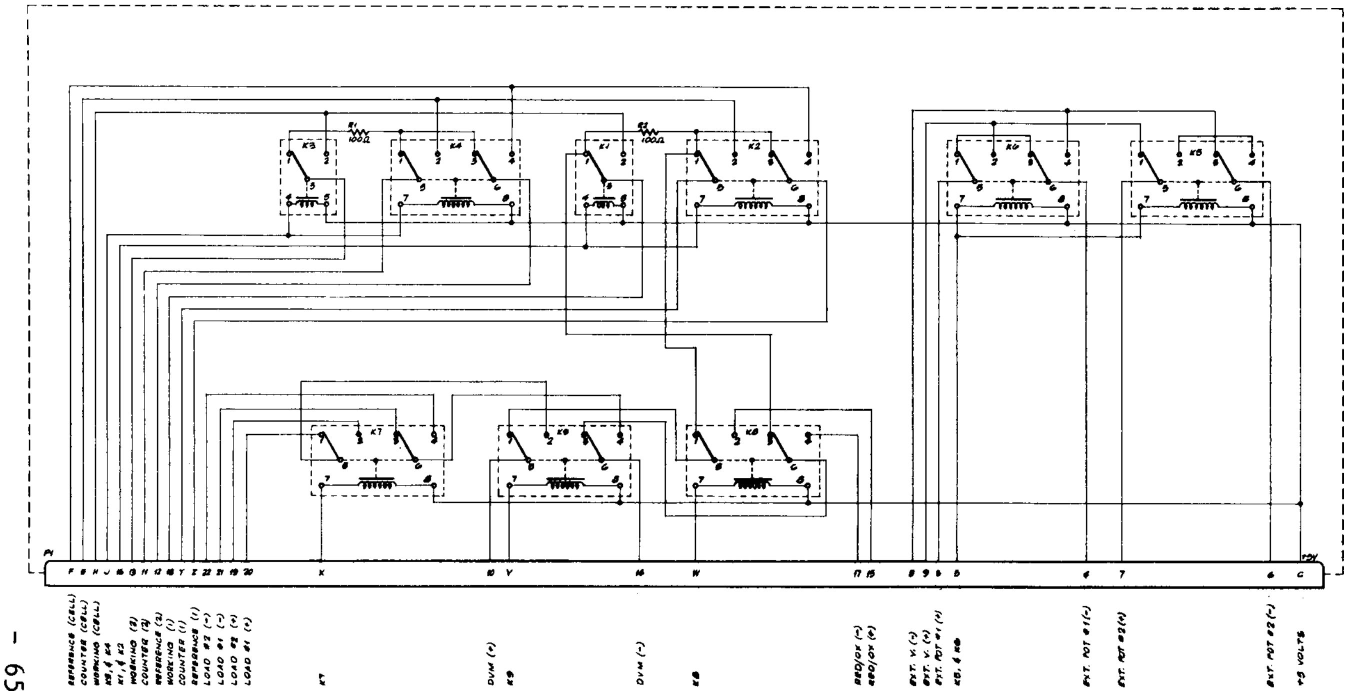
J.V. Cordaro	6-26-87
M.K. HOLLAND	6-10-87
W.F. AYRES	6-10-87
D.J. PAUTH	6-10-87
W.R. JACOBSEN	6-11-87
[illegible]	[illegible]

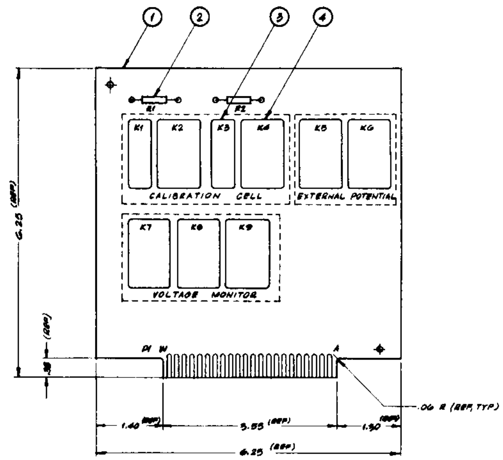
OTHER APPROVALS

K.E. SCHEFFTER	6-16-87

DATE 7-2-87 — SCALE NONE — FILE 20-60 MECH-ELEC — S5-2-15965

Analyze this print for
SAFETY CONSIDERATIONS





ITEM	PART DESIG.	PART AND DRAWING NO	REQD PER ASSY	DESCRIPTION
4	K2, K4, K5, K6, K7, K8, K9	C O M L	7	RELAY, 2 FORM C, 5VDC C.P. CLARE, # HGW2MT54111 000
3	K1, K3		2	RELAY, FORM C, 5VDC C.P. CLARE, # HGWM51111 K00
2	R1, R2		2	RESISTOR, 100Ω, .01 %, STABILITY, .005 % JULIE RESEARCH, TYPE [illegible]
1			1	BOARD, PRINTED CIRCUIT, POTENTIOSTAT, PRINTED WIRING SERVICES

REFERENCE DRAWINGS

S5-2-15966 AUTOMATION MODULE

REFERENCE STANDARDS

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S5-2-15966

LATEST REVISION ON THIS DRAWING

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772-F — PROBLEM NO. 2-5388

TITLE: COULOMETER SYSTEM AUTOMATION PRINTED CIRCUIT BOARD SCHEMATIC AND COMPONENT LAYOUT

DESIGNED BY J. V. CORDARO — DRAWN BY L. E. FEJTRAL
ENGINEER J. V. CORDARO — CHECKED BY

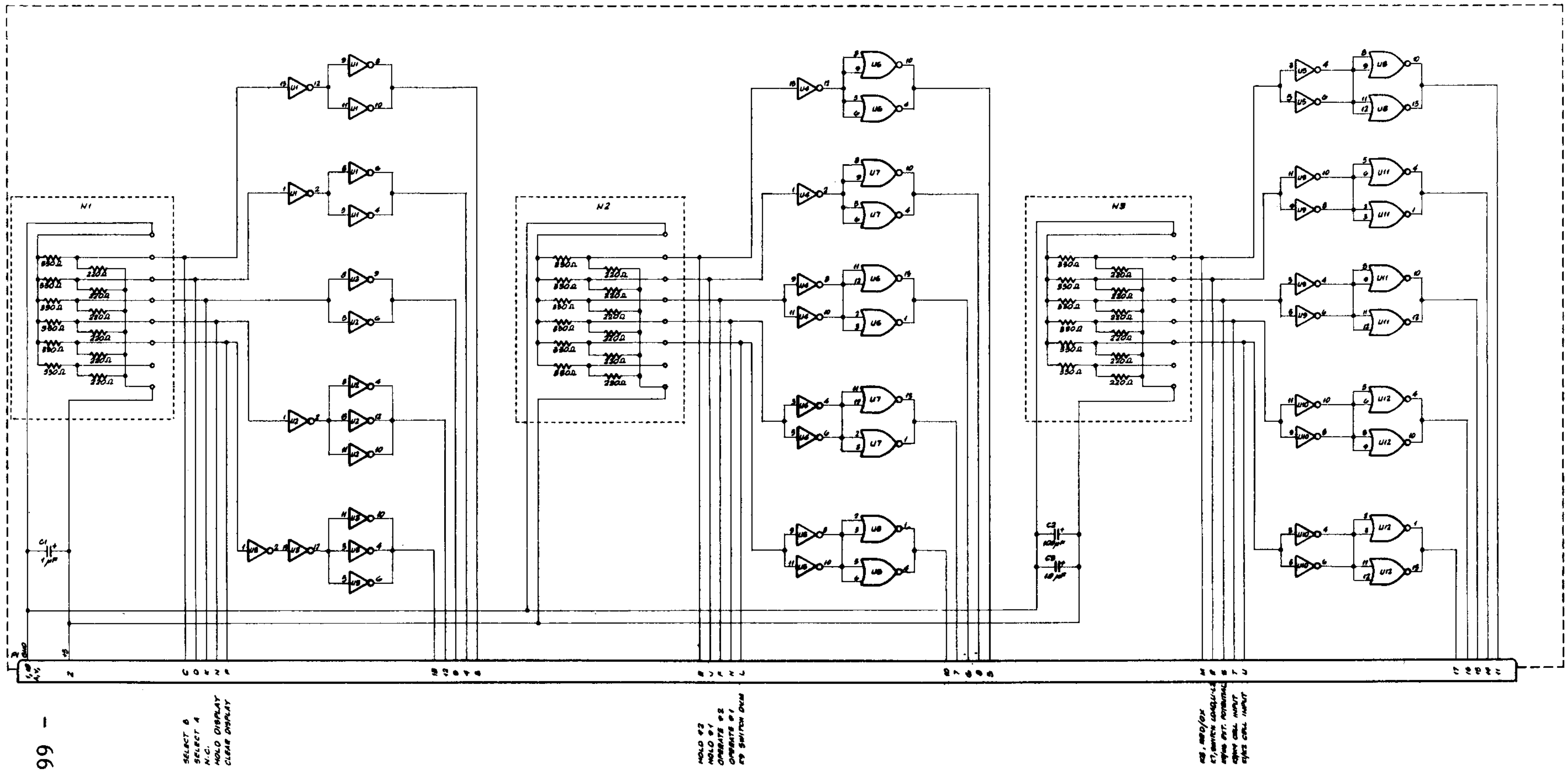
WORKS ENGRG APPROVALS
M. K. HOLLAND 6-10-87
W. F. AIRES 6-10-87
D. V. FAUTH 6-10-87
W. R. JACOBSEN 6-11-87

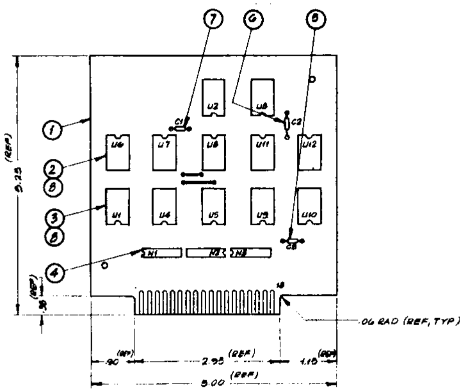
OTHER APPROVALS
K. J. SCHEFFTEG 6-16-87

DATE 7-2-87 — SCALE NONE — FILE 20-60 MECH-ELEC — S5-2-15966

Drawing 17

Analyze this print for
SAFETY CONSIDERATIONS





COMPONENT LAYOUT

Drawing 18

ITEM	PART DESIG	PART AND DRAWING NO	REQ'D PER ASSY	DESCRIPTION
8		COML	12	SOCKET, INTEGRATED CIRCUIT, 14 PINS, TEXAS INSTRUMENTS, C7214-09
7	C1		1	CAPACITOR, ELECTROLYTIC, 1μF, 50WV
6	C2		1	CAPACITOR, ELECTROLYTIC, 100μF, 50WV
5	C3		1	CAPACITOR, ELECTROLYTIC, 10μF, 50WV
4	N1, N2, & N3		3	RESISTOR, NETWORK, ALLEN BRADLEY, # 408B221B91
3	U1-U5 & U9, U10		7	INTEGRATED CIRCUIT, HEX INVERTER, SN7404N
2	U6, U7, U8 U11, U12		5	INTEGRATED CIRCUIT, 50 OHM LINE DRIVER, SN74128N
1		COML	1	BOARD, PRINTED CIRCUIT, DRIVER/INTERFACE BOARD, NEW BRUNSWICK LAB, MODEL # TLF

REFERENCE DRAWINGS: S5-2-15966 AUTOMATION MODULE

REFERENCE STANDARDS

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S5-2-15967

LATEST REVISION ON THIS DRAWING ○

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.

SAVANNAH RIVER PLANT — PROCESS: SEPARATIONS

BLDG. NO. 772-F — PROBLEM NO. 2-3558

TITLE: COULOMETER SYSTEM DRIVER/INTERFACE PRINTED CIRCUIT BOARD SCHEMATIC AND COMPONENT LAYOUT

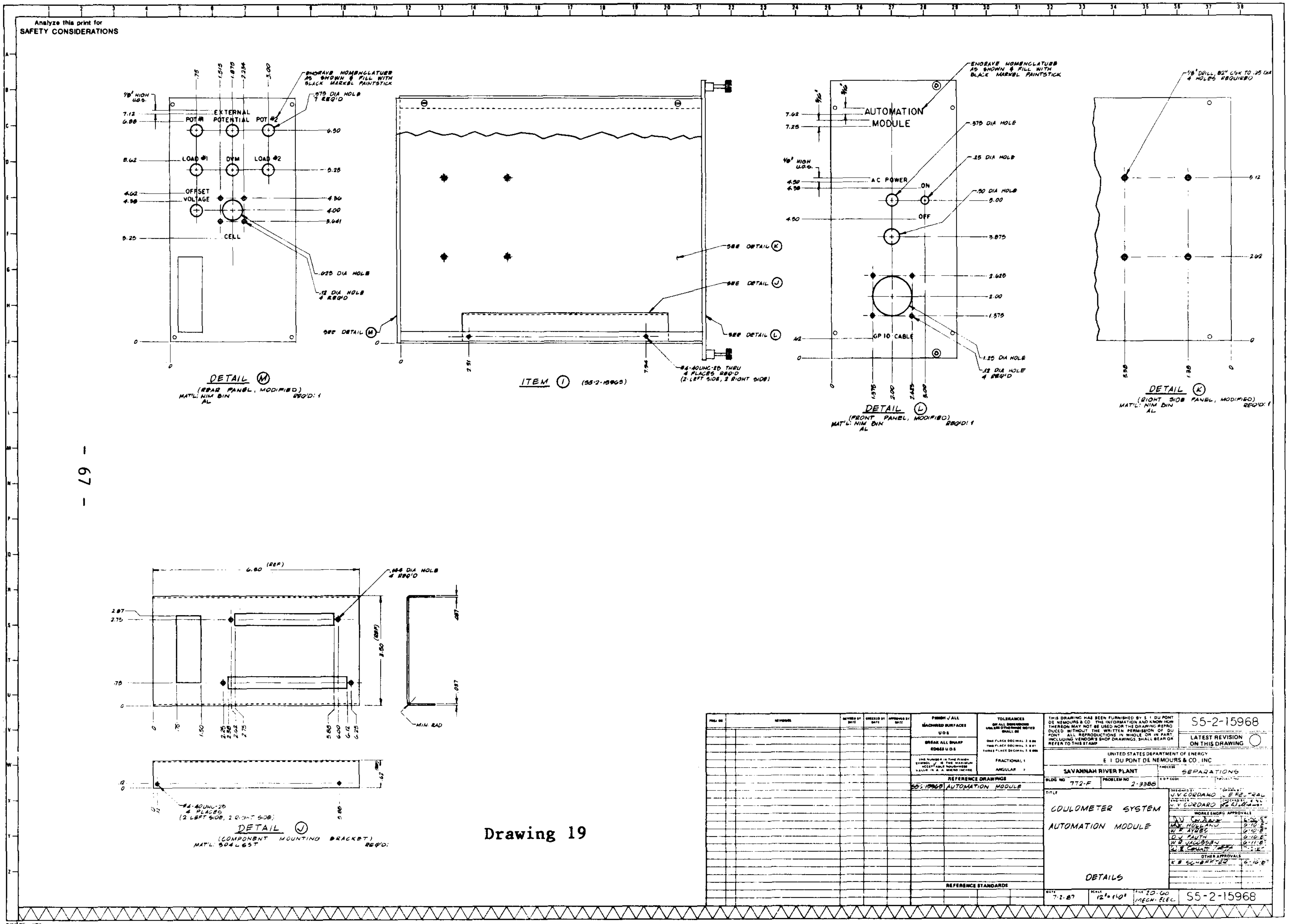
DESIGNED BY J.V. CORDARO — DRAWN BY L.E. FEJTRAL
ENGINEER J.V. CORDARO — CHECKED BY

WORKS ENGRG APPROVALS
M.K. HOLLAND
W.F. AYRES
D.J. FAUTH
W.E. JACOBSEN

OTHER APPROVALS
K.B. SCHEFFTER

DATE 7-2-87 — SCALE NONE — FILE 20.60 MECH-ELEC

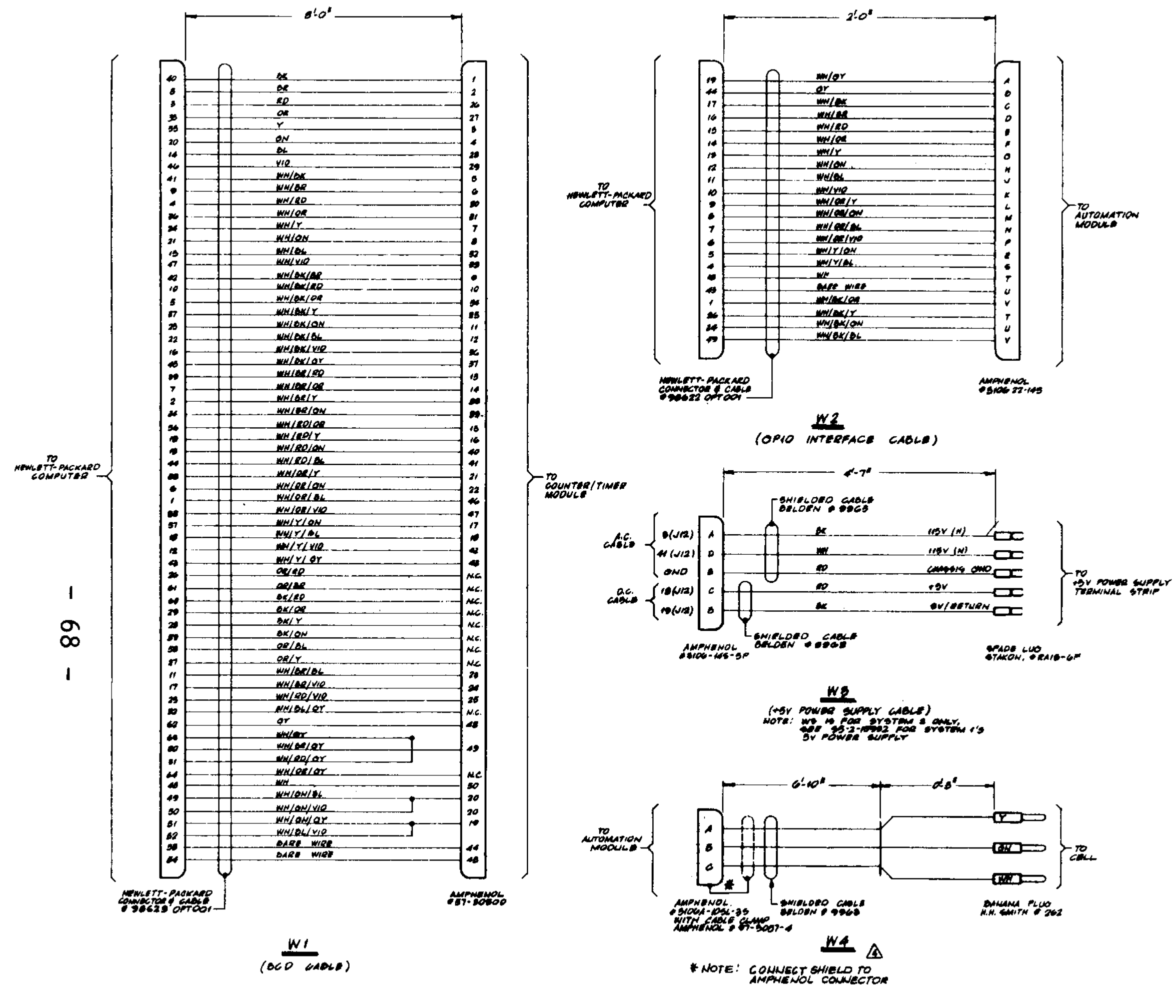
S5-2-15967



Analyze this print for SAFETY CONSIDERATIONS
EXTERNAL POTENTIAL
POT #1
POT #2
LOAD #1
DVM
LOAD #2
OFFSET VOLTAGE
CELL
DETAIL (M)
(REAR PANEL, MODIFIED)
MAT'L: NIM BIN AL
ITEM (1) (S5-2-15965)
SEE DETAIL (K)
SEE DETAIL (J)
SEE DETAIL (L)
SEE DETAIL (M)
AUTOMATION MODULE
AC POWER
ON
OFF
GP IO CABLE
DETAIL (L)
(FRONT PANEL, MODIFIED)
MAT'L: NIM BIN AL
DETAIL (K)
(RIGHT SIDE PANEL, MODIFIED)
MAT'L: NIM BIN AL
DETAIL (J)
(COMPONENT MOUNTING BRACKET)
MAT'L: 304L SST
S5-2-15968
LATEST REVISION ON THIS DRAWING
UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC.
SAVANNAH RIVER PLANT
SEPARATIONS
772-F
REFERENCE DRAWINGS
S5-2-15965 AUTOMATION MODULE
REFERENCE STANDARDS
COULOMETER SYSTEM
AUTOMATION MODULE
DETAILS
S5-2-15968

Drawing 19

Analyze this print for SAFETY CONSIDERATIONS



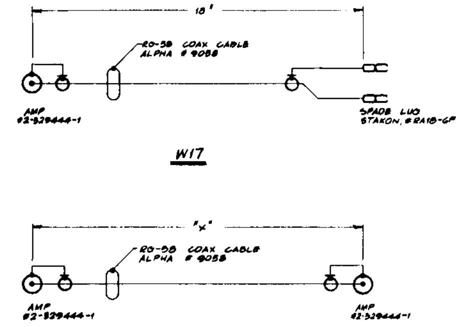
W1
(BCD CABLE)

W2
(OPIO INTERFACE CABLE)

W5
(+5V POWER SUPPLY CABLE)
NOTE: W5 IS FOR SYSTEM 2 ONLY. SEE S5-2-15952 FOR SYSTEM 1'S 5V POWER SUPPLY

W4

* NOTE: CONNECT SHIELD TO AMPHENOL CONNECTOR



W17

CABLE TABLE	
CABLE	LENGTH "X"
W5	8'
⚠1 ** W6	24" (MAX)
W7	3'
W8	5'
W9	10'
W10	15'
⚠2 ** W11	24" (MAX)
W12	6'
⚠3	
W14	3'
W15	3'
W16	8'
W18	80'

** DO NOT EXCEED MAXIMUM LENGTH

Drawing 20

SYM	REVISION
3	REVISED TABLE
4	REVISED W4 DIAGRAM

REFERENCE DRAWINGS: S5-2-15958 INTERCONNECTION DIAGRAM

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S5-2-15969

LATEST REVISION ON THIS DRAWING (4)

UNITED STATES DEPARTMENT OF ENERGY
E. I. DU PONT DE NEMOURS & CO., INC
SAVANNAH RIVER PLANT

PROCESS: SEPARATIONS
BLDG. NO. 772-F — PROBLEM NO. 2-3888

TITLE: COULOMETER SYSTEM CABLE DETAILS

DESIGNED BY: J.V. CORDARO — DRAWN BY: L.E. FEUTJAL
ENGINEER: J.V. CORDARO

WORKS ENGRG APPROVALS: W.K. HOLLAND 3-10-87; W.F. AYRES 6-10-87; D.C. FAUTH 6-10-87; W.R. JACOBSEN 6-11-87

OTHER APPROVALS: K.E. SCHEFFLER 6-16-87

DATE 7-2-87 — SCALE NONE — FILE GO-ELEC

S5-2-15969

APPENDIX B

VENDOR LIST

1) ACD-Elcor Products, Tel: 203-734-3510
   75R Wooster St.
   P. O. Box 244
   Bethel CT 06801

2) Analog Devices, Tel: 617-329-4700
   Two Technology Way
   P. O. Box 280
   Norwood MA 02062

3) Arrow Electronics, Tel: 919-725-8711
   938 Burke Street
   Winston Salem, NC 27101

4) Augat/Alcoswitch, Tel: 617-821-2372
   Canton, MA 02021

5) Burr-Brown, Tel: 602-746-1111
   International Aiport Industrial Park
   P. O. Box 11400
   Tucson AR.

6) Digi-Key Corporation, Tel: 800-344-4539
   701 Brooks Ave. South
   P. O. Box 677
   Thief River Falls, MN 56701

7) Dixie Electronics, 404-722-2055
   P. O. Box 2307
   Augusta GA

8) Grayhill Inc., Tel: 312-354-1040
   561 Hillgrove Ave.
   P. O. Box 10373
   Lagrange IL 60525

9) Hamilton Avnet, Tel: 404-447-7500
   5825 Suite D
   Peachtree Corners East
   Norcross GA 30092

10) Hewlett Packard, Tel: 803-732-0400
    Brookside Park 1 Harbinson Way
    Columbia SC

VENDORS LIST CONTINUED

11) Julie Research, Tel: 212-245-2727
211 West 61 St.
New York, NY 10023

12) Newark Electronics, Tel: 404-448-1300
6950 Peachtree Industrial Blvd.
Norcross GA 30071

13) Printed Wiring Services, 815-838-0005
11 Maryknoll Drive
Lockport, IL 60441

14) Radio Shack, Tel: 404-860-5965
3830 Washington Rd.
Martinez GA

15) Sorenson Company, Tel: 603-668-4500
676 Island Pond Road
Manchester, NH 03103

16) Teledyne Philbrick, Tel: 617-329-1600
Allied Dr. @RT128
Dedham, MA 02026

17) Tenneloc Corporation, Tel: 615-483-8405
601 Oak Ridge Turnpike
Oak Ridge, TN 37830

18) Texmate Inc., Tel: 619-481-7177
348 South Cedro Ave.
Solana Beach, CA 92075

19) Thermalloy Inc., Tel: 214-243-4321
2021 W Valley View LN
P. O. Box 810839
Dallas TX 75381

20) Vectron Labs (C/O Saber Associates) Tel: 800-327-0853
P. O. Box 1599
Melborn, FL

APPENDIX C

PARTS LIST

DESCRIPTION	QUANTITY	COST, EA	VENDOR
1) NIM Bin, Tenneloc No. TB3	1	450.00	17
2) NIM power supply, +/-12, +/-24 VDC , Tenneloc No. TC911.	1	515.00	17
3) Three Wide Blank NIM Bin Panel, Tenneloc No. NIM-BP3	1	25.00	17
4) NIM extender cable, Tenneloc No. NC-EXC-4-S, Add pins 3 to 3, 18 to 18, 19 to 19, 35 to 35, 36 to 36, 37 to 37.	1	110.00	17
5) Shielded Cable, 3 conductor, 20 AWG, Belden No. 9963	100 FT. (min)	62.45	12
6) Connector, Amphenol 3106A-10SL-3S	1	7.55	12
7) Cable Clamp, Amphenol 97-3057-1004	1	2.68	12
8) Power Supply, 5 VDC, 6 Amps Sorenson No. SLC5-6B	1	185.00	15
9) Banana Plug, White, Pomona No. 1325-9	1	.90	12
10) Banana Plug, Green, Pomona No. 1325-5	1	.90	12
11) Banana Plug, Red, Pomona No. 1325-2	1	.90	12
12) Coax Cable, RG 58, 3 inches length plus connector.	3	12.91	12
13) Coax Cable, RG 58, 13 inches length plus connector.	1	13.00	12
14) Coax Cable, RG 58, 5 inches length plus connector.	1	12.91	12
15) Coax shorting plug.	1	6.41	12
16) Contact Sockets for Standard NIM Bin, Tenneloc No. 2100-03-07	11	.45	17

DESCRIPTION	QUANTITY	COST, EA	VENDOR
17) HP 9826S Computer with 1 Meg RAM	1	8360.00	10
18) HP 98622A GPIO Interface	1	345.00	10
19) HP 98623A BCD Interface	1	40.00	10
20) HP 98613A Ram Based Basic 3.0	1	653.00	10
21) HP 8116A Pulse/Function Generator	1	3307.00	10
22) HP 5316A Electronic Counter	1	3307.00	10
23) HP 3456A Programmable DVM	1	3619.00	10
24) HP 2673A Graphics Printer	1	1500.00	10
25) HP 59501B DAC/POWER SUPPLY	1	760.00	10
26) Potentiostat Module	2	1042.02	
27) Digital Integrator Module	1	759.86	
28) Counter Module	1	510.15	
29) Automation Module	1	752.43	

TOTAL SYSTEM COST: 27,433.86

Note: Prices based on 1986 catalogs.

POTENTIOSTAT PARTS LIST

1.1 CHASIS

	DESCRIPTION	QUANTITY	COST, EA	VENDOR
1)	Switch, ALCOSWITCH Model MTA 206N.	2	3.66	4
2)	Switch, ALCOSWITCH Model MTA 106F.	1	3.93	4
3)	Switch, Rotary, by Grayhill Model No. 44D30-01-4-AJN	1	25.62	8
4)	Potentiometer, 2K Ohm, Helipot Series A 10 Turn, Wire Wound, Linearity .25	1	23.05	3
5)	Dial for Potentiometer, Series A	1	11.69	3
6)	Potentiometer, 20K Ohm, 10 Turn, Spectrol No. 536-1-1-203	1	6.27	12
7)	Connector, TRW Cinch, No. 50-22A-20	1	5.12	3
8)	Connector, TRW Cinch, No. 50-30A-30	1	3.78	3
9)	Connector, TRW Cinch, No. 50-20A-30M-1	1	6.07	3
10)	Battery, 1.5 Volt, Alkaline, Size AA	4	.25	12
11)	Holder, Battery, holds four AA Batteries, Radio Shack No. 270-397	1	1.79	12
12)	Knob, for 1/4 " shaft Radio Shack No. 274-407	1	2/1.29	12
13)	Connector, Amphenol 3102A-10SL-3P	1	5.09	12
14)	Connector, BNC, Amphenol 31-010	3	2.89	12
15)	Voltage Source, 6.2V, ACD-Elcor, No. AR6.2-10	1	230.00	1
16)	Voltage Meter, Texmate No. PM-45X, 200mV Range.	1	150.00	18

17) Blank NIM Module with NIM connector Tenneloc No. NIM-B3W	1	75.00	17
18) Jack, Banana, Red, Newark No. 81N1228	1	.46	12
19) Jack, Banana, Black, Newark No. 81N1229	1	.46	12
20) Capacitor, Polystryrene, 100nF, Mallory No. SXK010	1	1.26	12
21) Control Amplifier Card	1	355.15	
22) Switching and Load Card	1	119.64	
	SUB-TOTAL:	1042.02	

POTENTIOSTAT MODULE PARTS LIST CONT.

1.2 Control Amplifier Card

DESCRIPTION	QUANTITY	COST, EA	VENDOR
1) Amplifier, Teledyne Philbrick No. 1461	1	243.00	16
2) Heat Sink, Thermaloy No. 6007A	1	2.34	19
3) Amplifier, Burr-Brown No. 3521L	1	72.40	5
4) Trim Pot, 5K Ohm, Spectrol No. 70Y502	1	4.52	12
5) Trim Pot, 10K Ohm, Spectrol No. 70Y103	1	4.52	12
6) Transistor, 2N3906	1	.25	12
7) Resisitor, 3.9 Ohm, 1/4 Watt, 5%	2	.05	6
8) Resistor, 3.3M Ohm, 1/4 Watt, 5%	1	.05	6
9) Resistor, 820K Ohm, 1/4 Watt, 5%	1	.05	6
10) Resistor, 5.1K Ohm, 1/2 Watt, 1%	1	.67	12
11) Capacitor, 100pF, Mica Sangamo No. CM05FD101J03	1	.34	12
12) Capacitor, 1000pF, Mica Sangamo No. CM05FA102J03	1	.63	12
13) Capacitor, .01uF, ceramic Sprague No. 1C10Z5U103M050B	4	.09	12
14) Capacitor, 1uF, Electrolytic, 50WV Panasonic No. ECE-B1HV010S	4	.18	6
15) Capacitor, 100uF, Electrolytic, 50WV Panasonic No. ECE-B1HV101S	2	.45	6
16) Control Amplifier Circuit Board Printed Wiring Services	1	12/250.00	13
17) Integrated Circuit Socket, 14 pin Texas Instruments C7214-09	1	1.66	7
18) Integrated Circuit Socket, Round, 8 pins, Augat No. 8059-2G5	1	1.81	12

SUB-TOTAL: 355.15

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POTENTIOSTAT PARTS LIST CONT.

1.3 Switching and Load Card

DESCRIPTION	QUANTITY	COST,EA	VENDOR
1) Resistor, 1.0 Ohm, 25 Watts Dale No. RH-25	2	3.53	12
2) Resistor, 8.0 Ohm, 25 Watts Dale No. RH-25	1	3.53	12
3) Resistor, 4.0 Ohm, 25 Watts Dale No. RH-25	1	3.53	12
4) Resistor, 82K Ohm, 1/4 Watts, 5%	1	3.53	6
5) Capacitor, 1000pF, Mica Sangamo No. CM05FA102J03	1	.63	12
6) Diode, Switching, SI, PIV 75V, 10Ma 1N4151 or eqiv.	2	.12	
7) Relay, Form C, 5 Volts C. P. Clare No. HGWM51111K00	3	15.79	7
8) Relay, 2 Form C, 5 Volts C. P. Clare No. HGW2MT54111G00	1	32.92	7
9) Switching Load Card Circuit Board, Printed Wiring Services.	1	12/250.00	13

SUB-TOTAL: 119.64

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DIGITAL INTEGRATOR PARTS LISTS

2.1 Chasis

DESCRIPTION	QUANTITY	COST,EA	VENDOR
1) Switch, 3PDT, Alco Model MTA-306D	1	6.33	3
2) Resistor, 100 Ohm, 1/4 Watt, 5%	2	.05	6
3) Connector, Amphenol 31-010	5	2.89	12
4) Connector, TRW Cinch No. 50-30A-30	1	3.78	3
5) Blank NIM Module with NIM connector Tenneloc No. NIM-B1W	1	65.00	17
6) Voltage-to-Frequency Card	1	670.20	
		SUB-TOTAL: 759.86	

DIGITAL INTEGRATOR PARTS CONT.

2.2 Voltage-To-Frequency Card

DESCRIPTION	QUANTITY	COST,EA	VENDOR
1) Voltage-To-Frequency Convertor Module, Analog Devices No. 458L	2	182.00	2
2) Crystal Oscillator, 10K Hz, Vectron Labs No. C0235-T-3.	1	200	20
3) Voltage Regulator, uA7805CKC	1	1.43	7
4) Operational Amplifier, 741, 8 pin dip	2	.65	7
5) Quad Invertor, SN7404N	2	.45	7
6) Relay, Form C, 5 Volts, C. P. Clare No. HGW51111K00	1	15.79	7
7) Trim Pot, 500 Ohm, Spectrol No. 70Y501	1	4.95	12
8) Trim Pot, 1K Ohm, Spectrol No. 70Y102	2	4.52	12
9) Trim Pot, 10K Ohm, Spectrol No. 70Y103	2	4.52	12
10) Trim Pot, 20K Ohm, Spectrol No. 70Y203	2	4.52	12
11) Trim Pot, 50K Ohm, Spectrol No. 70Y503	2	4.52	12
12) Resistor, 5.1K Ohm, 1/4 Watt, 5%	1	.05	6
13) Resistor, 11K Ohm, 1/4 Watt, 5%	2	.05	6
14) Resistor, 43K Ohm, 1/4 Watt, 5%	1	.05	6
15) Resistor, 180K Ohm, 1/4 Watt, 5%	1	.05	6
16) Resistor, 221K Ohm, 1/4 Watt, 1%	2	.10	6
17) Resistor, 240K Ohm, 1/4 Watt, 5%	1	.05	6

18) Digital Integrator Card, Printed Wiring Service.	1	6/235.00	13
19) I. C. Socket, 8 pin dip Texas Instruments No. C7208-09	2	1.17	12
20) I. C. Socket, 16 pin dip Texas Instruments No. C7216-09	2	1.83	12

SUB-TOTAL: 670.20

COUNTER MODULE PARTS LIST

3.1 Chasis

DESCRIPTION	QUANTITY	COST,EA	VENDOR
1) Switch, Alcoswitch No. MPA-106F.	2	3.93	3
2) Switch, Alcoswitch No. MTA-206TA.	1	3.66	3
3) Switch, Alcoswitch No. MTA-106D	1	2.68	3
4) Switch, Alcoswitch No. MST-405N	1	7.80	3
5) Connector, TRW Cinch 50-50A-30	1	6.30	3
6) Connector, TRW Cinch 50-44A-30	1	5.12	3
7) Connector, BNC, Amphenol 31-010	3	2.89	12
8) Connector, Micro-Ribbon, Amphenol No. 57-40500	1	2.65	12
9) LED Display, 4 digit, Hewlett Packard No. HP5082-7414	2	3.00	10
10) Blank NIM Module with NIM connector, Tenneloc No. NIM-B2W.	1	65.00	17
11) Resistor, 1K Ohm, 5%, 1/4 Watt	1	.05	6
12) Display/Driver Card	1	64.76	
13) Counter/Multiplexer Card	1	329.60	

SUB-TOTAL: 510.15

COUNTER MODULE PARTS LIST CONT.

3.2 Display/Driver Card

DESCRIPTION	QUANTITY	COST,EA	VENDOR
1) Integrated Circuit, No. SN74LS151N Data Selector/ Multiplexer	4	.62	7
2) Integrated Circuit, No. SN74LS138N Decoder/ Demultiplexer.	1	.57	7
3) Integrated Circuit, No. CD4511BE BCD to 7 segment decoder/driver	1	1.43	7
4) Integrated Circuit, No. SN74LS293N 4 - bit binary counter.	2	1.13	7
5) Integrated Circuit, No. SN7404N Quad invertor.	1	.45	7
6) Integrated Circuit, No. SN7430N 8 - input NAND gate.	1	.45	7
7) Capacitor, 47uF, Electrolytic, 50 WV.	1	.36	6
8) Resistor, 1K Ohm, 1/4 Watt, 5%	1	.05	6
9) Resistor Network, 100 Ohm, Allen Bradley No. 316B	1	2.10	12
10) I. C. Socket, 16 pins, Texas Instrumnets C7216-09	8	1.83	12
11) I. C. Socket, 14 pins, Texas Instruments C7214-09	4	1.66	12
12) Display/Driver Circuit Board, Printed Wiring Service.	1	6/200.00	13

SUB-TOTAL: 64.76

COUNTER MODULE PARTS LIST CONT.

3.3 Counter/Multiplexer Card

DESCRIPTION	QUANTITY	COST,EA	VENDOR
1) Integrated Circuit, SN74143, 4 - bit Counter/Latch, 7-seg driver	21	8.90	7
2) Integrated Circuit, SN74LS153N, Dual 4-to-1 Line Selector	14	.66	7
3) Capacitor, .01uF, ceramic, Sprague No. 1C10Z5U103M050B	7	.09	12
4) I. C. Socket, 16 pins, Texas Instruments No. C7216-09	14	1.83	12
5) I. C. Socket, 24 pins, Texas Instruments No. C7224-09	21	3.24	12
6) Counter/Multiplexer Card, Printed Wiring Service.	1	6/235.00	13

SUB-TOTAL: 329.60

AUTOMATION MODULE PARTS LIST

4.1 Chasis

DESCRIPTION	QUANTITY	COST,EA	VENDOR
1) Power Supply, +/- 15 VDC, Sola No. 85-15-2150	1	227.63	12
2) Battery, Mercury, D size, 1.35 V, Duracell No. RM42R	1	13.20	12
3) Switch, ALCOSWITCH Model MTA-206N	1	3.66	4
4) Connector, BNC, Amphenol 31-010	5	2.89	12
5) Connector, Amphenol 3102A-10SL-3P	1	5.09	12
6) Connector, TRW Cinch No. 50-44A-30	1	5.12	3
7) Connector, TRW Cinch No. 50-36A-30	1	4.35	3
8) Connector, Amphenol 3102A-22-14P	1	9.55	12
9) Lamp, Dialight No. 507-4538-0931-610	1	4.83	12
10) Lamp Holder, Dialight No. 250-8745-14-504	1	3.38	12
11) Battery Holder for size D battery, Keysone No. 175	1	.81	12
12) Fuse Holder, Panel Mounting, Little Fuse No. 342001	1	1.15	12
13) Fuse, 3A, 3 AG	1	.38	12
14) Blank NIM Module with NIM connector, Tenneloc No. NIM-B3W.	1	75.00	17
15) Automation Card	1	317.13	
16) Receiver/Driver Card	1	66.70	

SUB-TOTAL: 752.43

AUTOMATION MODULE PARTS LIST CONT.

4.2 Automation Card

DESCRIPTION	QUANTITY	COST,EA	VENDOR
1) Relay, Form C, 5VDC C. P. Clare No. HGWM51111K00	2	15.79	7
2) Relay, 2 Form C, 5VDC C. P. Clare No. HGW2MT54111G00	7	32.92	7
3) Resistor, 100 Ohm, .01%, stability .003% per year, Julie Research No. R33	2	10.89	11
4) Automation Card Printed Circuit Board, Printed Wiring Services.	1	6/200.00	13

SUB-TOTAL: 317.13

4.3 Receiver/Driver Card

DESCRIPTION	QUANTITY	COST,EA	VENDOR
1) Integrated Circuit, SN7404N, Hex invertor.	7	.45	7
2) 50 Ohm Line Driver, SN74128N	5	1.13	7
3) Resistor Network, Allen Bradley No. 408E221331	3	1.26	12
4) Capacitor, Electrolytic, 1uF, 50WV Panasonic No. ECE-B1HV010S	1	.18	6
5) Capacitor, Electrolytic, 10uF, 50WV Panasonic No. ECE-B1HV100S	1	.24	6
6) Capacitor, Electrolytic, 100uF, 50WV Panasonic No. ECE-B1HV101S	1	.45	6
7) Receiver/Driver Circuit Board, Printed Wiring Service	1	6/200.00	13
8) I. C. Socket, 14 pins Texas Instruments C7214-09	12	1.66	12

SUB-TOTAL: 66.70