TECHNICAL MANUAL

POTENTIOSTAT/ GALVANOSTAT

MODEL PS-705

ELCHEMA
P.O. Box 5067
Potsdam, New York 13676

Tel.: (315) 268-1605 FAX: (315) 268-1709

TABLE OF CONTENTS

1. INTRODUCTION

The ELCHEMA Potentiostat, Model PS-705, is designed to maintain a known potential difference between two output connectors, **WE** and **REF** (the **Working Electrode** and **Reference Electrode**, respectively), regardless of changes in either the resistance or capacitance of the external circuit connected to these points by the user. The dynamic capabilities of the Potentiostat are designed to allow controlling experiments with fast changing potential programs, as well as to achieve a high degree of the system stability. The Model PS-705 with its rise time of 200 ns is one of the fastest potentiostat on the market and it allows the user to scan potential with scan rates up to 800 kV/s under favourable conditions. To achieve this high a scan rate, electrodes with very low capacitance have to be used. Recommended are electrodes with capacitance in the range from few pF to 200 pF. The resistance of electrodes and connections should also be kept as low as possible.

For the measurement set-up with PS-705, we recommend a fast Program Waveform Generator (Model FG-206F) and Digital Oscilloscope (Cat. # OSC-223). For slower transients and scan rates, a high precision 16-bit Data Acquisition System (DAQ-616) for IBM PC/AT compatible microcomputers and VOLTSCAN real-time data acquisition software (SFT-916) can be used. Further data processing, graphing and spreadsheet reporting can be done with Master Windows 3.2 (SFT-930).

2. SPECIFICATIONS

Current Measurement	
Maximum Current:	300 mA
Ranges:	100 mA to 10 nA
Resolution:	10 pA
Overload Signal:	*ca.* 3 times the nominal current range
Potential Control	
Range:	-10 V to +10 V
Applied Potential Accuracy:	0.1 % of reading + 0.15 % FS
Potential Program Source:	-10 V to +10 V (external)
Potential Program Input Impedance:	1 Mohm, differential input (shield referenced to ground through a 1 Mohm resistor)
Maximum Scan Rate:	500 kV/s (800 kV/s, typical)
Overload Signal:	-10.3 V, +10.3 V (approx.)
Other Measurements	
Galvanostatic Measurements	
Program Voltage Translation	1 Volt per nominal current range
Potential Measurement	-10 V to + 10 V
EMF (Electromotive Force)	
Input Impedance	> 10^{12} ohm (set CELL on, CONTROL off)
Measurement Range	±10 V (E-out)
Corrections	
IR Potential Drop	positive feedback

Recorder Output

Potential:	1 V per Volt
Potential Sign Convention:	more positive potentials for more anodic currents
Accuracy:	0.1 % of reading + 0.15 % FS
Output Range:	-10 V to +10 V
Load Resistance:	> 500 ohm
Current:	1 V per nominal current range (gain **x1**), 2 V per nominal current range (gain **x2**), 5 V per nominal current range (gain **x5**)
Sign Convention:	anodic currents positive (IUPAC Stockholm Convention)
Accuracy:	0.1 % of reading + 0.15 % FS
Output Range:	±1 V at gain **x1**, ±3 V max., ±2 V at gain **x2**, ±6 V max., ±5 V at gain **x5**, ±10 V max.,
Load Resistance:	> 500 ohm

Electrical Characteristics

Input Impedance:	> 10^{12} ohm
Output Impedance:	< 0.2 ohm
Offset Voltage:	< 80 uV
Slew Rate:	30 V/µs
Rise Time:	200 ns

Check with filters OFF, FAST mode, PS control, 1 kohm resistive load (*e.g.* internal dummy cell), 1 mA range, 10% to 90% of full signal, 1 V step

Compliance Voltage:	±15 V

Operating Parameters

Power Supply:	110/220 V 50 - 60 Hz, 100 W
Dimensions:	6.5 H x 17 W x 16.5 D, inch
Faraday Cage:	16 H x 12 W x 10 D, inch

Options

FG-206F	Fast Program Waveform Generator
OSC-223	Digital Oscilloscope
DAQ-616	16 bit Data Conversion Card
SFT-916	VOLTSCAN 3.8 Real-Time Data Acquisition Software with wave form generation
SFT-930	Master Windows Data Processing and Graphics Software
RTC-101	General Purpose ROTACELL Electrochemical Cell System
Electrodes	Wide selection of Working Electrodes, Reference and Counter Electrodes including microelectrodes and quartz crystal piezoelectrodes

3. CONTROLS

The front and back view of the Instrument are presented in Figures 1 and 2, respectively. For the front panel, the controls are described in the following order:

Input / Output Connectors
Switches
Diode Indicators
Other Controls

Read this Chapter carefully since it provides you with a full and systematic description of the functionality and limitations of all features and facilities available in the instrument. For exemplary schematics of connections and experimental measurement set-up, refer to the Chapter 5.

3.1 FRONT PANEL

Input / Output Connectors

1. **PROGRAM-IN**

BNC input socket to receive a potential program waveform from a fast function generator (*e.g.*, ELCHEMA Model FG-206F) or a digital-to-analog converter (*e.g.*, DAQ-616). This socket is identical (and electrically shorted) to the **P-IN** BNC socket provided for your convenience on the back panel of the instrument (if you do not change very often the program voltage source it may be more convenient to use the back panel socket **P-IN** and keep all the cable connections on the back). The **PROGRAM-IN** input is internally connected to a high speed differential amplifier. This input is symmetrical, *i.e.* you can change the sign of the program voltage by reversing the signal and guard lines (the signal line is internally referenced to the analog ground of the potentiostat through a 1 Mohm resistor and the guard line is also referenced to ground through a 1 Mohm resistor). The **PROGRAM-IN** input is a non-inverting input. This means that a +1000 mV program voltage (signal line *vs.* guard) will set the potential of the working electrode to the value E = +1000 mV *vs.* a reference electrode (in potentiostatic mode), or force a positive (anodic) current flow equal to the nominal current range (in galvanostatic mode). Because of the high input impedance, basically any type of a generator or waveform programmer can be connected to the **PROGRAM-IN** input. The input voltage range is from +10 V to -10 V vs. a.c. ground. Floating voltage sources will be referenced to ground with 1 Mohm resistance mentioned above. **Do not** connect to the program input any voltage sources which exceed the allowed potential range from +15 V to -15 V *vs.* a.c. ground.

2. **E-OUT** POTENTIAL output: BNC socket providing output voltage equal to the potential E of the working electrode (measured with respect to the potential of the reference electrode). Connect this socket to an external recorder monitoring the changes in E. The load impedance should not be lower than 2 kohm. This socket is identical (and electrically shorted) to the **E-OUT** BNC socket provided for your convenience on the back panel of the instrument.

3. **I-OUT** CURRENT output: BNC socket providing output voltage proportional to the current flowing through the electrochemical cell (or dummy cell). The output voltage of 1 V corresponds to the current equal to the CURRENT RANGE selected. For example, if the selected CURRENT RANGE is 10 mA and the output voltage is +1 V, the current flowing is +10 mA (anodic). If, for the same CURRENT RANGE of 10 mA, the output voltage is -1 V, the current flowing is -10 mA (cathodic). The actual current is also displayed on the CURRENT panel meter. The extended linearity of the I-OUT signal is from -3 V to +3 V. The load impedance should not be lower than 2 kohm. This socket is identical (and electrically shorted) to the **I-OUT** BNC socket provided for your convenience on the back panel of the instrument.

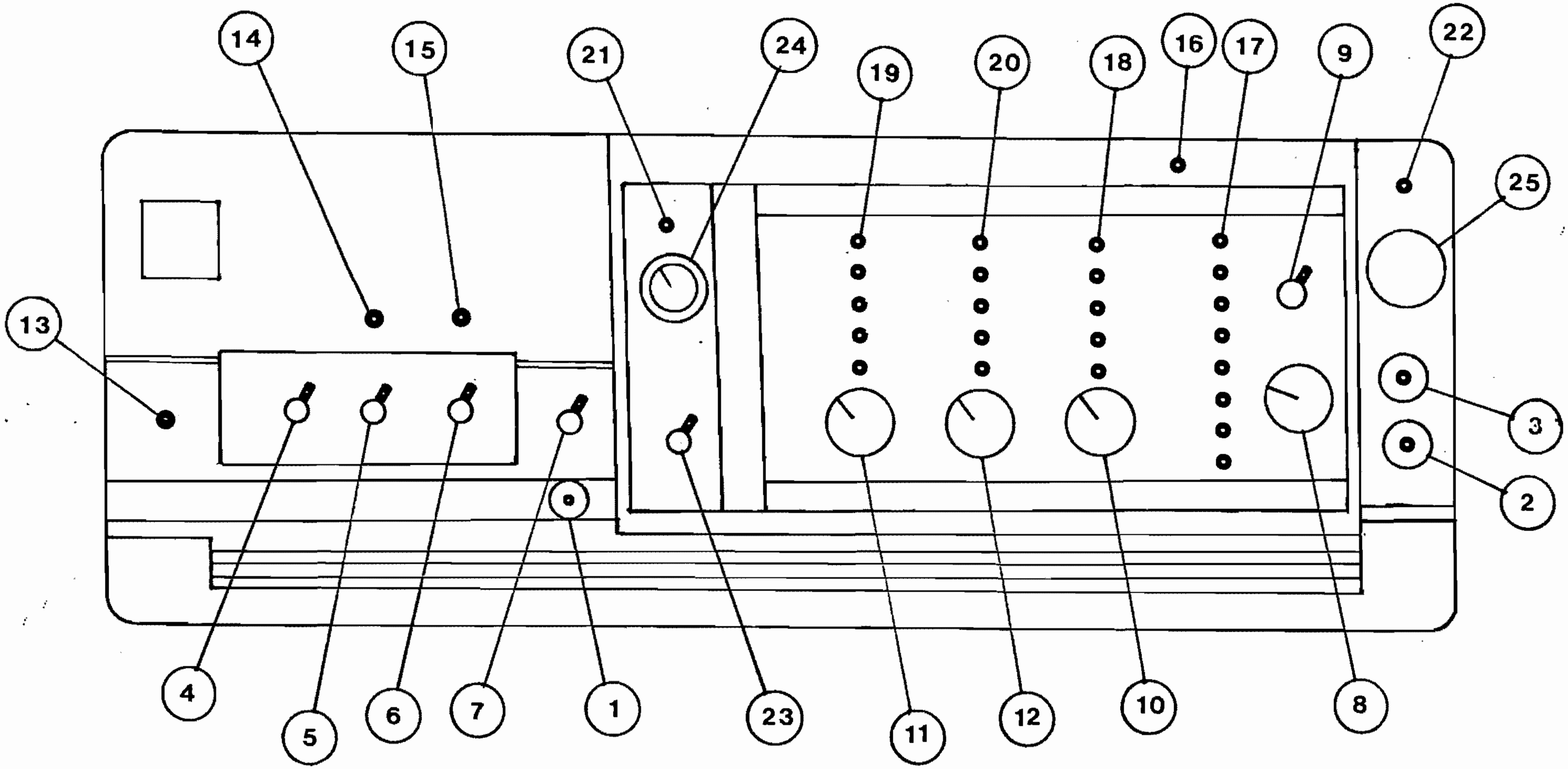

FIGURE 1. Front panel view of the Model PS-705 Potentiostat.

Switches

4. **MODE** Toggle switch with two positions:
PS - potential control (Potentiostat) and
GS - current control (Galvanostat).
If the Galvanostat option is not installed, the potential control is retained also in GS position.

5. **CELL** CELL SELECTOR with two positions:
OFF (or: **DUMMY CELL**) - In this position, an internal 1 kohm precision resistor is connected to simulate the electrochemical cell. (The resistor is connected between the WE' and CE' inputs of the potentiostat circuitry, and CE' is shorted to the REF' input. The BNC sockets on the front panel: **REF**, **WE**, and **CE**, are disconnected.) Use 1 mA CURRENT RANGE to work with dummy cell.
ON (or: **EXTERNAL**) - All three BNC sockets: **WE**, **CE**, and **REF**, are connected to internal circuitry to allow for a full potential or current control according to the **PS/GS** mode. Make sure the working electrode, reference electrode, and counter electrode are immersed in the electrolyte solution and properly connected to the potentiostat before you switch the EXTERNAL CELL on. If any of the overload diodes is activated, switch the cell OFF immediately (connect back to DUMMY CELL) and check the connections.

√ 6. **CONTROL**
Two position toggle or pushbutton switch to turn the potentiostatic or galvanostatic control ON and OFF:
OFF - the output of the power amplifier is disconnected from the CE socket, while WE and REF inputs to the internal circuitry are connected according to the CELL switch selection, i.e. to the dummy cell (when CELL switch is in the OFF position), or to the **WE** and **REF** sockets on the inside panel of the Faraday Cage (when CELL switch is the ON position). With CELL ON and CONTROL OFF, you can perform measurements of the rest potential, corrosion potential, or EMF. The Working and Reference Electrodes must be connected to the tip banana jacks **WE** and **REF**, respectively. Since the input resistance of the measuring circuitry is higher than 10^{12} ohms, the potential measurements for virtually any type of electrodes can be accomplished, even for those

with very high impedance.
ON - all three electrode inputs (**WE**, **REF**, and **CE**) are connected to the internal control system and the instrument controls either the potential (in **PS** mode), or current (in **GS** mode). The control is imposed on the external electrochemical cell when the CELL switch is in the ON position, otherwise the control is imposed on the internal dummy cell (10 kohm resistor).

7. **PROGRAM**

Toggle switch for the program voltage source connected to the **PROGRAM-IN** BNC input socket, with two positions:
ON - potential waveform applied to BNC socket marked **PROGRAM-IN** is presented to the program input of the summing amplifier.
OFF - zero Volts is applied to the program input of the summing amplifier.

8. **RANGE** CURRENT RANGE selector: Eight position rotary switch for current range selection, from 100 mA to 10 nA. The range selected is indicated by lite diodes. For each range, the extended linearity from -300% to +300% of the range value can be utilized.

9. **GAIN** Three position toggle switch to select gain for the recorder output signal **I-OUT**. The gains are: 1, 2, and 5.

10. **SPEED**

Rotary switch with five positions allowing to select appropriate frequency compensation for the given electrochemical cell. Usually, the position 2 or 3 should work best. Set this position of the SPEED control unless a better stability and less noise is found at other positions. For special cells, it is advised to observe on a digital oscilloscope the potentiostat response to a step function to determine the best selection of the SPEED control. Too high a speed would manifest itself by the appearance of overshoots, while too slow speed would cause a slow settling. In general, the system will be more stable on less sensitive current ranges and at a lower gain. If oscillations are encountered (blinking red indicator in the CURRENT RANGE section and/or extensive noise at the **I-OUT** recorder output), immediately turn the **CELL** switch off. Turning to a less sensitive current range, *e.g.* 100 mA, and reducing the gain to **x1** may also help. For low current ranges, we recommend to use the output filter and gain **x1** to achieve higher stability of the system.

FAST - Minimal frequency compensation is employed, so the potentiostat may react with an overshoot (for a step excitation), or even oscillate, for potential steps with fast rise times, or pure capacitive loads. (Avoid using FAST settings for IR-drop compensation.)

SLOW - Small frequency compensation is used to reduce overshoots and prevent oscillations while still maintaining very fast response. For slower scan rates and lower currents measured, use input and output filters to reduce noise, if any.

11. **INPUT FILTER** SELECTOR

Six position rotary switch for selecting the time constant of an input filter installed on the program input amplifier (external potential source **C**). The time constants are as follows:

FILTER POSITION	**LED #**	**TIME CONSTANT** ***ms***
0	none	Filter OFF
1	1	0.002
2	2	0.02
3	3	0.2
4	4	0.7
5	5	2

This filter is designed for cyclic voltammetry with scan rates up to 1 kV/s. For faster measurements, the input filter should be either turned OFF or in the position 1.

12. **OUTPUT FILTER** SELECTOR

Six position rotary switch for selecting the time constant of an output filter installed on the current amplifier. The time constants are as follows:

FILTER POSITION	**LED #**	**TIME CONSTANT *ms***
0	none	Filter OFF
1	1	3
2	2	100
3	3	250
4	4	600
5	5	1000

This filter is designed for slower scan cyclic voltammetry with scan rates up to 500 mV/s. For faster measurements, the output filter should be turned OFF. Slower scan rates and lower current ranges usually require higher time constants. Too high a time constant may affect not only the high frequency noise but also the signal itself. Check always if the general shape of the *i-E* or *i-t* curve recorded remains unchanged after selecting the higher time constant.

Diode Indicators

13. **POTENTIAL OVERLOAD**

Red LED activated when the measured potential of the working electrode (vs. reference electrode) exceeds the default potential range: -10.5 V to +10.5 V).

14. **CELL INDICATOR**

Yellow LED indicating if the external electrochemical CELL is ON.

15. **CONTROL INDICATOR**

Red LED indicating if the CONTROL is applied or not to the load (an external electrochemical cell or an internal dummy cell).

16. **CURRENT OVERLOAD**
    Red LED activated when the measured current exceeds approximately 3 times the actual current range.

17. **CURRENT RANGE INDICATORS**
    Green LED's indicating the CURRENT RANGE selection.

18. **SPEED INDICATORS**
    Green LED's indicating the frequency compensation (SPEED) selection.

19. **INPUT FILTER INDICATORS**
    Green LED's indicating the input filter selection.

20. **OUTPUT FILTER INDICATORS**
    Green LED's indicating the output filter selection.

21. **IR COMP.** INDICATOR
    Red LED indicating if the IR COMPENSATION is turned ON.

22. **POWER INDICATOR**
    Red LED indicating if the AC power is ON.

Other Controls

23. **IR COMP.** SWITCH
    Toggle switch with two positions:
    OFF - IR compensation is turned OFF,
    ON - IR compensation is turned ON. In this position, the ohmic potential drop corresponding to the resistance set with the IR compensation adjust potentiometer is being used to correct the potential of working electrode.

24. **IR COMP.** ADJUST

Scaled multiturn potentiometer used to set the resistance for Ohmic potential drop compensation. One full turn corresponds to 10 % of the current measuring resistor. The maximum compensation is equivalent to the value of the current measuring resistor (10 turns). The maximum value of the solution resistance $\mathbf{R}_{un}$ to be compensated at the current range i_{RANGE} is given by the following formula:

$$\mathbf{R}_{un} = 1/i_{RANGE}$$

with $\mathbf{R}_{un}$ expressed in [*ohm*], and i_{RANGE} expressed in [*A*].
Set the IR COMP. ADJUST potentiometer to a value slightly lower than the measured value of the resistance of the solution between Working Electrode and Reference Electrode. If this resistance is unknown, you can still compensate for the Ohmic potential drop using the following procedure:

(1) Set the IR COMP. ADJUST potentiometer to 0 (zero).

(2) Turn the IR COMP. SWITCH to ON.

(3) Slowly turn the IR COMP. ADJUST potentiometer clockwise until oscillations of the current and potential begin. At this point, the system is over-compensated. The beginning of oscillations can be observed on the oscilloscope or XY-recorder as an increased noise. Large oscillations are usually indicated by the POTENTIAL and CURRENT OVERLOAD warning diodes. Turn the dial back to a value just before the start of oscillations. Sometimes it is safer to slightly under-compensate to achieve greater stability of the system.

WARNING: When the system becomes unstable and begins to oscillate due to the IR potential drop over-compensation, your Working Electrode may be ruined by uncontrolled anodic or cathodic currents. Remember that potentiostat is capable of outputting up to 15 V at 1 A current. Often you can avoid IR compensation by minimizing the distance between WE and REF electrodes, using Luggin capillary, and/or increasing the conductance of the supporting electrolyte. If you experience a noise problem with your electrochemical cell, do not use any IR compensation. The uncompensated ohmic resistance actually stabilizes the system.

25. **POWER**

Main power switch. Power is **ON** in position **1**, and **OFF** in position **0**.

3.2. BACK PANEL

1. **P-IN** **PROGRAM INPUT** BNC socket. This socket is identical (and electrically shorted) to the **PROGRAM-IN** BNC socket located on the front panel of the instrument. Connect this socket to the output of an analog voltage source such as a ramp generator (*e.g.* ELCHEMA Model FG-206F), Waveform Programer (*e.g.* ELCHEMA Model-706), or a D/A Converter (*e.g.* our DAQ-616SC system). The **P-IN** input is internally connected to a high speed differential amplifier. This input is symmetrical, *i.e.* you can change the sign of the program voltage by reversing the signal and guard lines (the signal line is internally referenced to the analog ground of the potentiostat through a 1 Mohm resistor and the guard line is also referenced to ground through a 1 Mohm resistor). The **P-IN** input is a non-inverting input. This means that a +1000 mV program voltage (signal line *vs.* guard) will set the potential of the working electrode to the value E = +1000 mV *vs.* a reference electrode (in potentiostatic mode), or force a positive (anodic) current flow equal to the nominal current range (in galvanostatic mode). Because of the high input impedance, basically any type of a generator or waveform programer can be connected to the **P-IN** input. The input voltage range is from +10 V to -10 V vs. a.c. ground. Floating voltage sources will be referenced to ground with 1 Mohm resistance mentioned above. **Do not** connect to the program input any voltage sources which exceed the allowed potential range from +15 V to -15 V *vs.* a.c. ground.

2. **E-OUT** POTENTIAL output: BNC socket providing output voltage equal to the potential E of the working electrode (measured with respect to the potential of the reference electrode). Connect this socket to an external recorder monitoring the changes in E. The load impedance should not be lower than 2 kohm. This socket is identical (and electrically shorted) to the **E-OUT** BNC socket provided for your convenience also on the front panel of the instrument.

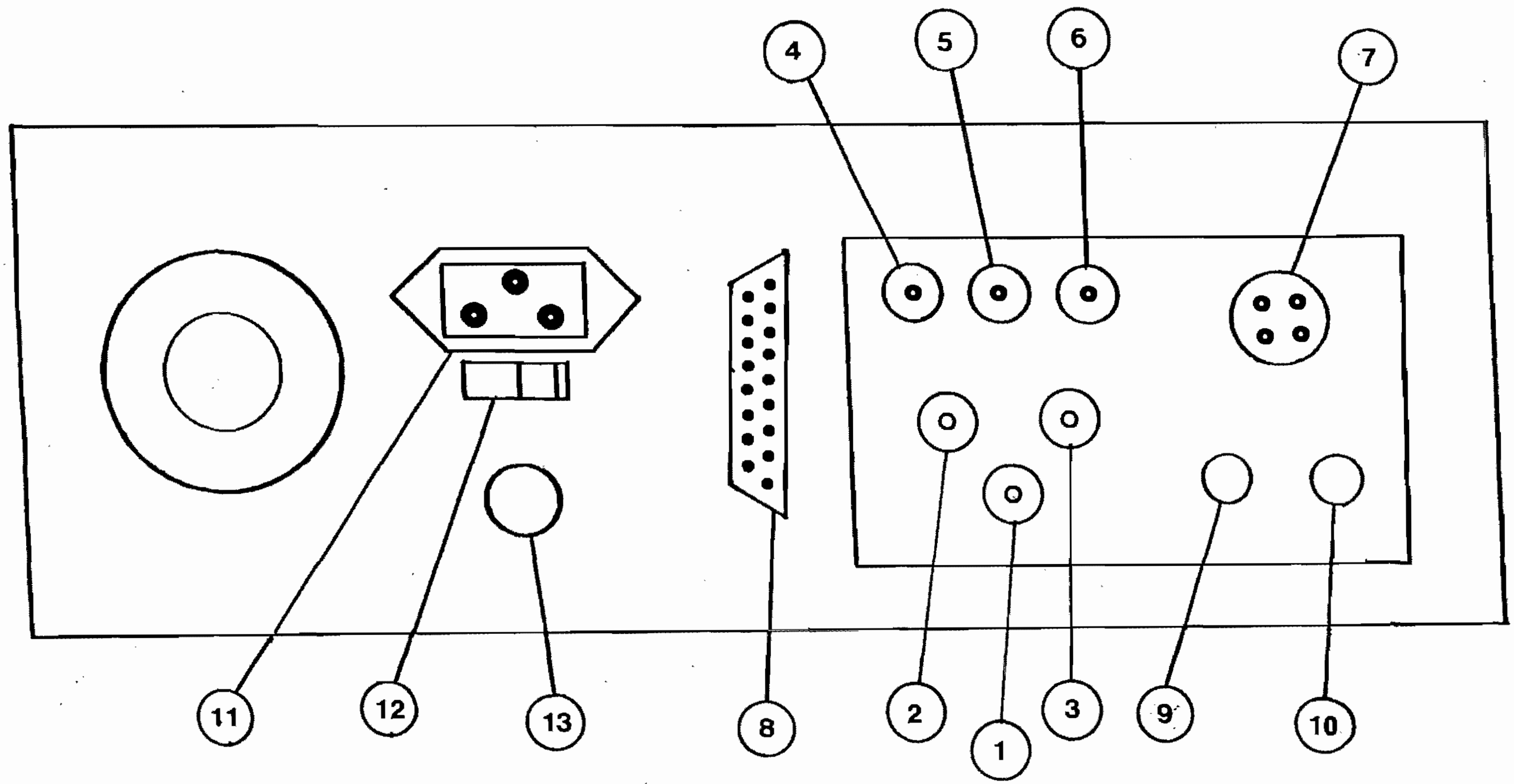

FIGURE 2. Back panel view of the Model PS-705 Potentiostat.

3. **I-OUT** CURRENT output: BNC socket providing output voltage proportional to the current flowing through the electrochemical cell (or dummy cell). The output voltage of 1 V corresponds to the current equal to the CURRENT RANGE selected. For example, if the selected CURRENT RANGE is 10 mA and the output voltage is +1 V, the current flowing is +10 mA (anodic). If, for the same CURRENT RANGE of 10 mA, the output voltage is -1 V, the current flowing is -10 mA (cathodic). The actual current is also displayed on the CURRENT panel meter. The extended linearity of the I-OUT signal is from -3 V to +3 V. The load impedance should not be lower than 2 kohm. This socket is identical (and electrically shorted) to the **I-OUT** BNC socket provided for your convenience also on the front panel of the instrument.

4-6. **C1, C2, C3**

BNC sockets to be connected to the respective BNC socket on the side panel of the Faraday Cage.

7. **SPLY** 6-pin audio-type socket for power SUPPLY lines to be connected with a multiconductor cable (provided) to a similar 6-pin audio-type socket on the back panel of the Potentiostat.

8. **I/O** Standard female DB-25 socket for digital input/output communication. It should be connected to the corresponding male DB-25 connector on the side panel of the Faraday Cage.

9. **GND** Black or brown isolated Banana socket connected to the analog ground of the instrument circuitry. The analog ground is floating, i.e. it is not connected directly to the instrument CHASSIS or to the power line ground wire. You can connect externally the **GND** socket to the instrument **CHASSIS** or analog ground of other instruments if necessary.

10. **CHASSIS** Banana socket shorted to the instrument chassis. The instrument chassis is connected internally to the power line ground wire (a.c. ground).

11. **POWER socket**

HP type socket for A.C. power inlet. It will accept 110 V or 220 V, 50 to 60 Hz. If the 110/220 V switch is not set properly for your power supply, turn the power to the instrument off, and change the position of the 110/220 V selector to the appropriate position. Use power cords supplied with the instrument. American, British, and European power cords are available.

12. **110/220 V switch**
Power line voltage selector. The switch is set to 110 V when shipped within the USA, and 220 V, elsewhere. Check the position of this switch before you connect power to the instrument.

WARNING: Make sure the power in the instrument is OFF before you change the position of the 110/200 V switch.

13. **FUSE** Power fuse. Use 250 V, 2 A slow melting fuse if replacement is necessary.

WARNING: Make sure the power in the instrument is OFF, and the power cord is disconnected from the instrument before you replace the fuse.

3.3. Faraday Cage (side panel)

1. **C1** BNC socket to be connected to the corresponding socket on the front panel of the potentiostat PS-705.

2. **C2** BNC socket to be connected to the corresponding socket on the front panel of the potentiostat PS-705.

3. **C3** BNC socket to be connected to the corresponding socket on the front panel of the potentiostat PS-705.

4. **I/O** Standard DB-25 male socket with proprietary communication bus lines to be connected to a DB-25 female socket on the back panel of the Potentiostat.

5. **SPLY** 6-pin audio-type socket for power SUPPLY lines to be connected with a multiconductor cable marked **PS-705 SPLY** to a similar 6-pin audio-type socket on the back panel of the Potentiostat.

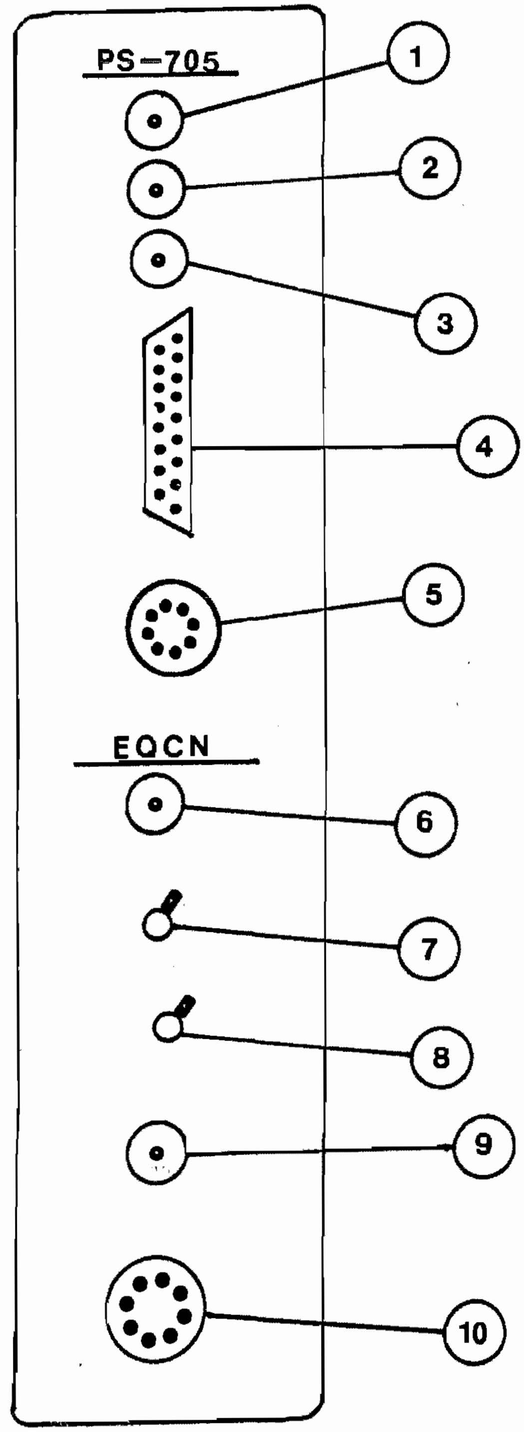

FIGURE 3. Side panel view of the Faraday Cage.

3.4. Faraday Cage (internal panel)

1. **CE** COUNTER ELECTRODE: pin tip banana jack (red) for connection to the *counter electrode* (*auxiliary electrode*) in the electrochemical cell. Use short wires for connections to the electrochemical cell.

2. **REF** REFERENCE ELECTRODE: pin tip banana jack (yellow) for connection to the *reference electrode* (e.g., Saturated Calomel Electrode, SCE). The input impedance is higher than 10^{12} ohm. Use as short a wire as possible.

3. **WE** WORKING ELECTRODE: pin tip banana jack (blue) for connection to the *working electrode* in the electrolytic cell. Use only short wires for the connection.

4-7 Pin tip banana jacks for measurements with Electrochemical Quartz Crystal Nanobalance system (refer to the EQCN Manual).

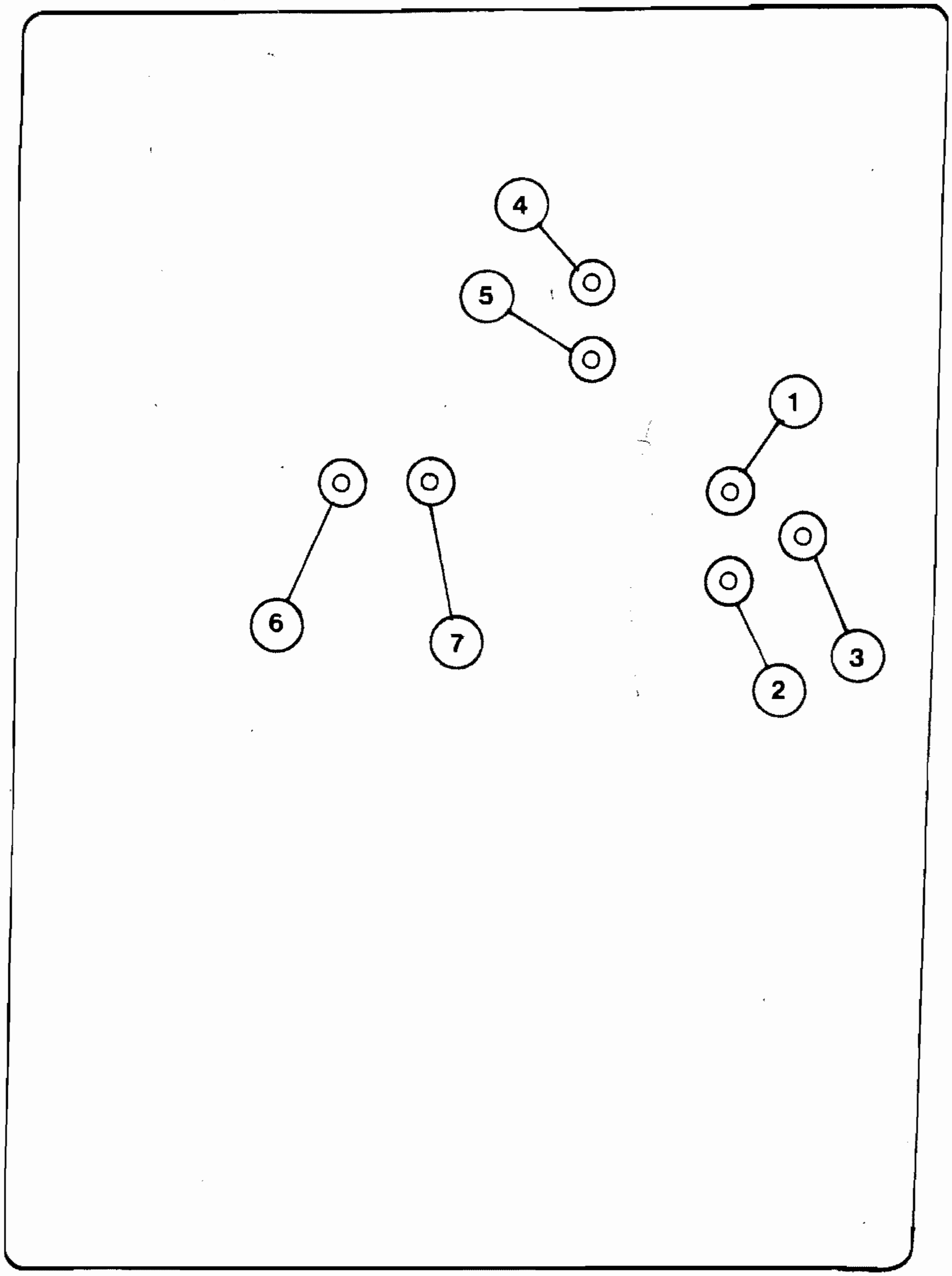

FIGURE 4. Inside panel view of the Faraday Cage.

4. INITIAL CHECKS

4.1. INSPECTION

After the instrument is unpacked, the instrument should be carefully inspected for damage received in transit. If any shipping damage is found, follow the procedure outlined in the "Claim for Damage in Shipment" section at the end of this Manual.

4.2. PRECAUTIONS

Care should be taken when making any connections to the instrument. Use the guidelines for maximum voltage at the inputs. There should be no signal applied to the inputs when the instrument is turned off. The outputs should not be loaded. They can only be connected to high input impedance devices such as plotters or oscilloscopes.

Use minimal force when putting on or taking off the BNC connections, otherwise they might become loose. You should push the BNC forward when making a connection or a disconnection in order to relieve the rotational tension on the BNC socket.

Operate the instrument in a cool and well ventilated environment.

Contact us in the event that any of our components do not operate properly. Our components are marked with seals. Do NOT open and attempt to repair anything yourself, otherwise your warranty agreement will be **nullified**.

4.3. GROUNDING AND ENVIRONMENTAL TRANSIENTS

It is very important to properly ground the instrument. Use only three-connector power cords with ground connector connected to a good ground. If necessary, you can additionally connect the instrument **CHASSIS** to a water pipe or other good ground connector. Use a thick cable for grounding purposes. Do not connect analog ground of the instrument (provided at the **GND** socket on the back panel) to the instrument **CHASSIS** ground, unless you find it beneficial in reducing noise.

High level transients generated in power supply lines by heavy-duty electric motors, lasers, arc welders, rf equipment, etc., may interfere with the normal operation of the potentiostat. In such a case, placing a power line stabilizer in the lab may solve the problem.

WARNING: Do not attach ground wires to a gas or heating pipe.

4.4. THERMAL SENSITIVITY

The instrument should be warmed up for 30 minutes in order to achieve the greatest accuracy. However, for general purposes the improvement might be insignificant and thus warmup could be omitted.

5. INSTALLATION

The operating instructions have been made short and simple but make sure they are followed in this exact order. **Bold** letters indicate connections and controls on the Potentiostat only.

5.1. Unpacking

Carefully remove all paper and tape used in shipping. Place instrument on a convenient bench. Check the items against the packing list.

Make sure the **POWER** in the Potentiostat is **OFF**, and nothing is connected to the instrument before you proceed with the Initial set-up procedure.

5.2. Initial set-up

(1) Make sure the **POWER** in the Potentiostat, and in all other devices, is **OFF**, and nothing is connected to the instrument.

(2) Check the **110/220** V power voltage switch located in the back panel of the instrument. Normally, this switch is set for 110 V operation (American) and 220 V (European). Change the position of this switch if necessary.

WARNING: Before you change the position of the **110/220 V** switch, the

POWER switch must be set to **OFF**.

(3) Attach the power cord to the back panel of the instrument. This is a standard cable with HP type plug on one end (the instrument end) and American, British or European plug on the other end.

(4) Attach the coaxial cables marked *C1, C2,* and *C3* to the coresponding BNC sockets **C1, C2**, and **C3** on the front panel of the potentiostat and the side panel of the Faraday Cage.

Note: These connections must be made even if only using dummy cell. RCR '06

(5) Attach the multiconductor data communication cable with standard DB-25 connectors to the coresponding DB-25 female socket **I/O** on the back panel of the potentiostat and DB-25 male socket on the side panel of the Faraday Cage.

(6) Attach the supply cable with 7-pin audio connectors to the **SPLY** socket on the back panel of the potentiostat and to the coresponding socket on the side panel of the Faraday Cage.

(7) Set the **CELL** switch to the **OFF** position. In this position, a **DUMMY** cell (1 kohm internal resistor) simulating the electrochemical cell is connected to the inputs of the potentiostat circuitry.

(8) Set the **MODE** switch to the **PS** position (potentiostat).

(9) Set the **PROGRAM** switcheto the **OFF** position. This will supply zero Volts to the potential program preamplifier.

(10) Set the current **RANGE** rotary switch to **1 mA**. You will always use this range with dummy cell since the internal dummy cell resistor is 1 kohm. This means that for the potential changes in the range from -1 V to +1 V, the current flowing through this resistor would be from -1 mA to +1 mA (i.e. from -100% to +100% of the nominal current range).

(11) Set the **IR COMP.** SWITCH to **OFF.**

(12) Connect the **I-OUT** BNC socket to the input of an analog recorder or a data acquisition system (if you are using our DAQ-616 Data Conversion Card and DAQ-617 Break-up Box, plug the BNC connector marked *I* to the **I-OUT** BNC socket in the potentiostat).

(13) Connect the **E-OUT** BNC socket to the input of an analog recorder or a data acquisition system (if you are using our DAQ-616 Data Conversion Card and DAQ-617 Break-up Box, plug the BNC connector marked *E* to the **E-OUT** BNC socket in the potentiostat).

(14) Connect BNC socket marked **PROGRAM-IN** to the output of a function generator. The program waveform should be within +1000 mV to -1000 mV. (If you are using DAQ-616/DAQ-617 Data Acquisition, the waveform may be supplied by the computer. In this case, connect the BNC connector marked *P* (for: PROGRAM) to the BNC socket for **PROGRAM-IN** input on the front panel of the potentiostat. Follow instructions of the VOLTSCAN Version 3.7 manual.)

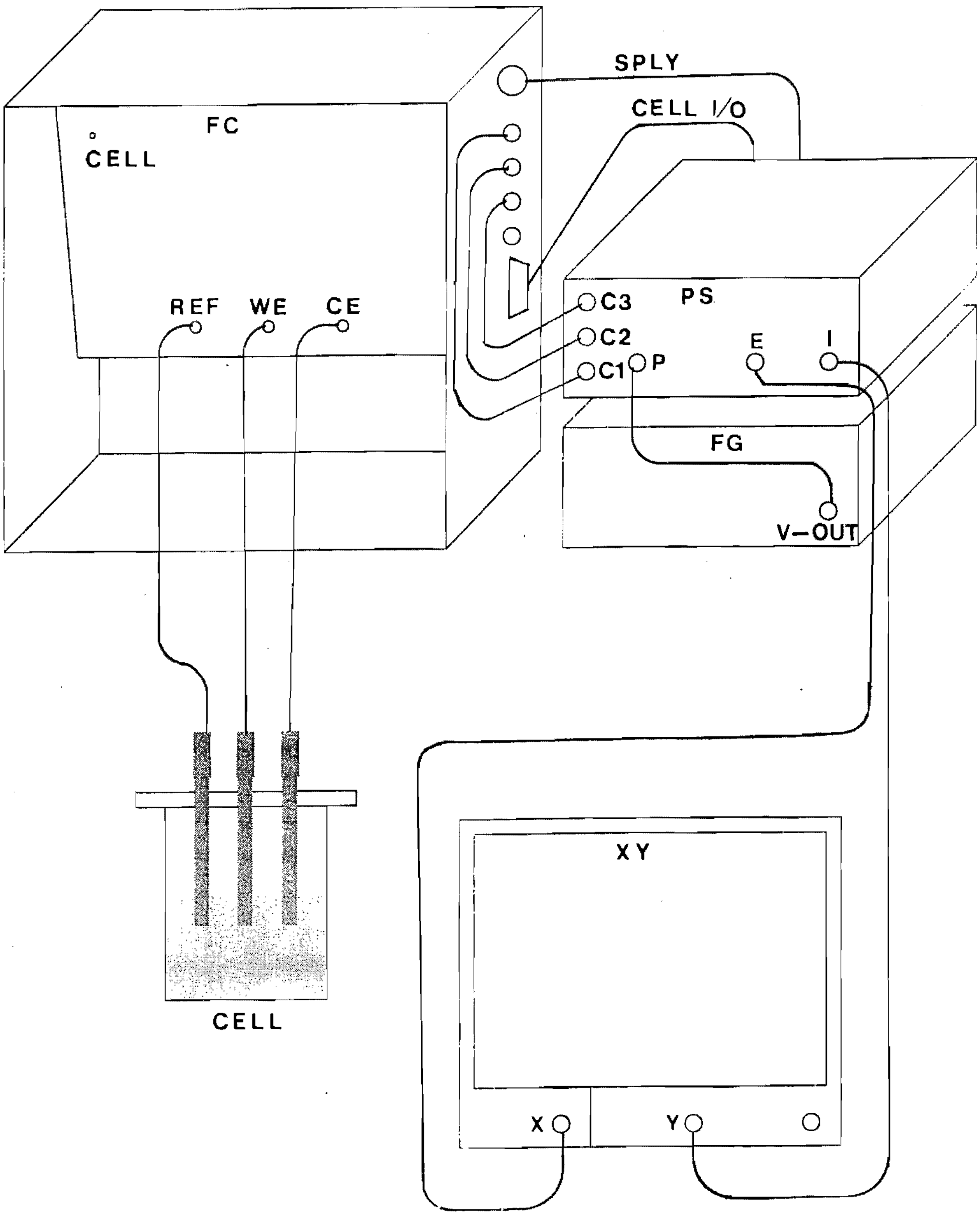

FIGURE 5*a*. Schematic diagram of an experimental set-up showing external connections to the Potentiostat Model PS−705. The potential (**E**) and current (**I**) outputs of the Potentiostat (**PS**) are connected to an XY-recorder (**XY**). The program input (**P**) is connected to the output (**V-OUT**) of a Waveform Generator **FG** (*e.g.*, Model FG-206F). Other symbols: **REF** - Reference Electrode, **WE** - Working Electrode, **CE** - Counter Electrode, **SPLY** - DC power supply cable, **C1, C2, C3** - BNC coaxial cable connections.

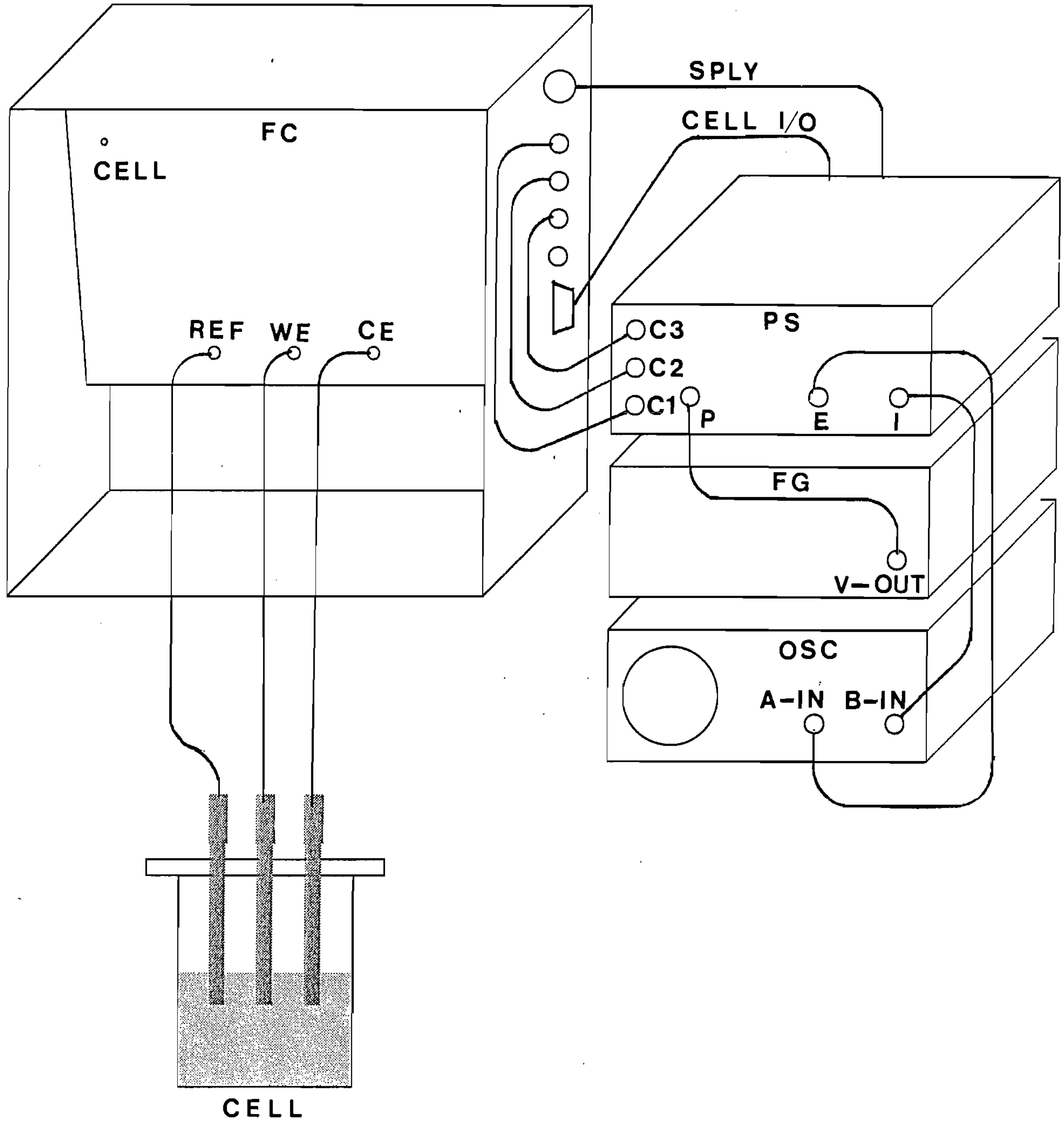

FIGURE 5*b*. Schematic diagram of an experimental set-up showing external connections to the Potentiostat Model PS—705 controlled by a Program Waveform Generator (*e.g.* Model FG-506) and a Digital Oscilloscope (*e.g.* OSC-T22). The potential (**E**) and current (**I**) outputs of the Potentiostat are connected to the inputs of channels A and B, respectively, of the oscilloscope. The program input (**P**) is connected to the output (**V-OUT**) of a Waveform Generator. Other symbols: **PS** - Potentiostat, **FC** - Faraday Cage, **FG** - Waveform Generator, **OSC** - oscilloscope, **REF** - Reference Electrode, **WE** - Working Electrode, **CE** - Counter Electrode, **SPLY** - DC power supply cable, **C1, C2, C3** - BNC coaxial cable connections.

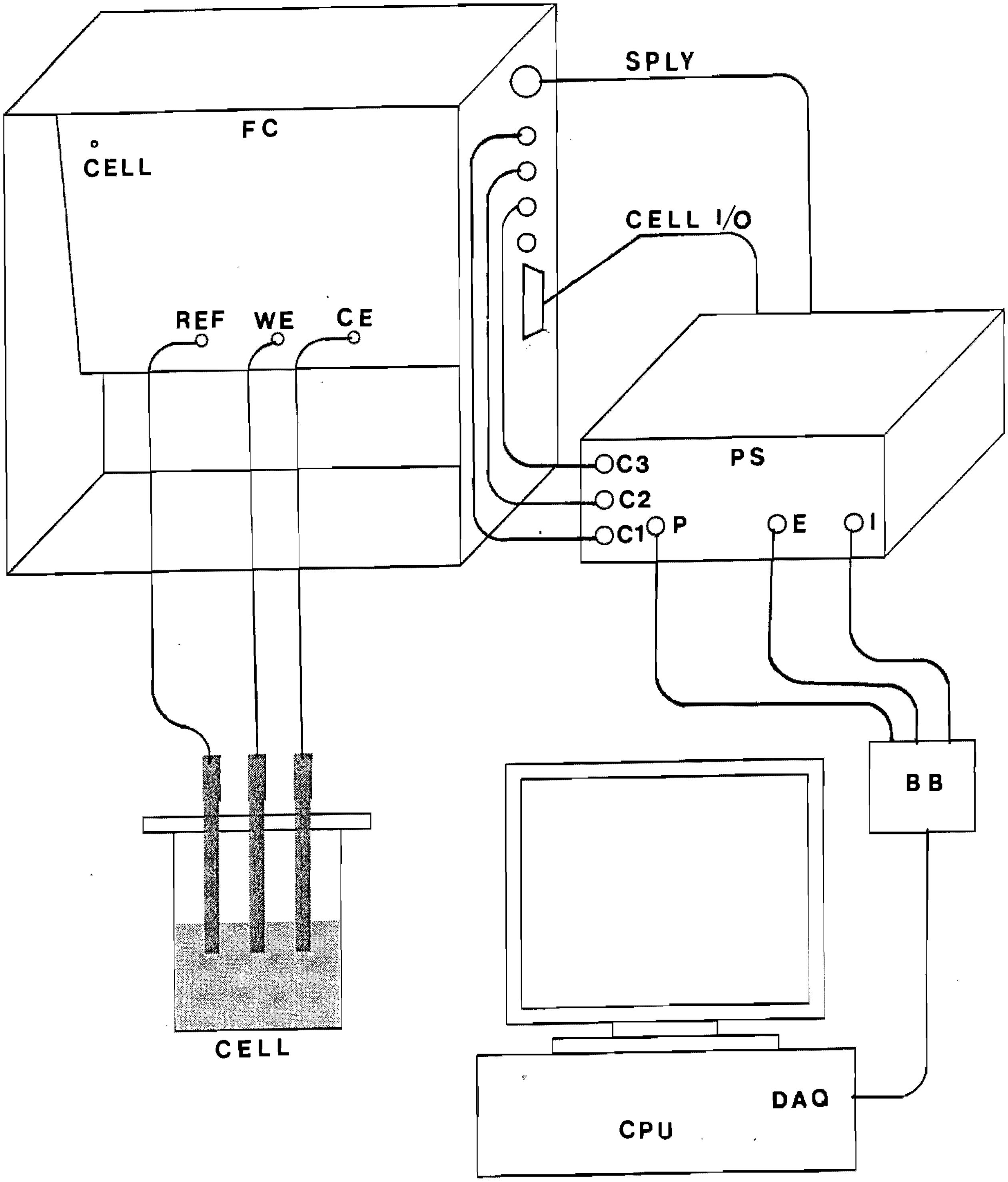

FIGURE 5*c*. Schematic diagram of a computerized experimental set-up showing external connections to the Potentiostat Model PS–705. The potential (**E**) and current (**I**) outputs of the Potentiostat are connected to a Data Acquisition Card **DAQ** (*e.g.* DAQ-616) through a Break-up Box **BB** (DAQ-617). The program input (**P**) is connected to the output of a Digital-to-Analog Converter which is a standard feature of the DAQ-616 system. Other symbols: **PS** Potentiostat, **FC** - Faraday Cage, **CPU** - microcomputer, **REF** - Reference Electrode, **WE** - Working Electrode, **CE** - Counter Electrode, **SPLY** - DC power supply cable, **C1, C2, C3** - BNC coaxial cable connections. (Note that unused inputs to the DAQ-616 should be shorted).

5.3 Power-on checks

(15) Set the potential channel sensitivity on your recorder to **2 V** FS (full scale) and the current channel sensitivity also to **2 V** FS. Position the recorder pen in the center of the chart using recorder Zero Offsets.

(16) Turn the **POWER** switch in the potentiostat to **ON** (position **1**).

(17) Turn the POWER to the recorder ON.

(18) On the potentiostat, panel meters should show now zero.

(19) Turn the function generator ON and set the **PROGRAM** toggle switch on the potentiostat to the **ON** position. The panel meters should show the same reading, e.g.: if the applied potential (i.e. the voltage supplied to the PROGRAM input) is +500 mV, the CURRENT panel meter should show 0.500 mA. (From the Ohm's law: 0.500 mA x 1,000 ohm = 500 mV potential drop across 1 kohm dummy cell resistor.) At the same time, the voltage output to the recorder on potential channel should be +500 mV, and on current channel should be +500 mV.
Note that for fast changing potential and current values, front panel meters may not show actual values because of the slow update rate.

(20) Turn the **PROGRAM** input toggle switch to **OFF**.
Turn the **CELL** switch to **OFF**.
Turn the **CONTROL** switch to **OFF**.
Turn the **POWER** switch to **OFF** (position **0**). Turn the recorder and the function generator OFF.

This completes the initial checking procedure.

5.4. Test experiment with external cell ON

You are now ready to use the potentiostat for measurements. If you want to perform a simple checking experiment, you can use, for example, a 10 mM copper(II) solution in 0.1 M HNO_3. Program your waveform generator for sweep from +500 mV vs. SCE to 0 mV and back to +500 mV. If you are using DAQ-616 Data Acquisition System and VOLTSCAN 3.0 real-time data acquisition software, start VOLTSCAN by typing: **vv [ENTER]**, enter password if any, and go to **PARAMETERS** table. Set:

E1 = 500 mV,	t1 = 0,	v1 = 100 mV/s,
E2 = 0 mV,	t2 = 0,	v2 = 100 mV/s,
E3 = 500 mV,	t3 = 0,	v3 = 100 mV/s,
E4 = 500 mV		
SCANS: 3		

Potentials assume Ag/AgCl ref.

and VOLTSCAN will provide you with the PROGRAM wave you need in your experiments.

Now, follow the important steps:

(1) Check if the ***reference electrode*** is placed in the solution and connected to the orange tip banana jack, marked **REF**, on the internal panel of the Faraday Cage.

(2) Check if the ***counter electrode*** is placed in the solution and connected to the red tip banana jack, marked **CE**, on the internal panel of the Faraday Cage.

(3) Check if the ***working electrode*** is placed in the solution and connected to the green tip banana jack, marked **WE**, on the internal panel of the Faraday Cage.

(4) Set the current **RANGE** on the potentiostat to **1 mA** FS.

(5) Set the **SPEED** switch to the position 2 or 3.

(6) Switch the **CONTROL** toggle to the **ON** position.

(7) Apply an appropriate potential (the *conditioning potential*) to the program input

P-IN from your waveform generator or D/A converter. Set the **PROGRAM** toggle switch to the ON position.

(8) Set the **CELL** switch on your potentiostat to the **ON (EXTERNAL** cell) position.

(9) Initiate the potential scan. (If you are using our automated data acquisition system with VOLTSCAN 2 or 3, follow the instructions supplied in the VOLTSCAN manual).

(10) Change carefully the cathodic potential limit to more negative value until copper deposition just begins to take place. On the voltammogram you should be able to observe an increase of the anodic peak due to the copper stripping.

(11) After you finish all experiments, set:

CONTROL OFF
CELL OFF

and then:

PROGRAM OFF

(12) Turn the **POWER** to the instrument **OFF**.

6. ELECTRICAL CIRCUITS

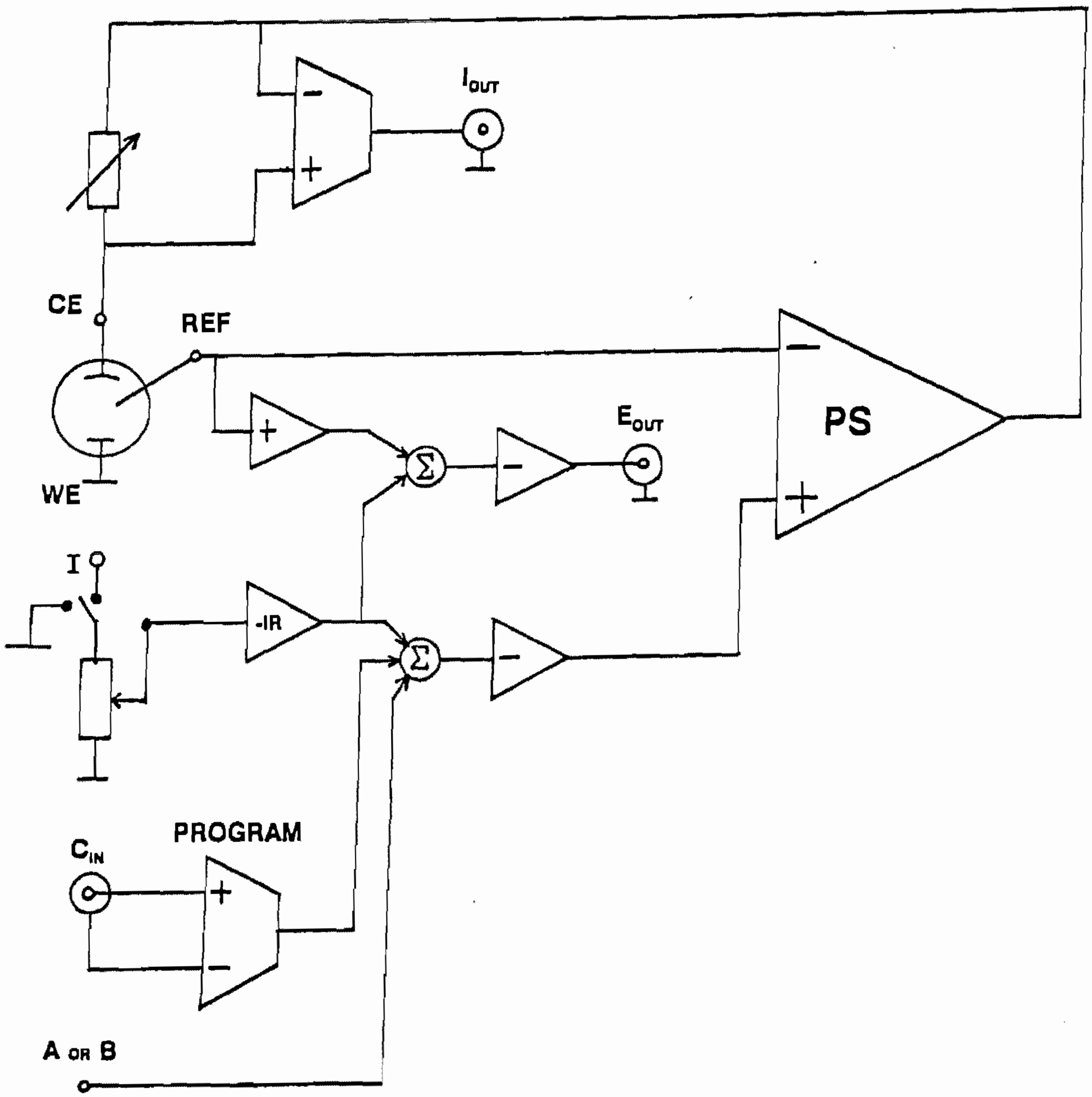

FIGURE 6. Simplified block diagram of an electronic circuit of a Potentiostat, Model PS-705. **PS** - main control amplifier, **WE** - Working Electrode, **CE** - Counter Electrode, **REF** - Reference Electrode, **PROGRAM** - program waveform amplifier.

7. SERVICING NOTES

In case of malfunction of the Potentiostat, Model PS-705, the unit may be returned to the factory for service. It should be returned postpaid. Since the equipment is guaranteed for one year, no charges for repair will be made for time and materials. The guarantee does not cover misuse of the Model PS-705 or damage due to improper handling or service. Before shipping the instrument, contact your local dealer or the factory:

ELCHEMA
Customer Service
P.O. Box 5067
Potsdam, NY 13676
FAX: (315) 268-1709
Tel.: (315) 268-1605

to receive the claim number.

WARRANTY

All our products are warranted against defects in material and workmanship for one year from the date of shipment. Our obligation is limited to repairing or replacing products which prove to be defective during the warranty period. We are not liable for direct, indirect, special, incidental, consequential, or punitive damages of any kind from any cause arising out of the sale, installation, service, or use of our instrumentation.

All products manufactured by ELCHEMA Company are thoroughly tested and inspected before shipment. If ELCHEMA receives notice from the Buyer of any defects during the warranty period, ELCHEMA shall, at its option, either repair or replace hardware products which prove to be defective.

Limitation of Warranty

A. The Warranty shall not apply to defects resulting from:
   1. Improper or inadequate maintenance by Buyer;
   2. Unauthorized modification or misuse;
   3. Operation in corrosive environment (including vapors, solids, and aggressive solvents);
   4. Operation outside the environmental specification of the product;
   5. Improper site preparation and maintenance.

B. In the case of instruments not manufactured by ELCHEMA, the warranty of the original manufacturer applies.

C. Expendable items, including but not limited to: glass items, reference electrodes, valves, seals, solutions, fuses, light sources, O-rings, gaskets, and filters are excluded from warranty.

THE WARRANTY SET FORTH IS EXCLUSIVE AND NO OTHER WARRANTY, WHETHER WRITTEN OR ORAL, IS EXPRESSED OR IMPLIED. ELCHEMA SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

For assistance of any kind, including help with instruments under warranty, contact you ELCHEMA field office of instructions. Give full details of the difficulty and include the instrument model and serial numbers. Service date and shipping instructions will be promptly sent to you. There will be no charges for repairs of instruments under warranty, except transportation charges. Estimates of charges for non-warranty or other service work will always be supplied, if requested, before work begins.

CLAIM FOR DAMAGE IN SHIPMENT

Your instrument should be inspected and tested as soon as it is received. The instrument is insured for safe delivery. If the instrument is damaged in any way or fails to operate properly, file a claim with the carrier or, if insured separately, with the insurance company.

SHIPPING THE INSTRUMENT FOR WARRANTY REPAIR

On receipt of shipping instructions, forward the instrument prepaid to the destination indicated. You may use the original shipping carton or any strong container. Wrap the instrument in heavy paper or a plastic bag and surround it with three or four inches of shock-absorbing material to cushion it firmly and prevent movement inside the container.

GENERAL

Your ELCHEMA field office is ready to assist you in any situation, and you are always welcome to get directly in touch with the ELCHEMA Service Department:

ELCHEMA
Customer Support
P.O. Box 5067
Potsdam, NY 13676
Tel.: (315) 268-1605
FAX: (315) 268-1709