SUBMERSIBLE-MOUNTED ELECTRO-SAMPLER

FOR USE IN FRESH WATER

OPERATING MANUAL

HARBOR BRANCH FOUNDATION TECHNICAL REPORT #56

BY

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MAY 20, 1985

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1.0 INTRODUCTION

The 1985 Michigan State University Lamprey Sampling Program in Lake Superior requires that the JOHNSON-SEA-LINK be equipped with a custom electro-sampler. The plan is to tease larval lampreys out of their burrows, stun them with an electric shock, and then capture the immobilized lamprey with a suction pump. Portable systems, developed by the U.S. Fish and Wildlife Service (USFWS) for use in streams, have provided a baseline for establishing system requirements, and the design, described below, is similar to those described by Don Allen.[1]

A FEW WORDS OF WARNING ARE IN ORDER CONCERNING THE SAFE OPERATION OF THIS SYSTEM: THE VOLTAGE AND CURRENT SUPPLIED BY THE ELECTRO-SAMPLER ARE SUFFICIENT TO CAUSE A FATAL ELECTRIC SHOCK. THE SYSTEM MUST NOT BE OPERATED IF THERE IS A DIVER OR SWIMMER IN THE VICINITY!

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[1] Allen, Donald H. Mark I and Mark II Electrofishing Units, Internal Report No. 83-7, U.S. Fish and Wildlife Service, February 1983.

2.0 SYSTEM DESCRIPTION

2.1 OVERVIEW

The planned operation of the electro-sampler requires that it be easily mounted on the JOHNSON-SEA-LINK submersible and convenient to use by the scientist riding in the sphere. As a research tool, the system must have a wide range of controls, so that the scientist can experimentally determine the optimum configuration for collecting the fish to be studied (primarily larval lampreys - but possibly other animal during later experiments). The lamprey-shocking electrodes are mounted on the JOHNSON-SEA-LINK manipulator so that a large area ahead of the submersible can be "swept". Most of the electronics are contained in a pressure housing near the manipulator support, and are connected to a small control box in the sphere. The interconnections of the system are shown in Figure 1.

2.2 SPECIFICATIONS

2.2.1 PULSE GENERATOR

Waveform	= Pulsed DC
Maximum Electrode Voltage	= 140 Volts
Maximum Electrode Current	= 2.2 Amps
Pulse Shape	= Rectangular
Rise and Fall Time	$\leq$ 1 μsec
Duty Cycle	= 25% (fixed)
*Pulse Rate (tease mode)	= 1, 3, 5, or 7 pps
*Pulse Rate (stun mode)	= 20 to 80 pps (continuously variable)
*Power Control	= ON/OFF (when ON, in tease mode)
*Level Control	= 0 to 2 Amps (continuously variable)
*Stun Control	= Push-button (when depressed, switches to stun mode)
*Monitor	= Peak Electrode Voltage or Current

2.2.2 POWER REQUIREMENTS

Voltage	= 22 to 32 V dc
Current	= 5 Amps (Average)
	= 15 Amps (Peak)

*Controls are located in hand-held control box within sphere.

2.2.3 MECHANICAL

Maximum Operating Depth	= 3,000 ft.
*Weight Electronic Housing	= 34 lb (in air)
	= 8 lb (in water)
**Weight Electrode Array	= 25 lb (in air)
	= 1 lb (in water)
Size Electronic Housing	= 6.7" diameter x 20" long
***Size Electrode Array	= 4" x 28" x 31"

*Including cabling
**Including Suction Nozzle
***Refer to Figure 6.

3.0 POWER ELECTRONICS

A wiring diagram of the power electronics is given in Figure 2 (C-551-272), and photographs of the assembly in Figures 3 and 4. Input power, at 28V dc, is supplied, through a two-pin male E.O. connector, (J1) and a polarity-protection diode, to a power inverter and a small DC/DC converter. The DC/DC converter provides 12-Volt control power to the electronics in the pressure housing, and also to the control electronics within the sphere (Inter-connection is made via a six-conductor cable).

Power for the pulse generator is supplied by a 250 Volt-Amp, 400 Hz, lightweight, static inverter. The output voltage of the inverter is regulated to 115 V rms within $\pm$ 1%, is full-wave rectified, and the resulting 160 Volts dc is filtered by the two parallel 80 μf capacitors (refer to Figure 2). The series five-ohm resistor serves as a surge-current limiter and provides the means to monitor the electrode current. ON/OFF control of the inverter is provided (in a fail-safe way) from the sphere control box.

The electrode current (connection is made via a universal E.O. connector J2) is controlled by a linear modulator, comprised of the four parallel enhancement-mode FETs (Field-Effect Transistors). The FETs are operated conservatively with respect to their voltage, current and power ratings:

RFK 10 N 50	MAXIMUM OPERATING	RATED
Peak Voltage	160 V	500 V
Peak Current	0.55 A	1.0 A (@ 150 V and dc operation)
Average Power	22 W	150 W

Transient voltage protection is provided by the 200 volt Zener Diode in parallel with the FETs. Limiting of the peak current which can flow through each FET is furnished by the resistors in series with the FET source terminals. Damping of high-frequency oscillations is effected by the shielding beads in series with the gate leads.

The FET control signal is a rectangular voltage pulse, generated within the control box inside the sphere (refer to the next section for a description). Normally the control voltage is zero and the FETs are biased off. A positive control voltage of 3 volts or greater will start to turn on the FETs, and progressively higher voltage will increase the electrode current, up to the point where the supply voltage or the electrode resistance limits the current. Linear current modulation allows the shocker to drive a low resistance load gracefully (a short circuit is OK).

Measurement of electrode voltage is accomplished with a conventional, differential-input instrumentation amplifier using a LM-324 integrated amplifier. The differential electrode voltage is scaled, filtered, and transmitted to the control box to provide a monitor of the peak electrode voltage.

IMPORTANT NOTE!

THE OUTPUT VOLTAGE AND CURRENT OF THE SHOCKER ELECTRONICS ARE CAPABLE OF DELIVERING A FATAL ELECTRICAL SHOCK. DO NOT OPERATE WHEN THERE IS A SWIMMER IN THE VICINITY OF THE ELECTRODES. DO NOT OPERATE WHEN THERE IS A POSSIBILITY OF ANYONE COMING IN CONTACT WITH THE OUTPUT CONNECTIONS OR ELECTRODES!

4.0 CONTROL ELECTRONICS

All controls for the electro-sampler are contained in the control box; these include:

ON/OFF - System Power Switch; when OFF, the Power Inverter is disabled. When ON, the system is in the TEASE mode.

LEVEL CONTROL - Amplitude of drive signal to FETs; in minimum position the FETs are off. Clockwise rotation increases the peak electrode current to a maximum of 2 Amps.

TEASE RATE - Selectable: 1, 3, 5, or 7 pps

STUN RATE - Adjustable: 20 to 80 pps

PUSH TO STUN - Push Button Switch; when depressed, the system switches from the TEASE mode to the STUN mode, for the time the button is depressed.

MONITOR - Switch and Meter; In the "I" position, the meter indicates the peak electrode current and in the "V" position the meter indicates the peak electrode voltage (multiply meter reading by 30 to obtain volts).

A wiring diagram of the control electronics is given in Figure 5. Power is supplied from the shocker electronics on pins A and B (12 V) through a polarity protection diode and the ON/OFF switch. A fusable resistor, in turn, supplies turn-on power to the power inverter. The

shocker pulse rate is controlled by a CMOS, CD-4047B Multivibrator* oscillator whose frequency is set by the TEASE RATE and STUN RATE controls. The 25%-duty-cycle drive waveform is generated by summing the multivibrator square-wave output (OSC) and divide-by-two output ($\bar{Q}$) with a 2N2222 bipolar transistor (this effects a logical AND function). Level control of the FET drive signal is provided by the 500 ohm potentiometer and the 2N2222 emitter follower.

Current or voltage monitoring is provided by the analog meter and DPDT switch.

*Refer to RCA CMOS Integrated Circuits DATABOOK for design details.

5.0 ELECTRODES

The electrodes are mounted on the JOHNSON-SEA-LINK manipulator so that they can be swept from side-to-side, a few inches above the bottom. A photograph of the array is given in Figure 6. The electrode resistance can be estimated from the following equation, which was derived for a "long" parallel-wire transmission line:

$$R = \frac{\rho \ln (2s/d)}{\pi \ell} \text{ Ohms}$$

where:

ρ = water resistivity (assume 7.7 Ohm-cm based on a water conductivity of 130 μmho/cm)

s = electrode spacing (24" for the present assembly)

d = electrode diameter (3" for the present assembly)

ℓ = electrode length (30" or 76 cm for the present assembly)

Therefore $R \simeq 89$ Ohms

Fringing, at the ends of the electrodes, will reduce the electrode resistance. In addition, the electrode geometry may be altered to increase current penetration into the bottom. In the photograph of Figure 6, a single insulating divider is shown; it can be moved, eliminated, or replaced with a pair of current-shaping vanes. Current shaping will generally increase the electrode resistance. To lower the resistance, it is possible to reduce the electrode separation, or increase their diameter.

6.0 MECHANICAL DESIGN

6.1 SHOCKER ELECTRONICS PRESSURE VESSEL

The housing for the shocker electronics is adapted from a proven design and is constructed of 6061-T6 aluminum. The removable end cap is sealed with a double o-ring seal for reliability. The complete assembly* is shown in Figure 7. The housing has been leak and pressure tested to 3,250 feet of water.

6.2 ELECTRODE ASSEMBLY

The electrode assembly is designed to be approximately neutrally buoyant in water; the two electrodes are sealed, schedule-40 aluminum pipe. The configuration of the electrodes (forward electrode positive, and insulator between negative electrode and manipulator) is designed to minimize electrolysis and corrosion.

6.3 SUCTION NOZZLE

An essential feature of the system is to collect the lampreys after they have been electrically stupefied. This is accomplished by mounting a narrow mouth funnel on the edge of the electrode array and using a suction pump to draw the lamprey into plexiglas sample containers.[2]

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*Refer to Drawing D-673-025

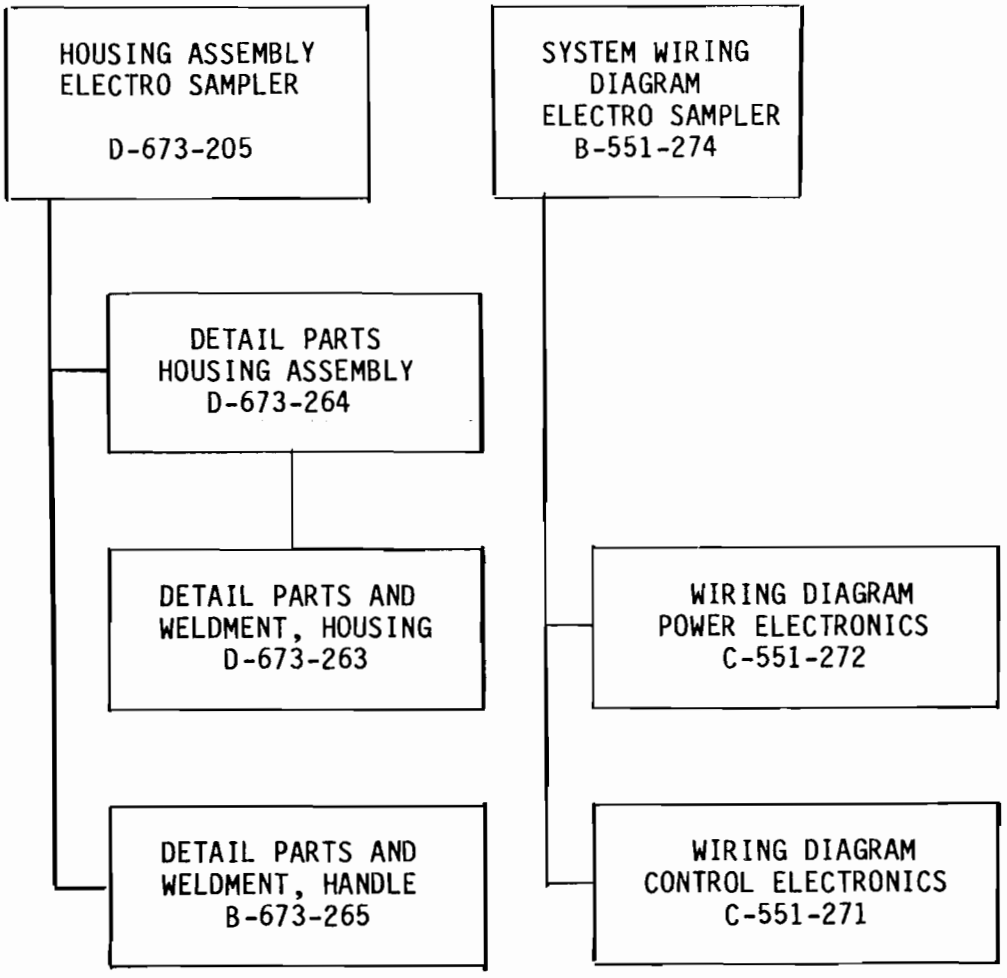
[2]Askew, Timothy M., Submersibles for Science - JOHNSON-SEA-LINK I & II, Proceedings of OCEANS '84, IEEE 1984.

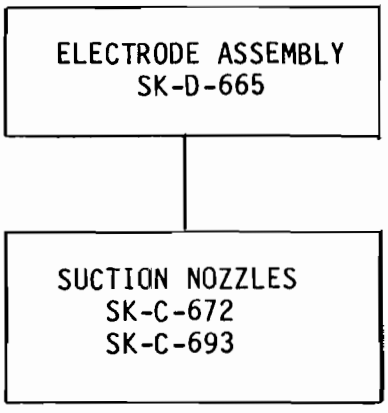
7.0 MAINTENANCE

Little maintenance of the system is expected to be required. Corrosion products may collect on the positive electrode; if so, the electrode should be lightly sanded. Connections to the electrodes may deteriorate with time since they necessarily involve mixed metals.

If the shocker electronics is opened for any reason, fresh desiccant should be installed.

8.0 DRAWINGS


HOUSING ASSEMBLY
ELECTRO SAMPLER
D-673-205
SYSTEM WIRING
DIAGRAM
ELECTRO SAMPLER
B-551-274
DETAIL PARTS
HOUSING ASSEMBLY
D-673-264
DETAIL PARTS AND
WELDMENT, HOUSING
D-673-263
DETAIL PARTS AND
WELDMENT, HANDLE
B-673-265
WIRING DIAGRAM
POWER ELECTRONICS
C-551-272
WIRING DIAGRAM
CONTROL ELECTRONICS
C-551-271


ELECTRODE ASSEMBLY
SK-D-665
SUCTION NOZZLES
SK-C-672
SK-C-693

9.0 SPARE PARTS

9.1 Electrodes

(Complete Assembly per SK-D-665)

9.2 Power Electronics (C-551-272)

1. One AI^2 Inverter - Model 2A 250-IC (60 Hz rather than 400 Hz)
2. Four Power FETs - RCA - RFK-10-N50
3. One Power Rectifier - IN - 1190R
4. One Bridge Rectifier - Motorola, MDA-970A6
5. One Power Zener - IN - 3015A
6. Two 9.1 V Zeners - IN - 757A
7. One Filter Capacitor - 80 μf, 450 V
8. One Resistor - 5 Ohm, 50 watt
9. One DC/DC Converter - Power General No. 478
10. One Integrated Circuit - LM324

C. Control Electronics (C-551-271)

1. One Meter - 0 to 5 mA.
2. One Resistor - 10 Ω, 1/10 Watt
3. One Multivibrator - RCA COS/MOS, CD4047A

D. Mechanical Parts

1. One O-ring - 2-257
2. One O-ring - 2-259
3. One Connector - B 53E2M-1
4. One Connector - B 53F6F-1
5. One Connector - 510E2U-6
6. One Cable - B 51F6M-1 both ends
7. One Cable - 51E1F-1 one end
8. One Cable - 51E1M-1 one end
9. Desiccant
10. One Suction Nozzle per SK-C-693
11. Test Cable

FIGURE LEGEND

1. Electro-Sampler, Interconnection Diagram (Ref. B-551-274)
2. Electro-Sampler, Power Electronics Wiring Diagram (Ref. C-551-272)
3. Electro-Sampler, Power Electronics Overall Assembly
4. Electro-Sampler, Power Electronics Detail Assembly
5. Electro-Sampler, Control Electronics Wiring Diagram (Ref. C-551-271)
6. Electro-Sampler, Electrode Assembly
7. Electro-Sampler, Housing Assembly

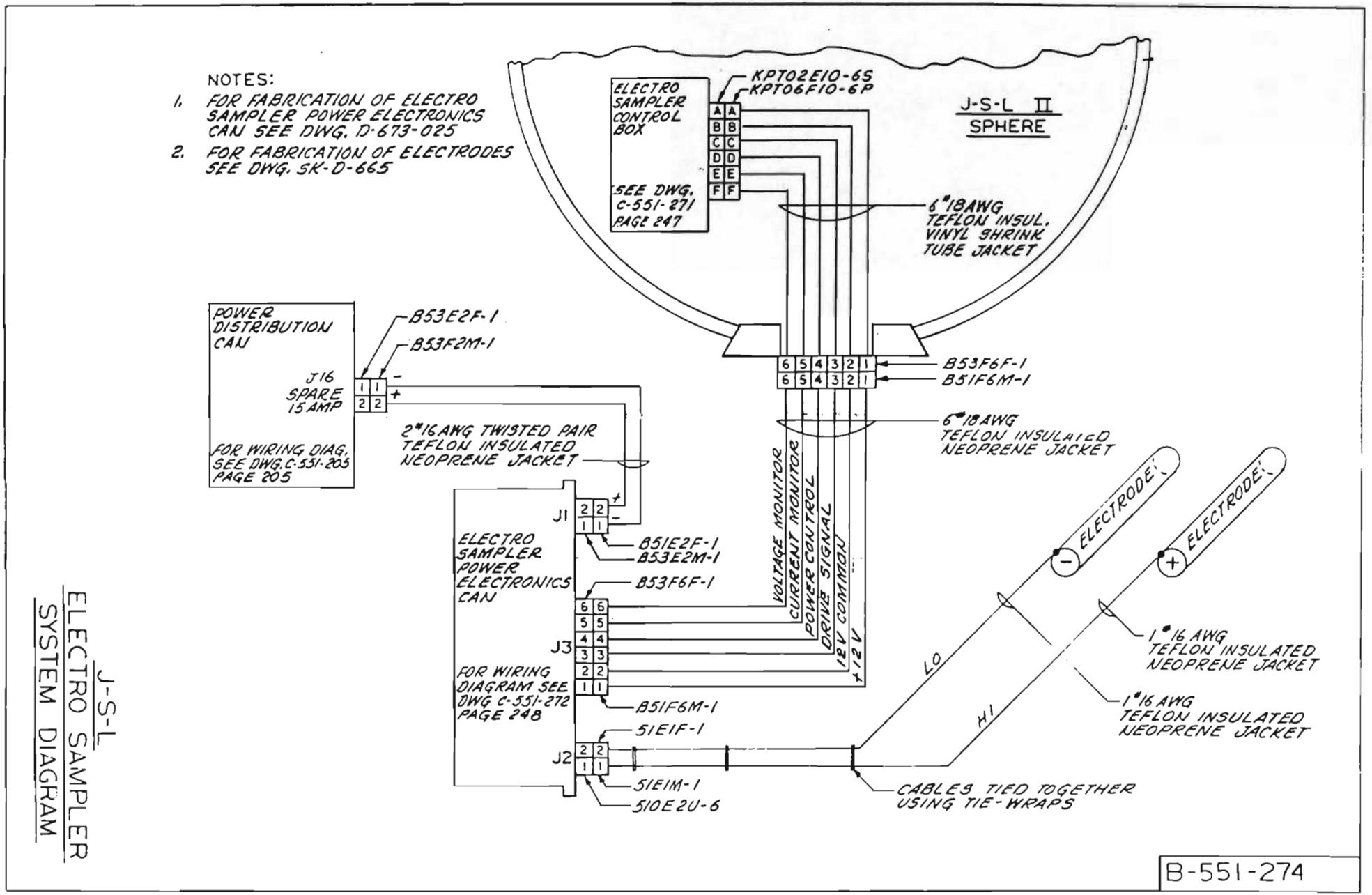


Figure 1. Electro-Sampler, Interconnection Diagram

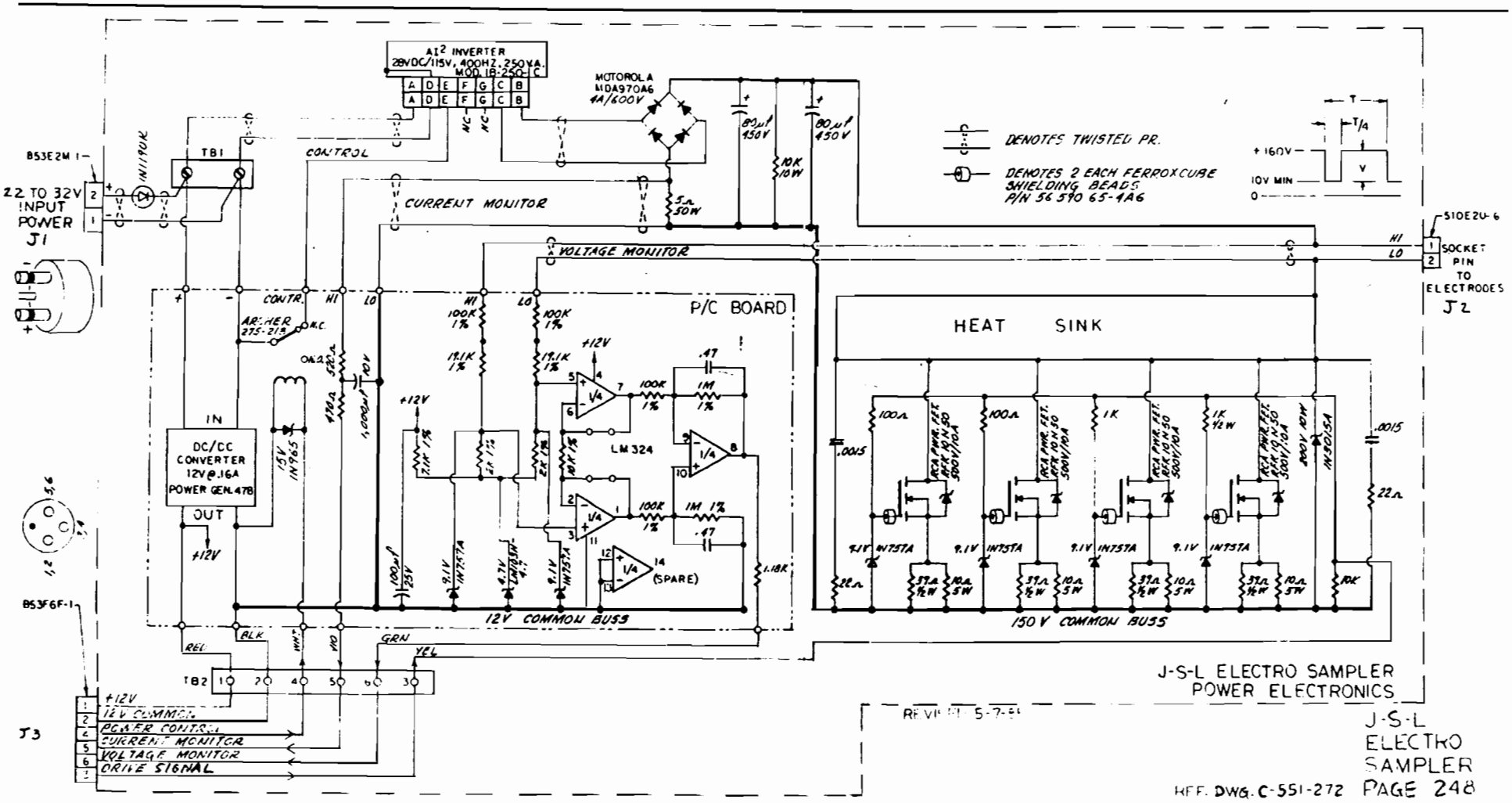


Figure 2. Electro-Sampler, Power Electronics Wiring Diagram

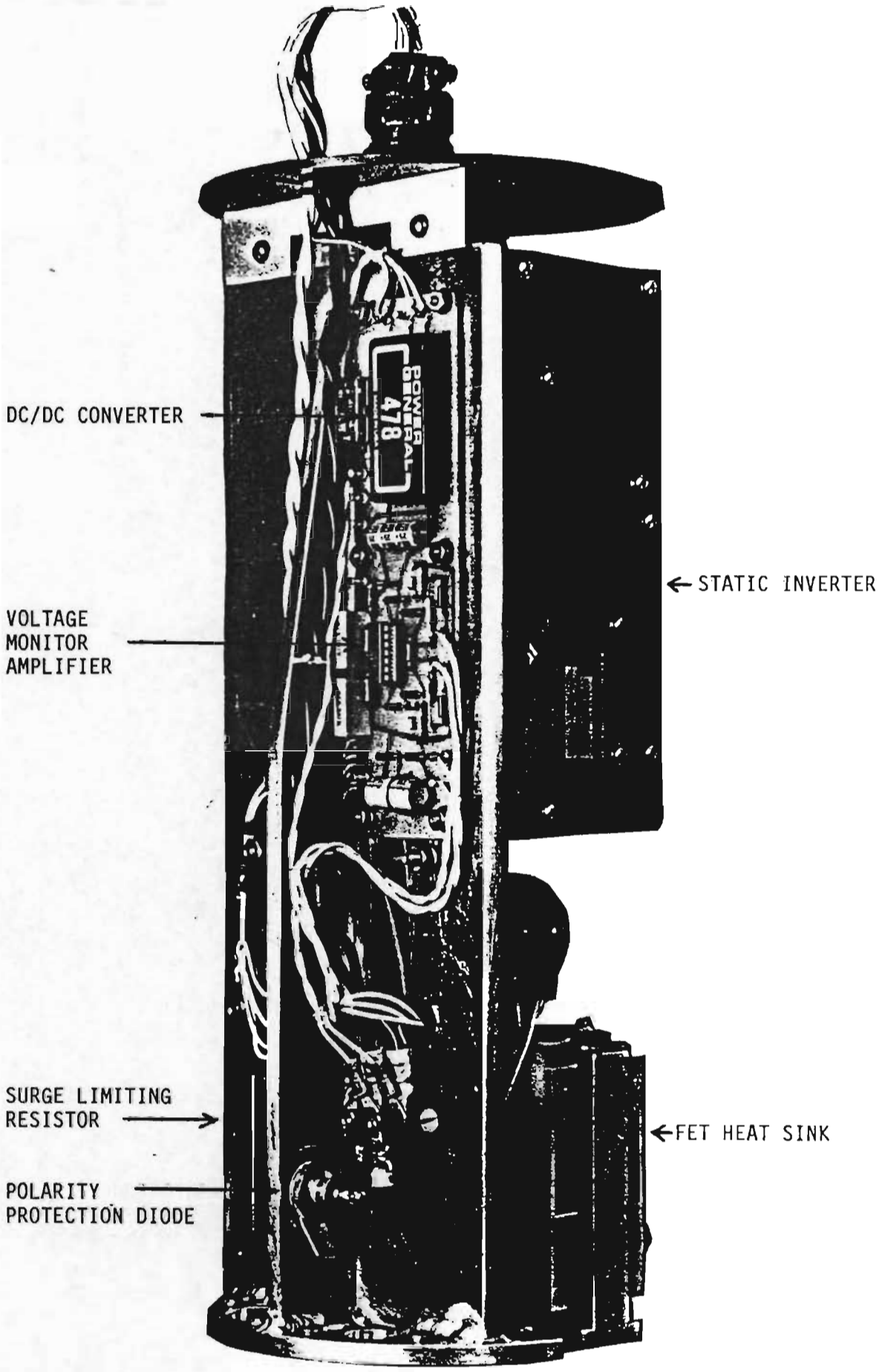


Figure 3. Electro-Sampler, Power Electronics Overall Assembly

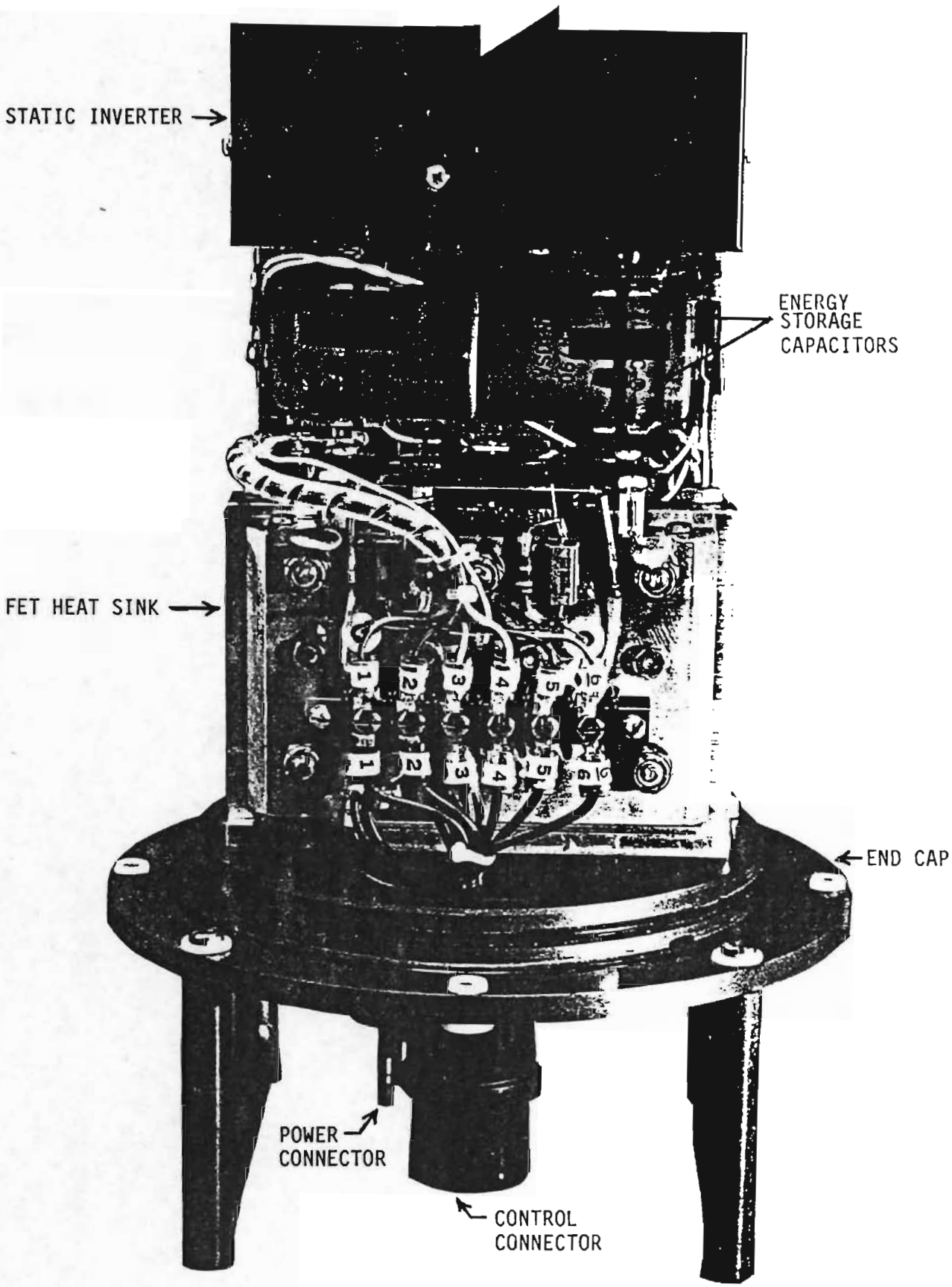
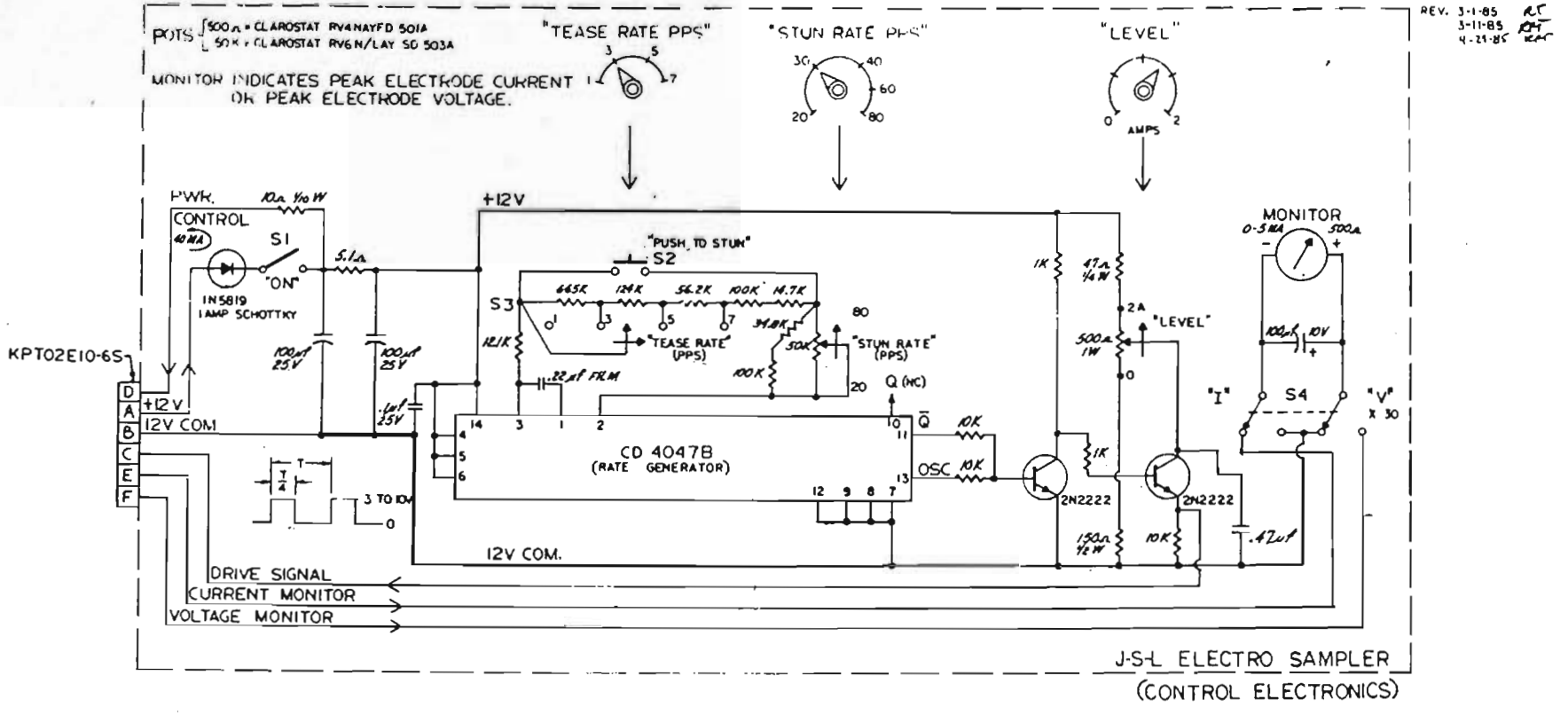


Figure 4. Electro-Sampler, Power Electronics Detail Assembly



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ELECTRO
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REF. DWG. C-551-271 PAGE 247

Figure 5. Electro-Sampler, Control Electronics Wiring Diagram

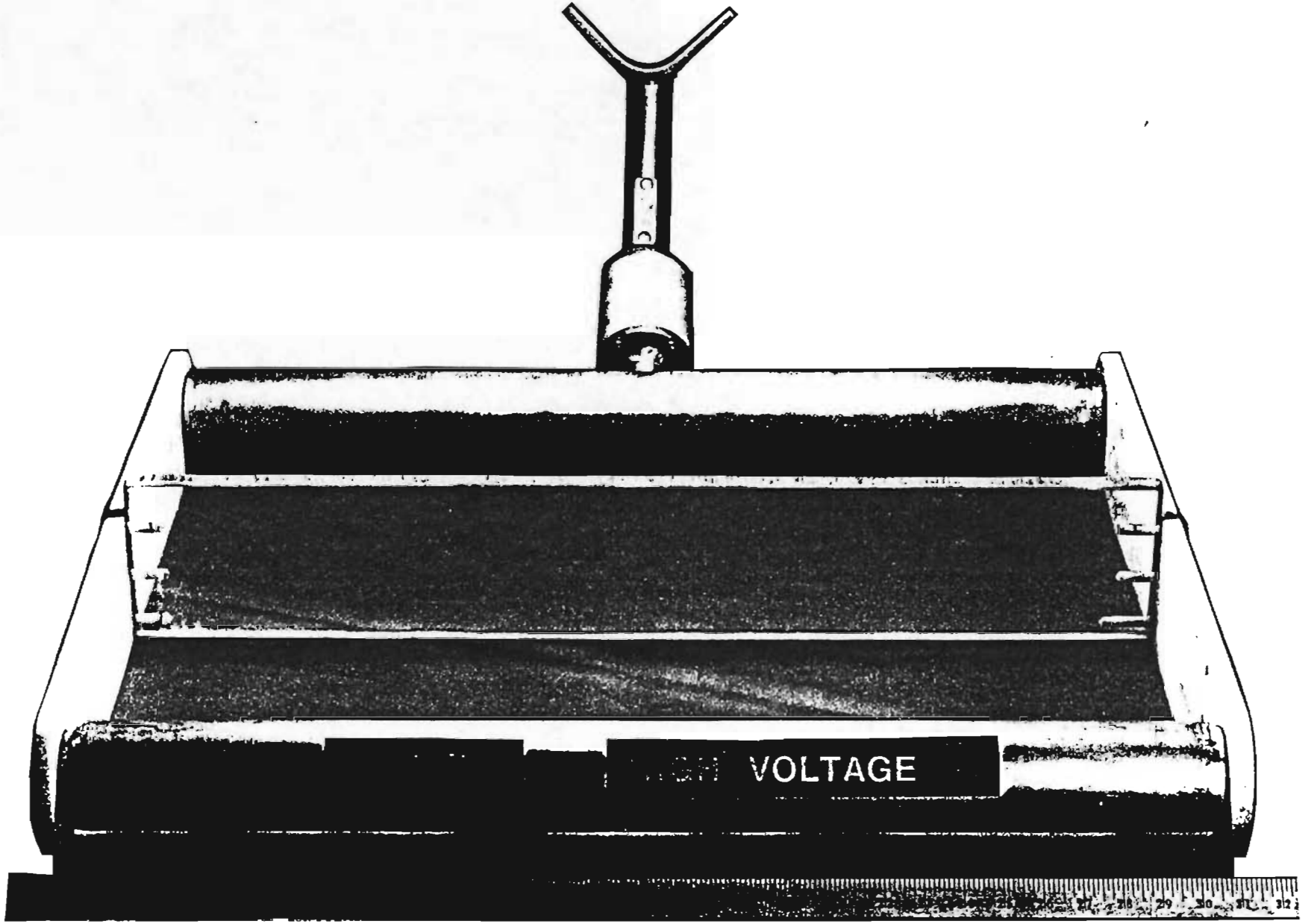

Figure 6. Electro-Sampler, Electrode Assembly

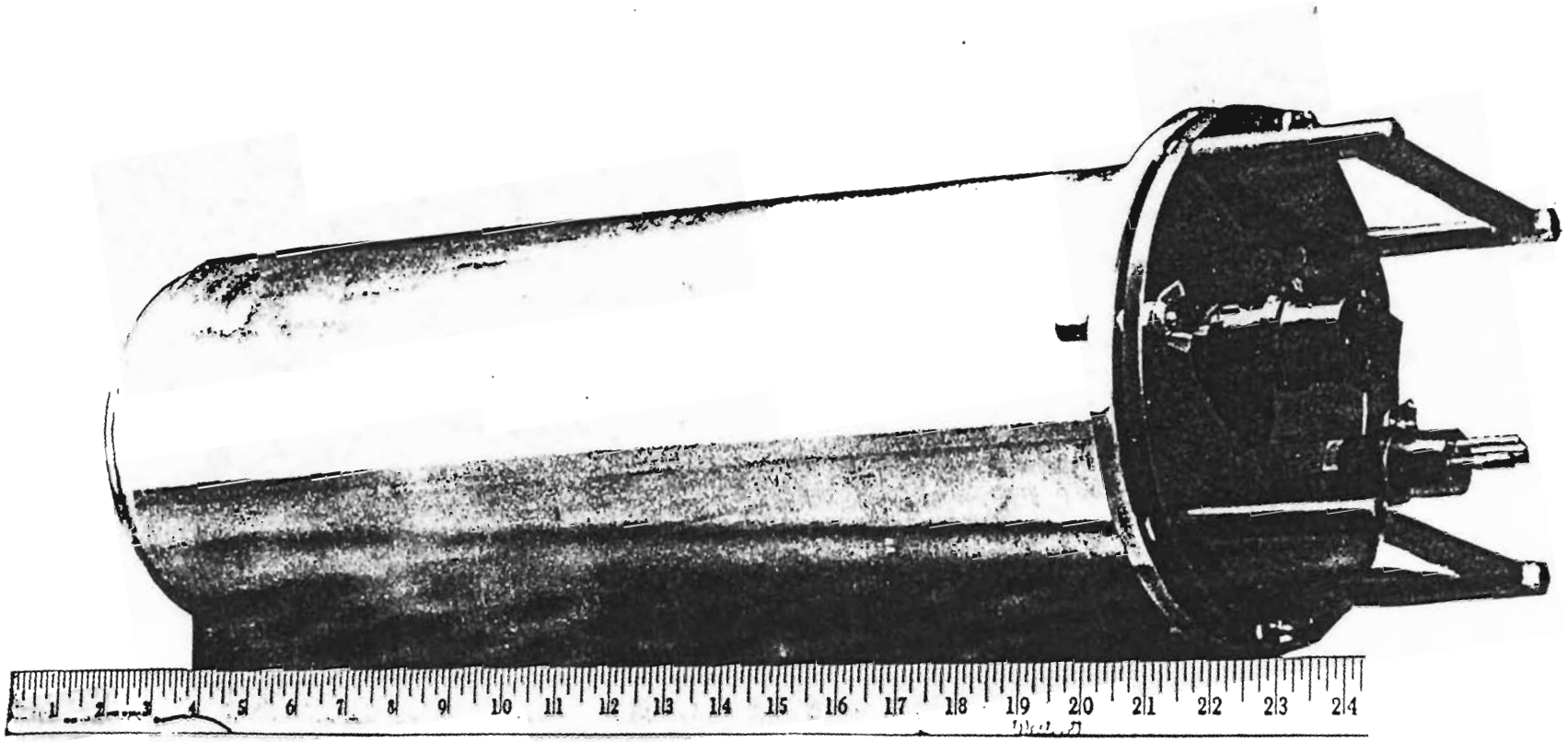

Figure 7. Electro-Sampler, Housing Assembly