A CONTINUOUS WATER-SAMPLING AND MULTIPARAMETER-MEASUREMENT SYSTEM FOR ESTUARIES

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ABSTRACT

Salinity, temperature, light transmissivity, oxygen saturation, turbidity, pH, pCO_2, and chlorophyll *a* fluorescence of a pumped water sample are continuously measured with a system designed primarily for estuarine studies. Near-surface water from a depth of 2 m is sampled continuously while the vessel is underway or water at depths to 100 m can be collected with an *in situ* pump, in which case the sampling depth and temperature are measured by an *in situ* probe. The system is comprised of commercially available instruments, equipment, and components, and of specialized items designed and fabricated by the authors. Data can be read from digital displays and analog strip-chart recorders. Tables and figures describing specialized items are included.

INTRODUCTION

This report describes the continuous water-sampling and -analysis system used by the U. S. Geological Survey in San Francisco Bay and other estuaries (Fig. 1). This system was specially designed for making measurements in estuaries, which are typically environments with large variations in parameters over relatively small distances. Near-surface water is continuously pumped from a through-hull fitting, and water to a depth of 100 m is delivered by an *in situ* pump. The pumped sample stream is continuously analyzed for salinity, temperature, light transmissivity, oxygen saturation, turbidity, pH, pCO_2, and chlorophyll *a* fluorescence. Temperature and depth measurements are made at the *in situ* pump. Data are continuously displayed on digital meters and recorded on analog charts.

The following text is limited to a brief description of the methods, components, and calibration procedures. When possible, commercially available equipment and instruments were selected for the system, and we refer the reader to the appropriate operation manuals for details (Table 1). Drawings and electrical diagrams of the specialized equipment and electronic circuits designed and fabricated by the authors are presented in the Appendix.

WATER PUMPING SYSTEMS

Water is pumped from a hull fitting located at the bow of the vessel about 2 m below the water line. The flexible-impeller centrifugal pump is located below the water line and within a few feet of the intake. A thermistor probe located in the hull fitting senses the water temperature. This system uses reinforced flexible vinyl tubing and PVC pipe and is capable of discharging over 100-Lpm on deck. Water not used for the measurements is discharged overboard to minimize the flushing time of the tubing (approximately 30 seconds).

The *in situ* pumping system consists of a temperature and depth (T/D) probe attached to a submersible well pump, 100 m of 1-in (ID) polyethylene tubing with electrical conductors, and an electrically driven winch assembly. The pump is constructed of stainless steel and bronze with lexan plastic impellers. Electrical cables for the pump power and T/D probe and a 3/32-in (OD) stainless-steel cable are fastened to the polyethylene tubing with plastic electrical tape. This system uses PVC pipe and is capable of delivering about 30 Lpm. The flushing time is relatively long, approximately 2 minutes, because of the tubing length.

INSTRUMENTATION AND DIGITAL DISPLAY PANELS

Water from either pumping system is delivered to instruments with flow-sample cells and other sensors which are immersed in the sample stream (Table 2). Each sensor and instrument is connected to one of four panels which display the signal levels on digital meters (Fig. 2). These panels, where appropriate, also contain measurement circuitry, scale or condition (filter, etc.) the input signals, and supply zero offset and signal voltages to the analog strip-chart recorders. Other features of these panels are discussed in the Appendix.

All digital displays, recorders, reference voltages, etc., are calibrated to a single voltage source located on the calibration panel (see Appendix). This panel also supplies additional voltages for testing and other non-calibration purposes.

Salinity, Temperature, and Depth

Salinity, bow-intake temperature, *in situ* temperature, and *in situ* pump depth are displayed on Panel 1 (see Appendix). Salinity is measured by an electrodeless induction salinometer with a flow-sample cell made of pyrex glass which passes through the induction head. A thermistor in the cell allows conversion of electrical conductivity to salinity. These data are verified by discrete samples analyzed with a high-precision laboratory salinometer. Results typically compare within ± 0.05 $^{o}/oo$ (parts-per-thousand).

Either the *in situ* temperature or the bow-intake temperature may be displayed and recorded. The temperature sensors (linearized thermistor elements) and measurement circuits are virtually identical for all temperature measurements in the system. The *in situ* temperature-measurement circuitry is contained in a stainless-steel pressure vessel with a depth transducer and voltage regulator (see Appendix). The bow-intake circuitry is contained in a water-proof container near the hull fitting. Temperature circuitry is routinely calibrated at the ice point ($0^{o}C$) and near $20^{o}C$.

The *in situ* pump depth is measured by a strain-gauge pressure transducer in the T/D probe. The specified accuracy of the transducer is ± 1 m; however, it resolves changes of less than 0.2 m. A zero-depth adjustment can be made on Panel 1. A "no data" depth signal (-1.000) is displayed when the *in situ* pumping system is not in use.

Oxygen Saturation, Temperature, and Light Transmissivity

Oxygen saturation, the oxygen-sample temperature, and light transmitted through a 10-cm path length of sample water are measured by sensors located in the sample stream and circuitry on Panel 2 (see Appendix). The oxygen-sample temperature is used in evaluating the error in the oxygen data due to changes in the sample temperature.

The oxygen sensor is a polarographic cell (Clark cell) isolated from the sample by an oxygen-permeable membrane. The sensor is polarized with -0.84 VDC and the resulting current is proportional to the partial pressure of oxygen in the sample. A thermistor in the probe varies the amplifier gain to compensate within 1 percent for the membrane diffusivity variation within the range of approximately 5 to 22^{o}C (Fig. 3).

The oxygen probe must be electrically isolated from the sample stream. This is accomplished by removing the excess membrane and covering the area between the "O" ring (which holds the membrane in place) and the probe body with a thin layer of silicone rubber sealant. This procedure also prolongs electrode life.

Data are recorded as percent oxygen saturation. 100 percent saturation is established by calibration in air, and zero is determined in a sodium sulfite solution. Oxygen probes are operated continuously and polarized for several hours before calibration in order to minimize drift. The air calibration is not sufficiently accurate and is essentially a coarse sensitivity adjustment. Data are related to oxygen saturation values calculated from discrete oxygen analyses (Winkler titration: Strickland and Parsons, 1968). Results agree within 5 to 10 percent (Fig. 4).

Light transmissivity is measured by a photometer in a flow-sample chamber. The current passed by the photo-resistive sensor is proportional to the energy transmitted. Data are referenced to an air calibration value of 100 percent and consequently do not relate directly to transmittance units in water. In estuarine waters both transmission and turbidity measurements detect primarily variations in the abundance of suspended particulate matter, although the transmission measurement also detects colored dissolved constituents (Fig. 5).

pCO_2, Temperature, and pH

Panel 3 displays the infrared-analyzer signal level, measures the temperature in the pCO_2 equilibrator, and isolates, converts, and displays the signal from the pH meter (see Appendix). The equilibration temperature is used to correct the pCO_2 data for changes from the *in situ* temperature.

The pCO_2 of air equilibrated with the sample stream is determined by an infrared analyzer. Details of this system are discussed in a separate section of this report.

The pH is sensed by a combination electrode located in the pCO_2 equilibrator. Digital signals from the meter are optically coupled to a digital-to-analog (D to A) converter on Panel 3. Optical isolation is necessary because the reference electrode is electrically grounded in the sample stream. The continuous pH-measurement system is not routinely calibrated with buffer solutions. Discrete pH measurements over a period of 4 to 8 hours are compared to the values continuously recorded. After correction, continuous pH values usually agree with discrete measurements within $\pm$0.025pH (Fig. 6).

Chlorophyll a Fluorescence and Turbidity

Panel 4 monitors and converts (D to A) the signals from two fluorometers (Model 10) and has an additional channel which can be used to display the signal from a Model 111 fluorometer. One Model 10 fluorometer and the Model 111 fluorometer measure *in vivo* chlorophyll *a* fluorescence (Lorenzen, 1966). The other Model 10 fluorometer has nephelometry flow cell and measures the relative turbidity of the water.

The *in vivo* chlorophyll *a* fluorescence is related to concentration by discrete spectrophotometric (trichromatic) analyses (Strickland and Parsons, 1968). The correlation is variable perhaps because of interference by dissolved fluorescent constituents, turbidity, and other factors (Fig. 7).

The turbidity measurement indicates the relative abundance of particles and is routinely compared with discrete suspended particle masses (Fig. 8). The method is sensitive to particle size as well as abundance. Consequently, the correlation with sediment mass and light transmissivity is variable.

pCO_2 MEASUREMENT SYSTEM

The major components of the pCO_2 measurement system (Fig. 9) are:

(1) an equilibrator which mixes a circulating volume of air with the continuous flow of sample water,

(2) a gas-flow controller which manually or automatically switches between calibration and measurement modes of operation, and

(3) a non-dispersive infrared analyzer which measures the CO_2 concentration in the air after equilibration.

The Equilibrator

The equilibrator efficiently mixes a circulating volume of air with the water sample stream so that the pCO_2 in the gas becomes equal to that in the liquid (Fig. 10). It is constructed of plastic sheets and tubing and is similar to designs described by Gordon and Park (1972) and Broecker and Takahashi (1966). Improved features include an adjustable overflow pipe and "O" ring seals at the top and around the overflow pipe (see Appendix).

The gas-inlet and -outlet fittings are stainless steel tube fittings. Gas lines are 1/4- or 3/8-in (OD) polypropylene, and water lines are 1/2-in (OD) Tygon. Pressure in the equilibrator is measured by a gauge on the gas-outlet fitting. The additional fittings allow insertion of a temperature probe, thermometer, and pH electrode.

Water enters the equilibrator at the top horizontal tube which sprays some water into the gas phase. The remaining flow enters the liquid phase. A screw clamp on the connecting tubing provides the necessary back pressure to spray water into the gas phase. Water drains freely from the overflow pipe into a sink. The equilibrator dimensions permit a water flow of approximately 4 Lpm. The flow rate is adjusted to near maximum in order to improve the response time of the system and to minimize error due to sample warming. Excessive flow rates carry bubbles through the overflow, resulting in pressure instability.

Air is dispersed into the water through a coarse glass fritt at a rate of 1 Lpm. The flow rate is adjusted by a needle valve on the vacuum side of the circulating pump. Water vapor is removed from the gas immediately after equilibration by dessicant (Drierite[1/]) preconditioned in the manner described by Gordon and Park (1972). In normal operation the equilibrator outlet fitting is occasionally vented to the room to account for variations in the circulating gas volume, which appear as pressure differences between the equilibrator and infrared analyzer.

<u>The Gas Controller</u>

The gas controller manually or automatically switches between the measurement and calibration modes (see Appendix). In the calibration mode, the controller switches between three states: the zero standard (purified nitrogen), a high-concentration standard, and a near-mid-scale standard. Additional standards are introduced manually. The controller provides an analog signal indicating the mode and state, and safety shutdown circuitry, which closes all valves, turns off the circulating-pump, and sounds an alarm if the water level in the equilibrator rises to an unsafe level. Gas flow rates to the pump and infrared analyzer are indicated by meters on the front panel.

Gas switching is accomplished by applying power to appropriate solenoid valves (see Appendix). Transistor-transistor logic (TTL) components are

[1/] The mention of brand names is for identification purposes and does not constitute endorsement by the U. S. Geological Survey.

used in the timing and control circuitry. The counter and decoder allow a total of ten possible states; the first three are the calibration mode and the remaining are the measurement mode. Stepping through the state sequence is accomplished manually or automatically at intervals of two minutes per state (calibration mode) or ten minutes per state (measurement mode). State 6 may be switch-selected to reset to the zero state, providing two possible measurement periods, 30 and 70 minutes, between calibrations during automatic operation.

Calibration and Standards

The pCO_2 measurements are related to mixtures of CO_2 in artificial air (oxygen plus nitrogen), which were commercially prepared by a gravimetric method (Matheson Gas Products: Primary Grade Standards). These mixtures (laboratory standards) are used to calibrate other CO_2-in-air mixtures, the routine field standards. Laboratory and field standards extend to approximately 2200 ppm by volume (Table 3). Field standards are prepared in increments of approximately 500 ppm.

The infrared analyzer response curve is approximated with a second- or third-order function, depending upon the measurement range. In the range of 0 to 1200 ppm the analyzer response is approximated within 1 percent by a second-order function based on a zero and two upscale standards (Fig. 11). Similarly, a third-order fit to a zero and four upscale standards approximates the analyzer response within 1 percent for the range of 0 to 2200 ppm (Fig. 12).

The analyzer response is not a true second- or third-order function but rather becomes more nonlinear with increasing concentration until the measurement cell becomes saturated and further increases in concentration are not detected. The curve may be defined by other functions, depending upon the individual instrument and the detection range. Our decision to use these functions resulted from laboratory studies which tested the ability of curves calculated from field standards to predict the concentrations of the laboratory standards. In each case the concentrations of the laboratory standards were determined within their accuracies (Table 4).

The analyzer response to the air circulated from the equilibration chamber is directly related to initial and final standard curves, assuming linear drift over a period as long as 2 hours. Reported pCO_2 values, therefore, are those of the dried gas and are not corrected for the pressure of water vapor removed after equilibration.

REFERENCES

Broecker, W. S., and Takahashi, Taro, 1966, Calcium carbonate precipitation on the Bahama Banks: J. Geophys. Res. v. 71, no. 6, p. 1575-1602.

Gordon, L. I., and Park, P. K., 1972, A continuous pCO_2 measurement system: Tech. Report 240, Corvallis, Oregon State University, 77 p.

Lorenzen, C. J., 1966, A method for the continuous measurement of *in vivo* chlorophyll concentration: Deep-Sea Res. v. 13, p. 223-227.

Strickland, J. D. H., and Parsons, T. R., 1968, A practical handbook of seawater analysis: Bulletin 167, Ottawa, Fisheries Research Board of Canada, 311 p.

Table 1. Manufacturers of Instruments and Equipment[1/]

Item	Model	Manufacturer
Bow Sampling Centrifugal Pump	6400	Jabsco Products, Costa Mesa, California
Submersible Pump	4CM2	Berkeley Pump Co., Berkeley, California
pH Meter	801	Orion Research Inc., Cambridge, Massachusetts
pH Combination Electrode	476050	Corning Instruments, Medfield, Massachusetts
Six Channel Analog Recorders	260	Gould, Inc., Cleveland, Ohio
Fluorometers (2)	10-000R	Turner Designs, Palo Alto, California
Fluorometer	111	G. K. Turner Associates, Palo Alto, California
Salinity-Temperature Meter	350	W. Petersen (Consultant), Palo Alto, California
Calibration Voltage Board	none	W. Petersen (Consultant), Palo Alto, California
Photometer Sensor	411	Hydroproducts, San Diego, California
Thermistor Elements	44018	Yellow Springs Instruments, Yellow Springs, Ohio
Oxygen Probe	5400	Yellow Springs Instruments, Yellow Springs, Ohio
Infrared Analyzer	215A	Beckman Instruments, Fullerton, California
Laboratory Salinometer	RS7-B	Beckman Instruments, Fullerton, California
Depth Transducer	PG143-161	Gentran Inc., Sunnyvale, California

1/ The mention of brand names is for identification purposes and does not constitute endorsement by the U. S. Geological Survey.

Table 2. Precision and Accuracy of Continuous Measurements

Measurement	Measurement Range	Precision	Estimated Accuracy
Salinity	0 to 39.9 $^{o}/oo$	± 0.01 $^{o}/oo$	± 0.05 $^{o}/oo$
Temperature	-5 to 35^{o}C	$\pm 0.1^{o}$C	$\pm 0.2^{o}$C
Depth	0 to 100 m	± 0.2 m	± 1 m
Light Transmissivity	0 to 199% relative to air	± 2%	
Oxygen Saturation	0 to 199%	± 1%	± 5%
pCO_2	0 to 2200 ppm	± 3 to 6 ppm	± 5% of value
pH	6.5 to 9.5	± 0.01	± 0.025
Chlorophyll *a*	variable	± 2% of full scale	
Turbidity	variable	± 2% of full scale	

Table 3. Laboratory and Field Standard CO_2 Gas Mixtures

Cylinder Number	Certified Conc.	Determined Conc.	Standard Type
DL-067320	249 ppm ±1%	249 ppm ±1%	Laboratory
DL-067755	499 ppm ±1%	499 ppm ±1%	Laboratory
DL-067508	748 ppm ±1%	748 ppm ±1%	Laboratory
DL-067710	1008 ppm ±1%	1008 ppm ±1%	Laboratory
DL-067749	1249 ppm ±1%	1249 ppm ±1%	Laboratory
DL-067762	1510 ppm ±1%	1510 ppm ±1%	Laboratory
DL-067310	1764 ppm ±1%	1764 ppm ±1%	Laboratory
DL-067676	2013 ppm ±1%	2013 ppm ±1%	Laboratory
13642	542 ±2%	536 ±1%	Field
17879P	549 ±2%	542 ±1%	Field
13626	1010 ±2%	1031 ±1%	Field
002017	1057 ±2%	1087 ±1%	Field
13610	1541 ±2%	1500 ±1%	Field
093174	2152 ±2%	2112 ±1%	Field

Table 4. Estimation of Laboratory Standard Concentrations from Second- and Third-Order Functions on the Basis of Infrared Analyzer Response to Field Standards

Standard	Second order[1/]		Third order[2/]	
Concentration	0 to 1200 ppm	% Lab. Value	0 to 2200 ppm	% Lab. Value
249 ±1%	250.3 ±1.7 ppm	100.5 ±0.1%	245.6 ±2.0 ppm	98.6 ±0.8%
499 ±1%	499.5 ±1.7 ppm	100.1 ±0.3%	499.1 ±1.5 ppm	100.0 ±0.3%
748 ±1%	745.5 ±1.7 ppm	99.7 ±0.2%	747.0 ±2.3 ppm	99.9 ±0.3%
1008 ±1%	1004.5 ±1.3 ppm	99.7 ±0.1%	1008.2 ±4.0 ppm	100.0 ±0.4%
1249 ±1%			1256.4 ±4.9 ppm	100.6 ± 0.4%
1510 ±1%			1512.1 ±5.7 ppm	100.3 ±0.2%
2013 ±1%			2013.9 ±2.5 ppm	100.0 ±0.1%
1764 ±1%			1768.9 ±3.7 ppm	100.3 ±0.2%

1/ Average and standard deviation of four comparisons

2/ Average and standard deviation of six comparisons

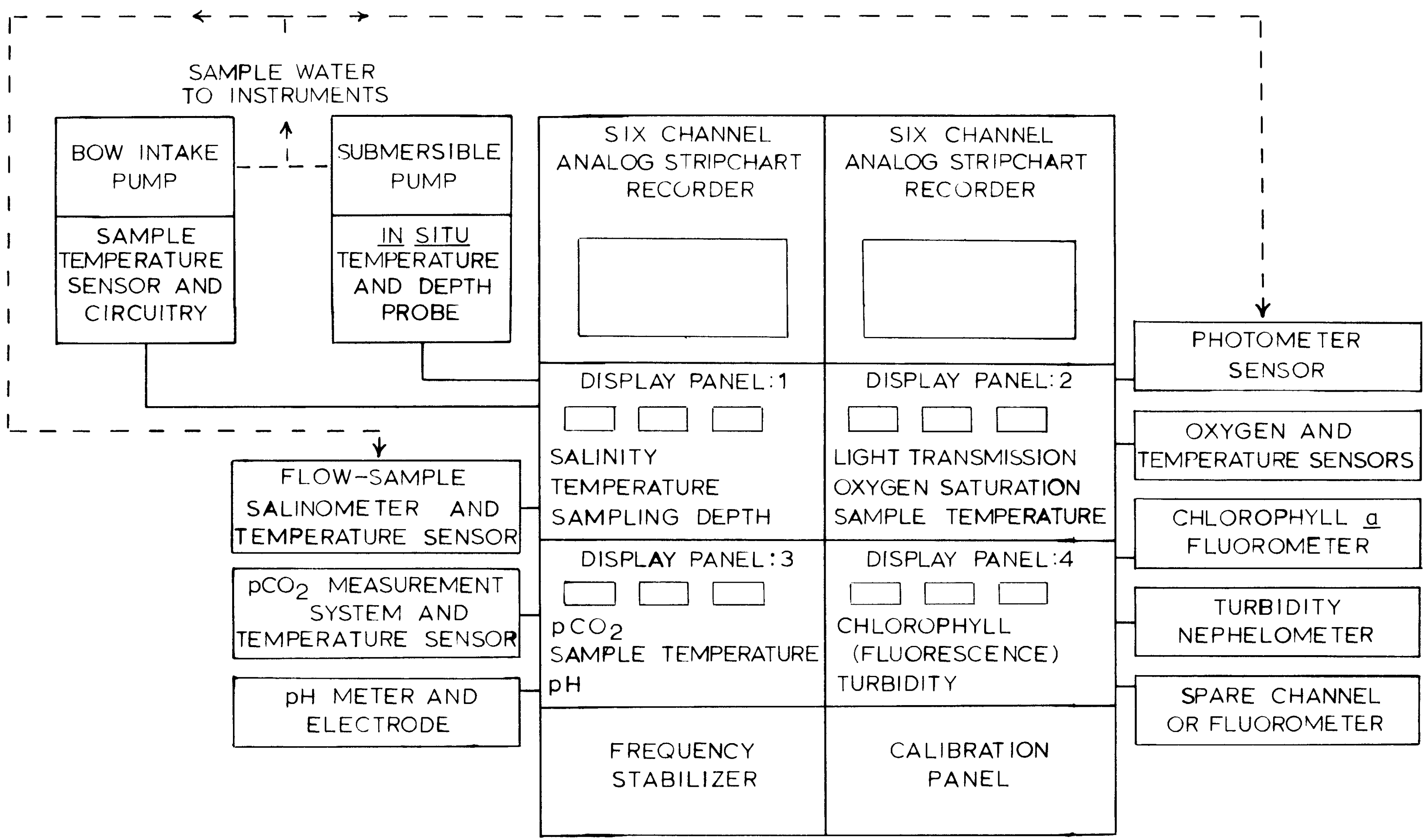

FIGURE 1 BLOCK DIAGRAM OF WATER SAMPLING AND ANALYSIS SYSTEM

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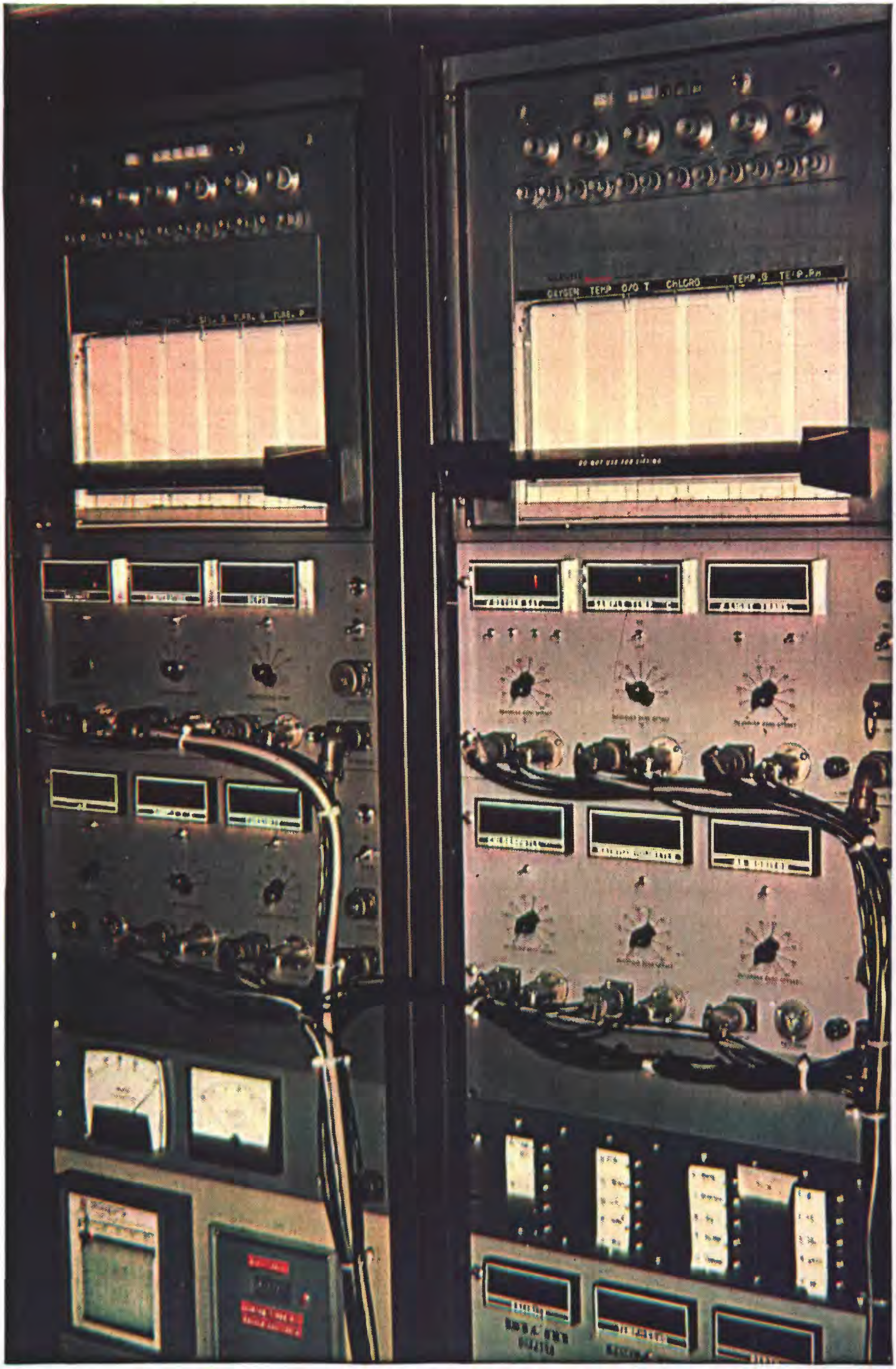

Figure 2. Digital display panels and analog recorders.

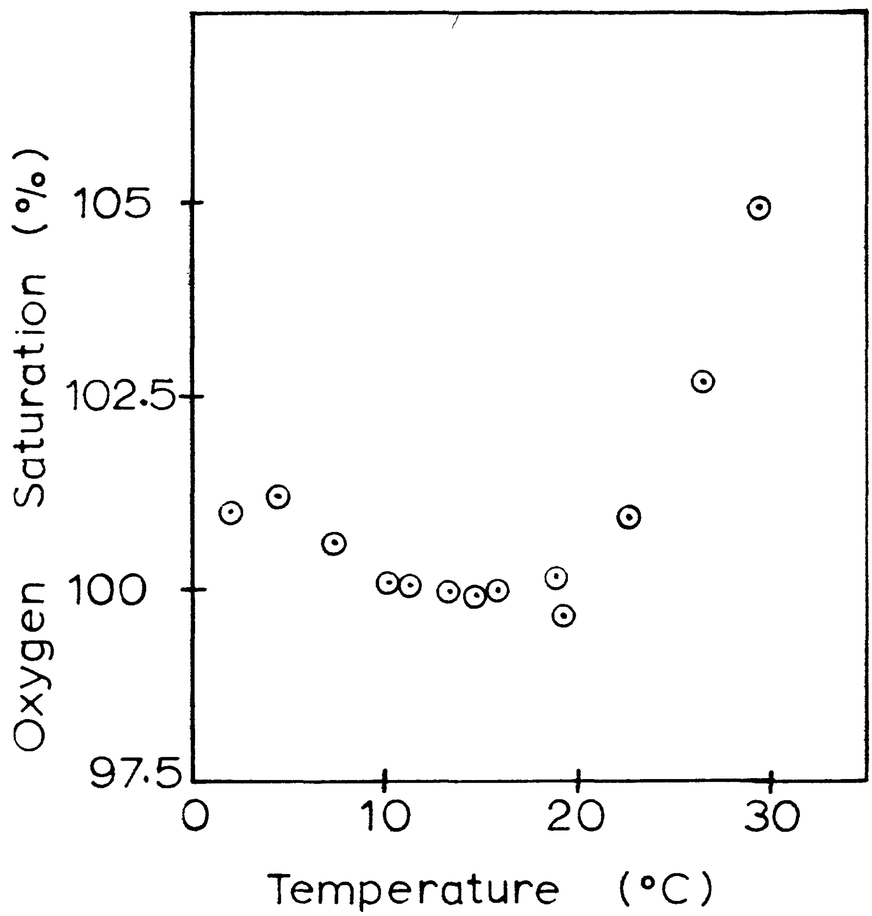

Figure 3. Response of dissolved-oxygen analyzer with respect to temperature in water saturated with oxygen.

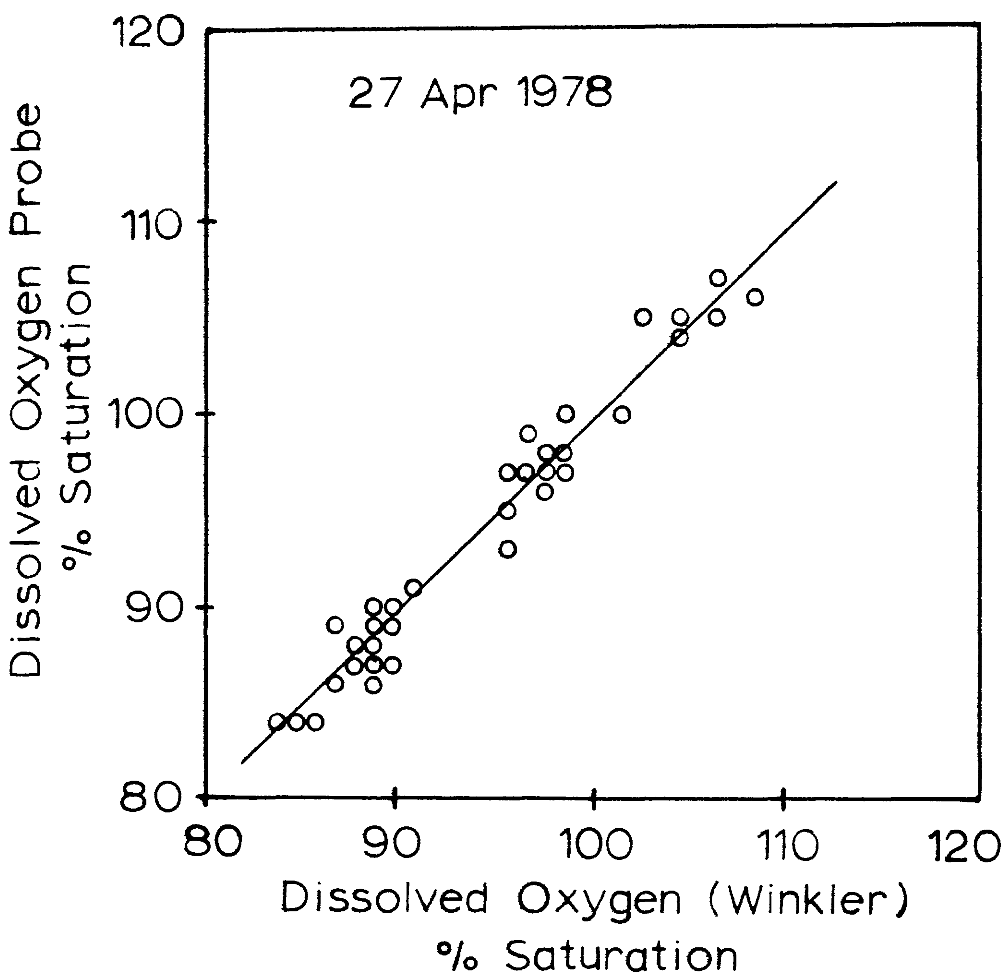

Figure 4. Comparison of oxygen saturation values determined by oxygen probe and calculated from Winkler titrations.

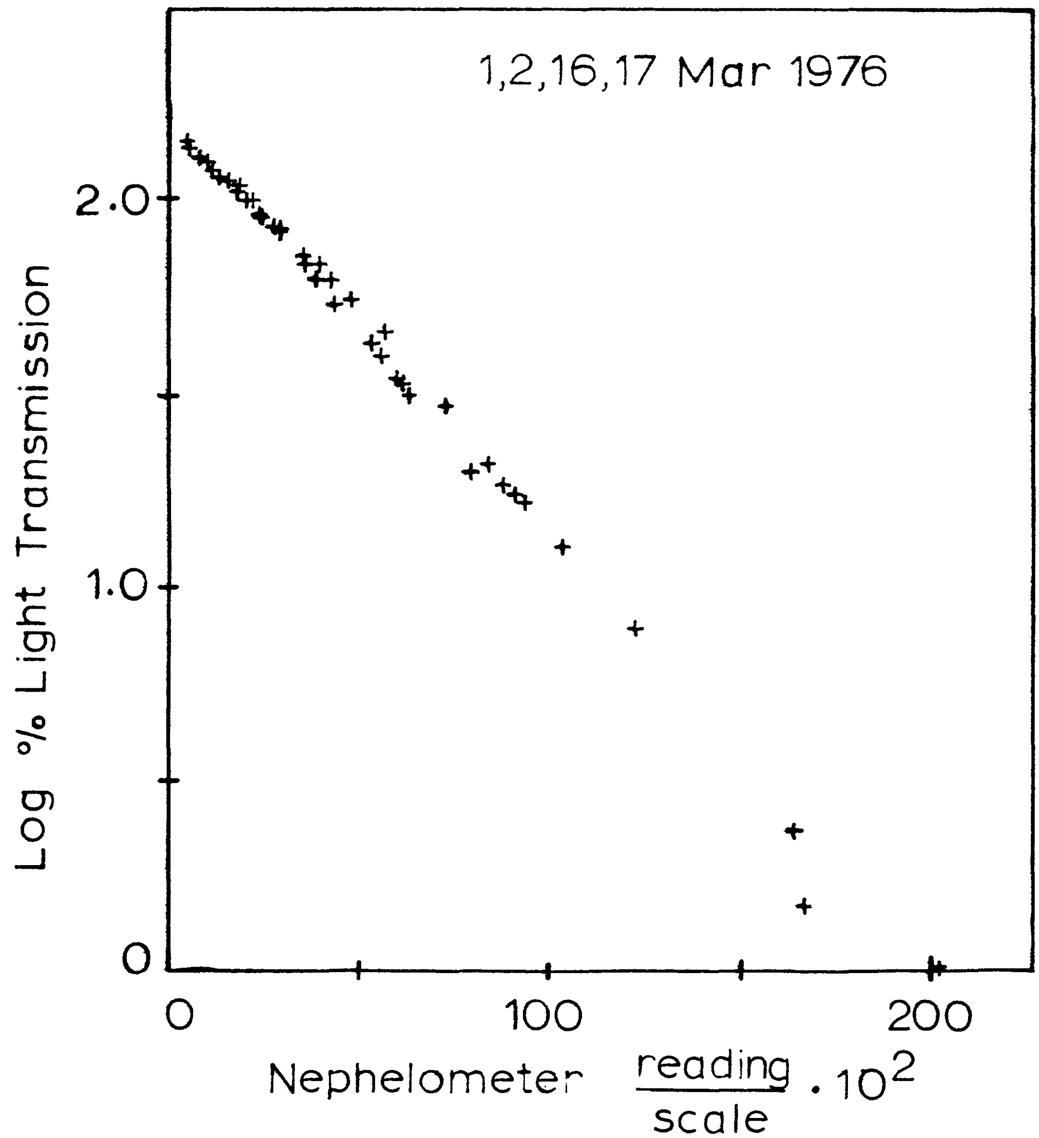

Figure 5. Correlation of light-transmission and turbidity measurements.

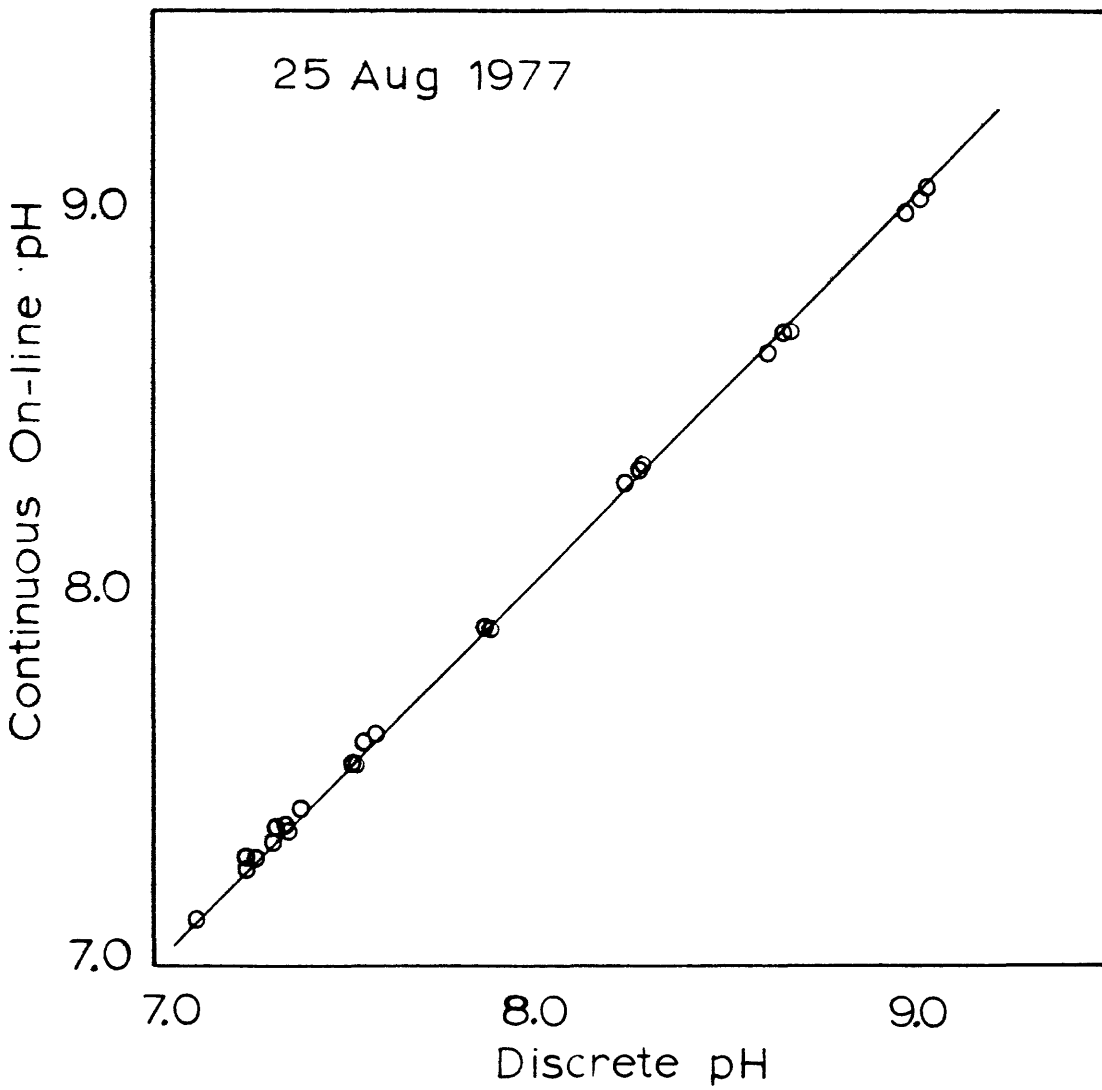

Figure 6. Comparison of continuous and discrete pH measurements.

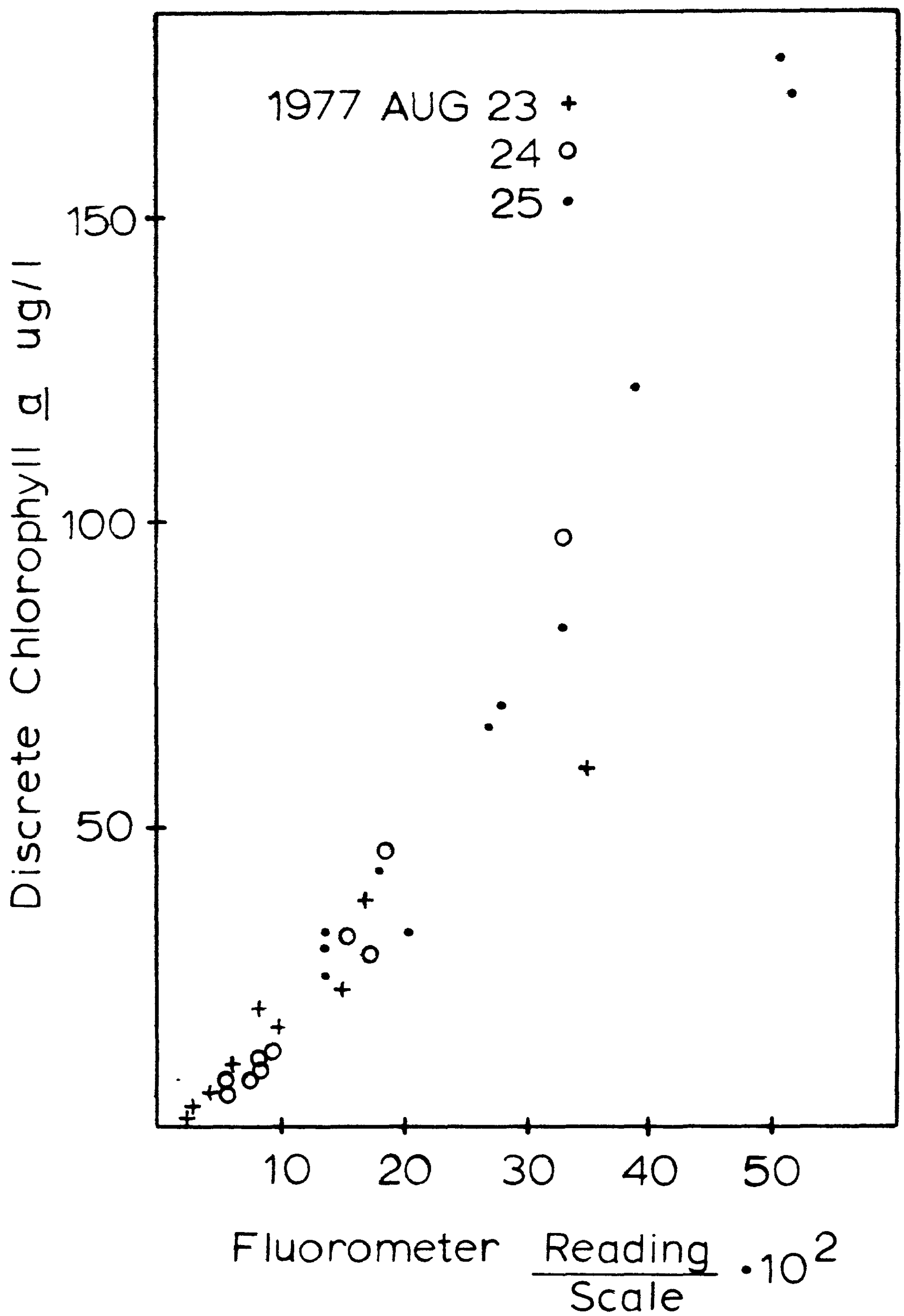

Figure 7. Correlation of discrete chlorophyll *a* analyses and *in vivo* chlorophyll *a* fluorescence.

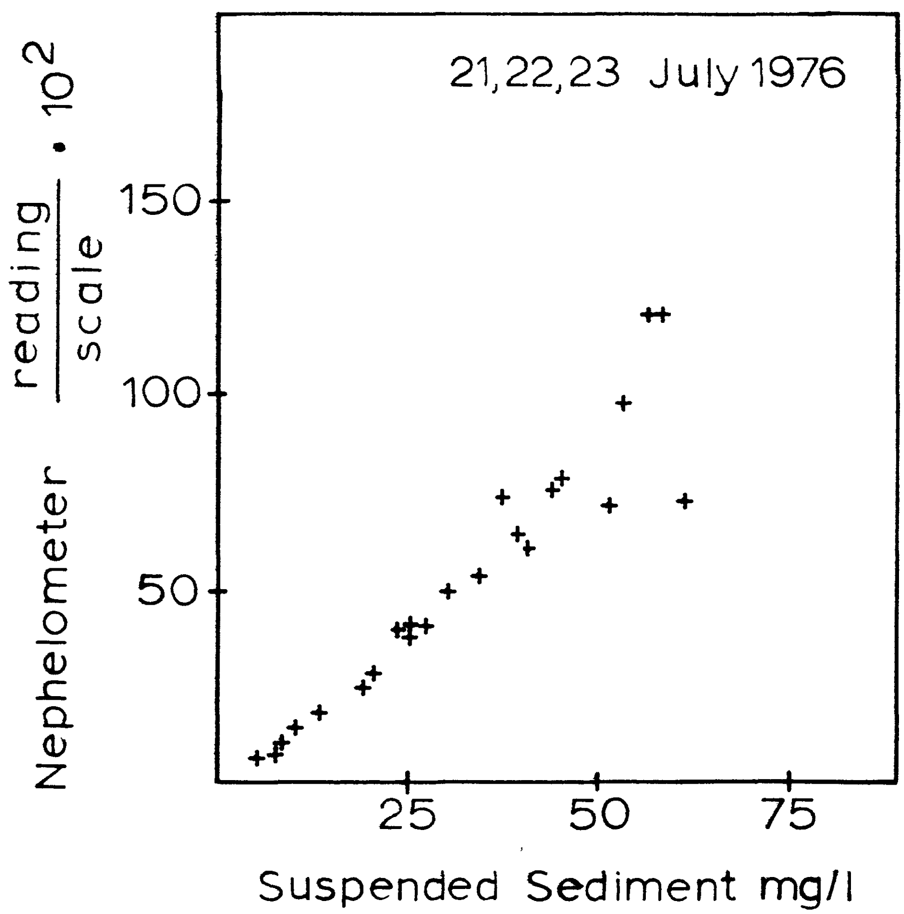

Figure 8. Correlation of turbidity and suspended-sediment mass measurements.

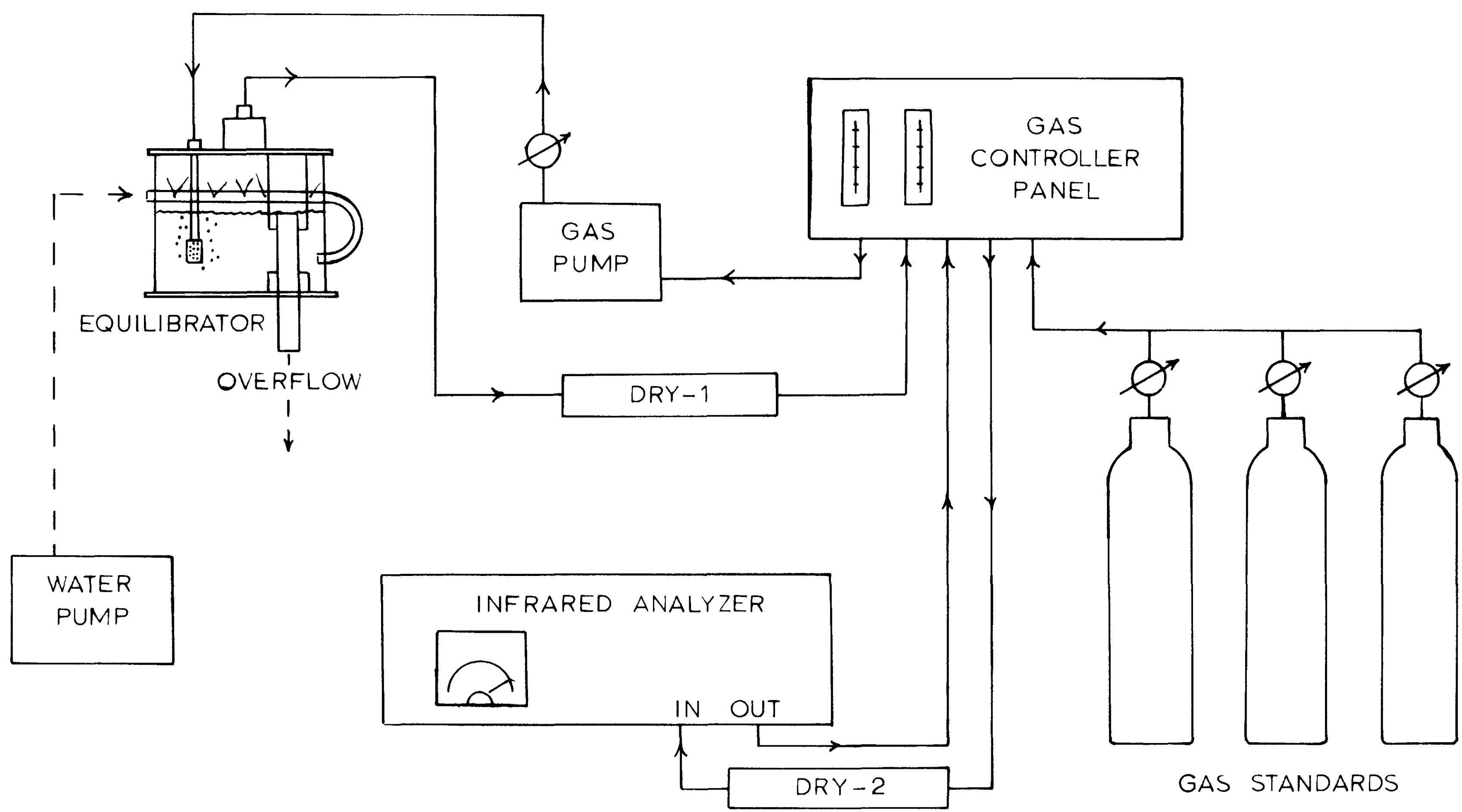

FIGURE 9 BLOCK DIAGRAM OF pCO_2 SYSTEM

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Figure 10. pCO_2 equilibration chamber.

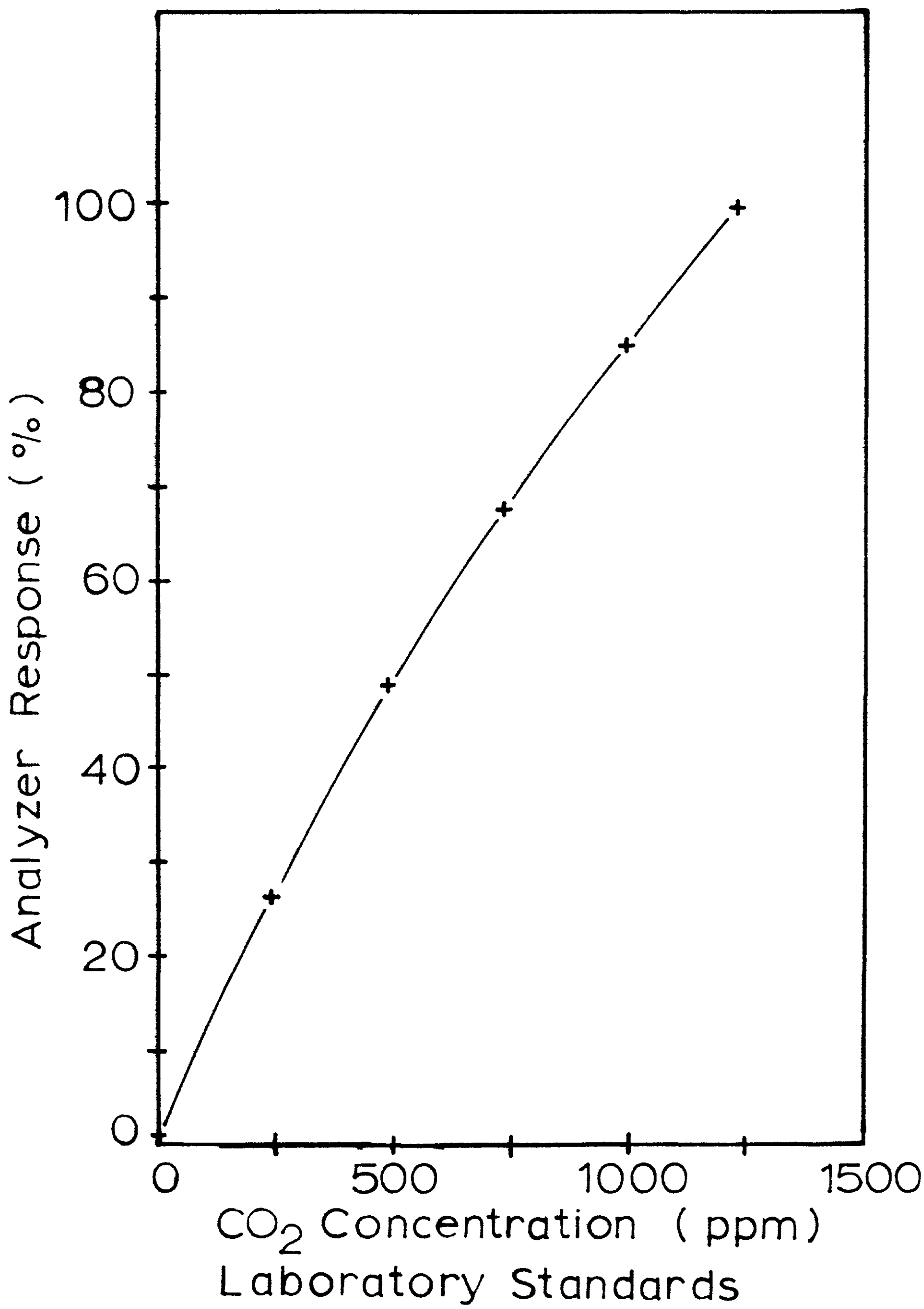


Figure 11. Infrared analyzer response curve: 0 - 1250 ppm range.

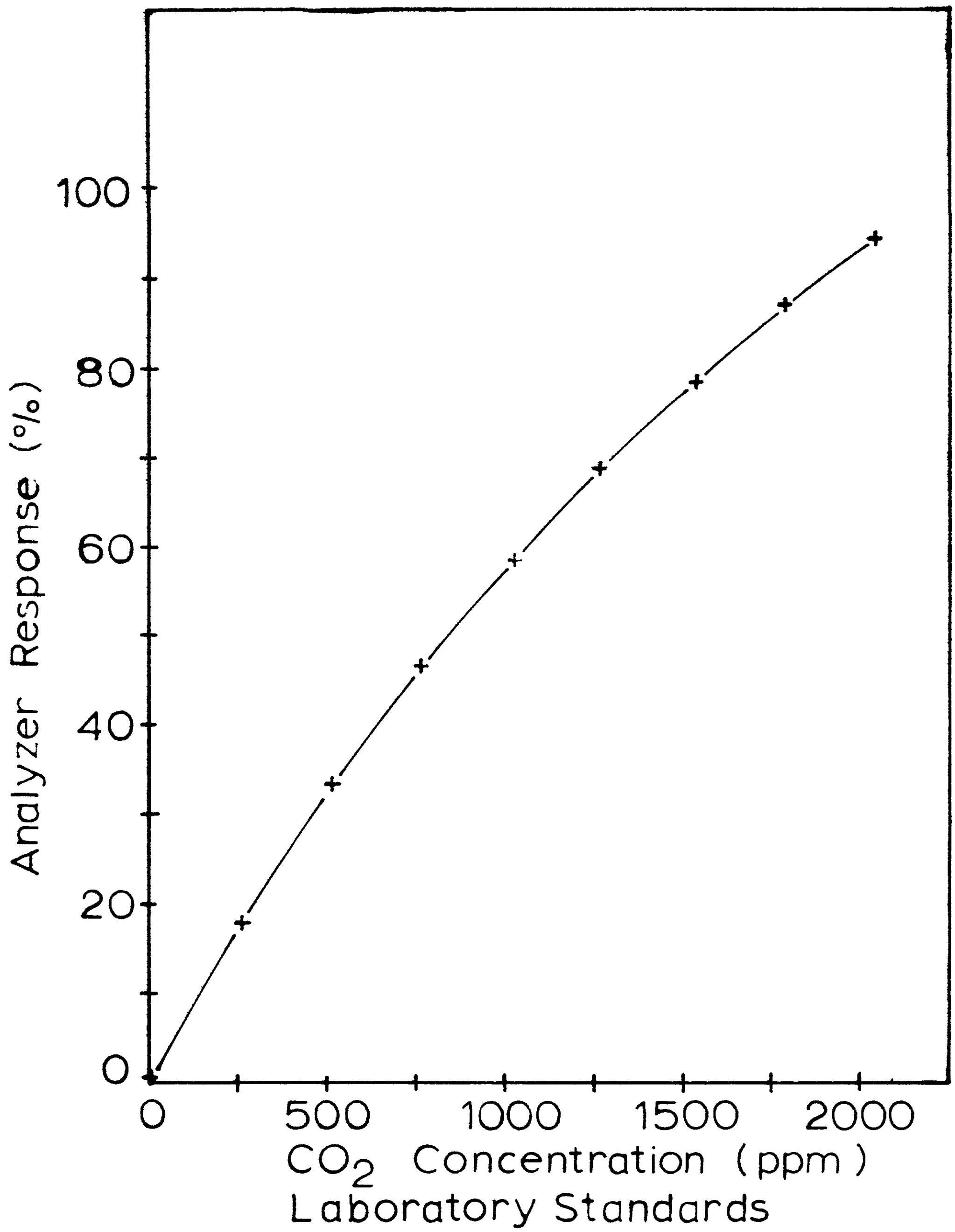


Figure 12. Infrared analyzer response curve: 0 - 2000 ppm range.

APPENDIX

LIST OF TABLES

LIST OF FIGURES

Drawings and electrical diagrams in the Appendix follow the number sequence of the digital-display panels referred to in the previous text. Sensors and instruments are shown with the section for the digital panel where their signals are displayed.

Digital-display panels perform one or more of the following functions per channel (parameter):

(1) provide digital display of the signal level from an instrument or sensor;

(2) scale, convert, or otherwise condition signals to make them compatible with the data-logging systems;

(3) provide zero (baseline) offset voltages for the recorder range expansion; and

(4) perform a measurement by means of a signal derived from a sensor located in the sample stream.

Each digital-display panel is a standard-width electronic rack panel, 8-3/4 in high, containing three digital panel meters, switches, circuitry, and connectors. Most of the electronic circuitry components are mounted on hand-wired circuit cards which plug into connectors attached to the panels. All panel circuitry and external sensors and probes are powered by regulated DC modular power supplies mounted on the panels.

The display panels have recorder zero offset circuitry for each of their three recorder outputs. This offset circuitry utilizes precision voltage dividers mounted on rotary switches. These are calibrated in percent of full-scale increments or in units of the parameter being recorded. The selected biasing voltage is applied to the low side of the differential recorder input, thus allowing a range of the parameter to be recorded on the entire width (4.0 cm) of the strip-chart.

The signal levels and slopes allow each parameter to be read directly from a DC volt meter with only a decimal-point correction (Table 5). Some signals are further divided below 2.0 VDC to interface with other data-logging systems.

Table 5. Instrument Signal Level Characteristics

Measurement	Range	D. C. Signal[1/]
Salinity	0 to 39.9 °/oo	0 to 3.999 VDC
Temperature	-5 to 35°C	-0.5 to 3.50 VDC
Depth	0 to 100 m	0 to 1.000 VDC
Light Transmissivity	0 to 199%	0 to 1.99 VDC
Oxygen Saturation	0 to 199%	0 to 1.99 VDC
pCO_2 (infrared analyzer)	0 to 100% of full scale	0 to 1.00 VDC
pH (meter output)	1.000 pH unit	1.000 VDC
Fluorescence (Model 10)	0 to 100%	0 to 1.00 VDC
Fluoreometer sensitivity	0 to 1.9 VDC nominal	consult schematic diagrams
No Data	-1.000 VDC	

[1/] All voltages are positive unless designated.

Table 6. Identification and Sources of Components of Digital Display Panels

Component		Manufacturer
Front panel connectors		
3-pin	MS 3102A-14S-1P	Amphenol, Div. Bunker Ramo
3-socket	MS 3102A-14S-1S	Oak Brook, IL
4-socket	MS 3102A-14S-2S	
6-socket	MS 3102A-14S-6S	
8-socket	MS 3102A-18-8S	
26-pin	PT02A-16-26P	Bendix Corp., Southfield, MI
3-pin	Type C3M	Switchcraft, Chicago, IL
Circuit boards		
Prototype boards with plated thru holes No. 05020-0189		Hewlett-Packard, Palo Alto, CA
30 contact end card connector No. 225-21521-401-117		Amphenol, Div. Bunker Ramo Oak Brook, IL
Power supplies		
Dual supply ±15 VDC/100 ma Md. 902		Analog Devices, Norwood, MA
Digital panel meters		
Model 300	0-1.999 V bipolar	Electro-Numerics Corp.
Model 300	0-19.99 V bipolar	Santa Clara, CA
Model 302	0-3.999 V bipolar	
Rotory switches		
1 pol.-11 pos. non-shorting Md. 1403		Centralab, Milwaukee, WI
Rack panels		
19" X 8-3/4" X 1/8" aluminum No. PA-1135		Bud Radio, Inc. Willoughby, OH

Table 7. Panel 1, front-panel connections

Connector	Function	Pin Designations	
J-1	Bow temperature sensor	A	+15 VDC
		B	common
		C	-15 VDC
		D	signal $V = T \times 10^{-1}$
		E	shield
J-2	*In situ* T/D probe	A	+15 VDC
		B	common
		C	-15 VDC
		D	temperature signal
		E	depth signal
		H	shield
J-3	Salinometer input	A	common
		B	salinity signal
		C	temperature signal
X-1	Aux. output	A	salinity signal
		B	temperature signal
		C	depth signal
		D	salinity signal divided by two
		E	temperature signal divided by two
		H	common
P-1	Line power input	A	high 115 VAC 60 HZ
		B	neutral
		C	earth ground
R-1,2,3	Recorder outputs	1	signal
		2	zero offset voltages
		3	shield

Table 8. Panel 2, front-panel connections

Connector	Function	Pin	Designations
J-1	Photometer input	A	lamp current
		B	-3.5 VDC
		C	photocell input
		D	lamp current return
		E	shield
J-2	Thermistor probe	A	thermistor red
		B	thermistor brown
		C	thermistor green
		D	shield
J-3	Oxygen probe	A	-0.84 VDC
		B	cell input
		C	internal thermistor
		D	internal thermistor
		E	shield
X-1	Aux. output	A	% light transmittance
		B	temperature signal
		C	% oxygen saturation signal
		D	temperature divided by two
		E	common
P-1	Line power input	A	high 115 VAC 60 HZ
		B	neutral
		C	earth ground
R-1,2,3	Recorder outputs	1	signal
		2	zero offset voltage
		3	shield

Table 9. Panel 3, front-panel connections

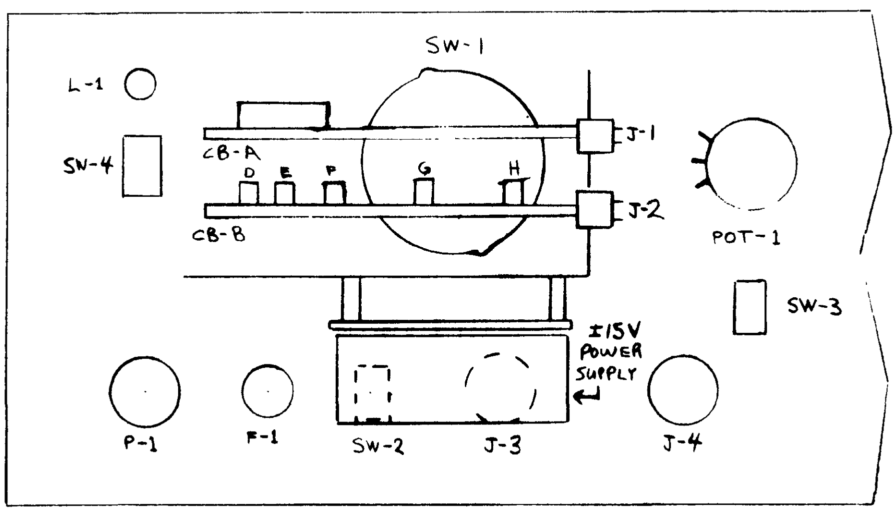
Connector	Function	Pin Designations[1/]	
J-3	Infrared analyzer	A	common
		B	signal input
J-2	Thermistor probe	A	thermistor red
		B	thermistor brown
		C	thermistor green
		D	shield
X-1	Aux. output	A	pH
		B	temperature signal
		C	pCO_2 signal
		D	open
		E	temperature divided by two
		F	common
P-1	Line power input	A	high 115 VAC 60 HZ
		B	neutral
		C	earth ground
R-1,2,3	Recorder outputs	1	signal
		2	zero offset voltages
		3	shield

[1/] See schematic for J-1 pin designations.

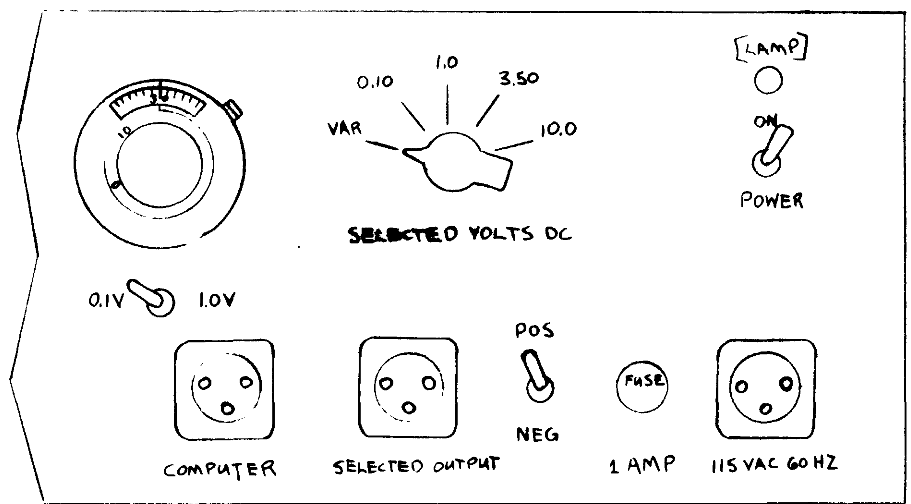
Table 10. Panel 4, front-panel connections

Connector	Function	Pin Designations
J-1	Spare input	A common
		B signal
J-2	Nephelometer input	A signal
		B analog range signal
		C TTL range multiplier signal
		D digital logic common
		E +5 VDC logic power
		F analog common
J-3	Fluorometer input	same as J-2
X-1	Aux. output	A chlorophyll a signal
		B turbidity signal
		C spare channel signal
		D turbidity range analog signal
		E chlorophyll a range analog signal
P-1	Line power input	A high 115 VAC 60 HZ
		B neutral
		C earth ground
R-1,2,3	Recorder outputs	1 signal
		2 zero offset voltages
		3 shield

REAR VIEW
HALF OF RACK MOUNTED PANEL



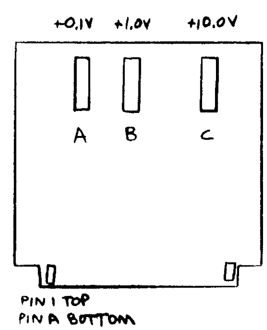
FRONT VIEW
HALF OF RACK MOUNTED PANEL



L-1	LAMP
F-1	FUSE
J-1 & J-2	PC BOARD CONNECTORS
J-3	SELECTED OUTPUT
J-4	COMPUTER OUTPUT
P-1	POWER CONNECTOR
POT-1	5K TEN-TURN POTETIOMETER
SW-1	SELECT VOLTAGE
SW-2	POLARITY FOR VARIABLE VOLTAGE
SW-3	+1.0 OR +0.1 V FOR VAR. VOLTAGE
SW-4	POWER SWITCH
CB-A & CB-B	CIRCUIT BOARDS

ADJUSTMENTS

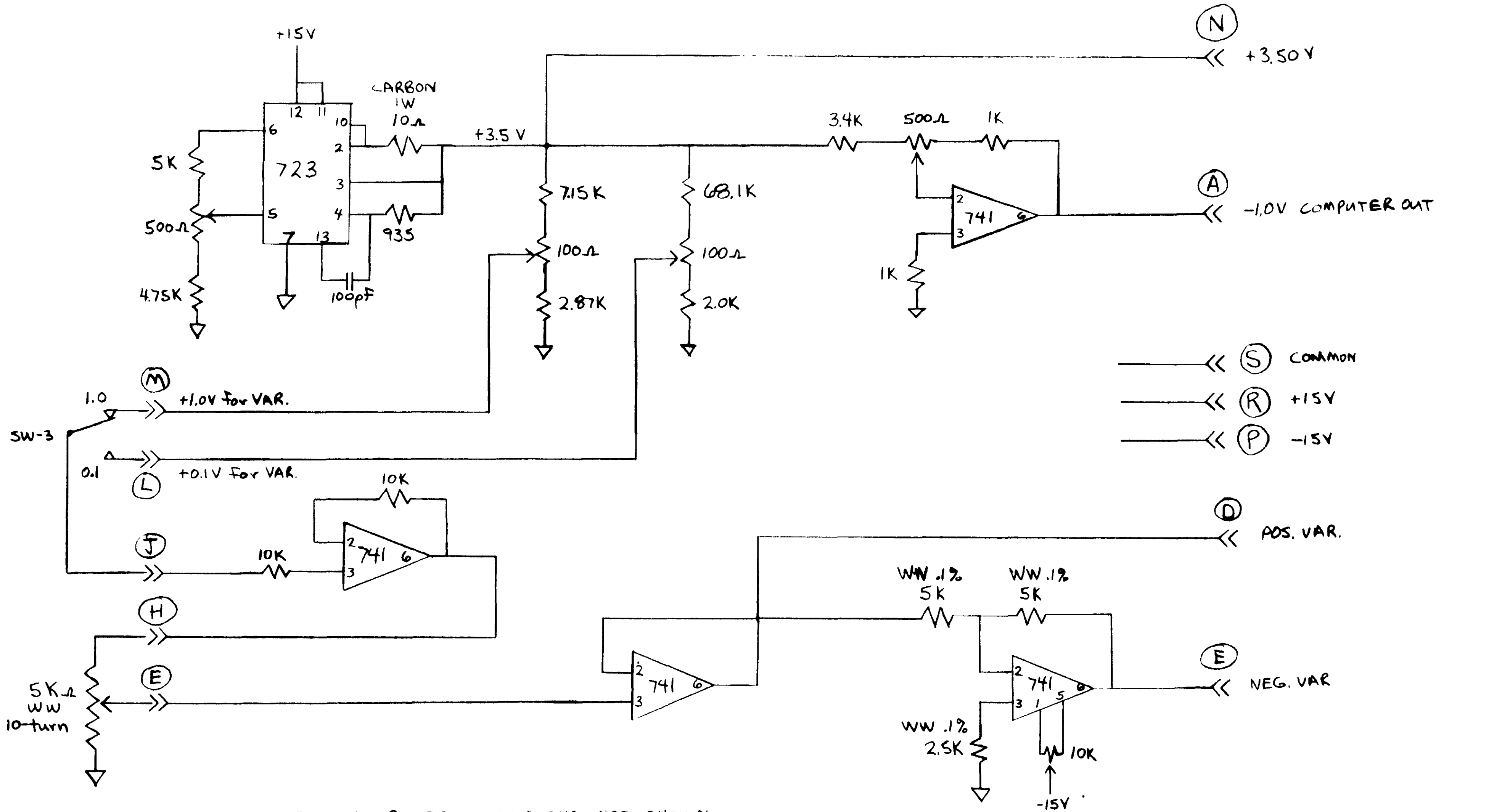
A	+0.1V ADJ	PRECISION VOLTAGE BOARD CB-A
B	+1.0V ADJ	
C	+10.0V ADJ	
D	+0.1V ADJ. FOR VAR. VOLTAGE	
E	+3.50V ADJ.	
F	ZERO NEG. VAR. VOLTAGE	
G	+1.0 V ADJ FOR VAR. VOLTAGE	
H	-1.0 V ADJ. FOR COMPUTER OUT	



CIRCUIT BOARD CB-A
ITEM ON TABLE 1.

FIGURE 13 CALIBRATION PANEL
PANEL LAYOUTS (FRONT & BACK)

L.D.
NOV. 1976



NOTE: IC POWER CONNECTIONS NOT SHOWN
RESISTORS ALL MTL FILM 1% UNLESS SPECIFIED.

FIGURE 14	CALIBRATION PANEL CIRCUIT BOARD CB-B SCHEMATIC DIAGRAM	DRAWN BY LD DATE NOV 1976

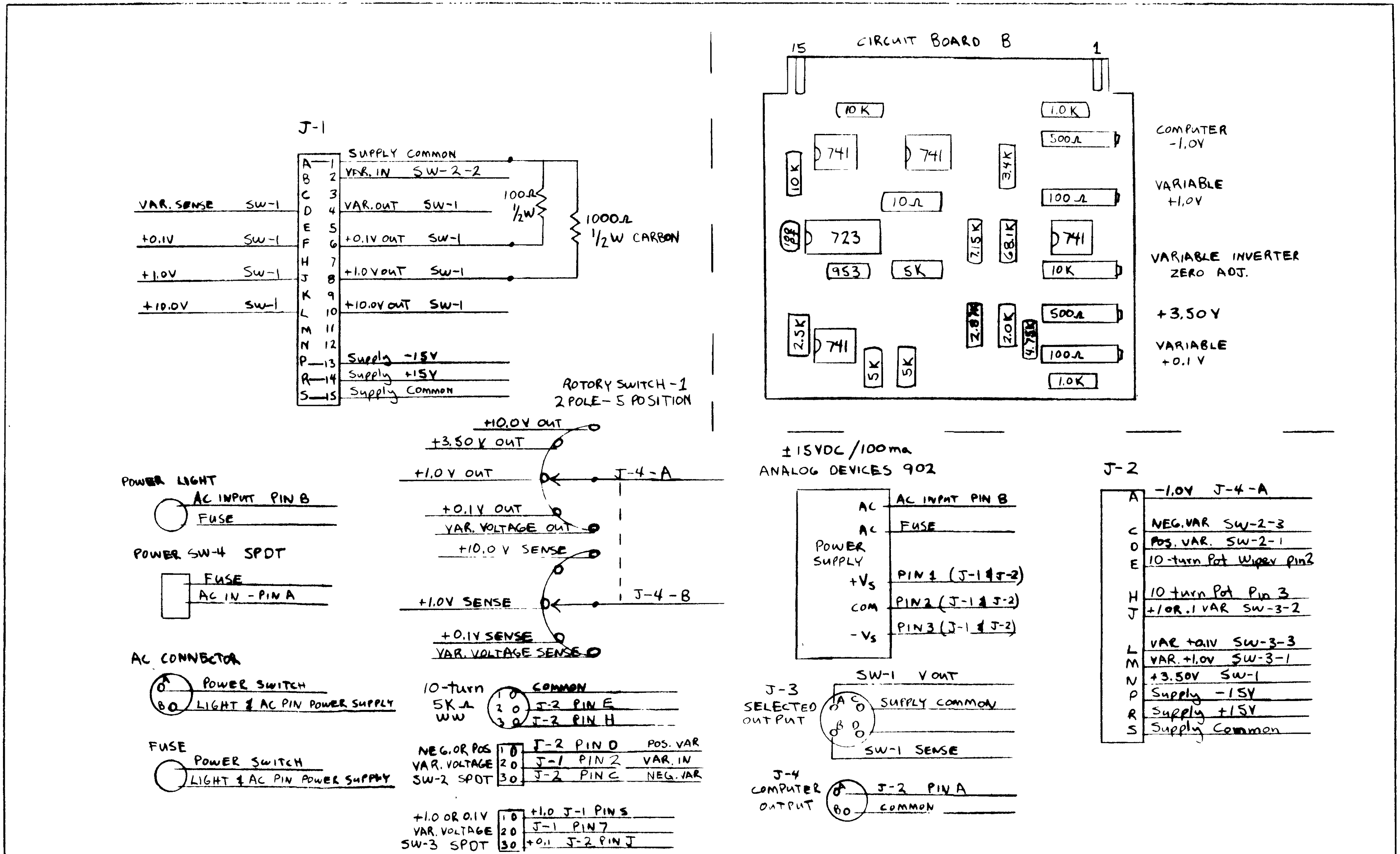


FIGURE 15 CALIBRATION PANEL
CIRCUIT BOARD-B LAYOUT AND PANEL WIRING DIAGRAM

DRAWN BY L.D
DATE NOV 1976

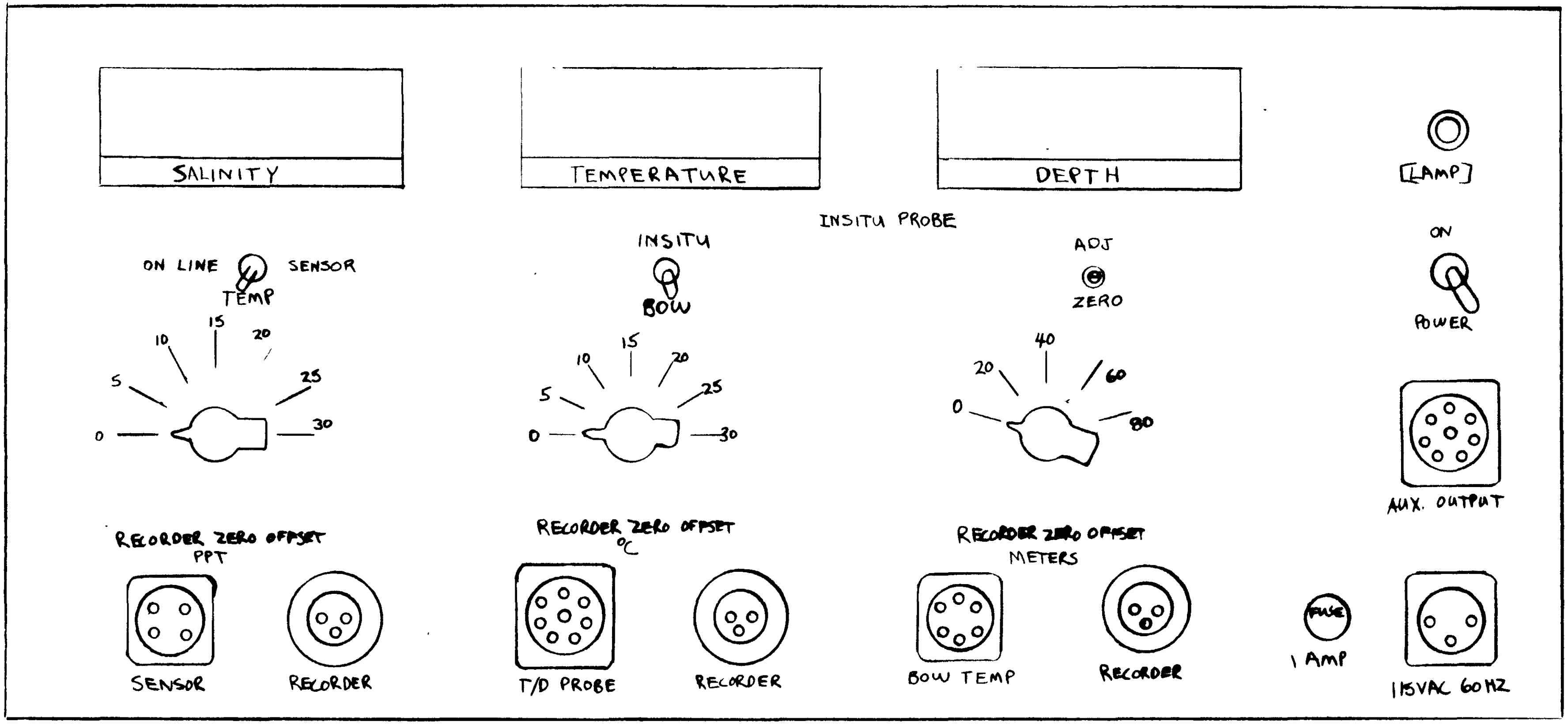
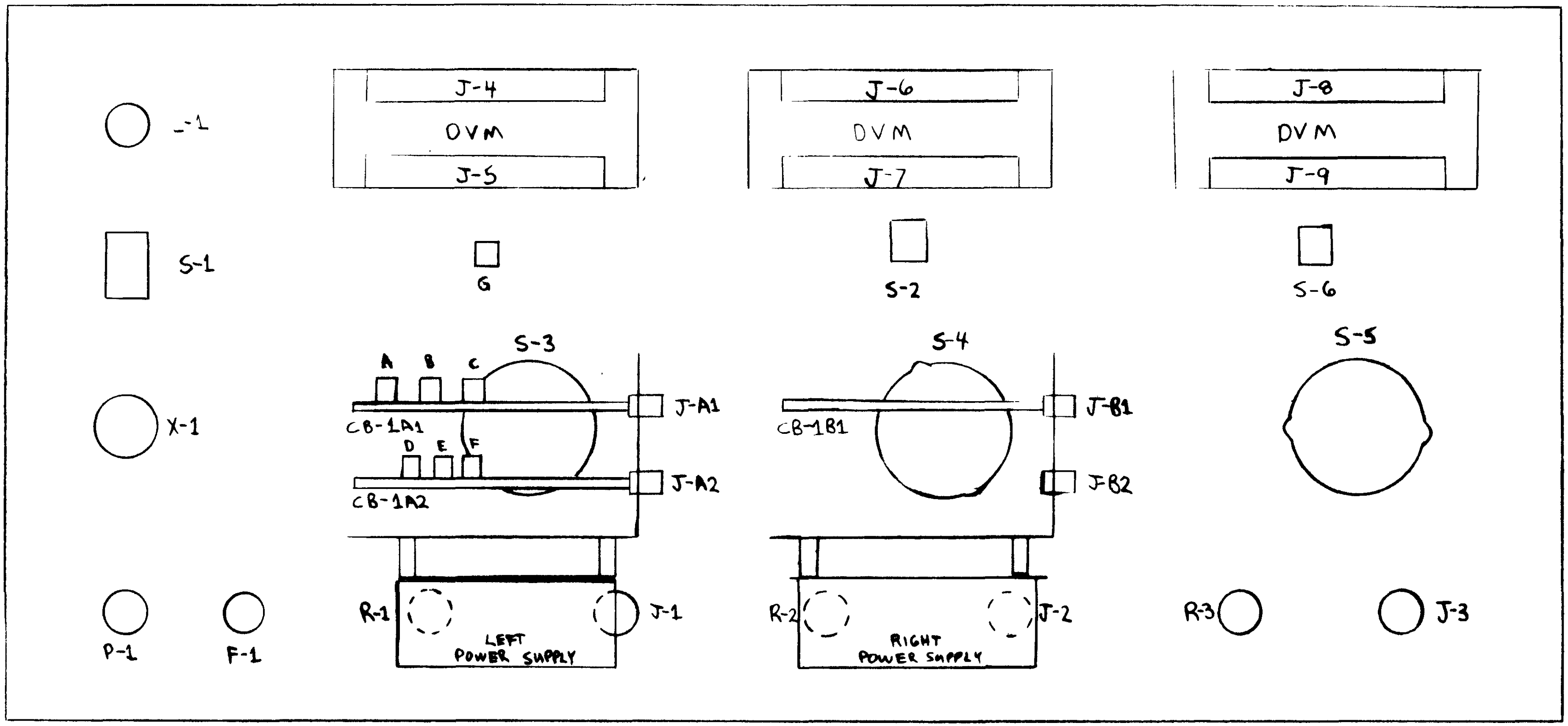


FIGURE 16	SALINITY, TEMPERATURE, DEPTH PANEL PANEL LAYOUT (FRONT)	PANEL NO. 1	DRAWN BY LD DATE NOV. 1976



F1	FUSE
L1	NEON LAMP
X-1	AUX. OUTPUT
P-1	POWER CONN.
R-1	REC. OUT. - DEPTH
R-2	REC. OUT - T°C
R-3	REC. OUT - S‰
J-1	T/D OUTPUT
J-2	T/D PROBE
J-3	SENSOR
J-4 THRU J-9	CONNECTORS FOR DVM'S
J-A1 THRU J-B2	CONNECTORS FOR BOARDS
S-1	POWER SWITCH
S-2	TEMPERATURE AND DEPTH - BOW OR INSITU
S-3	RECORDER ZERO OFFSET - DEPTH
S-4	RECORDER ZERO OFFSET - TEMP °C
S-5	RECORDER ZERO OFFSET - SALINITY
CB-1A1	FOLLOWER CIRCUITRY
CB-1A2	REGULATED POWER SUPPLY
CB-1B1	SALINITY-TEMP. INTERFACE & ZERO DEPTH CIRCUITS
S-6	THERMOSALINOGRAPH TEMPERATURE °C SWITCH
A	DEPTH RECORDER ZERO OFFSET NULL
B	TEMP. RECORDER ZERO OFFSET NULL
C	SALINITY RECORDER ZERO OFFSET NULL
D	-1.0 VDC ADJ.
E	+3.50 VDC ADJ.
F	-3.50 VDC ADJ.
G	ZERO DEPTH ADJ.

FIGURE 17. SALINITY, TEMPERATURE, DEPTH PANEL PANEL LAYOUT (BACK)

PANEL NO.	DRAWN BY L.D
1	DATE NOV 1976

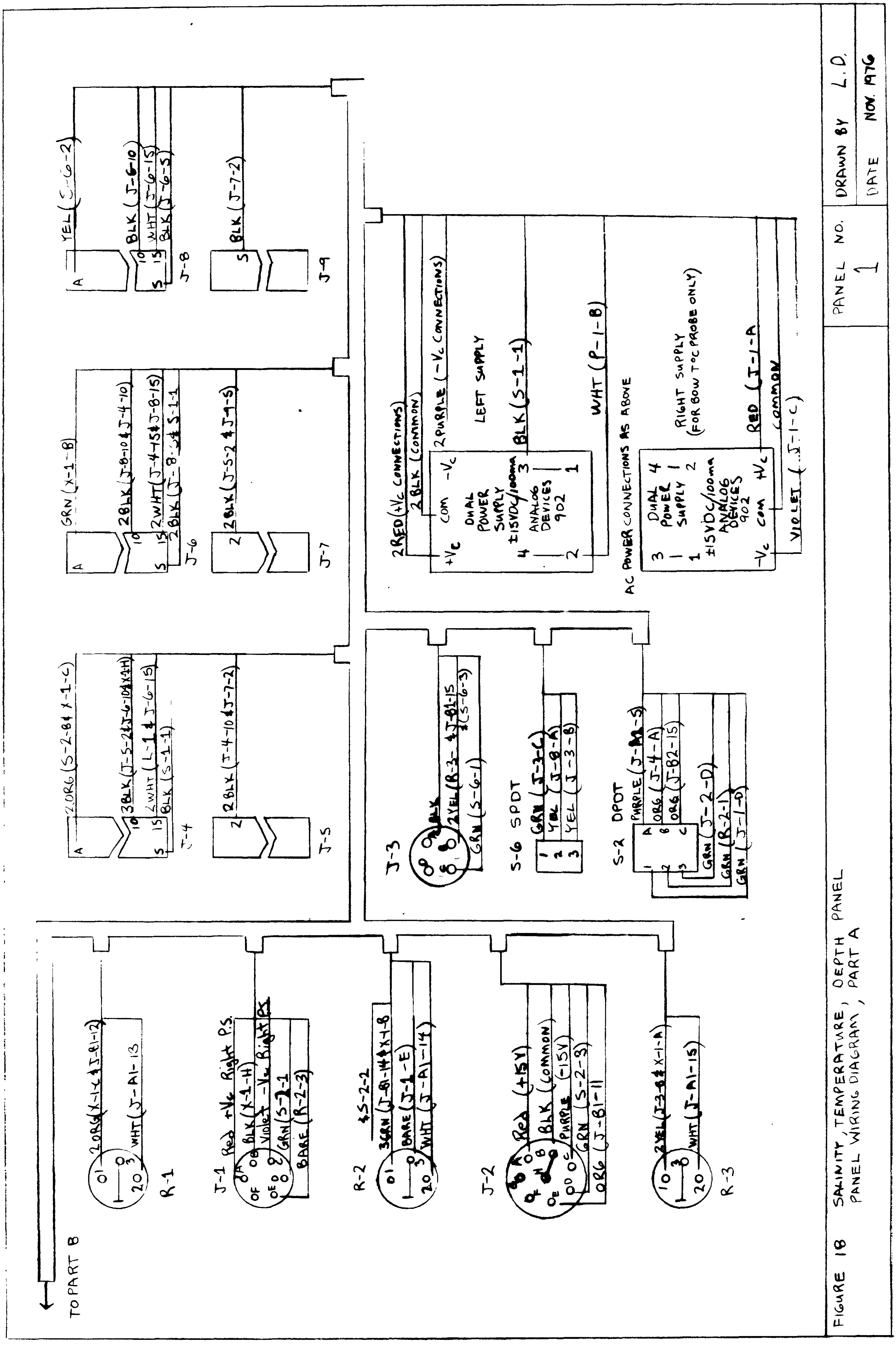


FIGURE 18
SALINITY, TEMPERATURE, DEPTH PANEL
PANEL WIRING DIAGRAM, PART A
PANEL NO. 1
DRAWN BY L.D.
DATE NOV. 1976
TO PART B
LEFT SUPPLY
RIGHT SUPPLY (FOR BOW T°C PROBE ONLY)
AC POWER CONNECTIONS AS ABOVE
DUAL POWER SUPPLY ±15VDC/100mA ANALOG DEVICES 902
S-6 SPDT
S-2 DPDT

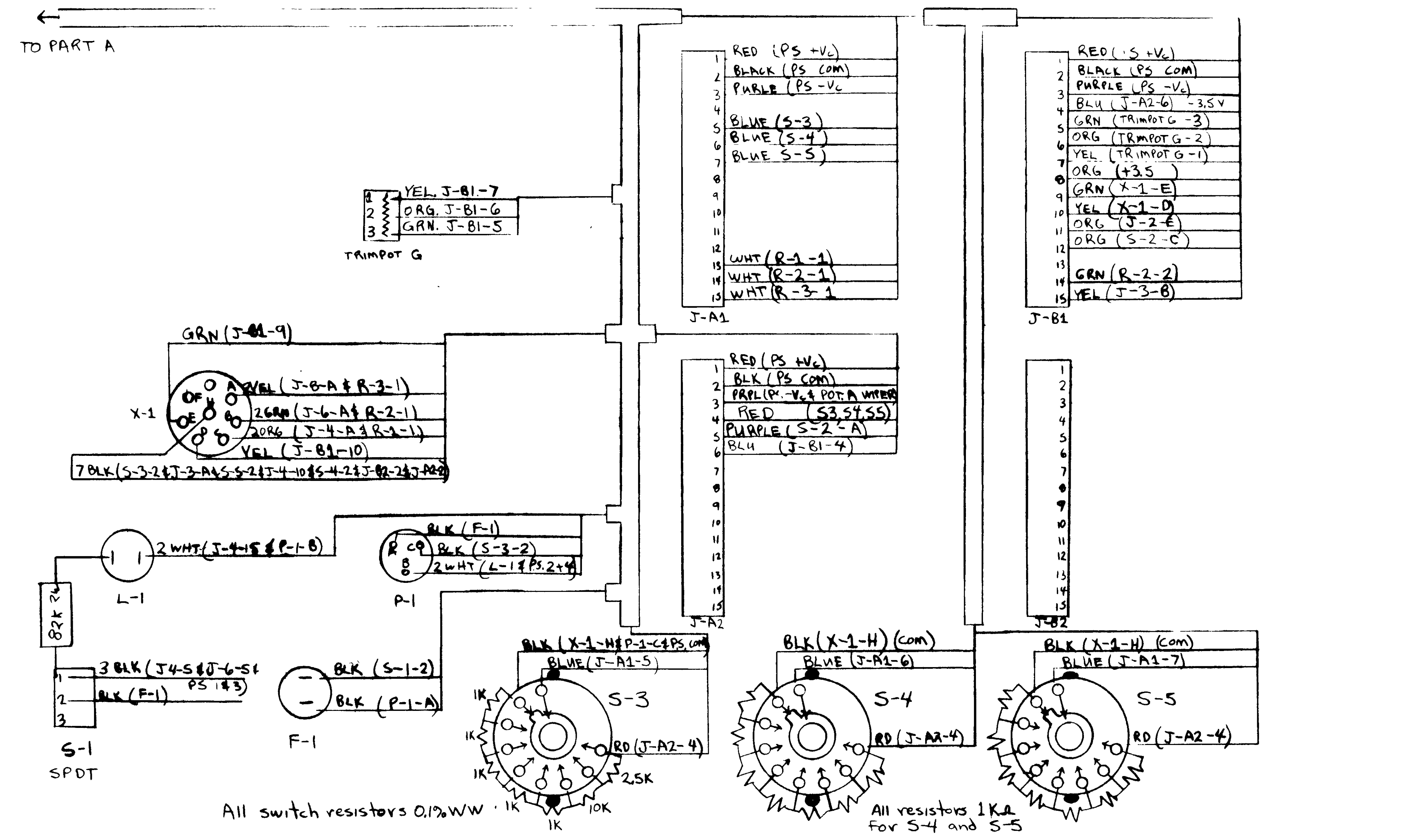
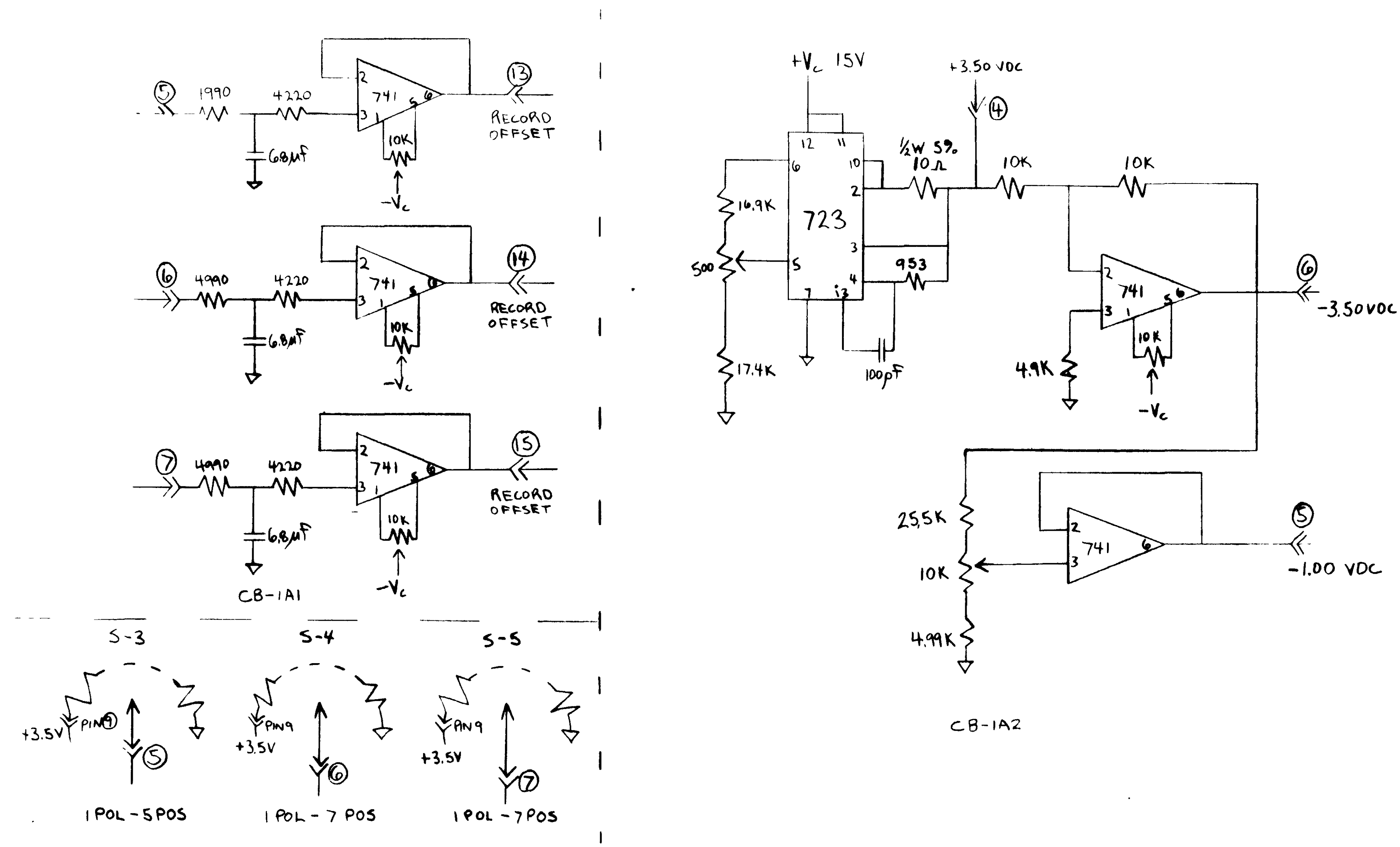


FIGURE 19 SALINITY, TEMPERATURE, DEPTH PANEL
PANEL WIRING DIAGRAM, PART B

PANEL NO	DRAWN BY LD
1	DATE NOV. 1976



NOTE: CENTRALAB NO. 1403 SWITCHES

NOTE: POWER CONNECTIONS TO IC'S ARE NOT SHOWN
RESISTORS ALL METAL FILM 1% UNLESS SPECIFIED

FIGURE 20 SALINITY, TEMPERATURE, DEPTH PANEL CIRCUIT BOARDS CB-1A1, 1A2 SCHEMATIC DIAGRAMS	CB-1A1 FOLLOWER CIRCUITRY & ZERO OFFSET SWITCHES CB-1A2 REGULATED POWER SUPPLY	PANEL NO. 1	DRAWN BY L.D. DATE NOV 1976

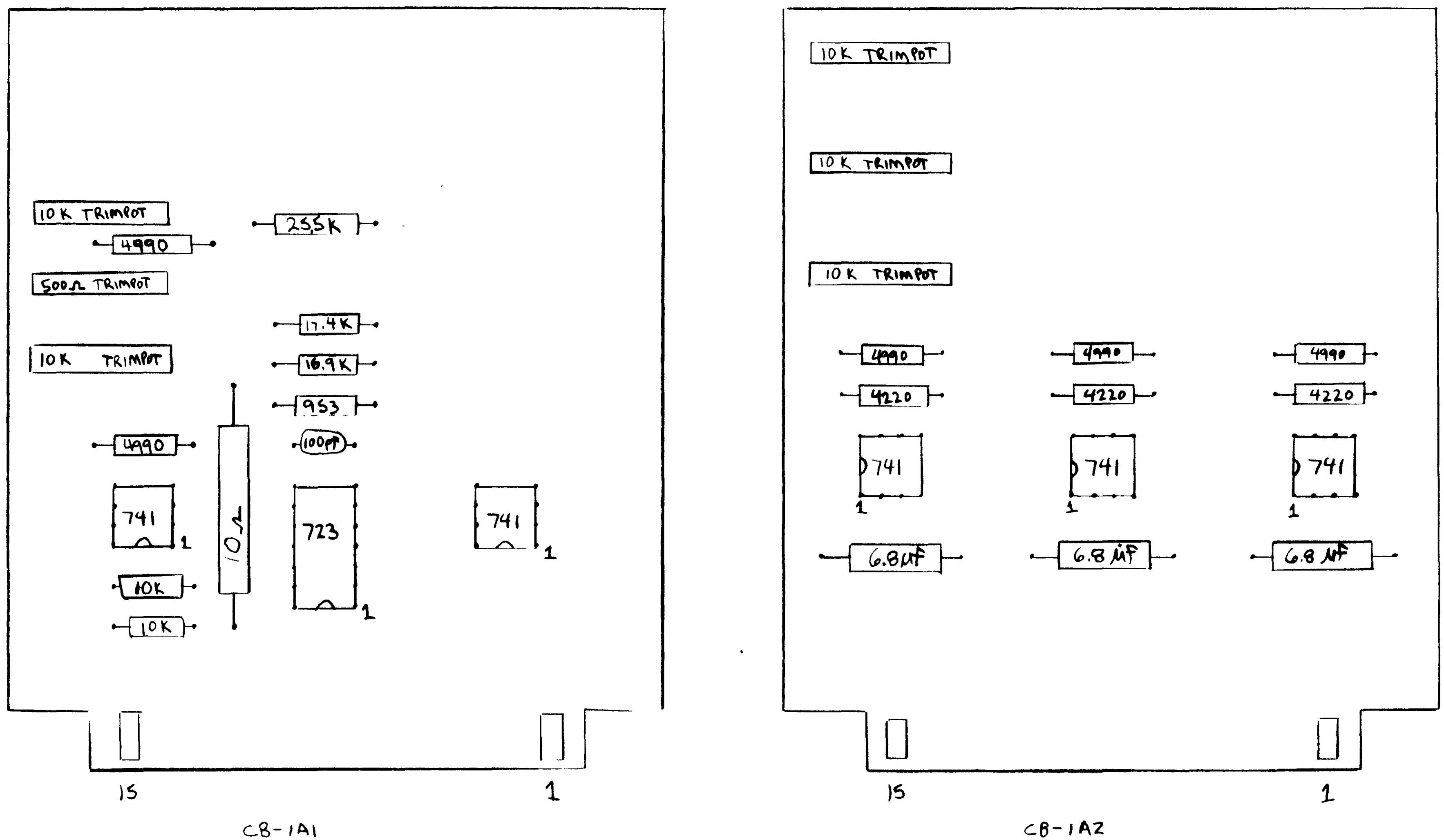
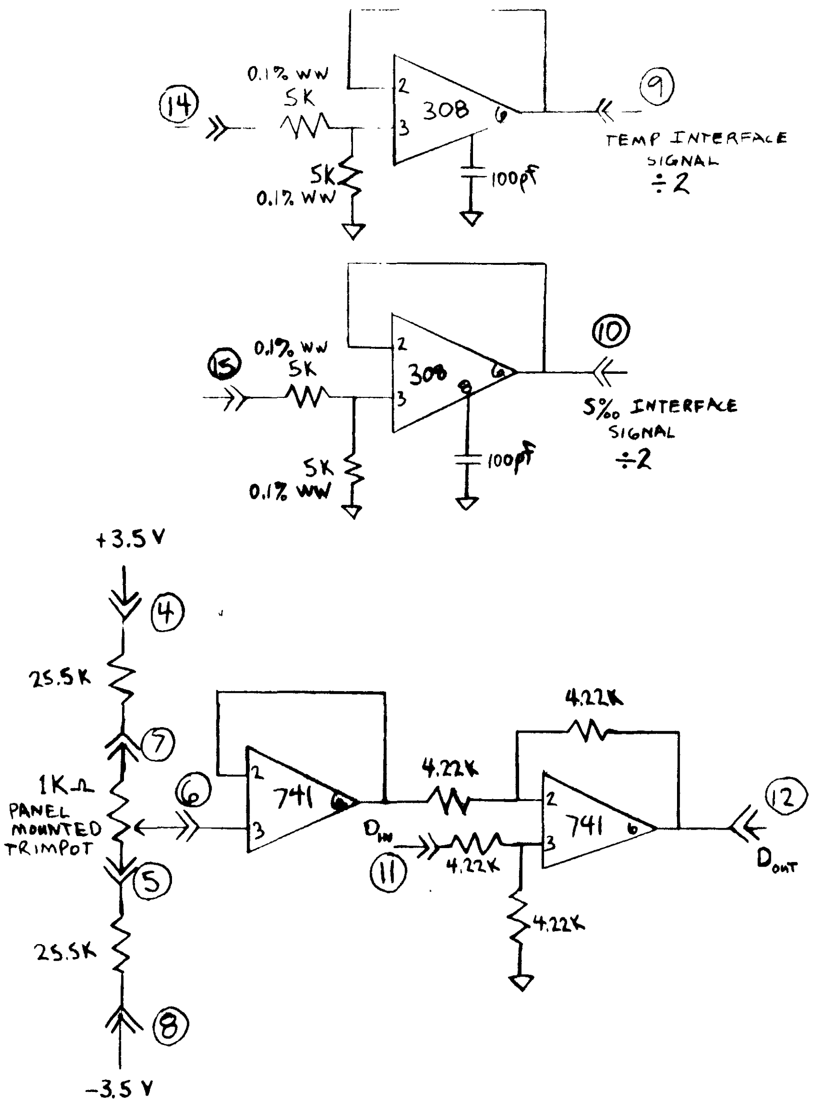


FIGURE 21 SALINITY, TEMPERATURE, DEPTH PANEL CIRCUITBOARDS CB-1A1, 1A2 LAYOUTS	CB-1A1 REGULATED VOLTAGE SUPPLY CB-1A2 FOLLOWER CIRCUITRY	PANEL NO 1	DRAWN BY LD DATE NOV. 1976



NOTE: IC POWER CONNECTIONS NOT SHOWN
RESISTORS ALL METAL FILM 1% UNLESS SPECIFIED

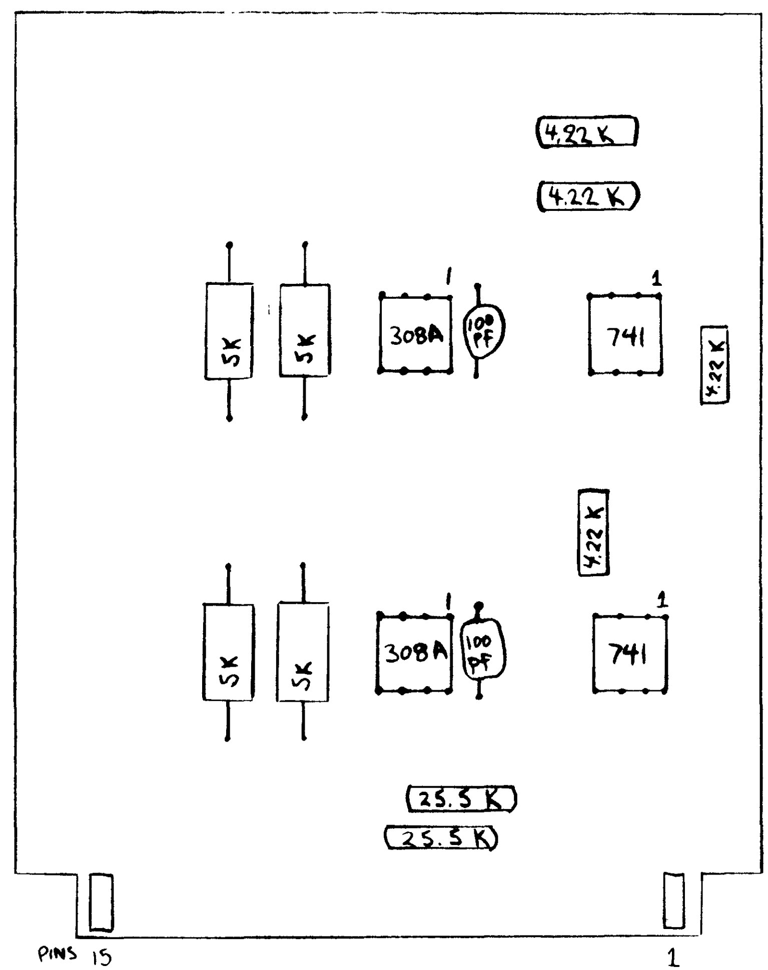


FIGURE 22 SALINITY, TEMPERATURE, DEPTH PANEL CIRCUIT BOARD CB-1B1 SCHEMATIC DIAGRAM AND LAYOUT	CB-1B1 SALINITY AND TEMPERATURE INTERFACE AND DEPTH ZERO ADJUSTMENT	PANEL NO. 1	DRAWN BY L.D DATE NOV 1976

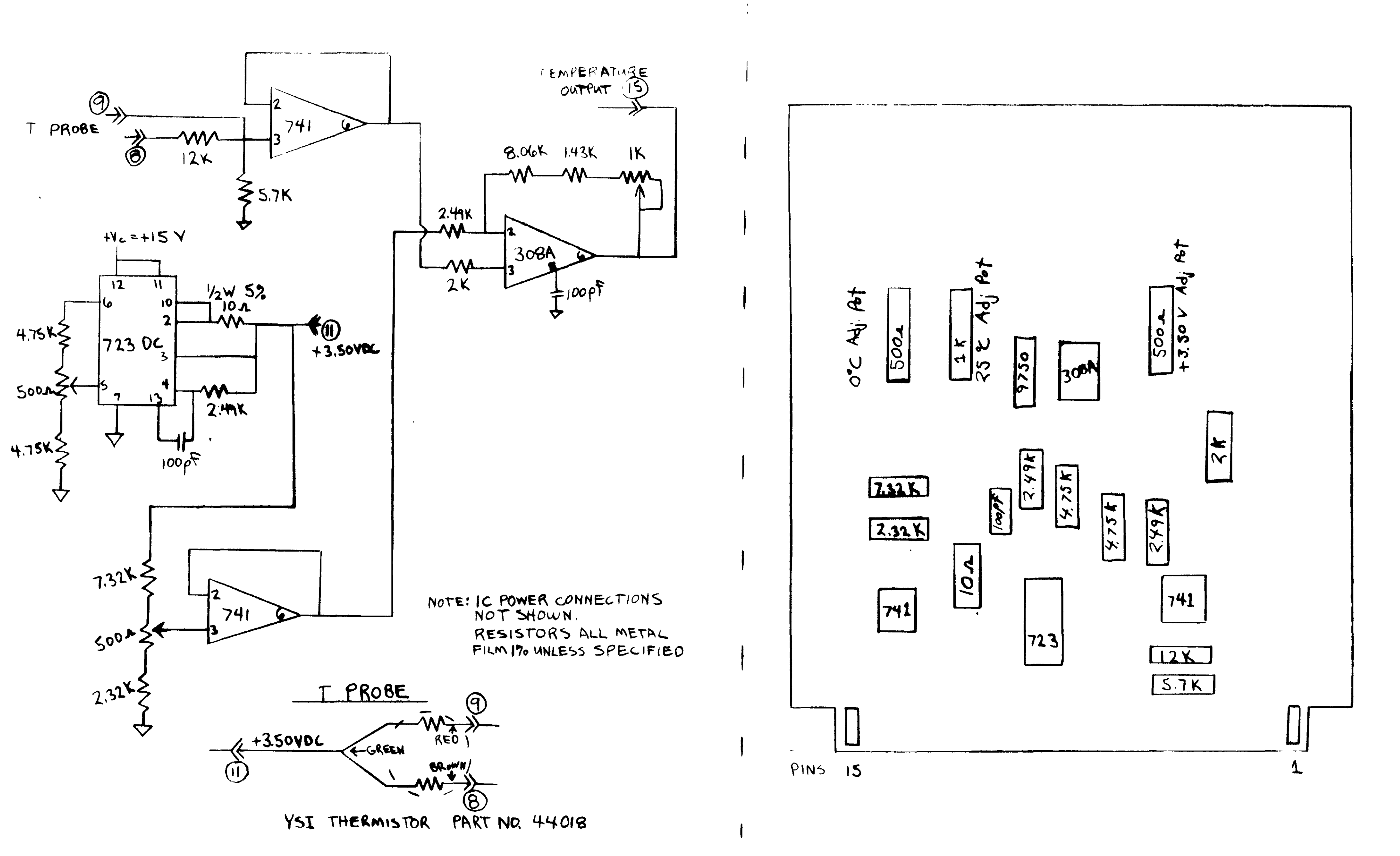


FIGURE 23 SALINITY, TEMPERATURE, DEPTH PANEL
BOW INTAKE TEMPERATURE SCHEMATIC DIAGRAM
AND BOARD LAYOUT

DRAWN BY LD

DATE NOV 1976

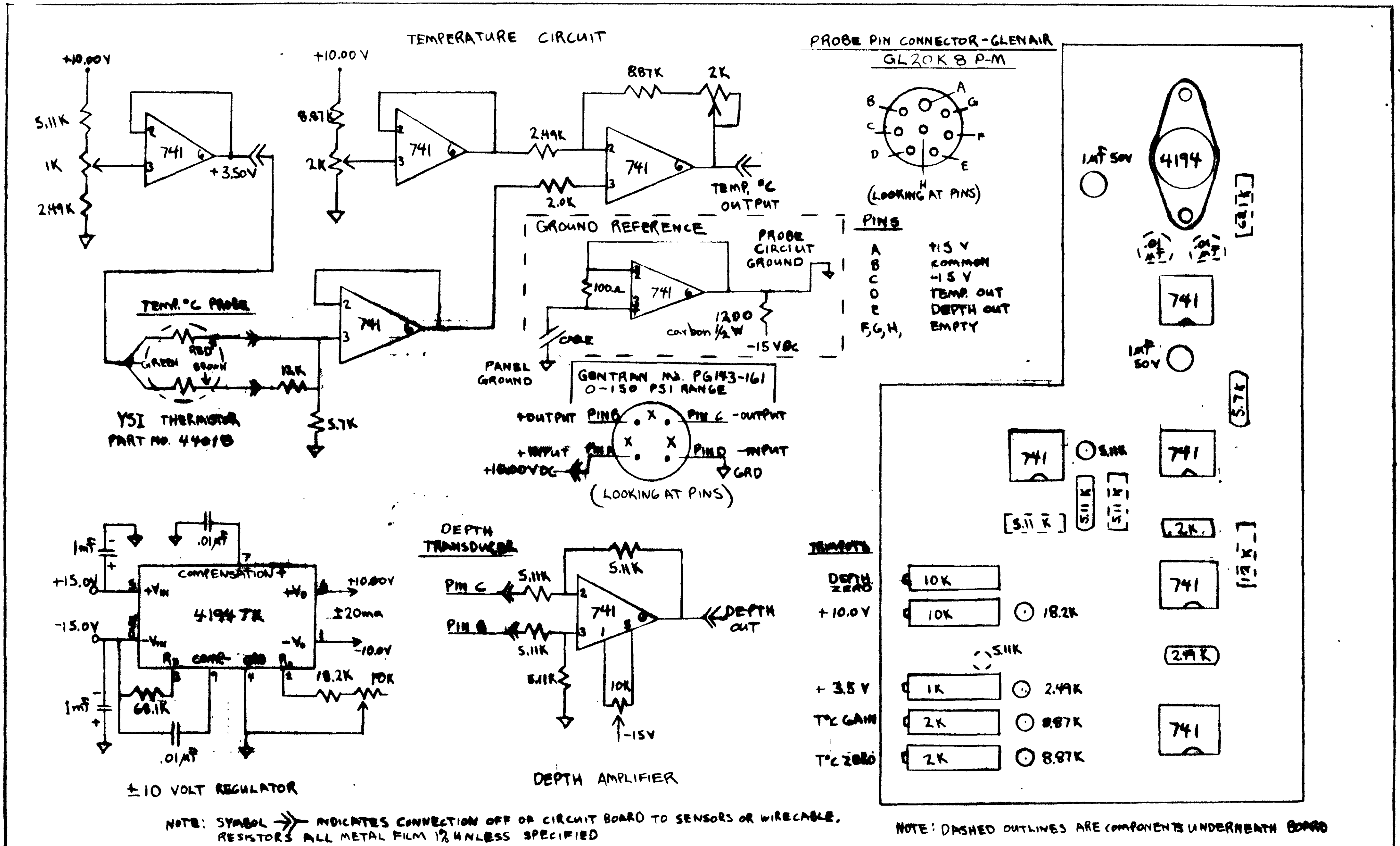
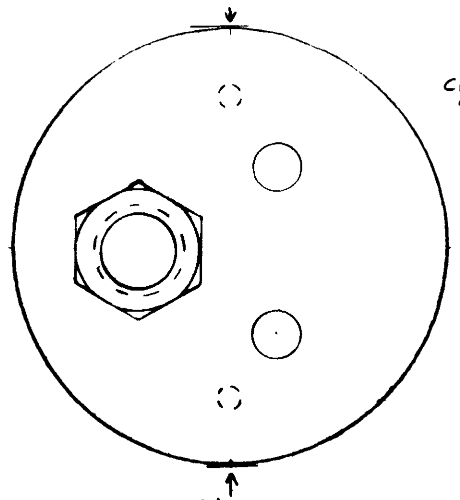
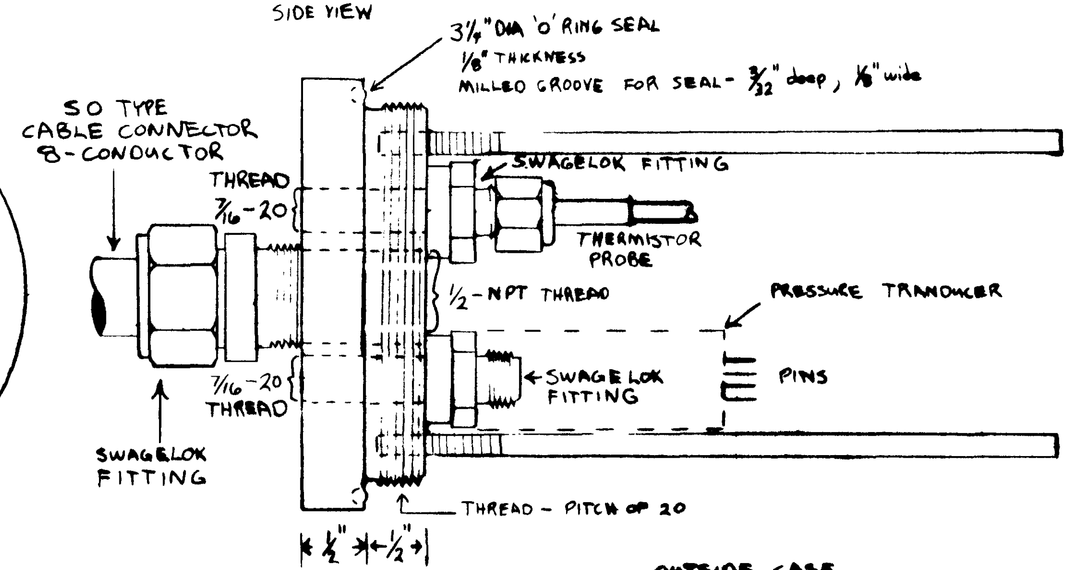
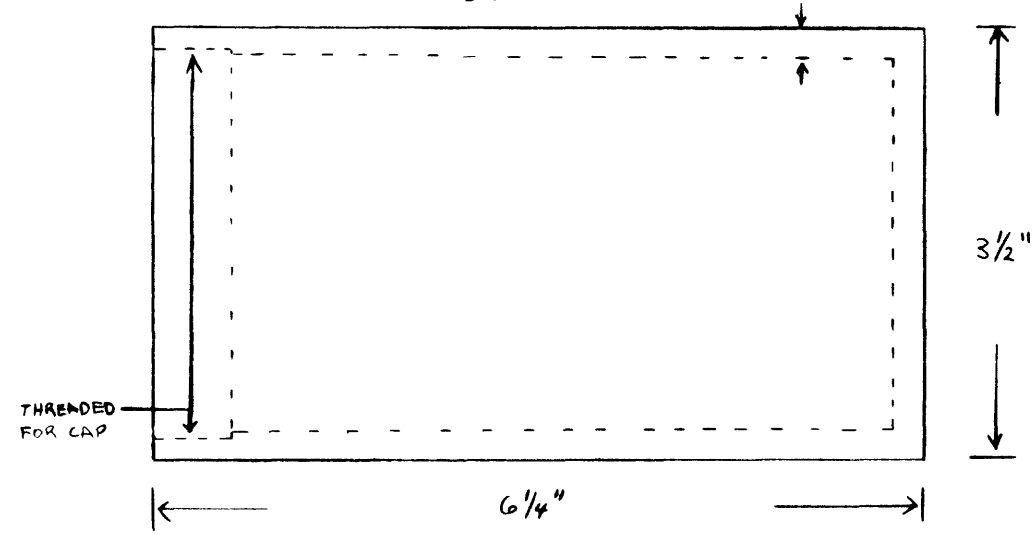


FIGURE 24 IN SITU TEMPERATURE/DEPTH PROBE SCHEMATIC DIAGRAM AND BOARD LAYOUT

DRAWN BY LD
DATE NOV 1976







PROBE CONTAINER

MATERIAL - STAINLESS STEEL 316
SMALLER FITTING - SWAGELOK SS-400-1-OR
LARGER FITTING - SWAGELOK SS-1010-1-OR
BRASS RODS - 3/16" O.D. THREADED
THERMISTOR PROBE - STAINLESS STEEL 1/4" O.D. TUBING
HOUSING YSI THERMISTOR ELEMENT

FIGURE 25 IN SITU TEMPERATURE/DEPTH PROBE PRESSURE VESSEL DRAWING	DRAWN BY L.D.
	DATE NOV 1976

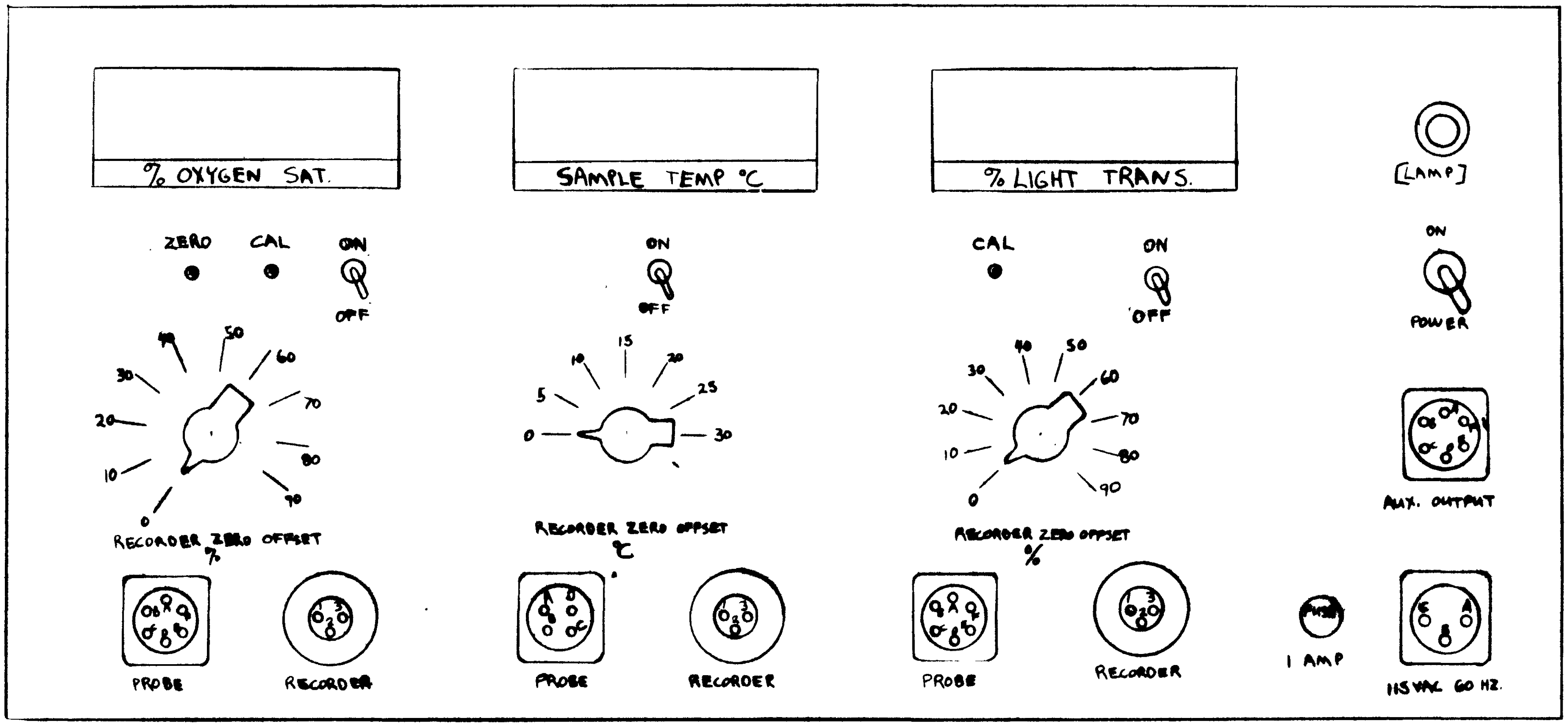
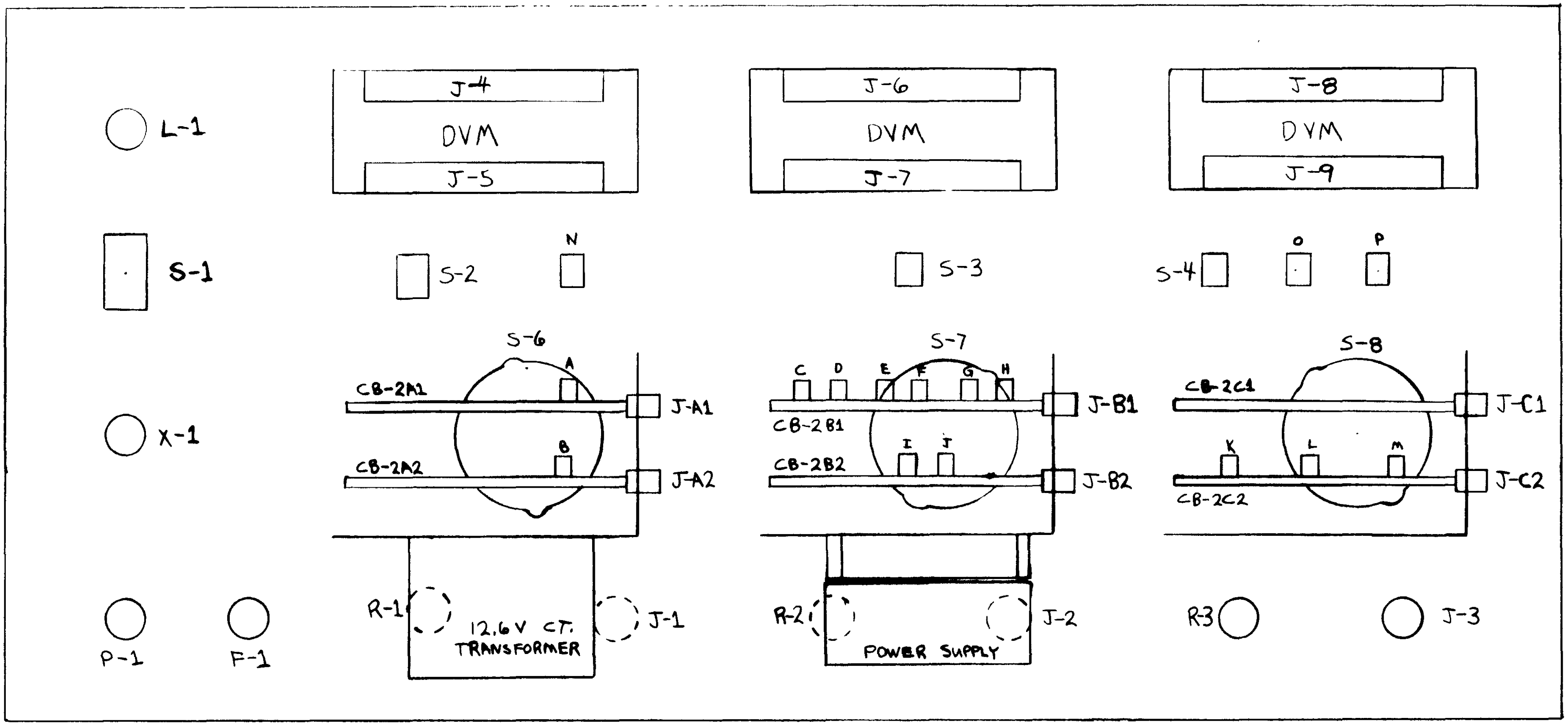


FIGURE 26 OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL PANEL LAYOUT (FRONT)	PANEL NO 2	DRAWN BY L D	DATE NOV 1976



F-1 FUSE
L-1 NEON LAMP
X-1 AUX. OUTPUT
P-1 POWER CONNECTOR
R-1 REC. OUTPUT - LIGHT
R-2 REC. OUTPUT - TEMPERATURE
R-3 REC. OUTPUT - OXYGEN
S-1 POWER SWITCH
S-2 SWITCH FOR % LIGHT TRANS.
S-3 SWITCH FOR TEMPERATURE
S-4 SWITCH FOR % OXYGEN
S-6 REC. ZERO OFFSET - LIGHT
S-7 REC. ZERO OFFSET - TEMP

S-8 REC. ZERO OFFSET - OXYGEN
CB-2A1 %T CONST. CURRENT SUPPLY
CB-2A2 %T MEASUREMENT CIRCUITRY
CB-2B1 ZERO SUPPRESSION CALIB. & FOLLOWER
CB-2B2 T°C MEASUREMENT CIRCUITRY
CB-2C1 D.O. MEASUREMENT CIRCUITRY
CB-2C2 REGULATED VOLTAGE SUPPLY
J4 THRU J9 PC CONNECTORS ON DVM'S
J-A1 THRU J-C2 CONNECTORS FOR BOARDS
J1 %T PROBE INPUT
J2 T°C PROBE INPUT
J3 DO PROBE INPUT

TRIMPOTS
A LIGHT TRANSMISSION LAMP CURRENT ADJ.
B " " SENSOR GAIN ADJ.
C % TRANSMISSION REC. OFFSET ZERO ADJ.
D " " " " FULLSCALE ADJ.
E SAMPLE TEMP. REC. OFFSET ZERO ADJ.
F " " " " FULLSCALE ADJ.
G DISSOLVED OXYGEN REC. OFFSET ZERO ADJ.
H " " " " FULLSCALE ADJ.
I TEMP. 0°C ADJ
J TEMP 25°C ADJ.
K +0.84 VDC ADJ
L +3.500 VDC ADJ
M −3.500 VDC ADJ.

N %T CALIBRATE
O D.O. CALIBRATE 100%
P D.O. CALIBRATE ZERO

FIGURE 27 OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL PANEL LAYOUT (BACK)	PANEL NO. 2	DRAWN BY L.D. DATE NOV 1976

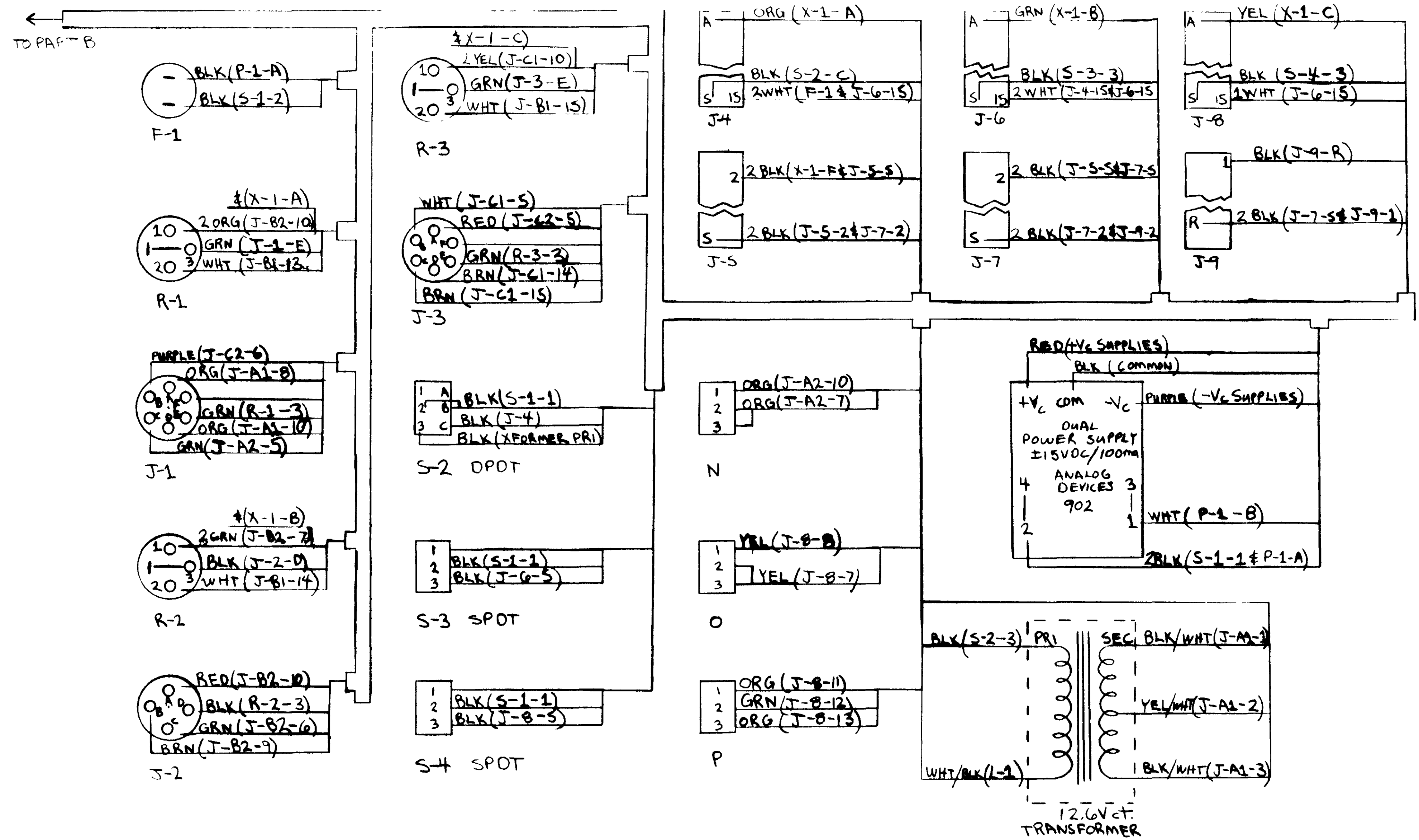


FIGURE 28 OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL PANEL WIRING DIAGRAM, PART A	PANEL NO. 2	DRAWN BY L.D. DATE NOV 1976

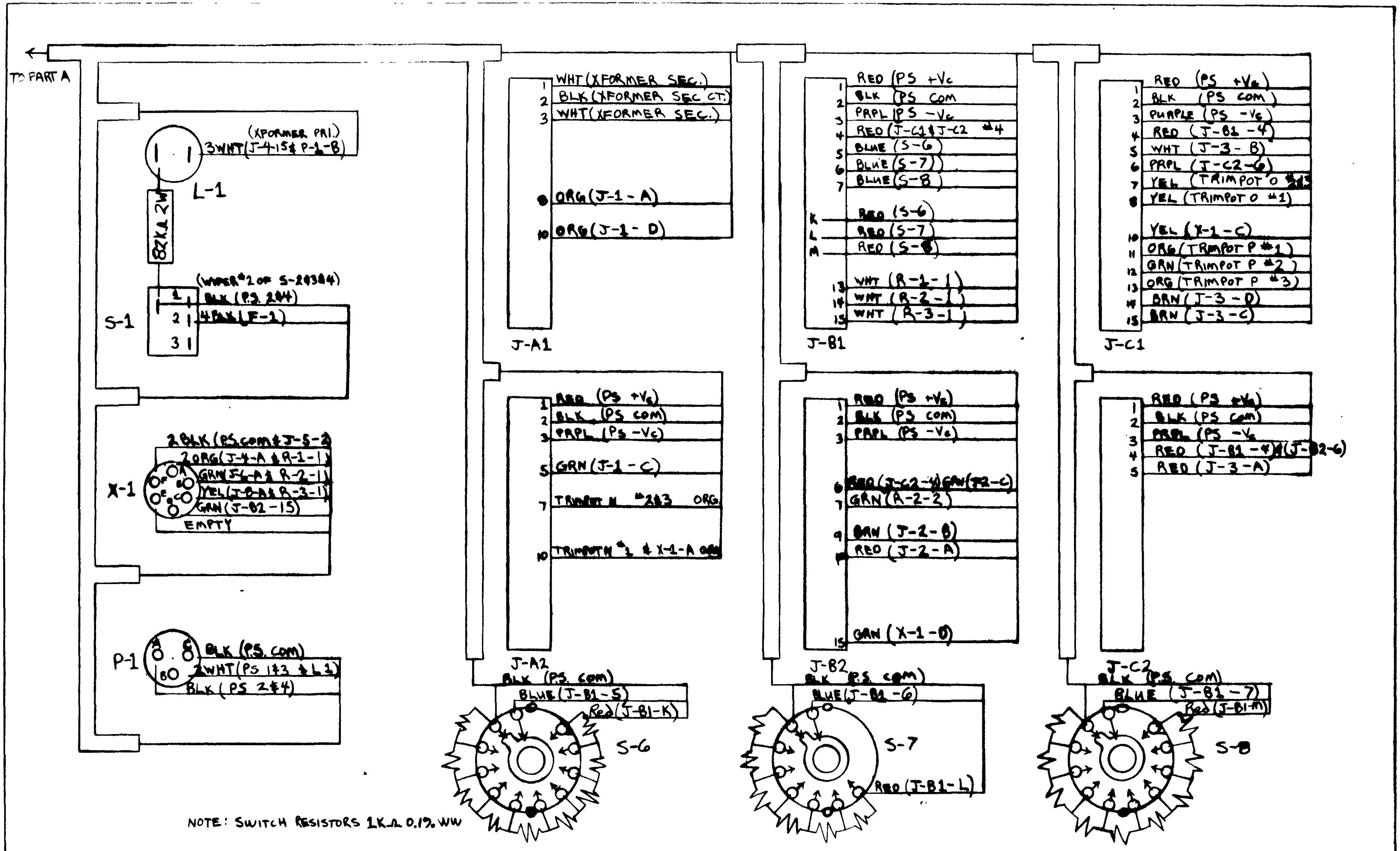
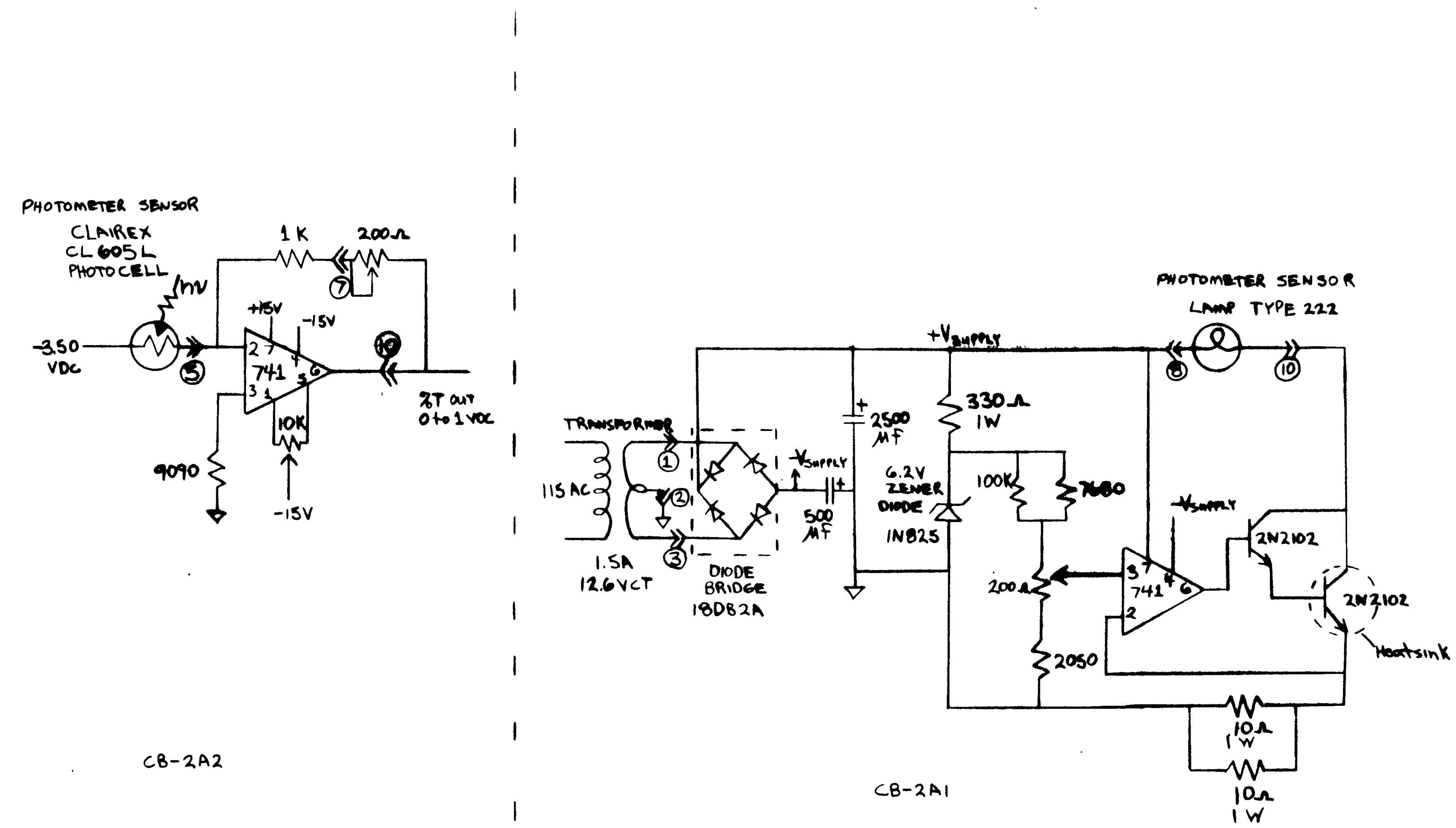


FIGURE 29 OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL
PANEL WIRING DIAGRAM, PART B

PANEL NO. 2

DRAWN BY L.D.

DATE NOV 1976



ALL RESISTORS METAL FILM 1% UNLESS SPECIFIED

FIGURE 30	OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL CIRCUIT BOARDS CB-2A1, 2A2 SCHEMATIC DIAGRAMS	CB-2A1 % TRANSMISSION CONSTANT CURRENT SUPPLY CB-2A2 % TRANSMISSION MEASUREMENT CIRCUITRY	PANEL NO. 2	DRAWN BY L.D. DATE NOV 1976

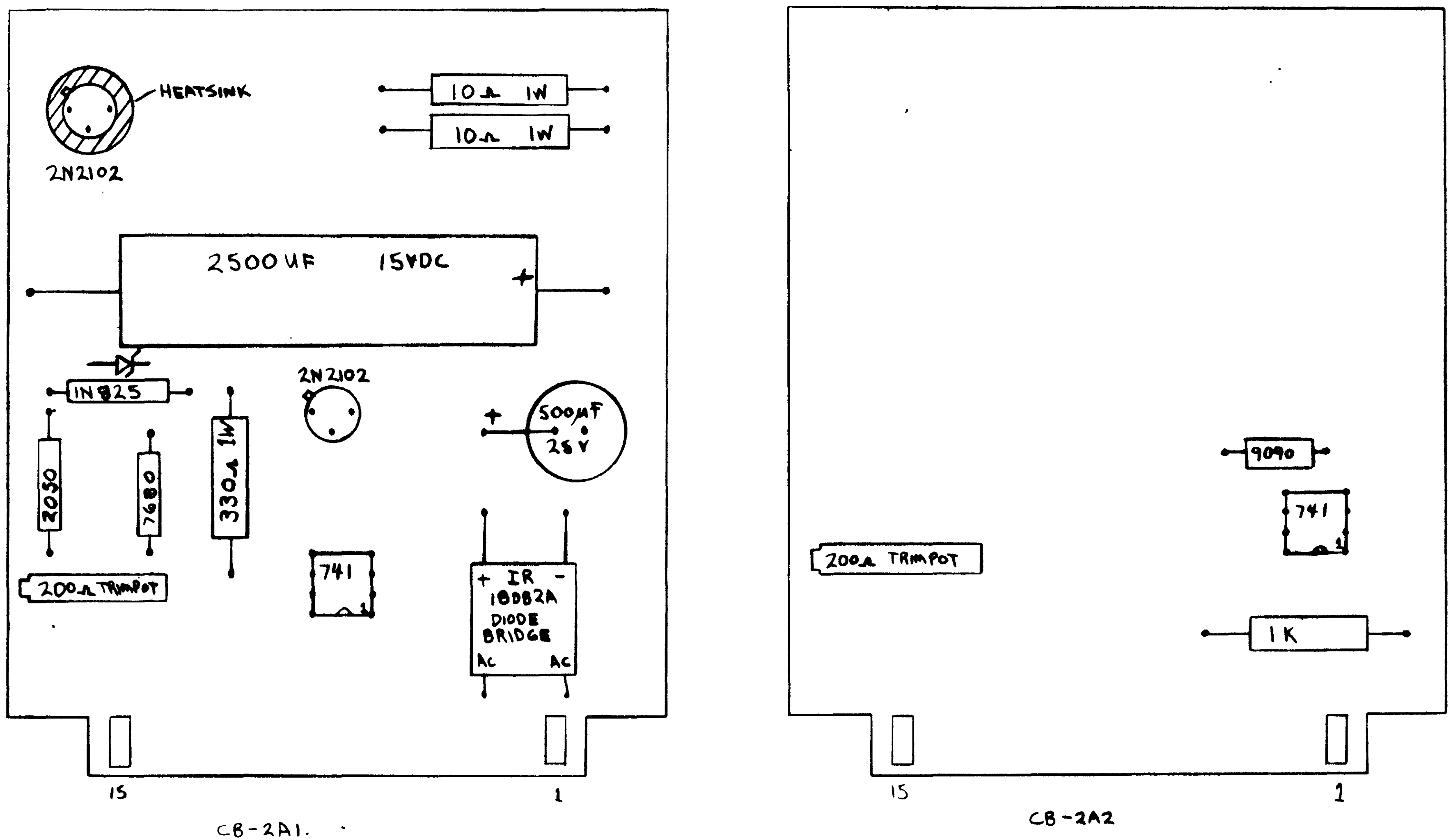
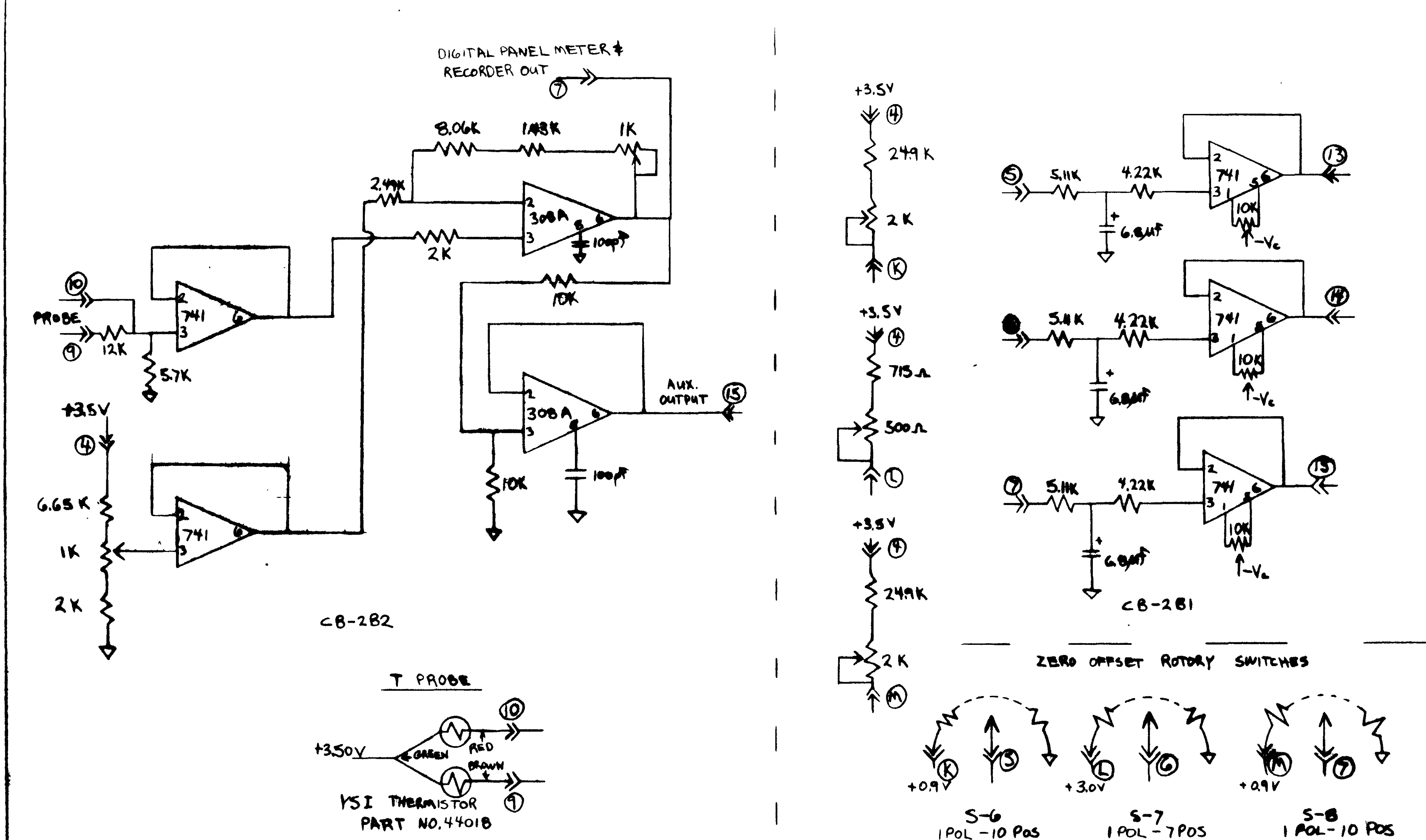


FIGURE 31 OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL PANEL CIRCUITBOARDS CB-2A1, 2A2 LAYOUTS	CB-2A1 % TRANSMISSION CONSTANT CURRENT SUPPLY CB-2A2 % TRANSMISSION MEASUREMENT CIRCUITRY	PANEL NO. 2	DRAWN BY L.D DATE NOV 1976



NOTE: POWER CONNECTIONS TO IC'S NOT SHOWN
RESISTORS ALL METAL FILM 1% UNLESS SPECIFIED (1/8W)

FIGURE 32 OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL PANEL CIRCUIT BOARDS CB-2B1, 2B2 SCHEMATIC DIAGRAMS	CB-2B1 ZERO SUPPRESION CALIBATION AND FOLLOWER CB-2B2 TEMPERATURE °C MEASUREMENT CIRCUITRY	PANEL NO. 2	DRAWN BY L.O. DATE NOV. 1976

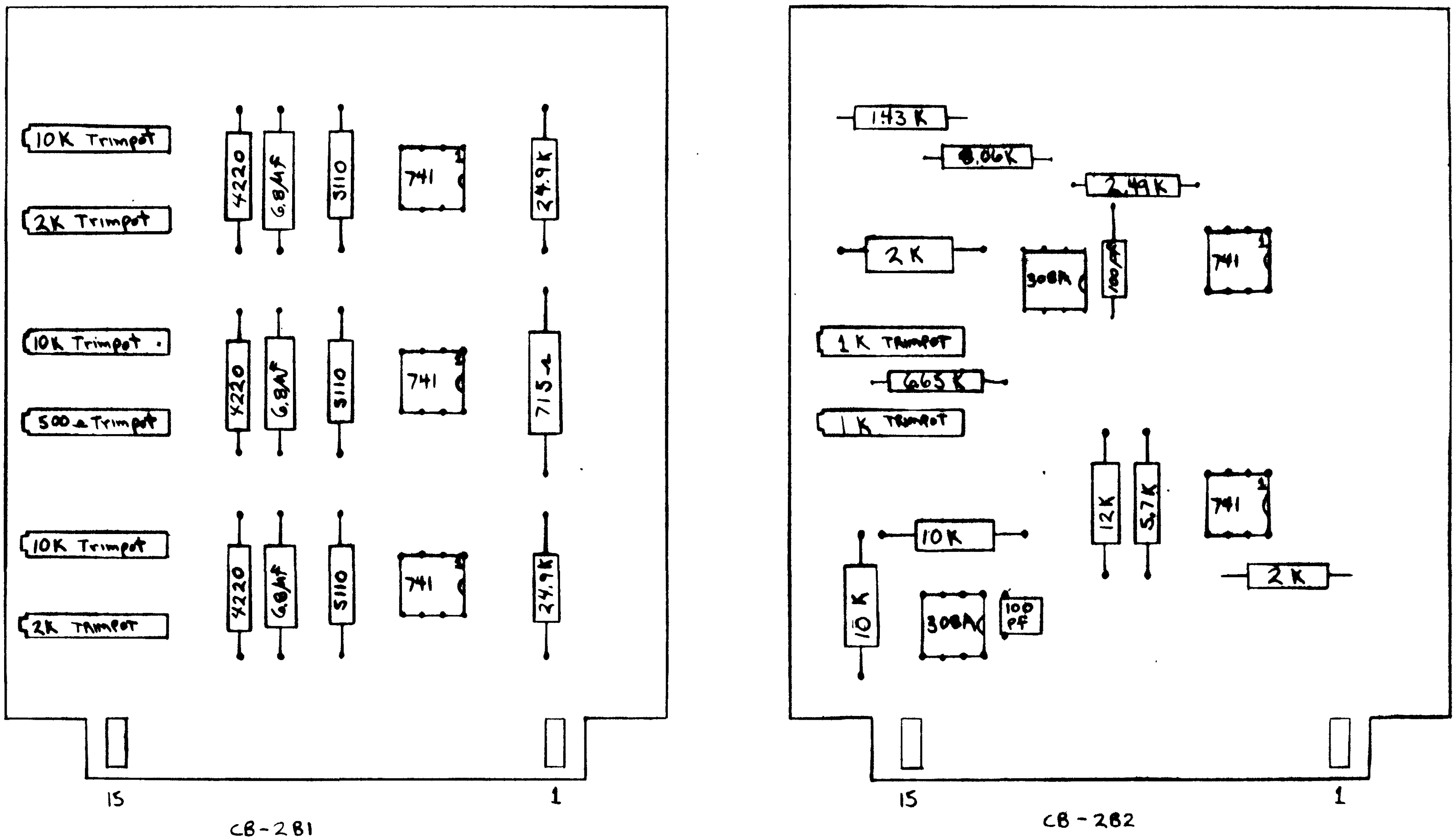
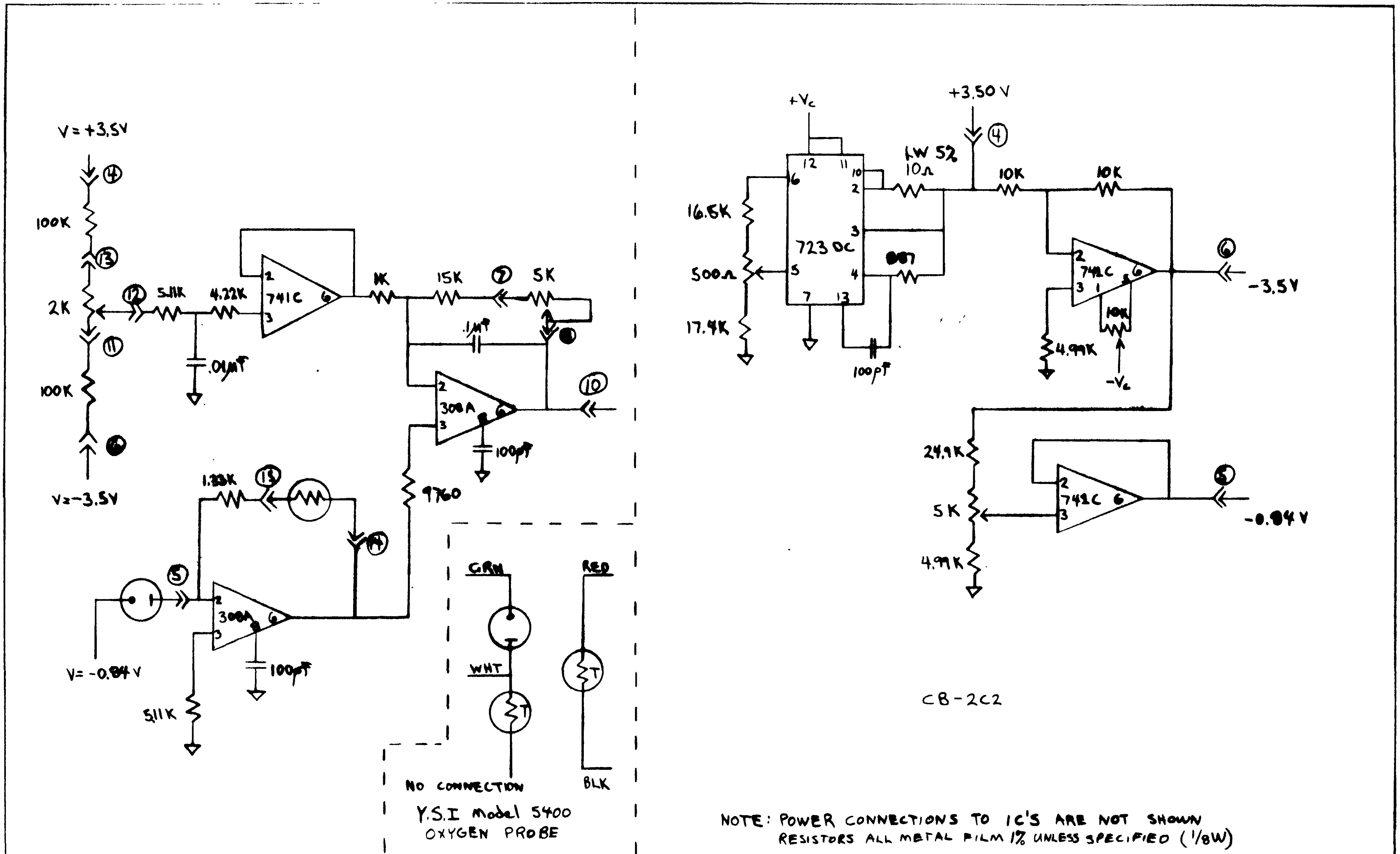


FIGURE 33 OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL PANEL CIRCUIT BOARDS CB-2B1, 2B2	CB-2B1 ZERO SUPPRESSION CALIBRATION AND FOLLOWER LAYOUTS CB-2B2 TEMPERATURE °C MEASUREMENT CIRCUIT LAYOUTS	PANEL NO. 2	DRAWN BY LD DATE NOV 1976



NOTE: POWER CONNECTIONS TO IC'S ARE NOT SHOWN
RESISTORS ALL METAL FILM 1% UNLESS SPECIFIED (1/8W)

FIGURE 34 OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL
PANEL CIRCUITBOARDS CB-2C1, 2C2 SCHEMATIC DIAGRAMS

CB-2C1	DISSOLVED OXYGEN MEASUREMENT CIRCUIT	PANEL NO.	DRAWN BY L.D.
CB-2C2	REGULATED VOLTAGE SUPPLY	2	DATE NOV 1976

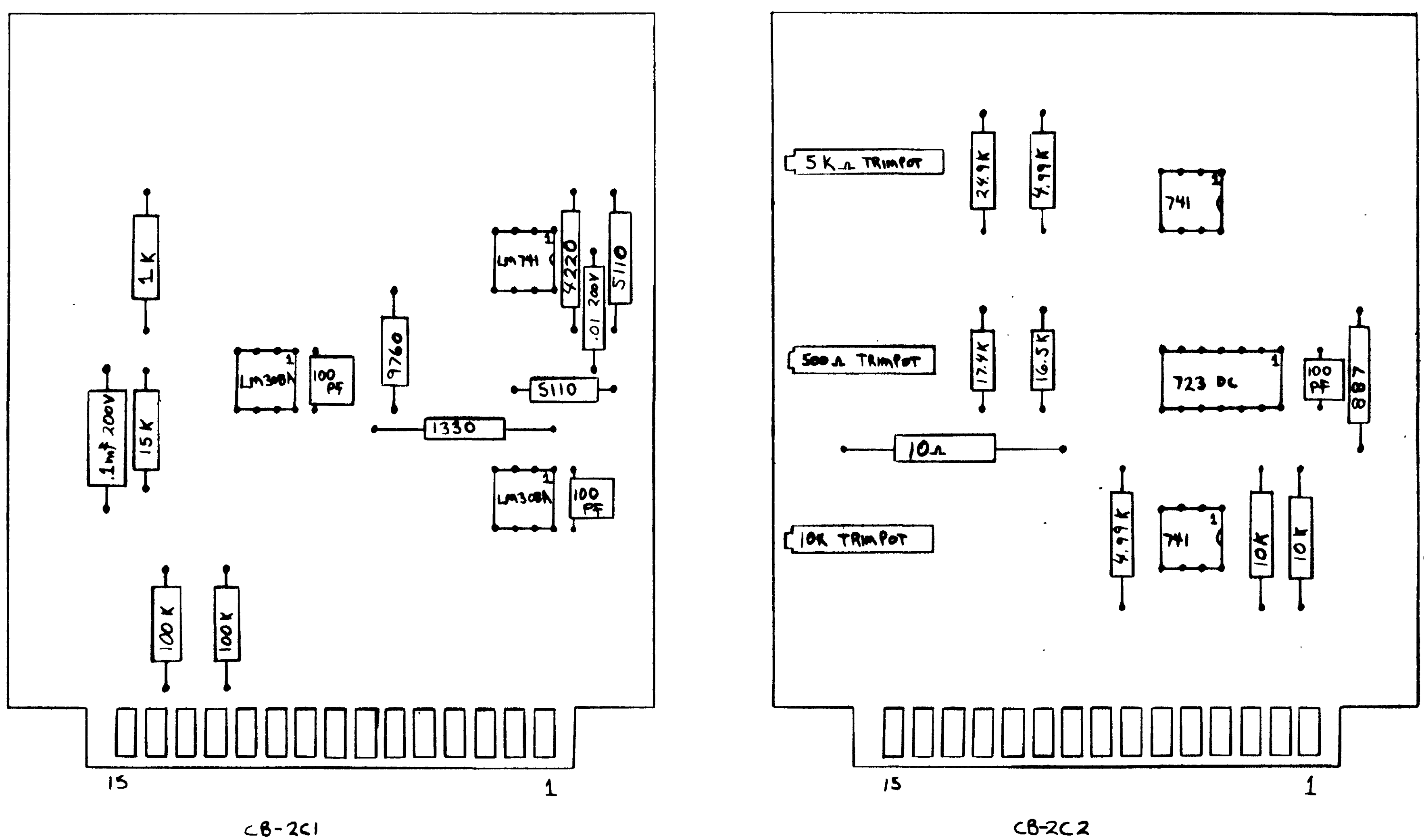


FIGURE 35 OXYGEN, TEMPERATURE, LIGHT TRANSMISSION PANEL PANEL CIRCUITBOARDS CB-2C1, 2C2 LAYOUTS	CB-2C1 DISSOLVED OXYGEN MEASUREMENT CIRCUIT CB-2C2 REGULATED VOLTAGE SUPPLY	PANEL NO. 2	DRAWN BY L.D. DATE NOV 1976

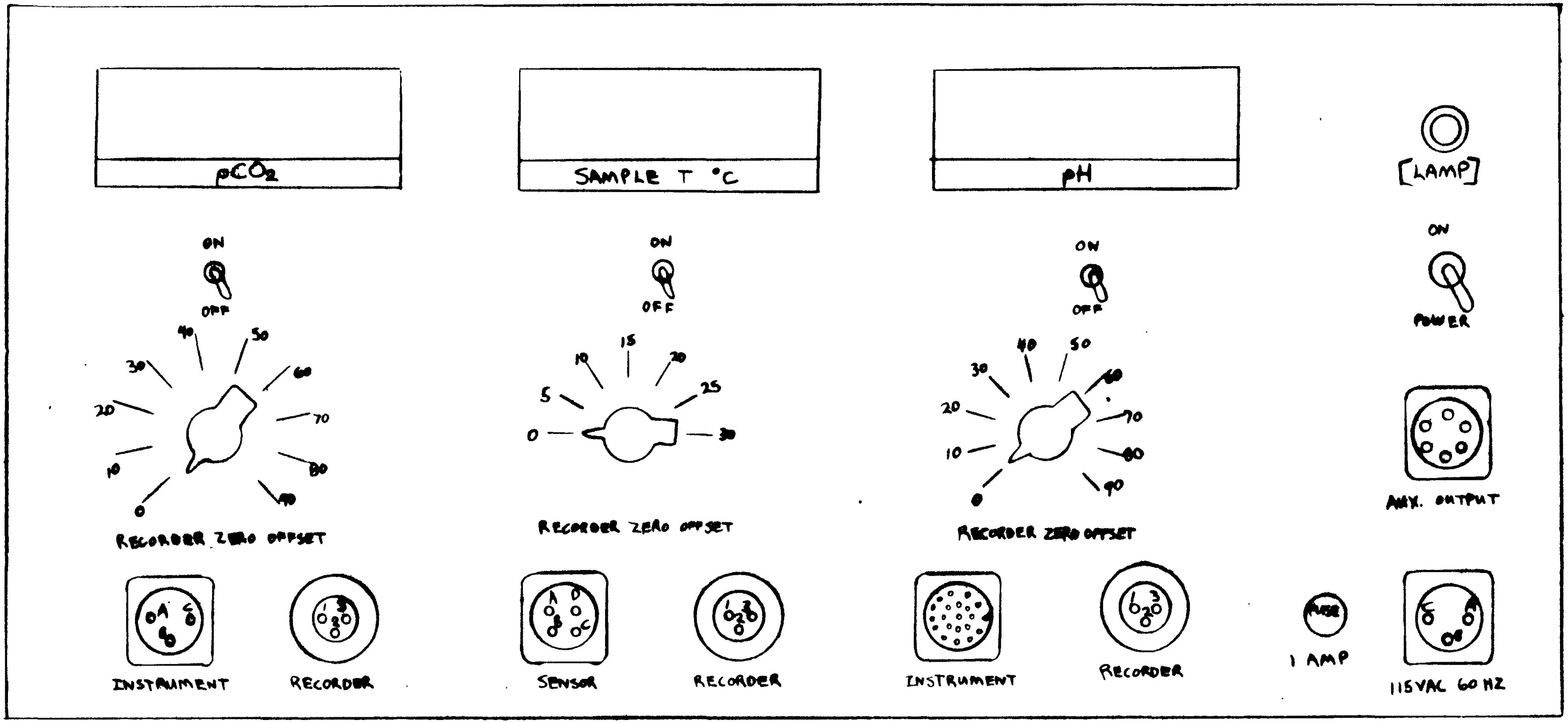
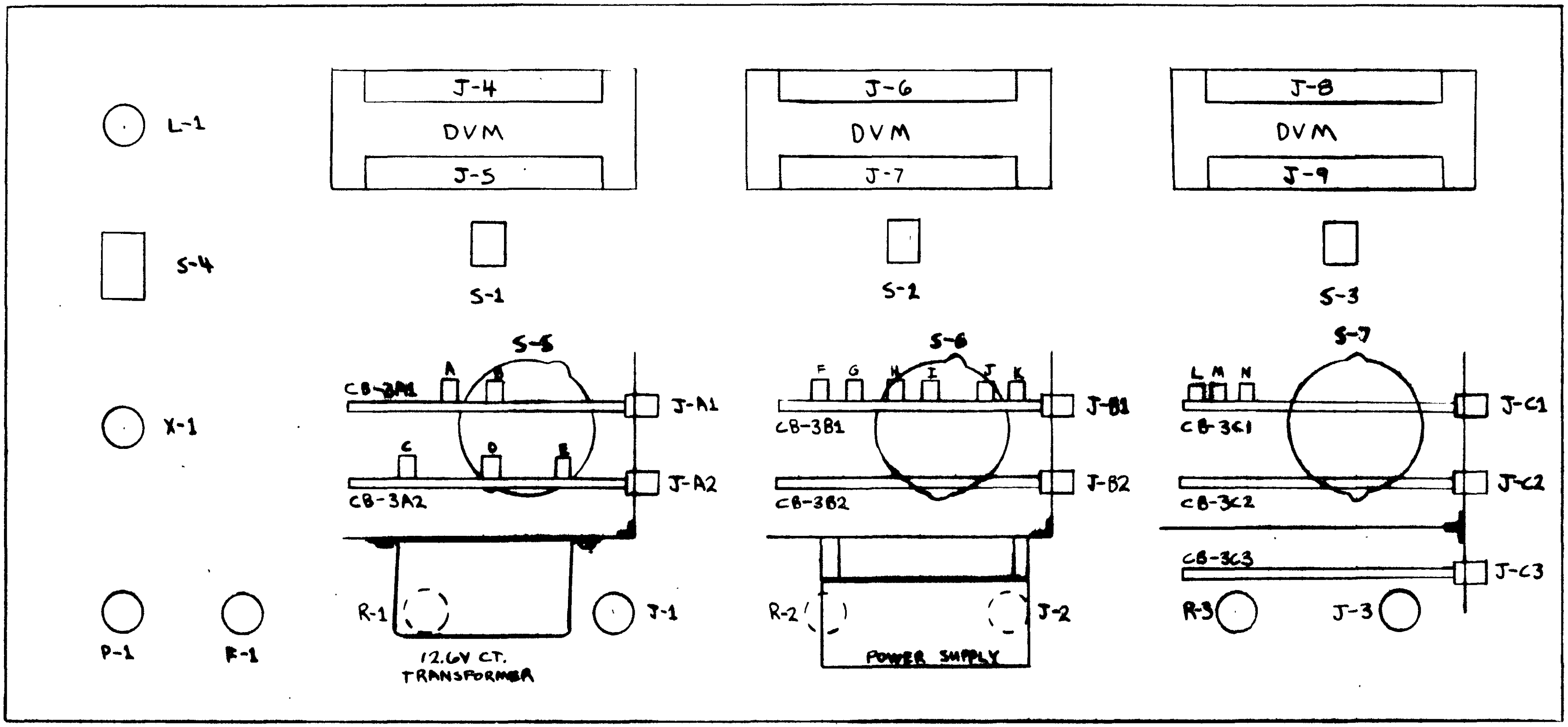


FIGURE 36	pCO_2, TEMPERATURE, pH PANEL PANEL LAYOUT (FRONT)	PANEL NO 3	DRAWN BY L.D. DATE NOV 1976



F-1	FUSE
L-1	NEON LAMP
X-1	AUX. OUTPUT
P-1	POWER CONNECTOR
R-1	REC. OUTPUT - pH
R-2	REC. OUTPUT - TEMPERATURE
R-3	REC. OUTPUT - pCO_2
J-1	INSTRUMENT INPUT FOR pH
J-2	SENSOR INPUT FOR T°C
J-3	INSTRUMENT INPUT FOR pCO_2
S-1	SWITCH FOR pH
S-2	SWITCH FOR TEMPERATURE
S-3	SWITCH FOR pCO_2

CB-3A1	T°C MEASUREMENT CIRCUITRY
CB-3A2	REGULATED VOLTAGE SUPPLY
CB-3B1	ZERO SUPPRESSION CAL. & FOLLOWERS
CB-3B2	pH D/A CONVERSION CIRCUITRY
CB-3C1	pH D/A CONVERSION CIRCUITRY
CB-3C2	pH D/A CONVERSION CIRCUITRY
CB-3C3	pH D/A CONVERSION CIRCUITRY
J-A1 THRU J-C3	CONNECTORS FOR BOARDS
J4 THRU J9	CONNECTORS FOR DVM'S
S-5	REC. ZERO OFFSET - pH
S-6	REC. ZERO OFFSET - T°C
S-7	REC. ZERO OFFSET - pCO_2
S-4	POWER SWITCH

TRIMPOTS

A	TEMP. 0°C ADJ.
B	TEMP 25°C ADJ.
C	-1.00 VDC ADJ.
D	+3.50 VDC ADJ
E	-3.50 VDC ADJ
F	pH REC. OFFSET ZERO ADJ.
G	" " " FULLSCALE ADJ.
H	SAMPLE TEMP. REC. OFFSET ZERO ADJ.
I	" " " " FULLSCALE ADJ.
J	pCO_2 REC. OFFSET ZERO ADJ.
K	" " " FULLSCALE ADJ.

L	pH READING SIGNAL ADJ.
M	D/A CONVERTER ZERO ADJ.
N	D/A CONVERTER GAIN ADJ.

FIGURE 37 pCO_2, TEMPERATURE, pH PANEL PANEL LAYOUT (BACK)	PANEL NO 3	DRAWN BY L.D. / DATE NOV 1976

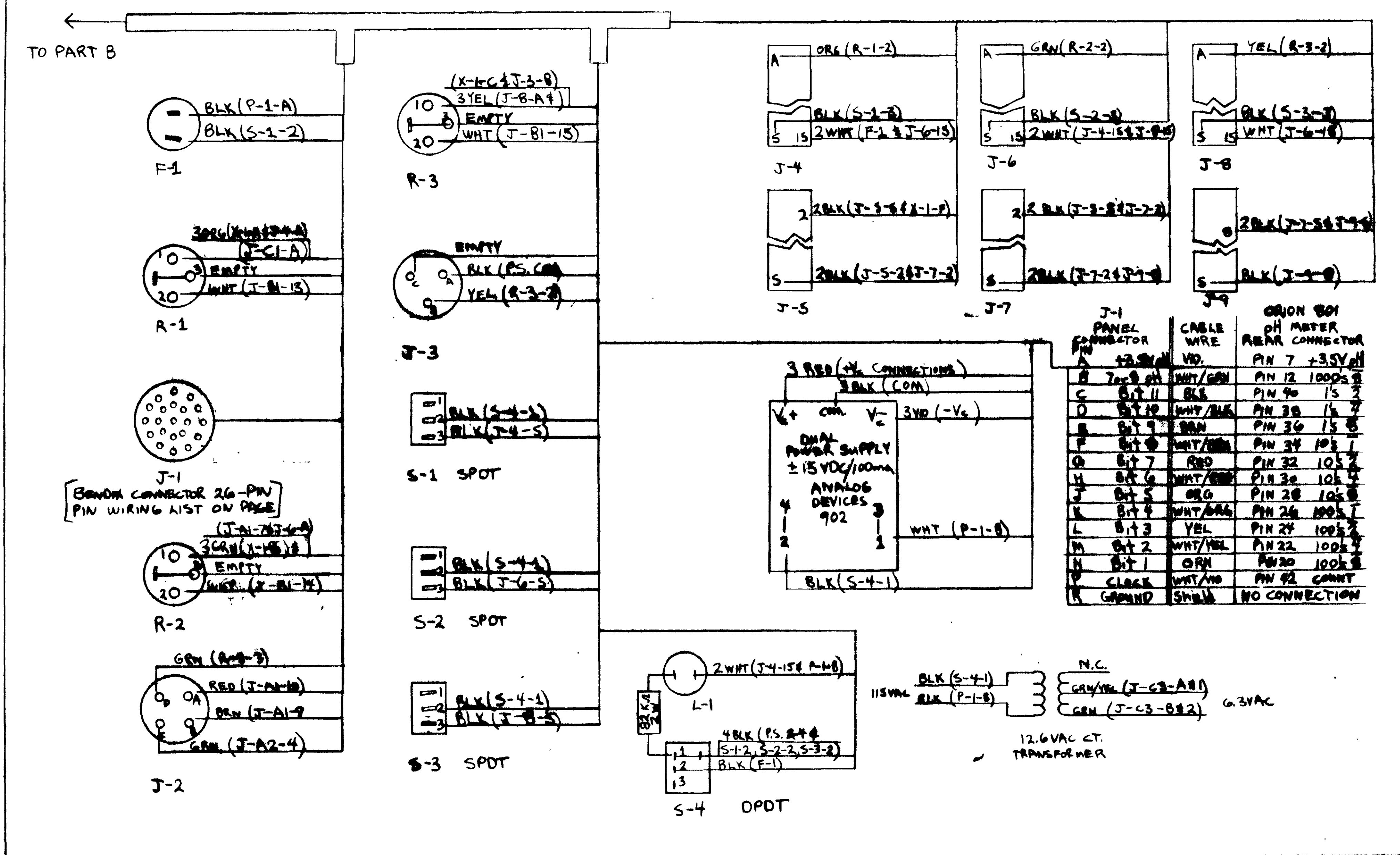


FIGURE 38 pCO_2, TEMPERATURE, pH PANEL WIRING DIAGRAM, PART A

PANEL NO. 3

DRAWN BY L.O.

DATE NOV 19[illegible]

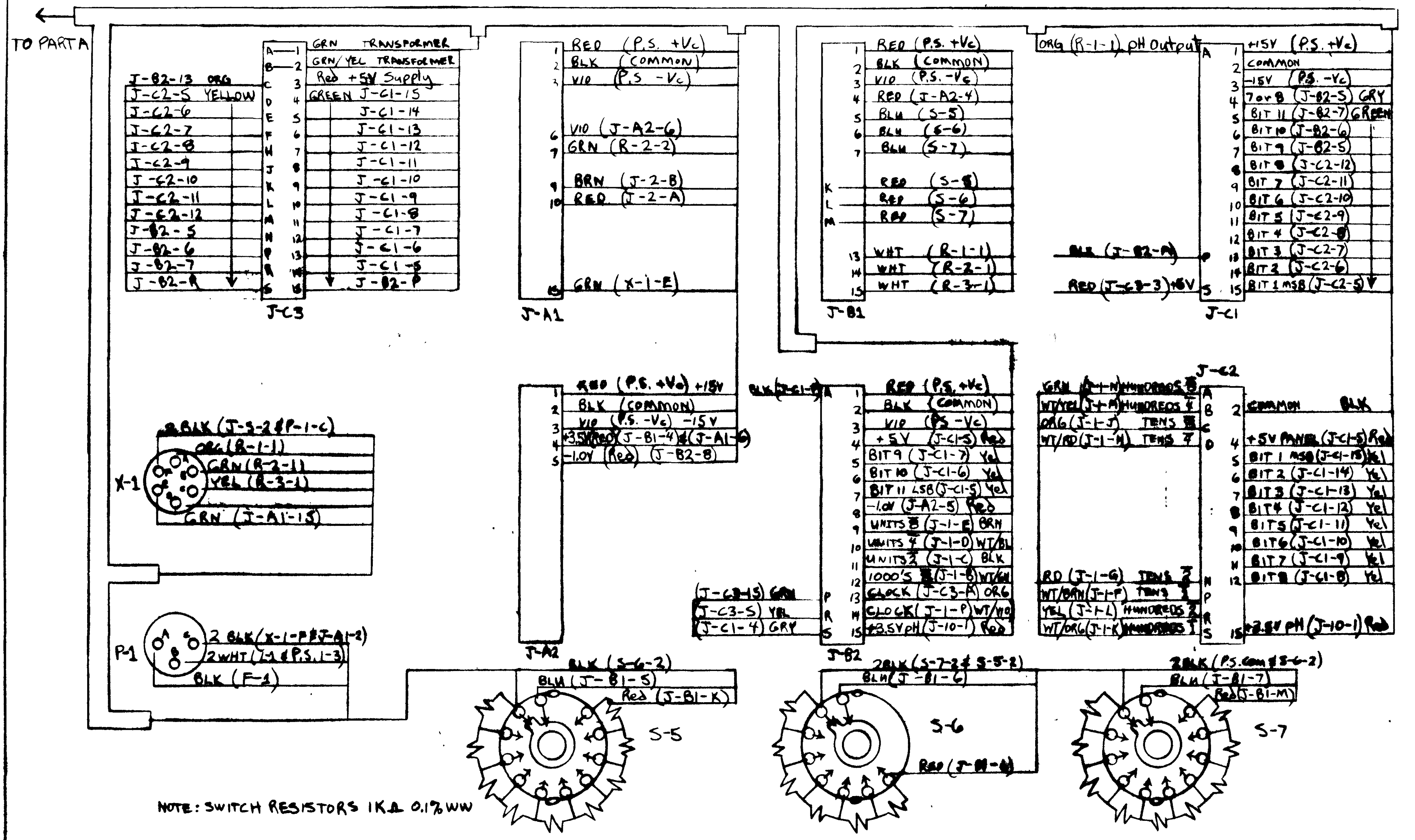
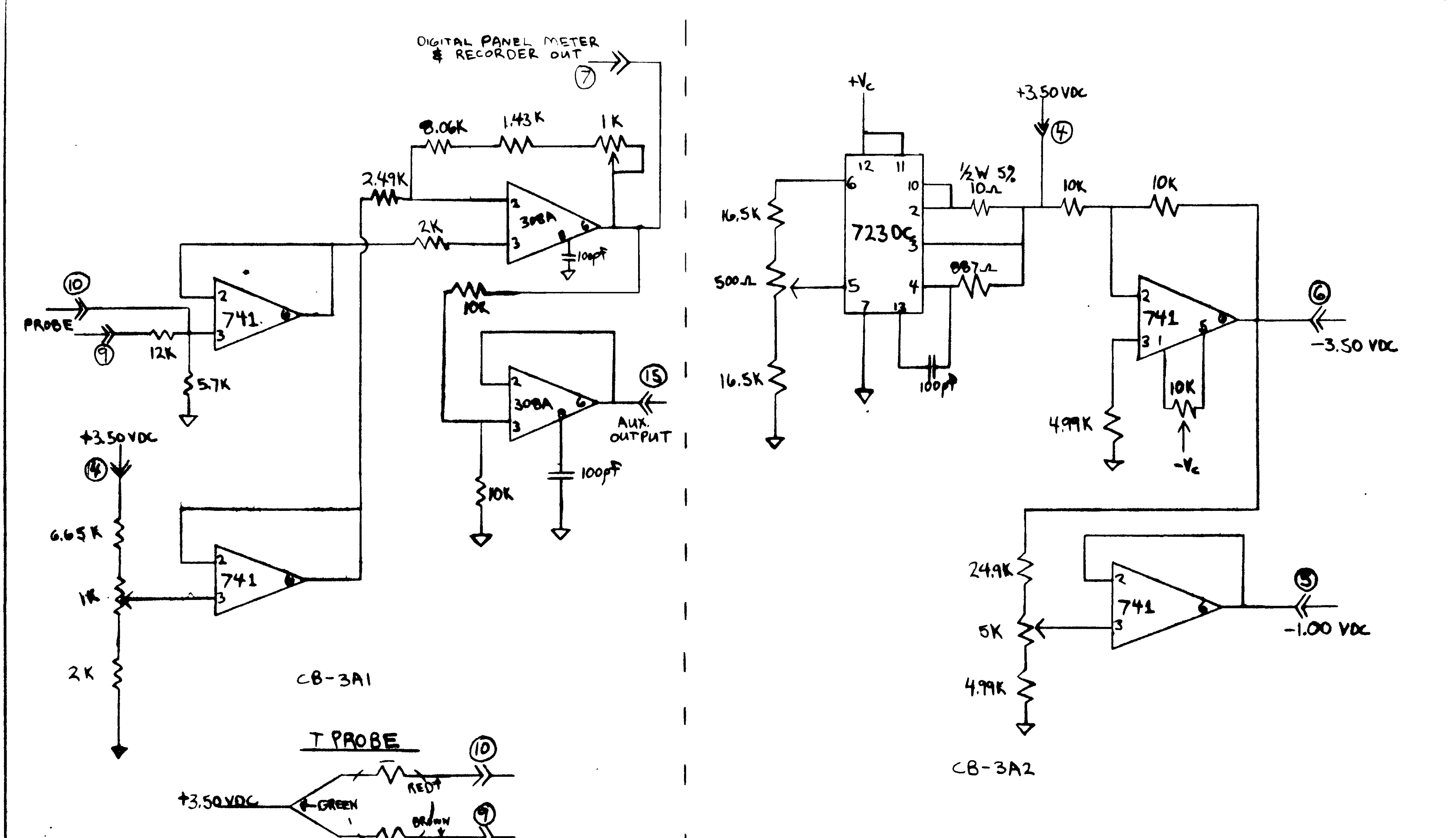


FIGURE 39 PCO_2, TEMPERATURE, pH PANEL WIRING DIAGRAM, PART B

PANEL NO 3

DRAWN BY L.O.

DATE NOV 1976



NOTE: POWER CONNECTIONS TO IC'S ARE NOT SHOWN
RESISTORS ALL METAL FILM 1% UNLESS SPECIFIED

FIGURE 40	pCO_2, TEMPERATURE, pH PANEL CIRCUIT BOARDS CB-3A1, 3A2 SCHEMATIC DIAGRAMS	CB-3A1 T°C MEASUREMENT CIRCUIT CB-3A2 REGULATED VOLTAGE SUPPLY	PANEL NO. 3
			DRAWN BY L.D. DATE NOV 1976

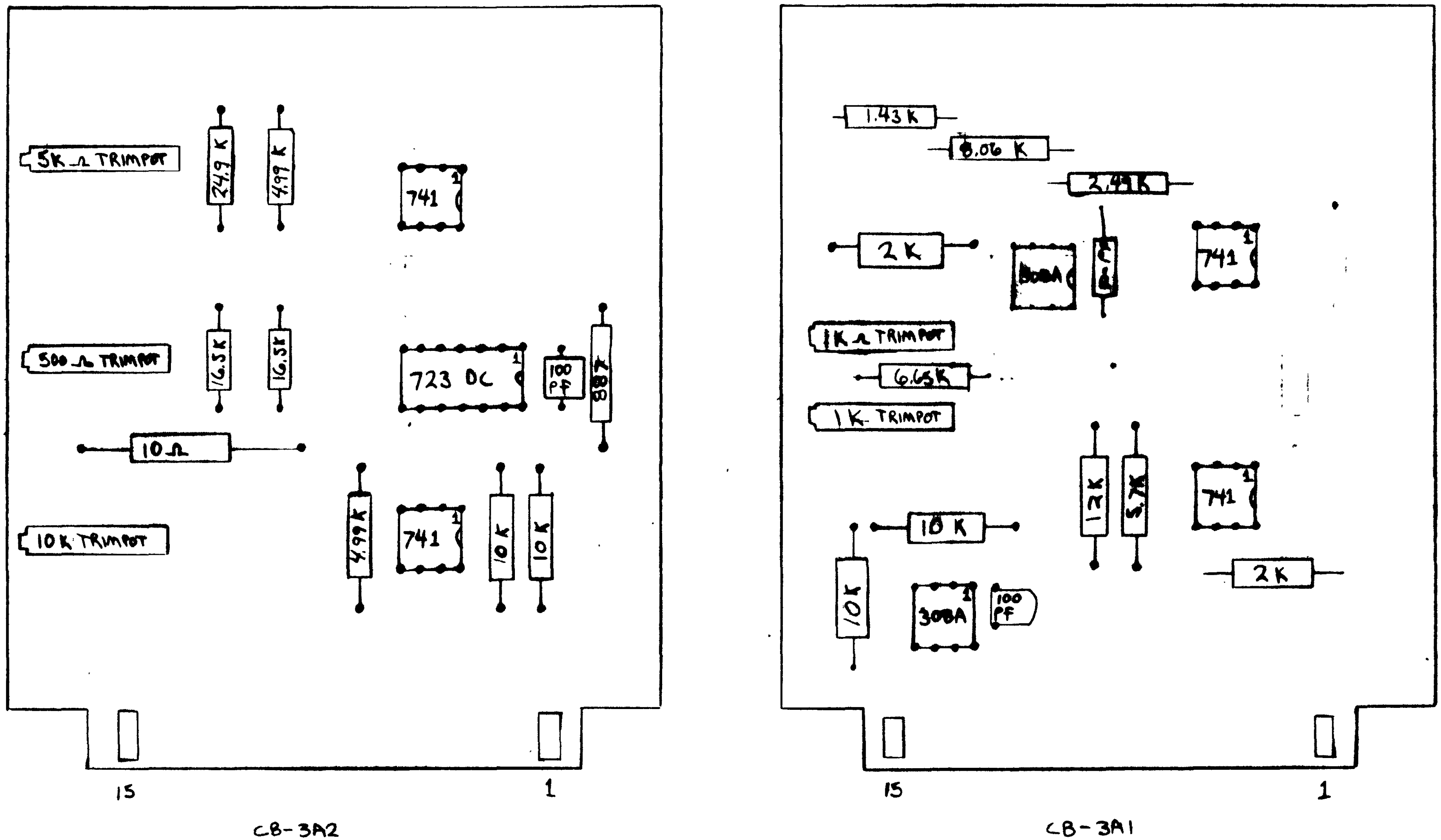


FIGURE 41 — pCO_2, TEMPERATURE, pH PANEL CIRCUITBOADS CB-3A1, 3A2 LAYOUTS	CB-3A1 T°C MEASUREMENT CIRCUITRY CB-3A2 REGULATED VOLTAGE SUPPLY	PANEL NO. 3	DRAWN BY L.D DATE NOV 1976

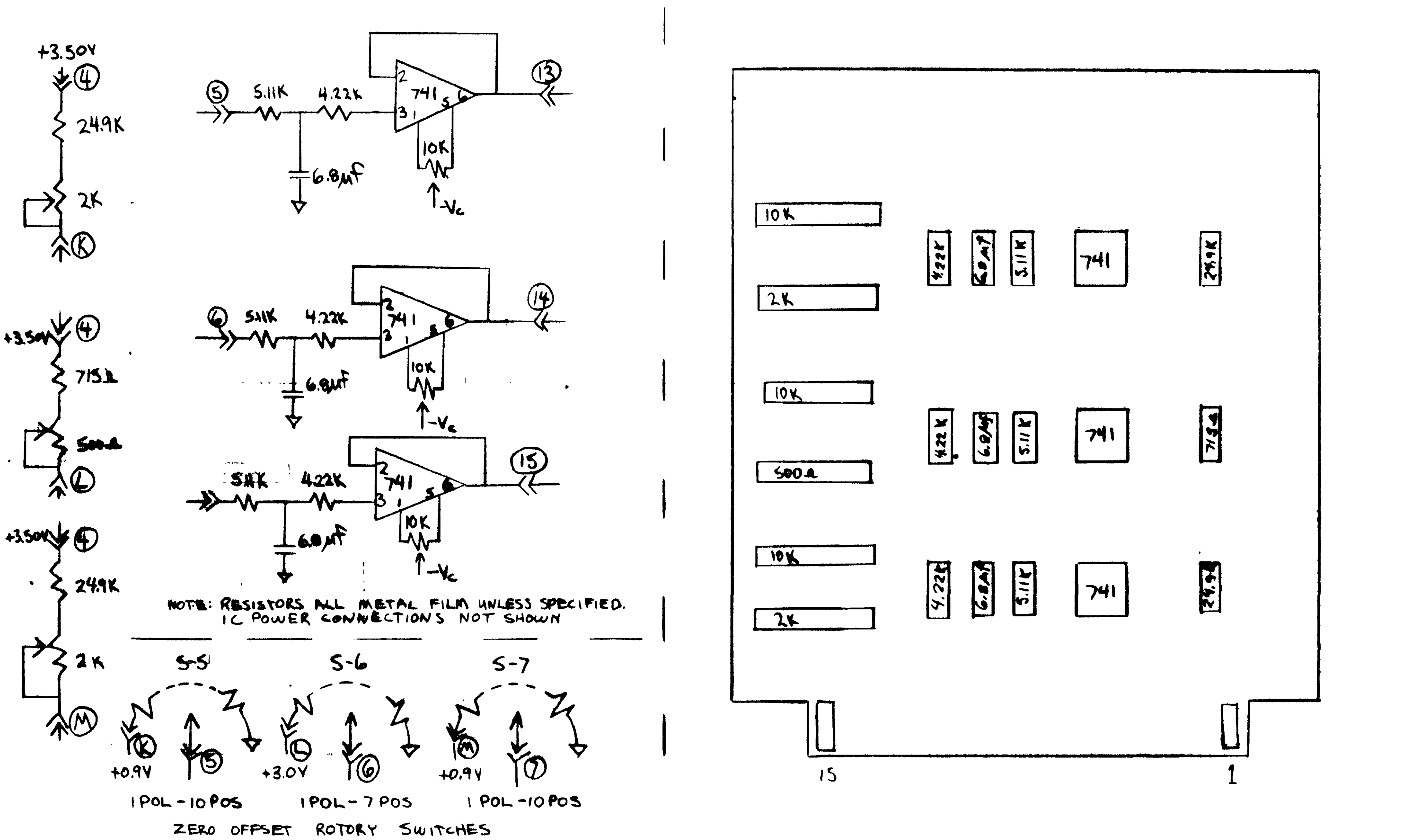
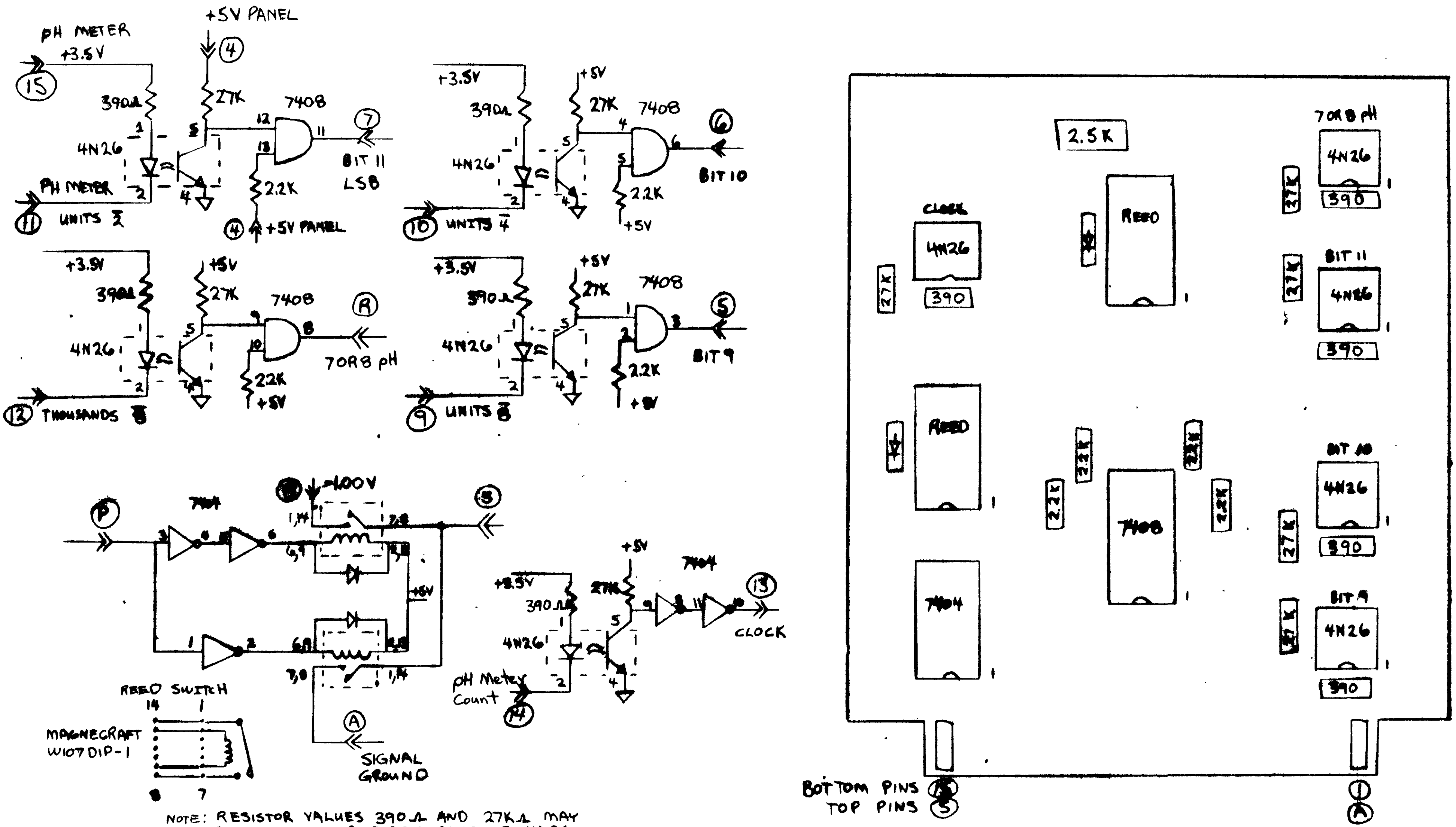


FIGURE 42	pCO_2, TEMPERATURE, pH PANEL CIRCUITBOARD CB-381 SCHEMATIC DIAGRAM AND BOARD LAYOUT	Panel 3	DRAWN BY LD DATE NOV 1976



NOTE: RESISTOR VALUES 390Ω AND 27KΩ MAY BE CHANGED FOR PERFORMANCE OF 4N26.
ALL RESISTORS 1/4W CARBON UNLESS SPECIFIED.
POWER CONNECTIONS TO IC'S 7400 & 7408 NOT SHOWN.

FIGURE 43 pCO_2, TEMPERATURE, pH PANEL CIRCUITBOARD CB-3B2 SCHEMATIC DIAGRAM AND BOARD LAYOUT PH DIGITAL TO ANALOG CONVERSION CIRCUITRY	PANEL NO. 3	L.D DATE NOV 1976

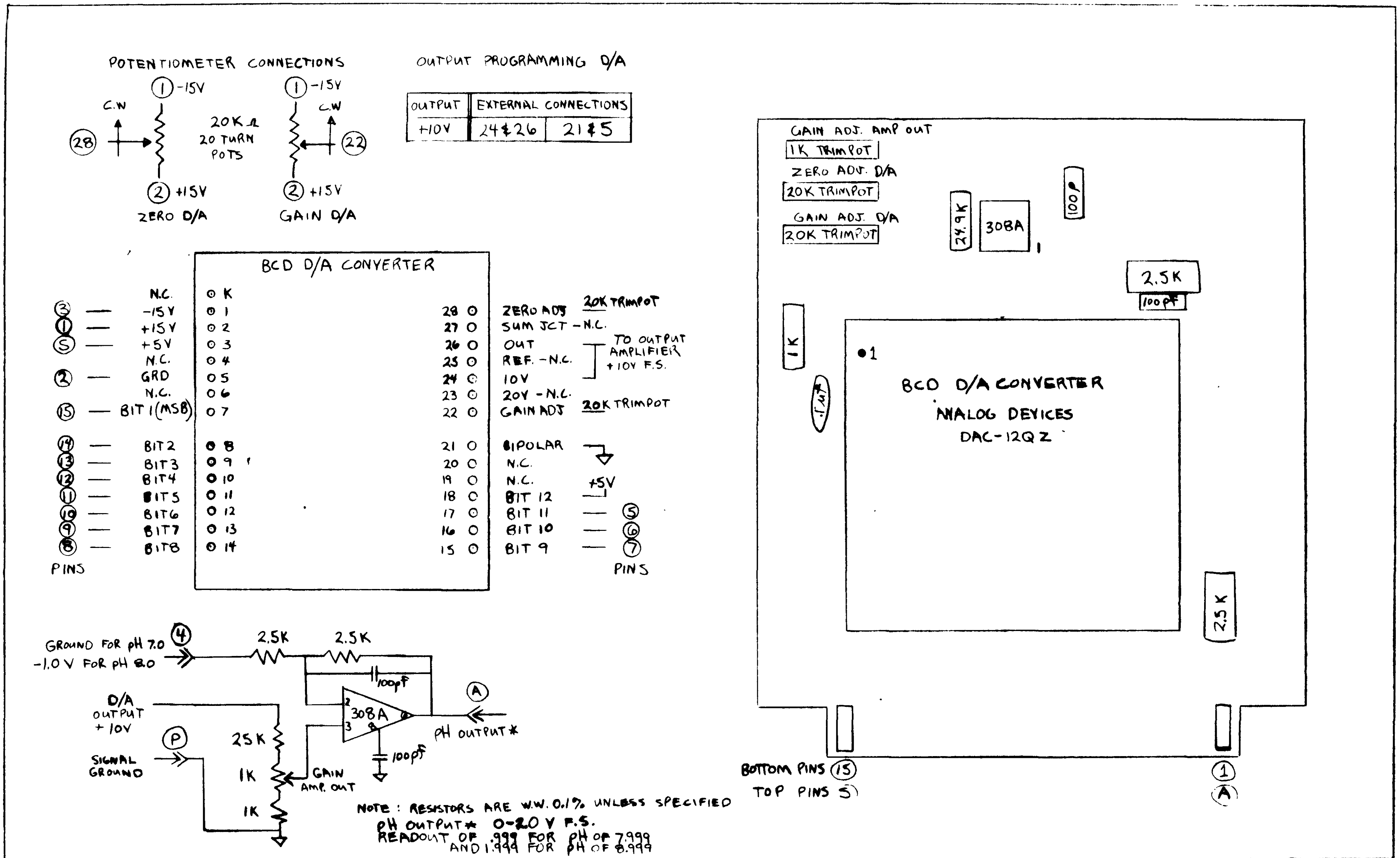
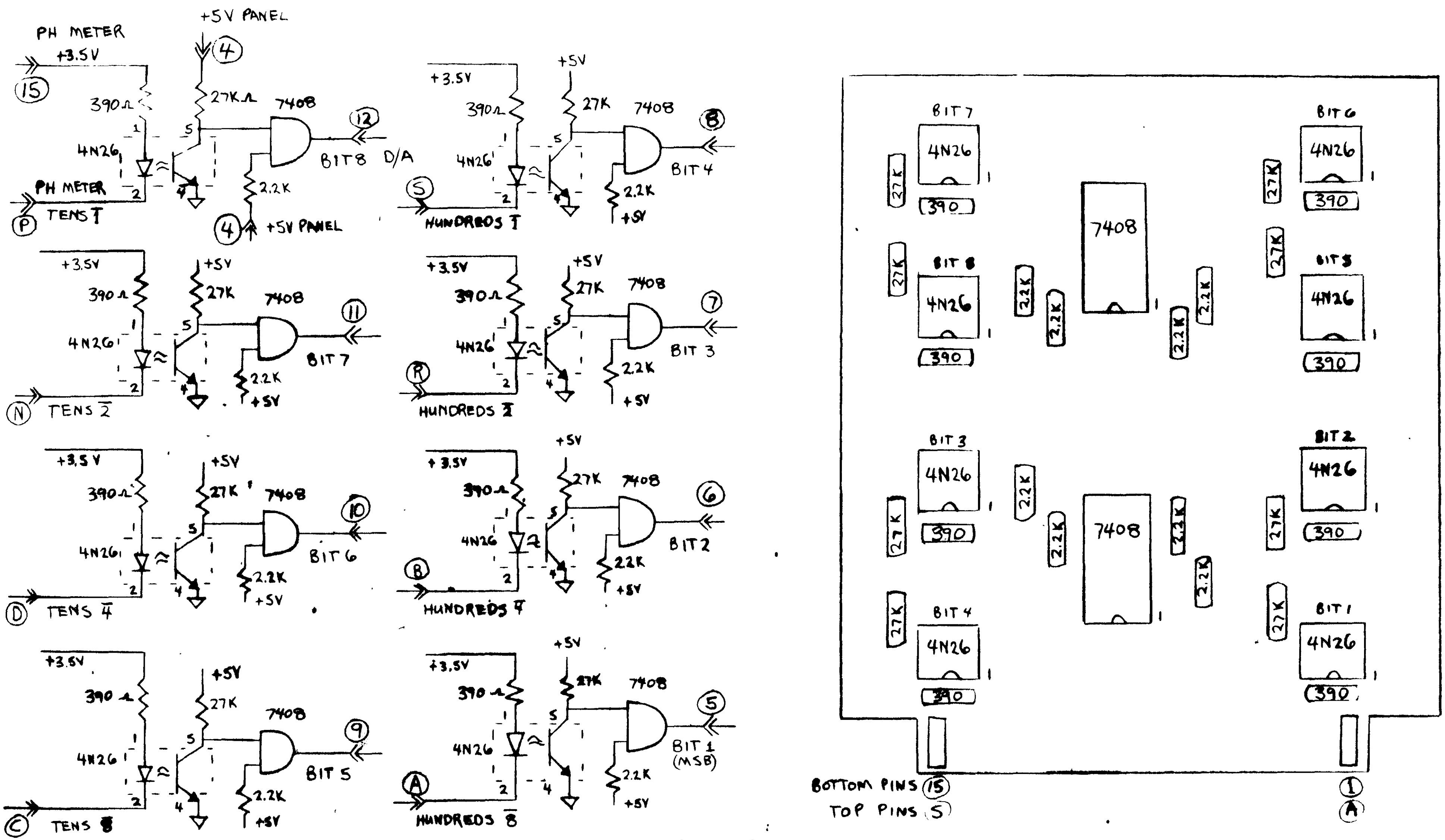


FIGURE 44 PCO_2, TEMPERATURE, pH PANEL CIRCUITBOARD CB-3C1 SCHEMATIC DIAGRAM AND BOARD LAYOUT pH DIGITAL TO ANALOG CONVERSION CIRCUITRY	PANEL NO. 3	L.D. DATE NOV. 1976



NOTE: RESISTOR VALUES OF 390Ω AND 27KΩ MAY BE CHANGED FOR PERFORMANCE OF 4N26. POWER CONNECTIONS TO 7408 IC'S NOT SHOWN.

FIGURE 45 pCO_2, TEMPERATURE, pH PANEL
CIRCUIT BOARD CB-3C2 SCHEMATIC DIAGRAM AND BOARD LAYOUT
pH DIGITAL TO ANALOG CONVERSION CIRCUITRY

PANEL NO	L.D.
3	DATE NOV 1976

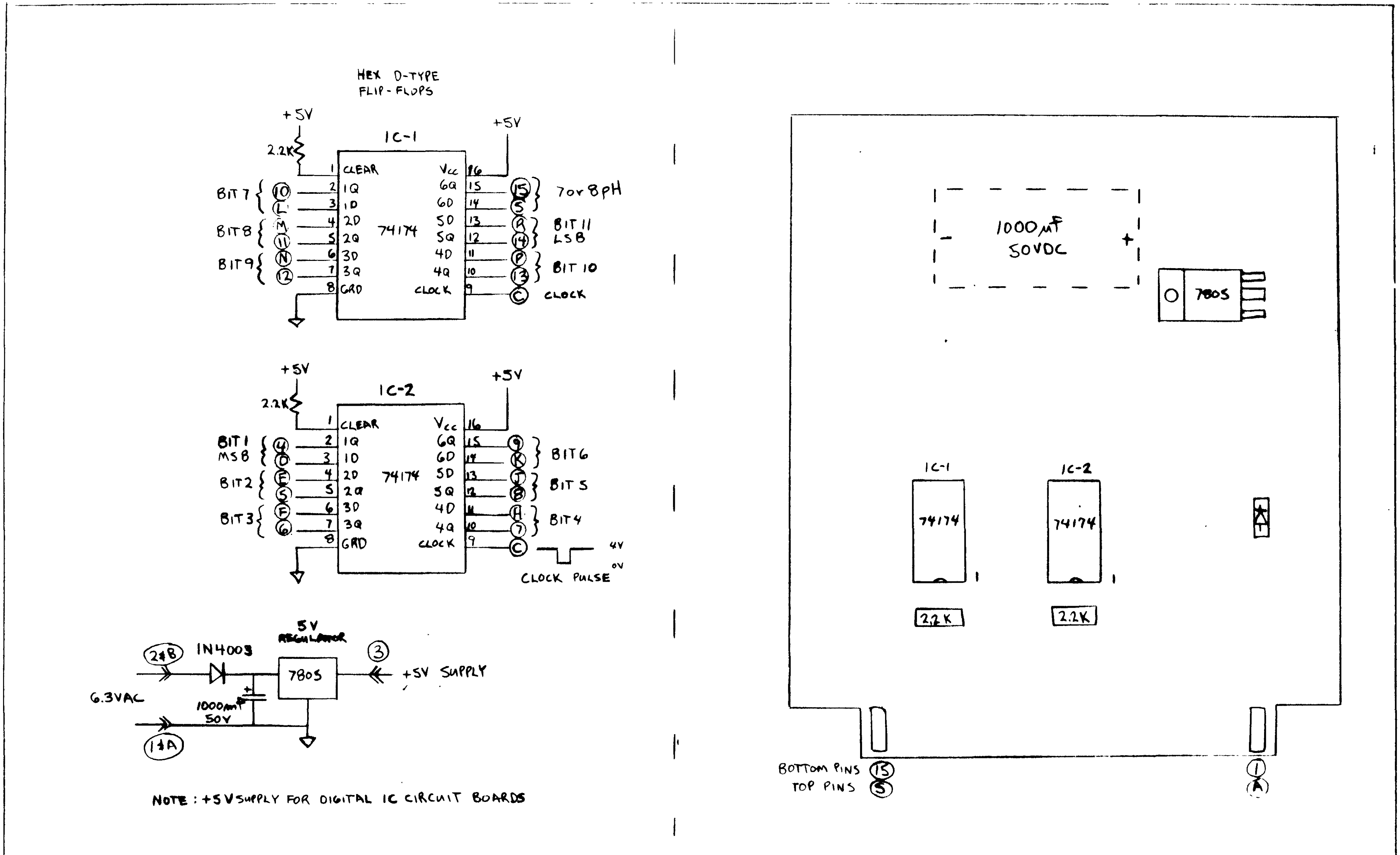


FIGURE 46 pCO_2, TEMPERATURE, pH PANEL CIRCUIT BOARD CB-3C3 SCHEMATIC DIAGRAM AND BOARD LAYOUT pH DIGITAL TO ANALOG CONVERSION CIRCUITRY	PANEL NO 3	L.D. DATE NOV 1976

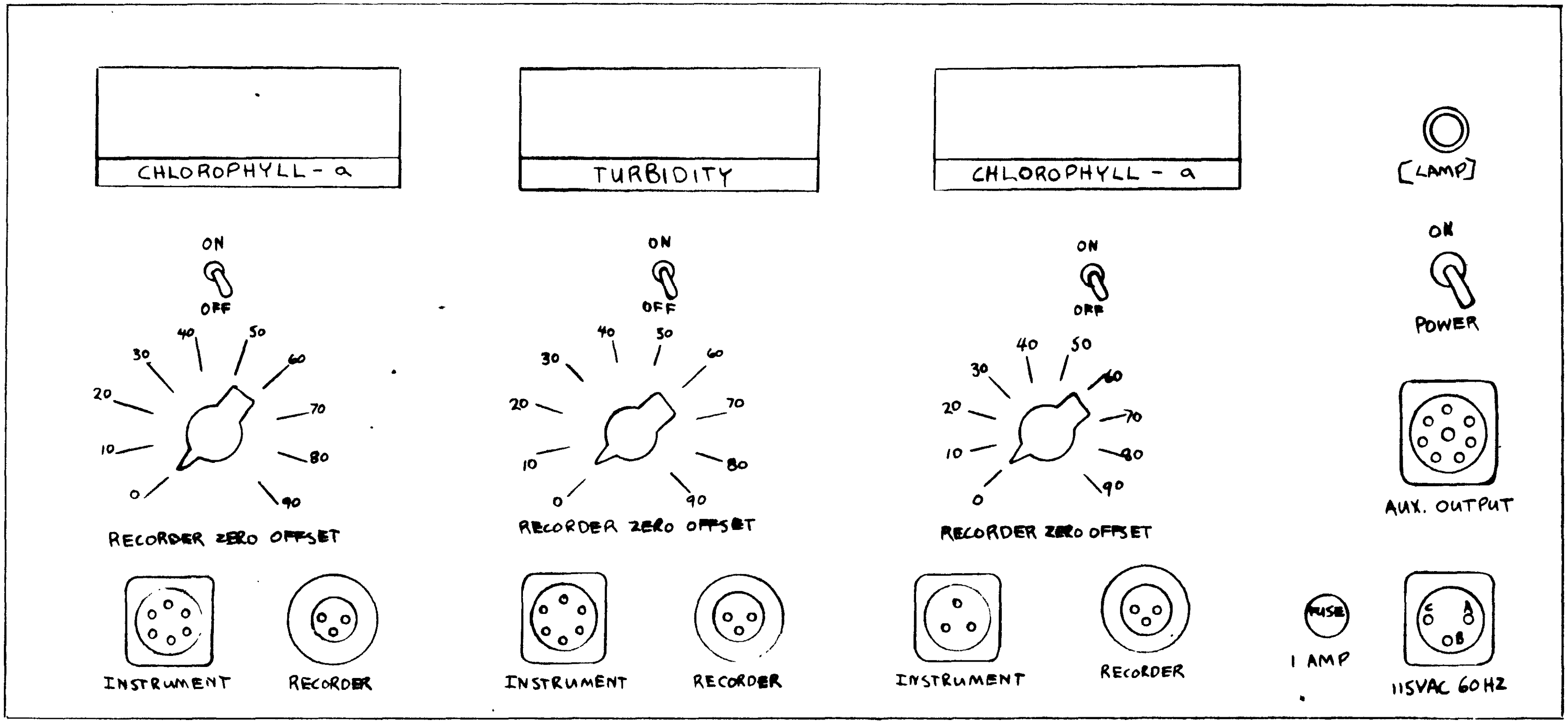
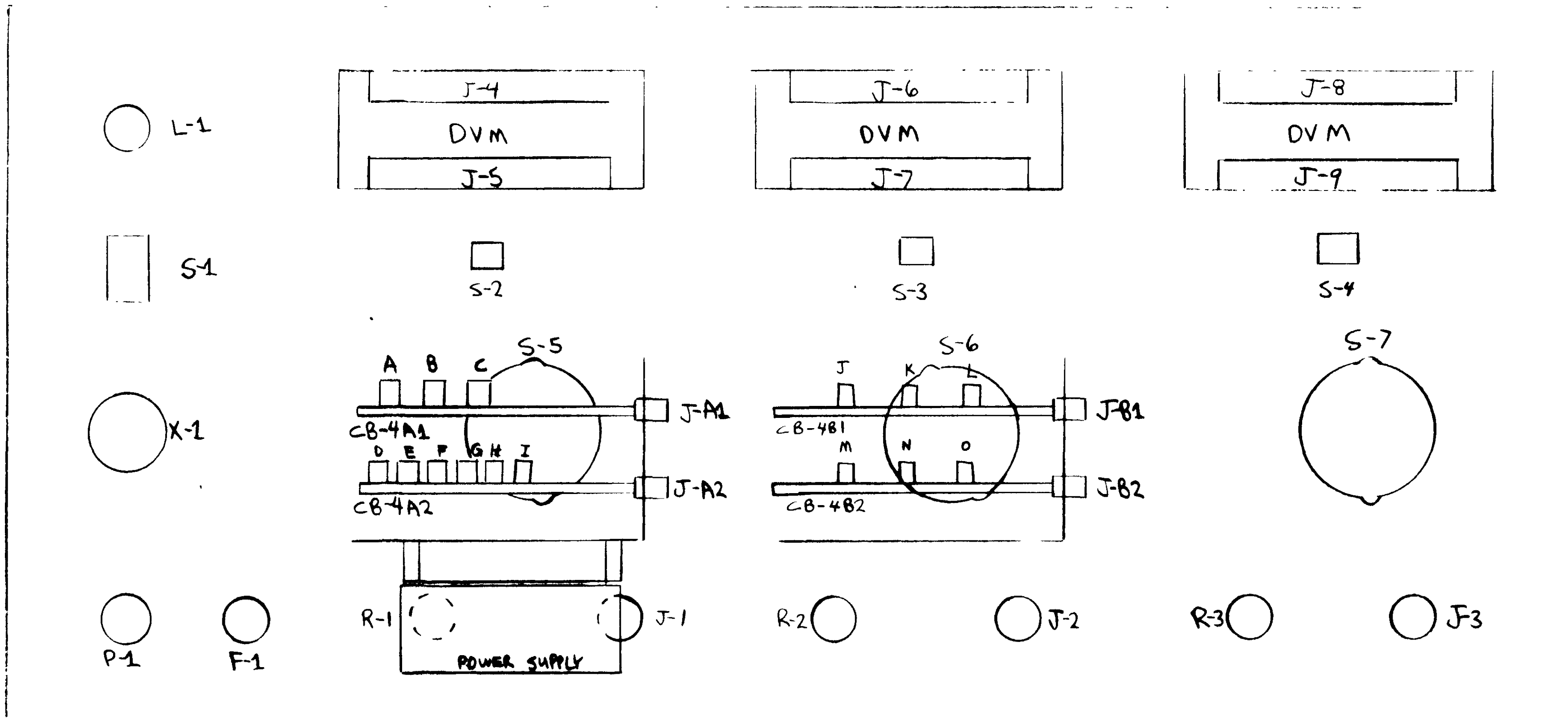


FIGURE 47	CHLOROPHYLL & TURBIDITY PANEL LAYOUT (FRONT)	PANEL NO. 4	L.O.
			DATE NOV 1976



F1	FUSE	S-2	CHLOROPHYLL-a ON-OFF SWITCH	F	- 3.50 VDC ADJ.
L1	NEON LAMP	S-3	TURBIDITY ON-OFF SWITCH	G	+ 3.50 VDC ADJ.
X-1	AUX. OUTPUT	S-4	CHLOROPHYLL-a ON-OFF SWITCH	H	- 1.00 VDC ADJ.
P-1	POWER CONNECTION	S-5	RECORDER ZERO OFFSET - CHLOROPHYLL-a	I	+ 0.90 VDC ADJ
R-1	RECORDER OUT	S-6	RECORDER ZERO OFFSET - TURBIDITY	J	ZERO ADJ } FLUOROMETER TURNER DESIGN MODEL 10
R-2	RECORDER OUT	S-7	RECORDER ZERO OFFSET - CHLOROPHYLL-a	K	SIGNAL LEVEL ADJ.
R-3	RECORDER OUT	CB-4A1	FOLLOWER CIRCUIT BOARD	L	RANGE CIRCUIT ADJ.
J-1	FLUOROMETER INPUT - Md. 111	CB-4A2	REG. POWER SUPPLY & CHLOROPHYLL-a	M	ZERO ADJ. } NEPHELOMETER TURNER DESIGNS MODEL 10
J-2	NEPHELOMETER INPUT - Md 10	CB-4B1	CHLOROPHYLL-a RANGE & DIVIDER	N	SIGNAL LEVEL ADJ.
J-3	FLUOROMETER INPUT - Md. 10	CB-4B2	NEPHELOMETER RANGE & DIVIDER	O	RANGE CIRCUIT ADJ.
J-4 THRU J-9	CONNECTORS FOR DVM'S	A	CHLOROPHYLL-a FOLLOWER ZERO ADJ	D	ZERO ADJ. } FLUOROMETER TURNER ASSOCIATES MODEL 111
J-A1 THRU J-B2	CON. FOR BOARDS	B	TURBIDITY FOLLOWER ZERO ADJ	E	GAIN ADJ
S-1	POWER SWITCH	C	CHLOROPHYLL-a FOLLOWER ZERO ADJ.		

FIGURE 48 CHLOROPHYLL & TURBIDITY PANEL LAYOUT (BACK)	PANEL NO. 4	DRAWN BY L.D. DATE NOV 1976

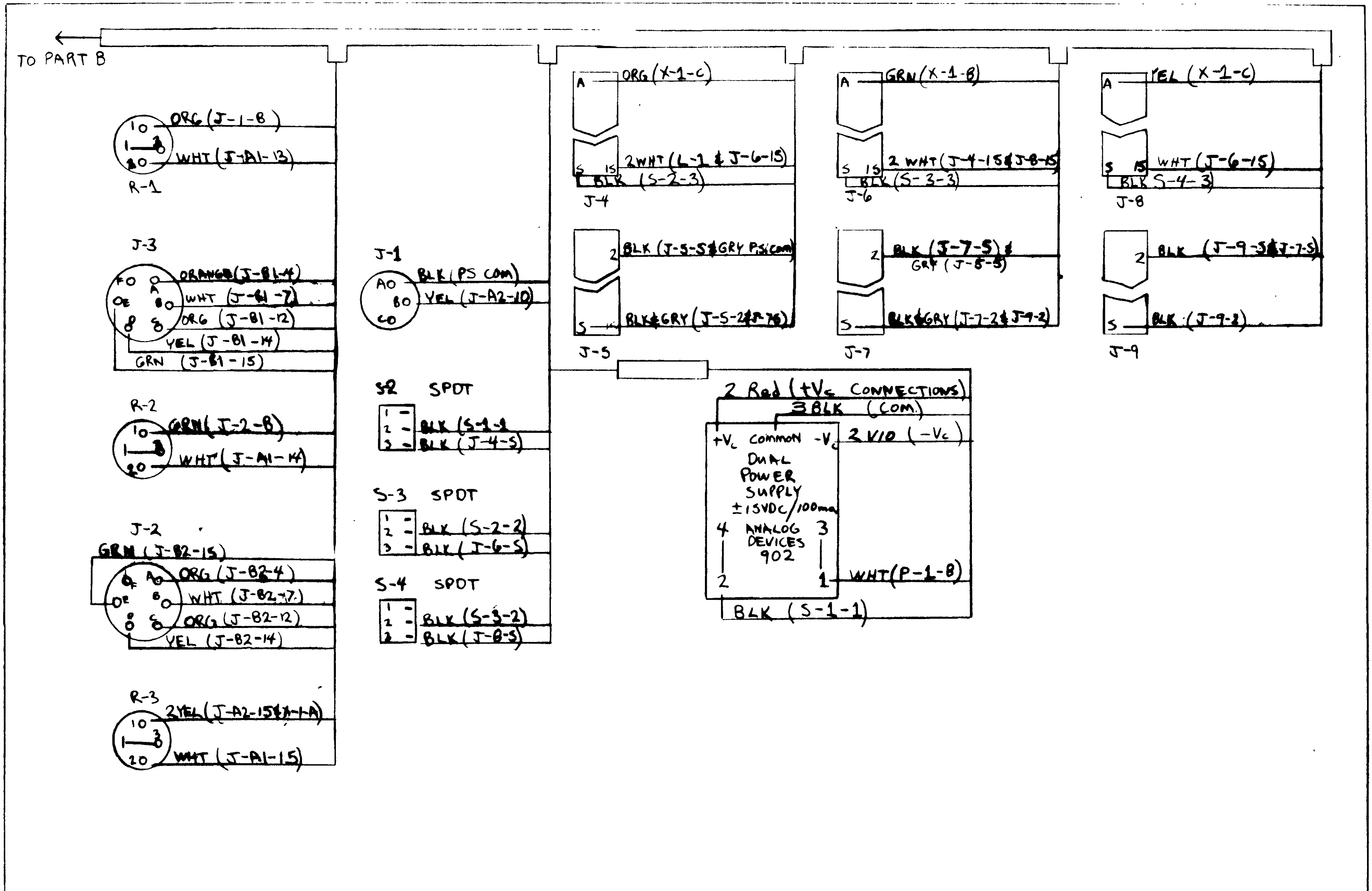
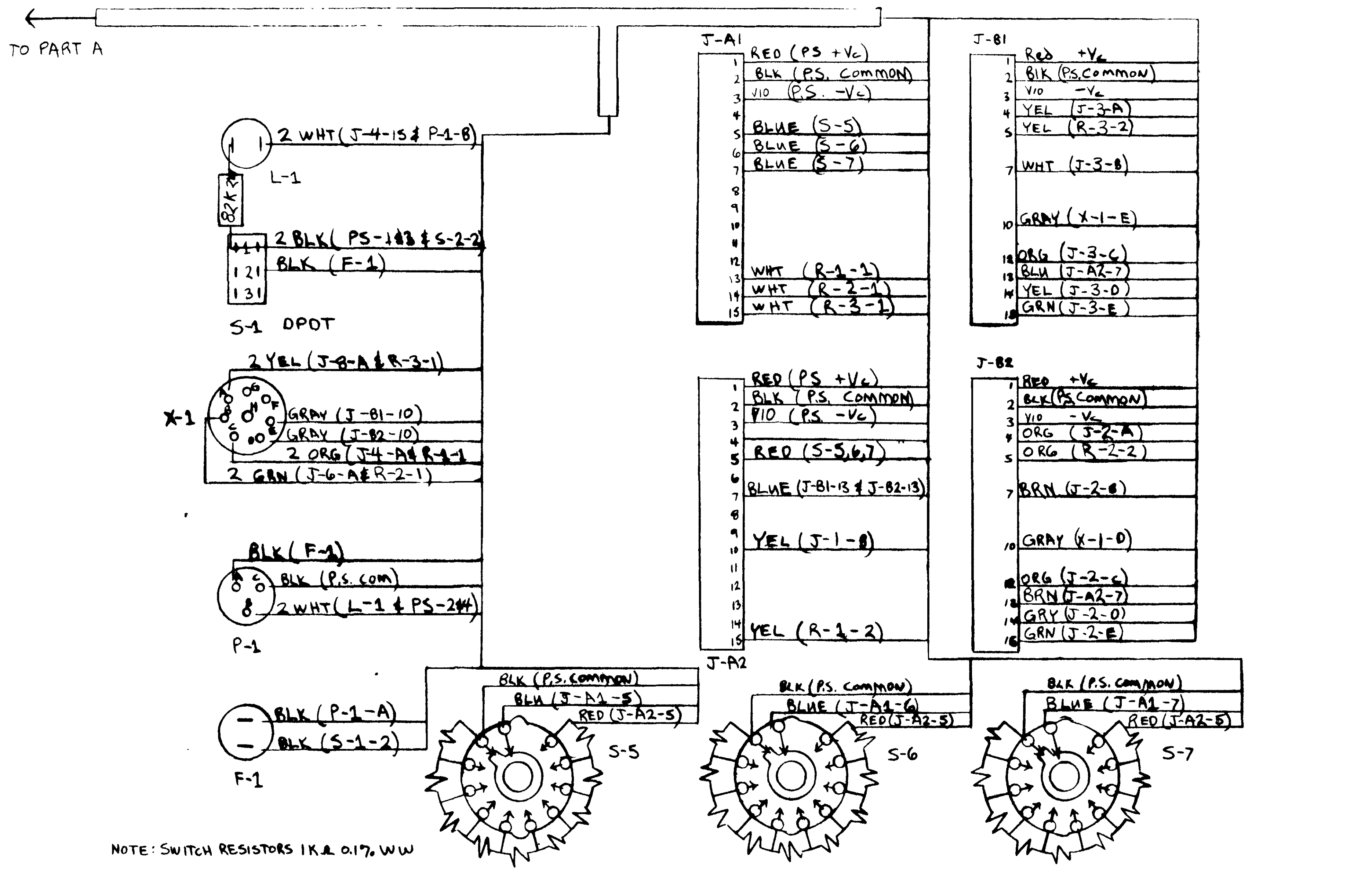


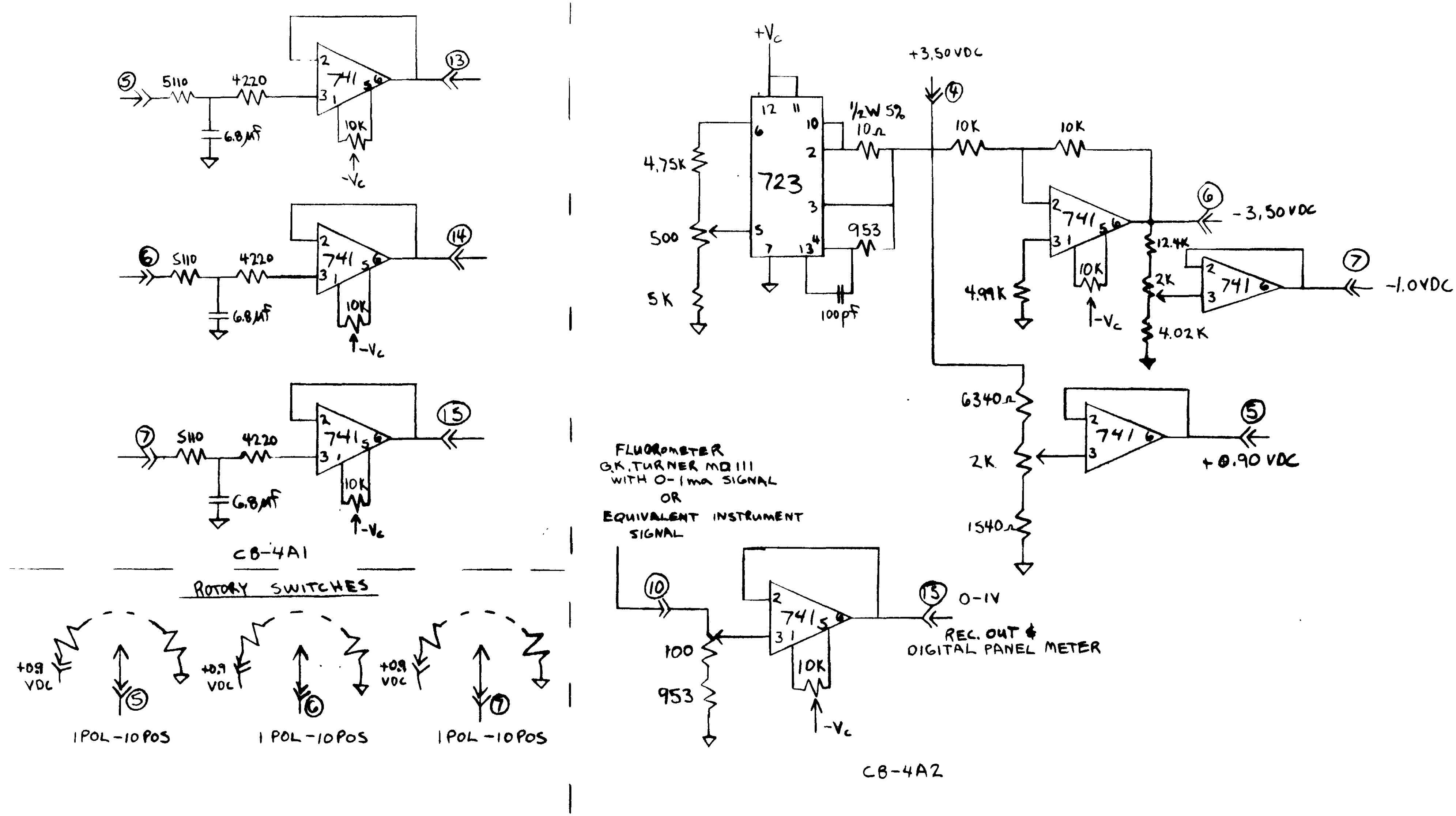
FIGURE 49 CHLOROPHYLL AND TURBIDITY PANEL WIRING DIAGRAM, PART A

PANEL NO	DRAWN BY LD
4	DATE NOV 1976



NOTE: SWITCH RESISTORS 1KΩ 0.1% WW

FIGURE 50	CHLOROPHYLL AND TURBIDITY PANEL WIRING DIAGRAM, PART B	PANEL NO. 4	DRAWN BY LD DATE NOV 1976



NOTE: POWER CONNECTIONS ARE NOT SHOWN
RESISTORS ALL METAL FILM 1% UNLESS SPECIFIED

FIGURE 51 CHLOROPHYLL AND TURBIDITY PANEL CIRCUITBOARDS CB-4A1, 4A2 SCHEMATIC DIAGRAMS	CB-4A1 FOLLOWER CIRCUITRY CB-4A2 REGULATED POWER SUPPLY AND CHLOROPHYLL - a MEASUREMENT	PANEL NO. 4	DRAWN BY LD DATE NOV 1976

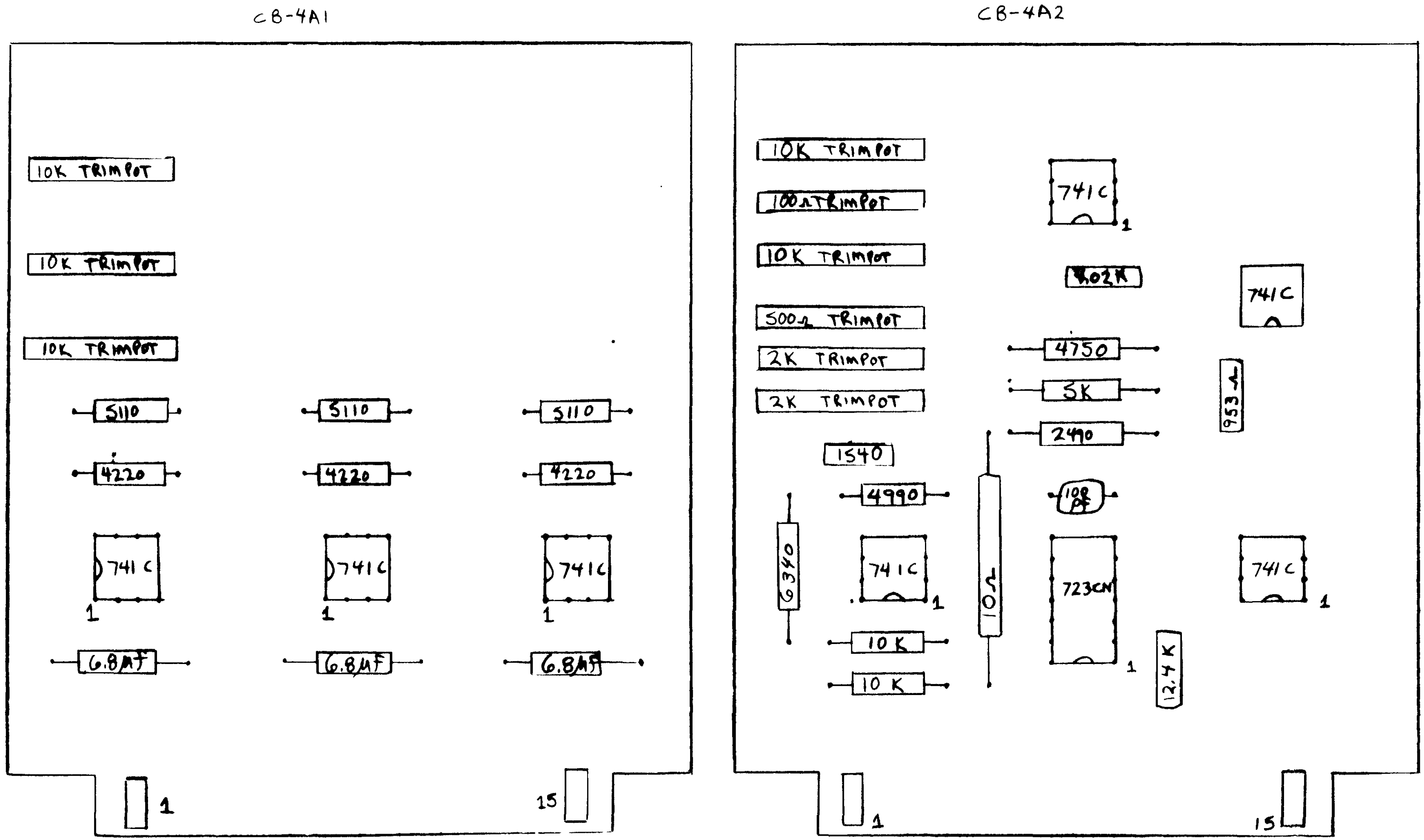
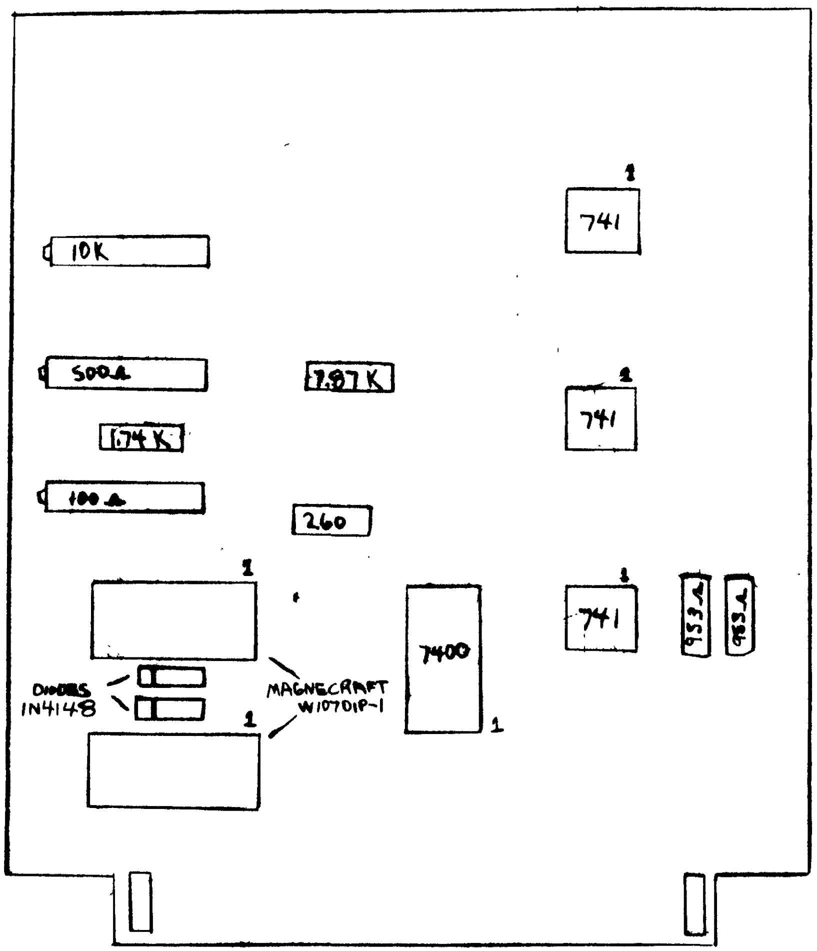
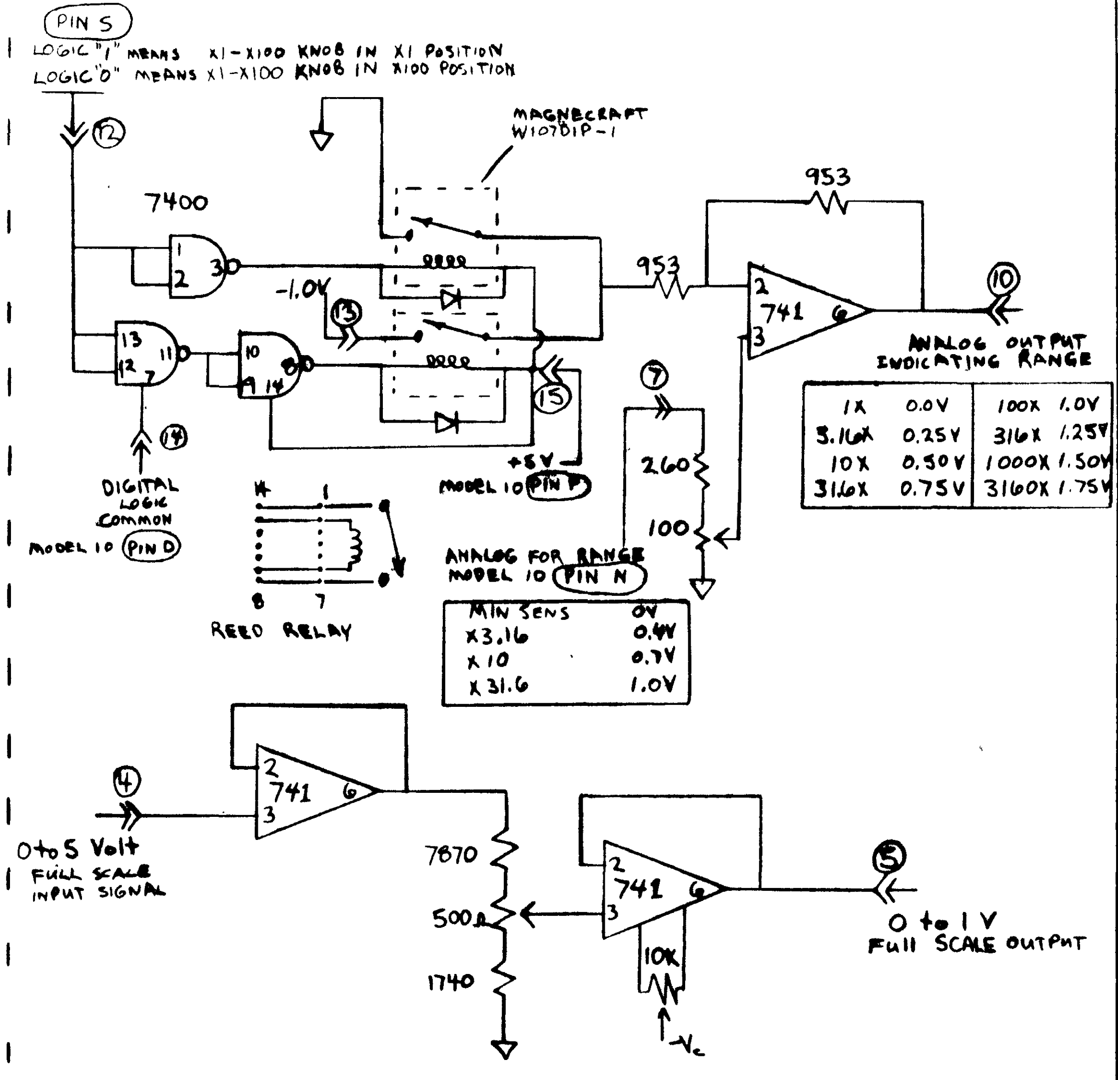


FIGURE 52 CHLOROPHYLL AND TURBIDITY PANEL CIRCUITBOARDS CB-4A1, 4A2 LAYOUT	CB-4A1 FOLLOWER CIRCUITRY CB-4A2 REGULATED VOLTAGE SUPPLY AND CHLOROPHYLL-a MEASUREMENT	DRAWN BY L.D DATE NOV 1976



CB-481 AND CB-482



CB-481 AND CB-482

NOTE: POWER CONNECTION FOR IC'S NOT SHOWN
RESISTORS ALL METAL FILM 1% UNLESS SPECIFIED

FIGURE 53 CHLOROPHYLL AND TURBIDITY PANEL CIRCUITBOARDS CB-481, 482 SCHEMATIC DIAGRAM AND BOARD LAYOUT. CONVERSIONS OF TURNER DESIGNS MD. 10 FLOUROMETERS.	IDENTICAL SCHEMATIC DIAGRAM AND BOARD LAYOUT FOR BOARDS CB-481 AND CB-482 FOR NEPHELOMETER AND FLOUROMETER	PANEL NO. 4	DRAWN BY L.D. DATE NOV 1976

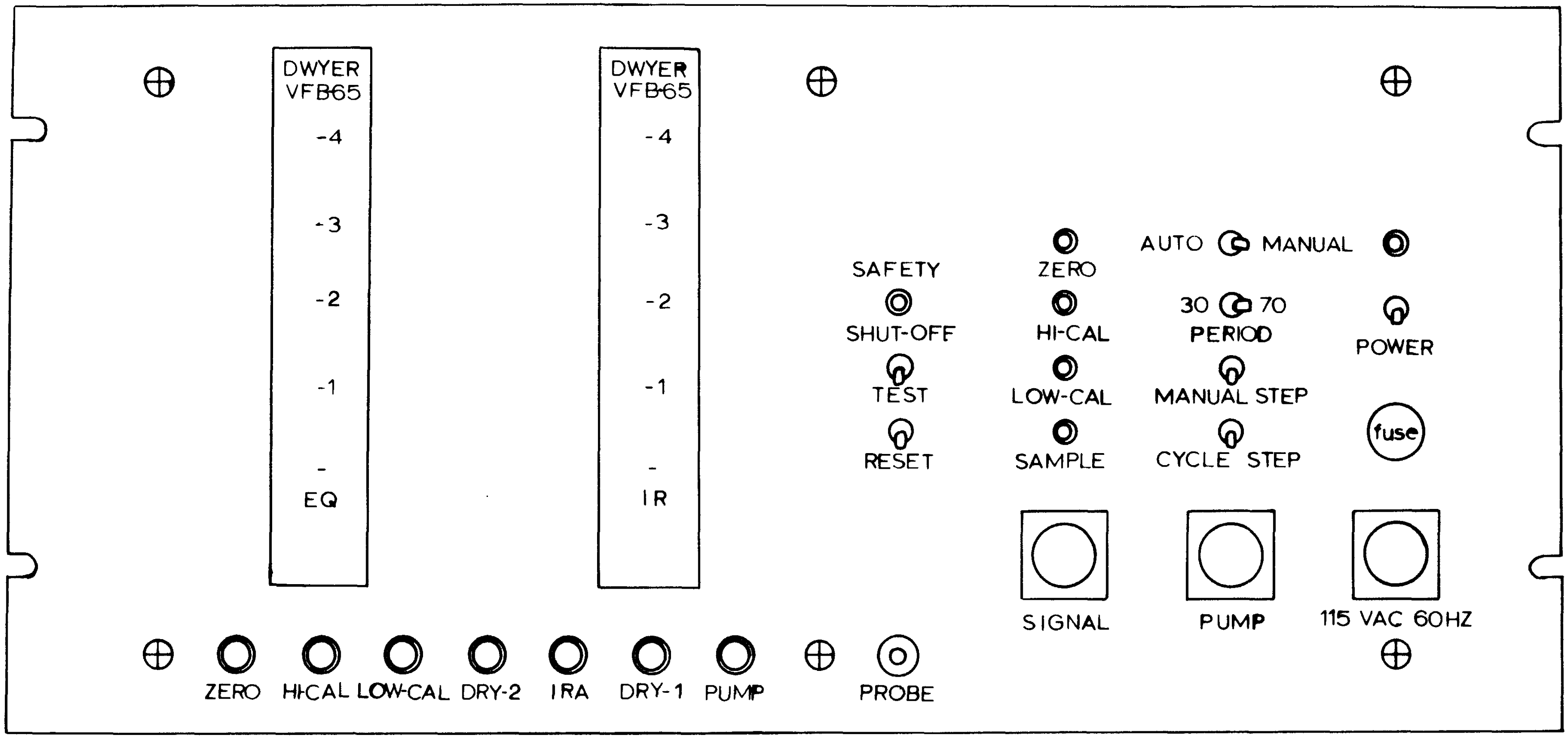


FIGURE 54 pCO_2 CONTROLLER PANEL
FRONT PANEL LAYOUT

L D

MAY 1978

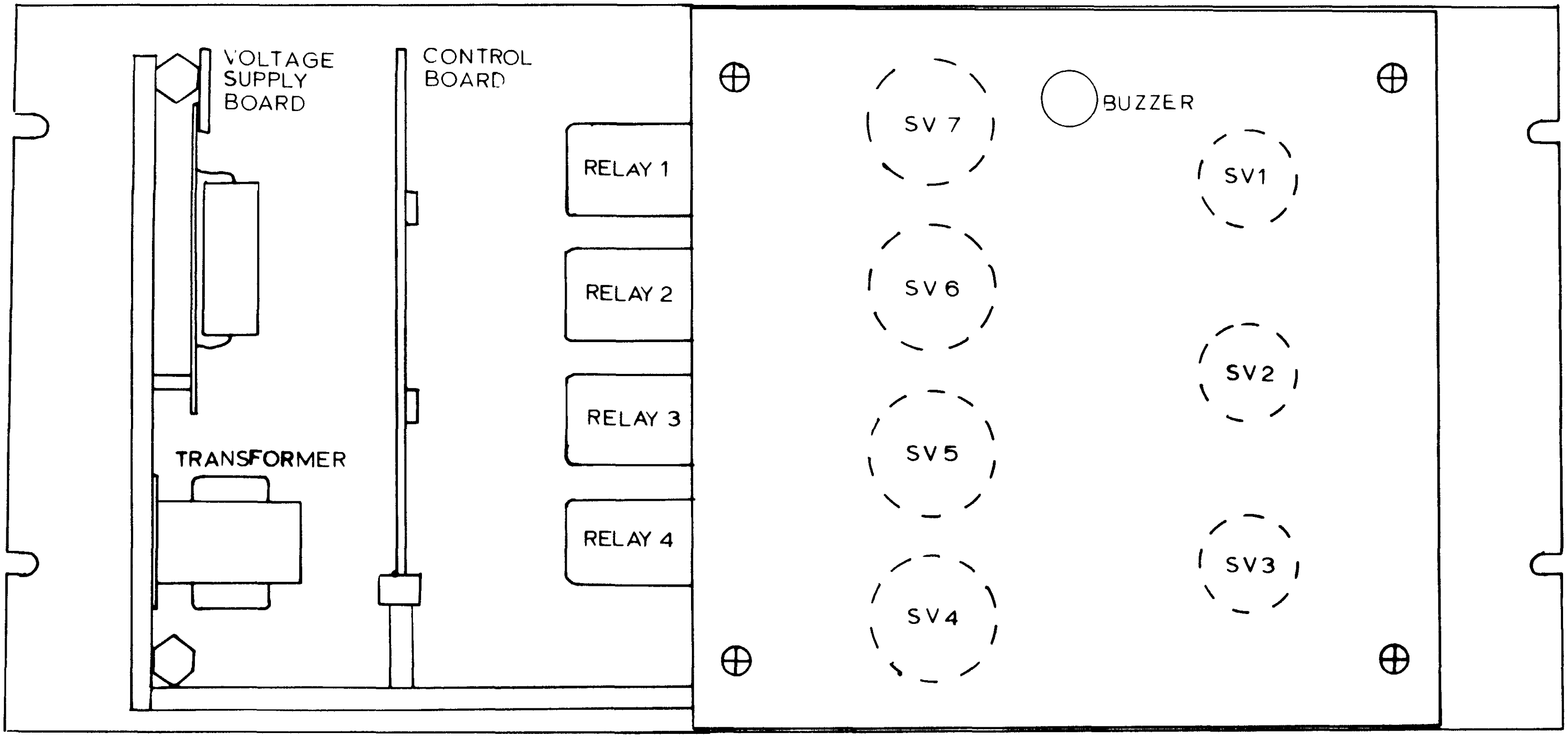


FIGURE 55 pCO_2 CONTROLLER PANEL REAR PANEL LAYOUT

L D

MAY 1978

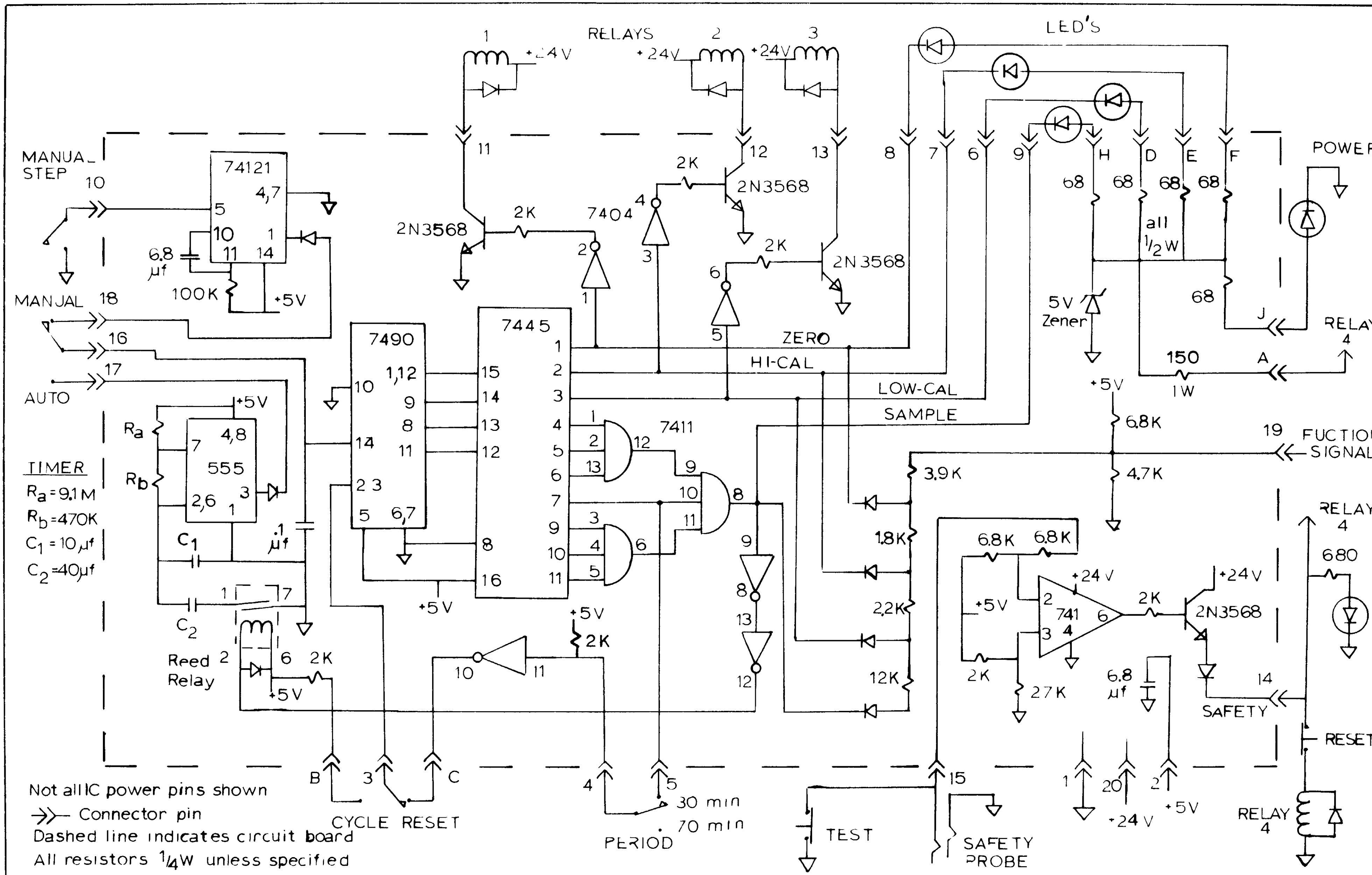


FIGURE 56 pCO_2 CONTROLLER PANEL
CONTROL BOARD AND EXTERNAL PARTS SCHEMATIC

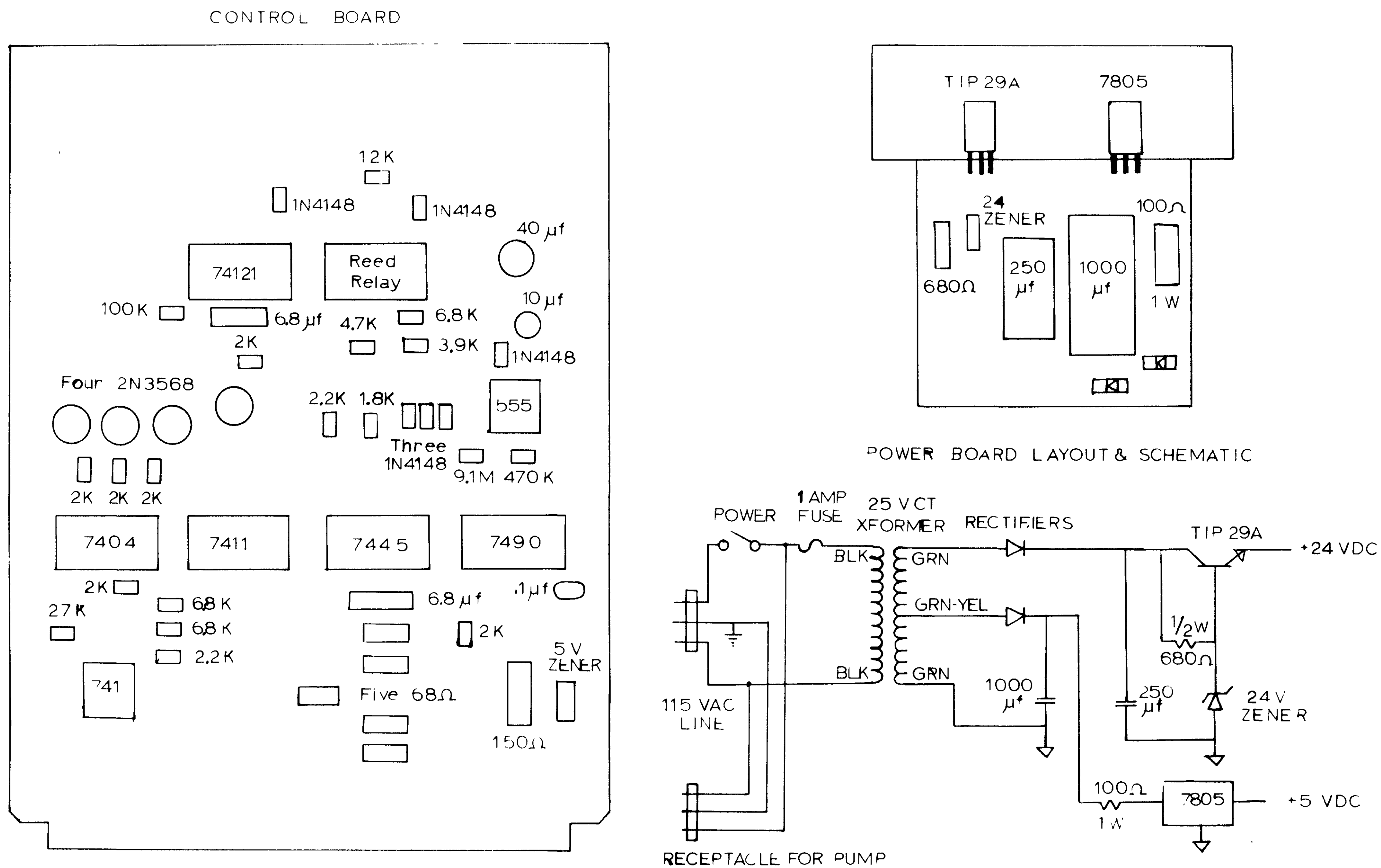


FIGURE 57 pCO_2 CONTROLLER PANEL CIRCUIT BOARD LAYOUTS AND POWER SUPPLY SCHEMATIC

L D

MAY 1978

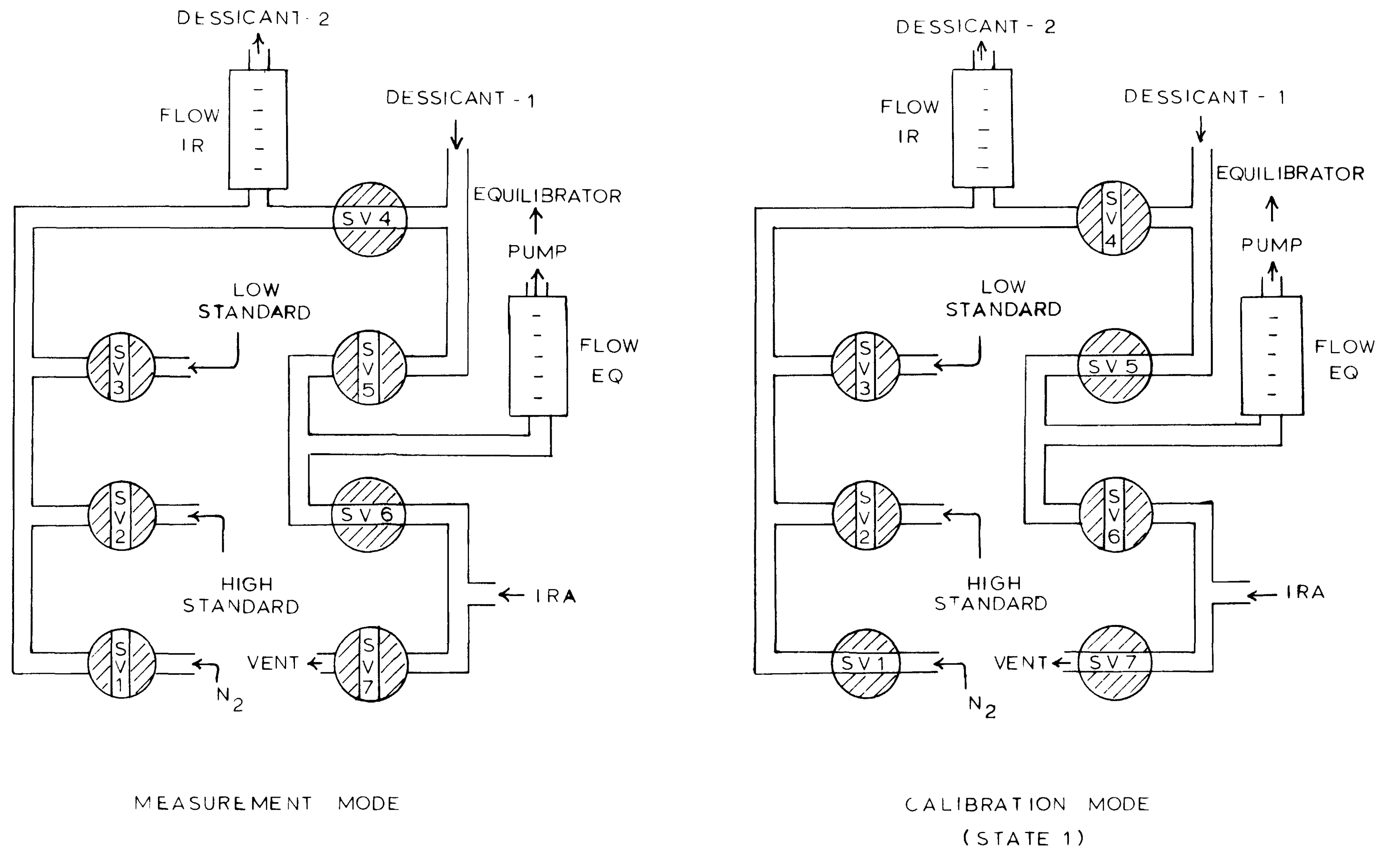


FIGURE 58 pCO_2 CONTROLLER PANEL
SOLINOID VALVE OPERATIONS MODES

L D

MAY 1978

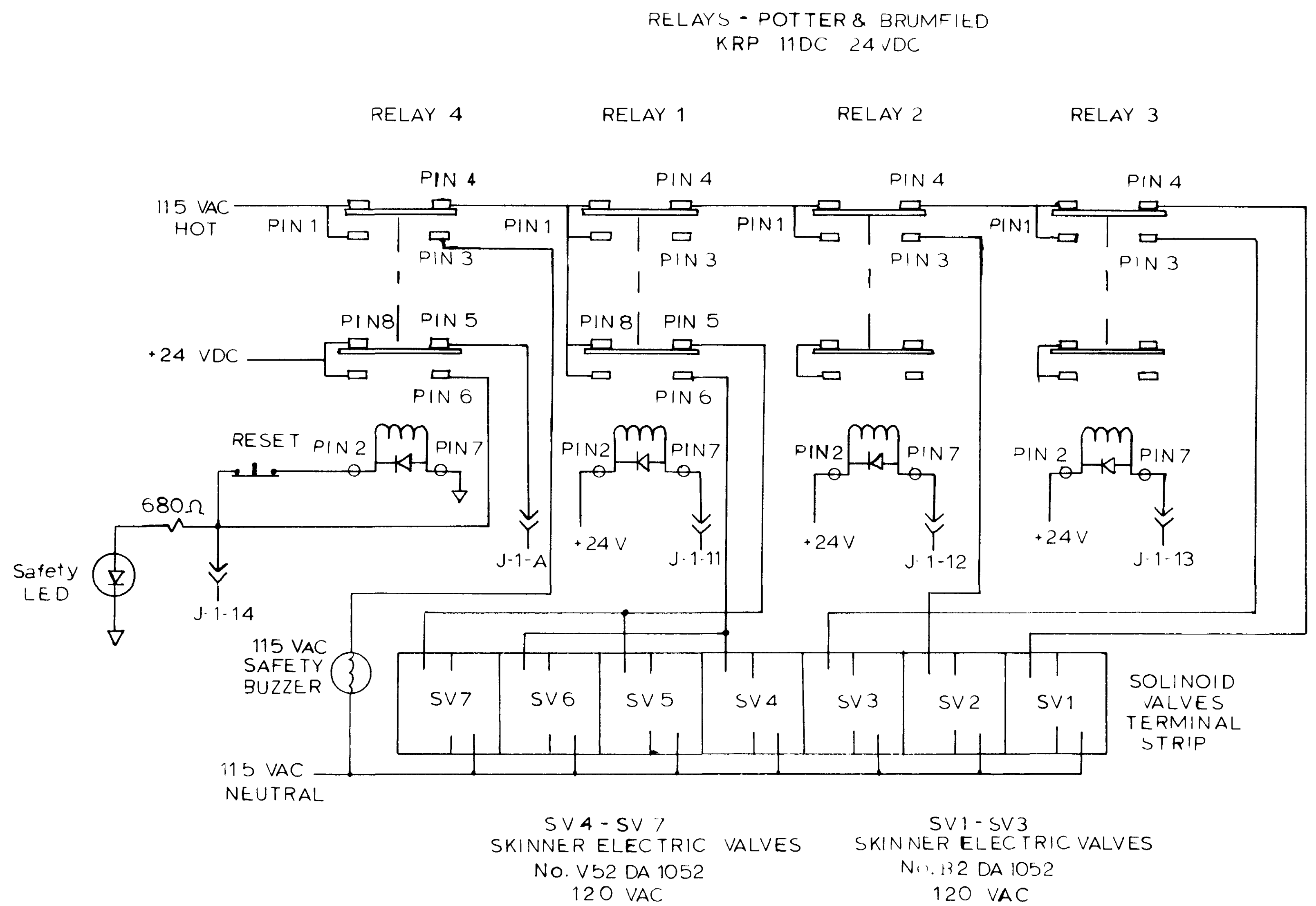


FIGURE 59	pCO_2 CONTROLLER PANEL RELAY WIRING DIAGRAM	LD
		MAY 1978

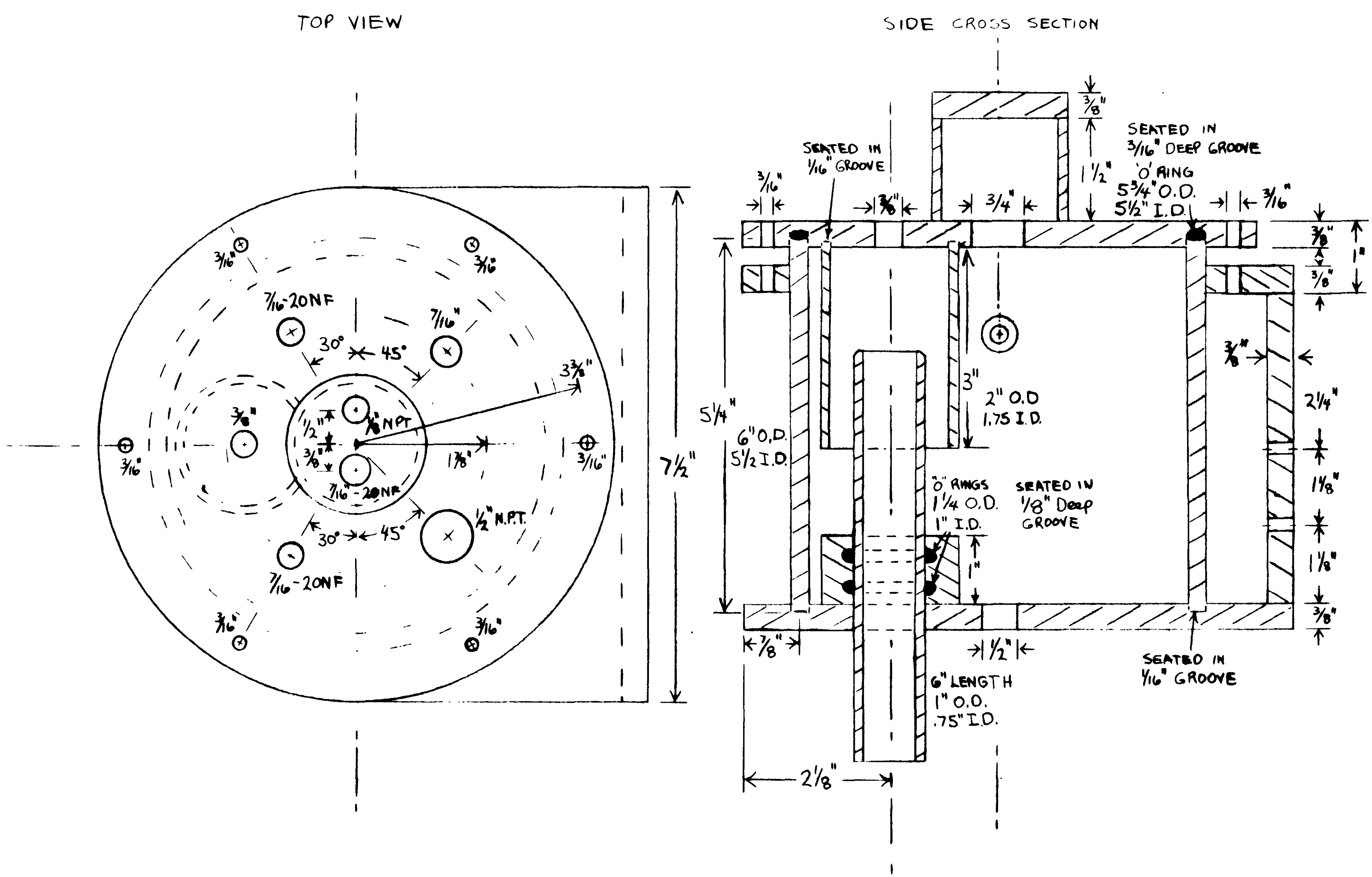


FIGURE 60 pCO_2 EQUILIBRATOR
EQUILIBRATOR TOP VIEW AND SIDE CROSS SECTION

L.O.
MAY 1977

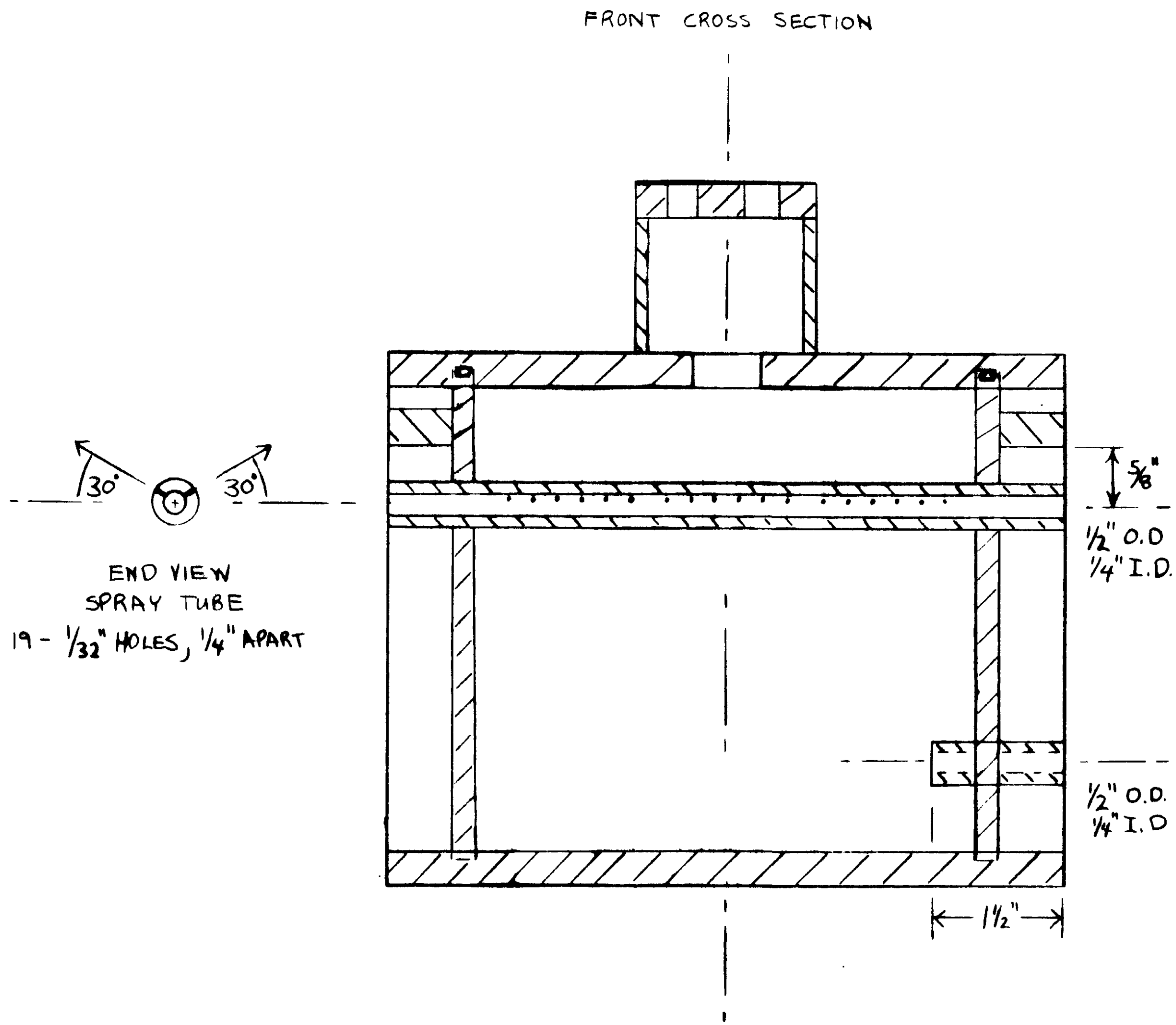


FIGURE 61 pCO_2 EQUILIBRATOR
EQUILIBRATOR FRONT CROSS SECTION

L.D
MAY 1977