LUDLUM MODEL 3-97EP
EXPLOSION-PROOF MICRO R METER

February 1998

Serial No. PR148235 and Succeeding
Serial Numbers

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LUDLUM MEASUREMENTS, INC.
501 OAK ST., P.O. BOX 810
SWEETWATER, TX 79556
325/235-5494 FAX: 325/235-4672

REV #	ALTERATIONS	DATE	BY
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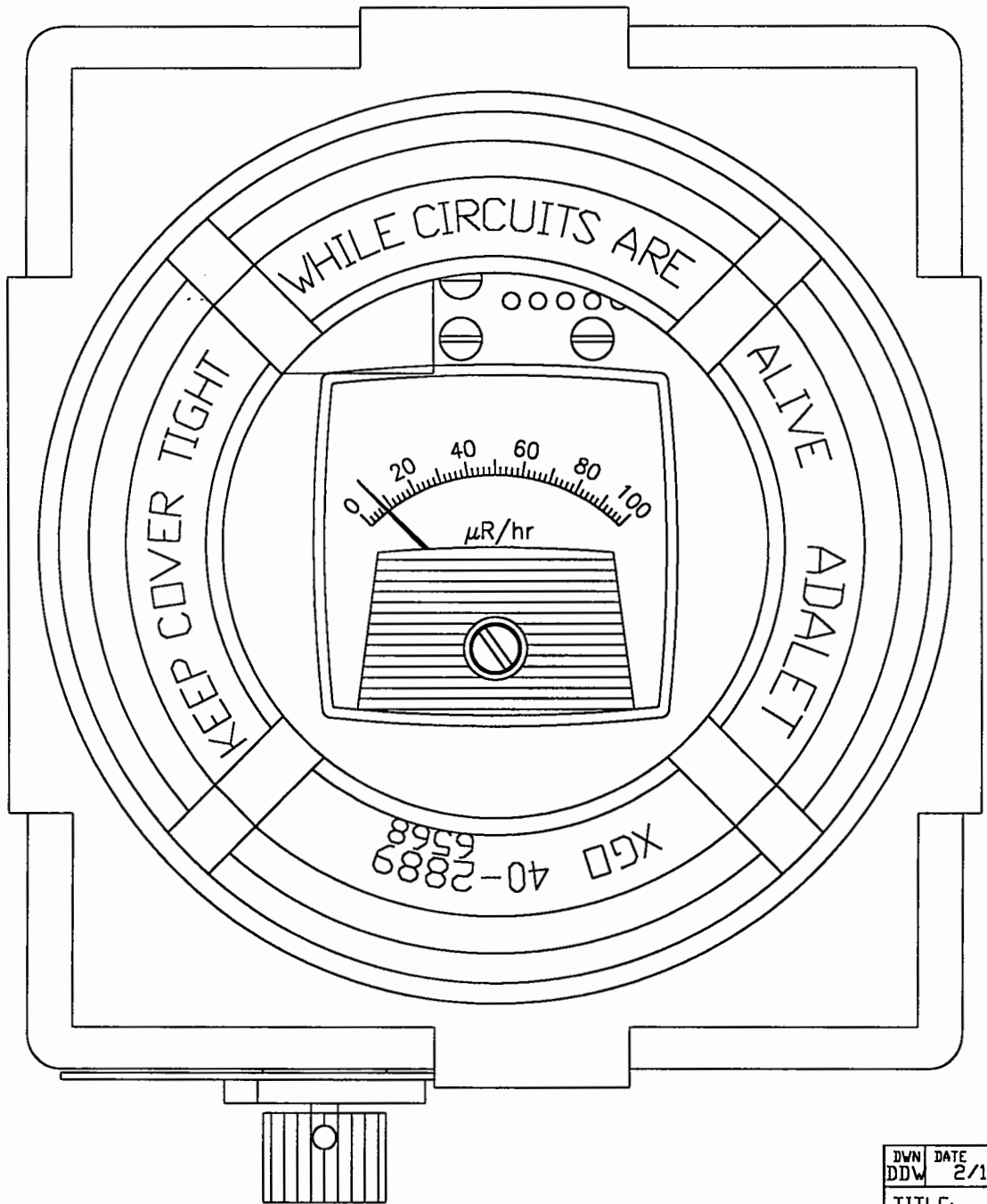

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DDW	2/13/98	R.C. 2/13/98	Len 2-13-98

TITLE: M 3-97 EP FRONT ASSY

LUDLUM MEASUREMENTS, INC.
501 OAK STREET
SWEETWATER, TEXAS 79556

SERIES	SHEET
459	31

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1. GENERAL

The Ludlum Model 3-97EP Explosion-Proof Micro R Meter utilizes an internally-mounted, 1-inch diameter by 1-inch thick sodium iodide [NaI(Tl)] crystal scintillator and an energy-compensated Geiger-Mueller (G-M) detector to offer optimum performance in counting low-level gamma radiation. The NaI scintillator is energy-dependent. Refer to the last page of this manual for an energy response curve of the Ludlum Model 44-2, which utilizes the same scintillator as in the Model 3-97EP.

Five range divisions are provided in the 1 – 100,000 micro R/hr spectrum. The meter face is provided with a 0 – 100 µR/hr scale and battery test. Five multipliers of X0.1 through X1000 (X1K) may be selected with the range switch.

The counter is mounted inside an explosion-proof box (ADALET XJTFGC) for compliance with National Electrical Code (NEC) Class 1, Groups C and D; Class II Groups E, F and G. Calibration controls are accessible by unscrewing the glass cover.

Two "C" size batteries power the instrument. The batteries are located under the meter housing and may be changed by removing the two cover mounting screws and lifting the cover up. Refer to Section "4. Operating Procedures" for special instructions on removing and replacing batteries.

WARNING

DO NOT OPEN THE EXPLOSION-PROOF BOX IN AN EXPLOSIVE ATMOSPHERE. THE UNIT CONTAINS INTERNAL BATTERIES THAT MAY BE A SOURCE OF IGNITION.

2. SPECIFICATIONS

- **LINEARITY**: plus or minus 5% full scale
- **INPUT IMPEDANCE**: 0.1 megohm
- **HIGH VOLTAGE**: variable from 400 to 800 volts DC, electronically regulated to within ±1%.
- **POWER**: Two standard "C" size batteries, located under meter
- **BATTERY DEPENDENCE**: Instrument calibration change less than 3% within battery check limits on the meter
- **COUNTING RANGES**: Meter scale presentation of 0 to 100 Micro R/hr with range multiples of X0.1, X1, Xl0, X100, and X1000; overall range of 0 – 100 mR/hr.
- **INPUT SENSITIVITY**: 30 ±10 mV for the low range detector (scintillation detector); 80 ±10 mV for the high range detector (G-M detector)
- **METER**: 1mA, 2 1/2-inch scale, with pivot-and-jewel suspension
- **DETECTORS**: Photomultiplier coupled to a 1" x 1" NaI(Tl) crystal for 0 – 1000 µR/hr and a G-M tube for 1000 – 100,000 µR/hr.
- **CALIBRATION CONTROLS**: Individual recessed potentiometers for each range
- **SIZE**: 16.5 cm (6.5")H X 23 cm (9")W X 21.6 cm (8.5")L, exclusive of handle
- **WEIGHT**: 7.25kg (16 lbs.)

3. DESCRIPTION OF CONTROLS AND FUNCTIONS

- **Range Multiplier Selector Switch**: A seven-position switch labeled "OFF," "BAT," "X1000," "X100," "X10," "X1" and "X0.1." Turning the range selector switch to one of the range multiplier positions (X1000, X100, X10, X1, or X0.1) provides the operator with an overall range of 0-100,000 μR/hr. Multiply the scale reading by the multiplier to determine the actual reading.

- **HV Adjustment**: Recessed panel control labeled 'HV" may be adjusted from 400 to 800 volts. This control should be set between 550 and 600 volts, allowing both detectors to operate on their plateau.

- **Range Calibration Adjustment**: Recessed potentiometers located inside the housing, accessible by unscrewing the glass cover. These adjustment controls allow individual calibration for each range multiplier.

4. OPERATING PROCEDURES

WARNING

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o Check batteries by turning the range switch to "BAT." The meter should deflect to the battery check portion of the meter (above "BAT OK"). (See instructions for battery replacement, taking special note of the warning.)

o Expose the internal detectors to a radiation check source. Confirm response on X0.1 through X10 ranges for the scintillation detector and X100 or X1000 for the G-M detector.

✔ **NOTE**: To access the batteries, the front panel must be removed. To remove the front panel, unscrew the glass cover and remove the two front panel mounting screws. Slide the front panel towards you. Dip the bottom of the front panel down and pull the top portion out first. Taking care to avoid breaking the wire harness, lift up the front panel. The batteries are located on the underside of the front panel.

When replacing batteries, note polarity direction, indicated in the bottom of the battery holder. Re-assemble harness, front panel and cover in reverse order of disassembly.

o Check calibration and proceed to use instrument.

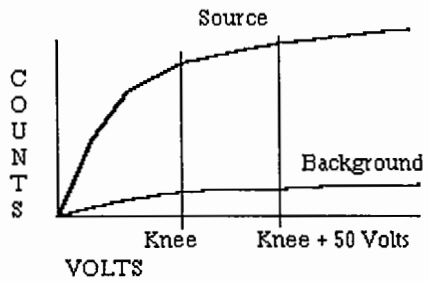
5. CALIBRATION

5.1 Determining Operating Voltage for Scintillation Detector

☐ Plateau scintillation detector with ^{241}Americium, using the Model 3-97EP potentiometer for high voltage (HV) adjustment on front panel. (See note below.) Use multiplier scale X0.1, X1 or X10.

✓ NOTE: To measure high voltage (HV), connect an 11 megohm input voltmeter through a 100 megohm, 1% resistor to P3, pin 8 on the Calibration board. Multiply voltage reading by 6,740 for HV reading.

☐ Increment the HV in 50 volts steps to produce a graph similar to the figure below.



■ The "plateau" is that portion of the curve from the knee to the point where either the source or background counts start to rapidly increase with a small change in detector high voltage.

☐ Adjust the HV 50 volts above the plateau knee. The plateau length should be at least 100 volts.

5.2 Calibration of G-M and Scintillation Detectors

Switch the Range multiplier to the X1000 position. Expose the instrument to a calibrated gamma radiation field that corresponds to approximately 80% of full meter scale. Adjust the X1000 range calibration control for proper reading. Position instrument in a field that corresponds to approximately 20% of meter scale and confirm that meter indicates within ±10% of the field. Repeat calibration for the X100, X10, X1, and X0.1 ranges.

✓ NOTE: On the X0.1 multiplier range, the background radiation exposure rate should measure approximately 8 μR/hr. Remember to add background radiation to range radiation for accurate calibration numbers.

6. MAINTENANCE

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration.

An instrument operational check should be performed prior to each use by exposing the detector to a known source and confirming the proper reading on each scale.

Recalibration should be accomplished after any maintenance or adjustment of any kind has been performed on the instrument. Battery replacements are not considered to be maintenance and do not normally require the instrument to be recalibrated.

Ludlum Measurements recommends recalibration at intervals no greater than one year. Check the appropriate regulatory agencies regulations to determine required recalibration intervals.

The batteries should be removed and the battery contacts cleaned of any corrosion at least every three months. If the instrument has been exposed to a very dusty or corrosive atmosphere, more frequent battery servicing should be used.

Refer to Section "4. Operating Procedures" for instructions on removing and replacing batteries.

WARNING

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7. THEORY OF OPERATION

7.1 Detectors

The scintillation detector consists of a crystal of sodium iodide with Thallium activation [NaI(Tl)] that gives off light pulses when penetrated by radiation photons.

The light pulses are converted to electrical pulses by the photocathode of the photomultiplier tube. The photomultiplier includes a 9-stage electron amplifier. This amplifier utilizes an electrostatic field for each stage, adding up to a required 500 to 650 volt supply.

The X100 and X1000 ranges utilize a G-M tube. Radiation photons yield electrical pulses with 500-650 volts applied to the G-M tube.

7.2 Input

Scintillation detector pulses are coupled from the detector through C3 to emitter follower Q5. R10 and R20 provide bias. R32 protects Q5 from input shorts. R5 couples the detector to the high voltage supply.

G-M detector (V2) pulses are coupled from the detector through C27 to emitter follower Q7. R45 limits the current to V2. R21 and R41 provide bias to Q7. R40 protects Q7 from input shorts. R39 couples scintillation detector (V1 on the wiring diagram) to the high voltage supply.

Detector V2 is used only when the range switch is in the X100 and X1K positions. In the X0.1, X1, and X10 ranges, the scintillation detector (V1) is used. When in the X0.1, X1, and X10 ranges, P1-13 is at ground potential, turning off Q6, allowing the pulses from Q5 to pass on to the amplifier. P1-14 is opened allowing R16 to bias Q8, pulling the pulses from the base of Q7 to ground and blocking them from the amplifier. In the X100 and X1K ranges, P1-14 are grounded, turning OFF Q8, allowing the pulses from Q7 to pass on to the amplifier. P1-13 are opened, allowing R47 to bias Q6, pulling the pulses from the base of Q5 to ground and blocking them from the amplifier.

7.3 Amplifier

A self-biased amplifier provides gain in proportion to R33 divided by R6 for the scintillation detector (V1) and R33 divided by R44 for the G-M detector (V2). Transistor (pin 6 of U1) provides amplification. Pin 12 and 15 of U1 are coupled as a current mirror to provide a load for pin 6 of U1. The output self-biases to 2 Vbe (approximately 1.4 volts) at pin 7 of U1. This provides just enough bias current through pin 6 of U1 to conduct all of the current from the current mirror.

Positive pulses from pin 7 of U1 are coupled to the discriminator.

7.4 Discriminator

Comparator U5 provides discrimination. The discriminator is set by the voltage divider, R8 and R50, coupled to pin 3 of U5. The output pulses are coupled to pin 5 of U6 for meter drive.

7.5 Digital Analog Convertor

Pins 10-15 of U1 are coupled as a current mirror. For each pulse of current through R9, an equal current is delivered to C22 and R42. This charge is drained off by R42. The voltage across C22 is proportional to the incoming count rate.

7.6 Scale Ranging

Detector pulses from the discriminator are coupled to univibrator pin 5 of U6. For each scale, the pulse width of pin 6 of U6 is

increased by a factor of 10 with the actual pulse width being controlled by the front panel calibration controls and their related capacitors. This arrangement allows the same current to be delivered to C22 by one-tenth of one count on the X.1 range as 100 counts on the X1000 range.

7.7 Meter Drive

The meter is driven by the emitter to Q3, coupled as a voltage follower in conjunction with pin 1 of U3.

For Battery Test, the voltage follower is bypassed, and the meter movement is directly coupled to the battery through R26.

7.8 Meter Compensation

When the unit is provided with a high torque meter movement, with 1.2 volt drive, a temperature compensation circuit (R15, R17 and R23) is provided on the Main Circuit board.

7.9 Low Voltage Supply

Battery voltage is coupled to U8 and associated components (a switching regulator) to provide 5 volts at pin 5 to power all logic circuits. Unregulated battery voltage is used to power the meter drive (Q3) and the high voltage blocking oscillator (Q2).

7.10 Low Voltage Reference

U7 provides a 1.22 volt precision reference for HV supply.

7.11 High Voltage Supply

High voltage is developed by blocking oscillator Q2-T1 and rectified by voltage multiplier CR2 and CR4. Output voltage increases as current through Q1 increases, with maximum output voltage with Q1 saturated.

High voltage is coupled back through R12 to opamp pin 6 of U3. R2 completes the high voltage circuit to ground. High voltage output is set by R3 (HV Set), which sets bias of pin 5 of U3. During stable operation, the voltage at pin 6 of U3 will equal the voltage at pin 5 of U3. Pin 7 of U3 will cause conduction of Q1 to increase or decrease until the high voltage seeks a level of stability.

7.12 Detector Over Range

The cathode of V2 is connected to the inverting (pin 6) input of voltage comparator U5. The R38 and R49 voltage divider supplies a reference voltage (at 0.38V) to the noninverting (pin 5) input.

When the voltage drop across R46 raises the voltage at pin 6 above pin 5, pin 1 of U5 goes low, driving the meter circuit to full-scale output.

PARTS LIST

Ref. No.	Description	Part No.
	Model 3-97EP Micro R Meter	
UNIT	Completely Assembled Model 3-97EP Micro R Meter	48-1428
	Main Board, Drawing 459 X 27	
BOARD	Assembled Circuit Board	5459-026
	• **CAPACITORS**	
C2	0.01µF, 100V, C	04-5523
C3	100pF, 3kV, C	04-5532
C4	0.0027µF, 3kV, C	04-5520
C5	10µF, 20V, DT	04-5592
C7	0.0015µF, 3kV, C	04-5518
C8	0.001µF, 100V, C	04-5519
C9	100µF, 10V, DT	04-5576
C10	100pF, 3kV, C	04-5532
C11	0.0015µF, 3kV, C	04-5518
C12	470pF, 100V, C	04-5555
C13	0.01µF, 100V, C	04-5523
C14	1µF, 35V, DT	04-5575
C15	0.1µF, 100V, C	04-5521
C18	330pF, 100V, C	04-5531
C20	0.001µF, 100V, C	04-5519
C21	100pF, 100V, C	04-5527
C22	10µF, 20V, DT	04-5592
C23	0.01µF, 100V, C	04-5523
C25	10µF, 20V, DT	04-5592
C26	100pF, 100V, C	04-5527
C27	100pF, 3kV, C	04-5532
C28	1µF, 35V, DT	04-5575
C29	47µF, 16V, DT	04-5550
	• **TRANSISTORS**	
Q1	2N3904	05-5755
Q2	MPS6534	05-5763
Q3	2N3904	05-5755
Q4	MPS6534	05-5763
Q5-Q7	2N3904	05-5755
Q8	2N7000	05-5820
	• **INTEGRATED CIRCUITS**	
U1	CA3096	06-6023
U2	ICM7555	06-6136
U3	TLC27M7IP	06-6248
U4	CA3096	06-6023
U5	TLC372	06-6265
U6	CD4098	06-6066
U7	LM385Z-1.2	05-5808
U8	MAX631	06-6249
	• **DIODES**	
CR2	1N4007	07-6274
CR4	1N4007	07-6274
CR5	1N4148	07-6272
	• **RESISTORS**	
R1	1 MEG	10-7028
R2	1.5 MEG	10-7038
R3	1 MEG TRIMMER	09-6752
R4	10 MEG	10-7031
R5	10k	10-7070
R6-R7	4.7k	10-7014
R8	47k	10-7020
R9	SAT (TYP. 33k)	10-7019
R10	100k	10-7023
R11	10k	10-7016
R12	1G	12-7686
R13	470k	10-7026
R14	10k	10-7016
R16	100k	10-7023
R17	301 OHM, 1%	12-7855
R18	47k	10-7020
R19	1k	10-7009
R20-R21	100k	10-7023
R22	10k	10-7016
R24	200 OHM	10-7006
R25	2.2k	10-7012
R26	2.37k, 1%	12-7648
R27	10k	10-7070
R28	100 OHM	10-7004
R29	8.2k	10-7015
R30	100k	10-7023
R31	10k	10-7016
R32	10k	10-7016
R33	82k	10-7022
R34	10k	10-7016
R35	100k	10-7023
R36	2.7 MEG	10-7029
R37	1k	10-7009
R38	220k	10-7066
R39	1 MEG	10-7028
R40	10k	10-7016
R41	100k	10-7023
R42	180k	10-7068

Ref. No.	Description	Part No.
R43	10k	10-7016
R44	4.7k	10-7014
R45	3.3 MEG	10-7044
R46	12k	10-7048
R47	100k	10-7023
R48	10k	10-7016
R49	18k	10-7018
R50	SAT (TYP. 15k)	
R51	100k	10-7023
R52	3.3 MEG	10-7044
•	**THERMISTORS**	
R15	R1006-98.4-59-D1	07-6332
R23	R1006-98.4-59-D1	07-6332
•	**INDUCTORS**	
L1	470UHY	21-9600
•	**TRANSFORMERS**	
T1	L8050	40-0902
•	**MISCELLANEOUS**	
V2	GM TUBE-LND 71210	01-5295
10 EA.	RECEPTACLE Cloverleaf 011-6809	18-8771
1EA.	CONNECTOR 640456-2 MTA100	13-8073
1EA.	CONNECTOR 1-640456-4 MTA100	13-8141
1EA.	CONNECTOR 640456-3	13-8081

Calibration Board, Drawing No. 459 X 23

BOARD	Completely Assembled Calibration Board	5459-023
•	**CAPACITORS**	
C120	0.047μF 100V C X7R	04-5565
C121-C122	0.0047μF 100V C X7R	04-5570
•	**RESISTORS**	
R112-R117	1 MEG TRIMMER	09-6778
R118	1.5 MEG	10-7038
R119	432k	12-7689
•	**RESISTOR NETWORK**	
RN123	NETWORK 10k SIP 10PIN	12-7727
•	**MISCELLANEOUS**	
P3	CONN-1-640456-0 MTA100	13-8066

Chassis Wiring Diagram, Drawing No. 459 X 26

•	**CONNECTOR**	
J1	CONN-1-640442-4 MTA100	13-8173
J3	CONN-1-640442-0 MTA100	13-8136
J4	CONN-640442-3 MTA100	13-8135
•	**SWITCH**	
S1	SWITCH ASSEMBLY	4459-036
•	**BATTERY**	
B1-B2	"C" Cell Alkaline Battery	22-9387
•	**MISCELLANEOUS**	
V1	M3-97EP SCINTILLATOR DETECTOR ASSY	4459-032
*	PM TUBE 1.125" ADIT B29B07-1	01-5638
*	ENCLOSURE ASSY	4459-033
*	EXPL-PROOF CASE	2310553
M1	METER ASSEMBLY	4173-166
*	METER #5025 2.5"	15-8048
*	HANDLE/GRIP	7459-020

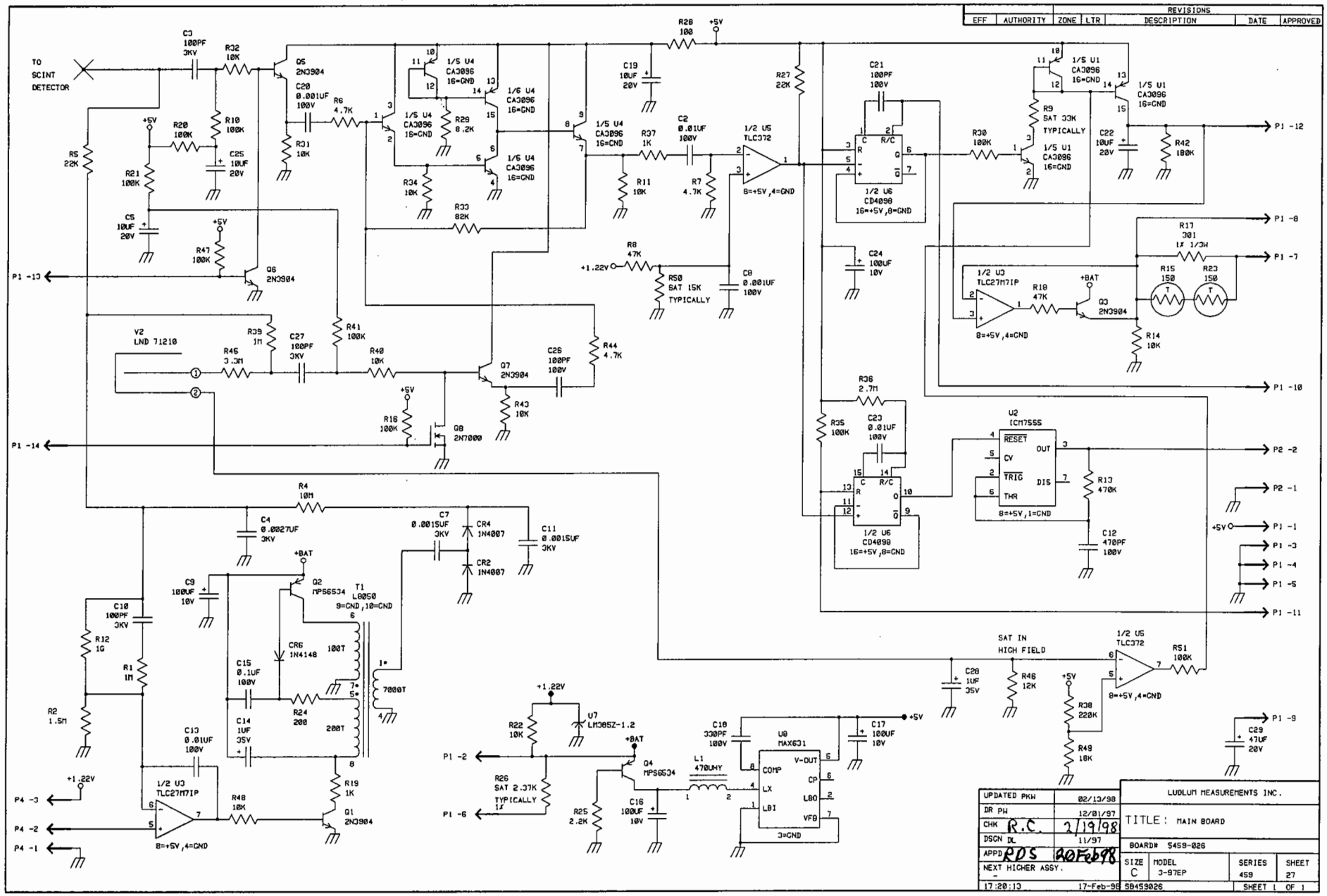
DRAWINGS AND DIAGRAMS

Main Circuit Board, Drawing 459 x 27
Main Board Component Layout, Drawing 459 x 35

Calibration Board, Drawing 459 x 23
Calibration Board Component Layout, Drawing 459 x 24

Wiring Diagram, Drawing 459 x 26

Energy Response Curve for Model 44-2 Detector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P1 -4
P1 -5
P1 -11
P1 -2
P1 -6
P1 -9
P4 -3
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P4 -1
+5V
+1.22V
+BAT
1/2 U5 TLC372
8=+5V,4=GND
1/2 U6 CD4098
16=+5V,8=GND
1/5 U4 CA3096 16=GND
1/5 U1 CA3096 16=GND
1/2 U3 TLC27M7IP
U2 ICM7555
U7 LM385Z-1.2
U8 MAX631
Q1 2N3904
Q2 MPS6534
Q3 2N3904
Q4 MPS6534
Q5 2N3904
Q6 2N3904
Q7 2N3904
Q8 2N7000
T1 L0050
9=CND,10=CND
7000T
100T
200T
CR1 1N4007
CR2 1N4007
CR4 1N4007
CR6 1N4148
V2 LND 71210
SAT IN HIGH FIELD
L1 470UHY
R1 1M
R2 1.5M
R4 10M
R5 22K
R6 4.7K
R7 4.7K
R8 47K
R9 SAT 33K TYPICALLY
R10 100K
R11 10K
R12 1G
R13 470K
R14 10K
R15 150
R16 100K
R17 30I 1% 1/3W
R18 47K
R19 1K
R20 100K
R21 100K
R22 10K
R23 150
R24 200
R25 2.2K
R26 SAT 2.37K TYPICALLY 1%
R27 22K
R28 100
R29 8.2K
R30 100K
R31 10K
R32 10K
R33 82K
R34 10K
R35 100K
R36 2.7M
R37 1K
R38 220K
R39 1M
R40 10K
R41 100K
R42 100K
R43 10K
R44 4.7K
R45 3.3M
R46 12K
R47 100K
R48 10K
R49 18K
RS0 SAT 15K TYPICALLY
RS1 100K
C1 0.0027UF 3KV
C2 0.01UF 100V
C3 100PF 3KV
C4 0.0027UF 3KV
C5 10UF 20V
C6 0.01UF 100V
C7 0.0015UF 3KV
C8 0.001UF 100V
C9 100UF 10V
C10 100PF 3KV
C11 0.0015UF 3KV
C12 470PF 100V
C13 0.01UF 100V
C14 1UF 35V
C15 0.1UF 100V
C16 100UF 10V
C17 100UF 10V
C18 330PF 100V
C19 10UF 20V
C20 0.001UF 100V
C21 100PF 100V
C22 10UF 20V
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CHK R.C 2/19/98
DSGN DL 11/97
APPD RDS 20Feb98
NEXT HIGHER ASSY. -
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LUDLUM MEASUREMENTS INC.
TITLE: MAIN BOARD
BOARD# 5459-026
SIZE C | MODEL 3-97EP | SERIES 459 | SHEET 27
5845926 SHEET 1 OF 1

BOARD
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HEIGHT=2.810"

MOUNTING HOLE
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Y=0.734"
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Y=0.250"
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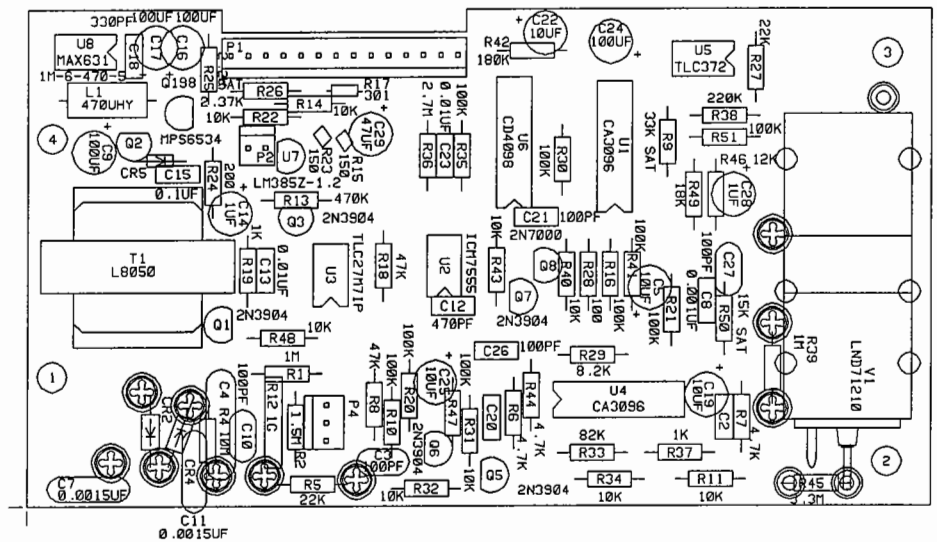
Y=2.560"
4. X=0.140"
Y=2.076"



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COMP PASTE ☐	COMP MASK ☐	SLDR PASTE ☐	SLDR MASK ☐

REVISIONS						
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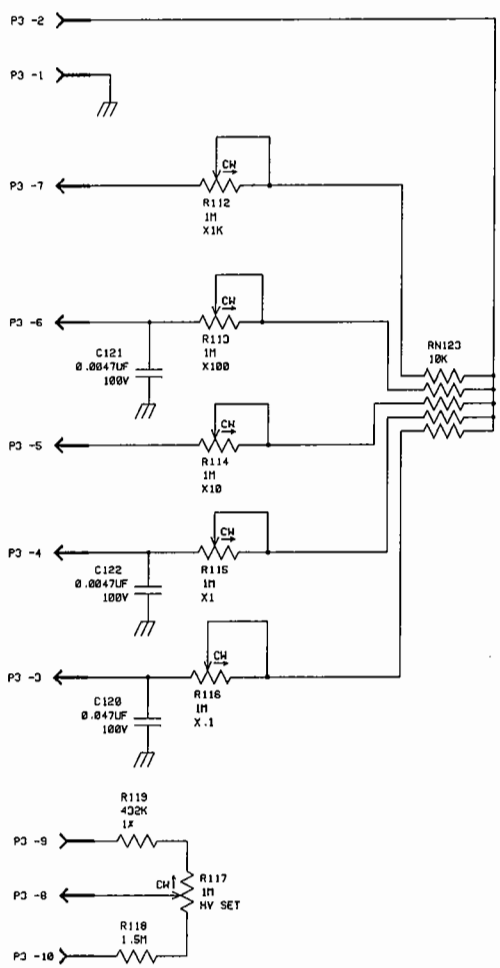

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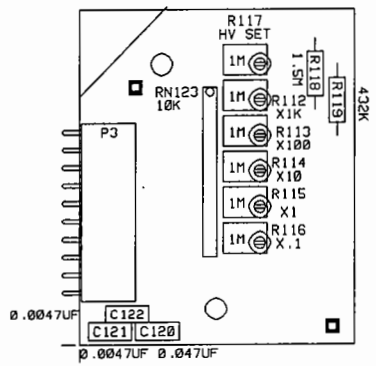

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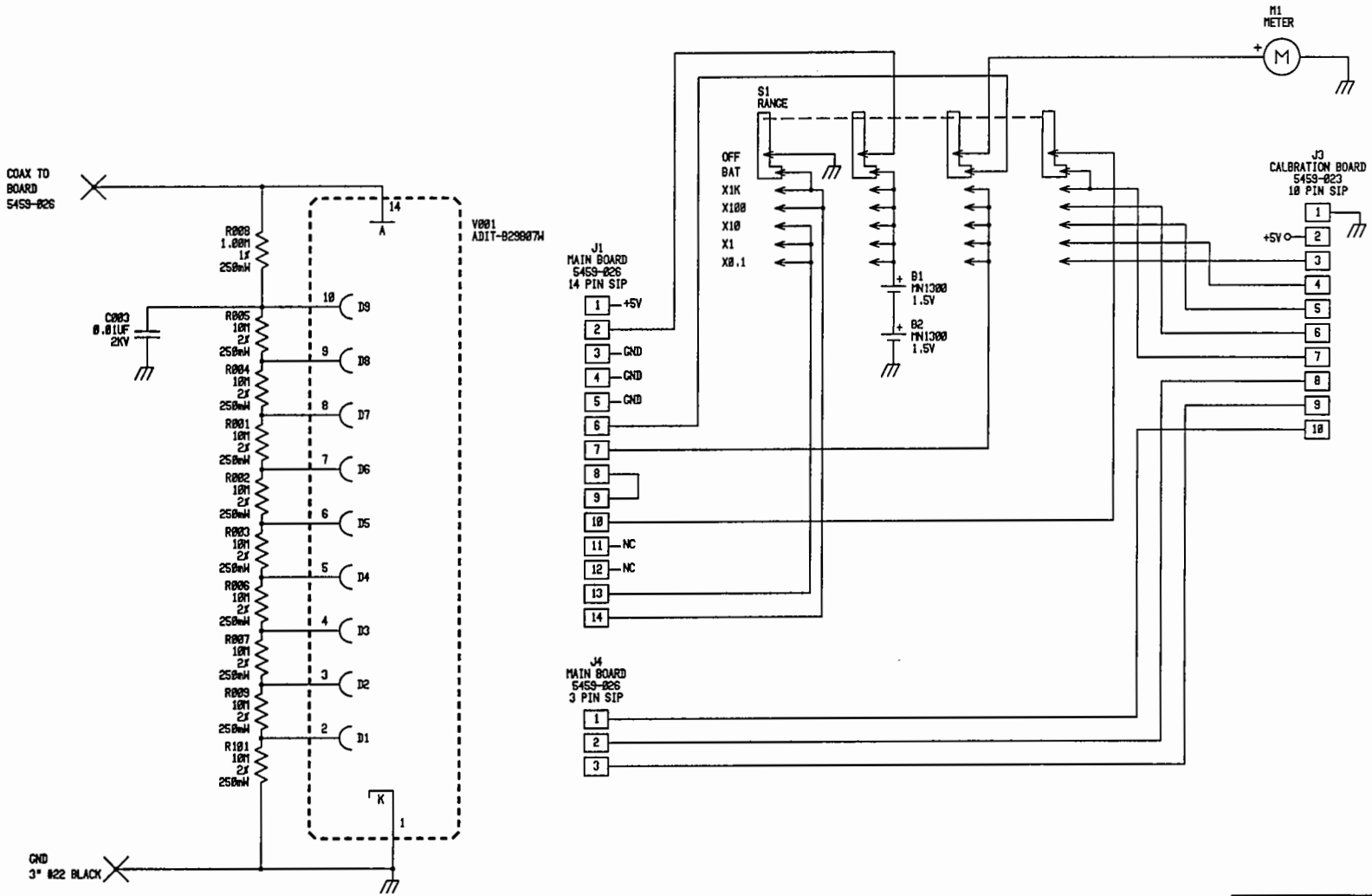
DR	PW	12/01/97	TITLE: CALIBRATION BOARD		
CHK	R.C.	2/13/98	BOARD# 5459-023		BS459023
DSGN	DL	11/97	MODEL 3-97EP	SERIES 459	SHEET 24
APP		2/13/98	COMP ARTWORK ☐		SLDR ARTWORK ☐
09:01:11		13-Feb-98	COMP OUTLINE ☐		SLDR OUTLINE ☐
COMP PASTE ☐		COMP MASK ☐	SLDR PASTE ☐		SLDR MASK ☐

REVISIONS						
EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED



UPDATED	PKW	02/13/98
DR PW		12/01/98
CHK	KB	20-FEB-98
DSGN	DL	11/97
APPD	JOW	2-20-98
NEXT HIGHER ASSY.		
16:10:10		20-Feb-98

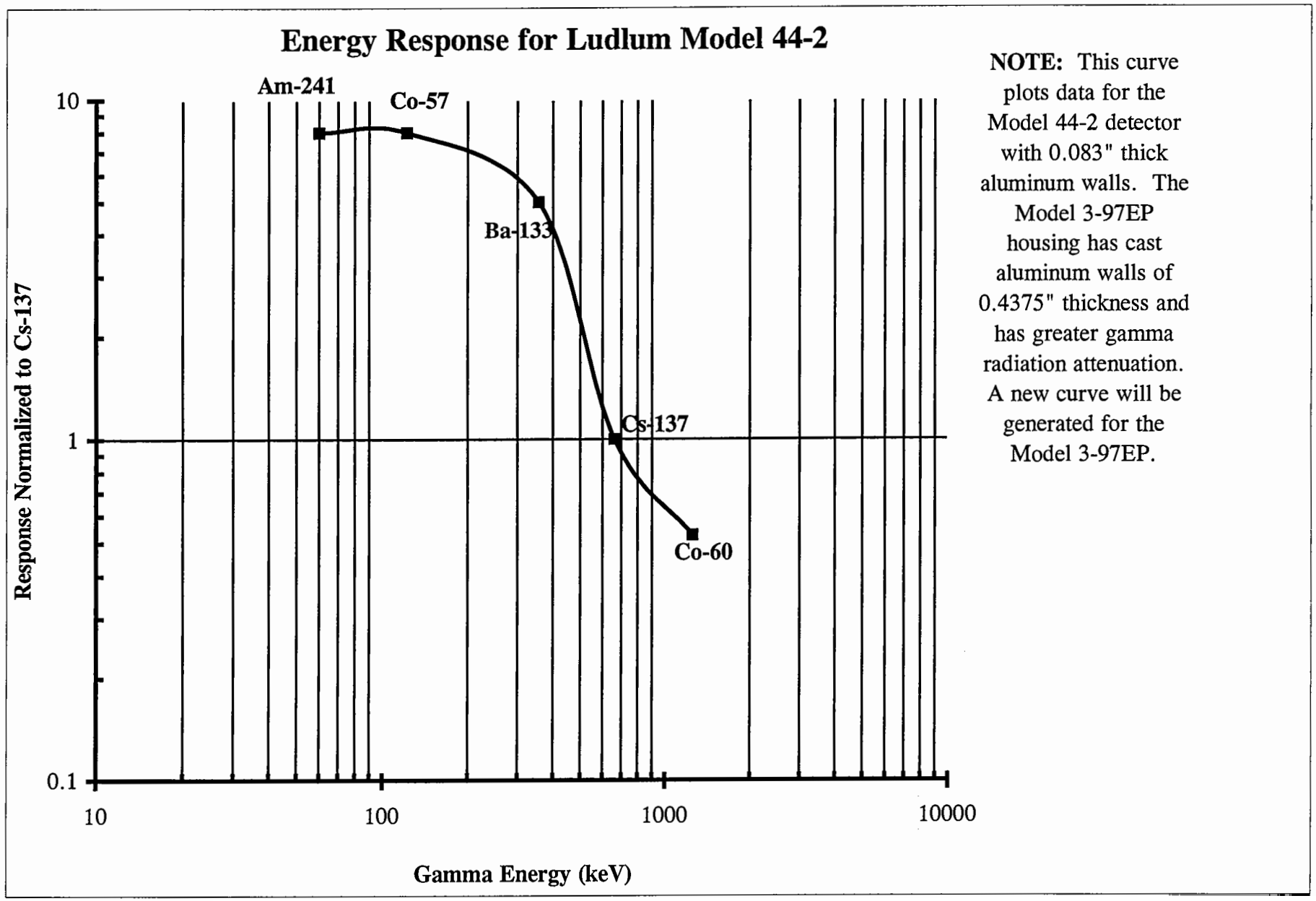
LUDLUM MEASUREMENTS INC.

TITLE: WIRING DIAGRAM

BOARD# 459-025

SIZE	MODEL	SERIES	SHEET
C	3-97EP	459	26

W459025 SHEET 1 OF 1


Energy Response for Ludlum Model 44-2
Am-241
Co-57
Ba-133
Cs-137
Co-60
10
1
0.1
10
100
1000
10000
Response Normalized to Cs-137
Gamma Energy (keV)
NOTE: This curve plots data for the Model 44-2 detector with 0.083" thick aluminum walls. The Model 3-97EP housing has cast aluminum walls of 0.4375" thickness and has greater gamma radiation attenuation. A new curve will be generated for the Model 3-97EP.