LUDLUM MODEL 15
NEUTRON COUNTER WITH
DETECTOR MODELS 44-7 & 42-14H

October 2015

Serial Number 228074 and Succeeding

Serial Numbers

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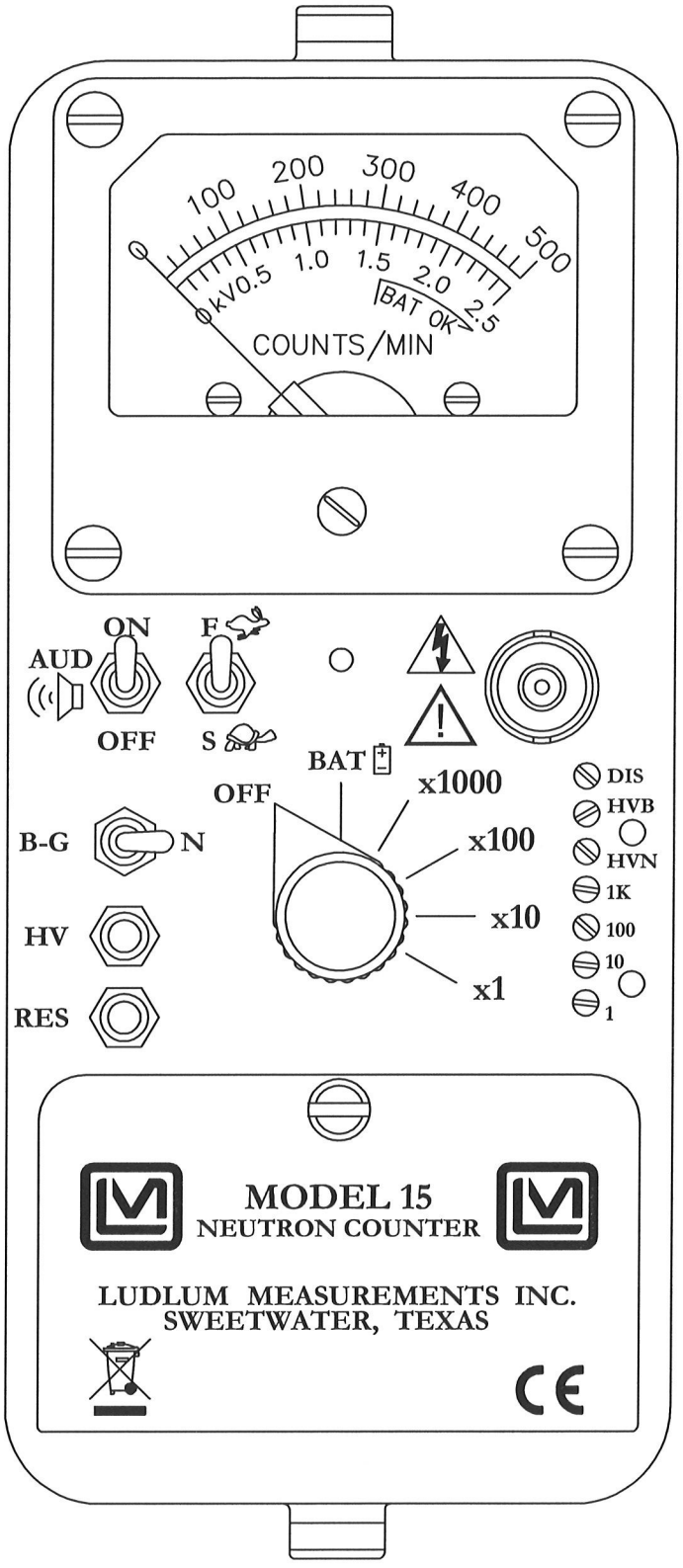
This Manual also applies to Serial Numbers of Model 15 Instruments where the accompanying BF-3 detector has been replaced by He-3. He-3 detectors are labeled with an "H"

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

REV #	ALTERATIONS	DATE	BY
1	VALID	12-6-89	BK
2	CHANGED ARTWORK	4-28-05	CMC
3	ADDED DO NOT DISCARD SYMBOL	11-21-06	CMC



DWN	DATE	CHK	DATE	APP	DATE
CMC	11-21-06			NDW	11-21-06

PART NUM: 4363-334	SCALE: FULL ☒ OTHER
TITLE M 15 NEUTRON COUNTER	

LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556	SERIES 363	SHEET 255

Table of Contents

Section

1

Introduction

The Model 15 is a Neutron Counter coupled to a Model 42-14H Neutron Detector and moderator, as well as a Model 44-7 GM Detector. This combination provides the required electronic circuitry and detectors for measuring and monitoring alpha, beta, and gamma radiation, in addition to fast and slow neutrons (removable moderator for thermal neutrons).

The instrument provides four linear ranges used in combination with a CPM (counts per minute) meter dial. The instrument features a regulated high-voltage power supply, unimorph speaker with audio ON-OFF capability, fast-slow meter response, meter reset button, and a six-position switch for selecting battery check or range multiples of ×1, ×10, ×100, and ×1000. Each range multiplier has its own calibration potentiometer.

Other controls include: two-position toggle switch for selection of alpha-beta-gamma (B-G) or neutron detection (N), high-voltage check (HV) and meter reset (RES) buttons, and front-panel calibration controls for independent high voltage and discrimination adjustments.

The unit body and meter housing are made of cast aluminum and the can is 0.23 cm (0.090 in.) thick aluminum. The unit is powered by two ″D″ cell batteries for operation from -20 to 50 °C (-4 to 122 °F). For instrument operation below 0 °C (32 °F), either very fresh alkaline or rechargeable NiCd batteries should be used.

Section

2

Getting Started

Unpacking and Repacking

Remove the calibration certificate and place it in a secure location. Remove the instrument and accessories (batteries, cable, detectors, etc.) and ensure that all of the items listed on the packing list are in the carton. Check individual item serial numbers and ensure calibration certificates match. The Model 15 serial number is located on the front panel below the battery compartment. Most Ludlum Measurements detectors have a label on the base or body of the detector for model and serial number identification.

Important!

If multiple shipments are received, ensure that the detectors and instruments are not interchanged. Each instrument is calibrated to specific detectors, and therefore not interchangeable.

To return an instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment.

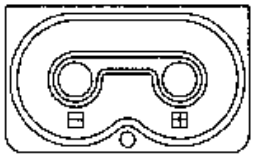
Every returned instrument must be accompanied by an **Instrument Return Form**, which can be downloaded from the Ludlum website at www.ludlums.com. Find the form by clicking the "Support" tab and selecting "Repair and Calibration" from the drop-down menu. Then choose the appropriate Repair and Calibration division where you will find a link to the form.

Model 44-7

When shipping a Model 44-7 by air, it is necessary to ship the tube in a sealed container to avoid sudden atmospheric changes, which could rupture the tube.

Battery Installation

Ensure the Model 15 range selector switch is in the OFF position. Open the battery lid by pushing down and turning the quarter-turn thumbscrew counterclockwise a quarter of a turn. Install two ″D″ size batteries in the compartment.



Note the (+) and (-) marks inside the battery door. Match the battery polarity to these marks. Close the battery box lid, then push down and turn the quarter-turn thumb screw clockwise a quarter of a turn.

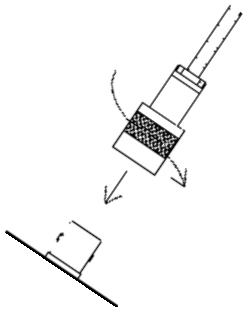
Note:

The center post of a flashlight battery is positive. The batteries are placed in the battery compartment in opposite directions.

Connecting a Detector to the Instrument

Caution!

The detector operating voltage (HV) is supplied to the detector via the detector input connector. A mild electric shock may occur if you make contact with the center pin of the input connector. Switch the Model 15 range selector switch to the OFF position before connecting or disconnecting the cable or detector.



Connect one end of a detector cable to the desired detector by firmly pushing the connectors together while twisting clockwise a quarter of a turn. Repeat the process in the same manner with the other end of the cable and the instrument.

Battery Test

The batteries should be checked each time the instrument is turned on. Move the range switch to the BAT position. Ensure that the meter needle deflects to the battery check portion on the meter scale. If the meter does not respond, check to see if the batteries have been correctly installed. Replace the batteries if necessary.

Instrument Test

Connect the GM detector if you have not already done so. Set the B-G/N switch to B-G. After checking the batteries, turn the instrument range switch to the ×1000 position. Place the AUD ON-OFF switch in the ON position. Expose the detector to a radiation check source. The instrument speaker should emit ″clicks″ relative to the rate of counts detected. The AUD ON/OFF switch will silence the audible clicks if in the OFF position. It is recommended that the AUD ON/OFF switch be kept in the OFF position when not needed in order to preserve battery life.

Press the HV check button and confirm that the meter indicates approximately 900 volts (same as indicated on calibration test sheet). Rotate the range switch through the lower scales until a meter reading is indicated. Record the reading.

While observing the meter fluctuations, select between the fast and slow response time (″F/S″) positions to observe variations in the display. The ″S″ position should respond approximately five times slower than the ″F″ position.

Note:

The slow response position is normally used when the instrument is displaying low numbers, which require a more stable meter movement. The fast response position is used at high rate levels.

Check the meter reset function by depressing the RES pushbutton switch and ensuring the meter needle drops to zero.

Turn the instrument off. Disconnect the GM detector and connect the neutron detector. Set the B-G/N switch to N. Press the HV check button and compare the high-voltage reading to the calibration test sheet reading (approximately 1275-1350 volts).

If a neutron source is available, expose the detector to the source (at a repeatable distance) and record the reading. Daily source checks may then be performed by orienting the detector and source in identical fashion, ensuring an instrument reading of ±20% of the initial reading. Failure to meet the ±20% criteria may indicate a detector malfunction.

Once this procedure has been completed, the instrument is ready for use.

Operational Check

To assure proper operation of the instrument between calibrations and periods of nonuse, an instrument operational check including battery test and instrument test (as described above) should be performed prior to use.

Section

3

Specifications

Instrument High Voltage: adjustable independently from 200 to 2500 V; can be read on the meter; electronically regulated to 1%; support of scintillation loads to 1500 V and proportional loads to 2500 V

Input Pulse Threshold: adjustable from -2 to -60 mV

Input Impedance: 0.1 megohm

Meter: 6.4 cm (2.5 in.) arc, pivot-and-jewel suspension

Meter Face: 0-500 cpm, 0-2.5 kV, BAT TEST (others available)

Instrument Range: typically 0-500,000 cpm, depending on the meter face utilized

Linearity: reading within 10% of true value with detector connected

Audio: built-in unimorph speaker with ON-OFF switch (greater than 60 dB at 0.61 m {2 feet})

Connector: series ″C″ (other available)

Power: two ″D″ cell batteries housed in a sealed externally accessible compartment

Battery Life: typically 600 hours with alkaline batteries (battery condition may be checked on the meter)

Battery Dependence: instrument calibration changes less than 3% within battery check limits on the meter

Size: 31.8 x 8.9 x 21.6 cm (12.5 x 3.5 x 8.5 in.) (H x W x L)

Weight: 3.7 kg (8.1 lb), including batteries

Construction: cast-and-drawn aluminum with beige powder coating

Cable: 99.1 cm (39 in.) with ″C″ connector (other available)

Model 42-14H Neutron Detector

Neutron Detector: 2 Atm ^{3}He tube, LND 25185 or equivalent; proportional detector with 7.6 cm (3 in.) diameter, cadmium-lined moderator for fast neutrons (remove detector from moderator for thermal neutrons)

Neutron Detector Operating Voltage: approximately 1275-1350 Vdc

Energy Response: count response nonlinear throughout energy spectrum (0.025-12 MeV)

Neutron Sensitivity: typically 55 cpm/mrem/hr (^{241}AmBe fast neutrons)

Detection Range: thermal to approximately 12 MeV

Gamma Rejection: typically 10 cpm or less through 10 R/hr (100 mSv/h) (^{137}Cs)

Model 44-7 Alpha-Beta-Gamma Detector

Alpha-Beta-Gamma Detector: thin end-window GM detector

Window: 1.7 ± 0.3 mg/cm^2 mica

Window Area: active is 6.4 cm^2 (1 in^2); open is 5.2 cm^2 (0.8 in^2)

Efficiency (4pi geometry): typically 2% for ^{14}C, 10% for ^{90}Sr^{90}Y, 7% for ^{239}Pu, and 7% for ^{99}Tc

Alpha-Beta-Gamma Sensitivity: typically 2100 cpm per mR/hr (^{137}Cs gamma)

Background: typically 40 cpm

Section

4

Identification of Controls and Functions

Meter: 6.4 cm (2.5 in.) arc, 1 mA analog type with pivot-and-jewel suspension. Typical meter dial is 0-500 cpm, 0-2.5 kV and BAT TEST.

Connector: used to connect the detector to the instrument. Typically series ″C,″ but can be ″BNC,″ ″MHV,″ ″UHF,″ or others.

Range Selector Switch: a six-position switch marked OFF, BAT, ×1000, ×100, ×10, and ×1. Turning the range selector switch from OFF to BAT provides the operator with a battery check of the instrument. A BAT TEST scale on the meter provides a visual means of checking the battery-charge status. Moving the range selector switch to one of the range multiplier positions (×1000, ×100, ×10, ×1) provides the operator with an overall range of 0 to 500,000 cpm. Multiply the scale reading by the multiplier to determine the actual scale reading.

Battery Compartment: sealed compartment to house two ″D″ cell batteries.

AUD ON-OFF Toggle Switch: in the ON position, operates the unimorph speaker, located on the left side of the instrument. The frequency of the clicks is relative to the rate of the incoming pulses. The higher the rate, the higher the audio frequency. This switch should be turned OFF when not required, in order to reduce battery drain.

RES Pushbutton: When depressed, this button provides a rapid means of driving the meter needle to zero.

F/S Toggle Switch: provides meter response. Selecting the fast, ″F″ position, of the toggle switch provides 90% of full-scale meter deflection in four seconds. In the slow, ″S″ position, 90% of full-scale meter deflection takes 22 seconds. In the ″F″ position there is fast response and large meter deviation. The ″S″ position should be used for slow response and damped meter deviation.

B-G/N: This switch allows for selection of the desired detector and is associated with the HV outputs. In the B-G position, the HV is adjusted for approximately 900 volts for use with GM detectors. In the N position, the HV is adjusted for approximately 1275-1350 volts when utilizing the Model 42-14H Neutron detector.

HV Pushbutton Switch: When depressed, displays the detector high voltage on the meter face, corresponding to the selected detector (B-G/N). The output resistance of the high-voltage supply is 1.5 megohms with a typical scintillation voltage divider of 100 megohms. The actual detector voltage will be 98.5% of the indicated voltage.

The following controls are located under the front-panel calibration cover:

Discriminator Adjustment (DIS): allows the input pulse threshold to be adjusted from 2 to 60 mV.

HVB Adjustment: provides a means of varying the alpha-beta-gamma high voltage from 200 to 2500 V; factory set at 900 V

Range Calibration Adjustments: These adjustment controls allow individual calibration for each range multiplier.

Section

5

Safety Considerations

Environmental Conditions for Normal Use

Indoor or outdoor use

No maximum altitude

Temperature range of -20 to 50 °C (-4 to 122 °F); may be certified for operation from -40 to 65 °C (-40 to 150 °F)

Maximum relative humidity of less than 95% (non-condensing)

Pollution Degree 3 (as defined by IEC 664) (Occurs when conductive pollution or dry nonconductive pollution becomes conductive due to condensation. This is typical of industrial or construction sites.)

Warning Markings and Symbols

Caution!

The operator or responsible body is cautioned that the protection provided by the equipment may be impaired if the equipment is used in a manner not specified by Ludlum Measurements, Inc.

Caution!

Verify instrument voltage input rating before connecting to a power converter. If the wrong power converter is used, the instrument and/or power converter could be damaged.

The Model 15 Neutron Counter is marked with the following symbols:

CAUTION, RISK OF ELECTRIC SHOCK (per ISO 3864, No. B.3.6) – designates a terminal (connector) that allows connection to a voltage exceeding 1 kV. Contact with the subject connector while the instrument is on or shortly after turning off may result in electric shock. This symbol appears on the front panel.

CAUTION (per ISO 3864, No. B.3.1) – designates hazardous live voltage and risk of electric shock. During normal use, internal components are hazardous live. This instrument must be isolated or disconnected from the hazardous live voltage before accessing the internal components. This symbol appears on the front panel. **Note the following precautions:**

Warning!

The operator is strongly cautioned to take the following precautions to avoid contact with internal hazardous live parts that are accessible using a tool:

1. Turn the instrument power OFF and remove the batteries.
2. Allow the instrument to sit for one minute before accessing internal components.

The "**crossed-out wheelie bin**" symbol notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding; each material must be separated. The symbol is placed on the battery compartment lid. See section 9, "Recycling," for further information.

The "CE" mark is used to identify this instrument as being acceptable for use within the European Union.

Cleaning and Maintenance Precautions

The Model 15 instrument and associated detectors may be cleaned externally with a damp cloth, using only water as the wetting agent. Do not immerse the instrument in any liquid. Observe the following precautions when cleaning or performing maintenance on the instrument:

1. Turn the instrument OFF and remove the batteries.
2. Allow the instrument to sit for one minute before cleaning the exterior or accessing any internal components for maintenance.

Section

6

Calibration and Maintenance

Calibration

Calibration controls are located on the front of the instrument under the calibration cover. The controls may be adjusted with a 1/8-inch blade screwdriver.

> Note:
>
> Measure high voltage with a Ludlum Model 500 Pulser or a high-impedance voltmeter with a high-meg probe. If one of these instruments is not available, use a voltmeter with a minimum input resistance of 1000 megohms.

Calibration of Discriminator

Set the instrument range switch to X10. Remove the calibration cover plate. Connect the Model 15 to the Model 500 Pulser. Set the pulser's pulse height to 10 ±0.5 mV for use without a GM detector. If a GM detector is used, set the pulse height to 30 ±0.5 mV. Set the pulser's pulse rate to 400 × 10 counts per minute.

Adjust the DIS control until the meter reading increases from 0 to a stable reading near 400 counts per minute. Check the adjustment by lowering the Model 500 pulser's pulse height to 9 mV for 10 mV setting or 29 mV for 30 mV setting. Meter reading should drop to 0. Increase the Model 500 pulse height to 12 mV for a 10 mV DIS setting or 32 mV for a 30 mV DIS setting. Meter reading should increase to a stable value near 400 counts per minute.

Calibration of Ratemeter

Set the Range switch to X1000. Set the pulser's pulse rate to 400 × 1K counts per minute. Set the pulser's pulse height to 20 mV for a DIS setting of 10 mV or 60 mV for a DIS setting of 30 mV.

Now adjust the X1000 calibration potentiometer until the Model 15 reads 400 × 1000 counts/minute. Reduce the pulser's pulse rate to 100 × 1K counts per minute. Confirm that meter reading is 100 ±10.

Set the pulser's pulse rate to 400 × 100 counts per minute. Set the Model 15 range switch to X100. Adjust the X100 calibration potentiometer until the Model 15 reads 400 ×100 counts per minute. Reduce the counts on Pulser to 100 × 100 counts per minute and confirm that the Model 15 reads 100 ±10. Repeat the procedure for the X10 and X1 ranges.

Calibration of High Voltage Readout

Open the instrument and locate the HV calibration control on the main circuit board. Connect the Model 15 to the Model 500 Pulser. Set the B-G/N switch to N. Press the HV Test switch and record the HV reading on both the Model 500 and the Model 15.

Adjust the HVN potentiometer for 1500 V on pulser readout. Press the HV button and adjust the internal Model 15 HV control until the meter reads 1500 V. Reduce the HVN control for 1000 V on pulser HV readout. HV test should indicate 1000 ±10%. Increase the HVN control to 2000 V on Pulser HV readout. HV test should indicate 2000 ±10% V.

Calibration of High Voltage

(For Beta Gamma Set B-G/N to B-G.) Press the HV test switch and adjust the HVB calibration potentiometer for a reading of 900 V.

Calibration of High Voltage For Neutrons

Switch the B-G/N switch to N. Connect the neutron probe. Press the HV test switch. Record readings in a known neutron field as the high voltage is varied from approximately 1200-1500 V in 50 V steps.

Expose Neutron detector to a 1 R/hr gamma field. Reduce the high-voltage setting until count rate is less than 10 counts per minute.

Plot the data from the previous two steps. Pick an operating point just above the knee of the count plateau, but at a voltage less than the Gamma cutoff found in the previous step. Record this voltage and adjust the HVN calibration potentiometer for operation at this voltage.

Efficiency Calibration

With the instrument fully calibrated, set the B-G/N switch to N. Connect the neutron detector within the moderator. Expose the detector to a known neutron field and determine counts/minute per mrem/hr for that energy source. Note that the Model 15 is energy dependent.

Repeat the above procedure with the B-G/N switch in the B-G position and the gamma detector connected and exposed to a known gamma field. Determine counts/minute per mR/hr.

Maintenance

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration. The Model 15 instrument may be cleaned with a damp cloth (using only water as the wetting agent). Do not immerse instrument in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument OFF and remove the batteries.

2. Allow the instrument to sit for one minute before accessing internal components.

Recalibration

Recalibration should be accomplished after maintenance or adjustments have been performed on the instrument. Recalibration is not normally required following instrument cleaning, battery replacement, or detector cable replacement of equal length.

Note:

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

Ludlum Measurements offers a full-service repair and calibration department. We not only repair and calibrate our own instruments but most other manufacturers' instruments. Calibration procedures are available upon request for customers who choose to calibrate their own instruments.

Batteries

The batteries should be removed any time the instrument is placed into storage. Battery leakage may cause corrosion on the battery contacts, which must be scraped off and/or washed using a paste solution made from baking soda and water. Use a spanner wrench to unscrew the battery contact insulators, exposing the internal contacts and battery springs. Removal of the handle will facilitate access to these contacts.

Note:

Never store the instrument over 30 days without removing the batteries. Although this instrument will operate at very high ambient temperatures, battery seal failure may occur at temperatures as low as 37 °C (100 °F).

Section

7

Troubleshooting

Occasionally, you may encounter problems with your LMI instrument or detector that may be repaired or resolved in the field, saving turn-around time and expense in returning the instrument to us for repair. Toward that end, LMI electronics technicians offer the following tips for troubleshooting the most common problems. Where several steps are given, perform them in order until the problem is corrected. Keep in mind that with this instrument, the most common problems encountered are: (1) detector cables, (2) sticky meters, and (3) battery contacts.

Note that the first troubleshooting tip is for determining whether the problem is with the electronics or with the detector. A Ludlum Model 500 Pulser is invaluable at this point, because of its ability to simultaneously check high voltage, input sensitivity or threshold, and the electronics for proper counting.

We hope these tips will prove to be helpful. As always, please call if you encounter difficulty in resolving a problem or if you have any questions.

Troubleshooting the Electronics

SYMPTOM	POSSIBLE SOLUTION
No power (or meter does not reach BAT TEST or BAT OK mark)	1. Check batteries and replace if weak. 2. Check polarity (see marks inside battery lid). Are the batteries installed backwards?

SYMPTOM	POSSIBLE SOLUTION
No power (or meter does not reach BAT TEST or BAT OK mark) (continued)	3. Check battery contacts. Clean them with rough sandpaper or use an engraver to clean the tips. 4. Check for loose or broken wires, especially between the main board and the high-voltage board.
Nonlinear Readings	1. Check the high voltage (HV) by pressing the HV TEST button. If a multimeter is used to check the HV, ensure that one with high impedance is used, as a standard multimeter could be damaged in this process. 2. Check for noise in the detector cable by disconnecting the detector, placing the instrument on the lowest range setting, and wiggling the cable while observing the meter face for significant changes in readings. 3. Check for "sticky" meter movement. Does the reading change when you tap the meter? Does the meter needle "stick" at any spot? 4. Check the "meter zero." Turn the power OFF. The meter should come to rest on zero.
Meter goes full-scale or "pegs out"	1. Replace the detector cable to determine whether or not the cable has failed, causing excessive noise. 2. Check the HV and, if possible, the input threshold for proper setting.

SYMPTOM	POSSIBLE SOLUTION
Meter goes full-scale or "pegs out" (continued)	3. Ensure that the instrument's can is properly attached. When attached properly, the speaker will be located on the left side of the instrument. If the can is on backwards, interference between the speaker and the input preamplifier may cause noise.
No Response to Radiation	1. Substitute a "known good" detector and/or cable. 2. Has the correct operating voltage been set? Refer to the calibration certificate or detector instruction manual for correct operating voltage. If the instrument uses multiple detectors, confirm that the high voltage is matched to the current detector being used.
No Audio	1. Ensure that the AUD ON-OFF switch is in the ON position. 2. Remove the instrument housing and check the connection between the circuit board and the speaker. Plug in the two-pin connector if necessary.

Section

8

Technical Theory of Operation

Input

Detector pulses are coupled from the detector through C57 to emitter follower Q96. R83, 89 provide bias. R137 protects Q96 from input shorts. R27 couples the detector to the high-voltage supply.

Amplifier

A self-biased amplifier provides gain in proportion to R63 divided by R70. Transistor (pin 6 of U1) provides amplification. Pin 12, 15 of U1 are coupled as current mirror to provide a load for pin 6 of U1. The output self-biases to 2 Vbe (approximately 1.4 V) 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.

Discriminator

Comparator U2 provides discrimination. The discriminator is set by the DIS (discriminator) control located on the front panel, coupled to pin 3 of U2. These pulses are coupled to pin 5 of U3 for meter drive and pin 12 of U3 for audio.

Audio

Discriminator pulses are coupled to univibrator pin 12 of U3. Front-panel audio ON-OFF selector controls the reset at pin 13 of U4. When ON, pulses from pin 10 of U3 turns on oscillator U5, which drives the can mounted unimorph through Q149 and T136. Speaker tone is set by R84, C112; duration by R86.

Digital Analog Converter

Pin 12, 15 of U4 are coupled as a current mirror. For each pulse of current through R72, and equal current is delivered to C105. This charge is drained off by R74. The voltage across C105 is proportional to the incoming count rate.

Scale Ranging

Detector pulses from the discriminator are coupled to univibrator pin 5 of U3. For each scale, the pulse width of pin 6 of U3 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 C105 by one count on the X1 range as 1000 counts on X1K range.

Meter Drive

The meter is driven by the emitter to Q6, coupled as a voltage follower in conjunction with pin 1 of U6. For ratemeter drive, the meter is coupled to C105 at P1 15.

For high voltage, the meter is coupled to R132 at P1 11.

For battery test, the voltage follower is bypassed and the meter movement is directly coupled to the battery through R150.

Meter Compensation

When the unit is provided with a high torque meter movement, with 1.2 V drive, a temperature compensation package may be located at the meter, internal or external.

Fast / Slow Time Constant

For slow time constant, C104 is switched from the output of the meter drive to parallel C105.

Low Voltage Supply

Battery voltage is coupled to U7 and associated components (a switching regulator) to provide 5 V at pin 5 to power all logic circuits. Unregulated battery voltage is used to power the meter drive (Q6) and the high voltage blocking oscillator Q145.

Low Voltage Reference

U101 provides a 1.22 V precision reference for HV supply. This unit also biases Q96.

High Voltage Supply

High voltage is developed by blocking oscillator Q145-T165 and rectified by voltage multiplier CR166, 167, 169, and 175. Output voltage increases as current through Q44 increases, with maximum output voltage with Q44 saturated.

High voltage is coupled back through R47, R90 to opamp pin 6 of U6. R147 completes the high-voltage circuit-to-ground. High-voltage output is set by front-panel control HV, which sets bias of pin 5 of U6. During stable operation, the voltage at pin 6 of U6 will equal the voltage at pin 5 of U6. Pin 7 of U6 will cause conduction of Q44 to increase or decrease until the high voltage seeks a level for stability.

Section

9

Recycling

Ludlum Measurements, Inc. supports the recycling of the electronics products it produces for the purpose of protecting the environment and to comply with all regional, national, and international agencies that promote economically and environmentally sustainable recycling systems. To this end, Ludlum Measurements, Inc. strives to supply the consumer of its goods with information regarding reuse and recycling of the many different types of materials used in its products. With many different agencies – public and private – involved in this pursuit, it becomes evident that a myriad of methods can be used in the process of recycling. Therefore, Ludlum Measurements, Inc. does not suggest one particular method over another, but simply desires to inform its consumers of the range of recyclable materials present in its products, so that the user will have flexibility in following all local and federal laws.

The following types of recyclable materials are present in Ludlum Measurements, Inc. electronics products, and should be recycled separately. The list is not all-inclusive, nor does it suggest that all materials are present in each piece of equipment:

Batteries	Glass	Aluminum and Stainless Steel
Circuit Boards	Plastics	Liquid Crystal Display (LCD)

Ludlum Measurements, Inc. products that have been placed on the market after August 13, 2005 have been labeled with a symbol recognized internationally as the "crossed-out wheelie bin." This notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding; each material must be separated. The symbol will be placed near the AC receptacle, except for portable equipment where it will be placed on the battery lid.

The symbol appears as such: 

Section

10

Parts List

	Reference	Description	Part Number
Model 15 Neutron Counter with Detectors	UNIT	Completely Assembled Model 15 Neutron Counter With Detectors	48-1614
Main Board, Drawing 363 × 532	BOARD	Completely Assembled Main Circuit Board	5363-676
CAPACITORS	C38	0.0047µF, 3kV	04-5547
	C40-C41	0.0047µF, 3kV	04-5547
	C42	0.0056µF, 3kV	04-5522
	C50	100pF, 3kV	04-5532
	C56	100µF, 10V	04-5576
	C57	100pF, 3kV	04-5532
	C102	100µF, 10V	04-5576
	C103	10µF, 20V	04-5592
	C104	100µF, 10V	04-5576
	C105	22µF, 35V	04-5594
	C106	0.001µF, 100V	04-5519
	C109	0.01µF, 100V	04-5523
	C111	0.01F, 100V	04-5523
	C112	470pF, 100V	04-5555
	C113	0.01µF, 100V	04-5523
	C115	0.01µF, 100V	04-5523
	C117	47pF, 100V	04-5533
	C119	0.001µF, 100V	04-5519
	C121	330pF, 100V	04-5531
	C122	0.0047F, 3kV	04-5547
	C126	10µF, 20V	04-5592
	C134	100µF, 10V	04-5576
	C163	0.01µF, 100V	04-5523
	C170	0.1µF, 100V	04-5521
	C171	1µF, 35V	04-5575

	Reference	Description	Part Number
	C176	0.0047µF, 3kV	04-5547
	C178	0.1µF, 100V	04-5521
	C179	0.01µF, 100V	04-5523
TRANSISTORS	Q6	2N3904	05-5755
	Q15	MPS6534	05-5763
	Q44	2N3904	05-5755
	Q96	2N3904	05-5755
	Q145	MPSU51	05-5765
INTEGRATED CIRCUITS	U1	CA3096	06-6023
	U3	CD4098	06-6066
	U4	CA3096	06-6023
	U2	TLC372	06-6265
	U5	ICM7555	06-6136
	U6	TLC27M7IP	06-6248
	U7	MAX631	06-6249
	U101	LM385Z-1.2	05-5808
DIODES	CR94	1N4148	07-6272
	CR166-CR167	MR250-2	07-6266
	CR169	MR250-2	07-6266
	CR175	MR250-2	07-6266
THERMISTORS	R1-R2	150	07-6332
POTENTIOMETER / TRIMMER	R132	1 MEG HV ADJ.	09-6814
RESISTORS	R3	634 OHM	12-7808
	R18	1k	10-7009
	R27	1 MEG	10-7028
	R28	4.7 MEG	10-7030
	R36	1 MEG	10-7028
	R46	10k	10-7016
	R47-R48	1 G	12-7686
	R63	82k	10-7022
	R64	1k	10-7009
	R65	10k	10-7016
	R66	1k	10-7009
	R68	8.2k	10-7015

	Reference	Description	Part Number
	R70	4.7k	10-7014
	R72	10K	10-7016
	R74	82k	10-7022
	R75	33k	10-7019
	R76	100 OHM	10-7004
	R77	2.2k	10-7012
	R78	22k	10-7070
	R79	100k	10-7023
	R81	10k	10-7016
	R83	100k	10-7023
	R84	470k	10-7026
	R86	2.7 MEG	10-7029
	R87	10k	10-7016
	R89-R90	100k	10-7023
	R91	4.7k	10-7014
	R128	100k	10-7023
	R137	10k	10-7016
	R138	1 MEG	10-7028
	R147	SAT (TYP. 432k)	12-7689
	R150	2.37k	12-7648
	R159	10k	10-7016
	R172	47k	10-7020
	R177	200 OHM	10-7006
CONNECTORS	P1	CONN-1-640456-6 MTA100	13-8134
	P2	CONN-640456-2 MTA100	13-8073
	8EA.	CLOVERLEAF RECEPTACLE	18-8771
INDUCTOR	L13	470UHY	21-9600
TRANSFORMER	T165	L8050	40-0902
Calibration Board, Drawing 363 × 585	BOARD	Completely Assembled Calibration Board	5363-735
CAPACITORS	C1	0.047µF, 100V	04-5565
	C2	0.0047µF, 100V	04-5570

	Reference	Description	Part Number
POTENTIOMETERS	R1	1 MEG, ×1	09-6814
	R2	1 MEG, ×10	09-6814
	R3	1 MEG, ×100	09-6814
	R4	100k, × 1000	09-6813
	R5	100k, HV NEUTRON	09-6813
	R6	100k, HV BETA/GAMA	09-6813
	R7	100k, DISCRIMINATOR (DIS)	09-6813
RESISTORS	R8	47k	10-7020
	R9	1k	12-7750
RESISTOR NETWORK	RN1	10k SIP 8P	12-7720
CONNECTORS	P3	CONN-640456-6	
		MTA100	13-8095
	P4	CONN-640456-4	
		MTA100	13-8088
Wiring Diagram, Drawing 363 × 587	J1	CONN-1-640442-6	13-8187
CONNECTORS	J2	CONN-640442-2	
		MTA100	13-8178
	J3	CONN-640442-6	
		MTA100	13-8171
	J4	CONN-640442-4	
		MTA100	13-8170
	J5	RECPT-UG706/U	
		SCREW IN "C"	13-7751
AUDIO	DS1	UNIMORPH, TEC-3526-PU	21-9251
BATTERIES	B1-B2	"D" CELL BATTERY	21-9313
SWITCHES	S1	PA-600-210	08-6501
	S2	#923 SWTCHCRFT	08-6518
	S3	30-1-PB	08-6517
	S4-S6	7101-SYZ-QE	08-6511
METER	M1	PORT BEZEL W/	
		MVMNT ASSY	4363-188

	Reference	Description	Part Number
MISCELLANEOUS	*	METER MOVEMENT (1mA)	15-8030
	*	PORT LATCH KIT W/O BATT. LID	4363-349
	*	PORT HANDLE (ROLLED) W/SCREWS	7363-139
	*	PORT HANDLE FOR CLIP W/SCREWS	7363-203
	*	REPLACEMENT CABLE (STD 39 inch)	40-1004
	*	CLIP (44-3 TYPE) W/SCREWS	7002-026-01
	*	CLIP (44-7 TYPE) W/SCREWS	7010-007-01
	*	CLIP (44-6 TYPE) W/SCREWS	7010-008-01
DETECTORS	*	MODEL 44-7 END WINDOW GM PROBE	47-1536
	*	MODEL 15 MODERATOR W/ 42-14H NEUTRON PROBE	47-1575

Section

11

Drawings and Diagrams

MAIN CIRCUIT BOARD, Drawing 363 × 532

MAIN CIRCUIT BOARD LAYOUT, Drawing 363 × 533

CALIBRATION BOARD, Drawing 363 × 585

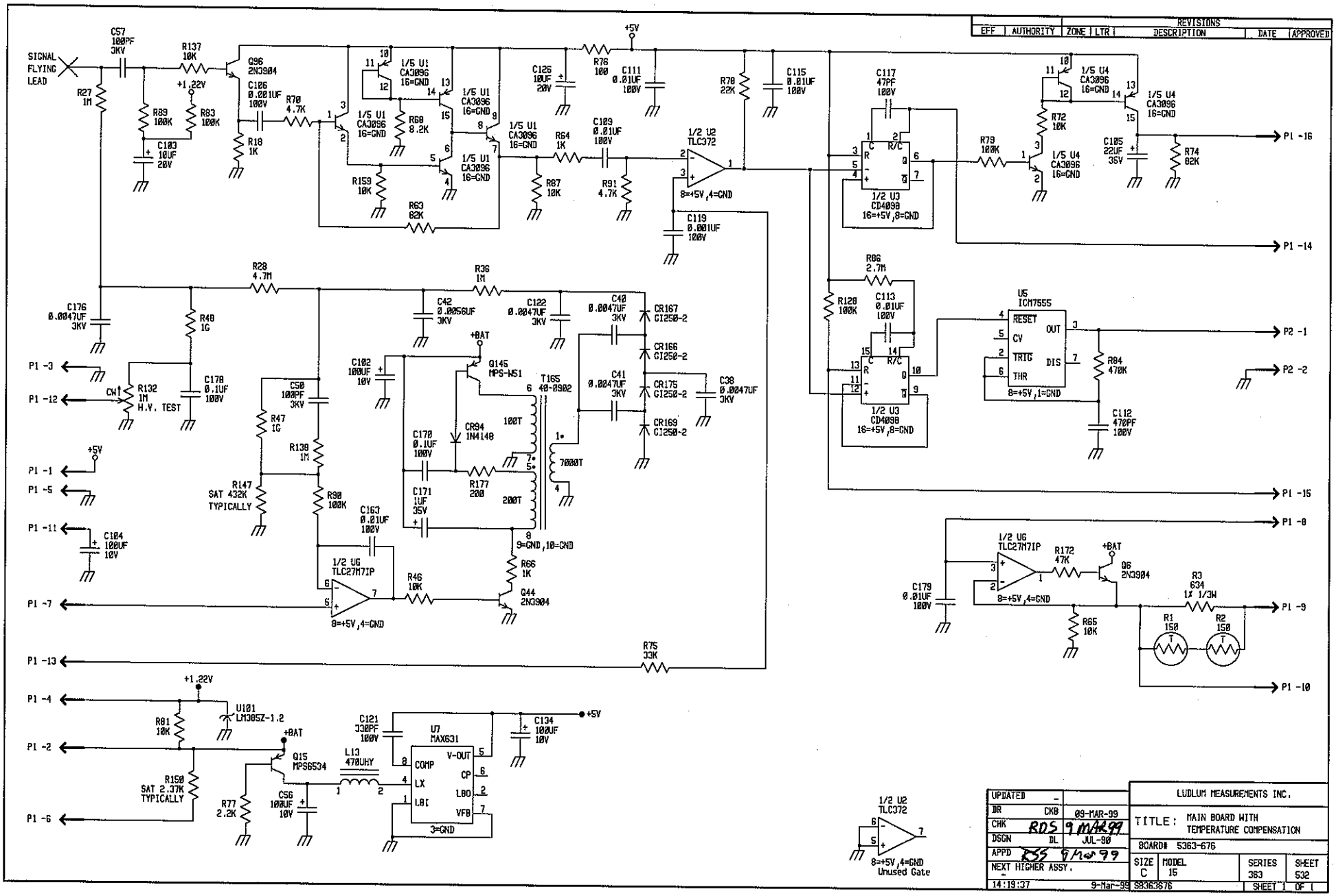
CALIBRATION BOARD LAYOUT, Drawing 363 × 586 (2 sheets)

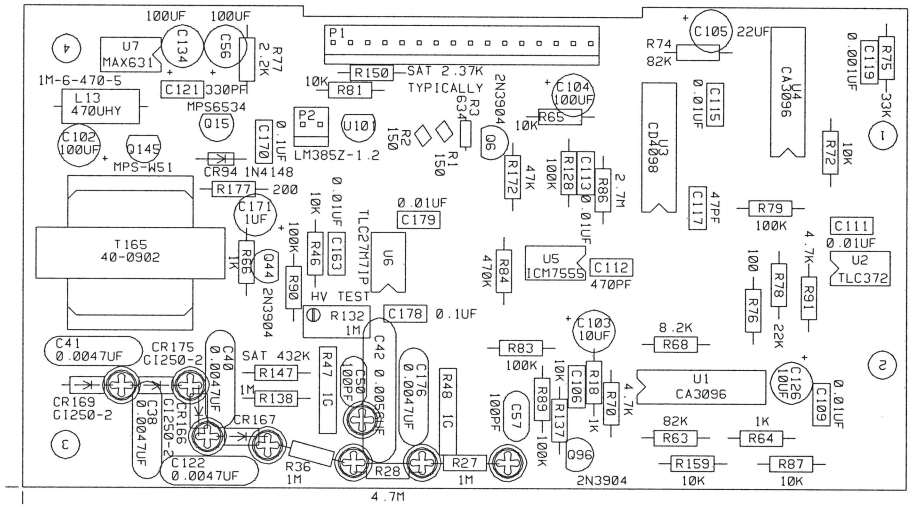
WIRING DIAGRAM, Drawing 363 × 587

MODEL 42-14H DETECTOR ASSEMBLY, Drawing 204 × 16

MODEL 44-7 DETECTOR ASSEMBLY, Drawing 2 × 157

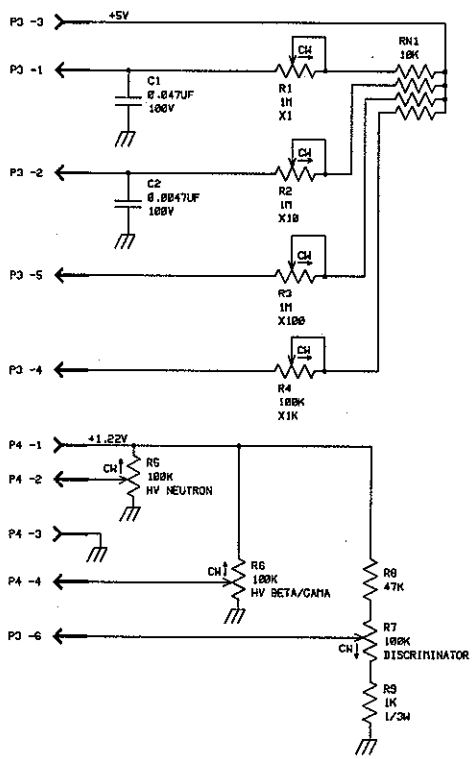
MODEL 44-7 ENERGY RESPONSE CURVE


REVISIONS
EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED
SIGNAL FLYING LEAD
C57 100PF 3KV
R137 10K
Q96 2N3904
C106 0.001UF 100V
R70 4.7K
R27 1M
R89 100K
R83 100K
+1.22V
C103 10UF 20V
R18 1K
1/5 U1 CA3096 16=GND
R88 8.2K
R159 10K
R63 82K
C126 10UF 20V
+5V
R76 100
C111 0.01UF 100V
R78 22K
C115 0.01UF 100V
C109 0.01UF 100V
R64 1K
R87 10K
R91 4.7K
1/2 U2 TLC372
8=+5V,4=GND
C119 0.001UF 100V
C117 47PF 100V
1/2 U3 CD4098 16=+5V,8=GND
R79 100K
1/5 U4 CA3096 16=GND
R72 10K
C105 22UF 35V
R74 82K
P1 -16
P1 -14
R28 4.7M
R36 1M
C176 0.0047UF 3KV
R48 1G
C42 0.0056UF 3KV
C122 0.0047UF 3KV
C40 0.0047UF 3KV
CR167 GI250-2
CR166 GI250-2
CR175 GI250-2
CR169 GI250-2
C41 0.0047UF 3KV
C38 0.0047UF 3KV
+BAT
Q145 MPS-H51
C102 100UF 10V
T165 40-0902
100T
7000T
200T
9=GND,10=GND
P1 -3
P1 -12
CW
R132 1M H.V. TEST
C178 0.1UF 100V
C50 100PF 3KV
R47 1G
R138 1M
C170 0.1UF 100V
CR94 1N4148
R177 200
C171 1UF 35V
R147 SAT 432K TYPICALLY
R90 100K
C163 0.01UF 100V
+5V
P1 -1
P1 -5
P1 -11
C104 100UF 10V
1/2 U6 TLC27M7IP
R46 10K
R66 1K
Q44 2N3904
P1 -7
8=+5V,4=GND
R86 2.7M
R128 100K
C113 0.01UF 100V
U5 ICM7555
RESET
CV
TRIG
THR
OUT
DIS
8=+5V,1=GND
R84 470K
C112 470PF 100V
P2 -1
P2 -2
P1 -15
P1 -8
1/2 U6 TLC27M7IP
R172 47K
+BAT
Q6 2N3904
C179 0.01UF 100V
R65 10K
R3 634 1% 1/3W
R1 150
R2 150
P1 -9
P1 -10
R75 33K
P1 -13
+1.22V
P1 -4
P1 -2
P1 -6
U101 LM385Z-1.2
R81 10K
Q15 MPS6534
R150 SAT 2.37K TYPICALLY
R77 2.2K
C56 100UF 10V
C121 330PF 100V
L13 470UHY
U7 MAX631
COMP
LX
LBI
V-OUT
CP
LBO
VFB
3=GND
C134 100UF 10V
1/2 U2 TLC372
8=+5V,4=GND
Unused Gate
UPDATED
DR CKD 09-MAR-99
CHK RDS 9 MAR 99
DSGN DL JUL-90
APPD RDS 9/Mar 99
NEXT HIGHER ASSY.
14:19:37 9-Mar-99
LUDLUM MEASUREMENTS INC.
TITLE: MAIN BOARD WITH TEMPERATURE COMPENSATION
BOARD# 5363-676
SIZE C | MODEL 15 | SERIES 363 | SHEET 532
S9363676 | SHEET 1 OF 1

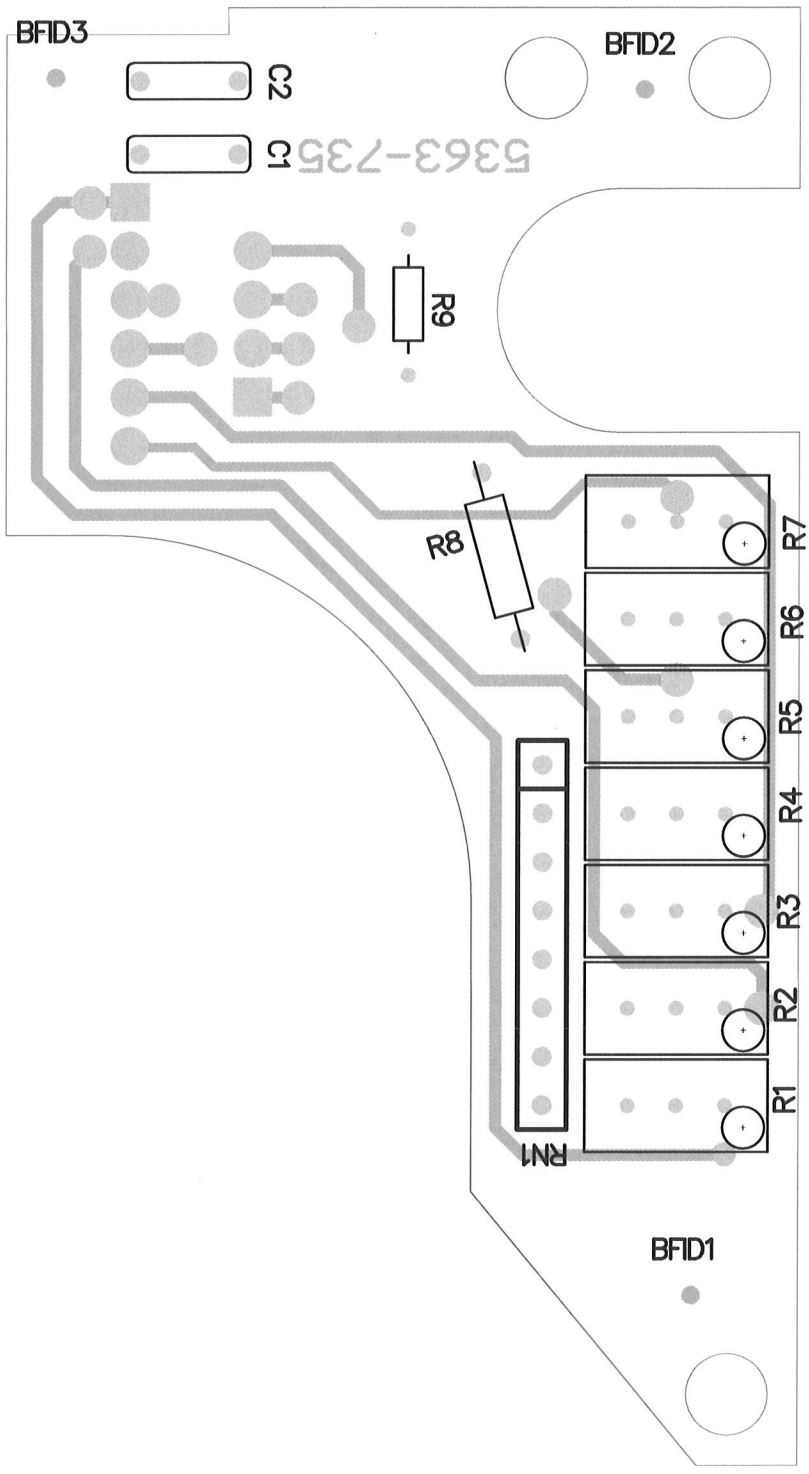


LUDLUM MEASUREMENTS INC. SWEETWATER, TX.			
DR CKB	08-MAR-99	TITLE: MAIN BOARD W/TEMP. COMP.	
CHK		BOARD: 5363-676	
DSGN DL	JUL-90	MODEL: 15	
APP BS 3/30/01		FILENAME: BS363676	
		11:45:55	13-Nov-01
COMPONENT	SOLDER	REVISION	SERIES / SHEET
OUTLINE	OUTLINE	1.0	363 / 533

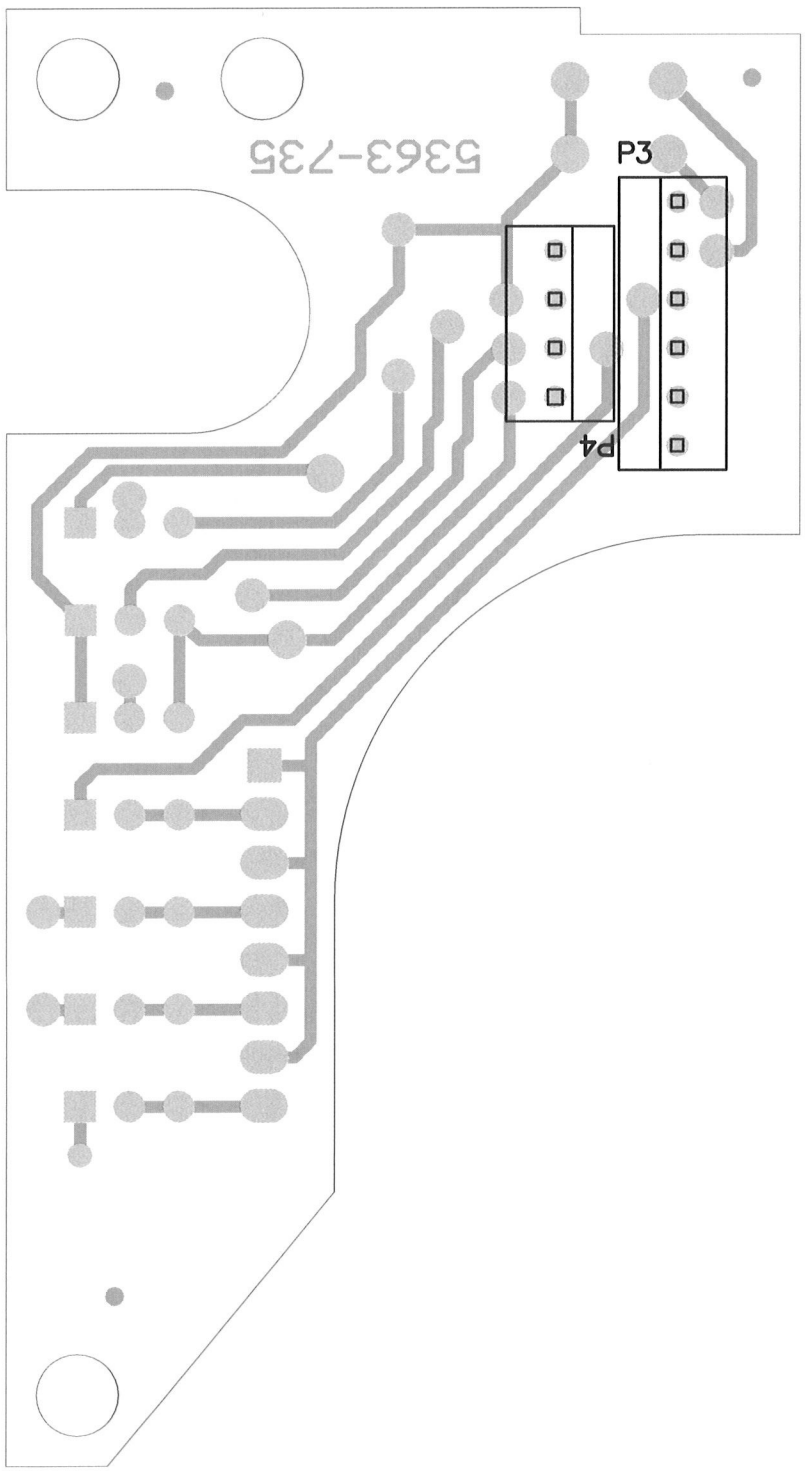
REVISIONS						
EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED



UPDATED -	/ /	LUDLUM MEASUREMENTS INC.			
DR CKD	09/22/92	TITLE: CALIBRATION BOARD			
CHK RW.	11/6/92	BOARD# 5383-735			
DSGN -	/ /				
APPD JGW	11/6/92	SIZE D	MODEL 15	SERIES 383	SHEET 695
NEXT HIGHER ASSY. -					
11:24:27	23-Sep-92	SB383735		SHEET 1	OF 1

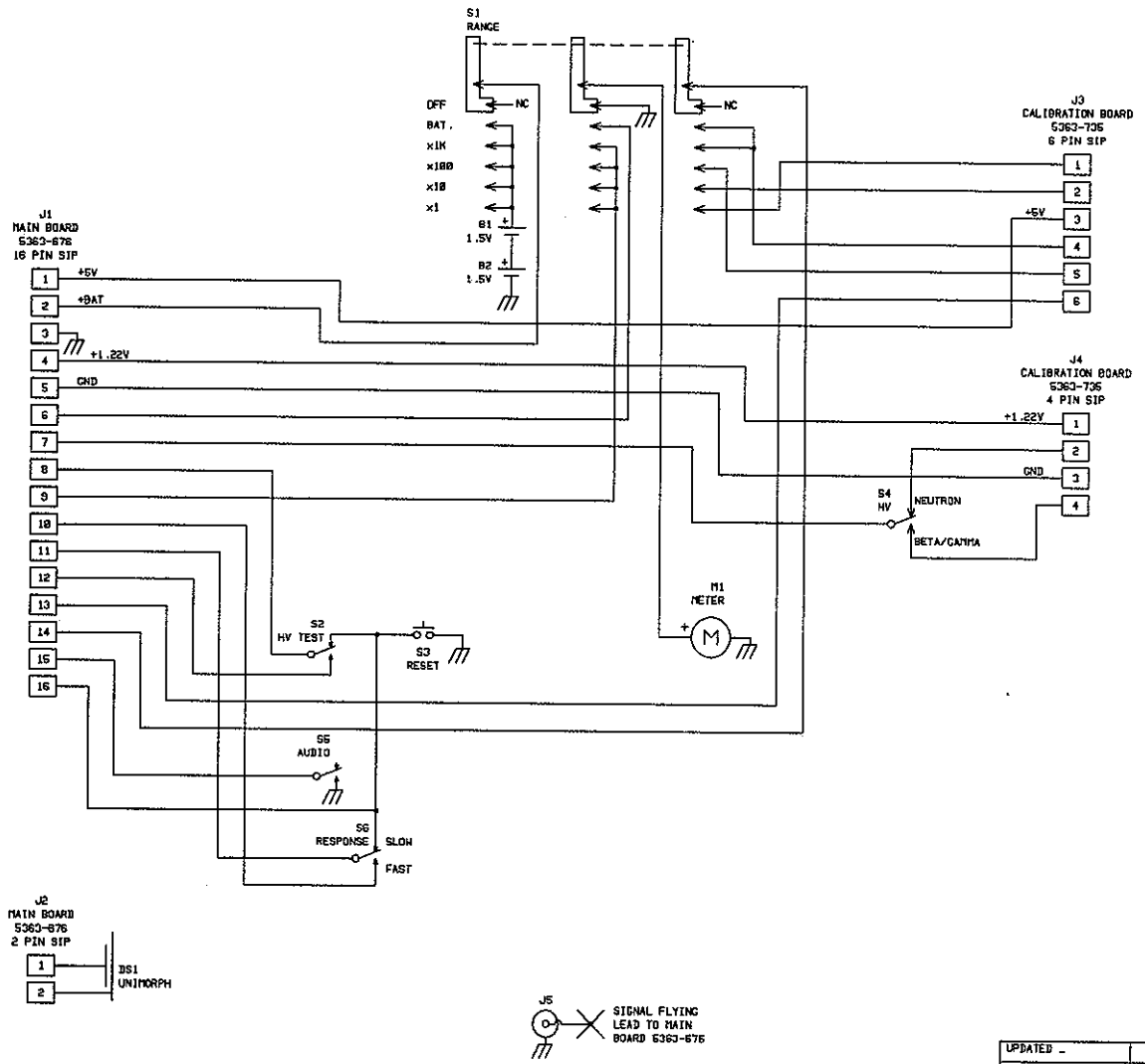


LUDLUM MEASUREMENTS, INC.	PO Box 810 501 Oak Street Sweetwater, TX 79556 U.S.A. 1-800-622-0828		
Title: CALIBRATION BOARD			
Drawn: CKB	09/23/92	**Model:** 15	
Design: Initials	MM/DD/YY	**Board#:** 5363-735	
Approve: RMS	24NOV14	**Rev:** 2	
PCBA Drawing		**SCALE: 1.05**	**Series** 363 / **Sheet** 586
Print Date: 11/20/2014 1:13:08 PM		Top Overlay	
W:\Projects\LM\M 15\5363-735\Rev2\363735R2_Assy.PcbDoc			



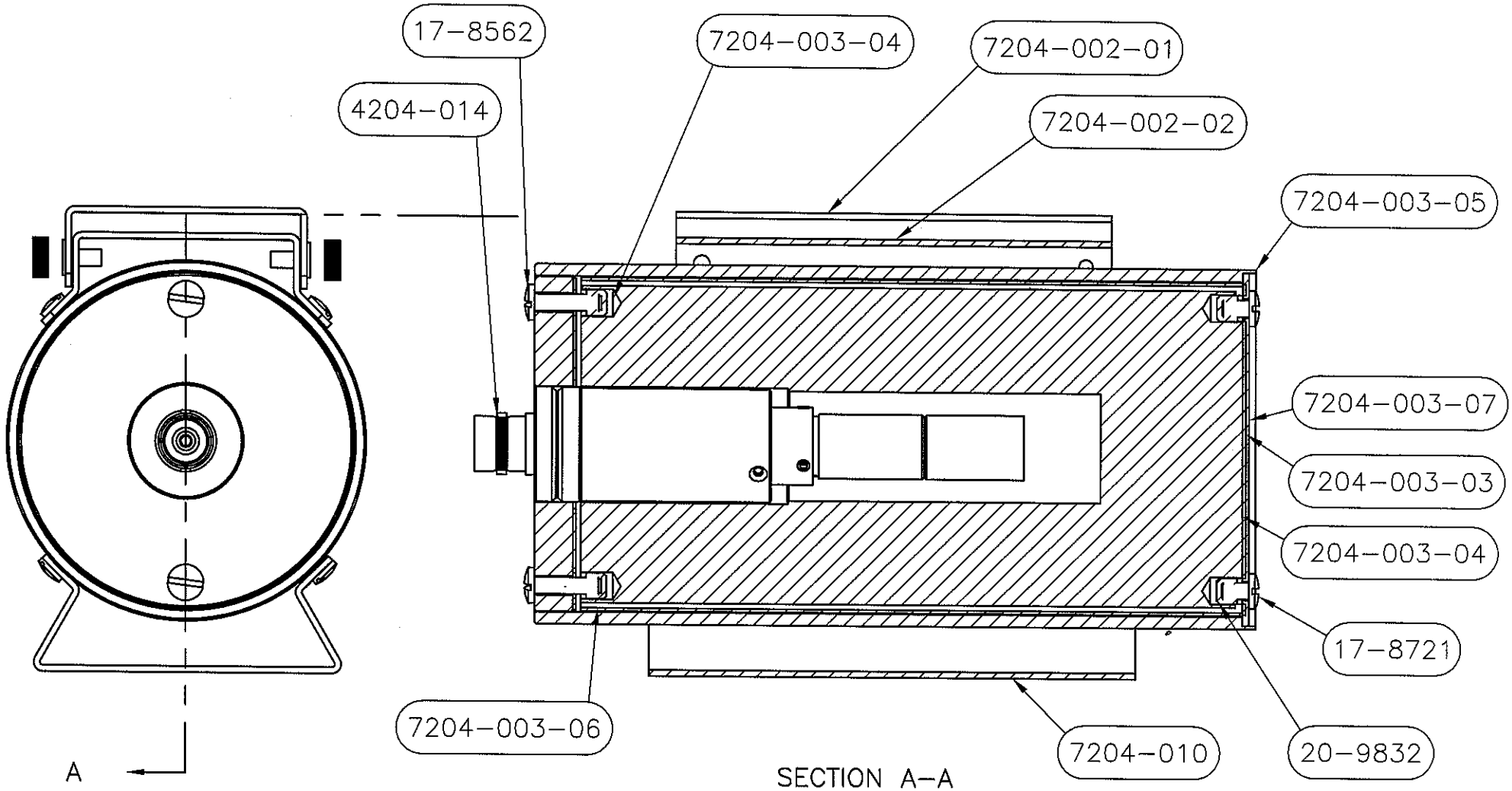
LUDLUM MEASUREMENTS, INC.		PO Box 810 501 Oak Street Sweetwater, TX 79556 U.S.A. 1-800-622-0828		
Title: CALIBRATION BOARD				
Drawn: CKB	09/23/92	**Model:** 15		
Design: Initials	MM/DD/YY	**Board#:** 5363-735		
Approve: RDS	24Nov14	**Rev:** 2		
PCBA Drawing		**SCALE: 1.05**	**Series** 363	**Sheet** 586
Print Date: 11/20/2014 1:13:12 PM		Bottom Overlay		
W:\Projects\LM\M 15\5363-735\Rev2\363735R2_Assy.PcbDoc				

REVISIONS						
EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED



UPDATED _	/ /	LUDLUM MEASUREMENTS INC.	
DR CKD	10/14/92	TITLE: WIRING DIAGRAM	
CHK P.W.	11/6/92	BOARD# 363-736	
DSGN DL	07/90		
APPD JGW	11/6/92	SIZE D / MODEL 16 / SERIES 363 / SHEET 687	
NEXT HIGHER ASSY. -			
13:51:15	6-Nov-92	S8363736	SHEET 1 OF 1

REV #	ALTERATIONS	DATE	BY
1	VALID	11/28/06	PW



DWN	DATE	CHK	DATE	APP	DATE
PW	11/28/06				

PART NUM: 4204-016 SCALE: FULL ☐ OTHER

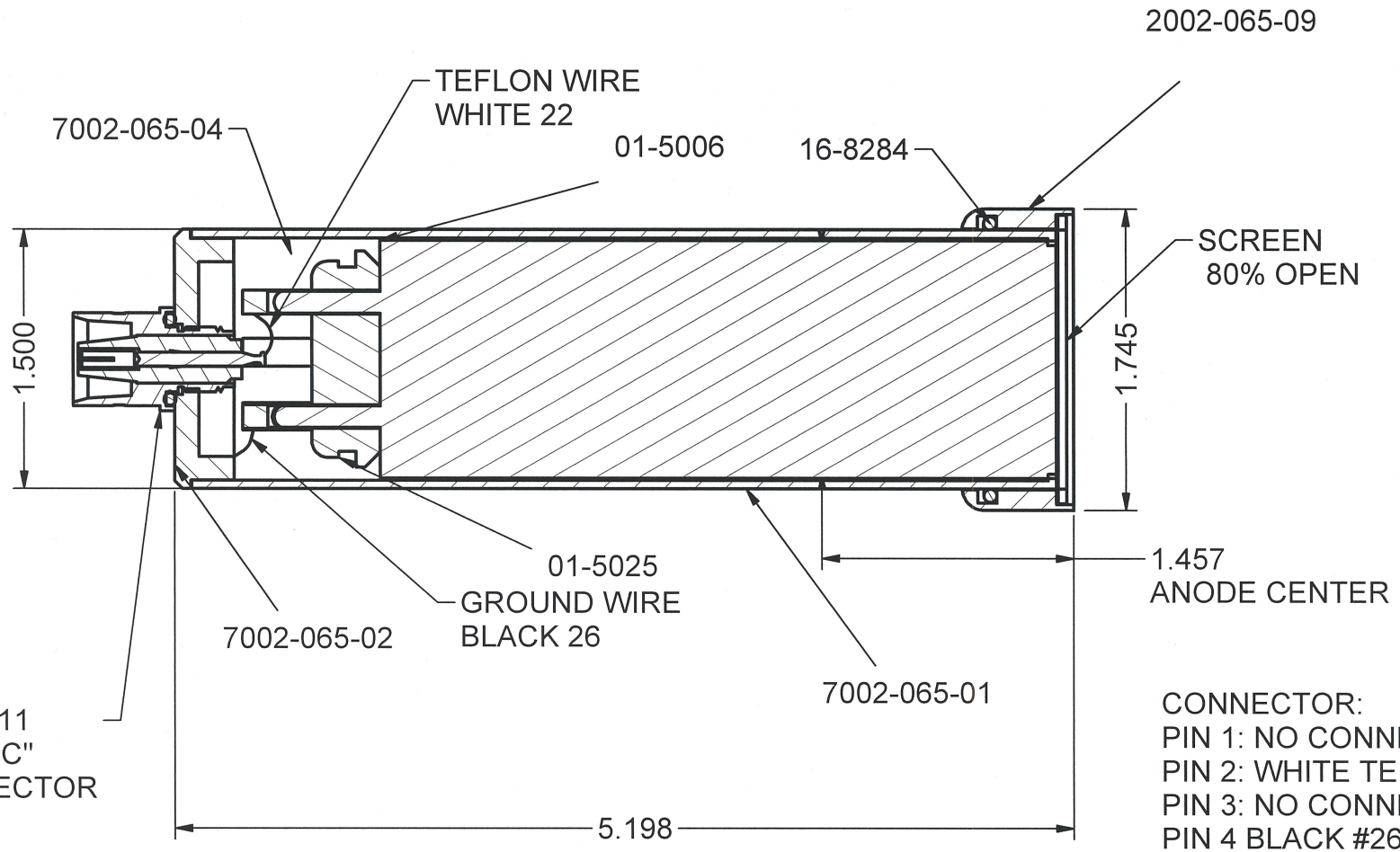
TITLE M 42-14 HE³ DETECTOR ASSEMBLY

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

SERIES 204

SHEET 16

REVISION HISTORY			
REV	DESCRIPTION	DATE	BY
1	VALID	2-15-95	CLG
2	UPDATED	7/9/12	TMM



CONNECTOR:
PIN 1: NO CONNECTION
PIN 2: WHITE TEFLON #22 WIRE
PIN 3: NO CONNECTION
PIN 4 BLACK #26 WIRE

DWN	DATE	CHK	DATE	APP	DATE
TMM	7/10/12			T.W.	7-10-2012

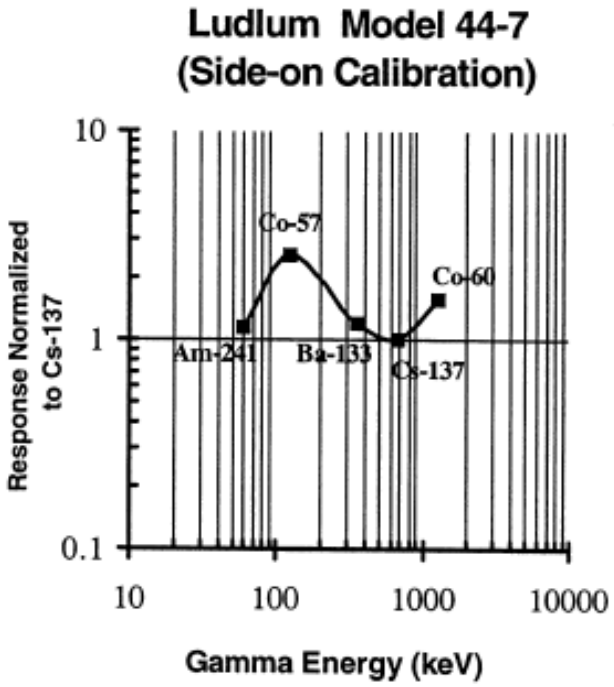
DWG NUM: 4002-212 SCALE: 1:1

TITLE M 44-7 ASSEMBLY VIEW

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

SERIES 2 SHEET 157

VF


Ludlum Model 44-7
(Side-on Calibration)
Response Normalized to Cs-137
10
1
0.1
Co-57
Co-60
Am-241
Ba-133
Cs-137
10
100
1000
10000
Gamma Energy (keV)