Model 276L
Low-Power Photomultiplier Base
Operating and Service Manual

Printed in U.S.A.

ORTEC® Part No. 762870
Manual Revision C

0702

Advanced Measurement Technology, Inc.

a/k/a/ ORTEC®, a subsidiary of AMETEK®, Inc.

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Quality Control

Before being approved for shipment, each ORTEC instrument must pass a stringent set of quality control tests designed to expose any flaws in materials or workmanship. Permanent records of these tests are maintained for use in warranty repair and as a source of statistical information for design improvements.

Repair Service

If it becomes necessary to return this instrument for repair, it is essential that Customer Services be contacted in advance of its return so that a Return Authorization Number can be assigned to the unit. Also, ORTEC must be informed, either in writing, by telephone [(865) 482-4411] or by facsimile transmission [(865) 483-2133], of the nature of the fault of the instrument being returned and of the model, serial, and revision ("Rev" on rear panel) numbers. Failure to do so may cause unnecessary delays in getting the unit repaired. The ORTEC standard procedure requires that instruments returned for repair pass the same quality control tests that are used for new-production instruments. Instruments that are returned should be packed so that they will withstand normal transit handling and must be shipped PREPAID via Air Parcel Post or United Parcel Service to the designated ORTEC repair center. The address label and the package should include the Return Authorization Number assigned. Instruments being returned that are damaged in transit due to inadequate packing will be repaired at the sender's expense, and it will be the sender's responsibility to make claim with the shipper. Instruments not in warranty should follow the same procedure and ORTEC will provide a quotation.

Damage in Transit

Shipments should be examined immediately upon receipt for evidence of external or concealed damage. The carrier making delivery should be notified immediately of any such damage, since the carrier is normally liable for damage in shipment. Packing materials, waybills, and other such documentation should be preserved in order to establish claims. After such notification to the carrier, please notify ORTEC of the circumstances so that assistance can be provided in making damage claims and in providing replacement equipment, if necessary.

CONTENTS

SAFETY WARNINGS AND CLEANING INSTRUCTIONS

DANGER Opening the cover of this instrument is likely to expose dangerous voltages. Disconnect the instrument from all voltage sources while it is being opened.

WARNING Using this instrument in a manner not specified by the manufacturer may impair the protection provided by the instrument.

Cleaning Instructions

To clean the instrument exterior:

- Unplug the instrument from the ac power supply.
- Remove loose dust on the outside of the instrument with a lint-free cloth.
- Remove remaining dirt with a lint-free cloth dampened in a general-purpose detergent and water solution. Do not use abrasive cleaners.

CAUTION To prevent moisture inside of the instrument during external cleaning, use only enough liquid to dampen the cloth or applicator.

- Allow the instrument to dry completely before reconnecting it to the power source.

SAFETY INSTRUCTIONS AND SYMBOLS

This manual contains up to three levels of safety instructions that must be observed in order to avoid personal injury and/or damage to equipment or other property. These are:

DANGER Indicates a hazard that could result in death or serious bodily harm if the safety instruction is not observed.

WARNING Indicates a hazard that could result in bodily harm if the safety instruction is not observed.

CAUTION Indicates a hazard that could result in property damage if the safety instruction is not observed.

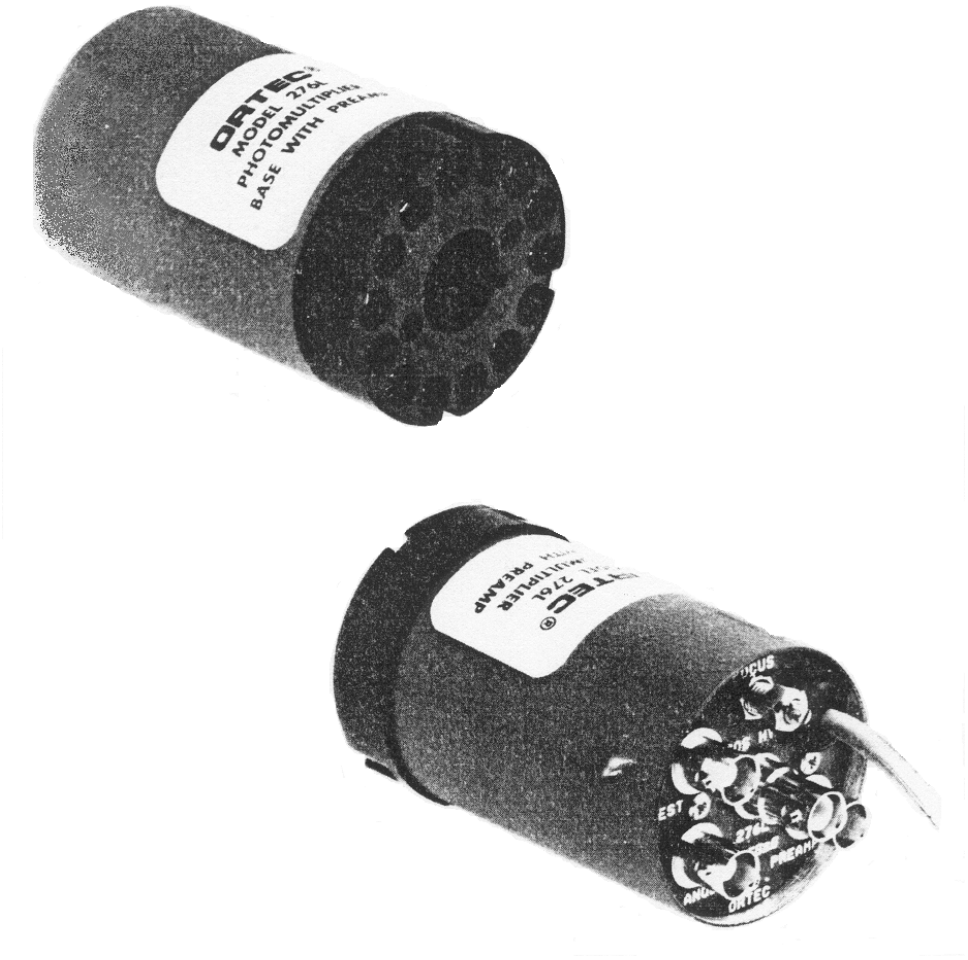
Please read all safety instructions carefully and make sure you understand them fully before attempting to use this product.

In addition, the following symbol may appear on the product:

ATTENTION – Refer to Manual

DANGER – High Voltage

Please read all safety instructions carefully and make sure you understand them fully before attempting to use this product.



MODEL 276L PHOTOMULTILIPER BASE

ORTEC MODEL 673 SPECTROSCOPY AMPLIFIER AND GATED INTEGRATOR

1. DESCRIPTION

The ORTEC Model 276L Low-Power Photomultiplier Tube Base and Preamplifier incorporates an integral low-noise preamplifier, a PMT base with low-power voltage divider network, and a focus control for optimum performance in scintillator detector applications. The unit is ideally suited for use with NaI(Tl) detectors and the ORTEC NOMAD™ Portable Spectrometer System.

The 276L provides two outputs: the preamplifier output for energy analysis, and the anode output for either timing or auxiliary energy analysis. The preamplifier is dc-coupled to simplify pole-zero cancellation in the main amplifier. A Test input accepts the output of a pulse generator to calibrate and test the preamplifier and the following system. The Model 276L has a diode protection network to prevent damage to the internal transistors due to sudden application or removal of high voltage to the unit. A simple internal modification in the unit allows the gain to be adjusted to any value desired by the user. The Model 276L is powered from the ORTEC NOMAD™ or any ORTEC main amplifier or preamplifier power supply.

The Model 276L is directly compatible with many commercially available integrated NaI-PMT assemblies including:

ORTEC Model 905-1, -2, -3, -4 NaI(Tl) Scintillation Detector Assemblies;

Bicron Model 2M2 and 3M3 Monoline Spectrometers;

Harshaw Model S288 and S332 Integral Line Assemblies;

Teledyne S-38-1 and S-1212-1 Integral Assemblies.

Also, the Model .276L is directly compatible with 10-stage PMTs that fit standard 14-pin sockets including:

Hamamatsu PM55, R208, R550, R594, R877, R878, R1507, R1512, R1513, R1612, R1791, R1836, R1847-07, R1848-07, and 7696.

Burle (formerly RCA) 4900, 5319, 6342A, 6655A, S83006E, S83013F, S83019F, S83020F, S83021E, S83022F, and S83025F.

Phillips XP2202B, XP2203B, XP2254B, XP2312S, and XP2412B.

The Model 276L is also compatible with other 10-stage tubes not listed above. Compatibility may be determined by comparison with those listed.

2. SPECIFICATIONS

2.1. PERFORMANCE

PREAMPLIFIER

Integral Nonlinearity <±0.02%, 0 to+10V.

Temperature Instability <±0.005%/°C, 0 to50°C.

Output Rise Time <100 ns for test input or fast scintillator.

Output Fall Time Time constant of 50 μs.

Output Noise <50 μV rms with ORTEC NOMAD Portable Spectroscopy System or with ORTEC main amplifier such as Model 672 and time constant of 1 μs.

Conversion Gain Nominally 5 μV/eV with 2- by 2-inch NaI(Tl) crystal and PMT gain of 10^6; the typical output for a 551-keV gamma-ray will be -50 mV.

Saturation Level + 10 V into an open circuit; + 5 V into 93-Ω load.

VOLTAGE DIVIDER Resistor-divider connected to 10-stage PMT base. Total resistance 5.6 MΩ resulting in bleeder current of 200 µA with typical high voltage of 1 kV. The distribution is linear to all stages with the focus adjustment on the grid.

2.2. CONTROL

FOCUS Single-turn locking potentiometer on panel for external adjustment of PMT grid potential.

2.3. INPUTS

POSHV SHV connector, AMP54494-2, for distribution of positive high voltage to PMT base; +2000 V maximum.

TEST BNC connector, UG-1094/U, accepts pulses from an ORTEC pulse generator for testing and calibration.

SIGNAL Preamplifier input is connected internally to dynode 10.

POWER Captive 4m (12 ft.) power cable terminated in Amphenol 17-20090 connector accepts preamplifier operating power; compatible with the ORTEC NOMAD Portable Spectrometer and with all ORTEC main amplifiers and the Model 4002P Portable Power Supply.

PM SOCKET JEDEC 614-38, Amphenol 59-417.

2.4. OUTPUTS

PREAMP BNC connector, UG-1094/U, furnishes preamplifier positive output pulse to the ORTEC NOMAD Portable Spectrometer or any ORTEC main shaping amplifier for linear energy analysis; Z_o = 93 Ω, dc-coupled.

ANODE BNC connector, UG-1094/U, furnishes negative anode output pulse for use for either timing or auxiliary energy analysis; Z_o = 1 kΩ, ac-coupled.

2.5. ELECTRICAL AND MECHANICAL

POWER REQUIRED For preamplifier, +24 V, 16 mA; -24 V, 16 mA; for PMT base, +2000 V maximum (use rated voltage for the tube that is installed).

WEIGHT
Net 0.65 kg (1.5 lb).
Shipping 1.3 kg (3.0 lb).

DIMENSIONS 5.58 cm (2.2 in.) diameter x 10.1 cm (4 in.) long; equipped with 40-0-m (12-ft.) captive power cable.

2.6. ORDERING INFORMATION

Model No.	Description
276L	Low-Power Photomultiplier Base with Preamplifier
C-36-12	RG-59A/U 75-Ω cable with two SHV female plugs, 12-ft length
C-24-12	RG-62A/U 93-Ω cable with two BNC male plugs, 12-ft length
T50	50-Ω Terminator, BNC

3. INSTALLATION

3.1. DETECTOR MOUNTING

For many applications, the Model 276L is used with an integral assembly consisting of a NaI(TI) scintillation detector mounted on a photomultiplier tube housed in a light-tight enclosure. Such assemblies are available from a variety of vendors (such as Bicron, Harshaw, and Teledyne) and can be obtained from ORTEC. For these integrated assemblies, simply mount the PMT into the base being careful not to stress the PMT connectors. Firmly press the PMT into the base to ensure a good contact.

For some applications it may be necessary to mount the scintillator to a PMT. Special care should be given to cleaning the surface of the PMT and the use of a high-quality light-coupling compound between the scintillator and the PMT face. The assembly must be made light tight for proper operation. Generally, an aluminum can is used to cover the scintillator and a good-quality black electrical tape is used to wrap the assembly covering the can and the PMT.

3.2. SYSTEM CONNECTION

Three cables must be connected between the Model 276L and the NOMAD (or main amplifier) for proper operation: the preamp power cable, the high voltage cable and the preamplifier output cable. In addition, a pulser can be connected to the TEST input for system calibration and the ANODE output can be connected to timing or auxiliary energy analysis equipment. Use high-quality coaxial cables, such as those listed in Section 2.6. Terminate the anode signal cable in its characteristic cable impedance.

For operation with the NOMAD, first ensure that the NOMAD high voltage is set for POSITIVE (Refer to the NOMAD Hardware Reference Manual). Turn the NOMAD Power Switch to the OFF position before connecting the 276L to the NOMAD. Plug the preamplifier power cable into the NOMAD PREAMP 9-pin D connector. Connect the 276L OUTPUT connector to the NOMAD Amplifier Input connector using a high-quality coaxial cable. Connect the 276L POS HV connector to the NOMAD HV Output connector using a high-quality, high-voltage coaxial cable. If the NOMAD high voltage Remote Shutdown internal jumper is in the ORTEC position, then a 0-, 50-, or 100-0 terminator should be connected to the NOMAD SD Input BNC connector. Alternatively, the NOMAD Remote Shutdown internal jumper can be changed from the ORTEC to the TTL position, where the terminator is not required.

For operation with ORTEC main amplifier and bias supply, first ensure that the high voltage is set for POSITIVE POLARITY. With the power supply OFF, connect the 276L preamp power cable to the amplifier PREAMP 9-pin D connector. Connect the 276L OUTPUT connector to the amplifier INPUT connector using a high-quality coaxial cable. Connect the 276L POS HV connector to the bias supply Output connector using a high-quality high-voltage coaxial cable.

If it is desired to test and calibrate the system, connect a pulser to the 276L TEST input. A 1-V test pulse should yield a 1-V pulse on the preamplifier OUTPUT. The test input is internally terminated in 93 Ω.

3.3. INITIAL ADJUSTMENTS

The only adjustment on the 276L is the Focus control, which optimizes the photocathode-first dynode electrical field.

1. Plug a PMT-Scintillator detector assembly into the 276L and ensure that it is light-tight. Connect the positive high-voltage supply.

2. Place a radiation source in the vicinity of the detector.

3. Observe the preamplifier output on a sensitive range of an oscilloscope and,slowly increase the high voltage.

4. If there is a large amount of unipolar "grass" (circuit noise), there is possibly a light leak. Cover the detector assembly with a black cloth to see whether the grass diminishes; if it does, the PMT was seeing the ambient light and should be rechecked for proper covering to eliminate the light leak.

5. With the high voltage at the desired level, observe the pulses that are radiation-induced scintillations and adjust the Focus control to obtain maximum pulse amplitude. This is the proper setting; lock the adjustment with the potentiometer lock nut.

4. OPERATION

Once the steps outlined in Section 3 are performed, Model 276L is ready for use. High voltage may be applied and adjusted for the appropriate gain associates with the specific application. The gain will vary by a factor of approximately 2 for each high-voltage change of 100 V. Normally, the PMT is operated at the lowest possible value of high voltage to prolong its lifetime.

5. CIRCUIT DESCRIPTION

Please refer to the Schematic Diagram, Drawing No. 767270, and the Printed Wiring Board Assembly, Drawing No. 466050, at the end of this manual.

5.1. CIRCUIT OPERATION

The divider string in this photomultiplier base is a linear resistance divider whose gain and signal quality has been carefully considered. The only control associated with this unit is the focus adjustment R3, which adjusts the input optics of the photomultiplier to achieve maximum gain.

The preamplifier section consists of a very low-noise, high-gain feedback operational amplif ier. The important characteristics of this amplifier are its very high-input impedance, its wide bandwidth, and its very low-output impedance. The feedback impedance consists of R23 and R24, and the closed loop gain of the voltage input becomes $V_{out}/V_{in} = [1 + (R_{23}/R_{24})]$, which is normally set to 5.

The photomultiplier charge output from the last dynode is dumped into the charge integrating capacitor C7. The voltage on this capacitor is sensed by the operational amplifier through the base of Q1. The discharge path of C7 is through R19 at a nominal time constant of 50 µs.

Q1, Q2, Q3, and Q4 form a high-input impedance low-noise differential Darlington pair. They are furnished with a constant current from Q8. The differential signal from the collector of Q1-Q4 is sensed and amplified by Q5. This signal propagates through R22 to the output emitter-follower Q6. The amplifier is dc-coupled to minimize the baseline shift due to count rate and to minimize the number of capacitors in the signal path which, in turn, minimizes overshoots and pile-up problems. Dl and D2 are protections diodes that are intended to clamp the input to positive or negative 24V in the event the high voltage is applied or released too quickly.

The output impedance of the operational amplified is <1Ω. R32 is a series termination resistor to match 93- and 100-Ω cables.

5.2. MODIFICATIONS

If the energy level, count rate, or other parameters are such that the preamplifier output is out of the dynamic range of usability, it is a simple procedure to change the integrating capacitor C7.

If the pulse amplitudes are excessive or the count rate shift is excessive, add a larger capacitor in parallel to C7 in the printed wiring board (PWB).

If the pulse amplitudes are too small to be usable, replace C7 with a smaller capacitor. If possible, us ia good-quality dipped mica or silver mica capacitor with a voltage rating of 50V or more.

If C7 is changed, it is recommended that R19 also be changed in order to maintain the decay time constant at ~50 µs, using

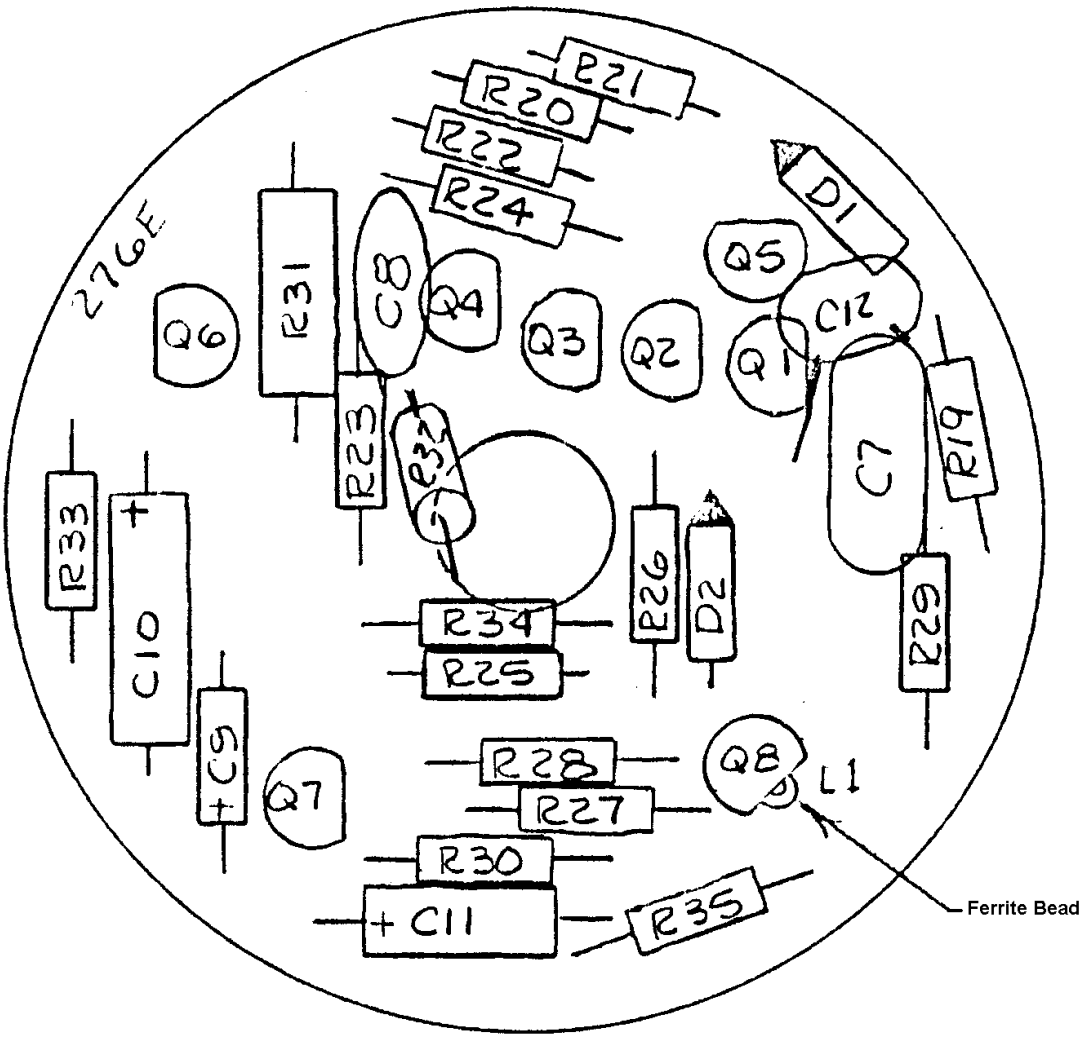
$$R19 \; + \; \frac{50 \; X \; 10^{-6} s}{C7(F)} \; (\Omega) \qquad (1)$$

Although there is no limit on the minimum value of R19 a practical maximum value is ~2 MΩ.

CAUTION

Before attempting to remove the case on this unit, remove the high voltage by disconnecting the cable to the SHV connector on the panel. DO NOT OPERATE WITH THE CASE REMOVED.

The anode is internally terminated in 1-kΩ impedance. If it is desired to feed this output to an integrating preamplified, the 1-kΩ resistor on the BNC (Rl8) must be replaced with a 1 - or 2-MΩ, 0.5-W resistor. With this larger value resistor, the anode and preamplifier pulse amplitude will be affected by the anode load; so care must be taken not to change the anode load during an experiment. A 2.2-MΩ resistor is furnished in parallel with R 18. For energy analysis, simply clip out the 1 -kΩ R18.



PMT BASE

6. MAINTENANCE

6.1. INSTRUMENT MAINTENANCE

The resistor divider string of this unit is composed only of passive components; the only maintenance to be expected is replacement of components that have failed because of age. Table 6.1 lists the approximate dynode voltages for comparative purposes. Almost all failures of the dynode string may be isolated by removing the PM tube and making these measurements. The ideal voltage values assume a voltmeter with infinite impedance. The measured voltage values were taken using a voltmeter with 10-MΩ input impedance.

The preamplifier operates as described in Section 5. Since the amplifier is a high, open-loop gain (~6000) operational amplifier with feedback via R23 and R24, failure of almost any component will cause the output to go to a dc level of ~±5V to ±24V.

Troubleshooting involves a careful analysis of the dc levels from Table 6.2. Replacement of the parts is not critical except that Q1-Q4 should be very high-gain (β or hfe) low-noise NPN transistors. R19, R23, and R24 should be precision metal film for low noise and good stability.

C7 should be a high-quality dipped mica or silver mica capacitor.

D1 and D2 have no role in the amplifier operation and are provided for circuit protection only. R19 X C7 product is the decay time constant. The 90% to 10% decay time in seconds should be ~2.2 X R19(Ω) X C7(F).

Table 6.1

HV = +1000V

PM Socket	Ideal Voltage	Measured Voltage*
1	127	121
2	214	198
3	301	273
4	388	347
5	476	422
6	563	500
7	650	581
8	737	668
9	825	765
10	912	720
11	999	816
12	NC	NC
13	0- + 127	0- + 121
14	Ground	Ground

Dynamic testing may be done with a pulser connected to the test input with the normal C_{test} of 100 pF and C7 of 500 pF the preamplifier output amplitude and the same polarity as the pulser input. The decay time should be ~110 µs, 90% to 10%. The rise time should be 80 to 100 ns.

Table 6.2. Preamplifier Voltages.

Power Cable	Nominal Volts	V O L T S (Min)	(Max)
Pin 7	+24	+23	+25
Pin 6	-24	-23	-25
Preamp			
Q1b	0	-0.05	+0.05
Q1e	-0.6	-0.4	-0.8
Q1c	+16.4	+15.0	+17.5
Q2e	-1.2	-0.7	-1.5
Q3b	-0.6	-0.4	-0.8
Q4b	0	-0.1	+0.1
Q4c	+4.0	+2.0	+5.0
Q5e	+17.0	+16.0	+18.0
Q6b	+0.6	0	+1.1
Q6e	0	+0.5	-0.5
Q6c	+20.0	+18.0	+22.0
Q7b	-12.0	-11.0	-13.0
Q7e	-12.6	-11.6	-13.6
Q8e	-12.6	-11.6	-13.6

6.2. FACTORY REPAIR

This instrument can be returned to the ORTEC factory for service and repair at a nominal cost. Our standard procedure for repair ensures the same quality control and checkout that are used for a new instrument. Always contact Customer Service at ORTEC, (865) 482-4411, or your local representative, before sending in an instrument for repair to obtain shipping instructions and so that the required Authorization Number can be assigned to the unit. Write this number on the address label and on the package to ensure prompt attention when it reaches the factory.