Calibrating Radioactive Monitors

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1. Introduction

This research will focus on the calibration of five radiation monitors. Two of the monitors are made by Eberline and both are ASP-2e models. Two of the other monitors are made by Technical Associates and are models TBM-3 and PUG-1AB. The last monitor is a Victoreen 190N. Each of the Technical Associates models has analog displays that read from 0 to 500 counts per minute. Both have x1, x10, and x100 settings while the PUG-1AB model also has a x1000 setting. The actual Geiger-Müller tube is on the bottom of these monitors unlike the Eberline and Victoreen models which have external Geiger-Müller detectors. The Eberline and Victoreen models also have digital outputs that show other information besides the radioactive counts. The Eberline models can be calibrated by a companion computer program and are connected to the computer using a 9-pin connection. Since both Eberline monitors are compatible with both probes, once one probe has been calibrated, its settings can be loaded onto either monitor. In previous years the monitors were sent to outside labs to be calibrated and this process took a number of months. Along with the time lost, the outsourced calibration was also expensive; for example, the cost of calibrating each Eberline monitor was over $1000. The only significant costs associated with calibrating the monitors within the department are related to buying the radioactive sources.

2. Theory

The theory for calibration being tested in this research follows the manual for each individual monitor and as per the instructions, involves two separate steps. The first step begins by applying low voltage pulses to each monitor at a known rate. Then, there are potentiometers on the monitors that can be manually adjusted so that the output reading matches the expected value. The second step involves using known radioactive sources to double-check that the previous method of calibration accurately adjusted the monitors. Before the latter part of the calibration, the Eberline monitors must also have their external probe calibrated The Eberline manuals outline this process which is done by a computer program while the monitor is connected. After calibrating the probe once, the information can be saved and then loaded onto the monitor each time that probe is used. Once the monitors are calibrated, they are checked against actual radioactive sources so their efficiencies can be calculated.

3. Experimental Procedures

A. Technical Associates Model TBM-3

As stated in the Technical Associates Manual of Operations for the TBM-3, the initial step for calibration is applying a 4000 pulse per minute (66.67 Hertz) signal to the detector. To produce this pulse an 8013B Hewlett-Packard signal generator was used. This is first connected to a Tektronix TDS 2024 oscilloscope to obtain the correct signal characteristics since the signal generator has analog controls with no. Every pulse used will be negative with an amplitude of minus one volt and a period of one microsecond. The number of pulses per second will be adjusted for the different multiplier ranges of the detectors. There are also warnings in the instructions to protect the pulser so the high voltage in the monitor does not damage it. In order to achieve this, two capacitors are used in series between the signal generator and the detector. For this experiment the capacitors used each have a 1200 pF capacitance. It may be necessary to connect the circuit after the capacitors to the oscilloscope again to make sure the width of the signal has not decreased. If it has decreased, simply increase the width on the signal generator until the original period of one microsecond is achieved again. A diagram of the circuit is shown in Appendix A. For the TBM-3, the ground is connected inside the detector where its own circuit is grounded. Then the live wire is connected to the meter with an alligator clip where the manual shows “Detector High Voltage”. A diagram of the TBM-3 is shown in Appendix B. After initially connecting the 66.67 Hertz signal, the manuals states that when the detector is turned on to the x10 position the output should read 400 counts per minute. To adjust this reading, the monitor has a set of variable resistors that can easily be adjusted with a small screwdriver. These resistors are labeled in the manual from R11 through R14. For this initial adjustment, the R11 resistor is to be modified to achieve an accurate reading. This first resistor calibrates the monitor broadly and now the other individual ranges needed to be checked. To achieve the same 400 counts per minute output for the x100 range, the input signal should be 666.67 Hertz. To modify this range's output, the R14 resistor is adjusted. Then the x10 range should be fine-tuned by applying the same 66.67 Hertz signal as originally done and then adjusting the R13 resistor. Next the x1 range needs to be calibrated. In this range, the ambient background count rates will affect the output. To account for this, turn the monitor to the x1 range with no input signal and record the average output reading. Then apply a 6.67 Hertz signal to the monitor and adjust the R12 resistor so that the output is 400 counts per minute plus the average ambient background count rate. Once the individual ranges are calibrated to the output of 400 counts per minute, the manual states that each range needs to be checked for 1/3 and 2/3 scale.

The second part of the calibration involves testing the monitors against known radioactive sources. Since the procedure for this part is the same for all monitors, turn to Experimental Procedures D.

B. Technical Associates Model PUG-1AB

The procedure for the PUG-1AB as stated in the Technical Associates Manual of Operations is the same as the procedure for the TBM-3, except for a few small differences. The circuit, which is shown in Appendix A, is still the same but the circuit is connected to the monitor differently than the TBM-3. For the PUG-1AB, the ground and live wire are attached together to the top of the monitor. A diagram of the PUG-1AB is shown in Appendix C. These resistors are also labeled differently in this manual from R19 through R23. For this initial adjustment, the R23 resistor is to be modified to achieve an accurate reading. This monitor also has a x1000 range setting and the R22 resistor is adjusted to fine-tune that range. Next, it is the R21 resistor that modifies the x100 range and the R20 resistor corresponds to the x10 range. Lastly the R19 resistor adjusts the x1 range. Again, once the individual ranges are calibrated to the output of 400 counts per minute, the manual states that each range needs to be checked for 1/3 and 2/3 scale.

The second part of this monitor's calibration also involves testing the monitors against known radioactive sources. The procedure for this part is again the same for all monitors, so refer to Experimental Procedures D.

C. Eberline ASP-2E

This radiation monitor comes equipped with computer software and probe that has a 9-pin computer connection. The ASP-2E has an internal memory where one complete set of probe information may be stored. To ensure that the probe connected is the one for which the stored parameters correlate to, put the ASP-2E in CHECK mode. While in this mode, the ASP-2E will scroll the model and serial numbers for which the stored data corresponds. For this instrument, the probe model is HP360 and the serial numbers are 2555. Also while in CHECK mode, the BATTERY icon in the lower right corner displays the percentage of the battery remaining.

To start using the computer software associated with the ASP-2E, after installing the software, double-click the ASP2 icon located on the desktop of the computer. For many functions within the program, a password will be needed. For this program the default password is *Eberline*. To familiarize oneself with the program, refer to Section 11 of the manual for an overview of the menus and icons.

Before using the monitor, the analog meter must be calibrated with the computer software. First initialize the Analog Meter Test from the meter calibration window. Click on each of the six calibration points (0, 20, 40, 60, 80, and 100% of full scale) and use the appropriate set of up and down buttons to bring the meter into calibration for each value. Cycle through the six points in both directions and verify that the needle comes to rest near the appropriate scale lines. If the needle’s final position is different when moving down from above than when moving up from below (the example given is when changing from 60% to 40% versus going from 20% to 40%), use calibration values which result in approximately equal errors.

Now the external probe must be calibrated. After the first calibration, the probe specifics can be saved to the computer and then loaded onto the monitor each time that probe is used. For this part of the calibration the manual suggests using ^{99}Tc sources. In this experiment ^{99}Tc was not available so the efficiency was checked the same as with the Technical Associates monitors. If ^{99}Tc sources were available, this is the suggested procedure. To calibrate the probe for the HP-360 follow along in Section 14, Appendix 2, page 14-11 of the technical manual. With the ASP-2E in the OFF mode, connect the computer and detector cables to the monitor. Then launch the WinASP2 program and turn the ASP-2E to CHECK mode. Click *Edit, Instrument/Probe Parameters* to display the information currently in the memory. If the ASP-2E is currently set up for the probe being calibrated, its memory will already contain appropriate parameters. Otherwise, parameters for this probe type must be loaded into the instrument. If the parameters are already saved on the computer, click *Edit, Load Setup From Disk*, then select the file for the specific probe and click *Load.*

If the probe has not been calibrated, from the main screen click *Edit, Instrument Parameters* and enter all parameters on the 'Probe' and 'Channel' display pages to match those given in the tables below. Then click *OK* to download to the ASP-2E.

Probe	**Parameters**
Dead Time (microseconds)	100
Max. High Voltage	900
Overrange (cps)	58000

Main Channel	**Parameters**
Channel Type	Beta
Units	cpm
Selected Window	Upper
High Voltage	900

Window Param's	**Lower**	**Upper**
Threshold (mV)	5.00	10.0
Counts/Count	1	1
Integrate Alarm	0	0
Rate Alarm	0	0
Click Divider	1	1

Now place the probe in an area of low background radioactivity. Select *Calibration,* and then *Determine Calibration Constant*. Make sure that the Upper Window and Background are selected and the count time set to 120 seconds. Click *Start* to begin the background count. Afterward click on *Calibration Constant*. Now the probe screen to a 47mm plated ^{99}Tc source of less than 20K cpm. Then click *Start* to begin determining the calibration constant. When that is completed, verify that the Beta Calibration Constant is greater than 0.25 but do not save this constant to the monitor. The calibration constants on the program should remain set at 1. From here, note the efficiency to record on the calibration report. Next, take two ^{99}Tc sources with known radioactivity, one of about 2K to 20K counts per minute and the other of 75K to 100K counts per minute, and record the actual counts per minute with the probe. Compute the efficiencies (100 x observed/nominal = % efficiency) and verify that they are within 10% of each other. If they are, select *Calibration,* then *Calibration Report*. Print the report and then the probe is calibrated.

Since the ^{99}Tc sources were not used, refer to Experimental Procedures D to check the efficiency of these monitors.

D. Calculating Efficiencies with Actual Sources

To begin calculating the detection efficiencies, it is necessary to gather known radioactive sources. While taking measurements with the different monitors, it is paramount that each monitor is the same distance away from each source. The radiation from the sources dissipates over distance and therefore if the monitors are not uniformly close to the source, the measurements will not be able to be compared accurately. While the activity of each source is known according to Equations 1-3 below, the surface activity is not known.

Equation 1: $N(t) = N_o e^{-\tau/t}$	Equation 2: $R(t) = R_o e^{-\tau/t}$	Equation 3: $t_{1/2} = \tau / \ln(2)$

For these equations τ stands for the decay constant. In Equation 1, N(t) stands for the number of radioactive nuclei versus time. In Equation 2, R(t) stands for the number of decays per second. In Equation 3, $t_{1/2}$ stands for the half-life of the source.

For accurate readings, the sources should be flat, have the same diameter as the detectors so that all the decays would be read, and have a known surface activity. Instead, the sources in this experiment were concentrated point sources with unknown surface activities. Because of this the overall decay rate was not known, including the intensity of decay in all directions. Since the decay rate is also not constant, it was advantageous to use the *integrate* mode on the monitors when possible. The monitors that have this capability are the Technical Associates TBM-3 and PUG-1AB, and the Victoreen 190N. For these measurements, the radiation was collected over a sixty second span. After collecting the data for each monitor, the deviation from the last monitor to be calibrated can be calculated. For this experiment the Eberline ASP-2e with probe number 2550 was the last monitor to be calibrated.

4. Results

Table I: Calibration for the Technical Associates TBM-3

Scale	% Signal	Input Signal (pps)	Analog Output
x100	3/3	666.67	400
	2/3	444.45	267
	1/3	222.23	133

Scale	% Signal	Input Signal (pps)	Analog Output
x10	3/3	66.67	400
	2/3	44.45	267
	1/3	22.23	133

Table II: Calibration for the Technical Associates PUG-1AB

Scale	% Signal	Input Signal (pps)	Analog Output
x1000	3/3	6666.67	400
	2/3	4444.45	267
	1/3	2222.23	133

Scale	% Signal	Input Signal (pps)	Analog Output
x100	3/3	666.67	400
	2/3	444.45	267
	1/3	222.23	133

Scale	% Signal	Input Signal (pps)	Analog Output
x10	3/3	66.67	400
	2/3	44.45	267
	1/3	22.23	133

These tables show the first part of calibration for the Technical Associates monitors when low voltage pulses are applied to each monitor and potentiometers are manually adjusted so the output reading matches the expected value.

The sources used for this experiment were Cesium 137, Sodium 22, Cobalt 60, Curium 244, and Strontium 90. The Cesium, Sodium, and Cobalt sources emitted gamma radiation. The Curium source emitted alpha radiation and the Strontium source emitted beta radiation. The following data table has the raw data for radiation detected. To distinguish the two Eberline ASP-2e models, the one with probe number 3314 and serial number 001652 will simply be *Old* Eberline and the model with probe number 2555 and serial number 000162 will be *New* Eberline.

Table III

	Radiation Detected by Each Monitor (cps)				
Source	New Eberline	Old Eberline	Victoreen	TBM-3	PUG-1AB
Cs-137	147.83	157.00	223.33	133.33	58.00
Na-22	805.00	835.00	995.00	666.67	425.00
Co-60	451.67	483.33	606.67	383.33	183.33
Cm-244	187.33	198.67	220.00	150.00	100.00
Sr-90	2.12	2.47	2.60	3.33	1.67

This table shows the raw counts per second of each detector corresponding to each of the five sources.

As stated before, the last monitor to be calibrated was the *New* Eberline so the readings from that monitor will be used as the control. Therefore to find the deviation from the control, the number of counts per second detected by the *New* Eberline is subtracted from the number of counts per second detected by each monitor and then that number is divided by *New* Eberline's number. The following table lists the deviation of each monitor against the *New* Eberline.

Table IV

	Old Eberline	Victoreen	TBM-3	PUG-1AB
Source	% Deviation	% Deviation	% Deviation	% Deviation
Cs-137	+ 6.2%	+ 51.1%	- 9.8%	- 60.8%
Na-22	+ 3.7%	+ 23.6%	- 17.2%	- 47.2%
Co-60	+ 7.0%	+ 34.3%	- 15.1%	- 59.4%
Cm-244	+ 6.1%	+ 17.4%	- 19.9%	- 46.6%
Sr-90	+ 16.5%	+ 22.6%	+ 57.1%	- 21.2%

This table shows how the measured count rate differed from the count rate in the *New* Eberline which was a calibrated detector.

5. Conclusion

In conclusion, the monitors from Technical Associates were able to be calibrated by passing pulses with known characteristics through their high voltage detectors and adjusting their variable resistors to gain the correct corresponding output.

Additionally, the calibration of the monitors from Technical Associates was very straightforward. Once the correct circuit was developed and the high voltage was protected by capacitors, the calibration process of each range of the monitors was fairly similar. One important characteristic of the circuit was that the signal needed to be readjusted after passing through the capacitors. The capacitors shortened the signal width and therefore when the pulse was connected to the TBM-3 model in particular, the resulting output was not stable. For the PUG-1AB model, this shortening of the signal did not affect the output. The reason for this discrepancy between the two very similar models was that the signal was passed into the PUG-1AB in a much more stable connection. The makeup of the TBM-3 required that the signal be connected using alligator clips, which are less reliable.

Another issue during the experiment was that the initial signal generator had knob controls, instead of digital, so an oscilloscope was needed to tell what the characteristics of the signal were. The oscilloscope used was unable to read signals less than 10 pulses per second as anything more specific than just *<10.* Therefore attempting to calibrate the x1 scale for either Technical Associates monitors was not possible.

Furthermore, the creation of a small box with the capacitors soldered together was very helpful in making a cohesive circuit. Before doing this, each piece of the circuit was connected using alligator clips, and as shown when connecting the circuit to the TBM-3, this does not always produce a stable current flow.

Before looking at the deviations and efficiencies of this experiment, there are previous calibration reports to reference. Appendix F is the calibration report for the Technical Associates TBM-3 monitor. As mentioned before, the distance between the probe and the source will affect the amount of radiation seen by the detectors. In Appendix F, the report says that during the efficiency determination the probe was about ¼" from the source. At this close proximity, the monitor still only averaged 12% efficiency. Note that the Nuclear Regulatory Commission only requires that the efficiencies be known. It is within regulations that the meters do not agree with each other.

Table IV shows that the monitor with greatest deviation from the *New* Eberline is the Technical Associates PUG-1AB. This poor efficiency is probably caused by the physical makeup of the monitor. The PUG-1AB has its detector located in an approximately six inch long tube. This is different from the other monitors who have detectors directly on the outside of the monitor, like the TBM-3, or on the outside of the probe, like the Eberline and Victoreen models. Since the calibration reports already show a low level of radiation detection, adding more space between the source and the detector will cause more radiation to dissipate. This is shown in the efficiency columns of Table IV which show that while the other monitors were generally reporting 70-80% efficiency, the PUG-1AB was reporting 40-50% efficiency.

The one area the PUG-1AB shows good efficiency is with the Strontium-90 source. As stated before, two Technical Associates monitors were unable to be calibrated at less than ten counts per second and the Strontium 90 source, as shown in Table III, produced less than four counts per second as detected in each monitor. Additionally, the TBM-3, which showed between 80.1% and 90.2% efficiencies, had an abnormally low efficiency of 42.9% for the Strontium 90. Therefore, the detection numbers for the TBM-3 and PUG-1AB can be discounted for the Strontium 90. Without this outlining number for the TBM-3, the efficiencies in relation to the *New* Eberline were very strong. These results are expected in relation to Appendix F which states that this monitor was recently calibrated in December of 2006.

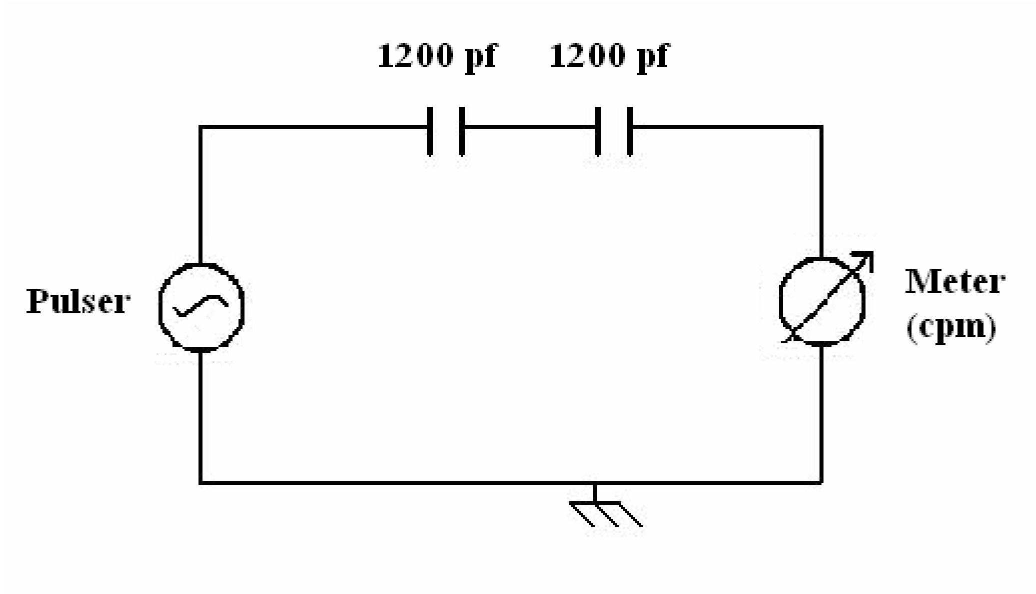
According to Appendix G, the Victoreen 190N was calibrated in August of 2006. Although its efficiencies in Table IV are not as high as some of the other monitors, they are still far above the efficiencies reported on the calibration report. In this experiment the efficiencies ranged between 48.9% and 82.6% while on the report the average was only 17.8%.

As expected the two Eberline monitors have very similar detection rates. For each of the sources, the *Old* Eberline detected slightly more radiation, as shown in Table III. Since the *Old* Eberline was last calibrated about three years before the *New* Eberline, it can be concluded that for this type of monitor, the error occurring over time is one of overestimating the radiation emitted.

In this experiment, three of the sources used emitted gamma radiation; one source emitted alpha radiation, and the other source emitted beta radiation. The two Eberline monitors had very similar detection rates for the gamma and alpha sources, but they have a 10% in beta radiation numbers. This may show that the Eberline probe is not as accurate for beta radiation. Additionally, the Victoreen monitor showed a much higher detection rate with alpha and beta particles versus gamma particles so that type of monitor may be more accurate with alphas and betas. Both Technical Associates monitors had relatively consistent readings for each of the sources, although the beta radiation results have been thrown out as stated before because of calibration issues.

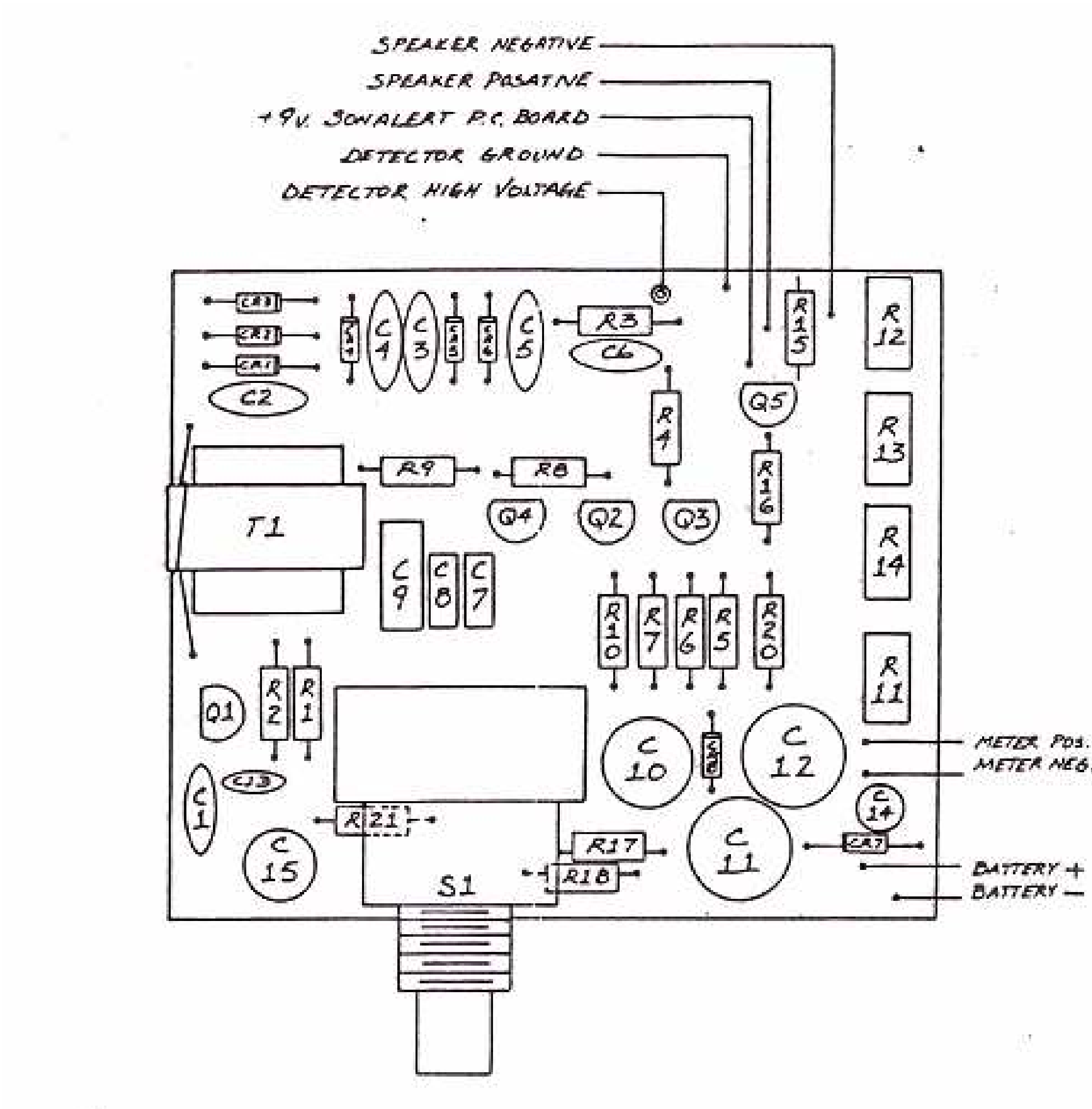
7. Appendix

A. External Circuit Diagram for Technical Associates Monitors

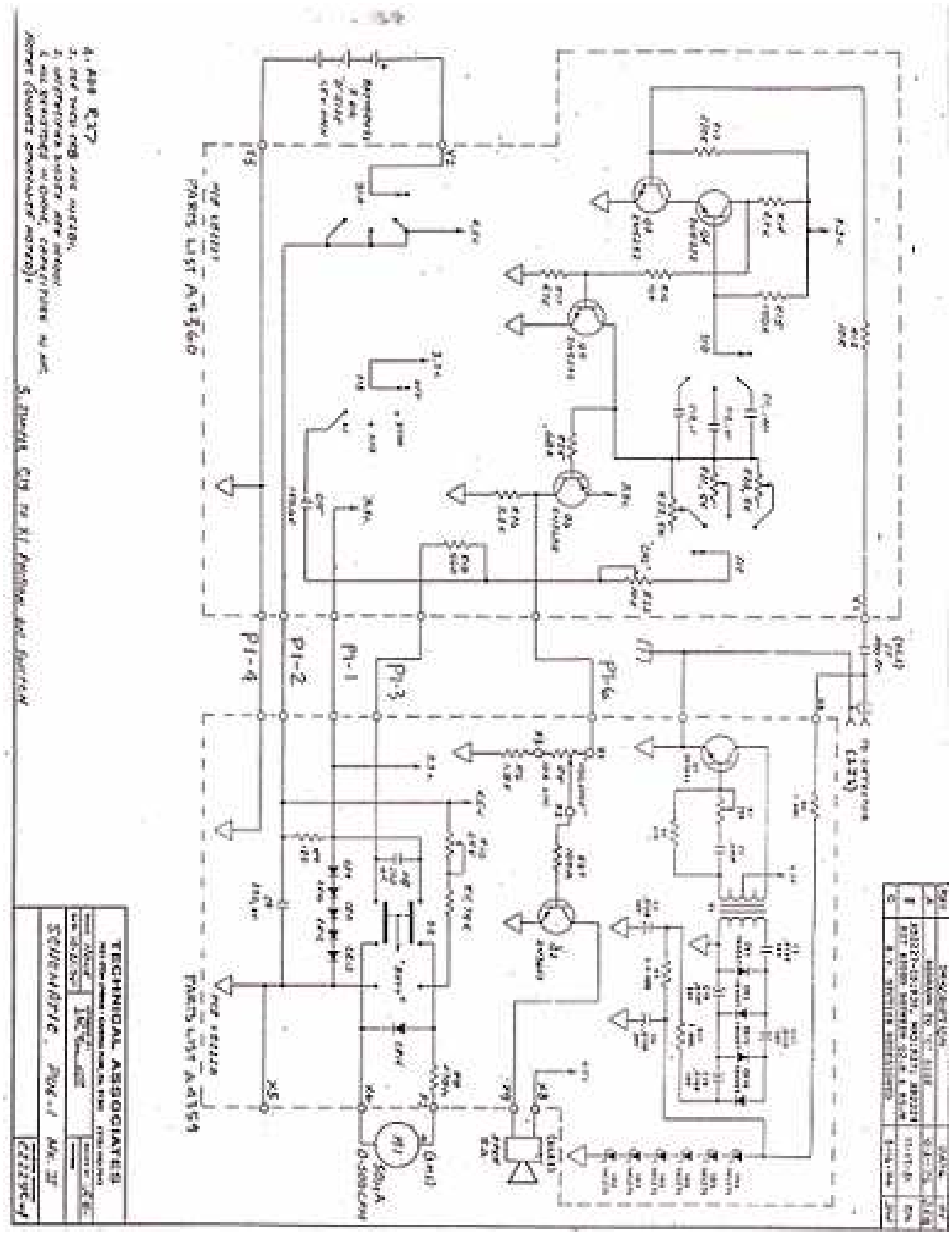


In this circuit, a low voltage pulse is sent through two capacitors in order to protect the pulser from the high voltage in the meter.

B. Monitor Diagram for Technical Associates TBM-3



C. Monitor Diagram for Technical Associates PUG-1AB



D. Calibration Report from ASP-2e Eberline 11/09/07
Serial Number 000162, Probe Number 2555

Thermo SCIENTIFIC	**Kalibrierprotokoll / Calibration Protocol ASP2**	Nr./No. :PRS-PK SF1040 Seite/Page : 1 Anzahl der Seiten / : 1 Number of pages

ASP-2 Serial Number : 162
Program Version :
Scalar Precision : 10%
Lower Threshold Slope : 1.00
Lower Threshold Intercept : 0.0 mV
Upper Threshold Slope : 1.00
Upper Threshold Intercept : 0.0 mV
Alarm Editing : Enabled
Auto Ranging : Enabled
Beep on Auto-Range : No
Star Key Ratemeter Function : Zero Display
Star Key Integrate Function : Zero Display
Scaler Display Units : Rate
Scaler Counting Mode : Fixed Time

ASP-2 Calibration Date : 11/09/07

PROBE DATA

Probe Serial Number : 2555
Probe ID : HP360
Dead Time : 100 usec
Max High Voltage : 900 Vdc
Overrange : 58000 cps
Channel : Main
Channel Type : Beta
Window : Upper
Rate Units : cpm
Response Times : 20,10,3 secs
High Voltage : 898 Vdc
Lower Threshold : 5.00 mv
Upper Threshold : 10.1 mv
Scaler Time : 10 secs
Upper Cal. Constant : 1.00 counts/count

Probe Calibration Date : 11/09/07

Calibration Sources are Traceable to the National Institute of Standards and Technology

Alpha Source: ______ %Eff: ______

Beta Source : Sr 90 / VV53 / 13320 cpm %Eff: 56

Gamma Source: ______ %Eff: ______

Linearity Field: 13320 cpm Response: 13550 cpm %Pass: 1,72

Linearity Field: 7320 cpm Response: 7000 cpm %Pass: -4,37

Cable Length: 36 inches

Signature: [illegible] Date: 09.11.07

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E. Calibration Report for Eberline ASP-2e 09/30/04
Serial Number 001652

EBERLINE ASP-2 CALIBRATION REPORT

ASP-2 Serial Number	: 1652
Program Version	: ASP2 V1.05
Scalar Precision	: 10%
Lower Threshold Slope	: 1.00
Lower Threshold Intercept	: 0.0 mV
Upper Threshold Slope	: 1.00
Upper Threshold Intercept	: 0.0 mV
Alarm Editing	: Enabled
Auto Ranging	: Enabled
Beep on Auto-Range	: No
Star Key Ratemeter Function	: Zero Display
Star Key Integrate Function	: Zero Display
Scaler Display Units	: Rate
Scaler Counting Mode	: Fixed Time

ASP-2 Calibration Date : 09/30/04

PROBE DATA

Probe Serial Number	: 3314
Probe ID	: HP360
Dead Time	: 100 usec
Max High Voltage	: 900 Vdc
Overrange	: 58000 cps
Channel	: Main
Channel Type	: Beta
Window	: Upper
Rate Units	: cpm
Response Times	: 20,10,3 secs
High Voltage	: 898 Vdc
Lower Threshold	: 5.00 mv
Upper Threshold	: 10.1 mv
Scaler Time	: 10 secs
Upper Cal. Constant	: 1.00 counts/count

Probe Calibration Date : 09/30/04

Linearity Check Results

Field 37800 cpm Reading 14000 cpm Efficiency 37 %
Field 81,800 cpm Reading 30,000 cpm Efficiency 36.6 %
Field ______ cpm Reading ______ cpm Efficiency ____ %

Calibration Sources are Traceable to the National Institute of Standards and Technology

Alpha Source: ______ %Eff: ______

Beta Source : T699 S/N 2751 C 37,800 cpm %Eff: 36.89%

Gamma Source: ______ %Eff: ______

Cable Length: 36 inches

F. Calibration Report for Technical Associates TBM-3 12/29/06

Duratek™

CALIBRATION CERTIFICATE

Duratek Instrument Services
628 Gallaher Road
Kingston, TN 37763
Phone: (865) 376-8337
Fax: (865) 376-8331

This Certificate will be accompanied by Calibration Charts or Readings where applicable

CUSTOMER INFORMATION		INSTRUMENT INFORMATION	
Customer Name: COLLEGE OF WILLIAM & MARY -		Manufacturer: Technical Associates	
Address: Campus Drive Williamsburg , VA 21385		Model: TBM-3	Serial Number: 99289
Contact Name: Todd Avert		Probe: GM	Serial Number: Internal
Contract/Task Number: 120055-TA	Work Order Number: 2006-04203	Calibration Method: Electronic and Source	

INSTRUMENT CALIBRATION INFORMATION

Instrument Range	Calibration Standard Value	Instrument Response*		Comments	
		Before Calibration	After Calibration	Calibrated in accordance with OEM Technical Manual.	
X1	100	100	100	Pulser: 120935	Cal Due: 05/27/07
X1	250	240	240	DVM: 88020324	Cal Due: 09/26/07
X1	400	390	390	D-812 2816	Cal Due: 05/04/07
X 10	1,000	900	900	Humidity: 958670	Cal Due: 03/29/07
X 10	2,500	2,400	2,400		
X 10	4,000	3,800	3,800	Temperature: 23.4 °C	
X 100	10,000	10,000	10,000	Pressure: 748mmHg	
X 100	25,000	24,000	24,000	Humidity: 21%	
X 100	40,000	39,000	39,000		

Efficiency Determination ~1/4" from 45 mm disc source				Audio: SAT	Mech. Zero: SAT
Instrument Range	Source Information	Net Counts (cpm)	Efficiency	BAT Test: SAT	Geotropism: SAT
X 1 EFF	Tc-99#119720 at 2,562dpm	360	11.0%		
X 10 EFF	Tc-99#119718 at 20,520dpm	2,760	13.5%	Background: 40 cpm	
X 100 EFF	Tc-99#109408 at 259,518dpm	26,000	11.5%		
AVG EFF	N/A	N/A	12%		
High Voltage	Fixed at 955 V				

STATEMENT OF CERTIFICATION

We Certify that the instrument listed above was calibrated and inspected prior to shipment and that it met all the Manufacturers published operating specifications. We further certify that our Calibration Measurements are traceable to the National Institute of Standards and Technology. (We are not responsible for damage incurred during shipment or use of this instrument).

Instrument Calibrated By: [signature] Reviewed By: [signature] Date: 12/29/06

Calibration Date: 12/28/2006 Calibration Due: 12/28/2007

G. Calibration Report for Victoreen 190N 08/21/06

Duratek™

CALIBRATION CERTIFICATE

Duratek Instrument Services
628 Gallaher Road
Kingston, TN 37763
Phone: (865) 376-8337
Fax: (865) 376-8331

This Certificate will be accompanied by Calibration Charts or Readings where applicable

CUSTOMER INFORMATION		INSTRUMENT INFORMATION	
Customer Name: COLLEGE OF WILLIAM & MARY		Manufacturer: Victoreen	
Address: Campus Drive Williamsburg VA 21385		Model: 190	Serial Number: 1323
Contact Name: Ed Lawrence		Probe: 489-110D	Serial Number: 898
Customer Purchase Order Number: 120055LA	Work Order Number: 2006-03918	Calibration Method: Electronic and Source	

INSTRUMENT CALIBRATION INFORMATION

Instrument Range (Auto Ranging)	Calibration Standard Value (cpm)	Instrument Response (cpm) Before Calibration	After Calibration	Comments	
X 10	20	20	20	Pulser: 101500	Cal Due: 09/28/06
X 10	50	50	50	DVM: TW12662	Cal Due: 02/23/07
X 10	80	76	76	D-814: 2551	Cal Due: 10/13/06
X 100	200	200	200	Humidity: 958670	Cal Due: 03/29/07
X 100	500	500	500		
X 100	800	800	800	Temperature: 23.3°C	Humidity: 64%
X 1,000	2,000	2,000	2,000	Pressure: 742mmHg	
X 1,000	5,000	5,040	5,040		
X 1,000	8,000	8,080	8,080	Optical Calibrator device not available.	
X 10,000	20,000	20,300	20,300	Audio: SAT	Batt. Check: SAT
X 10,000	50,000	53,400	53,400	Fast/Slow: SAT	Reset: SAT
X 10,000	80,000	89,700	89,700	HV Pushbutton: SAT	Overange: SAT
EFFICIENCY DETERMINATION (Using 180-15 jig)					
EFF X1	Tc-99#119720	2,562 dpm	16.0%	Background: 23cpm	Threshold: 270mV
EFF X10	Tc-99#119718	20,520 dpm	20.4%	Limited Use: X10,000 and X100,000 Scales for information only due to deadtime limitations. Calibrated in Counts/Min Mode only. Use with 489-110D. Check source reading: ~9100cpm (contact)	
EFF X100	Tc-99#109408	259,518 dpm	17.0%		
Average EFF	N/A	N/A	17.8%		
(Customer requested)	Th-230#119709	2,442 dpm	8.9%		
High Voltage	900V	918V	918V		

STATEMENT OF CERTIFICATION

We Certify that the instrument listed above was calibrated and inspected prior to shipment and that it met all the Manufacturers published operating specifications. We further certify that our Calibration Measurements are traceable to the National Institute of Standards and Technology. (We are not responsible for damage incurred during shipment or use of this instrument).

Instrument Calibrated By: Mike Pauli	Reviewed By: [signature]	Date: 8/21/06
Calibration Date: 08/21/06		Calibration Due: 08/21/07