# CALIBRATION OF THE PIC ON NEWNET STATIONS

**Purpose**

This Meteorology and Air Quality Group (MAQ) procedure describes the calibration of the pressurized ion chambers (PICs) on NEWNET stations.

**Scope**

This procedure applies to the routine calibration of the PICs on NEWNET stations.

**In this procedure**

This procedure addresses the following major topics:



**Signatures**

| Prepared by: | Date: |
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04/10/06

# General information about this procedure

**Attachments**

This procedure has the following attachments:

| Number | Attachment Title | No. of pages |
|---|---|---|
| 1 | Hazard Control Plan | 1 |
| 2 | Calibration Factor for NEWNET PICs | 4 |

**History of revision**

This table lists the revision history and effective dates of this procedure.

| Revision | Date | Description Of Changes |
|---|---|---|
| 0 | 1/8/02 | New document. |
| 1 | 12/22/04 | Quick-change revision to convert HCP to HR. |
| 2 | 4/12/06 | Add alternative calibration method and discuss calibration of other sensors. |

**Who requires training to this procedure?**

The following personnel require training before implementing this procedure:

- personnel assigned to calibrate NEWNET

Annual retraining is required and will be by self-study ("reading") training.

**Training method**

The training method for this procedure is "**self-study**" (reading) and is documented in accordance with the procedure for training (MAQ-024).

**Prerequisites**

In addition to training to this procedure, the following training is also required prior to performing this procedure:

- RadWorker Training
- MAQ-011, "Logbook Use and Control"
- Hazard Review "NEWNET Instrument and Station Maintenance"
- RRES-ES-Field, "Field Safety For All Employees"
- MAQ-Driving, "Driving and Towing Safety For All Employees"

# General information, continued

**Definitions specific to this procedure**

NEWNET: Neighborhood Environmental Watch Network.

PIC: Pressurized Ion Chamber.

PIC multiplier: The number in the data logger by which the PIC data are multiplied. This number is accessed within the PC208W program in NEWNET3.LANL.GOV.

**References**

The following documents are referenced in this procedure:

- MAQ-011, "Logbook Use and Control"
- MAQ-024, "Personnel Training"
- Reuter-Stokes Manual RSS-131
- Reuter-Stokes Manual RSS-1013
- RRES-ES-Field, "Field Safety For All Employees"
- MAQ-Driving, "Driving and Towing Safety For All Employees"

**Note**

Actions specified within this procedure, unless preceded with "should" or "may," are to be considered mandatory guidance (i.e., "shall").

# Calibration of the PIC with a source

**Calibration frequency**

As good practice and in accordance with the NEWNET QA plan, the NEWNET PICs should be calibrated on an annual basis. This means the calibrations should average one per year; it does not mean that they must be done at intervals of 365 days or less.

In addition to the annual calibration, a calibration should also be performed if there is any question about the performance, or if a PIC is replaced.

**Principles of PIC calibration**

PIC calibrations are performed in the field with the PIC connected in the normal way. Thus, the calibration includes the electronics and any possible software manipulation that occurs before the data are displayed on the NEWNET website (newnet.lanl.gov).

During maintenance and when changes are made, it is good practice to measure the voltages at the data logger and at other key locations. These values should be documented in the station logbook. Standard readings of this sort are helpful when troubleshooting the system. It is also useful to record the zero reading, i.e., the reading when the PIC electronics is set to "zero".

During a calibration, the response of the PIC will depend on:

- the type and activity of the radioactive calibration source,
- the distance from the source to the PIC, and
- the background radiation.

When a source is used, the calibration source must be cesium-137 (Cs-137). Corrections are made, as needed, for the activity, distance, and background. These details are discussed in the following sections.

Background data may be used to demonstrate that a previous source calibration remains valid, provided the station has not been disturbed and the background has not changed. This method is discussed in detail below.

**Handling and transporting the sources**

Keep each source in its dedicated storage box when not in use. Avoid carrying the source in a pocket. At a distance of 6 inches, the dose rate is 0.25 mrem/h, which is about twenty times the external radiation background.

These sources are "non-accountable" and do not need to be tracked nor have a formal source custodian. It is not a requirement to keep them locked; however, they should be stored in a locked cabinet at TA-54 Cave.

# **Calibration of the PIC with a source**, continued

**Activity of the source**

The calibration depends on the activity of the source, *C*, measured in curies or microcuries. The activity of the source is corrected for radioactive decay using the textbook formula: $C = C_0 \exp(-0.023t)$; the time *t* is in years and can be approximated to the nearest tenth of a year.

The two standard sources used with NEWNET were purchased from Isotope Products Lab (IPL) in August 2001. Specifications are as follows.

- Source number 812-44-1, 18.30 microcuries on 15-Aug-01.
- Source number 812-44-2, 17.71 microcuries on 15-Aug-01.

The two sources agree to better than 1%, i.e., source #1 has ~3% more activity and produces ~3% more radiation.

**Accuracy**

Aim for 1%. An accuracy of 5% is acceptable. The overall accuracy of the PICs depends on the energy of the gammas, as shown in the figures in the Reuter-Stokes manuals (e.g., see Figure 3 on page 11 of the RSS-131 manual and Figure 2.1 on page 4 of the RSS-1013 manual).

**Distance of the source**

The reading from the PIC depends on the distance and follows the inverse-square law. When the source is in its standard configuration, the effective mean distance from source to PIC is 5.7 inches. Therefore, a change in distance of 0.1 inch is significant.

The standard configuration for the source is as follows.

- Keep the source inside its half-inch-thick plastic box, with the quarter-inch-thick sponge pad between the source and the PIC.
- Orient the PIC in its standard configuration with the electronic connector underneath and the flat 12-by-12-inch surface of the PIC uppermost.
- Place the source within a quarter inch of the middle of the 12-by-12-inch surface. Note: horizontal displacement is much less critical than vertical displacement. If it looks centered, it's ok.

# **Calibration of the PIC with a source**, continued

**Background radiation**

The terrestrial and cosmic background radiation is about 5 to 8% of the source radiation, and therefore background must be measured and subtracted. The background should be measured to about 1 microR/h. This is straightforward, unless something unusual happens during the calibration. For example, a rain or snowstorm can change the background by several microR/h. In this case, the background will not be constant before and after the calibration, and the calibration will need to be repeated.

**Expected reading**

If the decay-corrected activity is *C* curies and the source is in the designated position described above (see "Distance of the source"), the expected reading, after subtracting background, is 13.9*C* R/h. For example, if $C = 17.5$ microcuries, the expected background-corrected reading is 243 microR/h.

**Steps to calibrate the PIC**

To calibrate the PIC, perform the following steps:

| Step | Action |
|---|---|
| 1 | Enter a NEWNET comment saying when the PIC will be calibrated. |
| 2 | Select one of the IPL Cs-137 sources and calculate the decay-corrected activity, *C*, using the standard textbook formula (see "Activity of the source", above). With the source in the designated position (see "Distance of source", above) the expected increase will be 13.9*C* R/h. |
| 3 | Optional step: with the source more than 10 feet from the PIC, record and average 10 background readings from the visual display, if this is available. |
| 4 | If you know the precise timing of the data logger interval, place the source in the designated position at least 1 minute before the beginning of the interval and leave it in place until at least 1 minute after the end of the interval. Alternatively, leave the source in place for at least 31 minutes. (See "Distance of source" for the designated position.) |
| 5 | Optional: if there is a visual display, record about 10 visual readings after the PIC has stabilized, and record 10 more visual readings after the source is removed 10 feet away. |
| 6 | The data recorded in the computer database should show: (a) a flat background (±1 microR/h) before and after the calibration; (b) a spike during the calibration interval; (c) significant increases (several microR/h) during the 15 minute intervals immediately before and immediately after the calibration interval. If not, the calibration should be repeated. |

*Steps continued on next page.*

## **Calibration of the PIC with a source**, continued

| Step | Action |
|---|---|
| 7 | Calculate the background by averaging about 10 readings from the flat regions before and after the calibration (described in step 6a). |
| 8 | Subtract the background from the spike to obtain the observed increase. (Optionally, compare this with the visual readings and discuss anomalies with the NEWNET project leader.) |
| 9 | Compare the observed increase with the expected increase. Consider long-term trends and adjust the multiplier in the data logger as needed to maintain the ±5% precision specified in the NEWNET QAPP. |
| 10 | Document the calibration in the NEWNET comments for that station. |

# Calibration of the PIC using background

**Calibration using Background data**

As an alternative to re-calibrating with a sealed source as described in the previous chapter, a source calibration may be extended by observing the background data, provided:
a) the station has not been disturbed since the latest source calibration; and
b) nearby sources of radiation are well understood.

**Time period for background calibrations**

The data must be averaged over a sufficiently long time interval, ideally a year. This is because rain, snow, and radon can cause up to 10% change in the natural background when averaged over a day.

Specifically, a large rain or snow storm can cause up to a 100% increase for about an hour, which is equivalent to about (100/24)% = 4% averaged over a day. This 4% increase is usually compensated by a decrease of up to 10% caused by the shielding of terrestrial radiation by the rain or snow, so rain or snow usually causes an overall decrease. During a month with a lot of snow the background can be 5% less than a dry month. Averaged over a year, however, the year-to-year variation is less than 1%.

**Variation of cosmic radiation**

The variation in cosmic radiation is negligible. The largest fluctuation ever observed by NEWNET was an increase of 0.5 microR/h for the 15-minute interval ending at 7:15 UTC, January 20, 2005. This blip was detected at all NEWNET stations, but by the next 15 minute interval the change was less than 0.2 microR/h and was lost in the noise.

**For East Gate location**

At East Gate, the radiation from LANSCE emissions, as calculated by CAP-88, is less than 10 mrem/y. The radiation measured by NEWNET is about half the CAP-88 value, so it could be as much as 4% of background in some years. A 5% calibration is satisfactory but consider correcting for the LANSCE emissions in order to achieve a more accurate result.

**For Area G location**

At Area G South, the radiation from the material in the domes is about 30% of the background. For the past few years, both the DPRNET data and the NEWNET data have been constant to about 5%. However, in future it may be necessary to use the DPRNET data to correct the calibration.

## **Calibration of the PIC using background**, continued

**For Kappa Site location**

At Kappa Site, prior to July 2004, the spikes are significant when averaged over a day but are less than 5% of background when averaged over a month and are negligible when averaged over a year.

**Steps to extend the calibration using background**

To extend the PIC calibration using background data, perform the following steps:

| Step | Action |
|---|---|
| 1 | Note when the station was last calibrated with a source, when the PIC multiplier was last changed, and the latest value of the multiplier. |
| 2 | Select a suitable time interval that represents the background data at the time of the last source calibration, e.g., the complete calendar year that includes the last calibration. Use newnet.lanl.gov to graph the data for this interval. Record the average in microR/h. |
| 3 | Look for anomalies in the data, e.g., bad data, extended periods of unusually high or low data, and significant changes. |
| 4 | If there is any doubt as to the reliability of the average, select time intervals that exclude the questionable data and obtain another average. Aim for 1%, though 5% is acceptable. |
| 5 | Select a suitable time interval that represents the latest background data, e.g., the latest complete year of data. Use newnet.lanl.gov to graph the data for this interval. Record the average in microR/h. |
| 6 | Repeat steps 4 and 5 to check the integrity of the latest data. |
| 7 | Calculate the ratio of the latest background average to the background average at the time of the source calibration, and multiply by the latest calibration ratio (see examples below). Consider long-term trends and adjust the multiplier in the data logger as needed to maintain the ±5% precision specified in the NEWNET QAPP. |
| 8 | After changing the PIC multiplier, verify that the results are as expected. |
| 9 | Store any spreadsheets and electronic notes in the NEWNET folder of the database drive. |

## **Calibration of the PIC using background**, continued

**Example of calibrations**

The following examples discuss the calibrations of January 2006.

**Espanola**

Source calibration of 10/22/2002: measured 261.9-12.5 = 249 microR/h;
expected 18*exp(-0.023*1.185)*13.9 = 243 microR/h;
calibration ratio = measured/expected = 1.02
The 2003 source cal on 7/9/2003 was invalid because source not in place for complete 15 min.
Annual background averages

| Year | average microR/h | |
|---|---|---|
| 2002 | 12.9 | |
| 2003 | 12.7 | |
| 2004 | 12.8 | |
| 2005 | 12.8 | maybe 1% decrease since 2002, so 2005 cal is 1-2% high. |

PIC multiplier = 1, no change.

**Area G South**

A new PIC multiplier = 1.055 was inserted on 12/16/2002.
Source cal 7/8/2003: measured 250.3-20.85=229 μR/h; expected 240;
calibration ratio = measured/expected = 0.95
Source cal 8/17/2004: measured 243.3-21.8=222 μR/h; expected 233 μR/h;
measured/expected = 0.95
Annual background averages

| Year | average μR/h | |
|---|---|---|
| 2003 | 21.1 | |
| 2004 | 21.7 | |
| 2005 | 21.9 | this may be a real increase in rad, perhaps also combined with |

gradual decline of PIC battery. Accuracy is no better than 5%.
2005 calibration was ~5% low; so the PIC multiplier was increased from 1.055 to 1.11 at 9 PM UTC Jan 9 '06.
Source calibration should be repeated in 2006 if possible.

**Buey East**

PIC multiplier was changed from 1 to 1.076 on Dec 16, 2002.
Source cal 6/27/2003: measured 261.1-18.85=242 μR/h; expected 240 μR/h
calibration ratio = measured/expected = 1.01
Annual background averages

| Year | average μR/h | |
|---|---|---|
| 2003 | 18.9 | |
| 2004 | 18.7 | |
| 2005 | 18.9 | same as in 2003 so calibration is ~1% high; |

(PIC multiplier = 1.076, unchanged)

# Calibration of the PIC using background, continued

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**DP West**

Source cal 8/16/2004, measured 248-17=231 μR/h, expected 233 μR/h
calibration ratio = measured/expected = 0.99
Annual background averages

| Year | average μR/h | |
|---|---|---|
| 2003 | 17.2 | |
| 2004 | 17.1 | |
| 2005 | 17.0 | about 0.5% per year, battery may be getting old. |

So cal is about 1% low; (PIC multiplier = 1.068, unchanged)

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**East Gate**

Source cal 8/16/2004, measured 265.4-16.3-10=239 μR/h, expect 233.5 μR/h
calibration ratio = measured/expected = 1.02
(Note: an extra 10 μR/h was subtracted; this was from the source on the adjacent station; see comment on 10/25/2002 and cal on 6/26/2003.)
Annual background averages

| Year | average microR/h | |
|---|---|---|
| 2004 | 16.4 | |
| 2005 | 16.4 | no change, so cal is 2% high. PIC multiplier = 1, unchanged. |

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**Kappa Site**

Source cal 8/11/2004, measured 249.2-15.2=234 μR/h, expect 234 μR/h, ok.
Calibration ratio = 1
Annual background averages

| Year | averageμR/h | |
|---|---|---|
| 2004 | 15.4 | |
| 2005 | 15.4 | no change so cal is ok. PIC multiplier = 1, unchanged. |

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**Mortandad Canyon**

Source cal 8/06/2004, measured 262-19=243 μR/h, expected 234 μR/h.
calibration ratio = measured/expected = 1.04
Annual background averages

| Year | average μR/h | |
|---|---|---|
| 2004 | 19.0 | |
| 2005 | 19.0 | no change so cal is 4% high. PIC multiplier = 1, unchanged. |

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**S Site**

Source cal 8/11/2004, measured 261-16=245 μR/h, expected 234 μR/h
calibration ratio = measured/expected = 1.05
Annual background averages

| Year | average μR/h | |
|---|---|---|
| 2004 | 16.0 | |
| 2005 | 16.0 | no change so cal is 5% high. PIC multiplier = 1, unchanged. |

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# Calibration of the PIC using background, continued

**TA54 Met Tower**

Source cal 6/27/2003, measured 248-17=231 μR/h, expected 240 μR/h.
calibration ratio = measured/expected = 0.96
Annual background averages

| Year | average microR/h | |
|---|---|---|
| 2003 | 16.8 | |
| 2004 | 16.8 | |
| 2005 | 16.6 | 1% lower than 2003 |

So cal is 5% low; multiplier should be increased from 1 to 1.05.

**LAHS**

Source cal 8/11/2004; there was light rain so the background increased by 1 or 2 microR/h.
Measured 244.6-14.5 or 245.9-16.3 = 230 μR/h, expected 234 μR/h.
calibration ratio = measured/expected = 0.98
Annual background averages

| Year | average μR/h |
|---|---|
| 2004 | 14.1 |
| 2005 | 14.1 |

So cal is 2% low; multiplier was increased from 1 to 1.05 at 9 PM UTC, Jan 9, 2006.

**San Ildefonso Pueblo**

Source cal 10/24/2002, measured 256-11=245 μR/h, expected 243 μR/h
calibration ratio = measured/expected = 1.01
Annual background averages

| Year | average μR/h | |
|---|---|---|
| 2002 | 16.8 | |
| 2003 | 16.8 | |
| 2004 | 16.8 | |
| 2005 | 16.6 | 1% low, so cal is ok. PIC multiplier = 1, unchanged. |

# Records resulting from this procedure

**Records**

The following records generated as a result of this procedure are to be completed within 1 month and are maintained in the MAQ database:

- Calibrations reported in the NEWNET comments.
- Additional details may be documented in Excel spreadsheets or Word documents in the NEWNET folder of the Database Drive.

Click here to record "self-study" trainir his procedure.

If you have read and understand the preceding document, click here to receive EDS credit.

# HAZARD REVIEW

| **Work tasks/Steps** | **Hazards, Concerns, and Potential accidents; Likelihood/ Severity** | **Controls, Preventive Measures** *(e.g., safety equipment, administrative controls, etc.)* | **Hazard Level** *from IMP 300-00-00 Hazard Grading Matrix* |
|---|---|---|---|
| Radiation exposure from calibration source (Cs-137) | occcasional / negligible = minimal | Sources are non-accountable. Follow the time-distance-shielding principles to minimize exposure.<br><br>Radiation exposure from calibration source (Cs-137) is very low energy and poses minimal risk even in long exposures. Personnel will not carry source in pockets and will minimize exposure time and maximize distance and shielding. Keep away from dosimeter badge. | Low |

**Wastes or residual materials resulting from process**

None.

**Emergency actions to take in event of control failure**

For all injuries, provide first aid and see that injured person is taken to Occupational Medicine (only if immediate medical attention is not required) or the hospital. Follow all site-specific emergency plans for any radiation or explosives emergencies.

# CALIBRATION FACTOR FOR NEWNET PICS

The calibration factor for the NEWNET PICs was determined from 31 PICs and compared with a calculation and with the environmental TLDs. This work was performed between 17-July-2001 and 24-October-2001 and is documented in the NEWNET database and in newnet2.lanl.gov\newnetcommon\Calibrations.

## BASIC CHECKS

Zero readings were less than 0.2 microR/h.

Background readings were checked and determined to be consistent within 0.5 microR/h.

The raw voltages from the PIC were consistent to better than 0.5%.

Three Cs-137 sources were compared; results were consistent to better than 1%.

1. Source No. 2S154, manufactured by Amersham, 12.02 microcuries (+/- 3.7%) on June 1 1985, British Calibration Service certificate of calibration R2042, obtained from gamma calibration set No. 1760 owned by Jose Gutierrez, ESH-12. Decay-corrected activity in July 2001 was 8.3 microcuries.
2. Source No. 812-44-1, type D, manufactured by Isotope Products Lab., 18.30 microcuries (+/- 3.1%) on August 15, 2001, owned by MAQ. Decay corrected activity in October 2001 was 18.2 microcuries.
3. Source No. 812-44-2, type D, manufactured by Isotope Products Lab., 17.71 microcuries (+/- 3.1%) on August 15, 2001, owned by MAQ. Decay corrected activity in October 2001 was 17.6 microcuries.

Three distances were compared and scaled with $1/r^2$ to better than 1%. The distances were 5.4 inches, 5.5 inches, and 5.7 inches. (Note: the effective mean distance was obtained by integration over the volume of the PIC, and is not equal to the distance to the center of the PIC; the integral that derives the familiar result for center of gravity involves components of vectors, and is only approximate this case.)

## CALIBRATION

A Cs-137 source was placed on each PICs as described in the NEWNET calibration procedure and the total response was measured, listed as "Total" in the table. With the source removed more than 10 feet from the PIC, the background was measured. The response of the PIC, listed in the table as "Source" = Total – Background.

The calibration factor, "Cal.Fac." is the source response divided by the source activity, normalized to a distance of 5.7 inches, which corresponds to an Isotope Products Lab. Type-D source inside its 0.5-inch-thick plastic box with the sponge pad between the source and the PIC. In this configuration, the expected response of the PIC (R/h) is the calibration factor multiplied by the decay-corrected activity of the Cs-137 source (Ci).

The original data are in the Excel spreadsheets in newnetcommon\Calibrations\Fy01.

| Name | ID | Total microR/h | Background microR/h | Source microR/h | Cal.Fac. R/h•Ci |
|---|---|---|---|---|---|
| Area G South | N4509 | 263.4 | 19.6 | 243.8 | 13.4 |
| Buey | EPA26 | 255.0 | 18.0 | 237.0 | 13.0 |
| Eastgate Synrgtcs | L3102 | 267.9 | 16.6 | 251.3 | 13.8 |
| Kappa | M222 | 268.6 | 16.3 | 252.3 | 13.9 |
| Met tower | M243 | 261.9 | 17.1 | 244.8 | 13.5 |
| TA54 test | | 262.4 | 20.1 | 242.3 | 13.3 |
| Eastgate Cmpbll | | 276.5 | 17.5 | 259.0 | 14.2 |
| DP | EPA100 | 254.3 | 15.6 | 238.7 | 13.1 |
| LAHS | M227B | 265.8 | 14.2 | 251.6 | 13.8 |
| San Ildefonso | M3356 | 269.6 | 13.3 | 256.3 | 14.1 |
| Ohkay Ow. | M239 | 257.1 | 12.3 | 244.8 | 13.5 |
| Santa Clara | M231 | 262.9 | 17.1 | 245.8 | 13.5 |
| Santa Fe | M245 | 271.2 | 15.0 | 256.2 | 14.1 |
| Espanola | M235 | 272.5 | 13.2 | 259.3 | 14.2 |
| S-site | M224 | 277.1 | 15.1 | 262.0 | 14.4 |
| RSS131-920 | 920 | 273.5 | 13.7 | 259.8 | 14.3 |
| RSS131-921 | 921 | 274.6 | 13.7 | 260.9 | 14.3 |
| RSS131-922 | 922 | 264.5 | 13.7 | 250.8 | 13.8 |
| RSS131-923 | 923 | 271.6 | 13.75 | 257.9 | 14.2 |
| RSS131-924 | 924 | 269.1 | 13.8 | 255.3 | 14.0 |
| 706849 | 706849 | 138.4 | 12.7 | 125.7 | 13.6 |
| 187339 | 187339 | 140.7 | 12.6 | 128.1 | 13.9 |
| M-252 | M-252 | 142.3 | 12.6 | 129.7 | 14.0 |
| 195599 | 195599 | 145.9 | 13.4 | 132.5 | 14.3 |
| M-3357 | M-3357 | 143.0 | 12.6 | 130.4 | 14.1 |
| 187340 | 187340 | 145.3 | 13.4 | 131.9 | 14.3 |
| 184514 | 184514 | 143.3 | 12.9 | 130.4 | 14.1 |
| M-248 | M-248 | 145.4 | 12.2 | 133.2 | 14.4 |
| RS-6-2217 | RS-6-2217 | 139.7 | 13.5 | 126.2 | 13.6 |
| gloss white | gloss white | 141.3 | 13.1 | 128.2 | 13.9 |
| RSS131-879 | 879 | 147.9 | 13.5 | 134.4 | 14.3 |

The mean calibration factor for a type-D Cs-137 source in its box with the sponge pad underneath is **13.9 R/h•Ci**. For a type-D Cs-137 source removed from its box and placed directly on the PIC the calibration factor must be scaled by the inverse-square law: 13.9(5.7/5.5)2 = **14.9 R/h•Ci**.

The standard deviation of all 31 measurements in the table is 2.8%, which is better than the expected accuracy of 5%.

Twenty-five of the PICs in the table were calibrated at the Nevada Test Site, whereas the six RSS-131 PICs were calibrated by Reuter Stokes using their calibration procedure RS-SOP-

238.1. The average calibration factor for the six RSS-131s is 14.1 R/h•Ci, which is in good agreement with the overall average of 13.9 R/h•Ci..

## CALCULATION

According to "The Health Physics and Radiological Health Handbook" (1992) page 53 and "Problems and Solutions in Radiation Protection" by James Turner (1992) page 42, the standard rule of thumb $X=6CE/r^2$ is 4% low for Cs-137. X is in roentgen/hour, C in curies, r is in feet, and E = 0.662*0.85 MeV for Cs-137. Therefore, at r = 5.7 inches, the calibration factor, R/C = $1.04*6*0.662*0.85(12/5.7)^2 = 15.6$ R/h•Ci.

About 10% of the gammas are abosorbed in the 1/8-inch-thick steel wall of the PIC and in the other materials between the source and the argon. (According to the NIST web site http://physics.nist.gov/PhysRefData/XrayMassCoef/cover.html
the mass absorption coefficient in iron is 0.028 $cm^2/g$. The estimate of the effective thickness is complicated by photon trajectories that are not radial and by photons that scatter into or out of the chamber and/or produce secondary electrons in the chamber.) So the expected calibration factor is approximately 15.6*0.9 = 14.0 R/h•Ci, which is in good agreement with the measured value of 13.9 R/h•Ci.

## COMPARISON WITH TLDS

I calculated the average NEWNET dose rate for a complete year (September or October 2000 to September or October 2001), omitting major anomalies; (one 15 microR/h glitch per day contributes a 1% error, so occasional glitches are not significant). Then I multiplied by 24 and by 365.25 to calculate mR/y and adjusted by the ratio of the individual PIC calibration to the average calibration (from the table above) to get the "Adjusted NEWNET" data (mR/y).

I divided the TLD data by 0.973 to convert mrem to mR. (Note: according to our procedures and Table 4, page 63, of NCRP 69, the correct factor should have been 0.96; however, the MAQ TLDs were calibrated by ESH-4 in mR/h and the results were actually multiplied by 0.973 to convert to mrem/h, i.e., dividing by 0.973 restores the original TLD calibration.)

The following table compares NEWNET with the TLDs.

| Station | raw NEWNET (μR/h) | Adjusted NEWNET (mR/y) | TLD (mR/y) | Ratio |
| --- | --- | --- | --- | --- |
| Espanola | 13.0 | 109 | 112 | 1.03 |
| Santa Clara | 15.9 | 141 | 146 | 1.04 |
| San Ildefonso | 13.4 | 114 | 119 | 1.04 |
| Met tower | 16.9 | 151 | 152 | 1.01 |
| East Gate | 16.4 | 143 | 147 | 1.03 |

The TLD data are 3% higher than the NEWNET data. This surprisingly good agreement results from a combination of factors, some favoring TLDs and others favoring NEWNET. Both the TLDs and the NEWNET PICs are calibrated with Cs-137 but they respond differently to lower energy gammas. The PICs have a higher response near 100 keV because Ar has a higher atomic number than LiF. The PICs have a lower response below 70 keV because they have 1/8 inch steel walls. And the TLD-100 chips contain natural lithium, which causes a slight response to cosmic-ray neutrons. In conclusion, the agreement is better than I expected.

## CONCLUSION

The calibration factor is **13.9 R/h•Ci** for a type-D Cs-137 source in its 0.5-inch-thick box with the black sponge pad between the source and the PIC.

# CALIBRATION OF METEOROLOGICAL DATA

## INTRODUCTION

One method of calibration is to remove the sensors from the field, place them in a controlled environment in the laboratory, and adjust the hardware to obtain correct readings. The disadvantage of this method is: a sensor may work differently in the laboratory and in the field. For example:

- A sensor may be installed incorrectly; or
- The computer may calculate the final data incorrectly.

An alternative approach that avoids the above disadvantages is to calibrate in the field by comparing NEWNET data with data from www.weather.lanl.gov . Disadvantage of this method is: the climate may differ between the NEWNET station and the nearest meteorology tower, especially between mesa tops and canyons or during localized rain showers.

## RELATIVE HUMIDITY

There are occasions when the relative humidity is close to 100%, e.g., during night-time rain or when there is extensive fog. These occasions are easy to recognize on a graph of humidity versus time: the resulting peak has a flat top indicating saturation. Often, there are several flat-topped peaks during a month. These provide definite calibration data. At the other extreme, when the relative humidity is low (<30%) it tends to be well correlated over a wide geographical area. There can be anomalies during local rain showers, but these are rare enough that they don't cause major problems.

The inherent accuracy of the relative-humidity sensors is indicated by three scatter plots:

- NEWNET versus met. data at the TA-54 met-tower location east of Area G;
- NEWNET Area G versus NEWNET Area G Test;
- NEWNET East Gate New versus East Gate Old.

(Note, the two anomalous data were bad satellite transmissions from East Gate Old.)

The 2002 data were quantified by calculating the mean and standard deviation of the differences, as follows.

| Location | Mean difference | Standard deviation of differences |
|---|---|---|
| Met. Tower | 1 % | 3 % |
| Area G | 1 % | 1 % |
| East Gate | 1 % | 1 % |

The 2002 correlations between the other NEWNET stations and the nearest met. towers are shown in the following table. The results are satisfactory.

| Location | Mean difference | Standard deviation |
|---|---|---|
| Kappa vs TA54 | -3 % | 4 % |
| G vs TA54 | -3 % | 4 % |
| S vs TA6 | 1 % | 6 % |
| LAHS vs TA6 | 1 % | 6 % |
| DP vs TA6 | -1 % | 6 % |
| East Gate vs TA53 | 0 | 5 % |
| Santa Clara vs TA6 | 2 % | 9 % |
| Espanola vs TA6 | 6 % | 17 % |
| Espanola vs TA6 (<30%) | 3 % | 4 % |
| Ohkay vs TA6 | 11 % | 16 % |
| Ohkay vs TA6 (<30%) | 1 % | 4 % |
| Espanola vs Ohkay | 5 % | 6 % |

The 2002 readings at 100% relative humidity are as follows.

| Location | Reading at 100% |
|---|---|
| Kappa | 96 % |
| G | 94 % |
| S | 97 % |
| LAHS | 94 % |
| DP | 101 % |
| East Gate | 97 % |
| Santa Clara | 94 % |
| Espanola | 95 % |
| Ohkay | 101 % |

## *SUMMARY OF RELATIVE HUMIDITY*

These 2002 relative humidity data were accurate to about 6%. This is satisfactory.

## *TEMPERATURE*

First, compare the data where there are two measurements at the same location. The 2002 data were quantified by calculating the mean and standard deviation of the difference as follows.

| Location | Mean difference | Standard deviation |
|---|---|---|
| Met Tower | 0.2 °C | 0.5 °C |
| Area G | 0.0 °C | 0.3 °C |
| East Gate | 0.2 °C | 0.4 °C |

There is no reason to expect the temperature to be exactly the same at two different locations. Nevertheless, the correlation is satisfactory.

| Location | Mean difference | Standard deviation of the differences |
| --- | --- | --- |
| Kappa vs TA54 | 0.9 °C | 1.2 °C |
| G vs TA54 | 0.8 °C | 1.5 °C |
| S vs TA6 | 0.2 °C | 0.8 °C |
| LAHS vs TA6 | 0.3 °C | 0.9 °C |
| DP vs TA6 | 1.3 °C | 0.9 °C |
| East Gate vs TA53 | 0.6 °C | 1.1 °C |
| Santa Clara vs TA6 | 1.1 °C | 1.7 °C |
| Espanola vs TA6 | 1.7 °C | 3.1 °C |
| Ohkay vs TA6 | 1.7 °C | 2.9 °C |
| Espanola vs Ohkay | 0.0 °C | 1.2 °C |

## *SUMMARY OF TEMPERATURE DATA*

The data were accurate to about 1 °C, which is satisfactory.

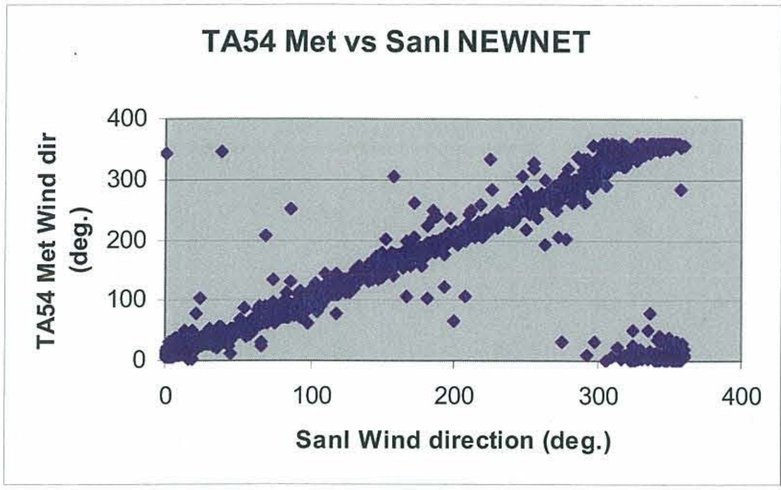
## *WIND DATA*

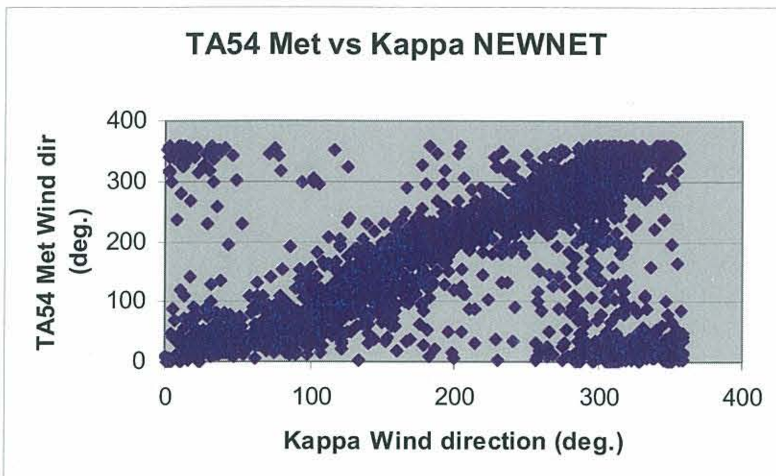
Wind speed and wind direction at NEWNET stations can be compared with Met. tower data. For example, the following tables compare the December-2005 TA54 Met. Tower with (a) the adjacent NEWNET station, 50 m away, and (b through f) the NEWNET stations at Area G, San Ildefonso Pueblo, Kappa Site, Canada del Buey, and East Gate. Row f compares the TA53 Met. Tower with East Gate.

| Location of NEWNET to be compared with Met. Tower | Mean difference of wind directions (Met. – NEWNET) | Standard deviation of the differences |
| --- | --- | --- |
| (a) nearest NEWNET | 10° | 15° |
| (b) NEWNET at Area G | 20° | 30° |
| (c) San Ildefonso Pueblo | 8° | 10° |
| (d) Kappa Site | 7° | 40° |
| (e) Canada del Buey | 0° | 30° |
| (f) East Gate vs TA54 | 0° | 50° |
| (g) East Gate vs TA53 | 0° | 20° |

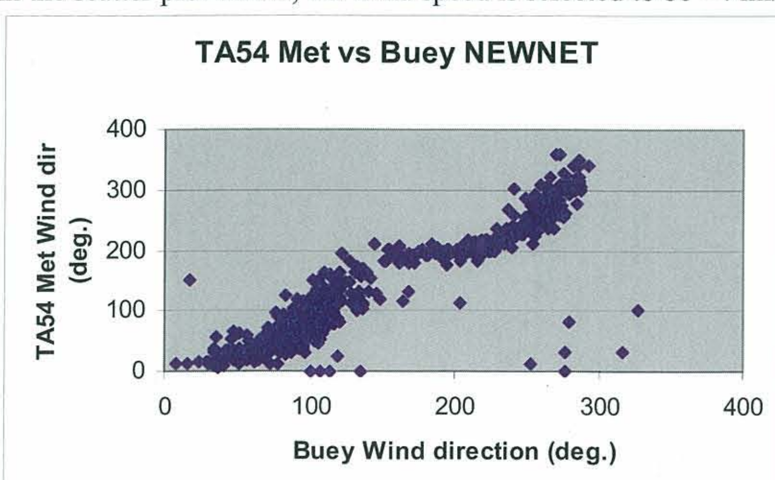
Notice that East Gate correlates better with the TA53 Met Tower than with TA54.

The San Ildefonso Pueblo data, below, look better than the Kappa Site data, probably because Kappa Site is influenced by the nearby canyons.




The Canada del Buey winds are affected by the canada (which is another word for canyon): when the Met. Tower wind is from the north or south, the canyon wind tends to be from the east or west. (Note: in the scatter plot below, the wind speed is selected to be >4 mi/h.)



The wind speeds correlate well, except in Canada del Buey where the wind speed is consistently less than at the Met. Tower, see below. This difference is probably caused by the canyon walls.

| Location of NEWNET to be compared with Met. Tower | Mean difference of wind speeds (mi/h) (Met. – NEWNET) | Standard deviation of the differences (mi/h) |
|---|---|---|
| (a) nearest NEWNET | 0.3 | 1 |
| (b) NEWNET at Area G | 0.1 | 2 |
| (c) San Ildefonso Pueblo | 0.2 | 1 |
| (d) Kappa Site | 0.0 | 2 |
| (e) Canada del Buey | 1.8 | 2 |
| (f) East Gate vs TA54 | 0.4 | 3 |
| (g) East Gate vs TA53 | 0.3 | 2 |

## CONCLUSION

The NEWNET meteorological data can be calibrated by comparison with the meteorology data.