ORTEC®

FoodGuard-1™

Food and Water Contamination Monitoring System for Microsoft® Windows® XP Professional SP3 and Windows 7 (FG-1-BW)

System User's Manual

Software Version 2

Advanced Measurement Technology, Inc.

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

WARRANTY

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NOTE!

We assume that you are thoroughly familiar with Microsoft®
Windows® usage and terminology. If you are not fully acquainted
with the Windows environment, including the use of the mouse,
please take time to familiarize yourself with a few simple
Windows applications before proceeding.

The convention used in this manual to represent actual keys
pressed is to enclose the key label within angle brackets; for
example, **<F1>**. For key combinations, the key labels are joined
by a + within the angle brackets; for example, **<Alt + 2>**.

1. INTRODUCTION

The ORTEC FoodGuard-1 system can be used to rapidly and accurately screen various food-stuffs for the radionuclides expected from events in nuclear power plants: ^{131}I, ^{103}Ru, ^{134}Cs, and ^{137}Cs. The naturally-occurring isotope, ^{40}K, is also reported and can be used to monitor system performance. The system is portable so it can be used where the foodstuffs are gathered, imported, sold, or consumed.

FoodGuard-1 consists of a sodium iodide (NaI) detector in a lead shield, a digiBASE® integrated PMT base and multichannel buffer (MCB), and a laptop or desktop PC running under 32-bit Microsoft® Windows® XP SP3 or Windows 7, or 64-bit Windows 7. The digiBASE supplies the multichannel analyzer function, the high voltage for the NaI detector, and all the signal processing electronics. The digiBASE is powered by the PC's USB port. The complete system is designed for use over a wide range of environmental conditions, and can be transported in two subunits: the shield/detector assembly and the PC. Figure 1 shows a cross-sectional diagram of the major system components.

Figure 1. FoodGuard-1 Assembly Cross-Section.

Samples are checked by placing the sample in a 1 liter Marinelli beaker. The beaker is then placed in the detector in the shield. The operator enters the identification data for each sample on the Food-Guard-1 software's data screens; then the software collects the data, analyzes the spectrum, checks the results against allowable limits, and prints the report. The spectra and reports are also saved on the PC hard disk. Samples that exceed user-defined alarm limits are noted onscreen and clearly marked on the report.

The spectrum analysis uses an "interference region-of-interest (ROI) matrix" method used in other ORTEC products and described by Baratte.[1] The matrix operations are based on *Numerical Recipes*.[2]

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[1]Edmond J. Baratte, Associate Chapter Editor, *AOAC Official Methods of Analysis* (1984), ¶ 48.025.

[2]W.H. Press, B.P. Flannery, S.A. Teukolsky, and W.T. Vetterling, *Numerical Recipes*, Cambridge Press (1986), used by permission.

There are two major workflow divisions in the FoodGuard-1 software:

- The password-protected *supervisor* functions allow you to pre-configure sampling information including sampling locations, sample types, test laboratory(s) or team(s), maximum acceptable radionuclide limits, and report contents (Sections 3.2 and 3.3); recalibrate the detector (Chapter 3.4); and generate reports on sampling results and system performance (Section 3.5).

- The *operator* functions are used for sample and background measurements. No password is required to perform these activities. See Chapter 2.

The FoodGuard-1 program works in conjunction with the accompanying MAESTRO® MCA Emulation Software. This manual tells you everything you need to know to operate both programs for the purposes of FoodGuard-1 sample analysis. For information on other features of MAESTRO, refer to its accompanying user's manual.

1.1. Manual Contents

- Chapter 2 gives stepwise instructions on background and sample measurements; then provides more detailed, illustrated information on each procedure.

- Chapter 3 covers all password-locked ("supervisor") software configuration steps.

- Appendix A discusses system installation.

- Appendix B explains FoodGuard-1's analysis methods.

- Appendix C contains maintenance information, and is intended to be used in consultation with your ORTEC representative or our Global Service Center.'

A PDF-format copy of this manual is also on the installation CD.

1.2. Host PC and Software Requirements

FoodGuard-1 and the digiBASE are designed for use with any PC running under 32-bit Microsoft® Windows® XP Professional SP3 or Windows 7, or 64-bit Windows 7; using the supplied version of MAESTRO and the CONNECTIONS Driver Update Kit.

2. MEASURING SAMPLES

This chapter jumps directly to the instructions for routine sample and background measurements. Before you can measure samples, the FoodGuard-1 system must be set up and calibrated according to the instructions in Chapter 3. Setup requires password access.

Once the system is calibrated and the data acquisition settings for the digiBASE are set up, FoodGuard-1 guides you through the steps necessary to control the digiBASE, acquire and analyze the data, and generate spectrum files and reports.

2.1. System Startup

From the Windows Start menu, select **FoodGuard**, then **FoodGuard-1** (Fig. 2).

Figure 2. Start FoodGuard-1.

FoodGuard-1 always opens on the Run screen (Fig. 3),[3] which displays the current sample measurement settings, which are pre-configured on the Setup tab (password required).
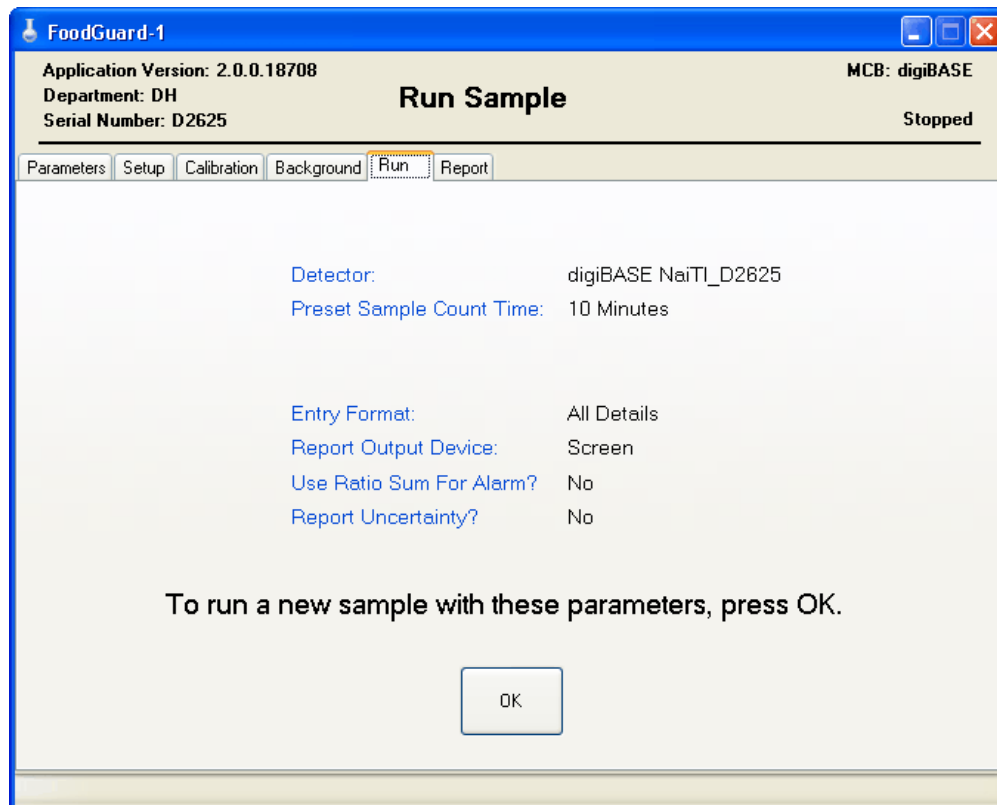
Figure 3. The Opening Screen (always opens on the Run tab).

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[3]If the detector high voltage is off, the high voltage warmup screen (Fig. 16) is displayed for 30 seconds.

2.2. Quick Reference: Daily Work Flow

The next two subsections list the basic steps for performing a background count and measuring sample radiation with FoodGuard-1.

For details on these procedures, including illustrations, see Section 2.3.

2.2.1. Background Count

If the system has been moved to a new location, a background count has not been collected in a long time, or it is suspected that the background has changed, be sure to perform a background count. Detailed instructions are in Section 2.3.1.

☞ Position the lead shield and digiBASE away from direct sunlight and contact with water.

☞ Turn on the PC and connect the digiBASE to it via USB cable.

☞ Check the inside of the shield for contamination, remove all sources from the vicinity, and make sure the ^{40}K check source ring is in position.

☞ Start the FoodGuard-1 software, click on the Background tab, and click on **OK** to display the background count screen.

☞ Select the **Location** from the droplist and click on **OK** to start data collection.

☞ At the end of the predefined count,[4] FoodGuard-1 will analyze the results and display them onscreen.

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[4]Setting the background count time requires password access. We recommend a minimum count of 30 minutes.

2.2.2. Sample Measurement

When you have acquired a background count that is valid for the current site, you are ready to measure samples. Detailed instructions are in Section 2.3.2.

☞   Prepare the sample in a 1 L Marinelli beaker.

☞   With the ^{40}K check source ring in place, put the sample beaker on the detector in the shield and close the lid.

☞   Click on the **Run** tab and select **OK** to accept the counting parameter summary shown on the screen.[5]

☞   If this is an **All Details** count, on the next screen select the **Sample Type**, **Sample Name**, **Sample Location**, **Team Name**, **Collection** date and time, **Imported** or **Local** status, the **Sample Weight**, and the **Food Origin**.

If this is a **Sample Code** count, on the next screen enter a valid **Sample Code** (see page 9), **Imported** or **Local** status, the **Sample Weight**, and the **Food Origin**.

☞   When you are satisfied with your selections, click on **OK** to begin the count.

☞   FoodGuard-1 will collect the spectrum for the predefined time, analyze it, and generate the report. Any activity above the alarm limits will be displayed on the report and posted on the status bar at the bottom of the FoodGuard-1 screen. To repeat a measurement, simply click on **OK**.

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[5]Setting the counting parameters requires password access.

2.3. Detailed Instructions: Background and Sample Counting

2.3.1. Background Count

When you click on the Background tab, the screen (Fig. 4) displays the current background information. These values will be used to calculate the net count rate until a new background count is completed.
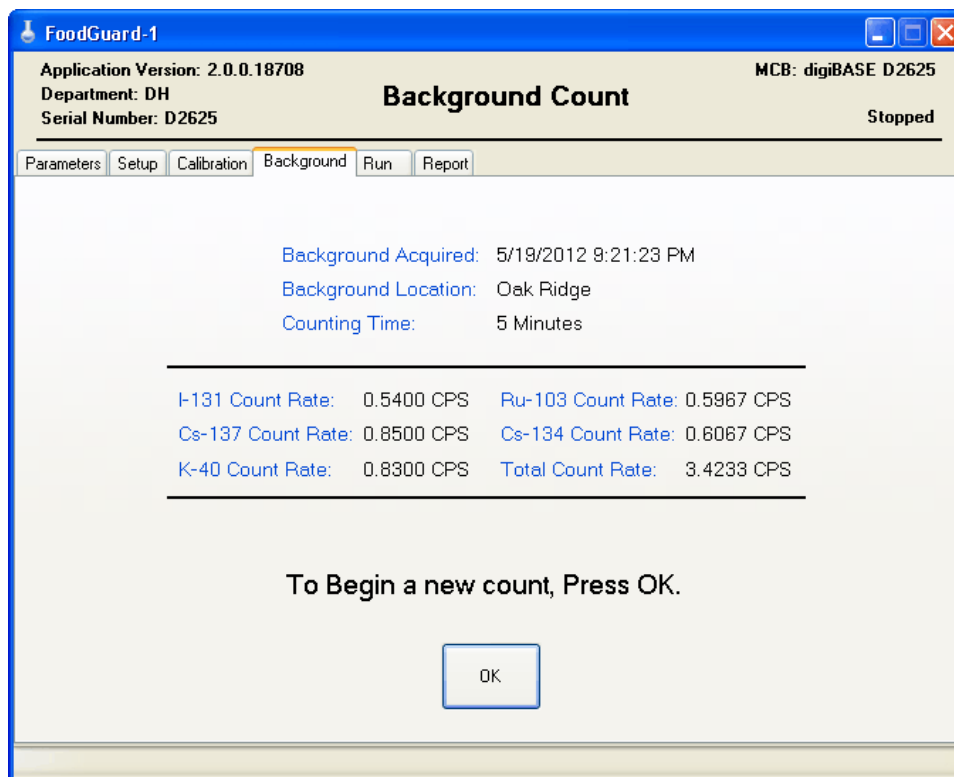
Figure 4. The Current Background Information.

To perform a new background count:

☞   Click on **OK** to display the next screen (Fig. 5).

☞   Choose the location from the droplist and click on **OK** to begin the background count. Figure 6 shows the screen while the count is in progress.

> **NOTE**   You can switch to the Parameters, Setup, and Report tabs while counting. However, you can only go to Calibration or Run tab by aborting the measurement. Clicking on either of these tabs opens a dialog that asks if you wish to quit the current background count. Click **No** to continue the background count. Click **Yes** to abort the count and go to the tab you selected.

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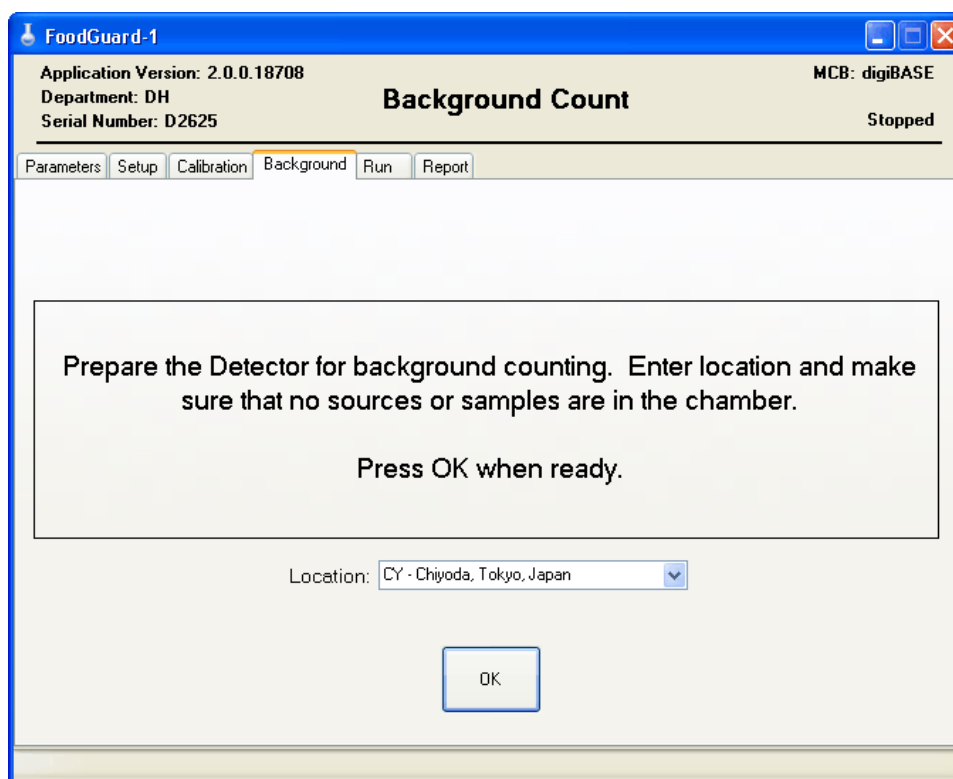
Figure 5. Choose the Location and Start the New Background Count.

Figure 6. New Background Count In Progress.

☞ To terminate the background count, click on either the Calibration or Run tab and answer **Yes**. The system will continue using the most recently completed background measurement for net peak count calculations.

☞ At the end of the predefined count, FoodGuard-1 will analyze the results and display them onscreen (Fig. 7).

☞ If the results are not acceptable, simply click on **OK** to start a new background count.

Figure 7. The Updated Background Information.

2.3.2. Sample Measurement

Clicking on the Run tab displays the screen shown in Fig. 8. To start a sample measurement:

☞ Click on **OK** to accept the counting parameter summary on the screen.
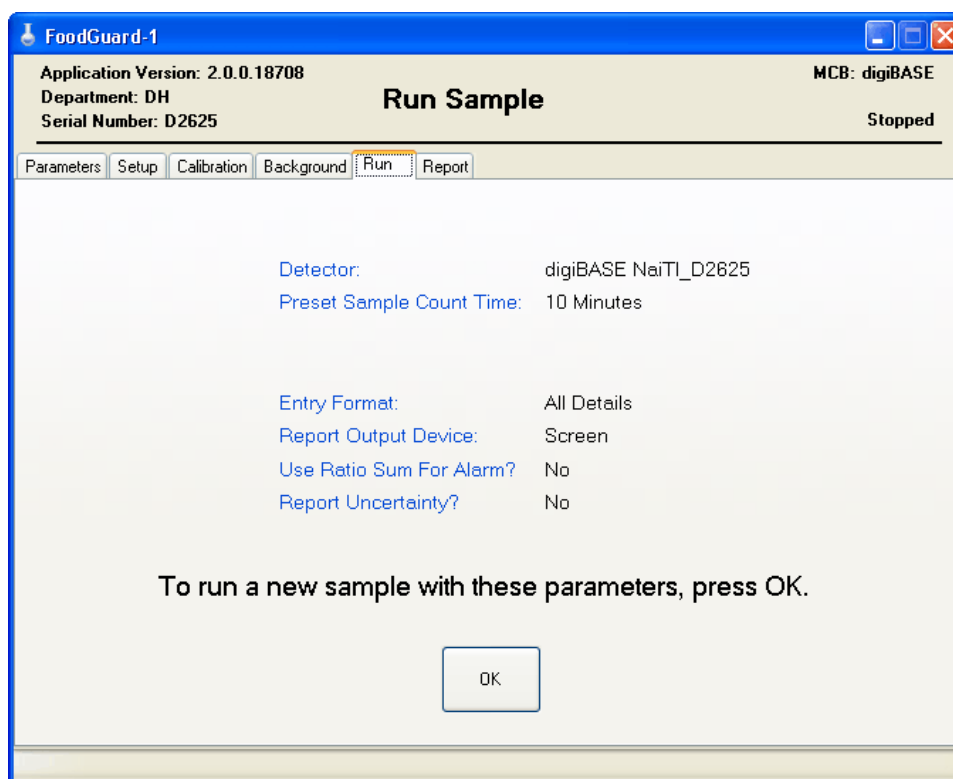
Figure 8. Click OK to Accept the Sample Count Parameters.

☞   The appearance of the next screen will depend on the currently selected **Entry Format**. If this is an **All Details** count, the screen will appear as shown in Fig. 9.

Figure 10 shows the screen for a **Sample Code** count. To be valid, sample codes must contain 21 characters, formatted as follows:

$$[SS]\text{-}[LL]\text{-}[YYMMDDhhmm]\text{-}[CC]\text{-}[T]$$

where SS is the 2-letter Sample Name code, LL is the 2-letter Location Code, YYMMDDhhmm is the sample collection date and time, CC is the 2-letter Department Code, and T is the 1-letter Team code. All codes must be predefined on the Parameters screen (Section 3.2).

In both cases, it is important that you enter the correct codes because they are used to catalog the results for later studies and to locate records for reporting. Suppose you assign a sample code that contains an incorrect sample collection date — for example, May 23, 2011 at 12:00:00 when the sample was actually collected in June and not May. If you then run a Sampling Statistics Report for all samples collected in June 2011, this record will not be retrieved.

Figure 9. The "All Details" Entry Format.

Figure 10. The "Sample Code" Entry Format.

☞   When you are satisfied with your selections, click on **OK** to begin the count. During the measurement, the screen will display status information for the measurement (Fig. 11).

> **NOTE**   You can switch to the Parameters, Setup, and Report tabs while the count is in progress. However, you can only go to Calibration or Background tab by aborting the measurement. Clicking on either of these tabs opens a dialog that asks if you wish to quit the current sample run. Click **No** to continue the measurement. Click **Yes** to abort the count and go to the tab you selected.
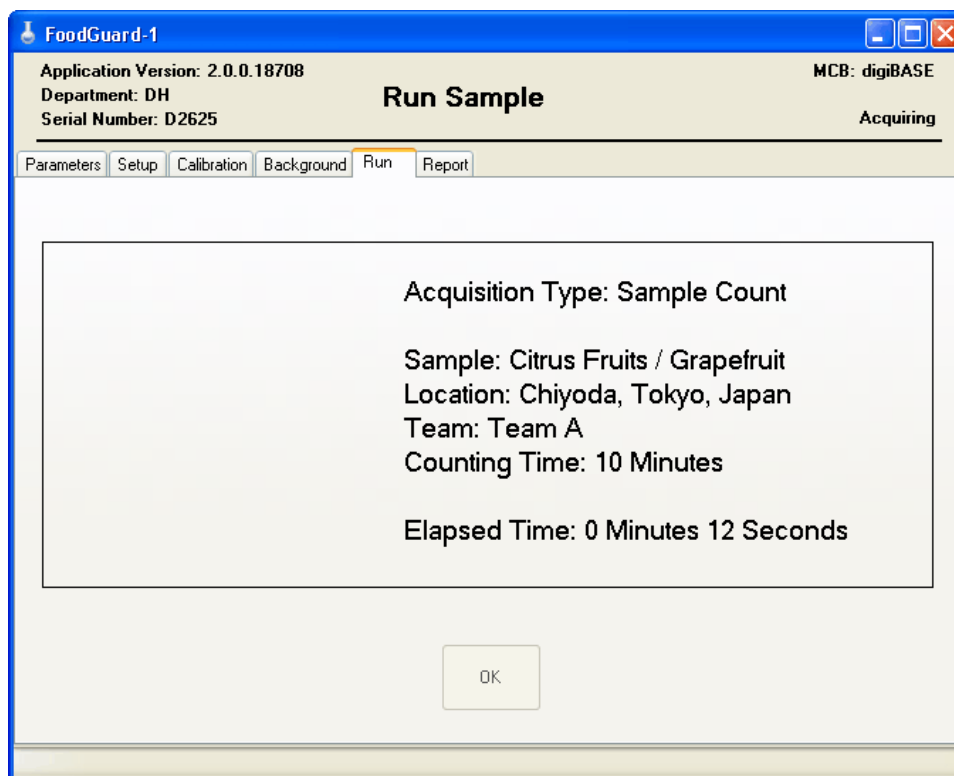
Figure 11. Sample Measurement In Progress.

☞   FoodGuard-1 will collect the spectrum for the predefined time, analyze it, display the results onscreen, and generate a report. Any activity above the alarm limits will be posted in red on the status bar at the bottom of the program window marked with an asterisk (*) on the report. Figures 12 and 13 respectively illustrate an alarm onscreen and on the report.

☞   The spectrum will also be saved as an ORTEC .CHN-format file in the folder C:\User\ FoodGuard-1\Spectra. The filename format is:

YY-MM-DD HH.MM.[minute fraction].CHN

☞   If the results are not acceptable, simply click on **OK** to repeat the count.

☞   To speed up sample processing, once you select a sample descriptor, it persists from measurement to measurement until you select a different value.
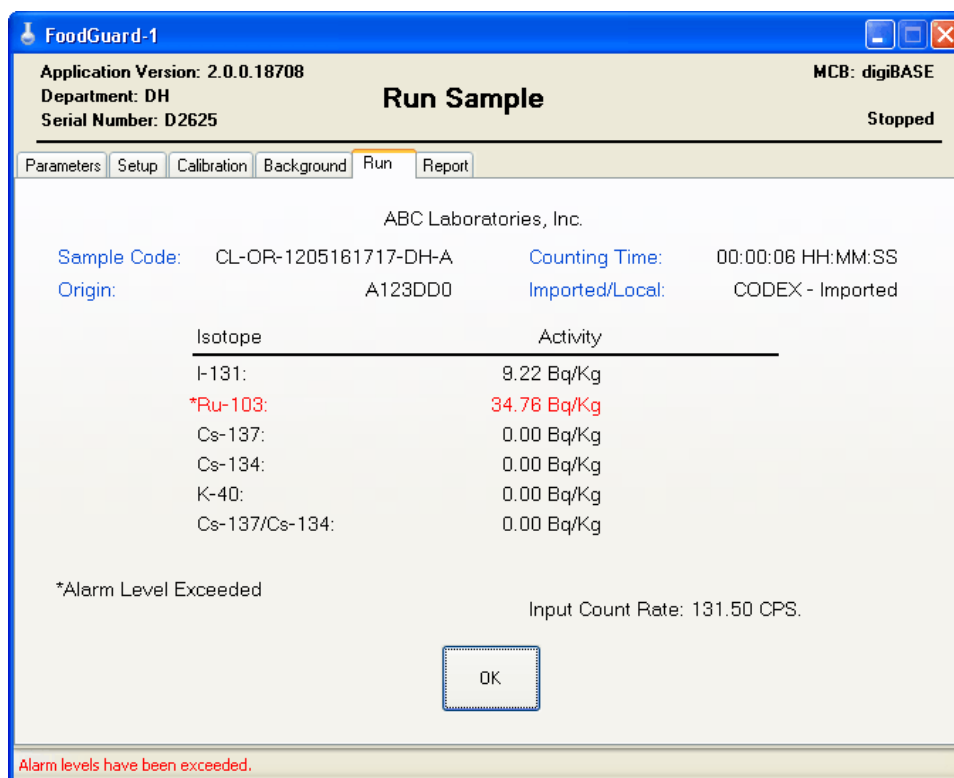
Figure 12. Sample Result: [103]Ru Activity Exceeds the Alarm Limit.

```
                        ABC Laboratories, Inc.

                    Contamination Monitoring Result by
                  Food/Water Contamination Monitoring System

From : Department of Health
CMS Serial No. : D2625
------------------------------------------------------------------------------
Sample Name/Type :    Lemons / Citrus Fruits
Sampling Location :   Oak Ridge
Detector :            digiBASE D2625 RANDT960
Sample Weight :       1.00 Kg
Alarm Reporting :     Absolute
Food Type :           CODEX - Imported Food
Sample Team :         Team A              Sample Code :   CL-OR-1205192202-DH-A
Sampling Date :       19 / 05 / 2012      Sampling Time : 22 : 02
                      DD / MM / YYYY                      HH : MM
Food Origin :         A123DD0
------------------------------------------------------------------------------
Measurement Location : Oak Ridge

Time and Date of Measurement : 22 : 02    19 / 05 / 2012
                               HH : MM    DD / MM / YYYY
Counting Time : 1.00 Min

                    Radionuclide            Activity (Bq/Kg)
                    ----------------------------------------
                    I-131                            0.00
                    Ru-103                          34.76*
                    Cs-137                           0.00
                    Cs-134                           0.00
                    K-40                             0.00
                    Cs-137/Cs-134                    0.00

  Ratio Sum         :     0.0000
  Input Count Rate :   131.5000

* Alarm Level Exceeded
==============================================================================

Originator : _____ Post : _____
             (Name & Signature)

Date :  __ / __ / ____    Time : __ : __
        DD / MM / YYYY           HH : MM
```

Figure 13. Sample Result Report Showing [103]Ru Alarm.

3. SUPERVISOR MODE

This chapter provides details on software setup, running calibration checks, and reporting; and tells how to run a quick system check using a sealed, pre-measured sample beaker of potassium chloride (KCl).

3.1. Software Startup

● From the Windows Start menu, select **FoodGuard** and **FoodGuard**-1 (Fig. 14).

Figure 14. Start FoodGuard-1.

● FoodGuard-1 always opens on the Run tab (Fig. 15) unless the detector high voltage is off.
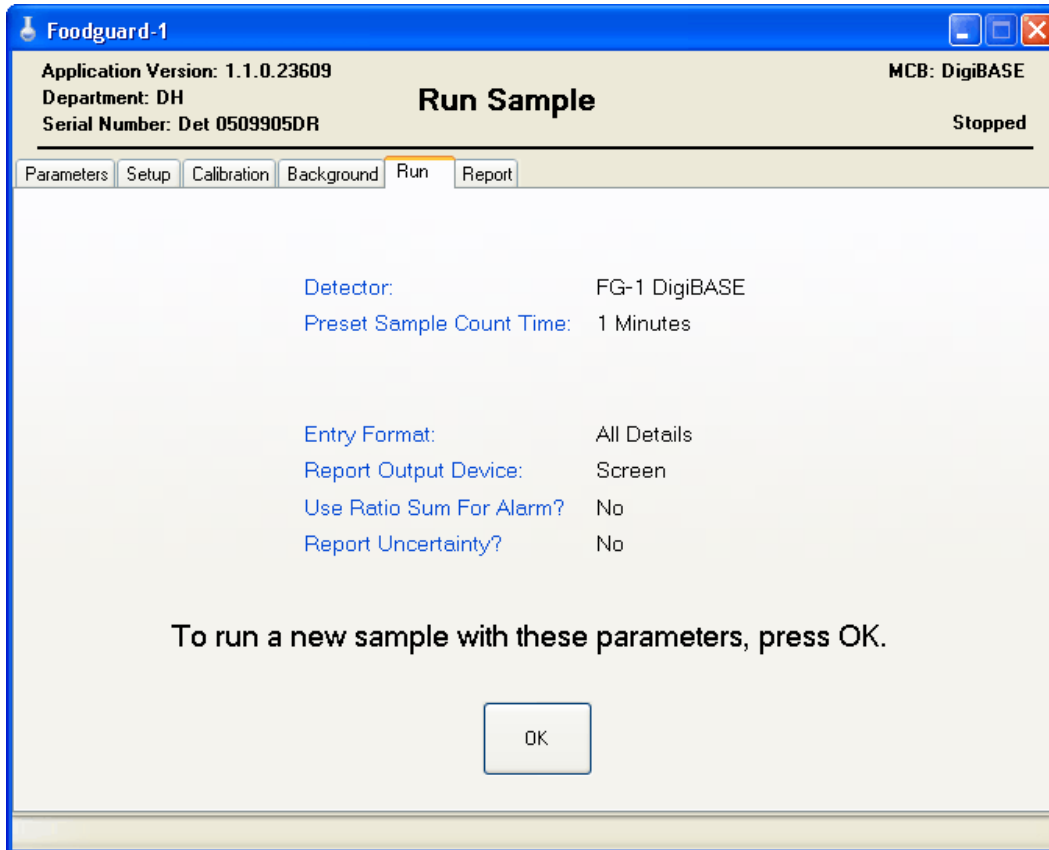
Figure 15. The Opening Screen (always opens on the Run tab).

● If the high voltage is off, the high voltage startup screen is displayed first (Fig. 16). This gives the detector high voltage 30 seconds to turn on and stabilize, after which the Run tab is displayed.
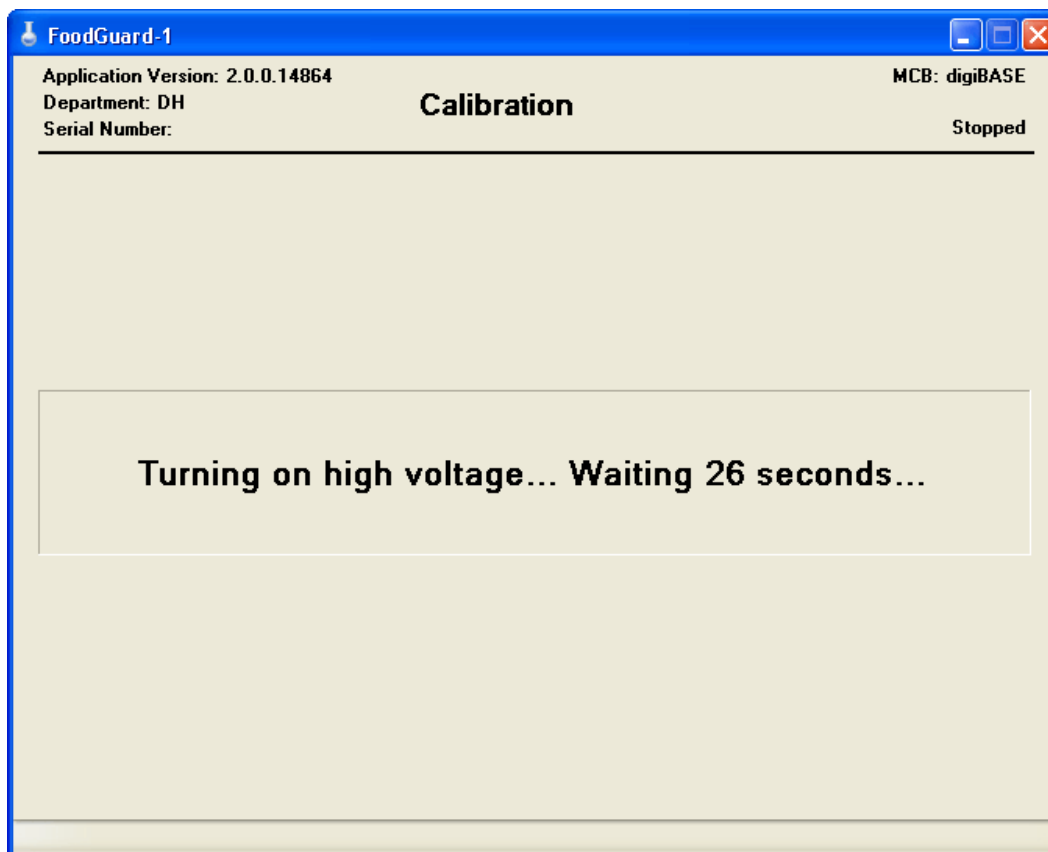
Figure 16. Detector High Voltage Startup Screen.

- After HV startup, the program displays the Run tab. If the power to the digiBASE is not interrupted between work sessions, the detector high voltage remains on, and on subsequent startup of the FoodGuard-1 program, the Run tab is displayed as soon as the splash screen fades.[6]

3.1.1. Password Locking/Unlocking

The Parameters, Setup, Calibration, and Report tabs are considered *supervisor mode* screens because they allow a user to configure and maintain the settings that govern and evaluate system operation. These screens are locked with a password set on the Setup screen (Section 3.3.9). The Run and Background tabs do not require a password.

NOTE   The password can contain both alphabetical and numerical characters and is case-sensitive. The factory default password is ORTEC (all uppercase).

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[6]If the detector is disconnected or cannot communicate with the FoodGuard-1 software, a red "detector not ready" message is displayed at the bottom of the Run tab (see Fig. 42 on page 43). Referring to Section 3.3, go to the Setup tab and, if necessary, select the digiBASE from the **Detector** droplist. In addition, check the USB cable, and confirm that the detector is still firmly seated in the digiBASE socket base.

Each time you start the FoodGuard-1 program, clicking on one of the four supervisor mode screens opens the password dialog (Fig. 17). Enter the password and click on **OK**. You can then access all software settings.

NOTE *To "re-lock" FoodGuard-1 for subsequent users, exit and restart the program.*
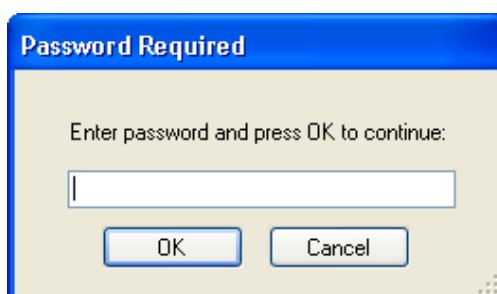
Figure 17. Enter the Password to Access Supervisor Mode.

3.2. Parameters

Figure 18 shows the initial Parameters screen. This screen should be configured first because other screens require some of the codes defined here. For example, the list of **Department Codes** is used on the Setup screen. ***The codes on this screen are alphabetical only; no numerals.*** However, the descriptions accept both types of characters.

Note that this screen is primed with one value per parameter type. When you begin adding your own values, you may delete the factory values if you wish (we recommend leaving one value in each parameter table).

Add — Click on this button to create a new entry for the corresponding parameter type. A data entry dialog will open; Fig. 19 shows the Add Sample Type dialog. Enter the desired abbreviation and description, and click on **OK**.

• **Sample Type** accepts a 1-letter **Code** and an alphanumeric **Description**.

• **Sample Names** (Fig. 20) requires you to select a Sample Type code, then enter a 1-letter "sub-class" code. For example, for the sample type C - Citrus fruits, you might wish to define Sample Names for specific types of citrus fruit (e.g., L for lemons).

• **Team Names** accepts a 1-letter code with no description. If you have multiple laboratories or system operators, this lets you determine which lab or other entity performed a particular measurement.

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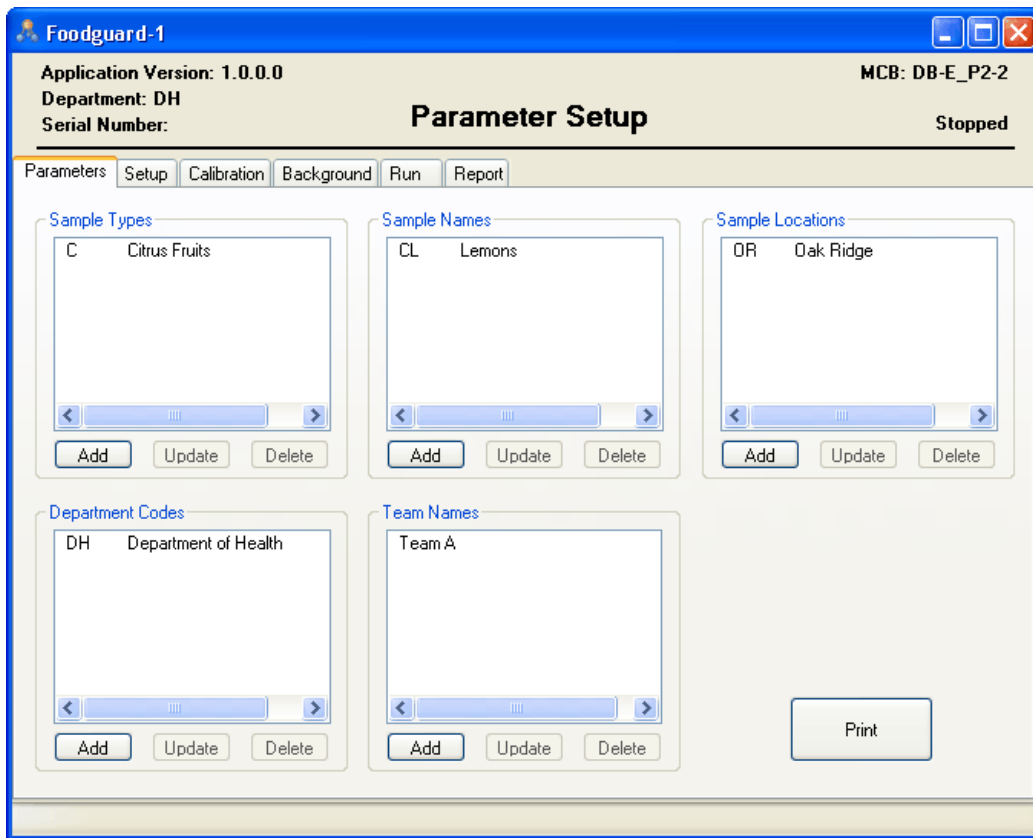
Figure 18. Initial Parameters Screen.

- The **Sample Locations** and **Department Codes** have 2-letter codes and an alphanumeric description.
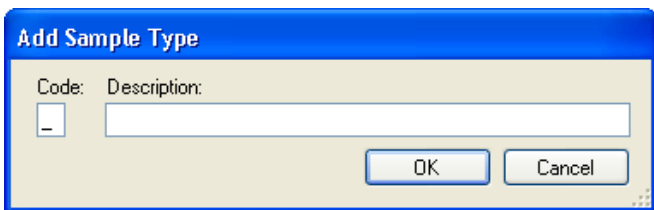
Figure 19. Add a New Sample Type.
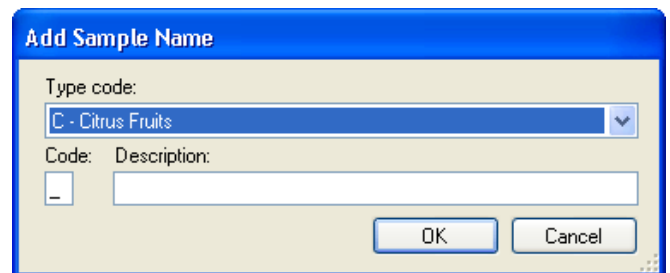
Figure 20. Select a Sample Type and Append a New Sample Name (Subcategory).

Update — To edit an existing value, click to highlight the entry, then click on **Update** to open a dialog similar to the Add dialog. Click on **OK** to accept the modified value.

Delete — To remove an entry, click to highlight it, then click on **Delete**. There is no "undo" for this operation, but restoring an accidentally deleted value is easy.

Figure 21 shows an example of a more fully configured Parameters screen.
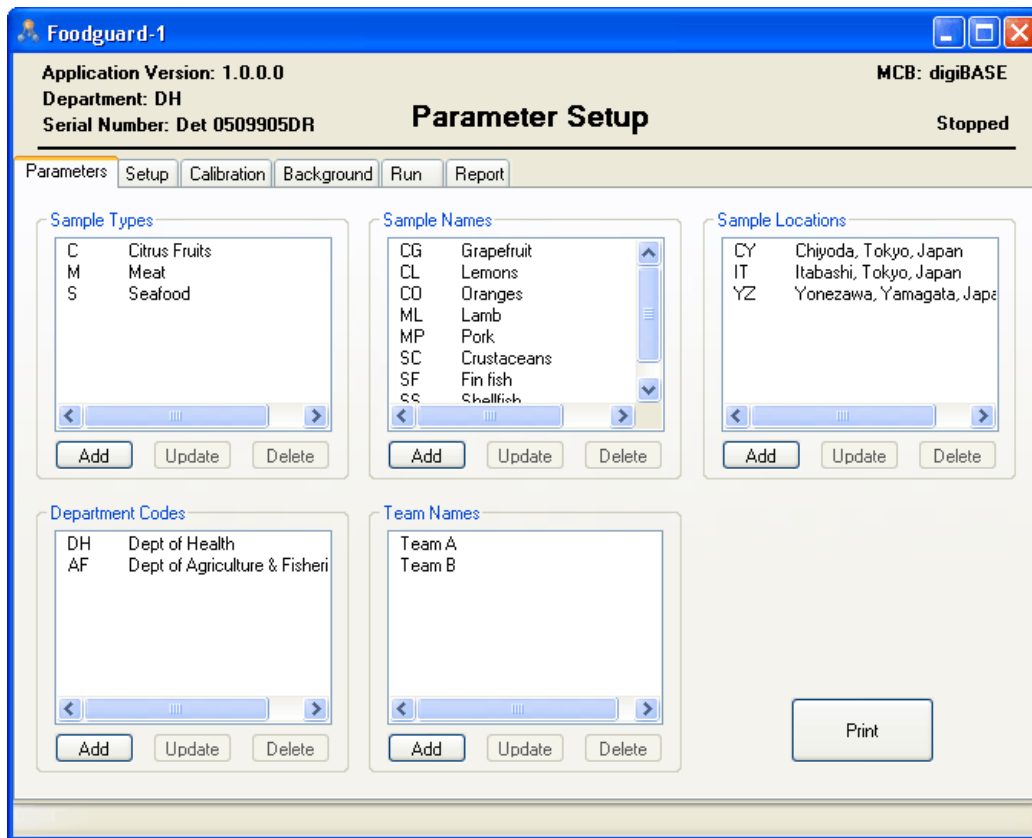
Figure 21. Parameters Screen.

3.3. Setup

Use the Setup screen to:

● Pre-select the **Detector** to be used, the count time presets for sample and background measurements; analysis mode, data entry, and reporting options; and administrative data including the **Department Code**, the detector's **Serial Number**, and the desired **Report Header** for the current set of measurements.

● Update the **Supervisor Password**.

● Select alarm thresholds based on input count rate and the sum of net counts for all monitored radionuclides.

● Use the underlying **Alarm Setup** screen to set the radiation alarm limits for each sample type and radionuclide.

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NOTE   The values on this screen can be changed at any time. There is no "undo," and the changes take effect immediately.

If you wish, you can **Print** a report that reflects the entries on this screen (except the password). This will open a report window that provides several basic viewing tools. Click on the report window's **Close** button to return to this screen.

Figure 22 shows a configured Setup screen.

Figure 22. The Setup Screen.

3.3.1. Count Presets

The **Preset Sample Count Time** entered here is used for sample measurements on the Run tab and cannot be changed there; i.e., only users with password access can change the count time.[7]

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[7]It is also used as the count time for each efficiency calibration source during manual calibration, and can be changed on that screen.

The **Preset Background Count Time** is used on the Background tab and cannot be changed there. It is also used as the suggested **Background Count** time on the Calibration tab, and can be changed there.

NOTE   *We strongly recommend a minimum background count time of 30 minutes*. A typical sample count time is half the background count time.

3.3.2. Maximum Input Count Rate Alarm

If the maximum input count rate, in counts per second (cps), exceeds the value in this field, a red alarm message is displayed on the status line at the bottom of the FoodGuard-1 screen.

3.3.3. Entry Format

The **Entry Format** determines the data fields the operator must complete before starting each sample measurement. The left and right sides of Fig. 23 compare the Run screen fields for the **All Details** and **Sample Code** choices, respectively.

Figure 23. Comparison of All Details and Sample Code Data Entry on Run Screen.

- **All Details** — In this mode, the operator chooses from multiple sample parameter droplists before the measurement, and enters the sample weight and food origin fields. The droplist selections for each sample are included in the reports and are also concatenated to form the name of each analysis record.

- **Sample Code** — This mode bypasses the multiple droplists. Instead the operator works from *a prepared list of samples*, each identified by a unique 21-character **Sample Code**. This code forms the name of each analysis record, and is translated into sample details for the report. The sample code is formatted as:

<div align="center">[SS]-[LL]-[YYMMDDhhmm]-[CC]-[T]</div>

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where SS is the 2-letter Sample Name code, LL is the 2-letter Location Code, YYMMDDhhmm is the sample collection date and time, CC is the 2-letter Department Code, and T is the 1-letter Team code. All codes must be predefined on the Parameters screen (Section 3.2), and the **Department Code** must be pre-selected on the Setup screen.

3.3.4. Reporting Options

The **Report Output Device** options let you choose whether to view the results report onscreen, print the report, or save it as an ASCII text file in C:\User\FoodGuard-1\Reports. You can also choose to report uncertainty.

3.3.5. Ratio Sum Alarm

If you mark **Yes**, the absolute level (**AL**) reporting values entered on the Alarm screen (Section 3.3.10) are used to calculate a Ratio Sum for each measurement of a food type. The Ratio Sum is calculated by summing the (net count rate / AL) values for all nuclides for a food type. An alarm is generated if the Ratio Sum is greater than 1.0 and the **Use Ratio Sum For Alarm?** option is marked **Yes**.

3.3.6. Report Uncertainty

Mark this option to display the sample measurement uncertainty (Section B.3) on the reports.

3.3.7. MDC Level Reporting

Use this option to count to the Minimum Detectable Concentration, which is defined as the Minimum Detectable Activity (MDA) divided by the volume or weight of the material being counted. The MDA is based on the smallest activity that can be measured with a given confidence level for true positives and false negatives (FoodGuard-1 uses a confidence level of 5% for each). This equates to a 95% identification of the nuclide when it is present at the MDA value. Table 3 in Section B.4 lists MDC values, which are based on measurements with a 1 L Marinelli beaker of water.

3.3.8. Use Stabilizer

This is an expert feature for use on samples containing radionuclides with gamma rays at energies near 1461 keV (requires an independent screening method to determine such gamma rays are present).

3.3.9. Update Password

As noted earlier, the default password is ORTEC (all uppercase). To update the password, simply type a new entry into the **Supervisor Password** and **Confirm Password** fields, then click on the

Update Password button. The next time the FoodGuard-1 program is started, the new password will go into effect. Passwords can be any combination of alphanumeric characters and are *case-sensitive.*

NOTE   *There is no master password.* If you change the password and subsequently lose it, you must contact your ORTEC representative or our Global Service Center for assistance.

3.3.10. Food Type Alarm Setup

Click on the **Alarm Setup** button to display the screen shown in Fig. 24. It allows you to define alarm limits for any combination of **Sample Type** vs. **Imported Food** or **Local Food**; and for any or all of the radionuclides monitored by FoodGuard-1. Thus, if you have three (3) Sample Types, and are measuring imported and local samples of all three, you will enter alarm limits on 2 × 3 = 6 screens (e.g., Sample Type #1/Imported, Sample Type #1/Local, Sample Type #2/Imported, Sample Type #2/Local, and so forth).

Figure 24. Setting Alarm Limits for Imported Citrus Fruits.

Each nuclide can have different alarm limits. You may change the limits and alarm reporting options at any time.

NOTE   There is no "undo," and the changes take effect immediately.

Samples that exceed alarm limits trigger a message on the status line at the bottom of the FoodGuard-1 screen and are marked with an asterisk (*) on the reports. (See Figs. 12 and 13 beginning on page 12.)

To define alarm limits:

- Click on the **Imported** button or the **Local** button, then select a **Sample Type** from the droplist.

- Select the desired **Alarm Reporting** option based on the nature of the sample., e.g., **Absolute Level** vs. **Percent**, and **Kilograms** vs. **Liters**.

- In the row labeled **DIL Bq/L** or **DIL Bq/kg**, enter the FDA Defined Intervention Level (DIL) for each radionuclide, according to the food type parameters.

- Enter the desired alarm types and limits. Repeat for each combination of sample type and imported/local food.

    — **AL**   Absolute level reporting (in Bq/kg or Bq/L). An alarm is generated if the net count rate is greater than the **AL** value entered here.

        NOTE   The values entered in the **AL** row are used for the Ratio Sum alarm (configured on the Setup screen; Section 3.3.5). The Ratio Sum is calculated by summing the (net count rate / AL) values for all nuclides. An alarm is generated if the Ratio Sum is greater than 1.0 and the **Use Ratio Sum For Alarm?** option on the Setup page is marked.

    — **AL (%)**   Percent reporting. An alarm is generated if (net count rate / DIL) $\times$ 100 is greater than the **AL (%)** value entered here.

Click on **Print** to generate a report of all alarm limits. This will open a report window that provides several basic viewing tools. Click on the report window's **Close** button to return to this screen.

Click on **System Setup** to return to the Setup screen, or simply click on another tab.

3.4. Calibration (Short Procedure)

This section guides you through a quick, straightforward calibration of your FoodGuard-1 system, which is very important for good results. No calibration standards are required, only the system's ^{40}K check source ring.

NOTE   *The FoodGuard-1 system requires only this short calibration procedure, except in extraordinary circumstances.* The manual calibration routine described in Appendix C is for diagnostic/maintenance purposes, and should only be performed in consultation with your ORTEC representative or our Global Service Center.

In this procedure, you simply adjust the detector amplifier's fine gain to center the 1461 keV peak of ^{40}K (from the ^{40}K check source ring) in channel 900 (Section 3.4.1). After that, recalibration takes just three mouse clicks to reload a subset of the original factory calibration (Section 3.4.2), and you're ready to begin background and sample counting!

Figure 25 shows the opening Calibration screen. The upper right section of the screen provides instructions. The left-hand sidebar shows the four **Calibration steps**. The checkboxes in the sidebar track the completion of each step. Below the sidebar is a progress bar and a "stop count" button ($\boxed{\times}$).
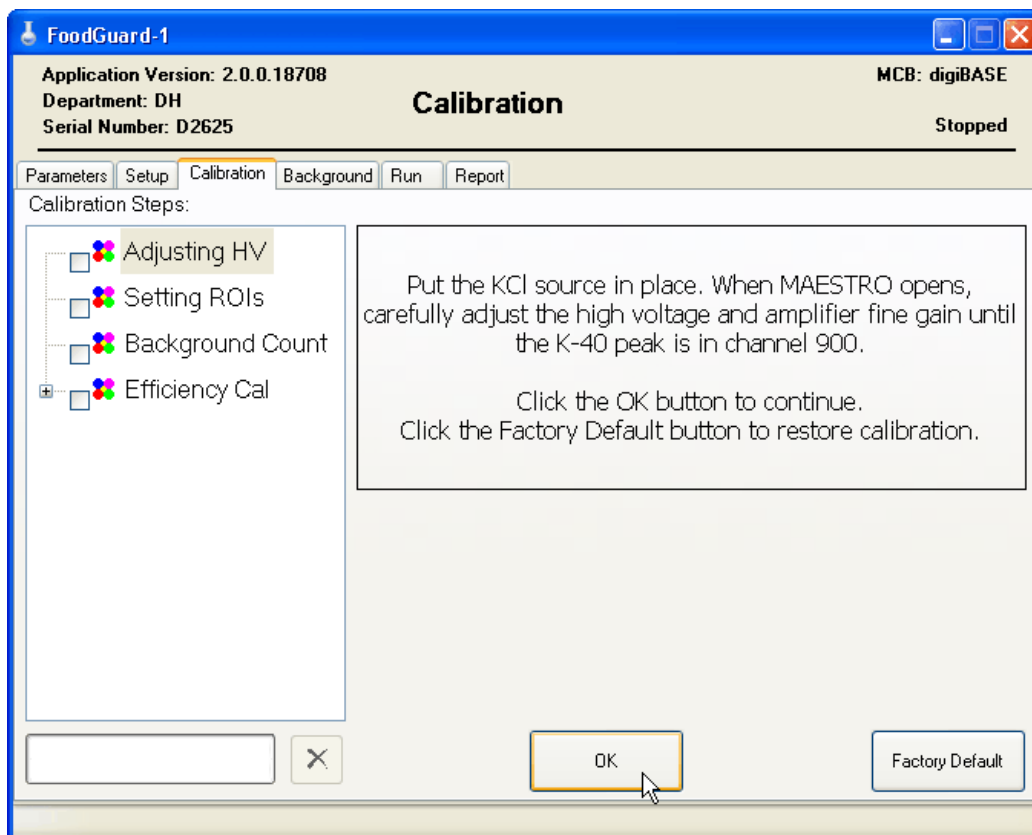
Figure 25. Calibration Screen.

3.4.1. Step 1: Positioning the ⁴⁰K Peak in Channel 900

- Before calibrating, check the Setup screen to ensure the digiBASE is listed in the **Detector** field. Return to the Calibration screen.

- With the ⁴⁰K check source ring in position, remove all other sources, and click **OK** to open MAESTRO. The Calibration screen will appear as shown in Fig. 26.

- After a few seconds, the spectrum window for the digiBASE will open with data acquisition underway. The right-hand Status Sidebar will display the real time, live time, and dead time for the current data acquisition.[8]

- Click in the spectrum window and press **<Alt+F7>** to display the full spectrum.
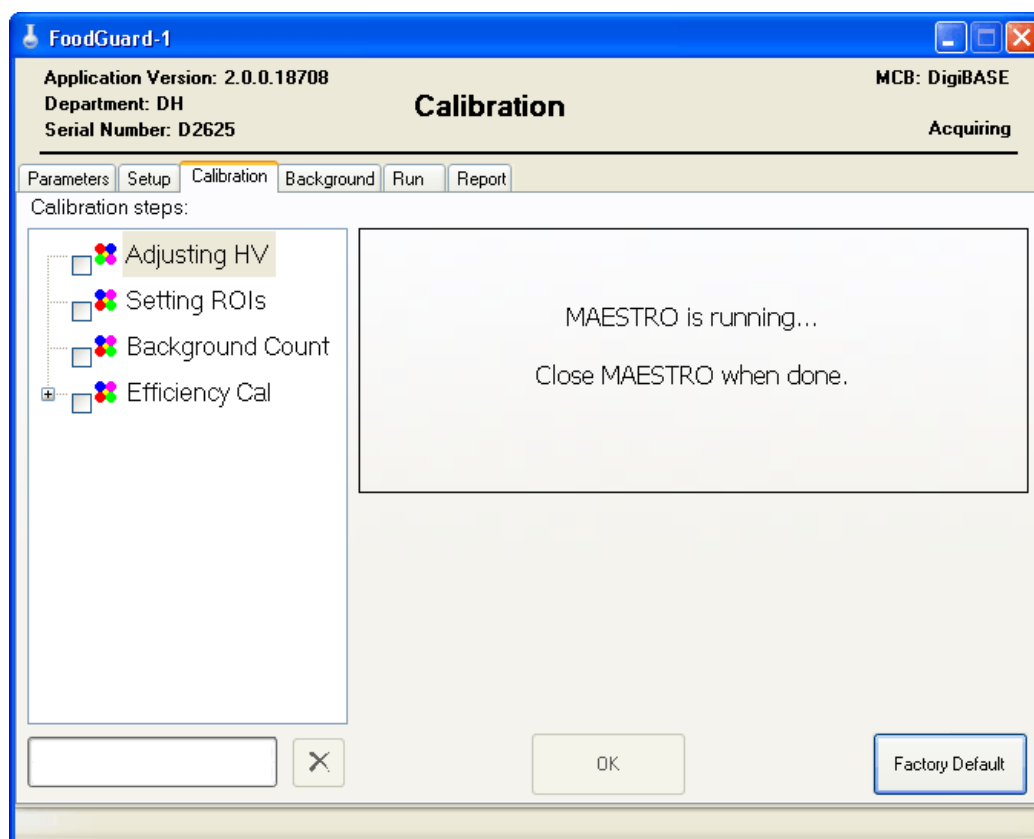
Figure 26. Calibration Screen During HV/Fine Gain Adjustment.

- Clear the detector memory by pressing **<Alt+3>** or clicking the **Clear** button on the toolbar (⌷).

---

[8]If signal from the digiBASE to the PC is interrupted during calibration, exit and restart the FoodGuard-1 program, then restart the calibration routine.

- You will now use the MAESTRO controls for high voltage and amplifier fine gain to center the 1461 keV peak of ^{40}K in channel 900 on the spectrum window. From the MAESTRO menu bar, click on **Acquire/MCB Properties**, select the High Voltage tab (Fig. 27).

- Acquire 10–30 seconds of data until you see the 1461 keV peak of ^{40}K begin to accumulate. The system is pre-configured at the factory, so the peak should already be located on the high-energy (right-hand) side of the spectrum window.
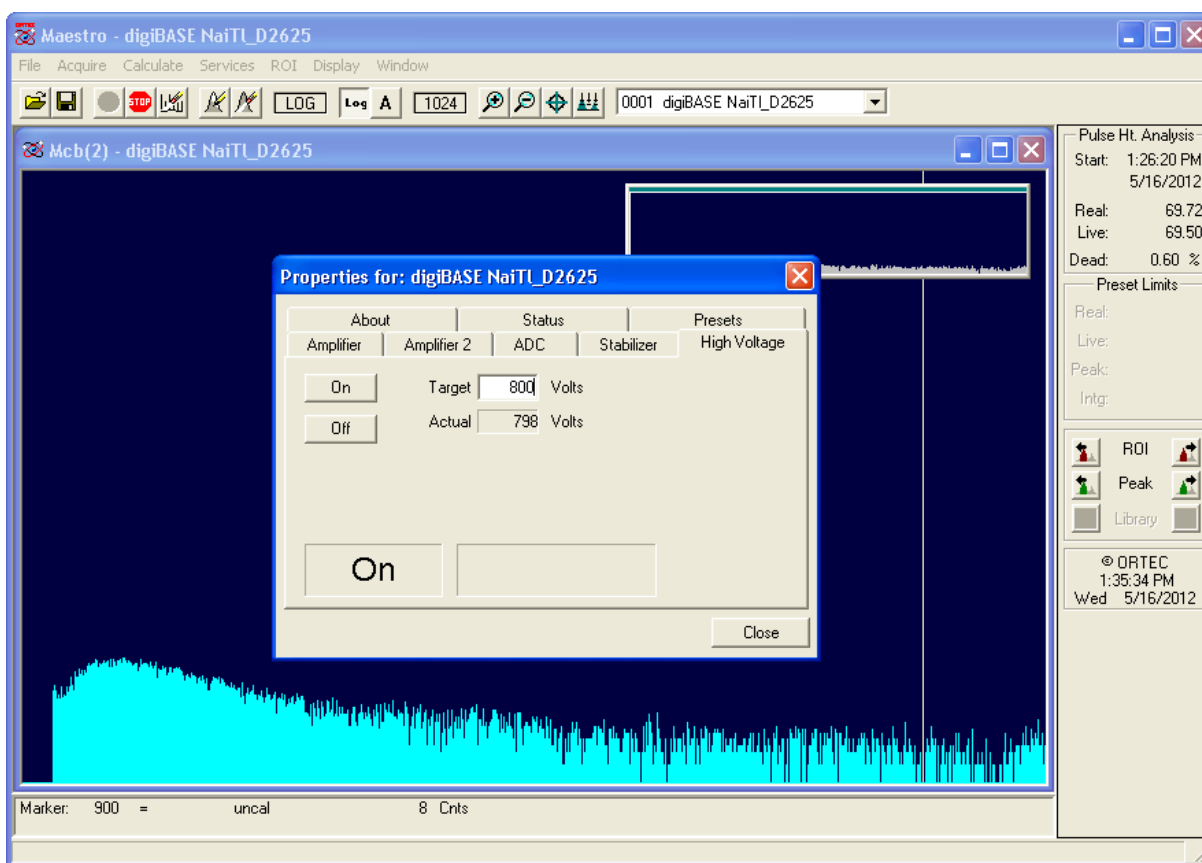
Figure 27. Adjust the Target High Voltage Value If Necessary.

— If you do not see the peak, click in the **Target** field and enter a value 10–25 V lower than the current value. The **Actual** field will update to show the HV being applied to the detector. Clear the detector memory and acquire another 10–30 seconds of data. Continue reducing the HV, clearing the detector memory, and acquiring more data until the 1461 keV peak is visible on the right-hand side of the spectrum window.

- Next, locate channel 900. To do this, click in the spectrum window to move the horizontal *marker* line to the spectrum channel you clicked, and read the **Marker** channel number in the area immediately below the spectrum window. Click as close as possible to channel 900,

then use the left/right arrow keys to position the marker on channel 900. (Zoom in, if you wish, with the keypad's + key.)

● Now adjust the HV as needed, clearing the detector after each adjustment, to position the 1461 keV peak near channel 900 or slightly higher (to the right).

● Switch to the Amplifier tab and enter slight adjustments of the **Fine** gain (clearing the detector memory and acquiring more data after each adjustment) to center the 1461 keV peak in channel 900. Start with a change of 0.01 gain units to get an idea of the amount of peak shift it will cause, then make iterative adjustments until the peak is properly centered in the target channel. To clearly locate the center of the peak for an accurate final adjustment, you will need to collect enough data (perhaps for several minutes) to obtain a relatively smooth, well-formed peak. See Fig. 28.

● When the 1461 keV peak is centered in channel 900, close MAESTRO by clicking on the upper-right **Close** (×) box, and return to the FoodGuard-1 Calibration screen.
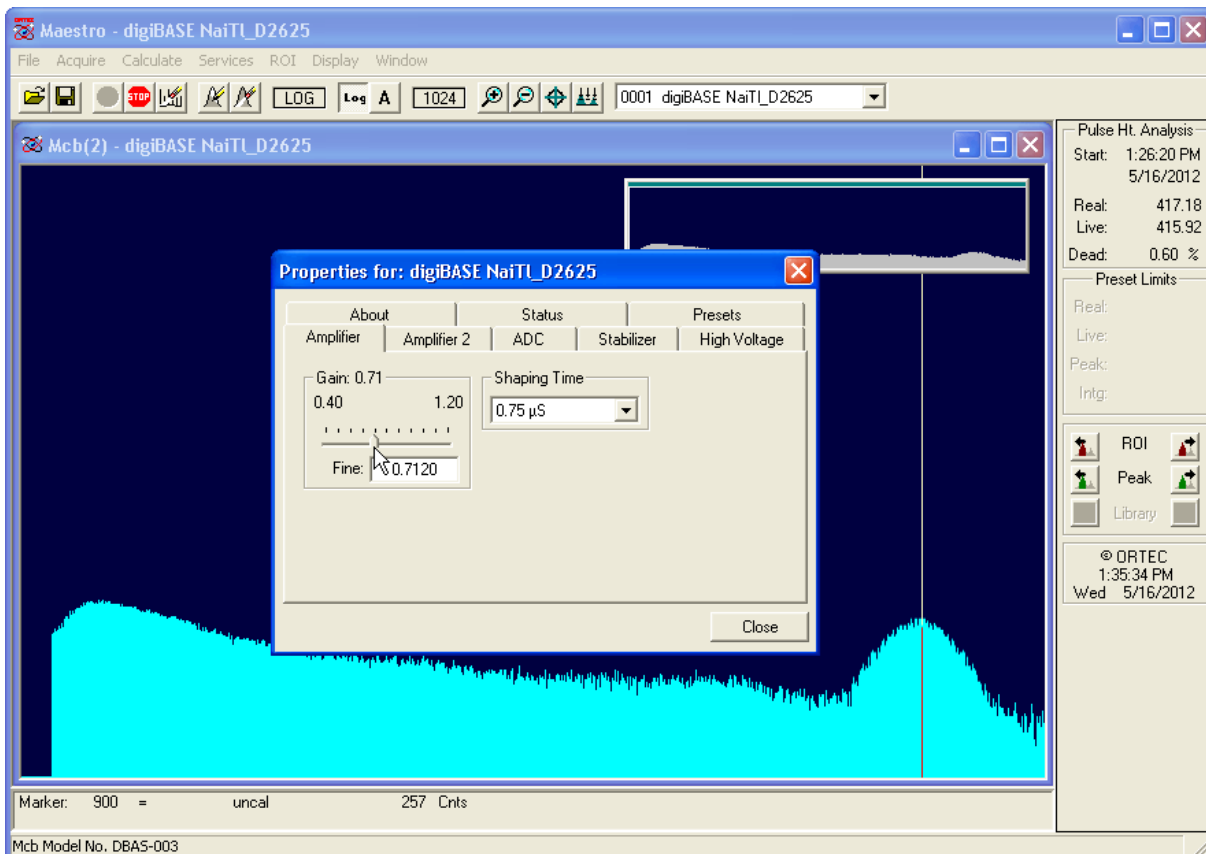
Figure 28. Put Marker in Channel 900 and Use Fine Gain to Center the 1461 keV Peak.

3.4.2. Step 2: Three Clicks Complete the Calibration

The final step: simply click the **Skip** button three times (this ignores the Setting ROIs, Background Count, and Efficiency Cal screens, which are for maintenance purposes only) until the Calibration is Complete! message is displayed and all four checkboxes in the left-hand sidebar are marked (Fig. 29).[9]

The system is now ready for food and water monitoring, *beginning with a background count* as detailed in Section 2.3.1.
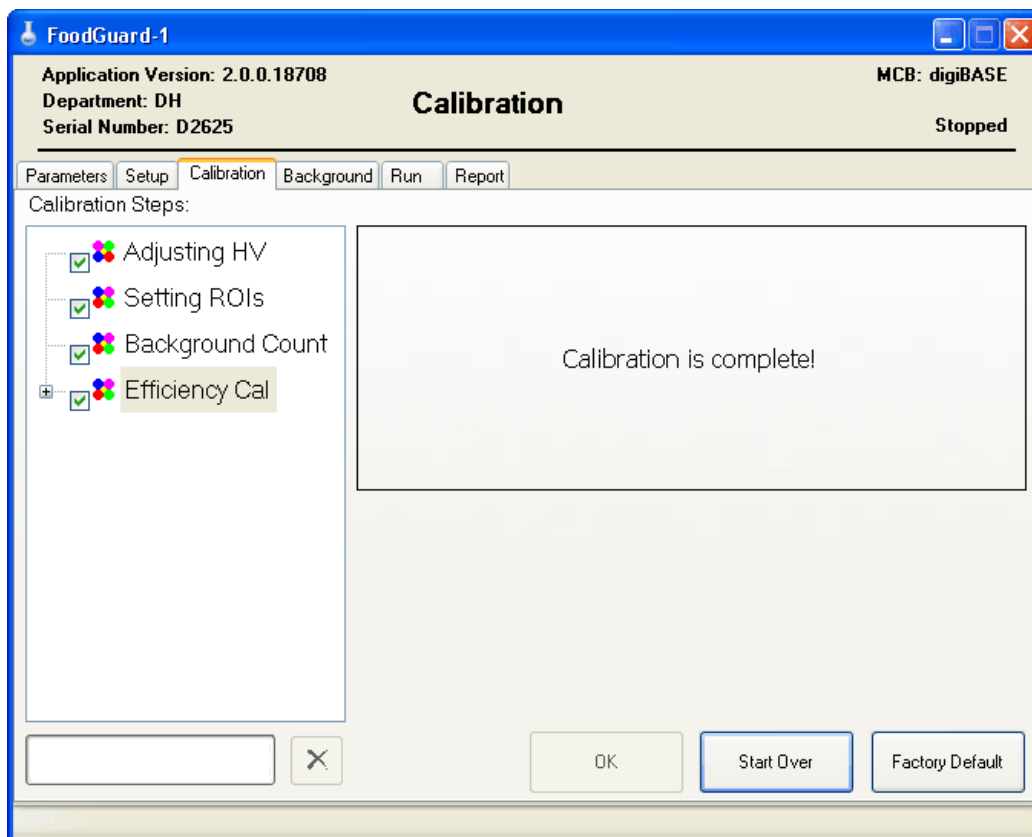
Figure 29. Calibration Is Complete.

---

[9]The screens you skip here are used in the manual calibration procedure, which is used only for maintenance purposes, and is intended to be performed in consultation with ORTEC.

3.5. Report

This screen lets you choose from six reports (**Data Operation**), complete the prompts for that option, choose the reporting format (**Screen**, **Printer**, **Disk**), and click on **Generate Report**.

The six reports available are:

- **Short Format**   Activity summary for a single measurement.
- **Full Format**   The standard sample measurement report.
- **Dual Format**   Select two measurements to compare the results.
- **Daily Summary**   A summary of the samples analyzed on a specified day, by nuclide.
- **Sampling Statistics**   Breakdown of samples by sample type for a specified range of dates.
- **Measurement Statistics**   Activity summaries by sample type and date range for one or all nuclides.

The last option on the droplist allows you to **Delete Records**. This is discussed in Section 3.5.1.

The **Report to Disk** option creates an ASCII text file (.TXT) text file with the name you assign. Reports are written to C:\User\FoodGuard-1\Reports. A message on the status bar at the bottom of the program window confirms the file has been created (Fig. 30).

Report: C:\User\FoodGuard-1\Reports\CL-OR-1105012250-DH-A.Txt created.

Figure 30. Text File Created.

The **Report to Screen** option opens a report window that provides several basic viewing tools. Click on the **Close** button to return to FoodGuard-1.

Figure 31 shows the Report screen for the short-format report, illustrating the **Select Sample** list.
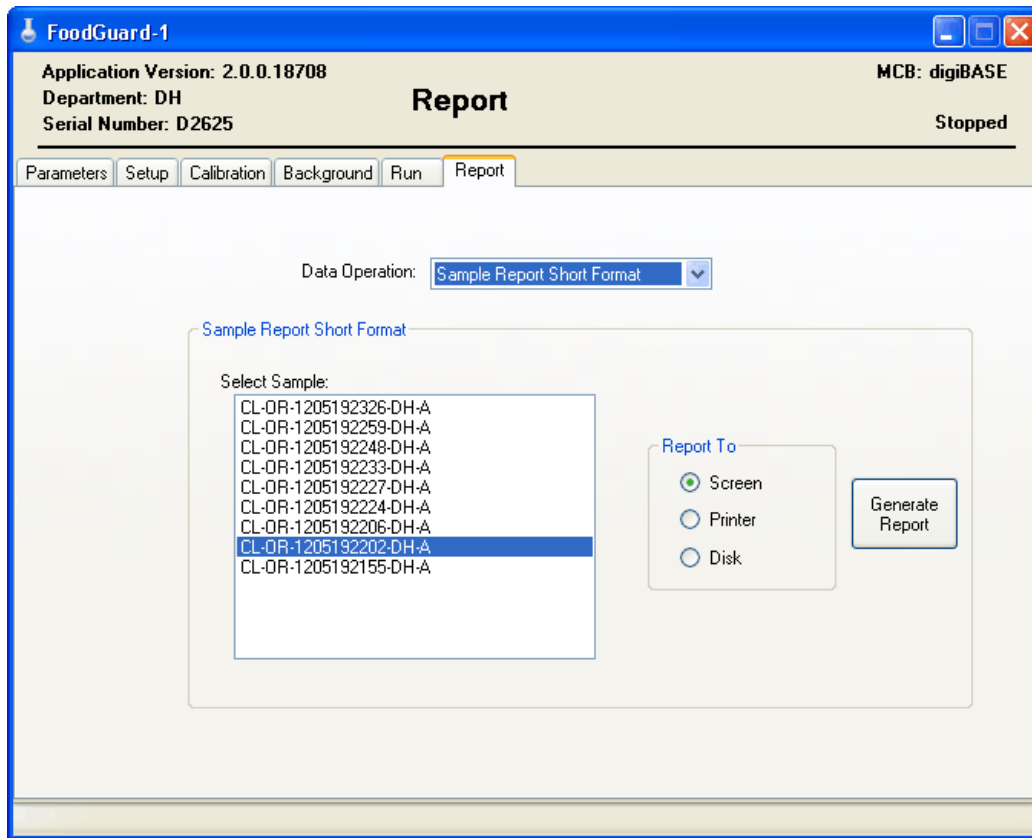
Figure 31. Short Format Report Screen.

Figure 32 shows the screens for the Sampling Statistics and Measurement Statistics reports, illustrating the other types of data prompts for the reports.
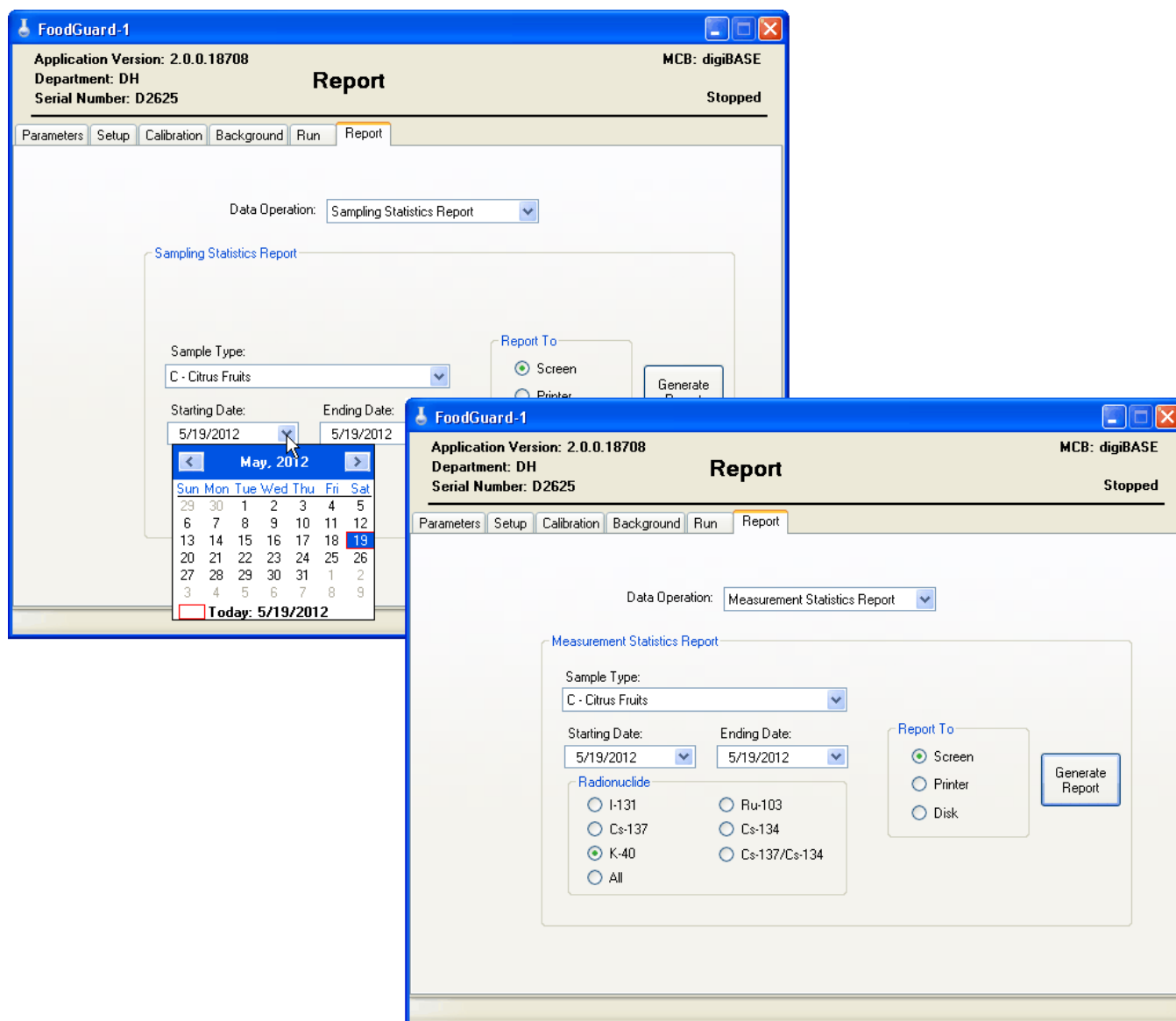
Figure 32. Sampling Statistics and Measurement Statistics Report Screens.

IMPORTANT   The Starting Date and End Date fields allow you to select the **Sampling period** that appears on the report. These dates refer to the *sample collection date and time*, as distinguished from the **Sampling date**, which is the date and time the sample was measured for radiation with FoodGuard-1.[10]

---

[10]This is the start-acquisition time captured in the .CHN spectrum file for the measurement.

For measurements using 21-character Sample Codes (see page 9), Food-Guard-1 reads the YYMMDDhhmm string in the sample code as the *sample collection date and time*, whether or not it is correct. If a sample is assigned an incorrect date, its **Sampling period** date will also be incorrect.

Figure 33 compares the short- and full-format reports for the same sample.
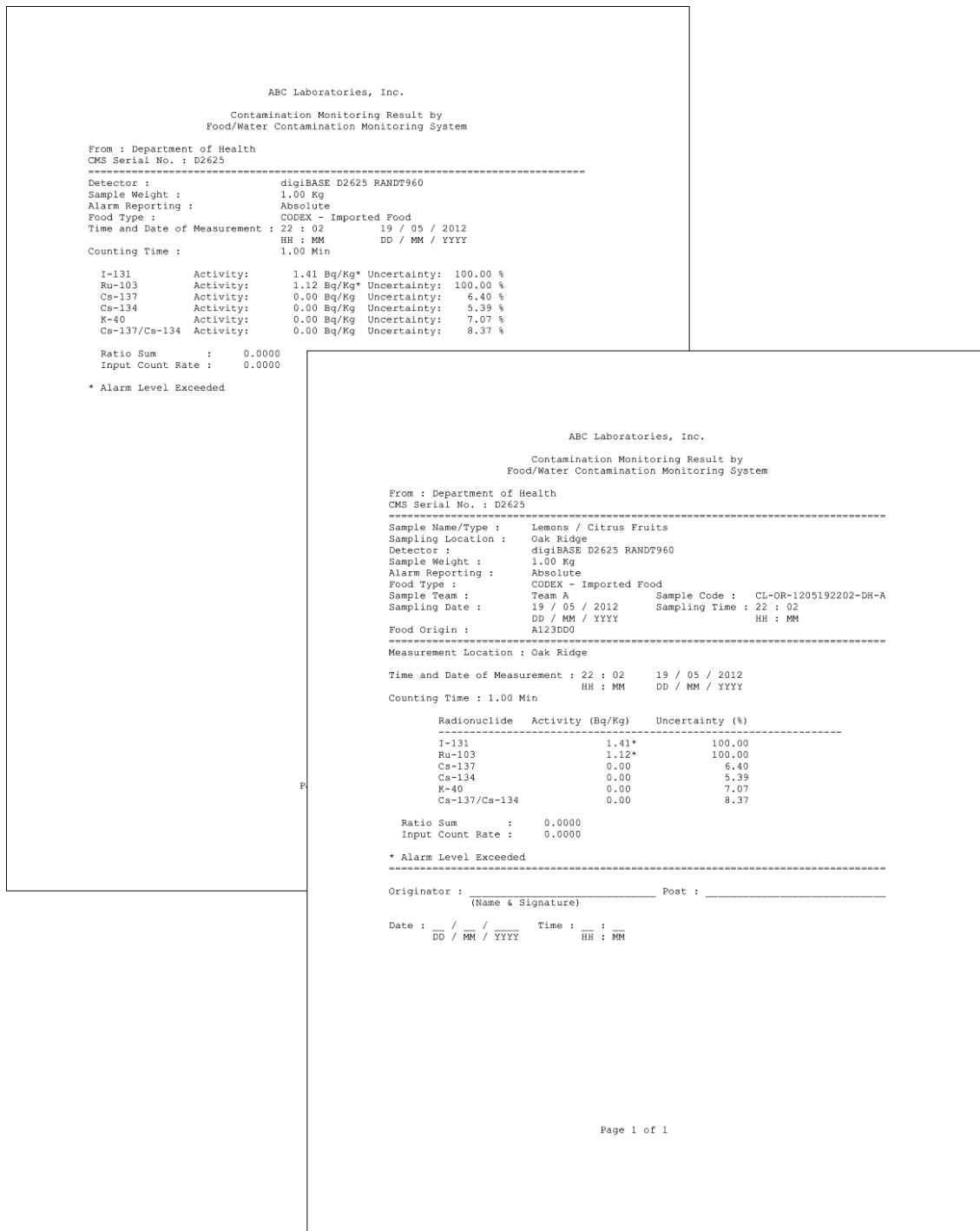
Figure 33. Comparison of Short- and Full-Format Reports.

Figure 34 shows an example Daily Summary Report.

```
                              ABC Laboratories, Inc.

                         Contamination Monitoring Result by
                       Food/Water Contamination Monitoring System

From : DH - Department of Health
CMS Serial No. : D2625
================================================================================
Measurement Date : 19 / 05 / 2012
                   DD / MM / YYYY
================================================================================
Sample Code            I-131    Ru-103   Cs-137   Cs-134     K-40   Cesium
---------------------  ------   --------  --------  --------  --------  --------
CL-OR-1205192326-DH-A  0.00     0.00      11.35     23.53    18125.33*  34.88
CL-OR-1205192259-DH-A  0.00     0.00      0.00      1.88     0.00       1.88
CL-OR-1205192248-DH-A  0.00     0.00      0.00      0.59     0.00       0.59
CL-OR-1205192233-DH-A  0.00     0.00      0.00      1.41     0.00       1.41
CL-OR-1205192227-DH-A  0.00     0.19*     0.00      1.99*    0.00       1.99*
CL-OR-1205192224-DH-A  1.55*    0.00      0.00      1.87*    0.00       1.87*
CL-OR-1205192206-DH-A  0.00     0.00      0.00      0.00     0.00       0.00
CL-OR-1205192202-DH-A  1.41*    1.12*     0.00      0.00     0.00       0.00
CL-OR-1205192155-DH-A  1.15*    0.22*     0.00      0.00     0.00       0.00


* Alarm Level Exceeded

Total number of samples : 9
No. of samples with alarm triggered: 5
================================================================================

Originator : _____  Post : _____
                 (Name & Signature)

Date : __ / __ / ____     Time : __ : __
         DD / MM / YYYY            HH : MM










                              Page 1 of 1
```

Figure 34. Daily Summary Report Screen.

Figure 35 compares the Sampling Statistics Report for a selected sampling period with the Measurement Statistics Report for ^{40}K for the same period.

```
                        ABC Laboratories, Inc.

               Food/Water Contamination Monitoring System
                       Sampling Statistics Report

Department Code : DH - Department of Health
CMS Serial No. : D2625
==============================================================================
SampleType : Citrus Fruits
Sampling Period : 19 / 05 / 2012 to 19 / 05 / 2012
                 DD / MM / YYYY    DD / MM / YYYY
==============================================================================
Sample Name                     Sampling Location          Sampling Date
------------------------------  ------------------------------  --------------
Lemons                          Oak Ridge                  19 / 05 / 2012
Lemons                          Oak Ridge                  19 / 05 / 2012
Lemons                          Oak Ridge                  19 / 05 / 2012
Lemons                          Oak Ridge                  19 / 05 / 2012
Lemons                          Oak Ridge                  19 / 05 / 2012
Lemons                          Oak Ridge                  19 / 05 / 2012
Lemons                          Oak Ridge                  19 / 05 / 2012
Lemons                          Oak Ridge                  19 / 05 / 2012
Lemons                          Oak Ridge                  19 / 05 / 2012

Total number of samples : 9
```

```
                            ABC Laboratories, Inc.

                   Food/Water Contamination Monitoring System
                          Measurement Statistics Report

    Department Code : DH - Department of Health
    CMS Serial No. : D2625
    ==============================================================================
    SampleType : Citrus Fruits
    Sampling Period : 19 / 05 / 2012 to 19 / 05 / 2012
                     DD / MM / YYYY    DD / MM / YYYY
    ==============================================================================
    Radionuclide : K-40

    Sample                Sample               Sampling         Activity   Alarm
     Name                 Location               Date           (Bq/Kg)  Triggered
    --------------------  --------------------  --------------  --------  ----------
    Lemons                Oak Ridge             19 / 05 / 12    18125.33     Yes
    Lemons                Oak Ridge             19 / 05 / 12       0.00      No
    Lemons                Oak Ridge             19 / 05 / 12       0.00      No
    Lemons                Oak Ridge             19 / 05 / 12       0.00      No
    Lemons                Oak Ridge             19 / 05 / 12       0.00      No
    Lemons                Oak Ridge             19 / 05 / 12       0.00      No
    Lemons                Oak Ridge             19 / 05 / 12       0.00      No
    Lemons                Oak Ridge             19 / 05 / 12       0.00      No
    Lemons                Oak Ridge             19 / 05 / 12       0.00      No

    Total number of samples : 9



                                  Page 1 of 1
```

Figure 35. Comparison of Sampling Statistics and ^{40}K Measurement Statistics Reports.

3.5.1. Deleting Records

This option lets you choose a range of dates and remove all records from that period from the current records database file, STATREC.DAT, simultaneously appending them to the file STATREC.DAT.BAK. (Both files are located in the C:\User\Foodguard-1 folder.) ***There is no "undo" for this operation.*** A message on the status bar at the bottom of the program window confirms the deletion and transfer (Fig. 36).

1 records deleted and STATREC.DAT backed up to STATREC.DAT.BAK.
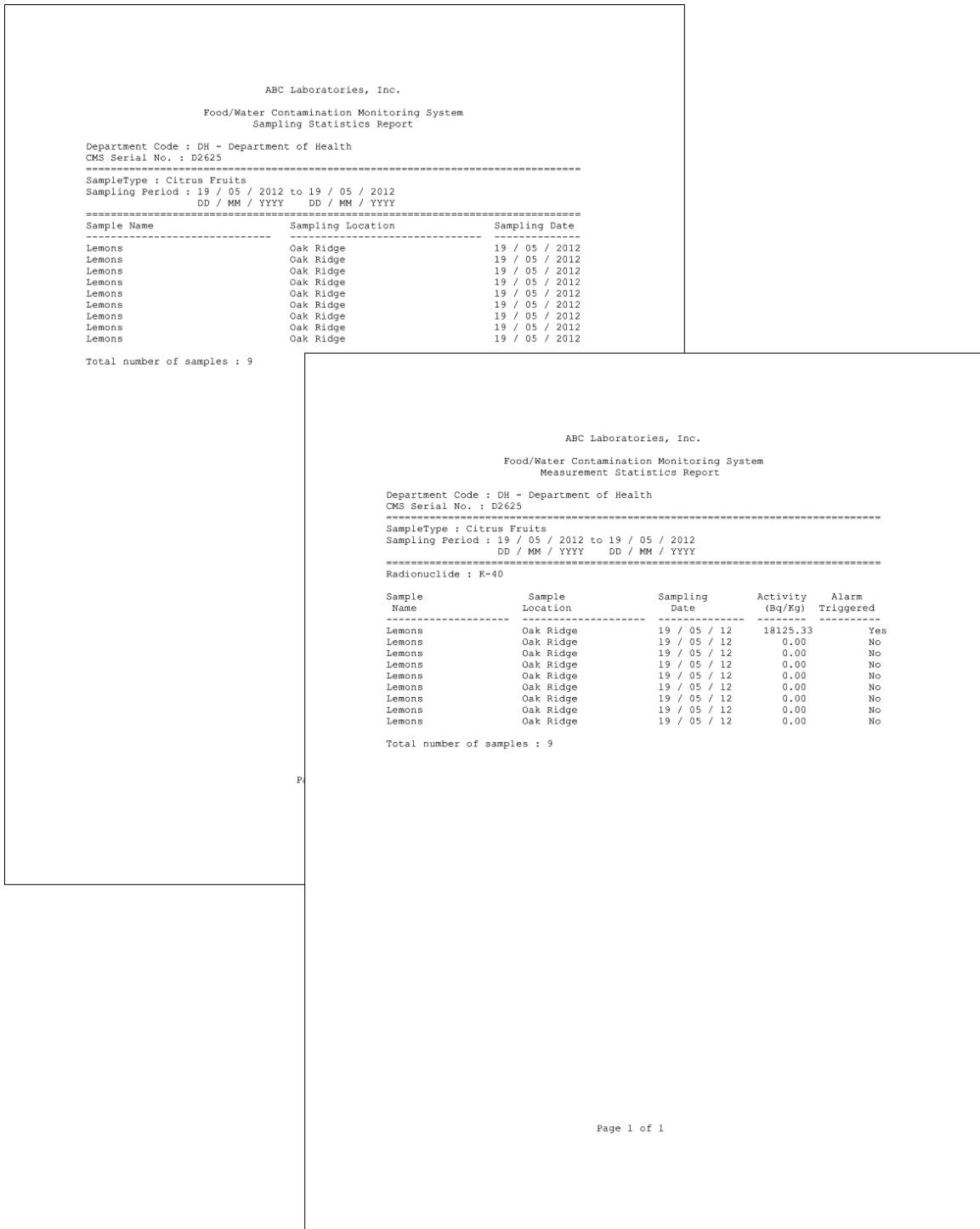
Figure 36. Records Moved to Backup File.

NOTE It is possible to view the deleted records in the .BAK backup file, *but to guarantee data integrity, be sure to backup both STATREC files first.* Temporarily rename your current STATREC.DAT records database file (for example, STATREC.DAT.SAFE), rename the backup file as STATREC.DAT, then exit and restart the program. FoodGuard-1 will now recognize the renamed backup file as the current records database. Use the Report screen features to access the deleted records. Finally, be sure to restore both STATREC files to their original names, then exit and restart the FoodGuard-1 program.

3.6. Performing a Simple System Check (Optional)

Once you have calibrated your system and performed a background measurement, you may wish to perform a quick system check using the potassium chloride (KCl) system check source beaker included with your system (P/N 132080). This is a sealed 1 L Marinelli beaker labeled with the quantity of KCl and the calculated activity of ^{40}K.[11]

To perform a system check, position the check source beaker in the lead shield, in the same position you will use for sample measurements. Perform a sample measurement for a few minutes (Section 2.2.2), and confirm that the detected activity is within expected tolerances.

---

[11]KCl contains ~16350 Bq/kg of ^{40}K.

APPENDIX A. SYSTEM INSTALLATION

As noted in Chapter 1, the information in this appendix is intended for maintenance and other special purposes, and is intended to be used only in consultation with your ORTEC representative or our Global Service Center.

A.1. Unpacking and Setup

When you receive the FoodGuard-1 system, the shipping carton(s) will contain the following components[12]:

- digiBASE® multichannel buffer with user manual (P/N 931003) and USB cable
- 3 in. × 3 in. NaI detector
- Low-background lead shield
- ^{40}K check source ring
- Sealed system activity check source (KCl in 1 L Marinelli beaker)
- CONNECTIONS Driver Update Kit (P/N 797230) CD
- MAESTRO® MCA Emulation Software CD
- FoodGuard-1 software CD

A.2. Hardware and Software Setup

Installing the FoodGuard-1 system takes six steps.

1. Install the accompanying version of the CONNECTIONS Driver Update Kit (p/n 797230), being sure to select **USB-based instruments** on the Instrument Families screen.
2. Install the accompanying version of MAESTRO.
3. Install the FoodGuard-1 software.
4. Assemble the digiBASE, detector, and lead shield; and connect the assembly to the USB port on the PC.
5. Run the MCB Configuration program to establish communication with your MCBs.
6. Start the FoodGuard-1 software for the first time and select the digiBASE on the Setup screen.

A.2.1. Step 1: Install the CONNECTIONS Driver Update Kit

The first step is to install the accompanying version of the CONNECTIONS Driver Update Kit according to its instruction sheet. This product must be installed before MAESTRO can be installed. On the Instrument Families page, be sure to mark the **USB-based instruments**

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[12]Bill of materials subject to change without notice; contact your ORTEC representative.

checkbox, as shown in Fig. 37. ***Otherwise the digiBASE will not be able to communicate with the PC and ORTEC software.***
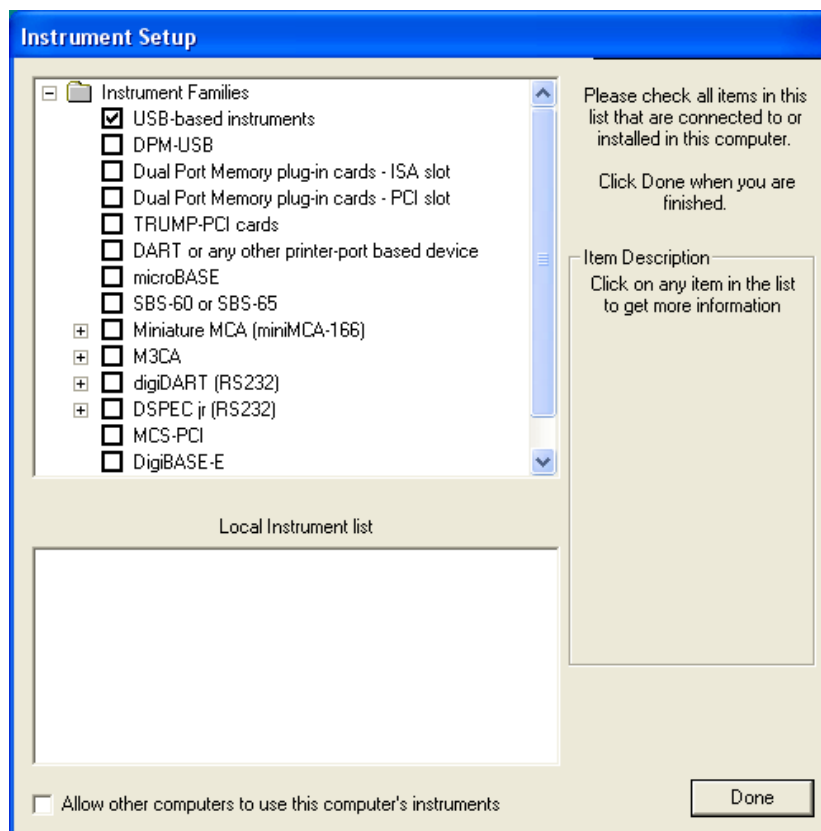
Figure 37. Choose 'USB-based instruments.'

A.2.2. Step 2: Install MAESTRO

Install the accompanying copy of MAESTRO according to the instructions in its *User's Manual*.

A.2.3. Step 3: Install the FoodGuard-1 Software

Insert the FoodGuard-1 CD. Select **My Computer**, navigate to the CD or DVD drive, and locate and open Setup.exe. In Windows XP this will start the installation wizard. In Windows 7 a message will indicate that Windows cannot verify the publisher of this software. Select the "install anyway" or "continue" option to start the FoodGuard-1 installation wizard.

If your PC does not have the required version of Microsoft .NET Framework, the install wizard will include it in the installation routine. Follow the wizard prompts to completion.

A.2.4. Step 4: Assemble the digiBASE/Shield Assembly and Connect to the PC

Figure 38 shows a representation of the system components, e.g., the lead shield, ^{40}K check-source ring, digiBASE, and 3×3 inch NaI detector. They are all identified by a system serial number. The digiBASE's coarse gain jumper is factory-set based on its accompanying detector.

Figure 38. FoodGuard-1 Assembly Cross-Section.

IMPORTANT

Factory testing and calibration was performed on this combination of components, and the results are included on the accompanying system test results sheet. These components should always be used together. (To amplify this point: *do not swap components, such as the ^{40}K check source ring, with other FoodGuard-1 systems*.)

To assemble the hardware:

- Insert the ^{40}K check source ring in the shield's sample well.

- Connect the USB cable to the digiBASE.
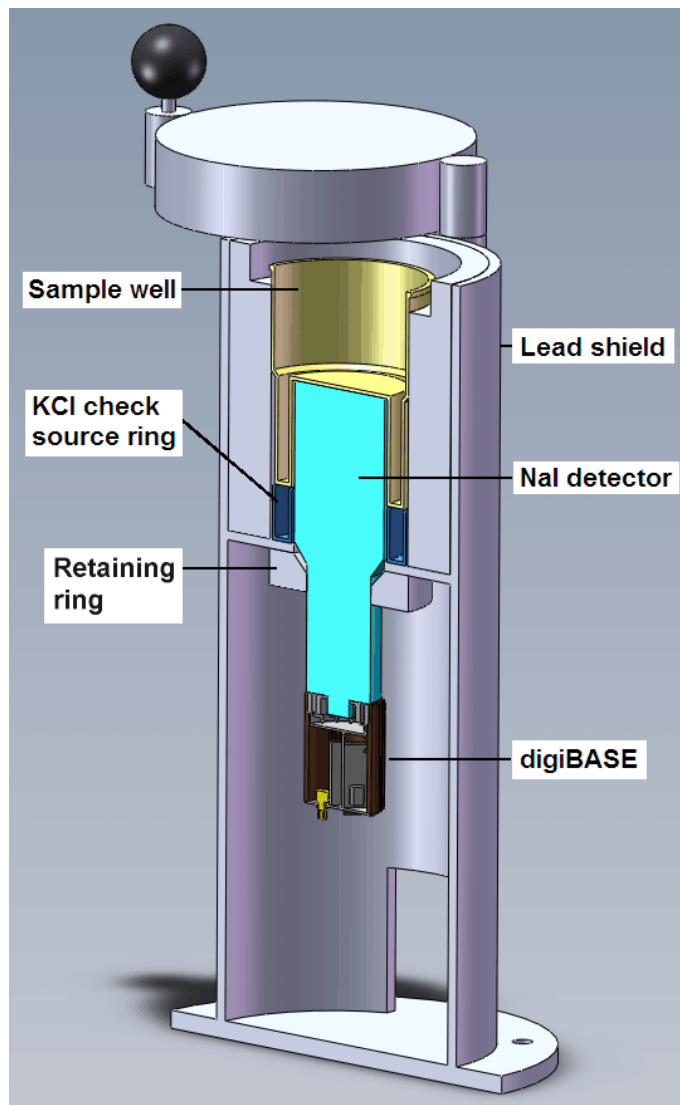
- Lower the detector into the sample well until it rests on the retaining ring. HINT: Rotate the detector so its PMT's "key" tab is pointing toward the shield's lid hinge.

- Insert the digiBASE through the opening in the lower part the shield bottom, rotated to match the orientation of the PMT's key tab.

- Raise the digiBASE until it engages the PMT pins, confirm that the base and PMT are properly keyed before applying any pressure, hold the top of the detector in place, then raise the digiBASE until it is firmly seated on the PMT pins.

- Hold the digiBASE/detector assembly at the desired height in the shield (you may wish to place a 1 L Marinelli beaker in the sample chamber), and use the provided 3/16 in. Allen (hex) wrench to snug the retaining ring's lock screw just enough to hold the detector assembly in position. HINT: When the ring feels snug, try to raise the detector a few millimeters. This will ensure the detector is centered in the retaining ring (not jammed slightly off-vertical with the retaining ring still loose).

  CAUTION   *Do not overtighten or you will damage the detector housing.*

- With the PC powered on, connect the digiBASE to the USB port on your PC.

- Windows will detect the digiBASE and start the New Hardware installation wizard. Click on **Next**, indicate you *do not* wish to connect to the internet or the Microsoft website to locate the driver, choose the "automatically locate driver" option, and follow the remaining prompts to completion.

A.2.5. Step 5: Run the MCB Configuration Program

This is an abbreviated discussion of the operation and use of the MCB Configuration program, tailored for a single FoodGuard-1 system.[13]

- With the PC powered on and the digiBASE connected to it, open the Windows Start menu and click on **MAESTRO 32**, then **MCB Configuration**; or, in Windows 7, enter **mcb con** in the "search programs and files" box, then click on the **MCB Configuration** search result. The MCB Configuration program will take a few minutes to locate the digiBASE connected to the PC.

- If this is the first time the digiBASE has been configured (that is, if the system has not been pre-configured), you will first see the dialog shown in Fig. 39, a reminder that all new instruments must be assigned a unique, *non-zero* ID number. Click on **OK** then click on the **Renumber New** button.

- The digiBASE will then be displayed on the *Master Instrument List* dialog, as shown in Fig. 40. (Note that the Description for your digiBASE will likely differ from the one in the illustration; it is based on information about your particular PC.)
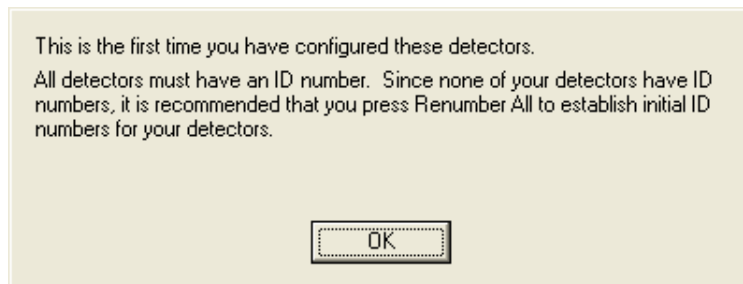
Figure 39. New Instruments Must Have a Non-Zero ID Number.

- If you wish to customize the Description for your digiBASE (for instance, you may find it useful to indicate the name or location of the PC, include the serial number of the system's detector to the Description, etc., although this is not necessary for operation), double-click on the entry in the master instrument list dialog to open an editing dialog. Edit the Description and click on **Close** to return to the master list dialog, then click on **Close**. See the CONNECTIONS Driver Update Kit for more detailed instructions on this procedure.

---

[13]We recommend that you also read the instructions for the CONNECTIONS Driver Update Kit for complete details on customizing MCB ID Numbers and Descriptions, changing your Windows firewall settings to allow MCB access across a network, enabling additional device drivers, and troubleshooting.
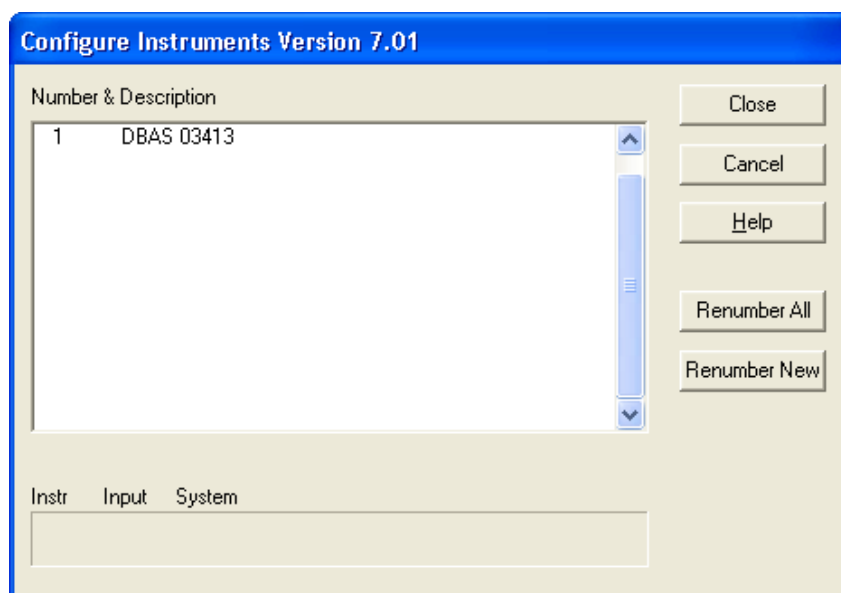
Figure 40. MCB Numbering and Descriptions.

A.2.6. Step 6: Initial Software Startup

● From the Windows Start menu, select **FoodGuard** and **FoodGuard**-1 (Fig. 41).

Figure 41. Start FoodGuard-1.

● Your system is pre-configured at the factory, so the FoodGuard-1 program should be ready to access the system's digiBASE. Because the detector high-voltage is off, on first use, the high-voltage startup screen (see Fig. 16 on page 16) will be displayed for 30 seconds. After the high voltage stabilizes, the Run tab will be displayed (see Fig. 15 on page 15).

— If the digiBASE has not been pre-selected in the FoodGuard-1 program, the program will open on the Run tab, which will display the "detector not ready" message shown in Fig. 42.[14] Referring to Section 3.3, click on the Setup tab, enter the factory-set password (Section 3.1.1), and select the digiBASE from the **Detector** droplist. Click on any other tab to start the 30-second high-voltage startup routine.'

---

[14]The "detector not ready" message is also displayed if the detector is disconnected or cannot communicate with the FoodGuard-1 software. On the Setup tab, confirm that the detector is still selected, check the USB cable, and confirm that the detector is still firmly seated in the digiBASE socket base. Click on any other tab to start the high-voltage startup sequence.
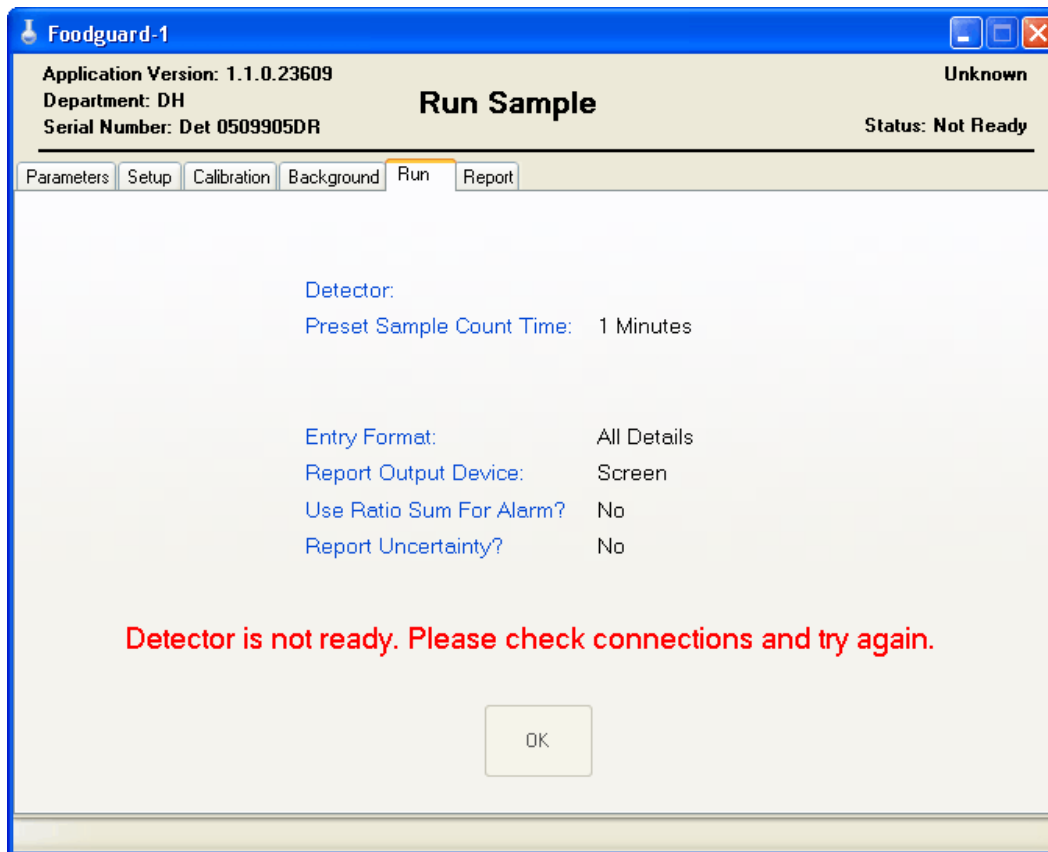
Figure 42. No Valid Detector Selected (go to Setup tab).

● You are now ready to set up the FoodGuard-1 program as discussed in Chapter 3.

APPENDIX B. ANALYSIS METHODS

B.1. Activity Calculation

The following method is based on an analytical method from Association of Analytical Community (AOAC).[15] If R_i is the measured net count rate in the spectrum region i and A_j is the activity of the jth nuclide, then the net count rates can be related to the source activities by a 5×5 matrix:

$$R_1 = f_{11}A_1 + f_{12}A_2 + f_{13}A_3 + f_{14}A_4 + f_{15}A_5 \tag{1}$$

$$R_2 = f_{21}A_1 + f_{22}A_2 + f_{23}A_3 + f_{24}A_4 + f_{25}A_5 \tag{2}$$

$$R_3 = f_{31}A_1 + f_{32}A_2 + f_{33}A_3 + f_{34}A_4 + f_{35}A_5 \tag{3}$$

$$R_4 = f_{41}A_1 + f_{42}A_2 + f_{43}A_3 + f_{44}A_4 + f_{45}A_5 \tag{4}$$

$$R_5 = f_{51}A_1 + f_{52}A_2 + f_{53}A_3 + f_{54}A_4 + f_{55}A_5 \tag{5}$$

where:

R_i = is the net count rate in the ith ROI.
A_j = is the activity of the jth nuclide.
f_{ij} = is the fractional contribution of the jth nuclide to the net count rate in the ith ROI.

The above equations can be represented in matrix form as:

$$R = f \cdot A \tag{6}$$

where **f** is a 5×5 matrix, **A** is the activity vector, and **R** is the net count rate vector.

If the matrix **f** is known and the inverse of the f matrix can be found, then the activities can be calculated from the measured count rates from:

---

[15]Association of Analytical Communities (AOAC), Official Method 973.67.

$$A = f' \cdot R, \quad f' = \frac{1}{f} \tag{7}$$

where **f** is the inverse matrix of the matrix **f**. Alternatively, the activities for the ith nuclide can be written as:

$$A_i = \sum f_{ij}' \cdot R_j, \quad j = 1,5 \tag{8}$$

The activity concentration of the jth nuclide in activity per unit volume or per unit weight is given by:

$$A^S_i = A_i / V \tag{9}$$

where V is the sample volume or the sample weight.

In general, the elements in the **f** matrix depend on the detection efficiencies and the branching ratios of the nuclides. For a fixed set of nuclides and a fixed detector/sample configuration, the **f** matrix can be obtained through a calibration process and should be invariant, unless the sample geometry or the detector system is changed.

FoodGuard-1 measures five nuclides: ^{131}I, ^{103}Ru, ^{137}Cs, ^{134}Cs, and ^{40}K. The CMSROI.ROI file sets a predefined ROI for each nuclide, as shown in Table 1.

Table 1. FoodGuard-1 Nuclide ROIs.

ROI	Nuclide	Peak Energy	Start/End Channels
1	^{131}I	365.5 keV	220–268
2	^{103}Ru	497.1 keV	298–358
3	^{137}Cs	661.7 keV	390–470
4	^{134}Cs	795.9 keV	486–546
5	^{40}K	1461 keV	850–950

The net count rates R_j can be calculated from the gross counts in an ROI minus the region's background counts. Thus, the activity can be calculated from the net counts using the matrix manipulation discussed here.

B.2. Manual Detector Calibration

Calibration of FoodGuard-1 requires a certified source for each of the five nuclides, and the source certificate. Each source is measured sequentially by placing it in a 1 L Marinelli beaker in the lead shield, as described in Section C.

B.2.1. Calibration Equations

When a single nuclide with known activity is measured, the gross and the net count rate in all five ROIs can be obtained. For the *j*th nuclide measured, the net count rate in the *i*th ROI, denoted as $(Rc)_{ij}$, can be calculated from:

$$(Rc)_{ij} = (R_G)_i^{\ j} - (R_B)_i, \qquad i = 1,5, \ j = 1,5 \tag{10}$$

where $(R_G)_i^{\ j}$ is the gross count rate from the *i*th ROI, due to the presence of the *j*th nuclide in front of the detector. $(R_B)_i$ is the background count rate of the *i*th ROI (measured in the absence of any sources).

For each nuclide, five net calibration count rates are calculated. With five predefined nuclides, there are 25 total net count rates which form the 5×5 matrix described by Eq. 10.

The net count rates $(Rc)_{ij}$ thus obtained can be related to the activity calculation equations, Eqs. 1 through 5. If we consider all but the activity of the first nuclide (A_1) as zero in Eqs. 1 through 5, we arrive at the following equations:

$$(Rc_{11}) = f_{11} A_1 + f_{12} \cdot 0 + f_{13} \cdot 0 + f_{14} \cdot 0 + f_{15} \cdot 0 \tag{11}$$

$$(Rc_{21}) = f_{21} A_2 + f_{22} \cdot 0 + f_{23} \cdot 0 + f_{24} \cdot 0 + f_{25} \cdot 0 \tag{12}$$

$$(Rc_{31}) = f_{31} A_3 + f_{32} \cdot 0 + f_{33} \cdot 0 + f_{34} \cdot 0 + f_{35} \cdot 0 \tag{13}$$

$$(Rc_{41}) = f_{41} A_4 + f_{42} \cdot 0 + f_{43} \cdot 0 + f_{44} \cdot 0 + f_{45} \cdot 0 \tag{14}$$

$$(Rc_{51}) = f_{51} A_5 + f_{52} \cdot 0 + f_{53} \cdot 0 + f_{54} \cdot 0 + f_{55} \cdot 0 \qquad (15)$$

From above equations, the matrix elements in the first column of the **f** matrix can be calculated from the measured net count rates and the corresponding nuclide activity. This process can be repeated to find all the elements in the **f** matrix.

B.2.2. Matrix Inversion

From Eqs 11 through 15, one can see that any elements in the **f** matrix can be determined from the following equation:

$$f_{ij} = (Rc)_{ij}/A, \qquad i = 1,5, \; j = 1,5 \qquad (16)$$

Thus, the **f** matrix can be determined completely by the calibration process described above. Once the **f** matrix is known, the LU Decomposition method[16] can be used to find the inverse matrix **f'**. With the inverse matrix, the activities of all five predefined nuclides can be calculated from the net count rates (see Eq. 8).

Since the inverse matrix **f'** is directly related to the activities, it is the inverse matrix, not the **f** matrix, which is saved in the FoodGuard-1 calibration file. The default calibration file is named `CALINFO.DAT`.

B.2.3. Factory Default Calibration

ORTEC FoodGuard-1 systems are pre-calibrated at the factory. Certified calibration sources in standard 1 L Marinelli beakers are used to calibrate. The whole system has excellent long-term stability. The system uses gain stabilization and an integrated ^{40}K check source ring to offset the peak centroid energy drift. Therefore, once the system is factory-calibrated, there is no need for the user to recalibrate the system except in extraordinary circumstances.[17] As noted elsewhere, *this recalibration should only be performed in consultation with your ORTEC representative or our Global Service Center.*

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[16]W.H. Press, B.P. Flannery, S.A. Teukolsky, and W.T. Vetterling, *Numerical Recipes*, Cambridge Press (1986), used by permission.

[17]For instance, after substantial radiation damage to the NaI crystal, or if the system must be used in an extreme environment, e.g., extreme cold or heat, or in an intense magnetic field.

The system's NaI detector has excellent counting efficiency and stability. Incident gamma rays interact with the NaI(Tl) crystal within the detector, resulting in photons through the photo-electric absorption process. The photons are detected by a photomultiplier tube (PMT) optically coupled with the NaI crystal. The efficiency of the photoelectric conversion process is very well known and stable.[18] Figure 43 plots the absorption efficiency of NaI as a function of the gamma-ray energy at various crystal thicknesses.[19]
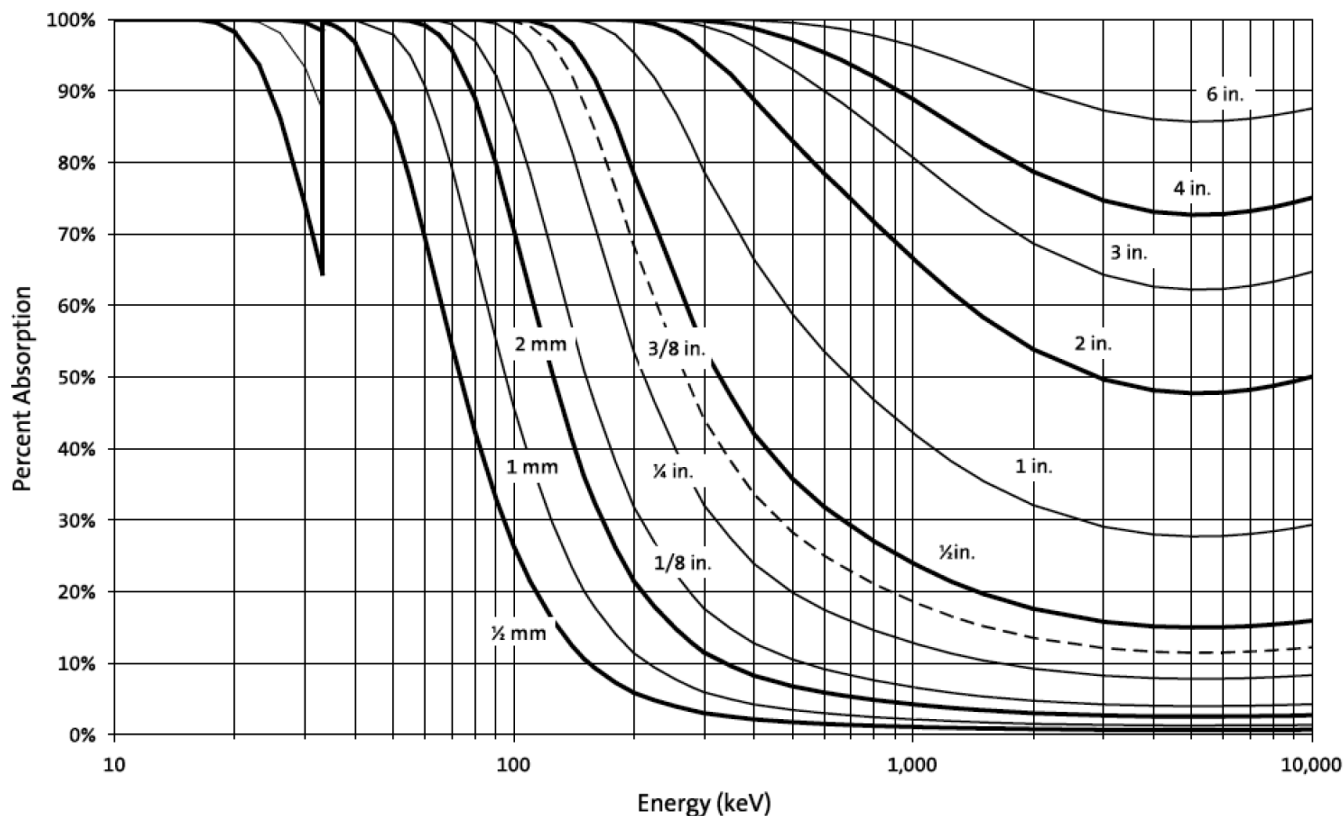
Figure 43. Absorption Coefficient of NaI Crystal.

FoodGuard-1 uses a 3-inch thick NaI crystal. As can be seen from the preceding figure, the absorption efficiencies of the crystal are relatively high.

The detection of ^{40}K is somewhat more complicated, since pair-production is also involved (the gamma ray energy is above 1022 keV). However, the ^{40}K content is used mainly for monitoring system performance, and is expected to be very stable over time.

The detection efficiency also depends on the source-detector geometry. In FoodGuard-1, the detector is hold at a fixed position inside a heavily shielded Pb housing (refer to Fig. 1). The

[18]G. A. Knoll, *Radiation Detection and Measurement*, 4th ed., 2010.

[19]Efficiency calculations from Saint-Gobain (http://www.detectors.saint-gobain.com).

system is configured to use a standard 1 L Marinelli beaker, which seats on the detector endcap, leaving almost no room for the source-detector geometry to vary. As long as you use this same detector-source geometry, there is no need for recalibration or geometry.

When the ambient temperature changes, the NaI crystal light output does change. The magnitude of the change is about 0.3% per degree Celsius at room temperature.[20] The light output also has temperature dependence which is broad and slow varying around the room temperature. Thus, for NaI detectors, temperature variation can shift peak centroids. But the FoodGuard-1's system electronics, in conjunction with the accompanying ^{40}K check source ring, hold the peak positions in fixed channels.

The peak FWHM is also a function of the detector temperature. From room temperature, a change of 10°C causes an estimated change in the peak FWHM of <1 keV for the ^{137}Cs peak centroid (662 keV). From Table 1, the ROI for ^{137}Cs is about 50 keV wide. Since most of the ^{137}Cs counts are near the center of the ROI, with a Gaussian distribution, the estimated change to the detection efficiency should be negligible compared to the default measurement precision of around 5%.

B.3. Activity Uncertainty

Activity uncertainties are calculated as follows, and are reported in percent.

B.3.1. The Calibration Matrix

This method defines a vector named $\mathbf{N_B}$ with five elements:

$$(N_B)_{ij} \;=\; (Rc)_{ij}/A_j, \qquad i=1,5, \; j=1,5 \tag{17}$$

where Rc is defined in Eq. 10. A calibration matrix $\mathbf{Cm}$ can be defined:

$$(Cm)_{ij} \;=\; (Rc)_{ji}/(Rc)_{ii} \tag{18}$$

All the diagonal elements of this matrix are at unity. In Eq. 18, note that the indices i and j are exchanged between the $\mathbf{Cm}$ and the $\mathbf{Rc}$ matrices.

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[20]NaI(Tl) data sheet from Saint-Gobain (http://www.detectors.saint-gobain.com).

The calibration matrix can be related to the **f** matrix by combining Eqs. 16 and 18.

$$(Cm)_{ij} = (f)_{ji} / (f)_{ii} \tag{19}$$

Since the calibration matrix is used in the uncertainty calculations, all the elements of the calibration matrix are also saved in the calibration file, together with other calibration parameters and results.

The total nuclide relative uncertainty for the *j*th nuclide is calculated as:

$$\sigma_j^2 = \sigma_{cj}^2 + \sigma_{nj}^2 + \sigma_{sj}^2 \tag{20}$$

where σ_{cj} is the counting uncertainty for the *j*th nuclide, σ_{nj} is the nuclide uncertainty for the *j*th nuclide, and σ_{sj} is the calibration source uncertainty for the *j*th nuclide. It is assumed that all the nuclide uncertainties are at 5%:

$$\sigma_{nj} = 0.05, \quad j = 1,5 \tag{21}$$

When the factory calibration is used, the calibration source uncertainties (σ_{sj}) can be found from the table below:

Table 2. Default Calibration Source Uncertainties.

Nuclide	Source Uncertainty (%)
^{131}I	2.0
^{103}Ru	3.0
^{137}Cs	4.0
^{134}Cs	2.0
^{40}K	5.0

When a manual calibration is performed, the source uncertainties, entered by the user from the source certificates, are used instead.

B.3.2. Counting Uncertainty

The counting uncertainty calculation is more involved. For the *j*th nuclide, the counting uncertainty is calculated as the summation over the index *i*, with $i = 1, 5$, and $i \neq j$, for the five predefined ROI regions:

$$\sigma_{cj}{}^2 = \sigma_{cjj}{}^2 + \frac{\sum \left[\left(2G_i - N_i \right) \cdot \left(Cm \right)_{ji} \right] \cdot \left(Cm \right)_{ji}}{\left(N_j \cdot N_j \right)}, \qquad i = 1,5, \ i \neq j \tag{22}$$

where:

$(Cm)_{ji}$ = elements of the calibration matrix defined in Eq. 19. Note that the indices i and j are switched in Eq. 22.

G_i = the gross counts in the ith ROI.

N_j = the "net counts" in the jth ROI, calculated from Eq. 24 below.

If the net count rate in the ith ROI from the measurement spectrum is denoted as $(R_N)_i$, and the live time of the measurement is t, then the net count rate is calculated from:

$$(R_N)_i = (G_i / t) - (R_B)_i, \qquad (R_N)_i \geq 0 \tag{23}$$

If the net count rate is negative, it is set to zero. When the radioactivity within the sample is close to the background level, this situation is very likely to occur due to statistical fluctuations.

The variable N_j, which is closely related to the net counts in the spectrum in the ith ROI, is calculated from:

$$N_j = t \cdot (N_B)_j \cdot (R_N)_j, \qquad N_j > 0.5 \tag{24}$$

where N_B is defined in Eq. 17 and the R_N is defined in Eq. 23. If $N_j < 0.5$ counts, it is set to zero counts.

When the index i is the same as j, and if the net counts >0.5, the quantity σ_{cjj} is calculated from:

$$\sigma_{cjj} = \frac{\sum \left[\left(2G_j - N_j \right) \cdot \left(Cm \right)_{jj} \right] \cdot \left(Cm \right)_{jj}}{\left(N_j \cdot N_j \right)}, \qquad N_j > 0.5 \tag{25}$$

Otherwise, σ_{cjj} is taken as zero.

When $N_j = 0$, the counting uncertainty cannot be calculated from Eqs. 21 and 25. In this case, the nuclide total uncertainty is calculated from the following equation:

$$\sigma_j{}^2 = \sigma_{nj}{}^2 + \sigma_{sj}{}^2 \tag{26}$$

In all cases, the FoodGuard-1 program limits the uncertainty to 100%. From Eq. 20, there is also a minimum uncertainty for each nuclide, since the counting uncertainties should all be positive. Combining the fixed nuclide uncertainty of 5% (see Eq. 21) for all nuclides and the default calibration uncertainties shown in Table 1, the minimum uncertainties for the nuclide are:

Nuclide	Minimum Uncertainty (%)
^{131}I	5.4
^{103}Ru	5.8
^{137}Cs	6.4
^{134}Cs	5.4
^{40}K	7.1

B.4. Minimum Detectable Concentration (MDC)

The MDC is the Minimum Detectable Activity (MDA) divided by the volume or weight of the material being counted. The MDA is based on the smallest activity that can be measured with a given confidence level for true positives and false negatives. These were set to 5% each, a common value. This equates to a 95% identification of the nuclide when it is present at the MDA value.

B.4.1. MDC Calculation

The half-lives of ^{131}I and ^{103}Ru are short, so the MDA was calculated based on the NuReg 4.16 formula:

$$MDA = \frac{4.66 * \sqrt{B}}{(t * \varepsilon * \gamma)} \tag{27}$$

where:

B = the background counts in the ROI (see Table 1 for the ROI start and end channels for each nuclide).
t = the live time.
ε = the efficiency.
γ = the branching ratio of the peak.

The NaI detector efficiency was measured for [134]Cs, ^{137}Cs, and [40]K. For ^{131}I and [103]Ru, it was estimated based on the detector manufacturer's published data.[20] The efficiency curves are plotted in Fig. 43. For [134]Cs and ^{137}Cs, calibrated standards were used. For [40]K, the specific activity for KCl based on the natural abundance of [40]K in natural potassium was used. The efficiencies are consistent with values in other literature for similar geometries. Then certified sources were measured at decreasing activities until the MDA values were reached.

The MDC values thus obtained for the nuclides are listed below in Table 3.

Table 3. MDC for FoodGuard-1.

Time (min)	MDC (Bq/L)				
	[131]I	[103]Ru	[137]Cs	[134]Cs	[40]K
10	14.8	13.6	14.9	21.7	224.4
20	10.5	9.6	10.3	15.2	143.6
30	8.6	7.8	8.5	12.4	123.4
60	6.1	5.5	6.0	8.8	57.1

The MDA values depend on the count time and the background counts in the ROI. From Eq. 26, if the background count rates are constant, the MDC decreases to half the value when the count time is quadrupled.

In FoodGuard-1, if the count time is different from the values listed in the table above, then the MDC is interpolated based on the time-dependence predicted by Eq. 27. It is easy to verify that the MDA is related to the square root of the count time.

B.4.2. Detect vs. Non-Detect

On the FoodGuard-1 analysis report, if the measured activity is greater than the MDC, then the nuclide is marked as detected. Otherwise, it is marked as "not detected." For example, after 60 minutes, if the measured activity for ^{137}Cs is >6 Bq/L, then ^{137}Cs is marked as detected on the report, since the MDC (from the table) is 6 Bq/L.

B.5. Combined ^{134}Cs and ^{137}Cs Activity Calculation

The combined cesium readout reports the sum of ^{134}Cs and ^{137}Cs activities, even if only one of the isotopes is detected. If neither nuclide is detected, then the combination is marked as not detected.

The ^{134}Cs/^{137}Cs combined activity a straight sum, and is also shown on the report:

$$A_{134/137} = A_{134} + A_{137} \tag{28}$$

B.5.1. Uncertainty for Combined ^{134}Cs and ^{137}Cs Activity

By design, FoodGuard-1 calculates and reports only relative uncertainties. All relative uncertainties are from 0 to 1.0 (or 0% to 100%). Assuming the relative uncertainty for then we have:

$$0 \le \sigma_{134} \le 1.00$$
$$0 \le \sigma_{137} \le 1.00 \tag{29}$$

where:

σ_{134} = the relative uncertainty for ^{134}Cs.
σ_{137} = the relative uncertainty for ^{137}Cs.

There are two scenarios for the calculation of the combined uncertainty.

Scenario 1: Total combined activity is positive

In this case, the combined relative total uncertainty is calculated from:

$$\sigma_{134/137} = \frac{\sqrt{(\sigma_{134} A_{134})^2 + (\sigma_{137} A_{137})^2}}{(A_{134/137})} \tag{30}$$

If $\sigma_{134/137} > 1.0$, it is reported as 1.0 (or 100%).

Scenario 2: Total combined activity is zero

In this case, the relative uncertainty is not well-defined, since the denominator is zero. For individual nuclides, the relative uncertainty is reported through Eq. 26, even if the nuclide activity is zero. The combined uncertainty is calculated from:

$$\sigma_{134/137} = \sqrt{(\sigma_{134}A_{134})^2 + (\sigma_{137}A_{137})^2} \tag{31}$$

If $\sigma_{134/137} > 1.0$, it is reported as 1.0 (or 100%).

APPENDIX C. MANUAL CALIBRATION

As noted in Chapter 1, the information in this appendix is intended for maintenance and other special purposes, and is intended to be used only in consultation with your ORTEC representative or our Global Service Center.

Manual calibration requires certified ^{131}I, ^{103}Ru, ^{137}Cs, ^{134}Cs, and ^{40}K sources, and the calibration certificate information for each source; otherwise the FoodGuard-1 software will not accept the new calibration, and you must restore the factory calibration. Two of the nuclides, ^{131}I and ^{103}Ru, have short half-lives. *This means that a calibration must be coordinated with the delivery of these sources.*

You will also need one or more Marinelli beakers similar in composition to those used for sample measurements.

NOTE   If you begin a manual calibration and, for any reason, find you cannot complete it or that it produces unexpected results, you can return the system to the ready state by clicking on the **Factory Defaults** button on the FoodGuard-1 Calibration screen, performing the "short procedure" calibration (Section 3.4), and running a new background (Section 2.3.1).

C.1. Step 1: Adjustment of HV and Gain, and Preliminary Measurement of Calibration Sources

The FoodGuard-1 efficiency calibration routine requires that you enter a count time that will be used for all 5 radionuclide measurements. To obtain a good-quality efficiency calibration, you will need to measure each calibration source long enough to accumulate a peak with at least 10,000 net counts. Because the activity of your five calibration sources varies, you must first determine the count time in which all five sources will accumulate a 10,000 net count peak.

The easiest way to do this is to start FoodGuard-1 and use the **Adjusting HV** step of the calibration routine, as discussed in Section 3.4.1.

- Follow the instructions in Section 3.4.1 to set the HV and amplifier gain so the 1461 keV peak of ^{40}K is in channel 900.

- On the menu bar, click on **ROI/Recall File...**, and from the \FoodGuard-1 folder open CMSROI.ROI. This will set five ROIs, one for each FoodGuard-1 peak.

- Now use MAESTRO to count each source individually until you determine the time required to accumulate 10,000 net counts for each. To monitor net counts, clear the detector memory, click in the center channel of the ROI for the current source, then right-click and select **Peak Info** from the context menu. Figure 44 shows a Peak Info box for a peak that has accumulated >13,000 net counts.
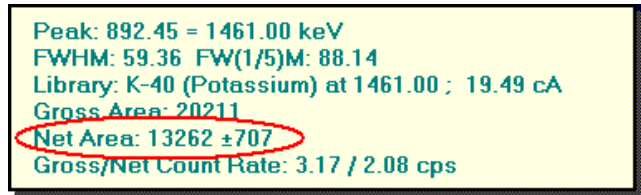

Peak: 892.45 = 1461.00 keV
FWHM: 59.36 FW(1/5)M: 88.14
Library: K-40 (Potassium) at 1461.00 ; 19.49 cA
Gross Area: 20211
Net Area: 13262 ±707
Gross/Net Count Rate: 3.17 / 2.08 cps

Figure 44. Monitor the Net Counts.

- Once you have determined which source takes the longest time to accumulate 10,000 net counts in its corresponding ROI, click on the FoodGuard-1 Setup tab and enter that as the **Preset Sample Count Time**.

- Return to the Calibration tab, click on **OK** to restart the **Adjusting HV** step, then close MAESTRO to move on to the next calibration step.

C.2. Step 2: Set ROIs for the Calibration Peaks

You are now ready to perform the **Setting ROIs** step of the calibration routine.

- Click on **OK** to reopen MAESTRO.

- On the menu bar, click on **ROI/Recall File...**, and from the \FoodGuard-1 folder open CMSROI.ROI. This will set the following ROIs in the spectrum window:

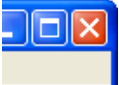| ROI	Nuclide	Peak Energy	Start/End Channels
1	^{131}I	365.5 keV	220–268
2	^{103}Ru	497.1 keV	298–358
3	^{137}Cs	661.7 keV	390–470
4	^{134}Cs	795.9 keV	486–546
5	^{40}K	1461 keV	850–950

- Perform a brief test acquisition with each source[21] to verify that the source peaks align with the ROIs in the table above. If your source peaks and the ROIs are in agreement, click on **Skip** and go to Section C.3.

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[21]Or multiple sources positioned so the system dead time, as monitored on MAESTRO's right-hand sidebar, is <70%.

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If a peak is shifted several channels to the right (higher-energy) or left (lower-energy) of the pre-set ROI, you may wish to shift the ROI position. If you do so, be sure to retain the same total number of channels.

NOTE   If you choose to manually mark the ROIs, make sure they do not overlap; i.e., there must be "unmarked" channels between ROIs.

Example — Suppose your ^{137}Cs peak is centered in channel 420 instead of 430. In this case, you would shift the ROI 10 channels to the left so that it spans channels 380–460. To do this:

— Zoom in on the ROI to be modified by pressing the keypad **<+>** key; alternatively, you can click and drag a *rubber rectangle* around the peak of interest, right click in the spectrum window, and select **Zoom In** from its context menu.

— Click the mouse in the spectrum window to set the vertical marker line about 10 channels left of the ROI. The **Marker:** readout immediately below the spectrum window shows the marker line's current channel position. Use the right/left arrow keys to put the marker in channel 420.

— Press the **<F2>** key once to put the marker in "ROI Marking" mode. Note the **Marking** indicator in the upper right of the MAESTRO window. Press the right arrow key 10 times to move the marker to channel 429. As the marker moves right, it will change the color of each channel it touches, marking them as ROI channels.

— Press **<F2>** twice to turn off the "ROI Marking" mode. The indicator in the upper right of the MAESTRO window will turn off.

— Use the mouse and arrow keys to put the marker in channel 470.

— Press **<F2>** twice to put the marker in "ROI Unmarking" mode. Note the **Unmarking** indicator in the upper right of the MAESTRO window. Press the left arrow key 10 times to move the marker to channel 461. As the marker moves right, it will change the channel color from the ROI color to the unmarked-spectrum color.

— Press **<F2>** once to turn off the "ROI Marking" mode. You have now shifted this ROI by 10 channels.[22]

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[22]You may wish to save a new **.ROI** file that preserves the ROI(s) you have just modified. To do this, click on **ROI/Save File...** and assign a descriptive filename. *Do not overwrite CMSROI.ROI.*

- If measuring individual sources, repeat this process for each source, clearing the detector between measurements. When you close MAESTRO, FoodGuard-1 will automatically read and store the ROIs. (If the FoodGuard-1 program does not accept your revised ROIs as valid, you must repeat this step. To repeat it, click on the **Skip** button twice to jump to the end of the calibration routine, then click on **Start Over** to begin repeating the calibration steps. This will restart the **Adjust HV** step. Just close MAESTRO to advance to the **Setting ROIs** step.)

- Exit MAESTRO and return to FoodGuard-1 to begin the background count.

C.3. Step 3: Background Count

- Leave the ^{40}K check source ring in the sample well, close the lid, remove all sources from the area, select your **Location** from the list, accept or revise the **Preset Background Count Time**, and click on **OK**. The progress bar, below the sidebar, will track the count.

- The"stop count" button (☒) allows you to pause and restart the background count. However, the only way to restart the background step is to **Skip** to the end of the calibration routine and **Start Over**, restoring the ROIs or **Skip**ping that step, then re-entering the **Background Count** step.

- At the end of the background count, FoodGuard-1 analyzes the data and displays the background activities for the target radionuclides. You are ready for Step 4.

C.4. Step 4: Efficiency Calibration

You are now ready to sequentially count each of the five certified sources. You will need the certificate information for each.

- Leave the ^{40}K check source ring in the sample well, insert the first source, and close the lid.

- From the certificate, enter the **Activity**, in becquerels; the calibration date and time; and the percent **Source uncertainty**; then click on **OK** to start the count.

- Repeat for the remaining sources, following the onscreen instructions.

At the end of all measurements, FoodGuard-1 will analyze the data and immediately begin using this new calibration. The system is now ready for sample measurements. If you obtain unexpected results, you can restore the original factory default calibration, ROIs, and background file by clicking on the **Factory Defaults** button on the Calibration screen. (See also the note on page 57).