OPERATING MANUAL

MBD-1
Personal Dosimeter

Document No: 2096 6832
Revision 1.0
4th May 2016

MIRION TECHNOLOGIES

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FCC Compliance Statement

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

The device is supplied in the package without the battery installed. (The battery is packaged separately in the package). The FCC-code is visible at the bottom of the battery compartment.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

—Reorient or relocate the receiving antenna.

—Increase the separation between the equipment and receiver.

—Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

—Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

1. Introduction

The MBD-1 design makes best use of the benefits of passive radiation detection with active, self-reading and recording functionality. The battery powered system includes on-board digital processing to provide a self-reading, accurate, reliable dose measurement on an integrated LCD display. Radiation exposure records are stored at a configurable frequency.
This active system is combined with the advantages of the patented DIS (Direct Ion Storage) passive detector technology. The passive radiation detectors are continuously responsive to radiation, with or without the field-replaceable battery. The internal electronics provide self-reading measurement display, digital memory, data logging, BLE (Bluetooth Low Energy) wireless communication, IR wireless switching, and on-board diagnostic testing during startup and operational modes. All data reside in non-volatile memory for dose-of-record processing so there is never any danger of losing stored data or configuration settings on battery failure. The diagnostics measure and display battery condition and fault conditions of the device. At issuance and during operation, the user will know when their device is working and when it requires attention. The dosimeter has no pushbuttons or switches and therefore operation is extremely simple.
The MBD-1 provides direct dose information to the wearer in the field. The display can be configured to show any measurement value (i.e. total dose, gamma dose or neutron dose), or automatically scroll through any combination.

The MBD-1 also stores a dose record once per day (default) to a nonvolatile memory. Data recording is configurable. This information is available for periodic reading and subsequent analysis to provide the dose-of-record information for the user.

1.1. History

The MBD-1 is based upon Mirion Technologies' patented Direct Ion Storage (DIS) technology. Direct Ion Storage technology is a method for detecting ionizing radiation through use of an ion chamber detector combined to a simplified method for computing dose from a voltage value from the detector.

DIS technology has been evolving from early 90's from the primary DIS-1 dosimeter through several iterations to the current design. Since the basic detecting technology is based upon the same physical properties as modern reference ion chambers, the technology itself provides an effective method to achieve accurate results under challenging measurement conditions present in mixed radiological environments. The technology is unique in that it provides accurate dose calculations even under extreme pulsed radiation environments where typically only passive TLD type devices perform well. This technology is superior because it can provide immediate read-out capability. A typical DIS detector combines an ion chamber with an analog memory element that converts exposure to a charge that is converted to a simple voltage signal that is measured and reported as dose.

2. Description

2.1. Physical Description

The MBD-1 Battlefield Dosimeter is a wrist worn (like a wrist watch) or chest worn (clipped to lanyard, pocket, etc.) measurement device providing the wearer real-time radiation exposure data. The MBD-1 features an LCD display, IR and BLE communication, adjustable wristband and/or clip, and field replaceable battery.

The MBD-1 displays incremental gamma, neutron and beta exposure in configurable display formats (individual scrolling channels, individual channel or total) and configurable measurement intervals. Exposure is displayed in units of (m)Rem or (m)Rad. Battery power level is reported using an interactive symbol found in commercial electronics.

Radiological performance covers the full Hp (10) photon energies and features flat energy response from 80 KeV to 1.25 MeV range. Recorded data is retained in the MBD-1 in non-volatile memory.

1. LCD Display
2. Screen Protector and Label
3. D-Clip (2) for Wristband
4. Battery Compartment Cover

Figure 2-1: MBD-1 Physical Features

The MBD-1 includes six separate detector elements:

- Three (3) elements are provided for gamma measurements,
- Three (3) elements are provided for neutron measurements.

Each detector element is listed in Table 2-1, MBD-1 Detector Table and Figure 2-2, MBD-1 Detectors and Measurement Range Chart below.
Note that while Figure 2-2 lists dose units in rem, any displayed results from the gamma accident range (DA) or neutron accident range (NA) detector elements are provided in rad.

Detector		Code	LLD	Upper Range
Deep - Gamma	DIS Low Range	DL	10 µSv (1 mrem)	600 mSv (60 rem)
	DIS High Range	DH	1 mSv (100 mrem)	6 Sv (600 rem)
	MOSFET	DA	10 mSv (1 rem)	20 Sv (2000 rem)
Deep – Neutron	ɣ+ n DIS	NL	1.5 mSv (150 mrem)	6 Sv (600 rem)
	ɣ DIS	NG	1.5 mSv (150 mrem)	600 rem (600 mSv)
	Pin Diode	NA	10 mGy (1 rad)	10 Gy (1,000 rad)

Table 2-1: MBD-1 Detector Table

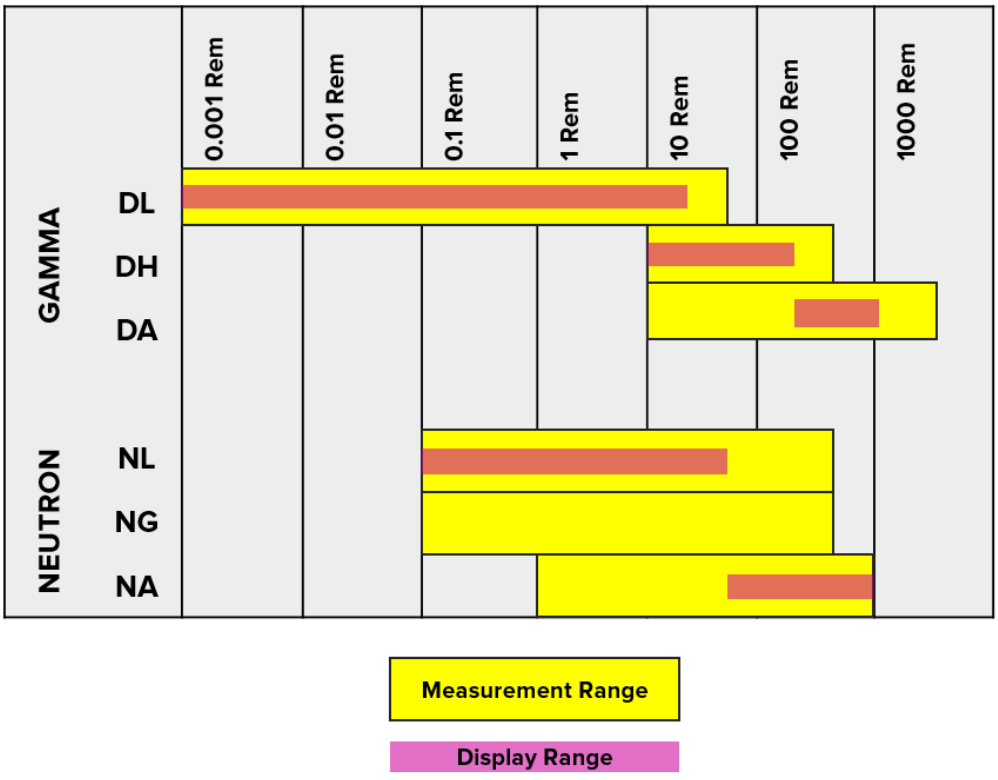


Figure 2-2: MBD-1 Detectors and Measurement Range Chart

The MBD-1 provides the user indication of gamma, neutron and beta radiation exposure on its LCD. This LCD is a four digit, seven-segment display that is easy to see, is not reflective and emits no glow. A fourth option (d tot) is available that displays the gamma plus neutron dose. Note that up to three values may be displayed and scrolled. If a single value is selected, the display will blink with the unit and value, with the exception of '**d tot**', where the display will stay solid with the total deep dose.

2.2. Power Management & Storage

The MBD-1 is designed for long term storage duration. The device may also be optimized for short term storage in an "action ready" environment. While possible, storage of the MBD-1 beyond a three year period is not recommended. A three year service program is recommended to maintain an "operational ready" condition and ensure optimal performance. End user operational logistics of the MBD-1 typically determine the storage configuration settings.

MBD-1 can be configured to optimize the battery life of both the primary 3V battery and the internal 6V batteries while in storage. In addition, the MBD-1 can be configured to limit the detector saturation potential of the internal detectors while in storage. These mode configurations are implemented using the MBD reader software.

Table 2.2 describes the power management options for the MBD-1:

Passive, **No Main Battery**	**Active,** **Main Battery installed**		
IN USE or STORAGE	**IN USE**	**IN STORAGE**	
		Sleep Mode	***Dormant Mode***
Detectors integrate dose from radiation background(2)	Detectors integrate dose from radiation background(2)	Limited maximum dose to integrate (1)	Detectors integrate dose from radiation background(2)
No Display Real-Time-Clock is Off	Display is On Real-Time-Clock is On	No Display Real-Time-Clock is On	No Display Real-Time-Clock is On
	Main Battery approx. 20 days	Main Battery approx. 4 years, completely discharged	Main Battery approx. 4 years, completely discharged
Internal battery life ≥10 years	Internal battery life ≥10 years	Consumes internal battery (7 years max) (3)	Internal battery life ≥10 years

(1) Maximum level is about one-third from the element range maximum
(2) Maximum level integrated is the range maximum
(3) Depends on storage /operation temperature
All battery life times are given in normal room temperature conditions.
Elevated temperatures may shorten the battery life time.
When device is active, the IR-wake-up is monitored and can wake the device if needed.
When main battery is completely depleted, the device will continue operating in passive mode.

Table 2.2 MBD-1 Power Management Matrix

2.2.1. Sleep Mode

The Sleep mode limits detector saturation potential, where the detector voltage is adjusted to limit the amount of dose that can be stored. The Sleep mode is an effective solution for concerns of detector saturation resulting from exposure to a nuclear detonation or other high radiation field.

In this state, the microprocessor is programmed to “wake-up” every 2 seconds to search for an IR communication signal. If discovered, the MBD-1 becomes active for connection to a MAC System, DAK or DC-1 field reader that is used to configure the dosimeter into an active mode. While in Dormant mode, the primary battery life is approximately 3 years. However, this mode has negative impact on the internal battery life, reducing estimated life to 8 years.

MBD-1 dosimeters can be stored without the primary battery installed. As a long term and short term storage solution, this method maximizes the primary battery life as the only effect on the primary battery is its self-discharge rate. The MBD-1 detector power is supported by the internal 6 V battery where there is only a very low draw of current from the detectors, less than 0.3 µA. The combined detector current draw and the self-discharge account for approximately 1 - 3% power loss per year of life. This rate is also dependent upon storage temperature (higher temperature, higher-self discharge rate). The resulting internal battery life is approximately 10 years.

2.2.2. Dormant Mode

The Dormant mode preserves the main battery life by disabling the LCD display and ceasing the storage of daily dose records. While in Dormant mode, the real time clock is active. In order to “wake” the MBD-1 from Sleep mode to an active state, an IR device (Reader Dongle or other field device) is required. In Dormant mode, the Main battery life is approximately 3 years and the internal battery life is 7 years.

3. Operation

The MBD-1 is designed to be worn with a wristband or strap similar to a watch. Once the battery is inserted, the MBD-1 is powered on and operates according to its configuration. There are no pushbuttons, switches, speaker or other annunciation feature.

3.1. Battery

3.1.1. Removal / Replacement

3.1.1.1. Removal

Prior to removing or installing the battery, remove the wristband, if used, to facilitate easier battery cover removal.

Turn the battery cover counter-clockwise to remove. The battery cover can easily be removed using a finger to “pull” one of the cover stems counter-clockwise, or by using two fingers and applying pressure while turning counter clockwise.

Figure 3-1: MBD-1 Battery Cover Removal

Remove the existing battery and dispose in accordance with site requirements.

3.1.1.2. Replacement

Insert a fresh battery into the compartment, positive (+) side facing up, as shown in Figure 3-2 below.
Verify the presence of the rubber O-ring next along the threading of the cover. If missing or degraded, replace.

Figure 3-2: MBD-1 Battery Cover Installation

Place the battery cover, recessed side down over the compartment, aligning the three stems in the three slots.

Turn the cover clockwise (to the right) until snug. Using a finger, push a stem until slightly centered in the slot.

NOTE: The use of a screwdriver or blunt object to tighten or remove the cover is not recommended. Damage to the MBD-1 may result due to improper technique.

3.1.1.3. Low Battery Indication

When the battery voltage is below 2.6V, a message appears on the display "**bAtt**" (battery low).

3.2. Start-up and Diagnostics

3.2.1. Start-up

When the battery is installed, the MBD-1 powers on. There are no switches to power on or off the MBD-1.

Upon start-up, the MBD-1 performs diagnostics and then becomes active with a live display.

3.2.2. Diagnostics

Table 3-1 below describes the diagnostics routine:

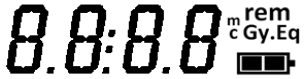
Start-up Routine	Operation with Warning and Effect	LCD Display Indication
LCD Display Segments	All segments illuminate for 3 seconds, then 1 second blank	
Post Start-up	Following start-up diagnostics, if no errors have been identified, a **nO.Er** message will display	
	If the MBD-1 becomes operational following an Error during start-up, the **PA.Er** message will appear on the Display, indicating an Error was recorded.	

Table 3-1: MBD-1 Start-up Diagnostics

NOTE: The MBD-1 may be stored with or without a battery.

3.2.3. Operation

The default LCD configuration is designed to display Gamma and Neutron measurement channels. The display measurement channels can be configured based on end-use requirements.

Figure 3-3: MBD-1 with Active Display

The LCD will cycle through two measurement channels over a twenty second period. This cycle is continuous while the MBD-1 is active. The twenty second interval is the default value. Other intervals include 40, 60 and 80 seconds.

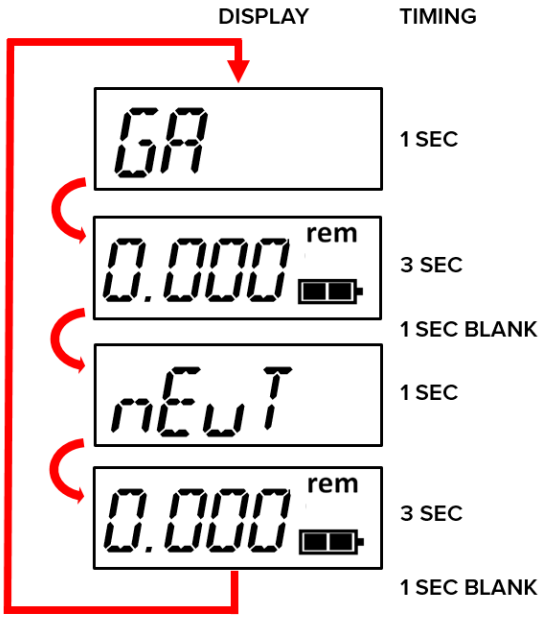


Figure 3-4: MBD-1 Default Display Cycle Timing

A third measurement channel, "**d.tot**", is displayed as the Total Deep Dose or, the sum of the Gamma and Neutron channels. The displayed measurement channels are configurable using the MBD-1 Service Software. The default display cycle and timing is shown above in **Figure 3-4**.

3.3. Interaction with Data Acquisition Kit (DAK-1)

3.3.1. DAK-1 Description

The DAK is a computer based reader station which can communicate, configure and transfer recorded data from the MBD-1 dosimeter. The DAK consists of a computer, Reader Dongle and MBD Reader Software.

The Reader Dongle uses IR and BLE to communicate with the MBD-1. The IR is used to initiate (wake-up) communication with the MBD-1, then the BLE establishes connectivity with the MBD for software commands.

NOTE: If the MBD-1 senses no Reader activity for 30 seconds, the MBD-1 will stop communication in order to preserve battery life. The Reader must re-initiate communication.

3.3.2. MBD Reader Software Operating Instruction

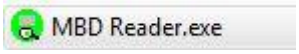
3.3.2.1. Set-up

- Turn on the computer
- Insert the Reader Dongle into an accessible USB Port.

Figure 3-4: Laptop PC with Reader Dongle

NOTE: The Reader Dongle should be positioned in an open area, like on a desktop, so that the MBD-1(s) can be placed in proximity for communication. If the USB is inaccessible, or behind a computer, a USB Extension Cord is an effective solution, as shown in **Figure 3-5** below.

Figure 3-5: Reader Dongle with USB Extension Cord

- Launch the MBD Reader Software 

3.3.2.2. Main Window

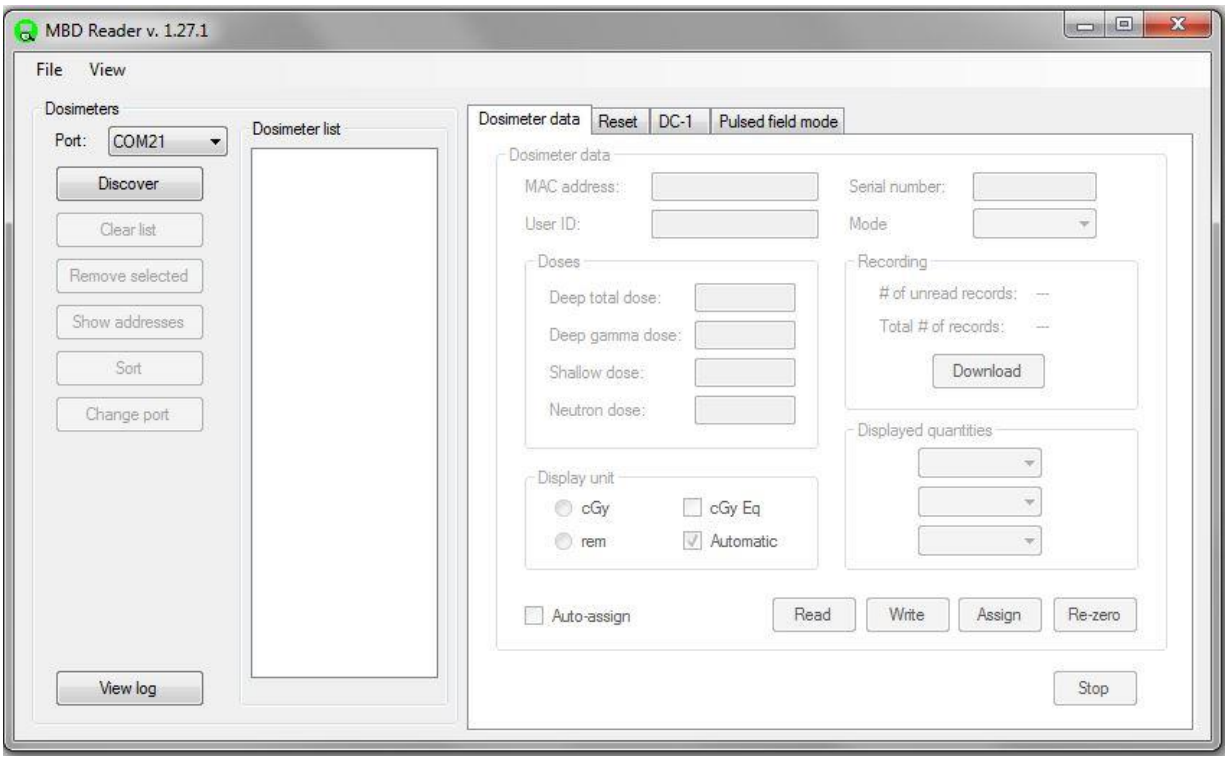


Figure 3-6: MBD Reader Main window

To wake-up the communication with the MBD-1 Dosimeter, place the MBD-1´s IR Receiver into proximity of the IR Dongle´s IR transmitter. Thereafter you can start the communication by clicking the **Discover** button.

3.3.2.3. Dosimeter Data Tab

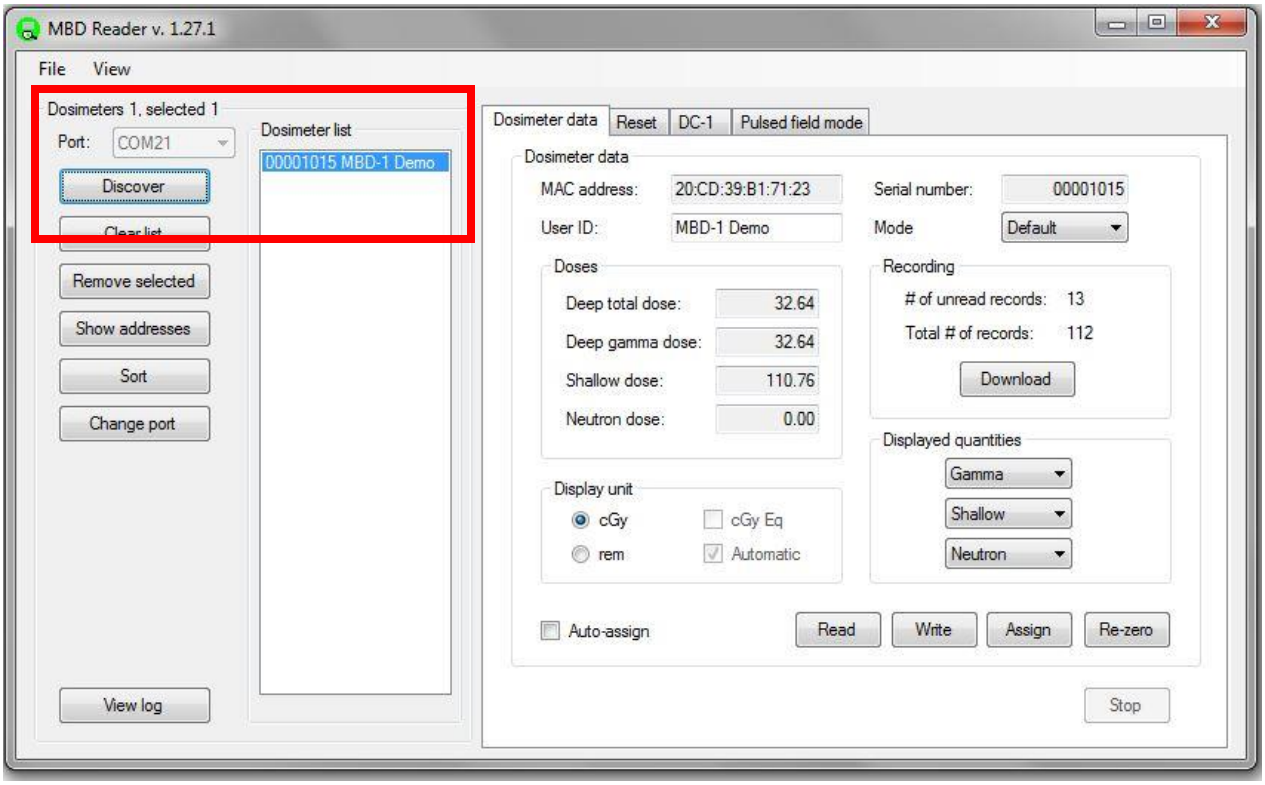


Figure 3-7: Dosimeter Data Tab

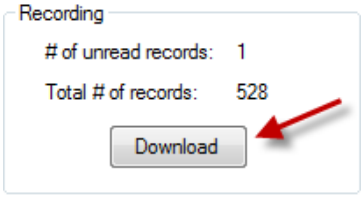
The MBD-1 Dosimeter serial number will be shown in the **Dosimeter List** window as soon as the communication link with the Dosimeter has been established and **Dosimeter Data** will be read automatically from the Dosimeter

Dosimeter Data:

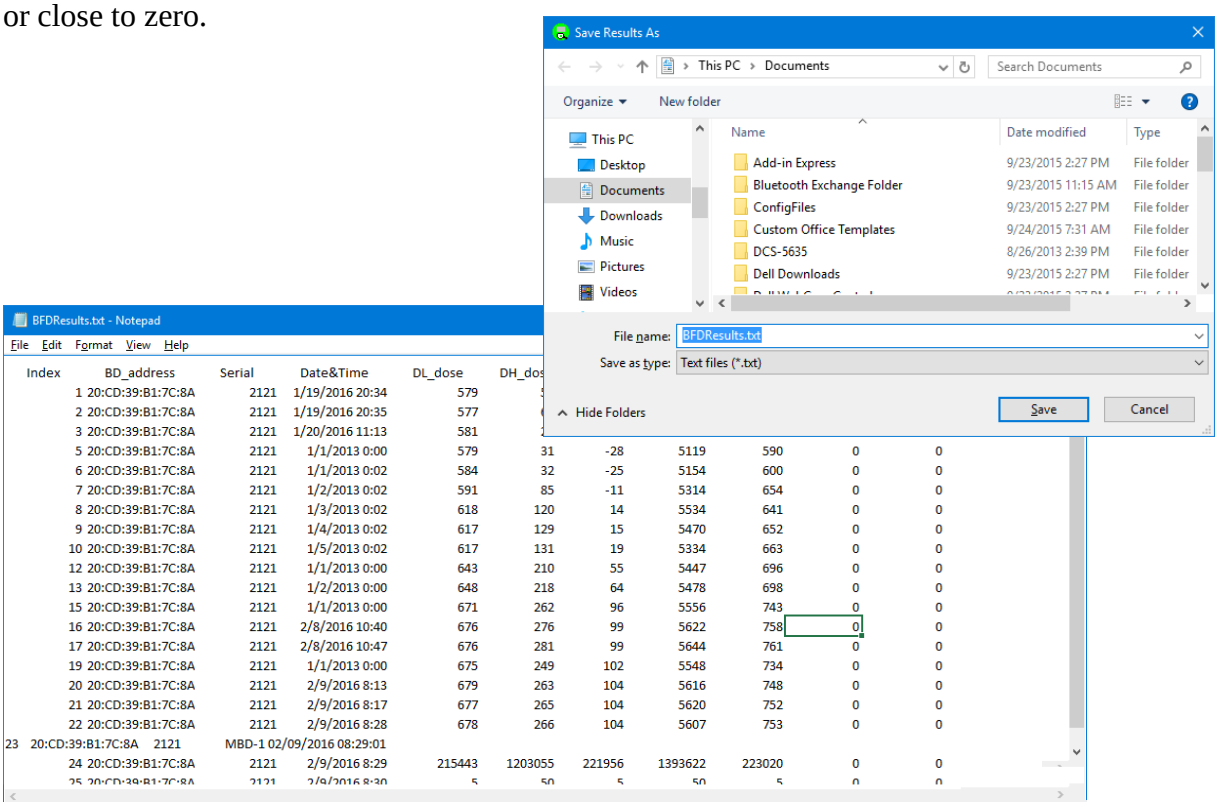
- MAC Address of the Bluetooth adapter
- Dosimeter's Serial Number
- User ID, which is stored into the Dosimeter
- Operating Mode selection
  - Default, normal operating mode
  - Test mode
- Dose Display selection
  - Deep Total Dose
  - Deep gamma Dose
  - Optional Shallow Dose
  - Neutron dose
- Recording selection
  - Number of unread dose records
  - Total amount of dose records
- Display units selection
  - Gamma
  - Shallow (optional)
  - Neutron

- Display Quantities selection
  - cGy
  - rem
  - cGy Eq
  - Automatic
- Auto Assign selection
- Read
  - Re-read Dosimeter data
- Write
  - Write Dosimeter data
- Assign
  - Assign dosimeter to a user
- Re-zero
- View log
  - Shows communication log events

3.3.2.4. Download Data Records



Click "Download" button (shown above). The software will ask for a location to save the information. Choose any location on the computer to initiate the download process. The process downloads about 80 records per minute. Download until the # of unread records is at or close to zero.



3.3.2.5. Reset Tab

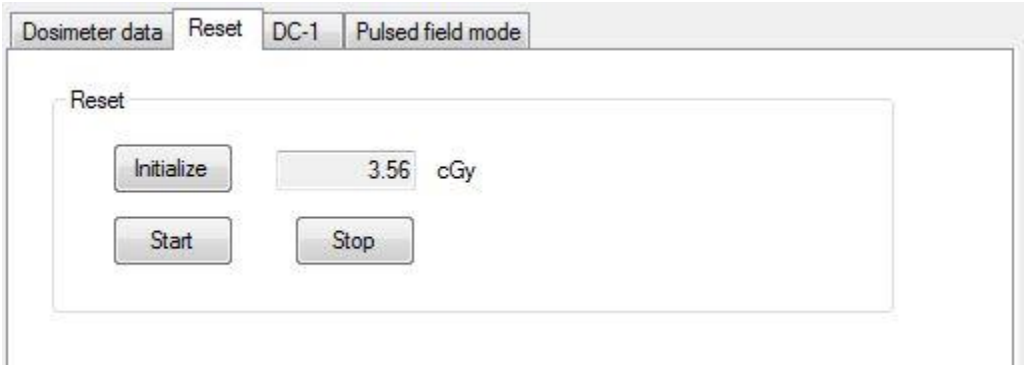


Figure 3-8: Reset Tab

Reset Process:

The reset process is achieved by delivering a specific amount of gamma or photon radiation to the MBD-1. The specific amount of gamma/photon radiation required is displayed in the Total MBD-1 Dose Box. Once the MBD-1 has been placed in Reset mode by clicking the Start button, the user will have one (1) hour to complete the reset process. In the event the required dose cannot be delivered in one (1) hour, multiple Resets will be required. When the required amount of gamma radiation is delivered, the user needs click the Stop button to end the Reset process. At the end of one (1) hour, the MBD-1 will automatically return to normal operation and begin accumulating dose again.

The Reset Process is as follows:

- Place an MBD-1 dosimeter between 4” – 6” from the IR/BLE Dongle (display facing dongle)
- When the MBD-1 display changes to “Conn”, click the Discover button to start communication between the MBD-1 and the MBD Reader Software.
- The MBD Reader Dosimeter list will populate the available MBD-1 dosimeter(s)

  Note: To reduce the time required for Initialization, the User should download the Recording History prior to pressing Initialize on the Reset tab. The less unread history events on the MBD-1, the faster the Initialization process will be.

- Click the Initialize button to begin the process of reading the accumulated dose on the selected MBD-1

	**CAUTION:** Once the Initialize button has been clicked, the user must complete the Reset Process. Failure to do so, will require a minimum of one (1) hour before the MBD-1 automatically returns to standard operation

- After the initialization has completed, the MBD-1 total Reset dose will be displayed in the Total MBD-1 Dose Box, in mrem or rem. The listed dose value is the amount of Reset dose required to reset the MBD-1 back to a value close to zero. The user shall prepare a gamma/photon source capable of delivering the specified dose in less than the one hour time out period

- Click the Start button to place the selected MBD-1 into Reset mode. From this "click" the MBD-1 will be capable of reset for one (1) hour. The user should complete the reset process before the one hour time limit expires

  Note: During the Reset process, the MBD-1 display will show "in it" until the reset process is stopped or times out

  If the user cannot prepare a gamma/photon source capable of delivering the specified dose in less than one hour, it will be necessary to repeat the process a number of times until the Reset is complete. Each successive time, a new Total MBD-1 Dose will be calculated during the Initialize process on the Reset tab.

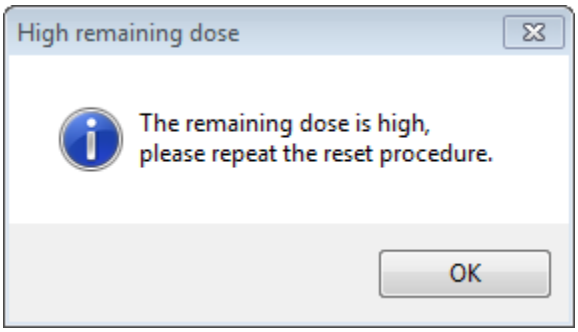
- Place the MBD-1 in the gamma/photon field

- After the specific dose is delivered, wake-up the communication again and open the Reset Tab.

  Note: The MBD-1 will remain "discoverable" during the entire Reset process and will not require the IR/BLE Dongle to "wake" the MBD-1 prior to populating in the MBD Reader Dosimeter List. If the one (1) hour time limit is exceeded, the MBD-1 will no longer be "discoverable".

- On the Reset tab, click the Stop button

  Note: If the Reset Process is not complete and a sufficient amount of gamma/photon dose is not delivered to the MBD-1, a warning will appear with the statement "The remaining dose is high, repeat the reset procedure".



- In the MBD Reader software, click on the Dosimeter data tab

- Click the Assign tab to assign the MBD-1 and re-zero the display
- The MBD-1 will display “in it” for about two (2) minutes, after which time the MBD-1 is ready for use

3.3.2.6. DC-1 Tab

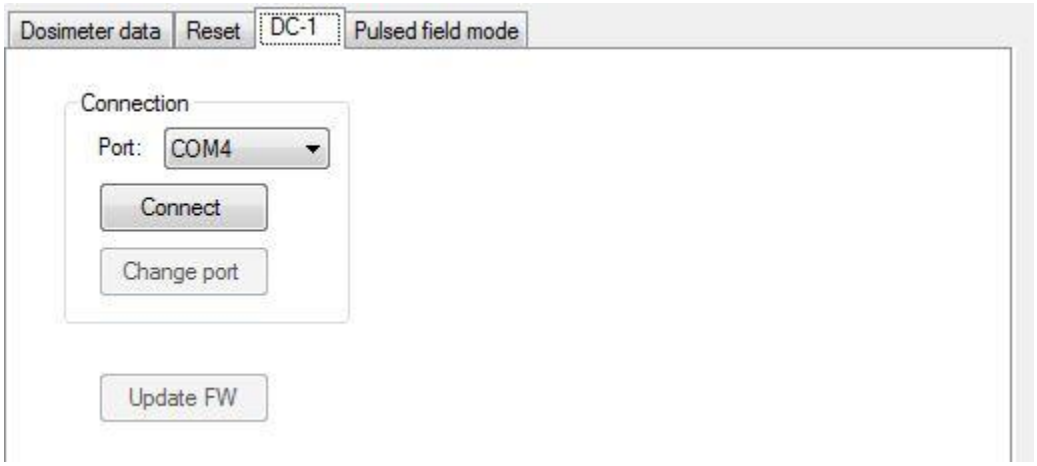


Figure 3-9: DC-1 Tab

Here you can connect into an optional external Data Collector Device.

3.3.2.7. Pulsed Field Mode Tab

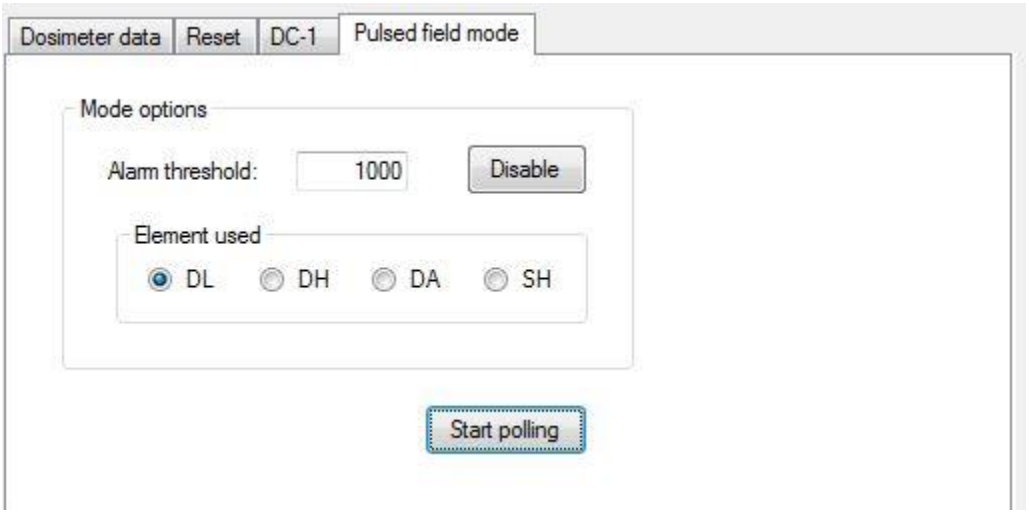


Figure 3-10: Pulsed Field Mode Tab

Here you can activate the Pulsed Field Mode for a specific dose element.

4. Technical Specifications

4.1. Radiological

Detector	Type	Designation	Range
DIS Low Range	Deep Gamma	DL	10 µSv to 600 mSv (1 mrem to 60 rem)
DIS High Range	Deep Gamma	DH	1 mSv to 6 Sv (100 mrem to 600 rem)
MOSFET	Deep Gamma	DA	10 mSv to 20 Sv (1 rem to 2000 rem)
DIS $\gamma + n$	Deep Neutron	NL	1500 µSv to 600 mSv (150 mrem to 60 rem)
DIS γ	Deep Neutron	NG	1,5 mSv to 6 Sv (150 mrem to 600 rem)
Pin Diode	Deep Neutron	NA	10 mGy to 10 Gy (1 rad to 1000 rad)

- Energy Range: 80 keV – 2 MeV

4.2. Physical Characteristics

- Dimensions: (LxWxH) 53 x 56 x 22 mm (2.08 x 2.2 x 0.86 inches)
- Weight: 48 g (1.7 oz) with battery

4.3. Environmental Characteristics

- Operating Temperature range: -20°C to +50°C (-4°F to 122°F)
- Storage Temperature range: -40°C to +70°C (-40°F to 158°F)
- Humidity: Up to 95 % relative humidity
- Water Resistance: -20°C to +50°C (-4°F to 122°F)
- Drop Test: 1 m height on hard wood surface in case
- RF-RI-EMI Emission: RS101, RS02, RS103, RE102 compliant
- Sand/Dust, Salt Fog & Fungus: Compliant IAW MIL-STD 810G

4.4. Electrical Characteristics

- Main Battery (Field Replaceable): Renata CR2430, 3 V, lithium coin cell
  Autonomy: 700 hours
- Internal (non-replaceable): Renata CR1216MFR, 6 V, lithium coin cell
  Autonomy: >10 years