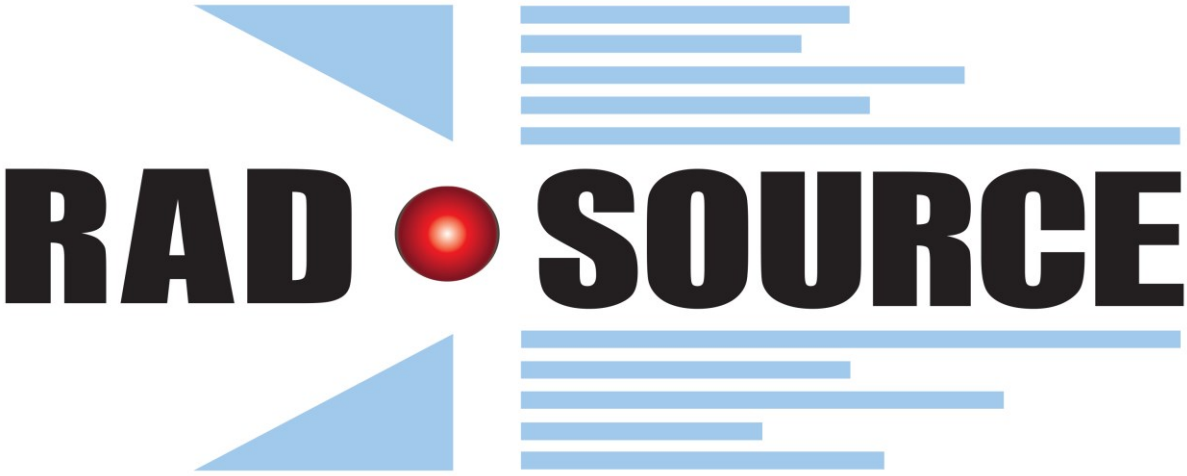

RS-2000 Series Operator's Manual

Rad Source Technologies, Inc.

Website: www.radsource.com

Published 14 Dec. 2016

MKT013 REV 1

ABOUT THIS MANUAL

The RS 2000 Series includes the following models:

RS-2000
RS-2000 Pro
RS-2000 Pro 225
RS-2000 XE
RS-2000 SE

The contents within this manual are applicable for all of these machines within the RS-2000 series.

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Safety Information and Symbols Used

Specific notations are used in this manual to call attention to conditions that could potentially result in injury, damage to equipment, or require special attention.

DANGER, WARNING, CAUTION, NOTE, and the symbols below may be used throughout this manual and on the RS-2000 Series to emphasize important and critical information. You must read these statements to help ensure safety and to prevent product damage. The statements are defined below.

⚠ DANGER - indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.

⚠ WARNING - indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

⚠ CAUTION - indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury. It may also be used to alert against unsafe practices.

NOTE: – used to notify people of installation, operation, or maintenance information that is important, but not hazard-related.

 - This symbol may be found on the RS-2000 Series and is used to reference the observer to the manual for further information.

- This symbol is found on the RS-2000 Series and is used to reference the observer that X-Rays are produced by this machine when energized.

Introduction:

General Radiation and X-Ray Information

Both federal and state governments regulate the manufacture and use of X-Ray instruments. Current regulations require that a variety of safety devices be built into X-Ray instruments that make it very difficult for anyone to even, accidentally, expose her or himself to the dangerous incident X-Ray beam.

However, it is important to have some basic knowledge of radiation, protection from radiation, and its health risks. In this section, we hope to make you generally aware of this information. This section is NOT a replacement for your local or national radiation safety training. It is intended only to make the operator generally aware of the uses of the machine.

Goals of this section:

- Explain what Radiation is.
- Explain what can protect you from radiation.
- Explain what X-Rays are.
- Explain the hazards of X-Ray devices.
- Explain requirements and responsibilities for the safe use of X-Ray devices.
- Help you recognize and respond to unsafe conditions.

What is radiation?

Radiation is energy in the form of waves or particles. Radiation high enough in energy to cause ionization is called ionizing radiation. It includes particles and rays given off by radioactive material. Ionizing radiation includes x-rays, gamma rays, beta particles, alpha particles, and neutrons. Ionizing radiation starts in the wavelength range less than the visible spectrum of light.

Radiation energy is determined by its wavelength and frequency. Below is a copy of the electromagnetic spectrum that shows different forms of radiation and their energies.

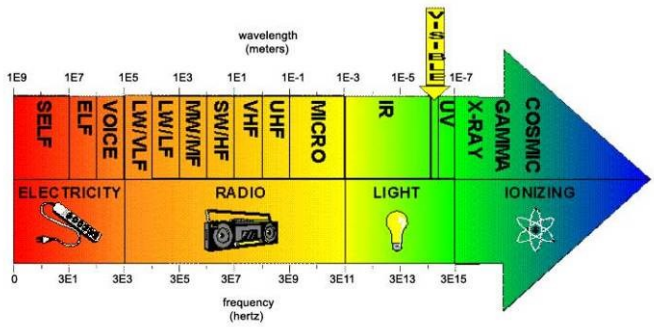


Figure 1: Electromagnetic Spectrum (Safety Services -Ionizing Radiation)

Without the use of monitoring equipment, humans are not able to sense ionizing radiation. In contrast to heat, light, and noise, humans are not able to see, feel, smell, or hear ionizing radiation. Specialized equipment such as an ion chamber is needed to measure this type of radiation.

What are X-Rays?

X-Rays are a form of radiation that is generated when accelerated electrons strike and interact with a high-density material. The energy of the accelerated electrons is converted to X-Ray photon energy. The quantity of X-Ray photons is proportional to the number of accelerated electrons. X-Ray energy differs from other sources of radiation in that the spectrum is polychromatic as opposed to the monochromatic nature of gamma ray, such as produced by a cobalt or cesium source.

X-Rays were discovered in 1895 when Wilhelm Conrad Roentgen observed that a screen coated with a barium salt fluoresced when placed near a cathode ray tube. Roentgen concluded that a form of penetrating radiation was being emitted by the cathode ray tube and called the unknown rays, X-Rays.

X-Ray tube

An x-ray tube requires a source of electrons, a means to accelerate the electrons, and a target to stop the high-speed electrons.

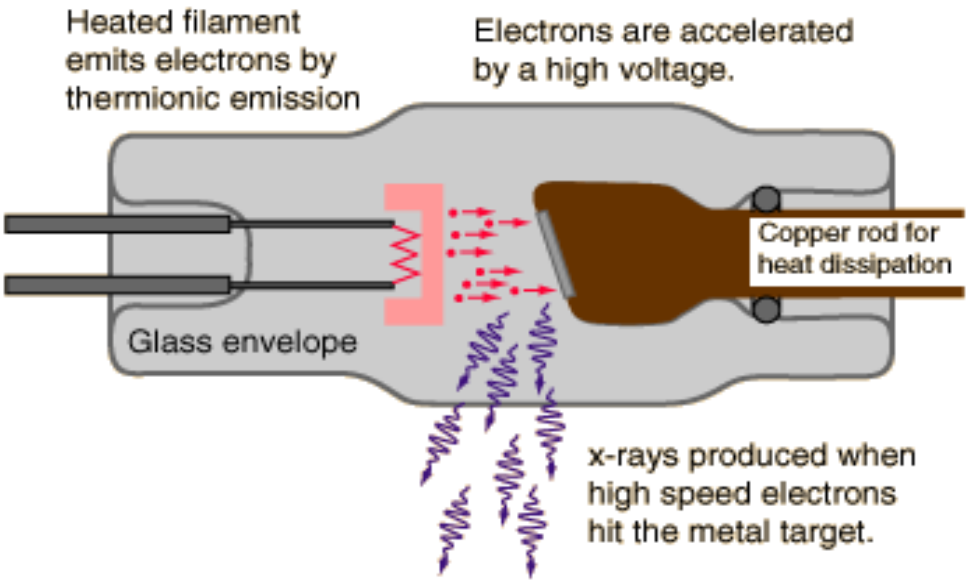
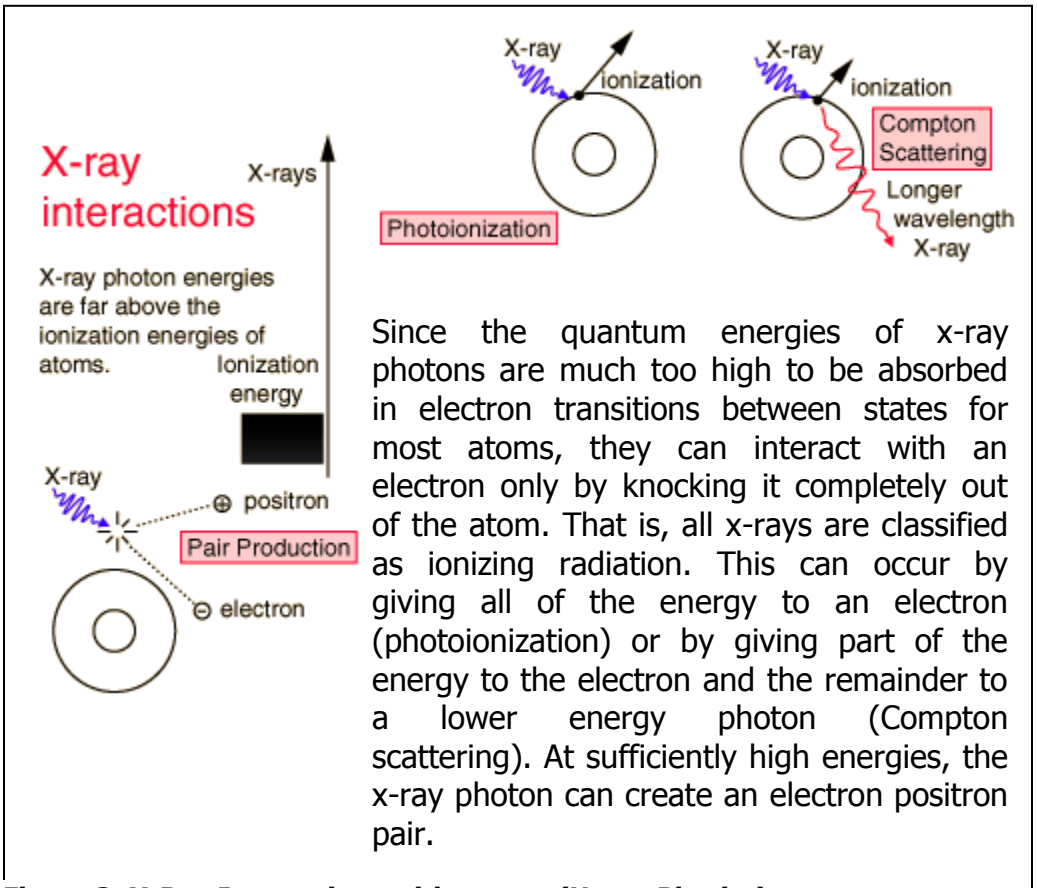


Figure 2: Typical X-Ray Tube Operation (ARPANSA - X-Rays, 2008)

X-Ray interactions

In passing through matter, energy is transferred from the incident x-ray photon to electrons and nuclei in the target material. An electron can be ejected from the atom with the subsequent creation of an Ion. The amount of energy lost to the electron is dependent on the energy of the incident photon and the type of material through which it travels.

X-Rays interact with matter in three basic methods:



Since the quantum energies of x-ray photons are much too high to be absorbed in electron transitions between states for most atoms, they can interact with an electron only by knocking it completely out of the atom. That is, all x-rays are classified as ionizing radiation. This can occur by giving all of the energy to an electron (photoionization) or by giving part of the energy to the electron and the remainder to a lower energy photon (Compton scattering). At sufficiently high energies, the x-ray photon can create an electron positron pair.

Figure 3: X-Ray Interactions with matter (Hyper Physics)

Radiation Protection

Radiation protection is generally considered to be achieved through three methods:
(Reactor Concepts Manual)

- **Shielding -** Shielding is essentially placing an attenuating material between a worker and the x-ray tube or source. Different forms of radiation react differently when obstructed by different materials. The diagram below is in simple terms how shielding materials work. The frequency of the rays determines how far the radiation will travel and how well it penetrates. More dense materials give better shielding properties than less dense materials. Lead panels are used for the exposure chamber in Rad-Source machines due to its good shielding properties, accessibility and, workability.

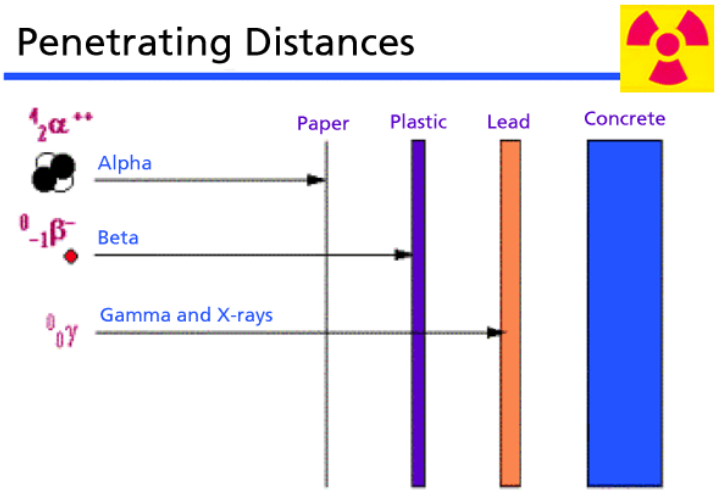


Figure 4: Penetrating Distances (Radiation Basics)

- **Distance-** The amount of radiation at a given distance from a point source varies inversely with the square of the distance. This simply means the farther away you are form the source the less radiation you will receive. For Example: the exposure of an individual sitting 4 feet from a radiation source will be 1/4 the exposure of an individual sitting 2 feet from the same source.

Figure 5: 2 ft. Exposure

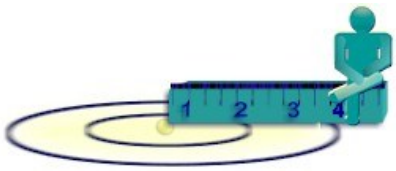


Figure 6: 4 ft. Exposure

(Radiation Protection Basics, 2010)

- **Time-** The dose of radiation received is directly proportional to the amount of time in a radiation field. This is simply the less time you are receiving radiation the lower the dose you will receive. Broadly, there are regulations in every country that limits the allowable dose over time. The following information provides some explanation on dose and exposure limits.

"Dose" is a broad term that is often used to mean either absorbed dose, or dose equivalent, depending on the context. The absorbed dose is measured in both a traditional unit called a rad and an International System (S.I.) unit called a gray (Gy). Both grays and rads are physical units (1 Gy = 100 rad) that measure the concentration of absorbed energy. The absorbed dose is the amount of energy absorbed per kilogram of absorber. Physical doses from different radiations are not biologically equivalent. For this reason, a unit called the dose equivalent, which considers both the physical dose and the radiation type, is used in radiation safety dosimetry. The unit of dose equivalent is called the rem in traditional units and the sievert (Sv) in S.I. units (1 rem = 0.01 Sv). For beta and gamma radiation, 1 rad ≡ 1 rem (1 gray ≡ 1 sievert).

Regulatory Limits for Occupational Exposure

Many of the recommendations from the ICRP and other groups have been incorporated into the regulatory requirements of countries around the world. In the United States, annual radiation exposure limits are found in Title 10, part 20 of the Code of Federal Regulations, and in equivalent state regulations. For industrial radiographers who generally are not concerned with an intake of radioactive material, the Code sets the annual limit of exposure at the following:

1) The more limiting of:

- *A total effective dose equivalent of 2 rems (0.02 Sv) or*
- *The sum of the deep-dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 50 rems (0.5 Sv).*

2) The annual limits to the lens of the eye, to the skin, and to the extremities, which are:

- *A lens dose equivalent of 15 rems (0.15 Sv)*
- *A shallow-dose equivalent of 50 rems (0.50 Sv) to the skin or to any extremity.*

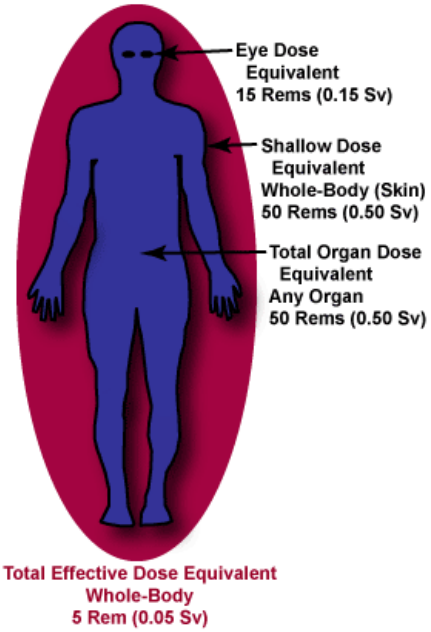


Figure 7: Total Effective Dose Equivalent (Brian Larson)

***The shallow-dose equivalent is the external dose to the skin of the whole-body or extremities from an external source of ionizing radiation. This value is the dose equivalent at a tissue depth of 0.007 cm averaged over and area of 10 cm^2. The lens dose equivalent is the dose equivalent to the lens of the eye from an external source of ionizing radiation. This value is the dose equivalent at a tissue depth of 0.3 cm. The deep-dose equivalent is the whole-body dose from an external source of ionizing radiation. This value is the dose equivalent at a tissue depth of 1 cm. The total effective dose equivalent is the dose equivalent to the whole-body.* (Brian Larson)**

Possible Health Effects

Health effects of exposure to X-Ray radiation come in two general types, direct or indirect. X-Rays are thought to create radicals in cells. Exposed cells may break or modify chemical bonds within critical biological molecules. As a result, (1) cells may be injured or damaged, although many cells repair themselves, resulting in no residual damage, (2) cells may die, which millions of body cells do every day and are replaced in a normal biological process, (3) or cells may incorrectly repair themselves resulting in a biophysical change. Finally, X-Rays may pass through the body with no interaction. (Radiation Exposure Minimization)

Factors that determine biological effects:

- Dose rate
- Total dose received
- Energy of the radiation
- Area of the body exposed
- Individual sensitivity

- Cell sensitivity
- Most sensitive: Eyes, Blood-forming, reproductive, and digestive organs
- Least sensitive: Nervous system, muscle and connective tissues

Table 1: Exposure Levels

Below are the possible health effects at various levels of exposure. (US EPA, 2010)

Exposure (rem)	Health Effect	Time to Onset (without treatment)
5-10	changes in blood chemistry	
50	nausea	hours
55	fatigue	
70	vomiting	
75	hair loss	2-3 weeks
90	diarrhea	
100	hemorrhage	
400	possible death	within 2 months
1,000	destruction of intestinal lining	
	internal bleeding	
	and death	1-2 weeks
2,000	damage to central nervous system	
	loss of consciousness;	minutes
	and death	hours to days

As with all types of ionizing radiation, X-Rays cause the most damage to rapidly growing, undifferentiated cells. Thus, women who are pregnant or suspect that they may be pregnant should take special care to protect their fetus, especially during the first trimester. No one under 21 may work around X-Rays

Causes of Exposure Using X-Ray

- Putting fingers in X-Ray beam to change sample
- Aligning X-Ray beam visually
- Modification of shielding
- Failure to read & follow manufacturers X-Ray operating instructions

⚠ WARNING

Any of these actions could cause an unnecessary exposure and a potential negative effect.

Unsafe conditions

Examples of unsafe conditions:

- Load door interlocks do not work.
- Shielding has been damaged.
- Viewing window (if installed) is cracked.
- Evidence of machine tampering.

⚠ WARNING

IF AN UNSAFE CONDITION ARISES WITH YOUR X-RAY DEVICE

1. Stop work immediately!
2. Push in the red Emergency Stop Button. (This will remove power from the High Voltage Power Supply, X-Ray Tube, and the Cooling System. An X-Ray device requires power to produce radiation.)
3. Notify your Principal Investigator.

Electrical Hazard

⚠ CAUTION

Another serious hazard from an X-Ray instrument is electrical shock. The X-Ray generator is a highly regulated DC power supply that operates at an applied voltage of up to 160 kV in order to achieve an optimum flux of X-Rays.

General X-Ray Equipment Safety Procedures

⚠ CAUTION

NOTE:
No unauthorized personnel may defeat or override any safety features on the X-Ray generators, the safety enclosures, or the collimators, tube shields and shutters without the permission of the manufacturer.

IMPORTANT SAFETY INSTRUCTIONS

⚠ WARNING This unit is to be installed only by factory-authorized persons. DO NOT ATTEMPT to install or otherwise apply, or attach any electric power to the unit prior to contacting Rad Source Technologies, Inc. (see www.radsource.com or call 678-765-7900).

⚠ WARNING This unit is to be serviced by trained personnel only. Do not remove any covers or adjust any screws, bolts, or related fasteners.

⚠ WARNING This manual instructs you how to use the RS-2000. If you disregard the instructions or information in the manual, you could be assuming responsibility for damages, costs, or injury incurred by such disregard.

⚠ WARNING This device is equipped with safety interlocks incorporated into the chamber door and X-Ray Tube access panel to prevent the unit from operating when the chamber is open. Overriding, modifying, adjusting or in any way defeating these interlocks is hazardous.

⚠ WARNING Please keep unit dry. When cleaning, do not allow cleaners or water to drip into panels or chamber. Only use damp cloth with mild soaps for cleaning.

⚠ WARNING Do not attempt to move the unit once in place. The unit is very heavy and attempting to move it may cause damage to main wall power connections or the unit may become unstable and tip over resulting in a hazardous situation.

⚠ WARNING If any obvious mechanical damage is detected or suspected, cease use immediately and contact Rad Source Technologies, Inc., 678-765-7900.

⚠ CAUTION Do not use the top of the unit as a storage area or place any heavy items or items containing liquids or materials that may harm the unit if leaked or spilled on top or inside

Interactive Components of the RS-2000 Series

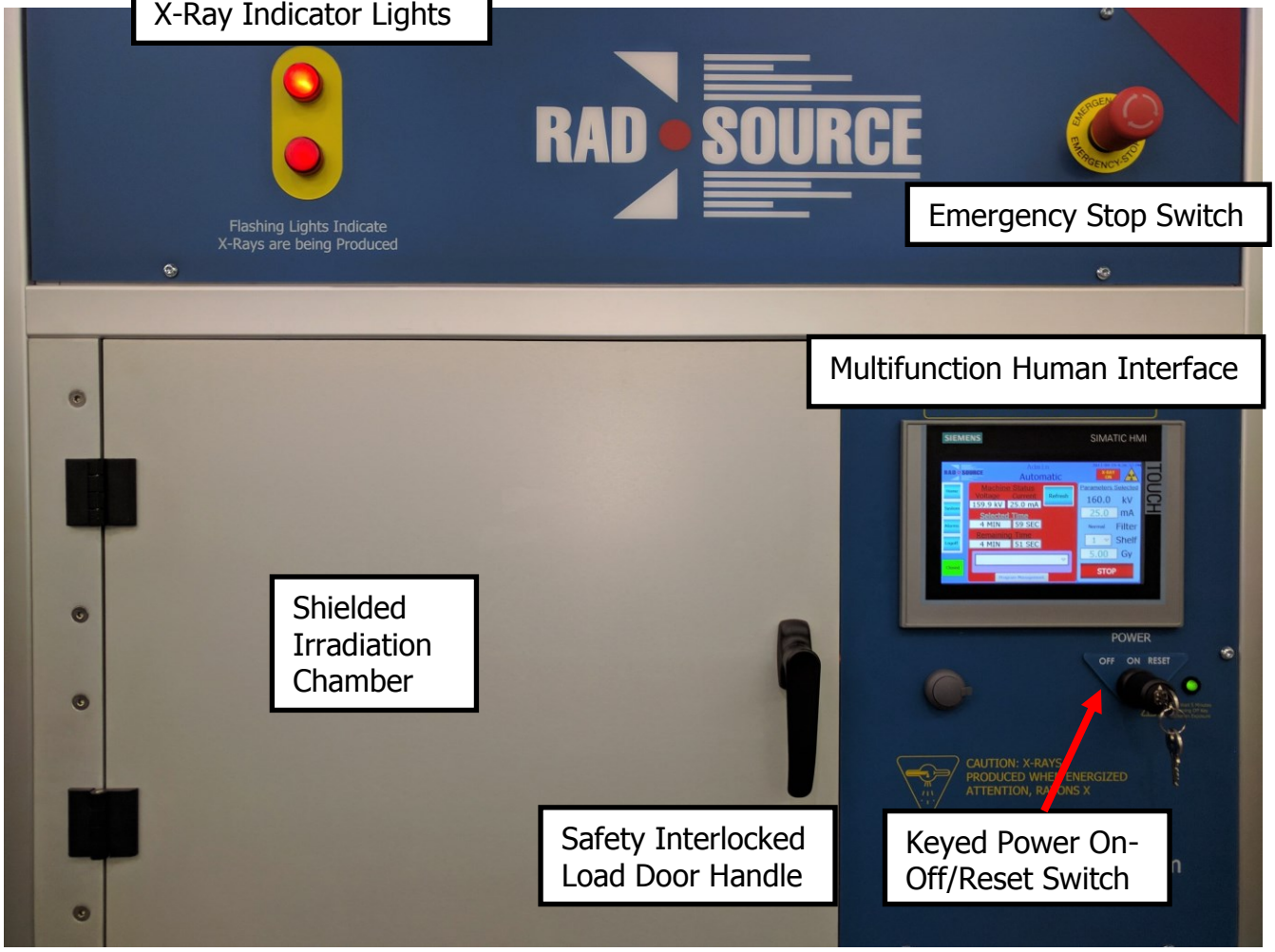
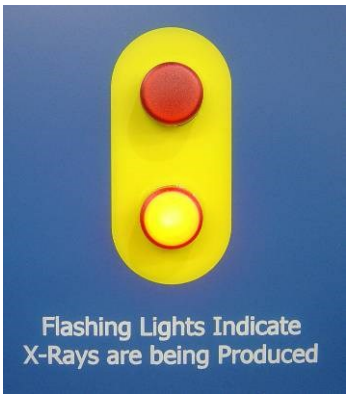


Figure 8: RS-2000 Series Operator View

Figure 9: Storage area slide door

On the Left Side of the Machine, a Sliding door with port for use and storage of an optional Ion Chamber Dose Meter

Integrated Safety Features

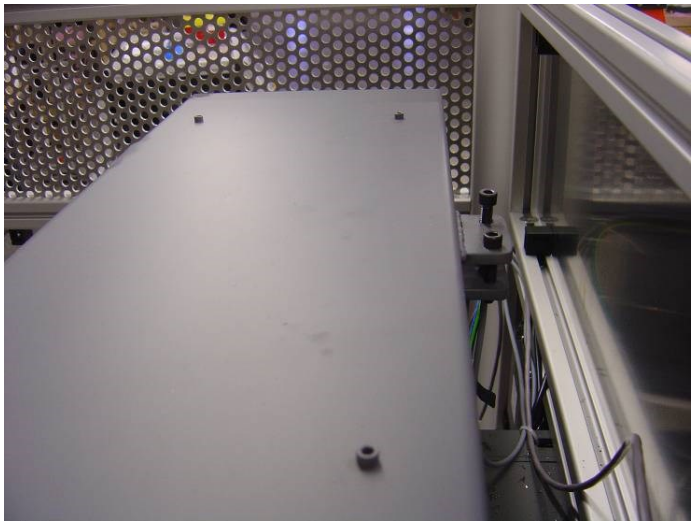


Flashing X-Ray Indication Lights show when X-Rays are being produced

Figure 10: X-Ray Indicator Lights

Door Handle Double Safety Interlocked to prevent X-Ray production while door is un-latched

Figure 11: Load (Front) Door Handle



Shielded and Interlocked X-Ray Tube Chamber, to prevent X-Ray production if panel should be open

Figure 12: Tube Chamber Area

Fully self-contained cooling system

Figure 13: Coolant Flow and Temperature Sensors

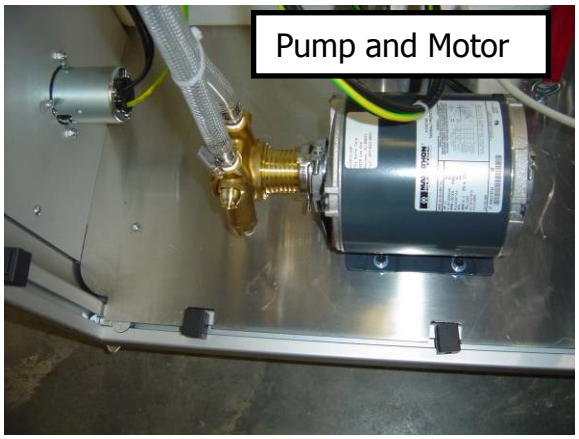


Figure 14: Coolant Pump and Motor

(uses separate rotary-vane flow sensor & J-type thermocouple temperature sensor)

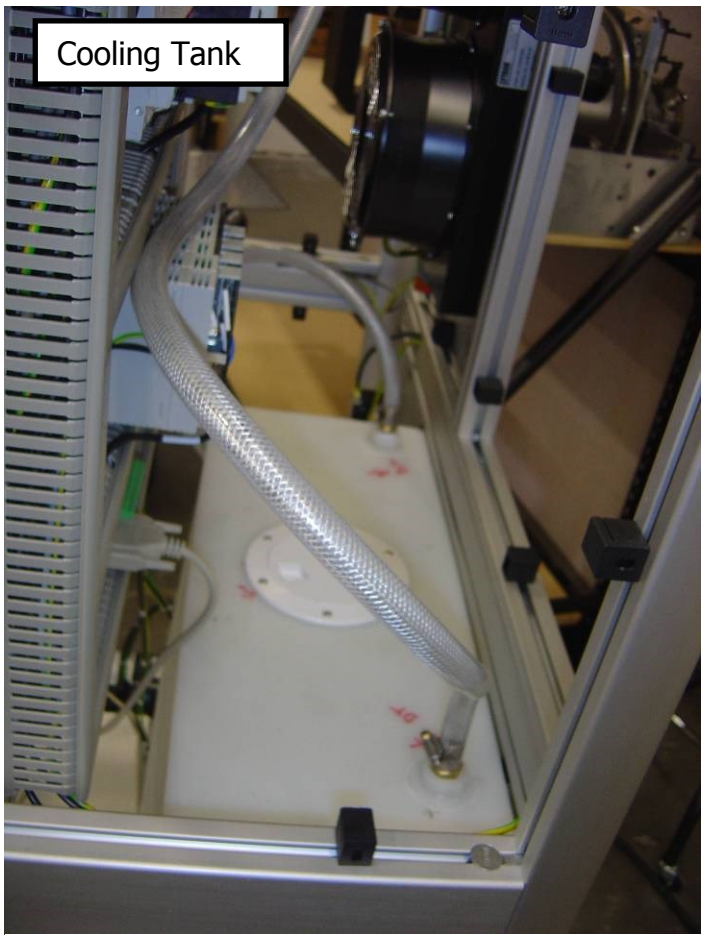


Figure 15: Coolant Tank

Figure 16: Heat Exchanger

Access and Other Important Locations

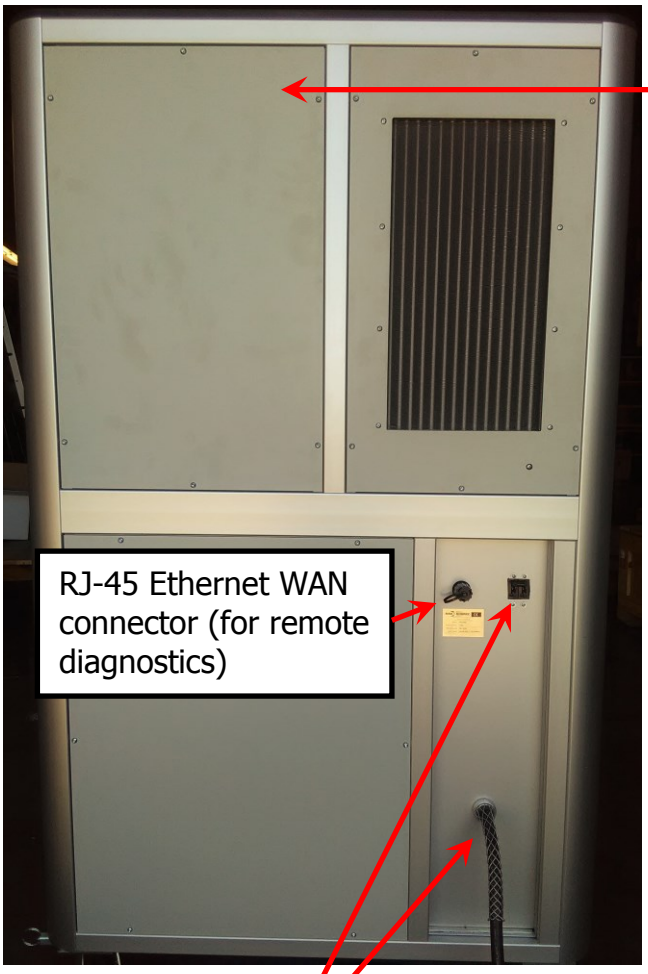


Figure 17: Machine Rear

Figure 18: Machine Left Side

ENVIRONMENTAL CONDITIONS, ELECTRICAL REQUIREMENTS, AND COOLING:

Environmental Conditions and limitations for operating this equipment:

- Indoor Use
- Altitude up to 2000 Meters
- Temperature 10 degrees Celsius to 40 degrees Celsius
- Maximum relative humidity 80% for temperatures up to 31 degrees C decreasing linearly to 50% relative humidity at 40 degrees C
- Mains supply voltage fluctuations up to +/-10% of the nominal voltage
- Category II Equipment
- Pollution Degree 2 Equipment

Electrical Ratings:

208 - 240 VAC, 1ϕ (single-phase), 50 / 60 Hz, grounded

⚠ WARNING - Unit must be connected only to supply voltage rating marked on the unit (see label on back of unit and ratings noted above) and any power receptacle must be of GROUNDED TYPE.

Power Connection:

A power cord is supplied as an integral part of the machine. The end is left open for installation to a power box.

Installation of the power supply cable to the power box is the responsibility of the customer. It should be performed by a qualified licensed electrician or construction personnel.

Once the plug is connected, turn the mains power on and turn the main machine breaker to the ON position.

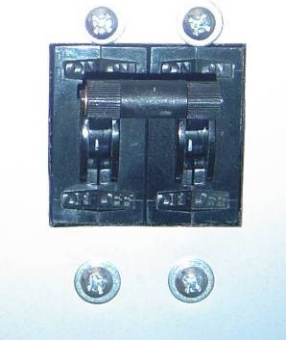


Figure 19: Main Power Breaker

Cooling:

⚠ CAUTION The cooling fans on the back of the unit should be clear of any obstruction to allow free airflow when they are operating. At least 6 inches clearance should be allowed in an open room environment and outside vents should be attached if the unit is operated in a closed area such as a closet.

The RS-2000 Series uses a heat exchanger cooling system. The unit must be filled with CLEAN WATER ONLY (PREFERABLY DISTILLED WATER). The reservoir accepts approximately 30 gallons of fluid. It is also recommended to add 1 cup of isopropyl alcohol to the water when filling. All RS-2000 Series may be equipped with an optional secondary heat exchanger located on the bottom left panel, as pictured to the right.

Figure 20: RS-2000 Series Optional Heat Exchanger

⚠ CAUTION - When filling the coolant tank, have a dry towel or similar means available to dry up any overflow or spills that may occur while filling.

To fill, remove the upper left panel to expose the top of the coolant tank open the cover and pour the coolant in, filling to within 2" of the top.

USE OF THE RS-2000 SERIES AND OPERATING CONTROLS

This is an industrial cabinet X-Ray device and is not approved for use on humans. It is for use only by properly trained operators for research laboratory and other specialty applications where ionizing radiation is required.

⚠ WARNING Any use of this equipment not for its intended use may result in an unsafe condition. Do not insert any flammable or potentially explosive materials into the unit, or apply toxic or corrosive chemicals.

If you have any questions about its use, please contact Rad Source Technologies, Inc. at 678-765-7900 or email to info@radsource.com prior to using.

How to Use the RS-2000 Series

Getting Started

To prepare for operation of the RS-2000 Series, close the front door and turn the handle clockwise until fully engaged.

NOTE: Door will not close unless latch is first in its open position.

NOTE: Safety interlocks are incorporated into the unit to only allow operation if the door is properly closed.

If the Emergency Stop is engaged, verify that it is safe to use the machine, then release the Emergency Stop by twisting the knob clockwise and letting it pop back out.

Turn the Power On-Off/Reset Key fully to the right and hold in the Reset position until the green light turns on (should take no more than a few seconds), and then release the switch to On (middle position). The Touch Panel Control Screen will boot up and illuminate, control power will be applied to the high voltage power supply, and after a few more seconds, the following screen will be displayed.

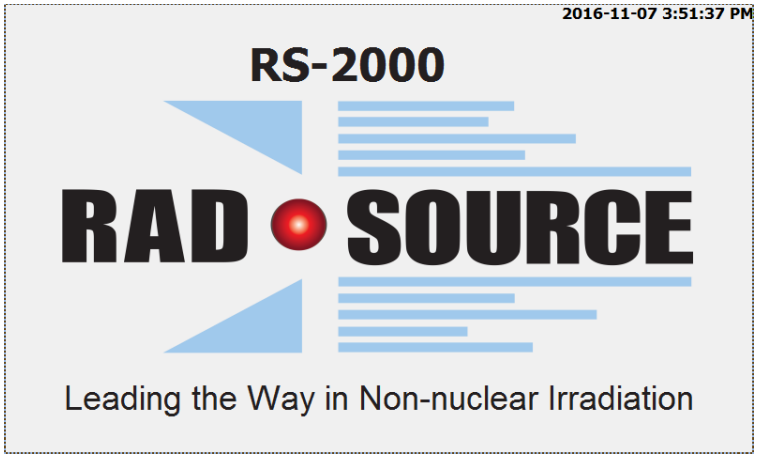


Figure 21: Opening Screen

Administration Information

Adding a user

1. Touch the screen to bring up the Login window.
2. If this is the first use of the system, login using the following:
   User name: admin
   Password: password
   Tap the screen at the box for each field and type in the appropriate value for that field followed by the Enter key (↵) using the on-screen keyboard that will appear.

3. Press *OK*, then touch anywhere on the screen again to complete the login process.

   NOTE: Admin should change password once logged in (see USER INFORMATION).

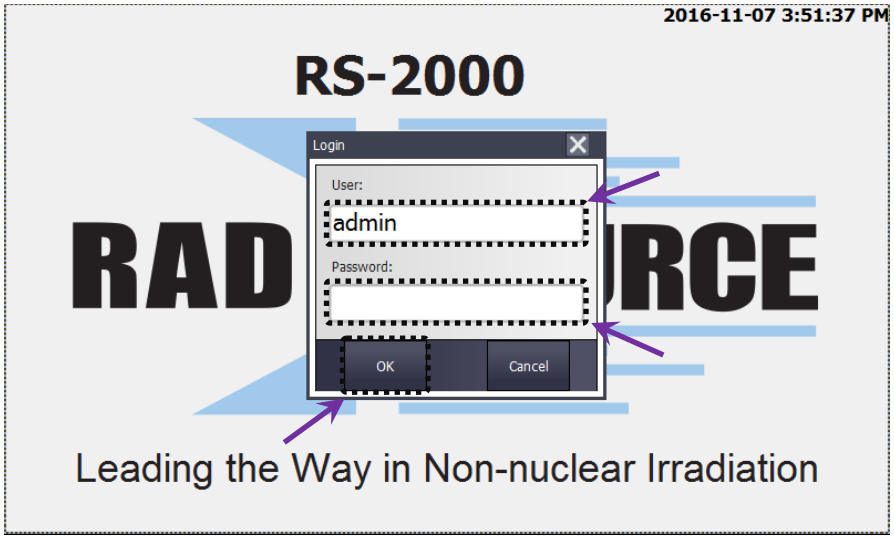


Figure 22: Login Screen

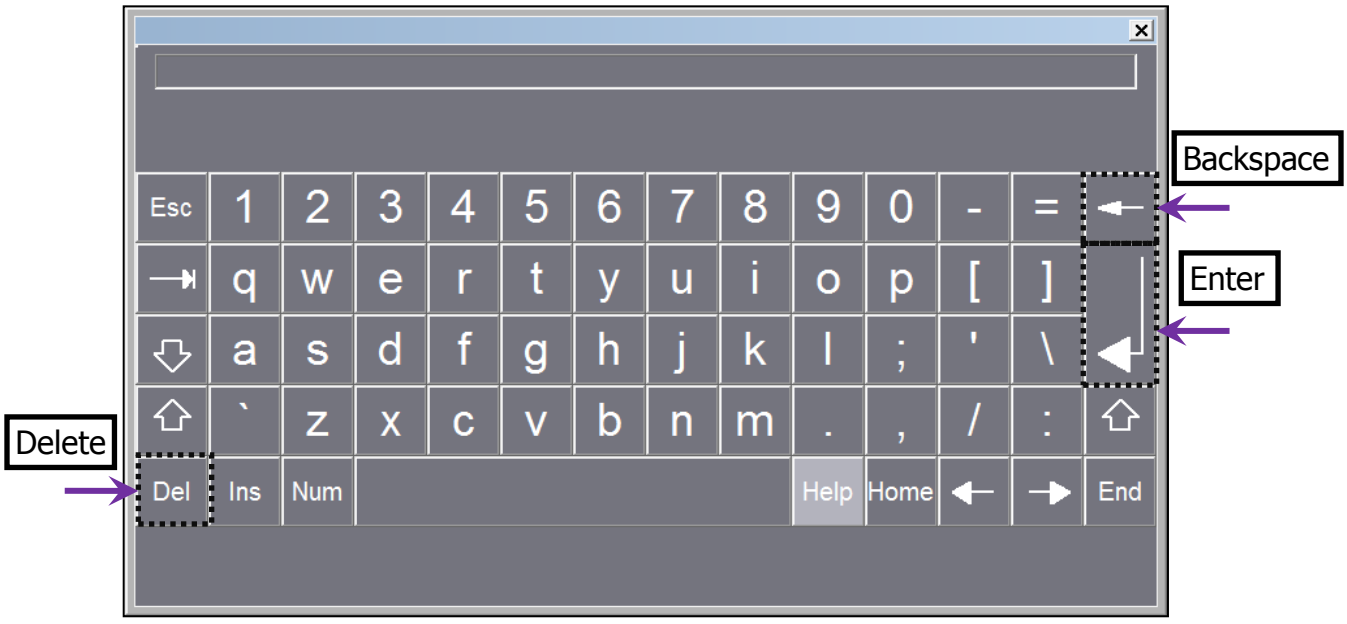


Figure 23: On-screen keyboard (with Enter, Backspace, and Delete keys marked)

4. Select System – by pressing the *System* button.

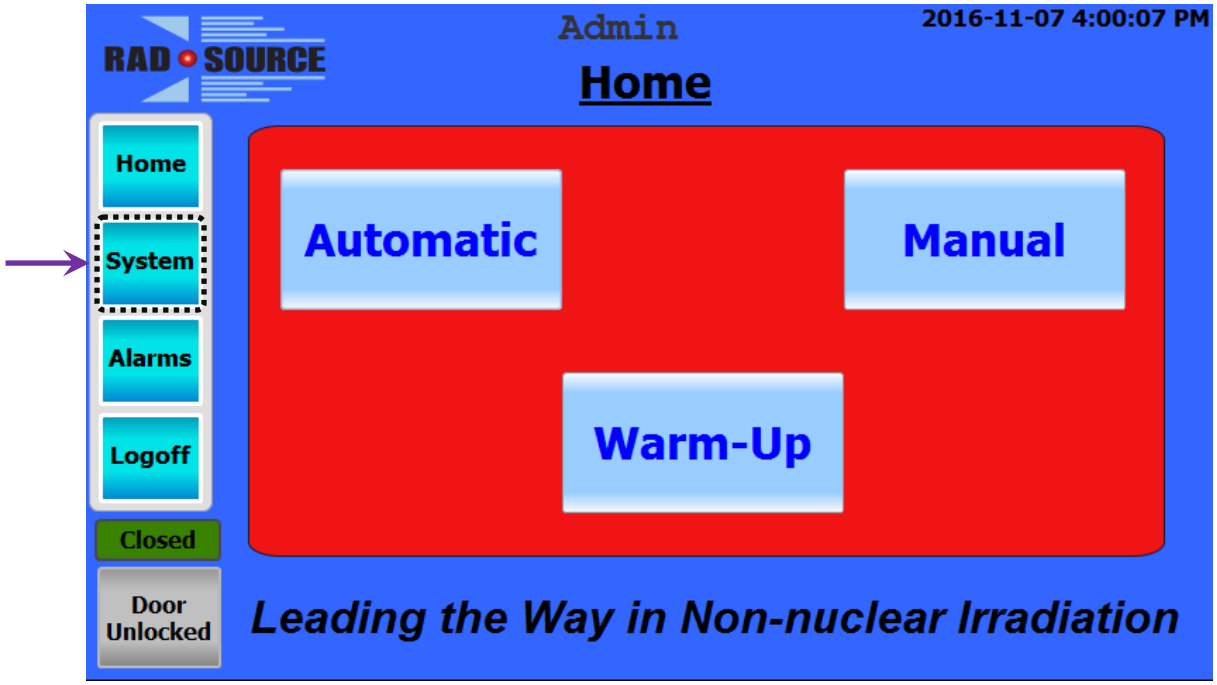


Figure 24: System Button

5. Select Users Administration – by pressing the *Users Administration* button.

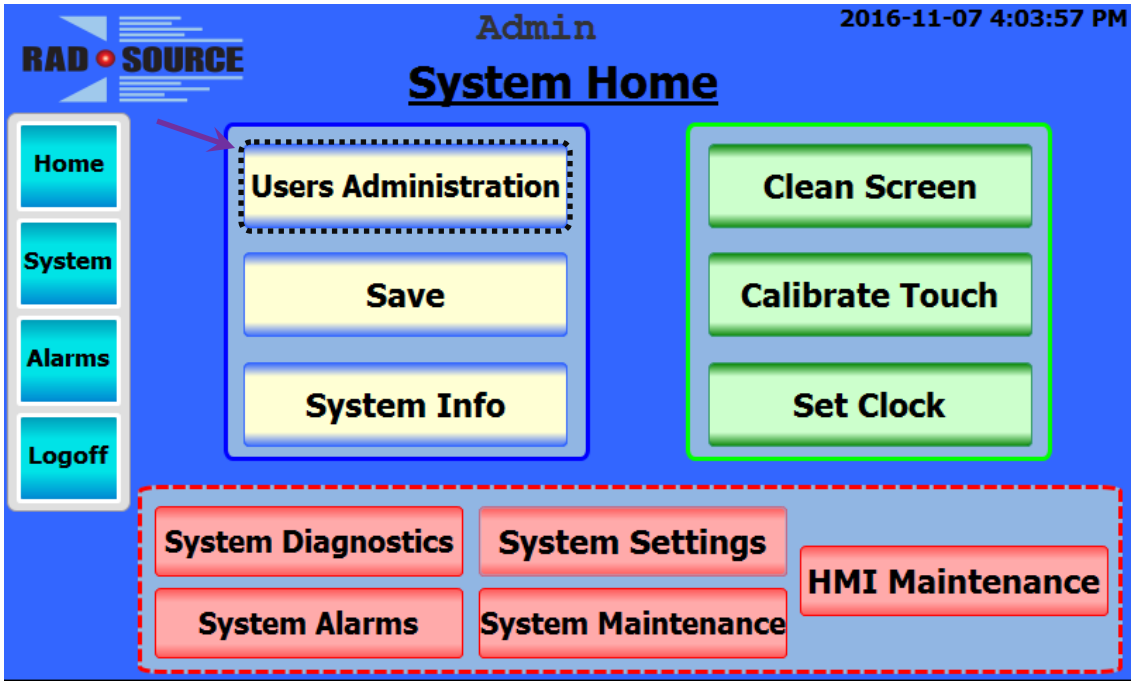


Figure 25: Users Administration Button

6. In the *User* column, double-tap directly below the last user field to bring up the on-screen keyboard.

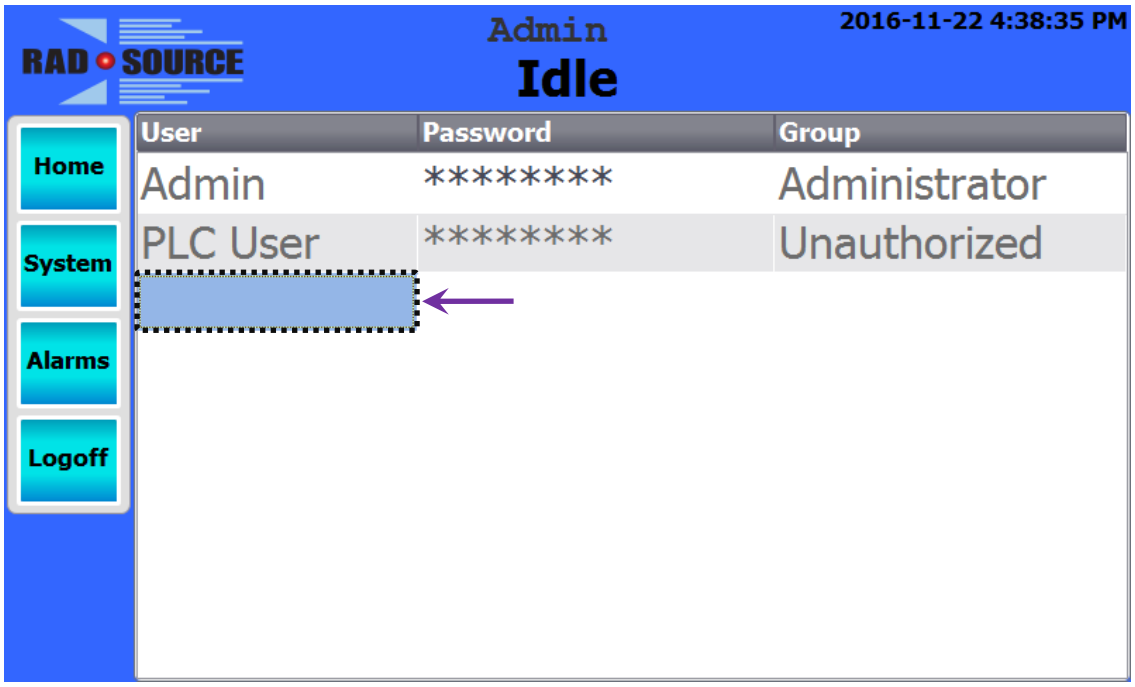


Figure 26: New User Field

7. Enter desired user name (40 character limit) then press the Enter key (↵). Please do not include any commas.

8. Double tap the field to the right under the *Password* column.

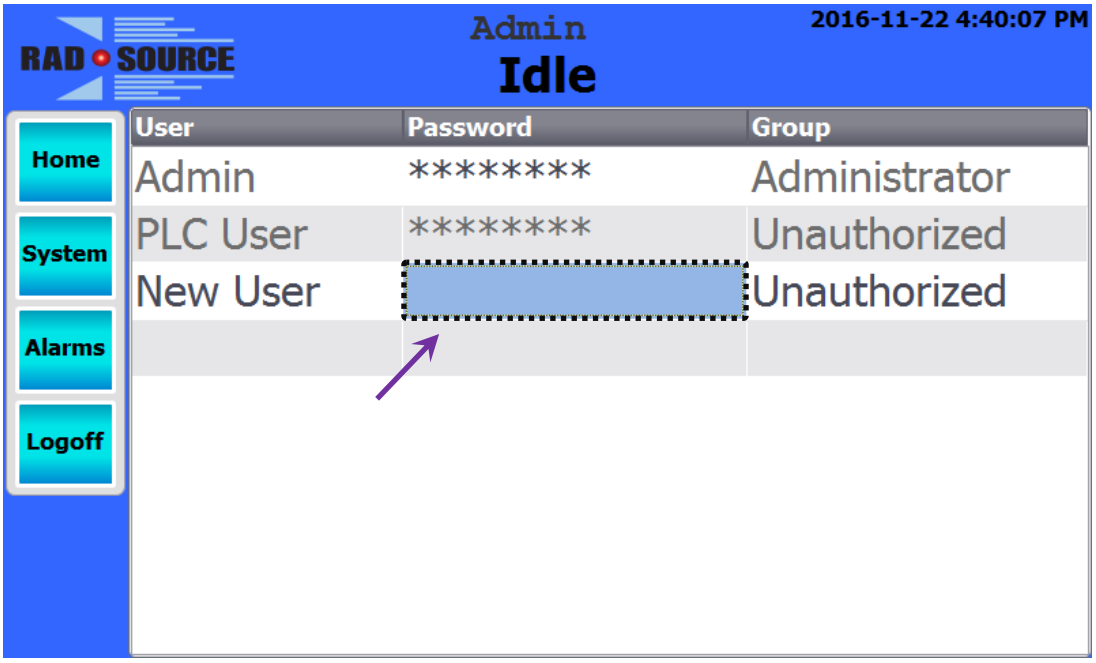


Figure 27: Password Field

9. Enter and record a generic password (4-24 character limit, without any special characters [such as /, *, %, (, or)]), and repeat the password in the confirmation box below. Press the *OK* button to store.

   NOTE: New users should be notified to change the password upon login (see USER INFORMATION). For security reasons, eight asterisks (*) will always be displayed in password fields.

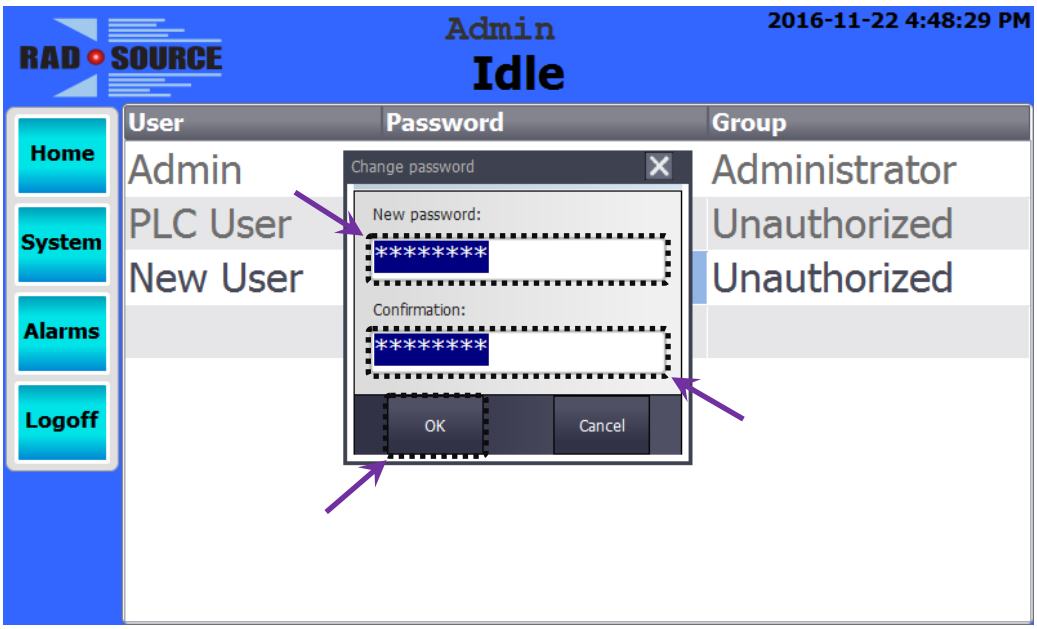


Figure 28: Create Password

10. After the password is created, the users list will sort alphabetically.
11. Press the field to the right of the new user to highlight the group column.
12. Use the selection arrow to the right to reveal the available assignment groupings.

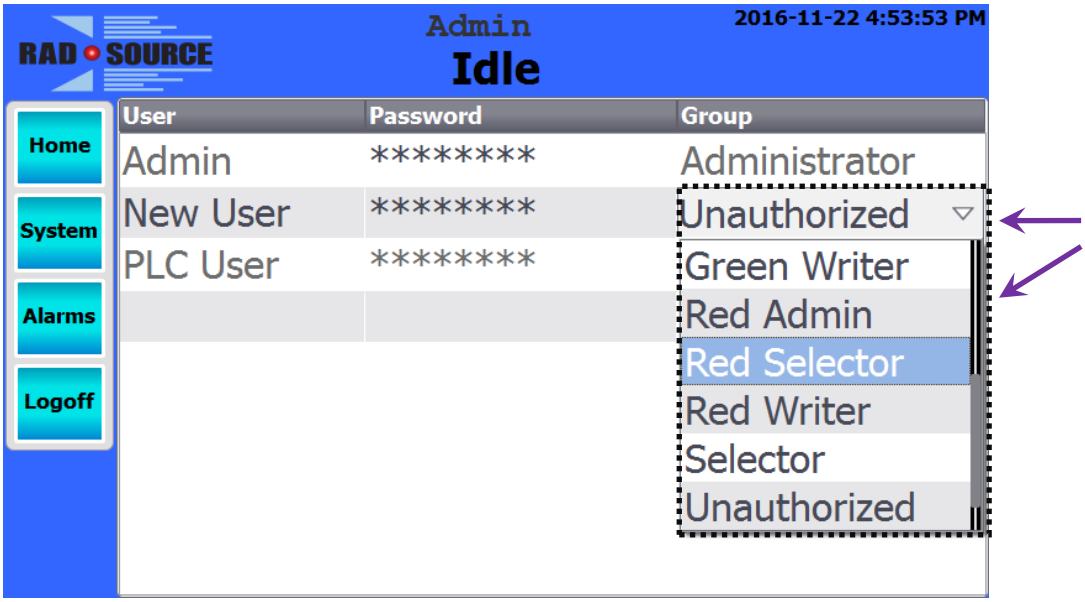


Figure 29: Group Field

Using the table below, assign the user to the appropriate group based on the authorized privileges. Administrators should only assign personnel for their appropriate groups/sections.

There are three program groups of colors (Blue, Green, and Red) and a fourth generic group (shown as purple in Auto mode program selection and Program Management). Each of these four program groups has its own set of up to 500 Auto Programs and has three sub-groups of Admin, Selector, and Writer users. The following table shows the permissions for each sub-group of users.

NOTE: Some functions (such as system maintenance and configuration) are only available to authorized field technicians.

Table 2: User Group Authorization Table

	Blue Admin / Green Admin / Red Admin / Administrator	Blue Selector / Green Selector / Red Selector / Selector	Blue Writer / Green Writer / Red Writer / Writer
Monitor machine status	X	X	X
Select and run programs in Auto mode	X	X	X
Program Management (edit programs)	X		X
Create and run experiments in Manual mode	X		X
Create / Assign Users	X		
System menu access	Full	Limited	Limited

13. When finished, press *Logoff* (all changes will be saved). Then, select *Log Off* again.

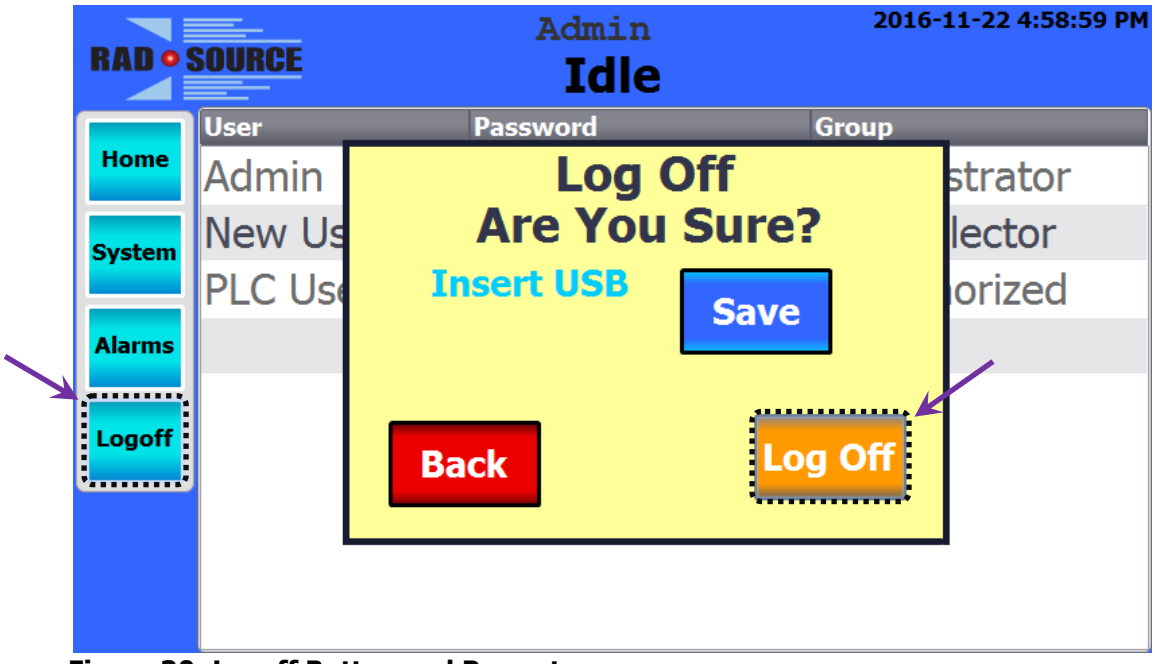


Figure 30: Logoff Button and Prompt

Removing a User

1. Select *System*. (See Fig. 24.)
2. Select *Users Administration*. (See Fig. 25.)
3. In the *User* column, double tap the *User* field of the user that you wish to remove which will bring up the on-screen keyboard. (See Fig. 23.)
4. Completely delete the *User* name by using the Delete key (Del) or the Backspace key (⟵), and then press the Enter key (↵). Afterward, all fields for that user should be removed.

User Information

Changing a password

1. Touch the screen to bring up the login. (See Fig. 22.) New Users should sign in using the information given to them by the administrator.
2. Press *OK*, then touch anywhere on the screen again to complete the login process.
3. Select *System*. (See Fig. 24.)
4. Select *Users Administration*. (See Fig. 25.)
5. Double tap the *Password* field to the right of your user name and create a new password (4-24 character limit, without any special characters [such as /, *, %, (, or)]). Confirm by re-entering the same password. (See Fig. 27 and 28.)

   NOTE: For Security reasons, eight asterisks (*) will be displayed in the password field.
6. Press the *Home* button to return to the main screen.

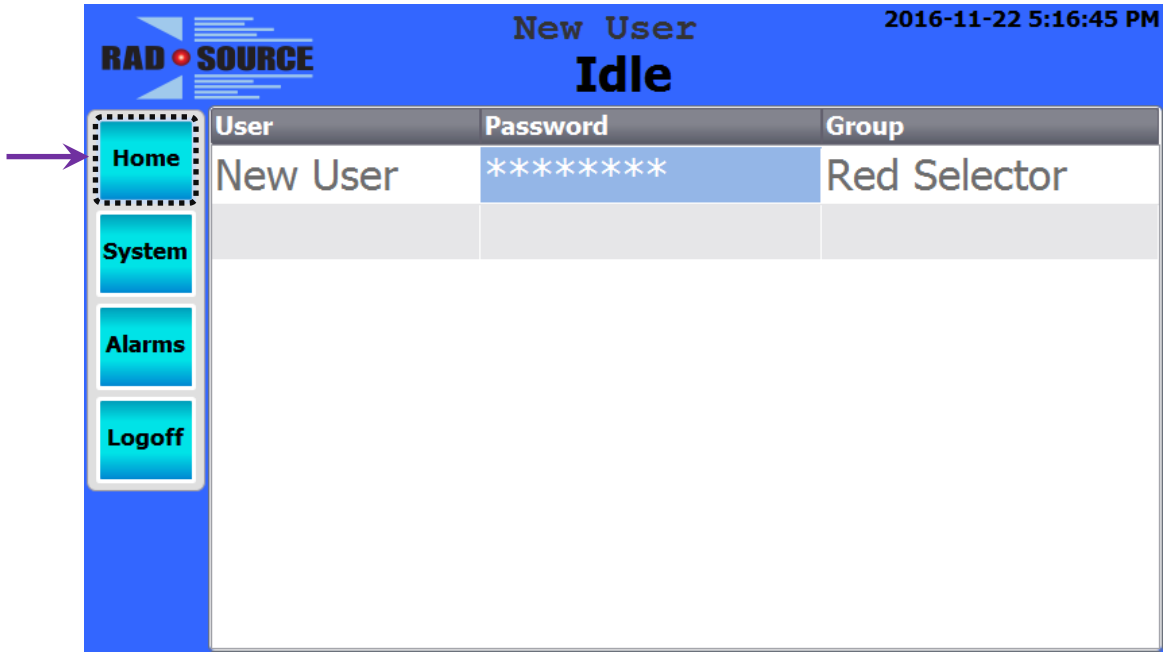


Figure 31: Home Button

Machine Operation

Performing an X-Ray Tube Warm-Up

1. An indication will appear if a warm-up is needed. (See Fig. 32.)
2. Press the *Warm-up* button to change the screen.

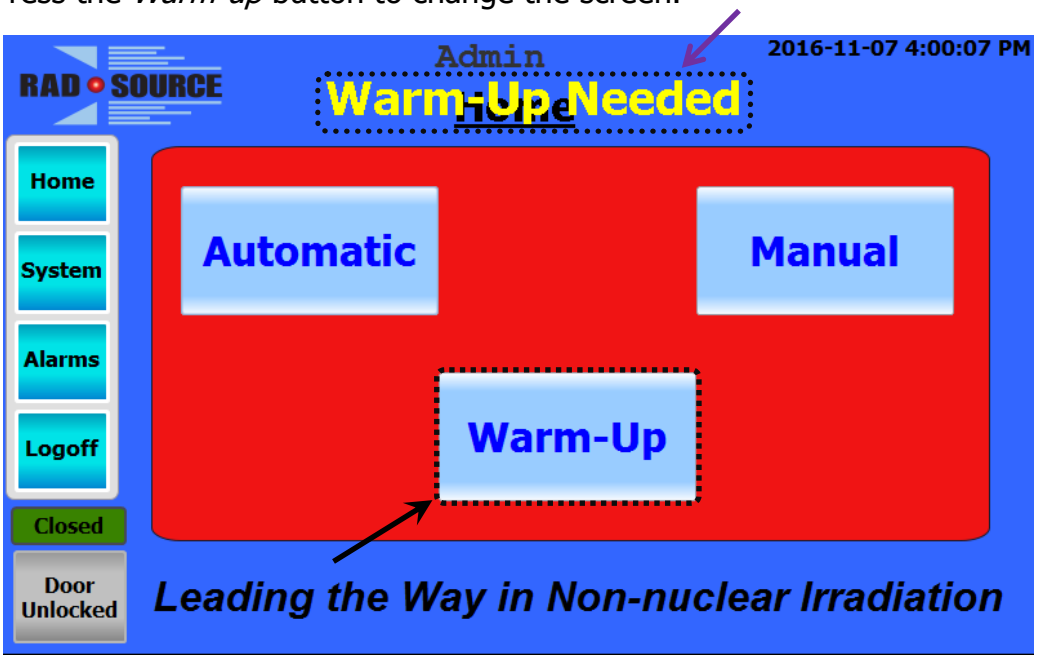


Figure 32: Warm-Up Needed

3. The top-right button of the Warm-Up screen shows the current mode. In Extended Warm-Up, "Extended" replaces "Normal" and a longer Approximate Time Remaining is shown. If the machine has been inactive for more than a week, Extended Warm-Up is recommended. If you wish to toggle between the two modes, press the *Normal* / *Extended* button. (See Fig. 33 and 34.)

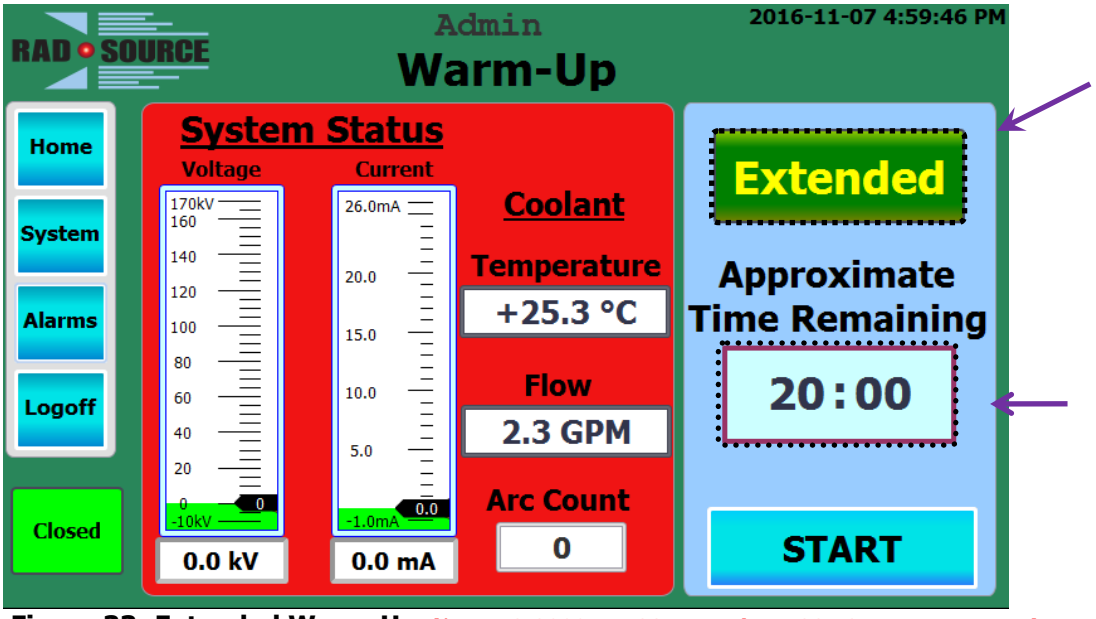


Figure 33: Extended Warm-Up ***(*For RS-2000 Pro 225, Max kV = 225 & Max mA = 17.7)***

4. Door status is shown in the bottom left. Close the door and turn handle to locked position, if not already closed and locked. (See Fig. 11 and 34.) Press the *Start* button, and confirm starting by pressing the *Yes* button in the prompt that pops up.

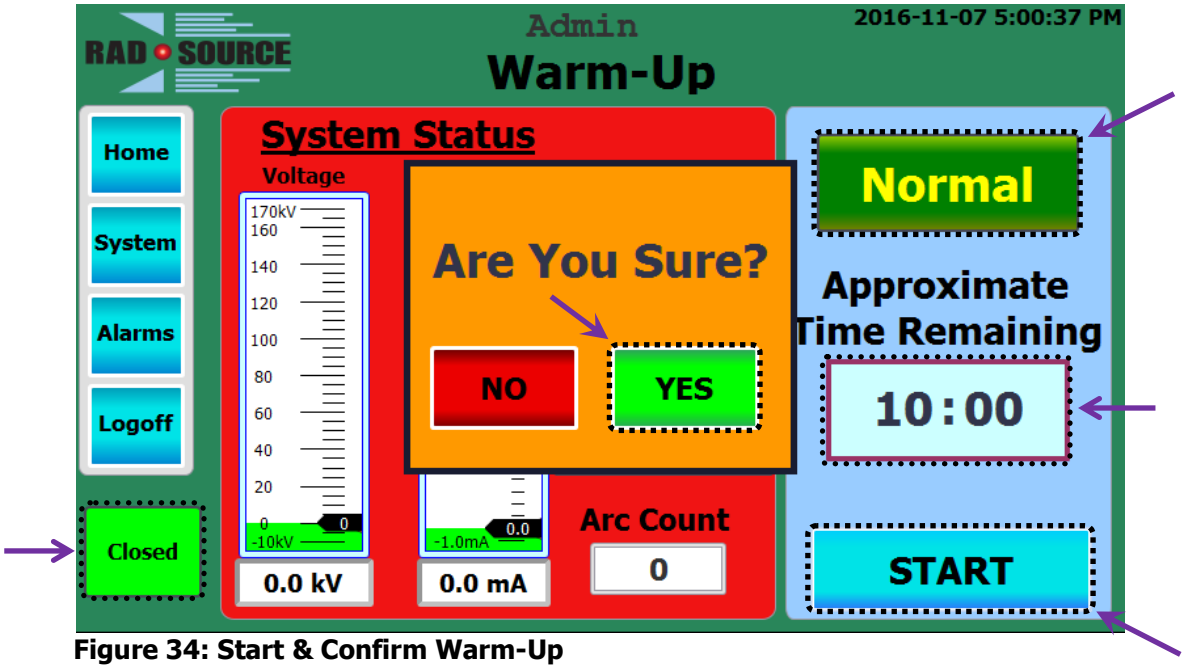


Figure 34: Start & Confirm Warm-Up

Writing a new (or editing an existing) Automatic Program (as Admin or Writer)

1. Login: Tap the screen to bring up the *Login* prompt. Log in using your user name and password that has been assigned to the program (color) group to be managed. Press the *OK* button, then tap anywhere on the screen again to complete the process.
2. Select *Automatic* to change operation mode. At the bottom of the screen, press *Program Management* to change to the *Auto Programs* screen.

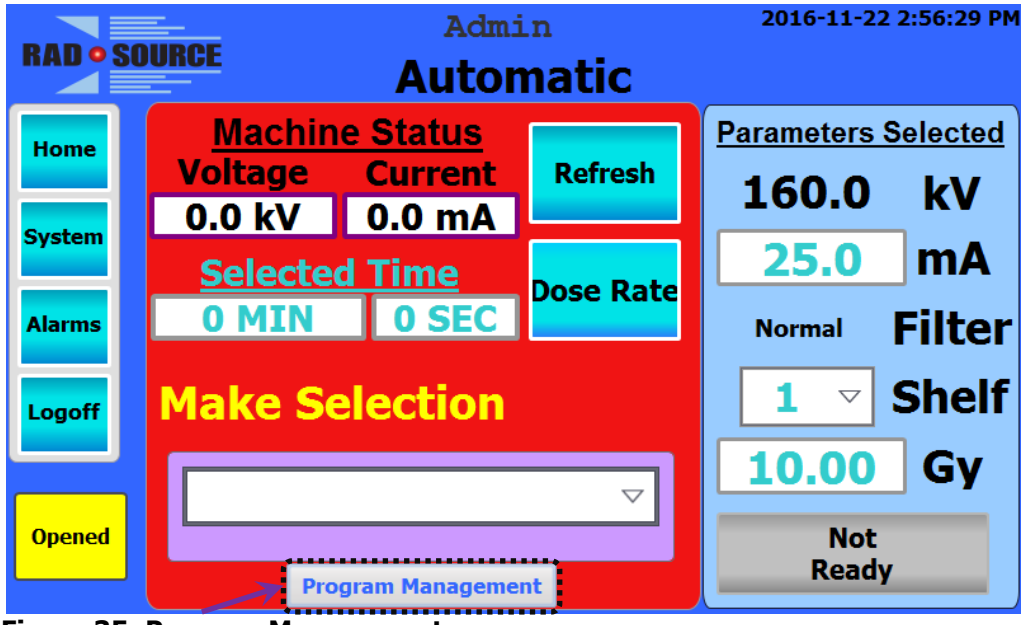


Figure 35: Program Management

3. At the bottom of this screen, press *New*, then tap the top box to bring up the on-screen keyboard and enter a program name. Or, to edit an existing program, tap the arrow on the right side of the box and select the program's name. (See Fig. 36 and 23.)

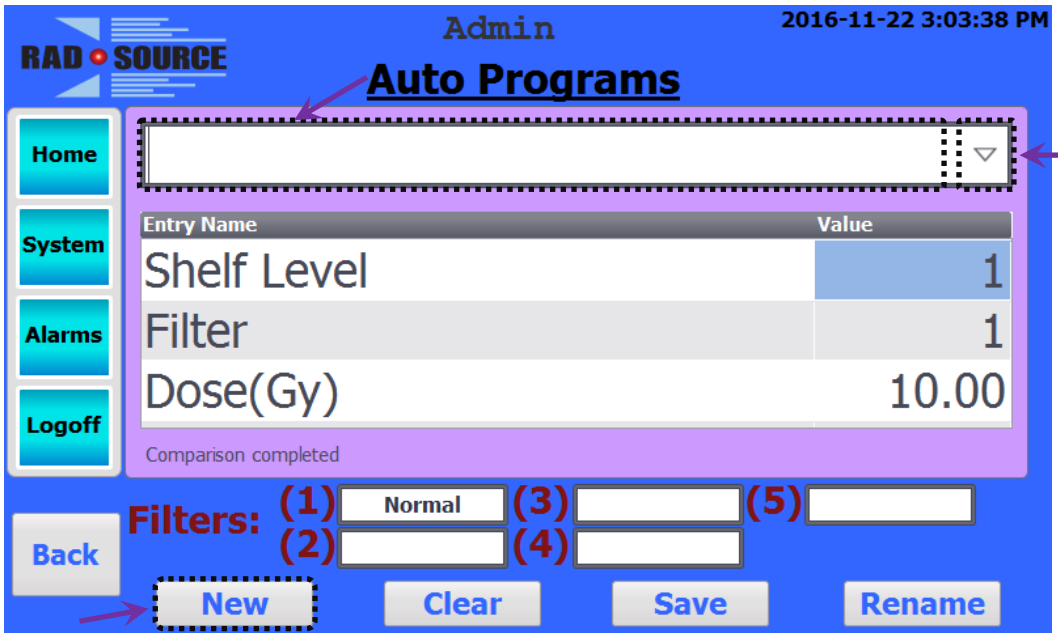


Figure 36: New or Existing Program

4. Under the *Value* column, enter the desired Shelf Level (1 - 6).

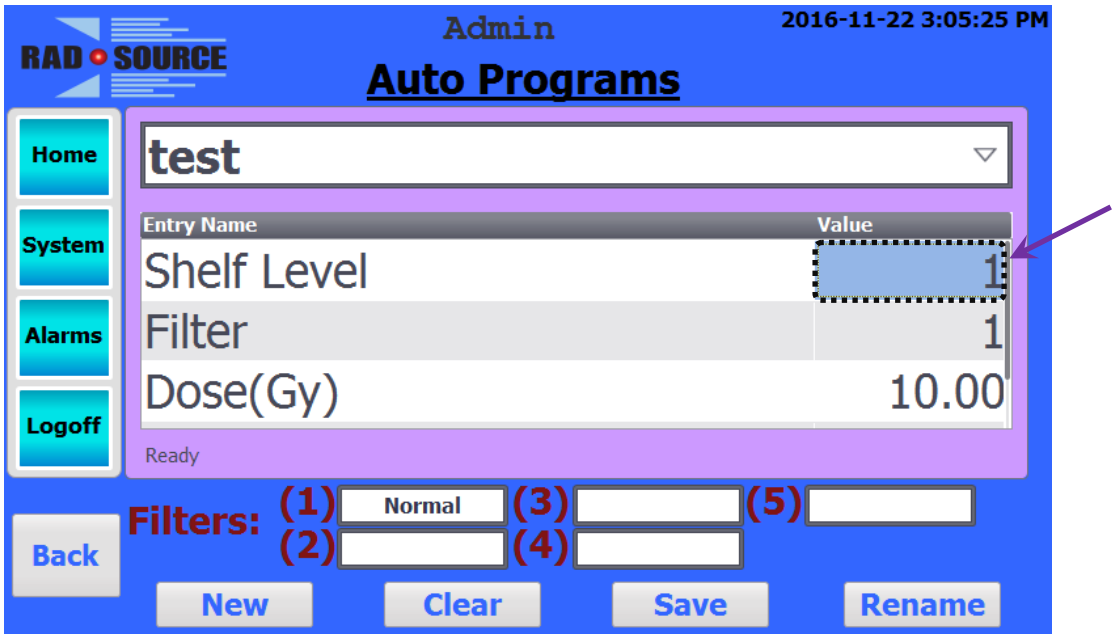


Figure 37: Shelf Level Entry

5. If a filter is required, input the number (shown in parentheses) that corresponds to the desired filter into the *Filter* value column.

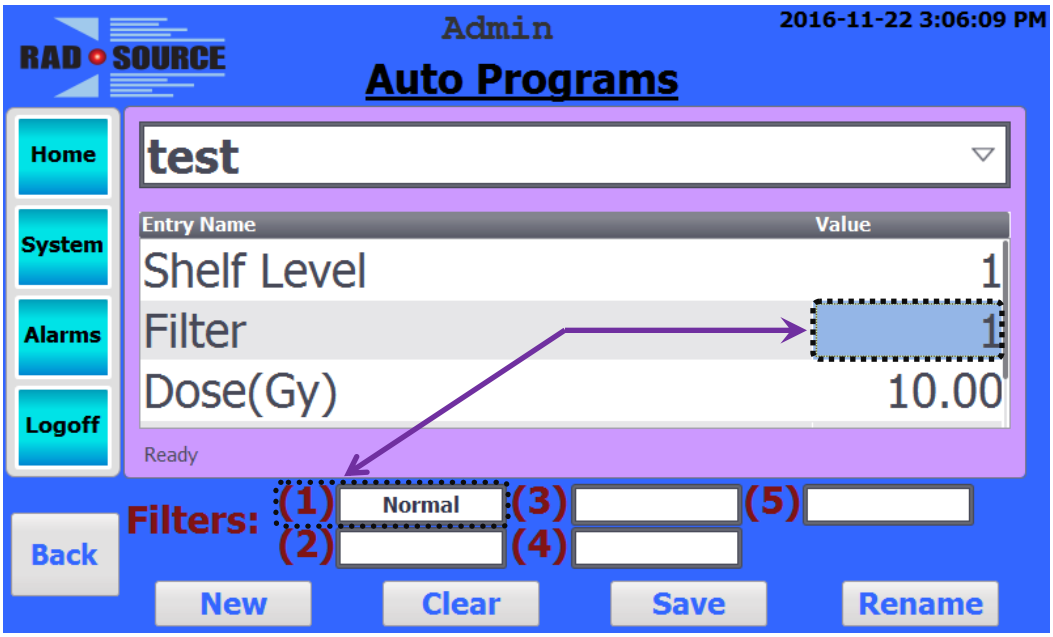


Figure 38: Filter Selection

6. Input the desired total dose value in gray (Gy) into the *Dose(Gy)* field using the on-screen keyboard that pops up after tapping its Value field (range: 1.0 to 999.99 Gy).

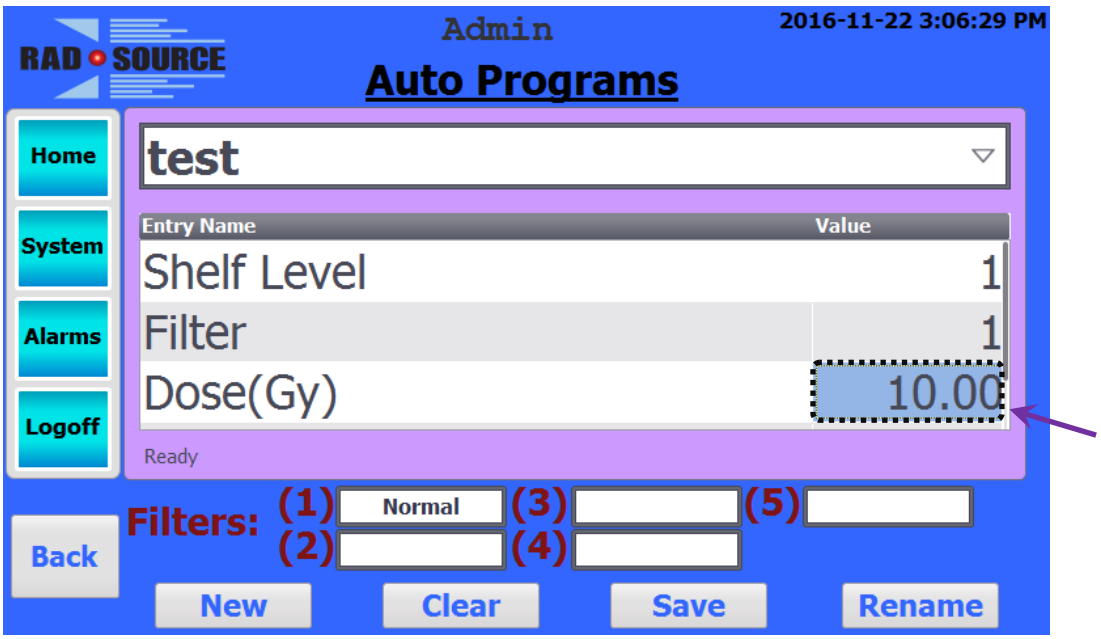


Figure 39: Dose (gray) Entry

7. Optionally, on recent software, the X-Rays current value can be entered into the *mA* field to reduce the dose rate (and proportionally increase the time to deliver the requested dose) after scrolling to the mA Entry and tapping its Value field to bring up the on-screen keyboard.

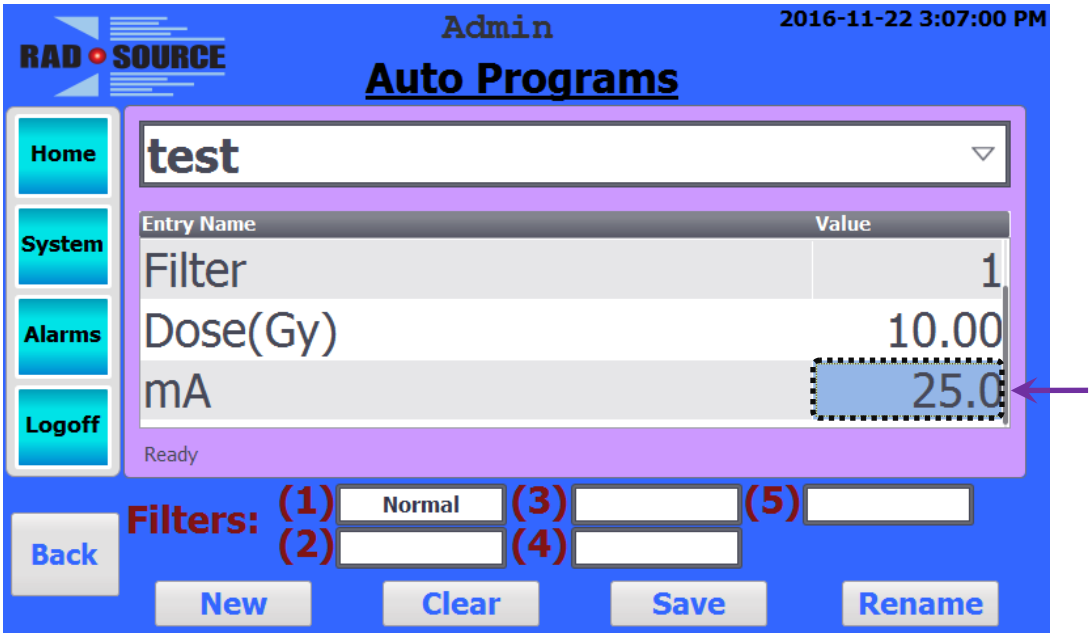


Figure 40: mA Entry ***(*For RS-2000 Pro 225, Max kV = 225 & Max mA = 17.7)***

8. Press *Save* and accept any save or overwrite prompt.

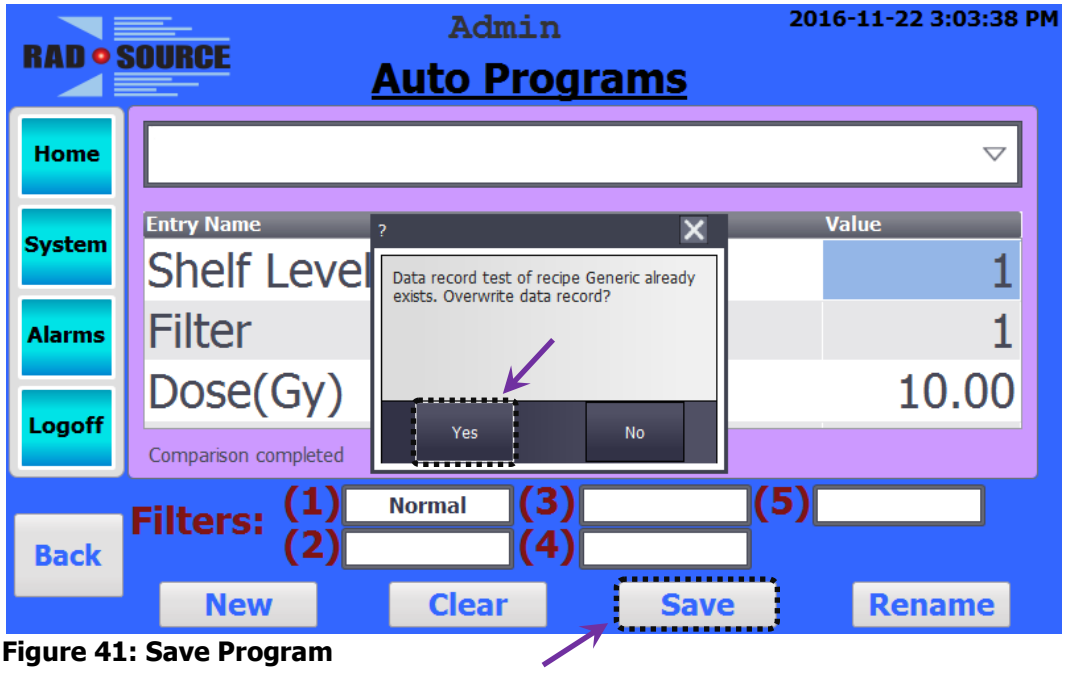


Figure 41: Save Program

Running an Automatic Program (as Admin, Writer, or Selector)

1. Press the *Home* button. Select *Automatic*. (See Fig. 32.)
2. At the bottom of the screen, select the desired program from the drop down menu.

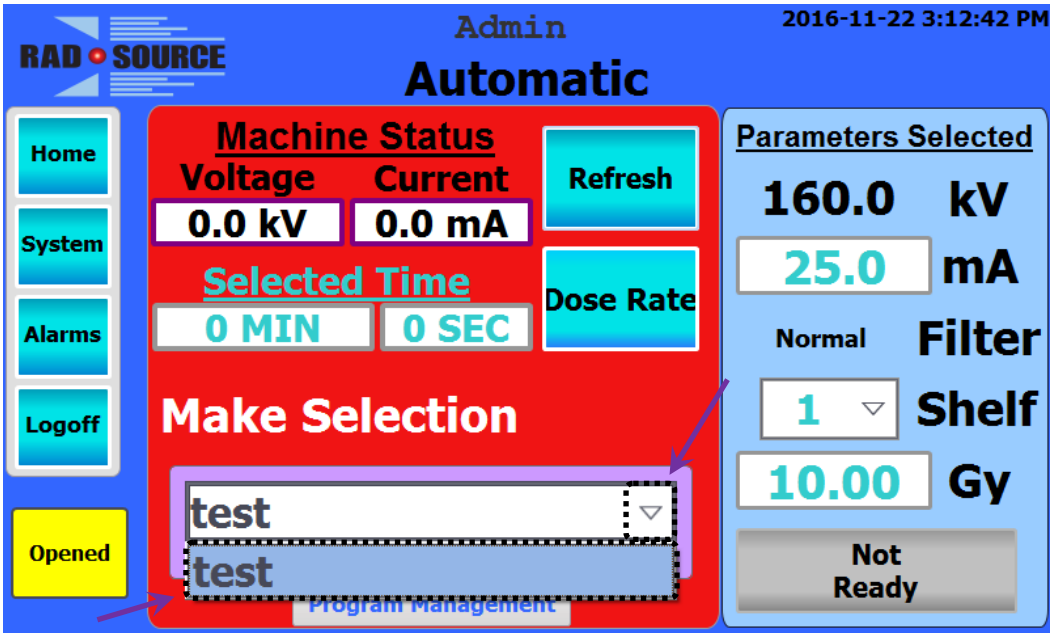


Figure 42: Select Program

3. Verify that the parameters shown on the right side of the display are correct.

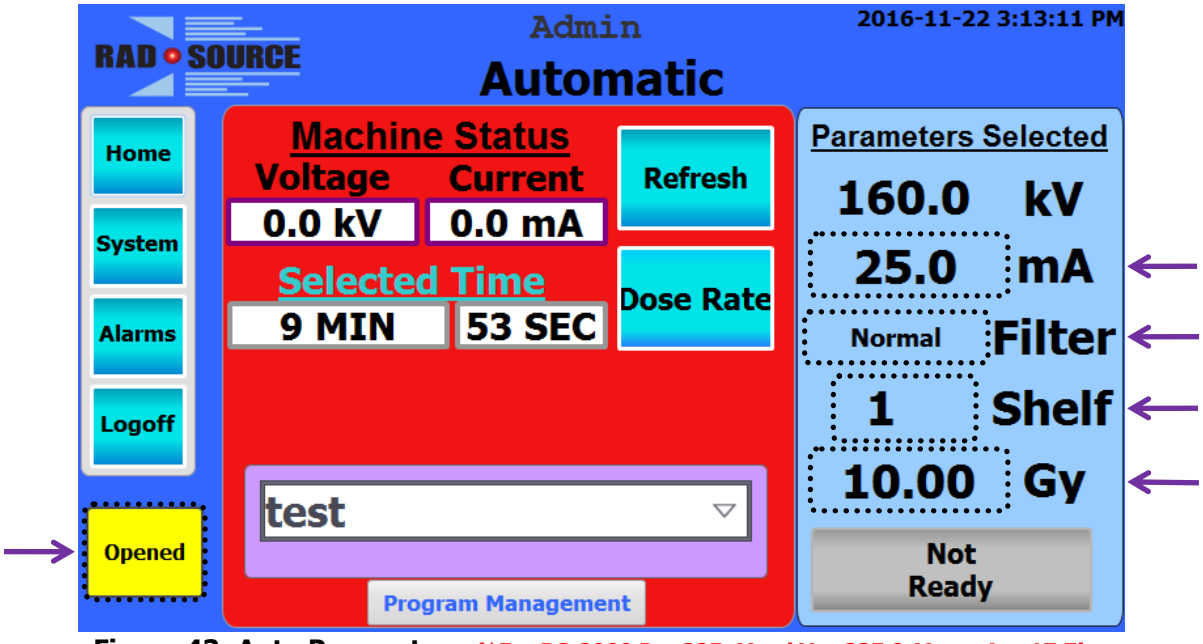


Figure 43: Auto Parameters ***(*For RS-2000 Pro 225, Max kV = 225 & Max mA = 17.7)***

4. Turn the door handle to its unlocked position, and open the door. Load your sample. Close the door, and turn the handle back to the locked position. (See Fig. 11, 43, and 44.)

5. Press *Start* and confirm start by pressing the *Yes* button at the prompt.

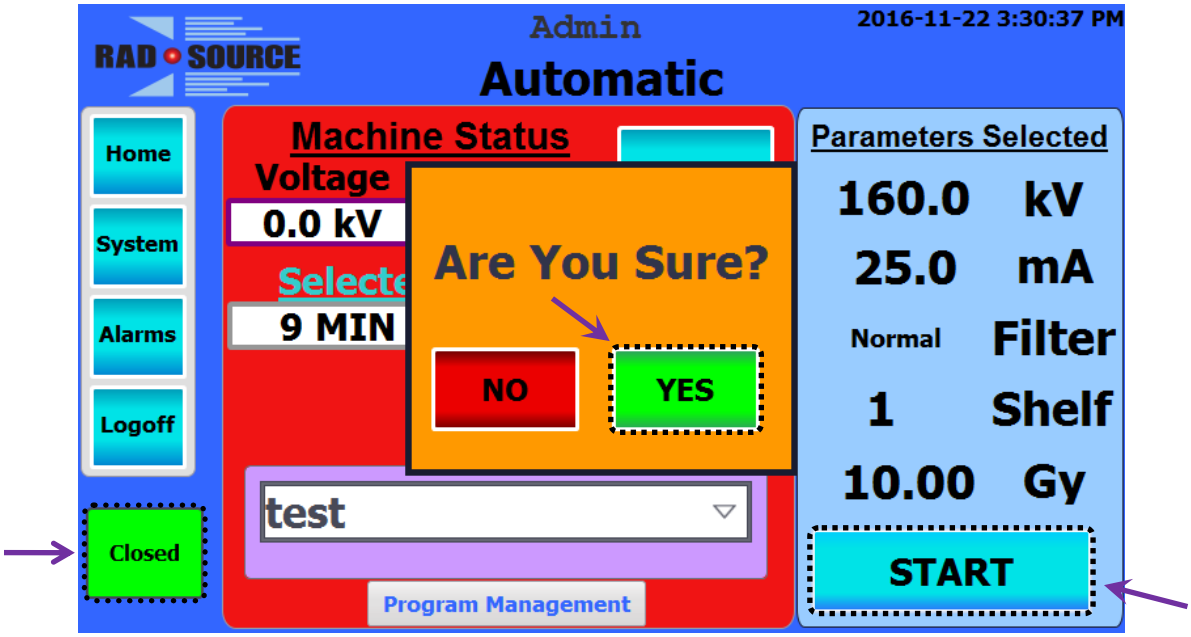


Figure 44: Start & Confirm Automatic Cycle

NOTE: To cancel a running cycle, press the *Stop* button (which replaces *Start*).

6. When the exposure is complete, the buzzer will sound.

Running a Timed Exposure

1. Press *Home*, then *Automatic*; or, in Automatic, press *Refresh*. (See Fig. 32 and 45.)
2. Input the desired time (min & sec), shelf position, and, if available, X-Rays current (mA). The corresponding dose (Gy) will be displayed in the parameters window.

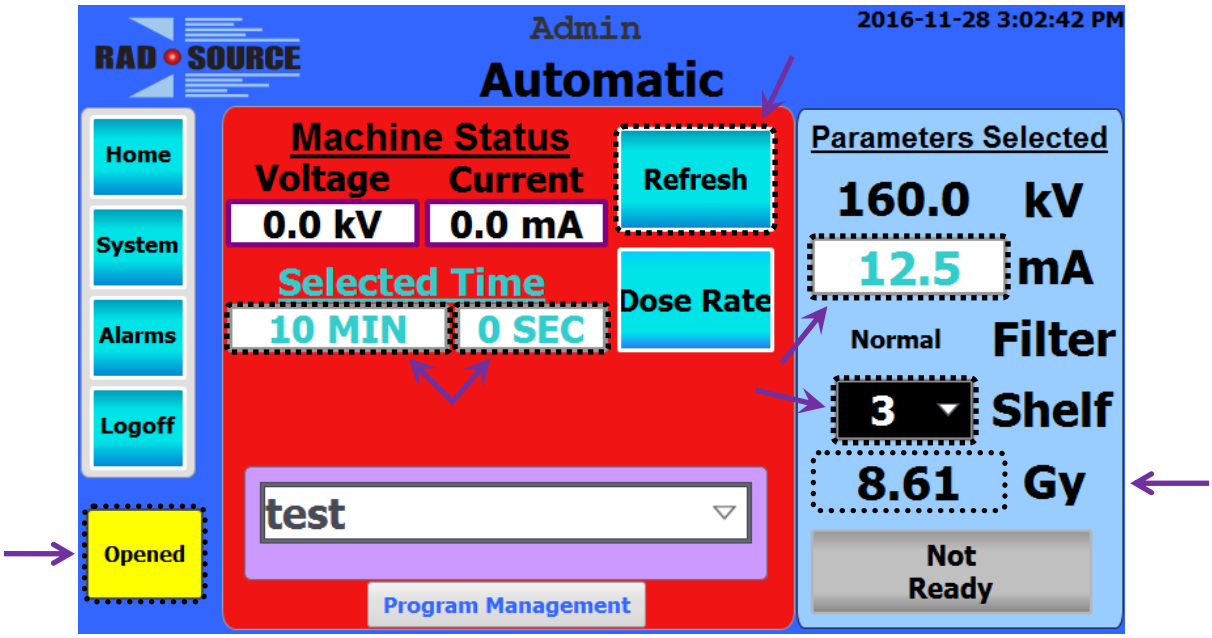


Figure 45: Time, Shelf, & mA Input ***(*For RS-2000 Pro 225, Max kV = 225 & Max mA = 17.7)***

3. Turn the door handle to its unlocked position, and open the door. Load your sample. Close the door, and turn the handle back to the locked position. (See Fig. 11, 43, and 44.)
4. Press *Start* and confirm start by pressing the *Yes* button at the prompt. (See Fig. 44.)

   NOTE: To cancel a running cycle, press the *Stop* button (which replaces *Start*).

5. When the exposure is completed, the buzzer will sound.

Running a Desired Dose Exposure

1. Press *Home*, then *Automatic*; or, in Automatic, press *Refresh*. (See Fig. 31 and 46.)
2. Input the desired dose and select the shelf position. The corresponding time will be displayed under *Selected Time*.

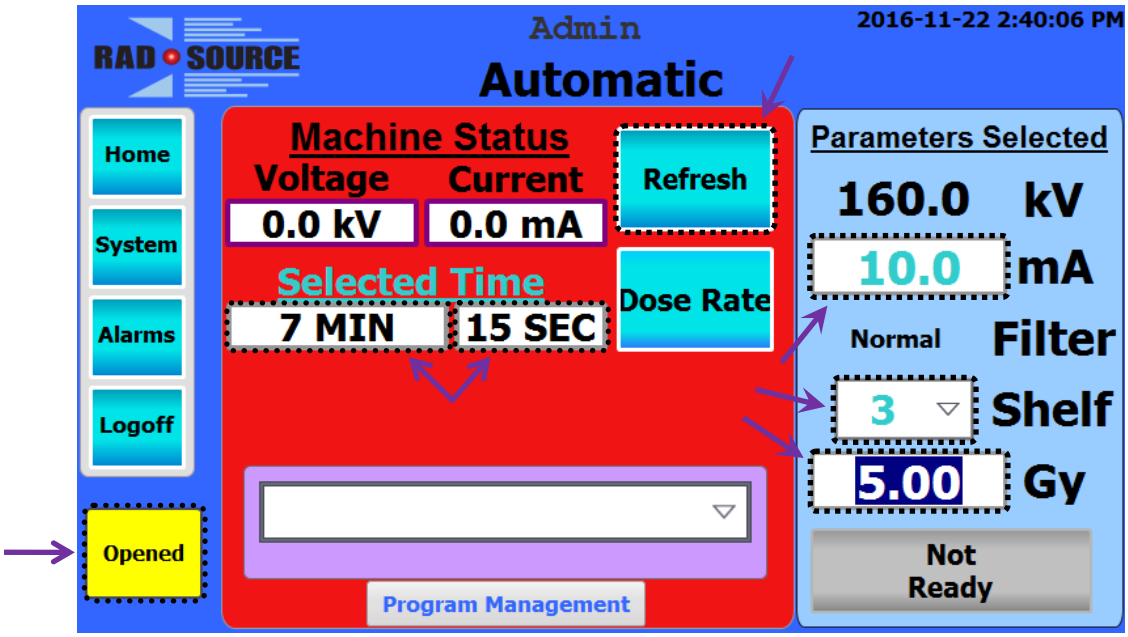


Figure 46: Dose, Shelf, & mA Input ***(*For RS-2000 Pro 225, Max kV = 225 & Max mA = 17.7)***

3. Turn the door handle to its unlocked position, and open the door. Load your sample. Close the door, and turn the handle back to the locked position. (See Fig. 11, 43, and 44.)
4. Press *Start* and confirm start by pressing the *Yes* button at the prompt. (See Fig. 44.)

   NOTE: To cancel a running cycle, press the *Stop* button (which replaces *Start*).

5. When the exposure is completed, the buzzer will sound.

Manual Mode [lower power option]

1. Press *Home*. (See Fig. 31.)
2. Press *Manual*.

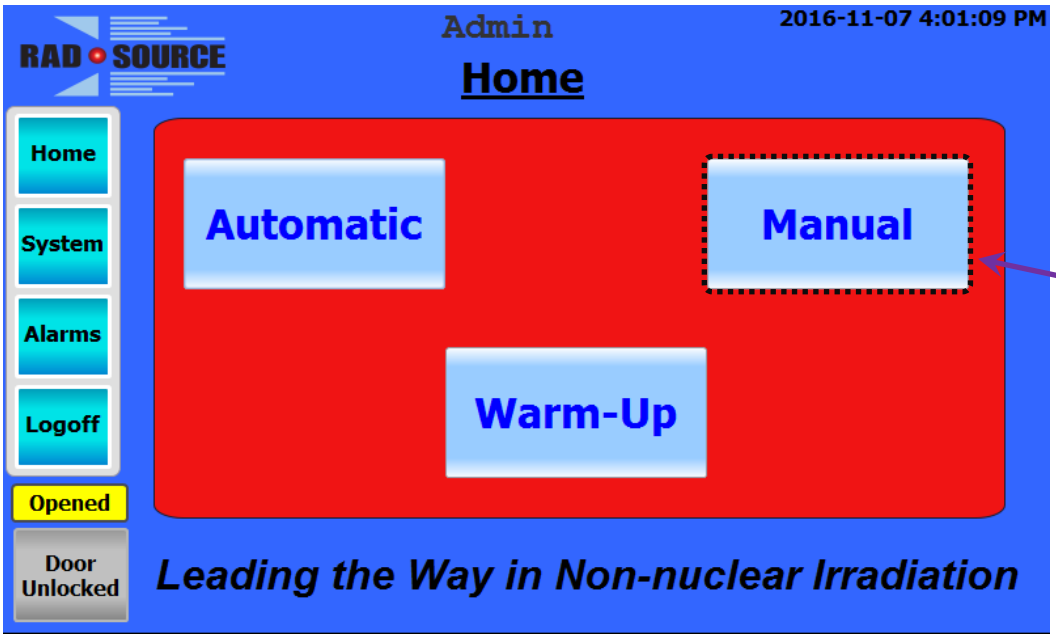


Figure 47: Manual Button

3. On the right, change the kV, mA, shelf position, filter, and time to the desired parameters.

NOTE: No calibrated dosage information will be available when using this mode.

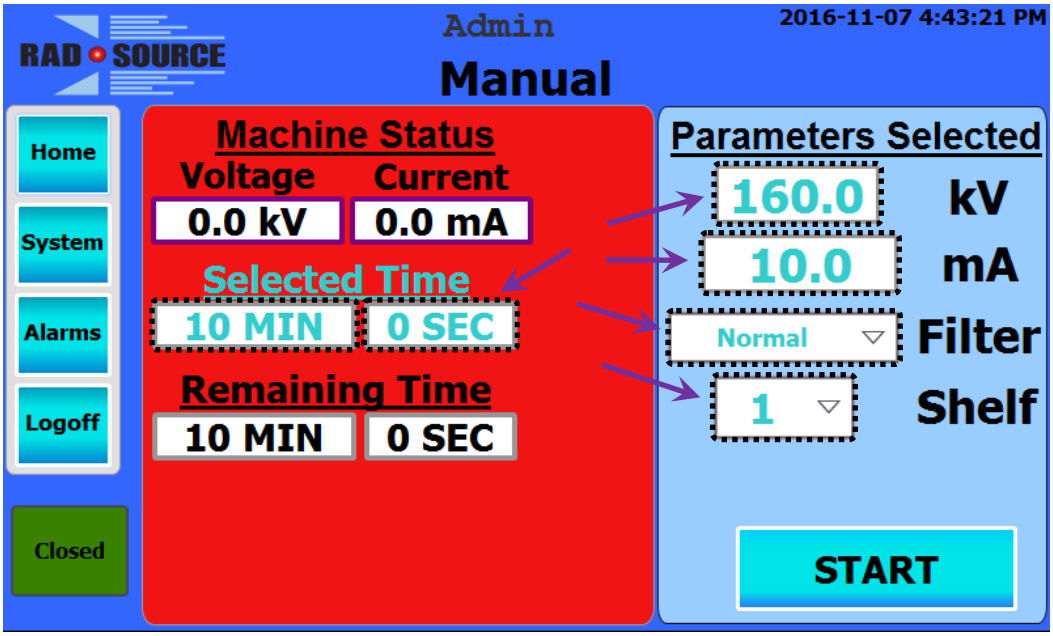


Figure 48: Manual Parameters ***(*For RS-2000 Pro 225, Max kV = 225 & Max mA = 17.7)***

4. Turn the door handle to its unlocked position, and open the door. Load your sample. Close the door, and turn the handle back to the locked position. (See Fig. 11 and 49.)
5. Press *Start* and confirm start by pressing the *Yes* button at the prompt.

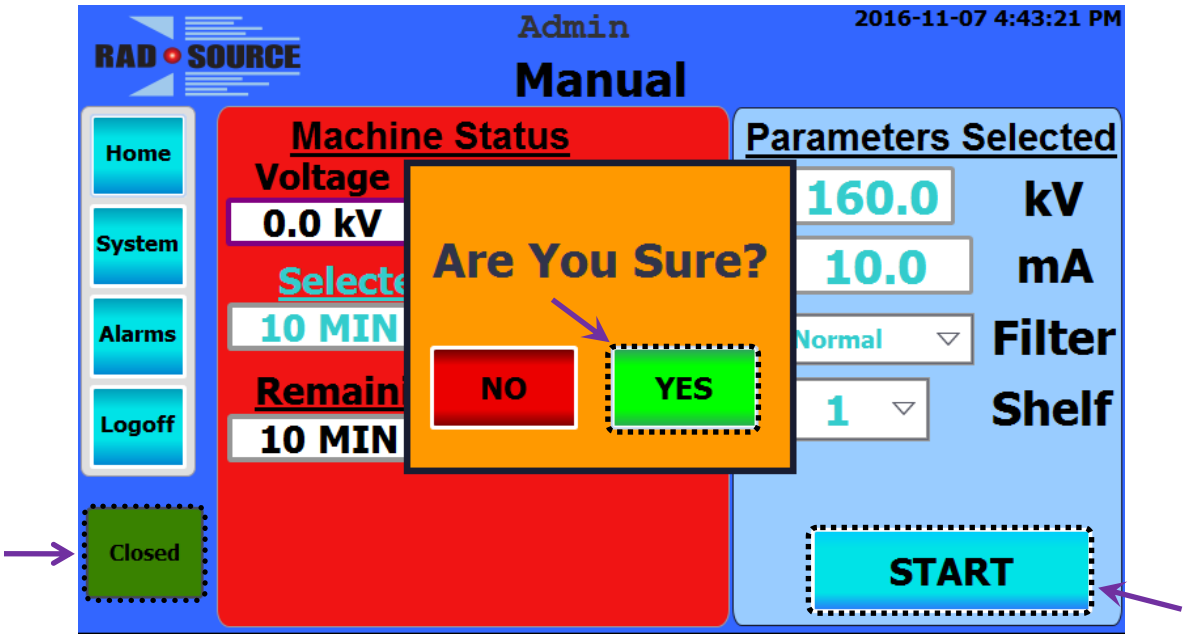


Figure 49: Start & Confirm Manual Cycle

NOTE: To cancel a running cycle, press the *Stop* button (which replaces *Start*).

6. When the exposure is complete, the buzzer will sound.

Saving and Logoff

1. On the left, press *Logoff* button.
2. Insert USB storage device.
3. Press *Save*.
4. Remove USB storage device when prompted.
5. Press *Logoff*.

X-Ray On Lamps

During Pre-Warn, after *Start* has been pressed and before X-Rays are produced, both lamps will be lit as a warning prior to X-Ray generation, and whenever X-Rays are being produced, the X-Ray On Lamps will flash alternately. These are critical safety features of the RS-2000 and, therefore, the lamps are continuously checked for correct functioning. If only one of the lamps fails to turn on, a Warning message stating which lamp failed will be displayed in the alarms status screen. Conversely, if a lamp is detected as on when it should be off, a Warning message indicating which lamp incorrectly lit up will be shown. If both lights fail, the machine will fault with a Critical Alarm and X-Rays cannot be produced. To prevent this occurrence, always replace a non-functioning light bulb.

Alarms

If the alarm sounds or the *Alarms* button changes color to indicate an alarm condition, press *Alarms* on the left and read the information displayed in the Alarms screen. Press *Reset Alarms* in the bottom right of the screen to clear all alarms that are no longer active. Any alarm that is still active will have to be made inactive by resolving the cause of the alarm before it can be cleared.

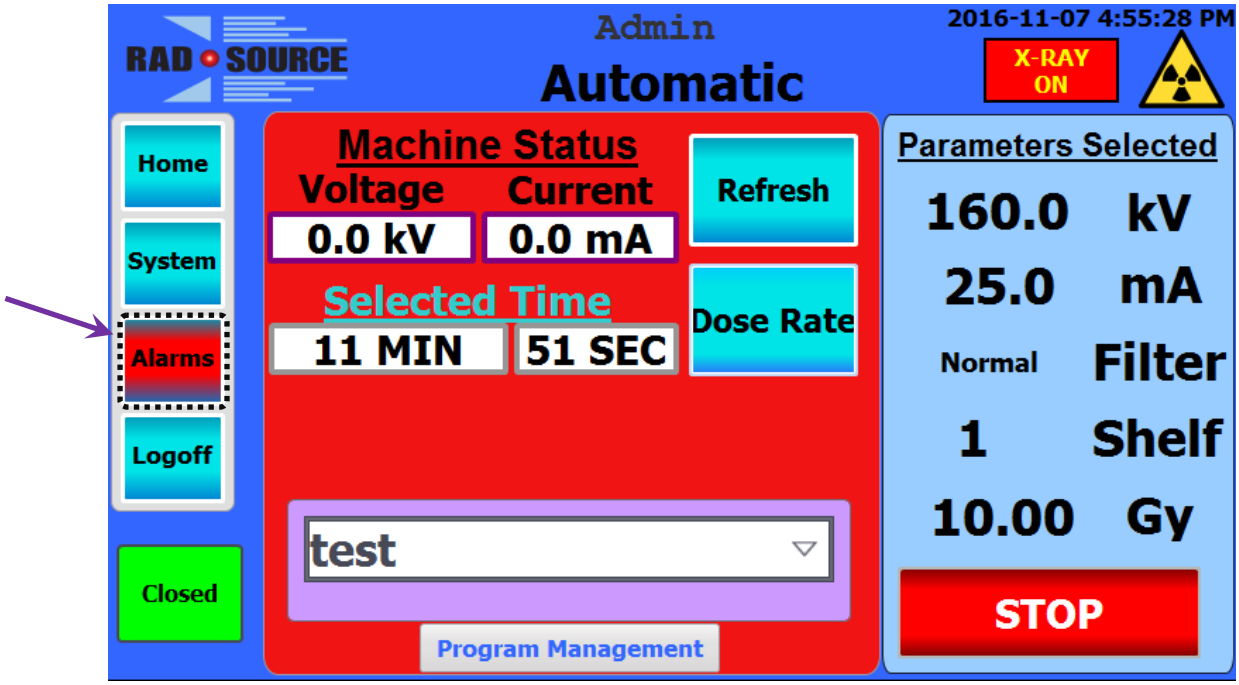


Figure 50: Alarms Button

The possible alarms and the corrective actions are given in the following table. A Warning will not cause the machine to stop operation but is an indication that a problem may exist and should be investigated before it gets worse. A Non-Critical Fault will cause an operation to pause and, in Automatic or Warm-Up modes, the machine will automatically attempt to resume operation after a short delay. A Critical Fault will stop any in-progress operation and operation cannot resume nor be started until the fault is cleared.

Table 3: Alarms and Possible Corrective Actions

ID	Warning	Corrective Action
5	X-Rays On Lamp One Failure	Replace Light Bulb. Check Lamp Failure Detection Circuit.
6	X-Rays On Lamp Two Failure	Replace Light Bulb. Check Lamp Failure Detection Circuit.
11	Coolant Temperature Too Low	The Coolant Temperature Measured at the X-Ray Tube is Very Low. Check Sensor.
12	Coolant Temperature Low	The Coolant Temperature Measured at the X-Ray Tube is Below Normal Operating Range.
13	Coolant Temperature High	The Coolant Temperature Measured at the X-Ray Tube is Above Normal Operating Range. Check Cooler.
14	Coolant Temperature Too High	The Coolant Temperature Measured at the X-Ray Tube is Very High. Check Sensor.
17	No High Voltage	Check Power to the Generator.
18	High Voltage Out of Range	Tube Arc
19	kV Monitor Does Not Equal Command	Control System Malfunction
20	mA Monitor Does Not Equal Command	Control System Malfunction
21	X-Ray Fail To Start	An X-Ray On Command was sent to the Generator But an X-Ray Status was Not Returned.
26	Requested kV Out of Range	An Incorrect kV Value Was Entered, Try Again.
27	Requested mA Out of Range	An Incorrect mA Value Was Entered, Try Again.
30	X-Rays On Lamp One Detection Failure	Check Lamp Failure Detection Circuit.
31	X-Rays On Lamp Two Detection Failure	Check Lamp Failure Detection Circuit.
38	No HVPS Communications	Check Data Cable and Auxiliary Power Connections to High Voltage Power Supply.

ID	Non-Critical Fault	Corrective Action
10	High Voltage Arc	Power Supply Arc Fault. (Most often caused by a Tube Arc or a High Voltage Connection Problem.)
15	No High Voltage Current	Power Supply Under-Current Fault. May Indicate an Open Filament.
16	High Voltage Current Out of Range	Power Supply Over-Current Fault. (Most often caused by a Tube Arc or a High Voltage Connection Problem.)

Table 3: Alarms and Possible Corrective Actions (continued)

ID	Critical Fault	Corrective Action
1	Low Coolant Flow	Check That Cooling System is Turned On. Check Coolant Flow Sensor.
2	High Coolant Temperature	Let Cooler Run without X-Rays On to cool down Coolant. Check Thermocouple.
3	Loading Door Open	Close Front Loading Door. Check That Door Prox Sensor is being Activated when the Door is Closed.
4	Access Door Open	Close Maintenance Access Door. Check That Door Prox Sensor is being Activated when the Door is Closed.
7	Failure of Both X-Rays On Lamps	Replace Both Light Bulbs. Check Lamp Failure Detection Circuit.
8	High Voltage Power Supply Fault	Power Supply Fault: See System Info, and Check Circuit Breakers. Refer to Power Supply Manual.
9	High Voltage Power Supply Interlock Fault	Power Supply Interlock Fault: Check Power Supply Data Cable and LEDs on Side of Power Supply. Refer to Power Supply Manual.
24	X-Ray Status Inconsistence	Check High Voltage Power Supply Data Cable connection and LEDs on Side of Power Supply. Refer to Power Supply Manual.
25	Number of Arc Faults Exceeded Maximum Value	Re-Run Warm-Up / Conditioning Routine.
32	High Voltage Power Supply Fault Missing	Power Supply Fault Signal Not Detected: Check High Voltage Power Supply Data Cable and LEDs on Side of Power Supply. Refer to Power Supply Manual.
33	High Voltage Power Supply Interlock OK Fault	Power Supply Interlock OK Fault: Check Interlock Outputs from PLC, Power Supply Data Cable, and LEDs on Side of Power Supply. Refer to Power Supply Manual.
34	Failure of Both X-Rays On Lamp Detectors	Check Lamp Failure Detection Circuit.
35	Low Coolant Level	Check Coolant Tank Level Float Sensor.
36	Generator X-Ray Status Relay Bad	Check Relay K8 (Power Supply Circuit).
37	Generator Main Contactor Bad	Check Power Supply Mains Contactor.
39	HVPS Communications Error	Check Data Cable and Auxiliary Power Connections to High Voltage Power Supply.

Technical Specifications

Table 4: Technical Specifications

Input Voltage	208 - 240 VAC, 1 Phase, 50/60 Hz, 3-Conductor (L1, L2/N, Gnd.)
Input Current	40 Amp, Circuit Breaker Protected
Cooling System	High Capacity Water to Air Heat Exchanger, Self-Contained
Operating kV Range *(RS-2000)*	10 kV to 160 kV Continuously Adjustable
Operating kV Range *(RS-2000 Pro 225)*	10 kV to 225 kV Continuously Adjustable
Operating mA Range	0 to 30 mA Continuously Adjustable (limited by maximum power)
Maximum Power	4000 Watts
Output Radiation	(see included document for individual machine)
Beam Uniformity	Better Than ±3% within a 6” Radius from Beam Center Line
kV Set Resolution	0.1 kV
mA Set Resolution	0.1 mA
Time Set Resolution	1 Second
kV Monitor Resolution	0.1 kV
mA Monitor Resolution	0.1 mA
Max Dose Set	999.99 Gy
Max Time Set in Manual Mode	99 Minutes, 59 Seconds
Modes of Operation	Manual Mode, Automatic Exposures, and System Warm-Up
Manual Mode	kV, mA, and Time, independently adjustable
Automatic Mode	Up to 4 groups of 500 preset Timed Programs, Programmable in Minutes and Seconds or gray (dose)
System Warm-Up	Automatically prompted based on time between exposures. Less than 24 hours: no Warm-Up necessary; more than 24 hours: Warm-Up routine of 10 or a 20 minutes is required; more than 1 week: Extended Warm-up of 20 minutes recommended.
System Set-Up Screen	Password Protected. Maximum kV and mA values may be entered in this screen and a Warm-Up Routine requirement may be bypassed.
System Fault Detection	The Following System Faults are monitored and Displayed: Power Supply Faults, Cooling Water Temperature and Water Flow, X-Ray On Lamp Failure, Interlock, etc.
Cabinet Size *(RS-2000)*	Width 42”, Depth 33”, Height 72”
Cabinet Size *(RS-2000 Pro 225)*	Width 48”, Depth 33”, Height 72”
Exposure Chamber Size *(RS-2000)*	Width 17 ¼”, Depth 15”, Height 16 ¼”
Exposure Chamber Size *(RS-2000 Pro 225)*	Width 17”, Depth 14 3/8”, Height 16”
Standard Accessories	Assorted Beam Filters, Animal Cages, Exposure Tray

X-Ray Tube Filament:

Operational Theory:

The X-Ray tube filament is not unlike the filament in an incandescent light bulb, they both have similar failure modes. A filament will fail usually by breaking, causing an open circuit, which is caused by thermal shock, poor vacuum, excessive operating temperature, or mechanical shock. To improve the lifetime of a filament, the above-mentioned items must be controlled. Thermal shock is usually what will cause an X-Ray tube filament, just like most light bulbs, to fail at turn on. To reduce thermal shock, the temperature of the filament, which is a function of demanded mA, must ramp up slowly to its operating point. However, thermal shock will only cause the filament to open if it has thinned and become brittle which is caused by excessive operating temperature and a poor vacuum. The temperature of the filament is used to control the mA. A hotter filament causes more mA at a constant kV. However, at a constant temperature, a higher kV causes more mA. Therefore, to keep the temperature of the filament as low as possible, program as low an mA and as high a kV as useable in Manual Mode. Automatic mode operates at the maximum allowable kV (either 160 kV or 225 kV, according to machine model). The allowable mA is also limited by the maximum power of the X-Ray tube and power supply combination to 4000W. The following table lists the maximum allowable mA for given kV.

Table 5: Maximum Allowable mA Chart

kV	Max mA
10	2.5
20	5.0
30	7.5
40	10.0
50	12.5
60	15.0
70	17.5
80	20.0
90	22.5
100	25.0
110	27.5
120	30.0
130	30.0
140	28.5
150	26.6
160	25.0

kV	Max mA
170	23.5
175	22.8
180	22.2
185	21.6
190	21.0
195	20.5
200	20.0
205	19.5
210	19.0
215	18.6
220	18.1
225	17.7

High Voltage Cable Connections and Maintenance:

The high voltage cable connects the high-voltage power supply to the X-Ray tube. The cable is tri-axial and conducts high voltage (up to 225,000 volts) and filament potential. The cable has conductors for high voltage and two filaments.

⚠ CAUTION In the following procedures insure that the high-voltage power supply's main breaker is turned to off.

⚠ CAUTION Always discharge the high voltage cable by touching the tip of the cable or pins on the flat connector to ground.

The high-voltage plug connects to the R-24 / R-28 receptacle on the rear of the high-voltage power supply. The first step in making a connection is to remove any residual insulating silicone grease left over from the last connection. To clean the plug and receptacle used pure 100% alcohol and lint free cloth or paper towels. Use caution when cleaning the inside of the receptacle because of the metal contacts at the base. The plug has a threaded flange; back the flange away from the tip of the plug approximately five turns so any grease under the flange can be removed. Once the plug and receptacle are clean and free from grease, apply a coating of new silicone grease onto the plug. The silicone grease is packaged in a tube with about a 4 mm opening; apply two beads of grease about 4 inches long on opposite sides of the plug. Spread the grease around the plug, staying away from the tip and flange. Insert the plug into the receptacle, ensuring that the tip of the plug bottoms out. Holding the plug firmly in the receptacle, turn the flange clockwise until there is a 5 mm gap between the flange and the receptacle. Place the bolts in the flange, and gradually tighten in a circular pattern. The 5 mm gap ensures that the plug is compressed correctly and that no air is remaining in the connection.

Figure 51: R-24 Connector

Failure Indication of the High Voltage Connection:

The most likely failure of the high voltage connection is a short to ground. This can occur at the R-24 / R-28 plug on either end. The indication of a high voltage fault is an instantaneously occurring arc fault upon turn on of high voltage.

The arc fault may initially occur at a high voltage but will rapidly degrade to a lower voltage with persistent arcing. As bad as this may sound, an arc to ground can, in most cases, be repaired.

Determine which end of the cable has arced by inspection.

Their will be a noticeable arc track on the plug and receptacle. Clean away the burned tracks, some sanding may be required on the receptacle, and re-install the plug using the above procedure. Take care to insure that the plug is rotated so that the arc trace on the plug is opposite from the arc track on the receptacle.

Normal Devices Used for Radiation Dose and Surveys

- A radiation survey meter in compliance with local and national regulation should be used for annual safety inspections or repairs.
- Any of the same instruments we use are available as an optional purchase.
- Rad Source uses a Fluke Biomedical Inovision Radiation Survey Meter for inspections.
- Rad Source uses a Rad-Cal Ion Chamber Dose Meter for mapping the chamber and radiation field.

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