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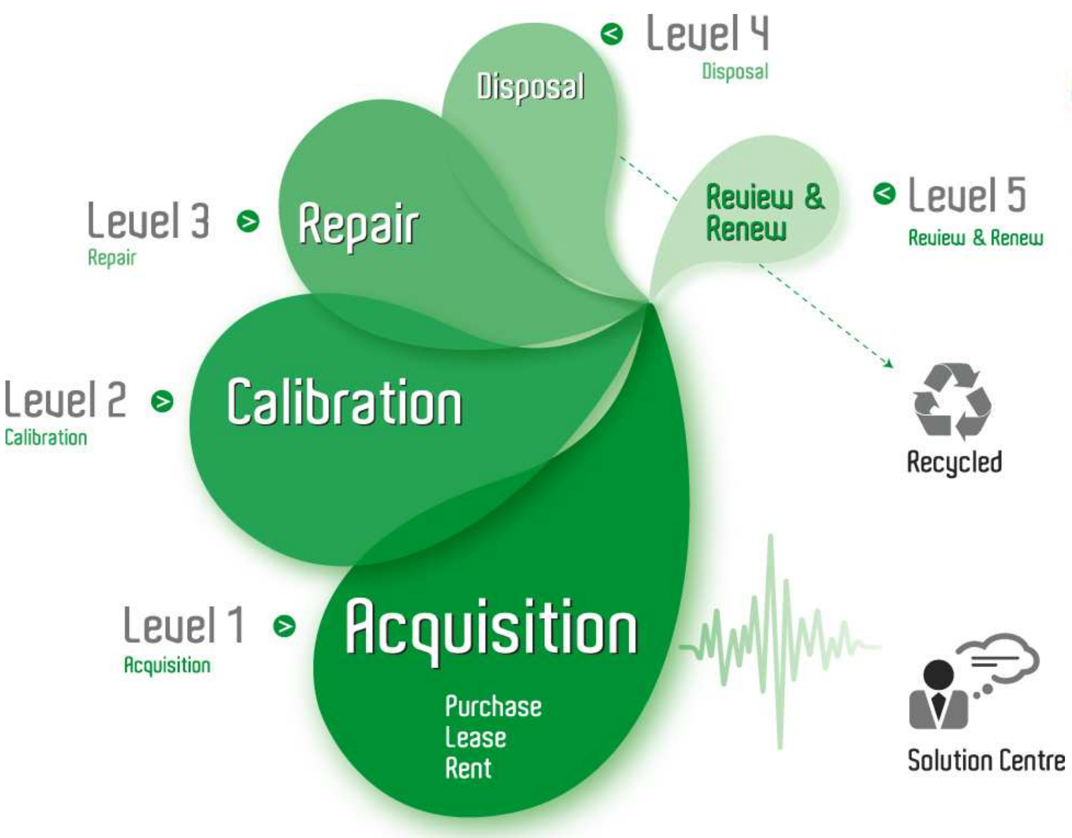

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BRUKER AXS HANDHELD

S1 TRACER Portable XRF Analyzer

User Manual

June 2008

415 North Quay • Kennewick, WA 99336
509-783-9850

Caution: X-Ray Radiation

Bruker AXS Handheld manufactures an XRF analyzer, designated as the S1 TRACER, which contains an X-ray tube. It is registered with the United States Food and Drug Administration (FDA) Center for Devices and Radiological Health. Specific safety requirements are provided for any purchased analyzer which uses an X-ray tube.

The S1 TRACER does not emit radiation when turned off. It is designed with fail-safe circuitry including switches, lamps, and interlocks to minimize the risk of accidental exposure to the user during operation.

The safety features of the S1 TRACER have been verified by radiation safety authorities. So long as there is no physical damage to the analyzer, there should be no danger of exposure to radiation above permissible levels. If the analyzer is damaged, store it in a secured area and contact Bruker AXS Handheld at (800) 466-5323.

● ***Note***
Most countries and states regulate the use of X-ray generating devices such as XRF analyzers. Regulations for XRF analyzers vary by location. Contact your appropriate agency for specific information.

All XRF analyzers should be operated only by individuals who have completed an approved radiation safety training program.

 Note
Countries or states may require registration and/or licensing. A fee payment may be required. If you are planning to transport a Bruker AXS Handheld XRF analyzer into another location, contact the appropriate authority in that jurisdiction for their particular requirements before transporting the analyzer.

The red LED on the analyzer indicates that the X-rays are on. **Do not point the analyzer at any person when the analyzer is activated.** While measuring, make sure that the analyzer is in contact with the sample material and that the entire aperture, as well as the infrared (IR) sensor, is covered by the material. **While measuring, do not hold the sample material with your hand. Keep your eyes away from the nosepiece of the S1 TRACER while the trigger is pulled.**

NOTE: Bruker XRF, Bruker AXS Handheld S1 TRACER, Bruker S1 TRACER and S1 TRACER, as used throughout this manual, refer specifically to the device manufactured by Bruker AXS Handheld.

Important Notes for Bruker AXS Handheld XRF Analyzer Customers

The Bruker S1 TRACER is classified as a portable hand held open-beam X-ray tube based analytical X-ray device. It is registered (Accession Number 0191097-01) with the United States Food and Drug Administration (FDA) Center for Devices and Radiological Health. Specific safety requirements are provided for any purschased analyzer which uses an X-ray tube.

This Bruker S1 TRACER User Manual provides training for Bruker S1 TRACER XRF analyzers. The following four sections plus Appendix A contain important information on the safe use of this XRF device. These are:

2. S1 TRACER Operator Radiation Safety Requirements
3. Principal Components of the S1 TRACER
4. Preparing the S1 TRACER for Use
5. Operation/General Purpose Measure

Appendix A. Basic Radiation Safety Information

Section 2. contains operator safety requirements specific to the Bruker S1 TRACER and Appendix A contains basic radiation safety information.

Responsibilities of the Customer

- Before using the S1 TRACER, all users shall read and understand the Operator Radiation Safety Requirements (Section 2) and Basic Radiation Safety (Appendix A) of this manual. Because the S1 TRACER produces X-ray radiation, the analyzer shall only be used by trained personnel who have passed the Bruker AXS Handheld Radiation Safety Examination.

- **Damage to a Bruker AXS Handheld analyzer may cause unnecessary radiation exposure.** If a Bruker XRF analyzer is damaged, immediately contact Bruker AXS Handheld at (800) 466-5323 or (509) 783-9850.

- **Disassembly of or tampering with any Bruker AXS Handheld XRF analyzer component, except to replace the batteries or remove the handheld computer (PDA), voids the warranty and compromises the integrity of the instrument. Harm or serious injury may result in cases where disassembly or tampering has occurred.**

- Comply with all instructions and labels provided with the S1 TRACER and do not remove labels. **Removal of any label will void the warranty**.

- Test the S1 TRACER for correct operation of the ON/OFF mechanism every six months and keep records of the test results. If the analyzer fails this test, call Bruker AXS Handheld immediately for instructions.

- Maintain a record of S1 TRACER use, installation (if applicable), and any service to shielding and/or containment mechanisms for two years or until ownership of the analyzer is transferred or the analyzer is decommissioned.

- Report to the appropriate authority any possible damage to shielding and any loss or theft of the analyzer. Do not abandon any XRF analyzer.

- Transfer the S1 TRACER only to persons specifically authorized to receive it and report any transfer to the appropriate regulatory authority 15 to 30 days following the transfer, if required. Report the transfer of the analyzer to Bruker AXS Handheld at (800) 466-5323 or (509) 783-9850.

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1. S1 TRACER Overview

The Bruker S1 TRACER, produced by Bruker AXS Handheld, is a portable, wide range elemental analyzer intended for a variety of applications, including alloys, environmental analysis, and hazardous substance detection. It provides a method for chemical analysis or material identification (sorting) directly for materials of various forms. The S1 TRACER is based on energy dispersive X-ray fluorescence technology (ED-XRF) and uses an X-ray tube as its excitation source. Tubes may use a bulk Rhodium (Rh) or Silver (Ag) target, depending on the purchased configuration. The instrument contains a high-resolution, Peltier cooled, Silicon PIN (Si-PIN) diode detector.

The S1 TRACER is a fully field portable analyzer with an integrated PDA (Personal Digital Assistant) computer (see Figure 1.1). The removable PDA provides the user interface for operating the instrument and contains the BrukerS1 analytical program. This program enables the user to select analytical modes, view spectra, and save data. The display is a color touch screen (TFT), which can be operated with either a fingertip or the provided stylus. The instrument is factory calibrated for measurements of:

- Aluminum alloys
- Titanium alloys
- Low alloy steels
- Stainless steels
- Tool steels
- Nickel alloys
- Cobalt alloys
- Copper alloys

Figure 1.1: Portable configuration of the S1 TRACER

The S1 TRACER has an internal mechanism called a filter wheel which inserts various filters into the primary X-ray beam. The filter wheel contains five filter positions; one position contains no filter material. Selection of a particular filter is completely automatic and depends on the test method chosen in the BrukerS1 program (as described in section 5.3.4). When the “Method” setting is changed, the filter wheel can be heard briefly spinning inside of the analyzer. The filter wheel is also heard shortly after the analyzer power has been turned on. This sound is normal and indicates that the analyzer is working properly.

In some cases, it may be more convenient to use the S1 TRACER in a stationary, bench top configuration. Figure 1.2 shows the S1 TRACER in the stand provided. There are grooves in the body and the handle which slide into the stand.

Figure 1.2: Bench top configuration

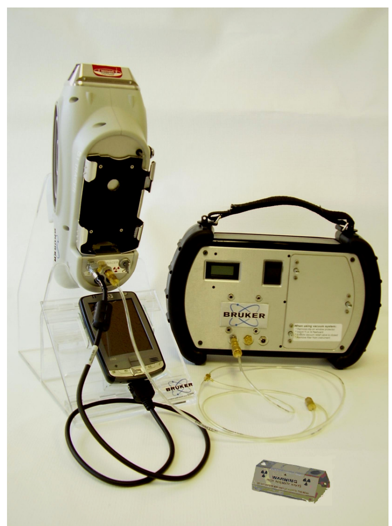

Figure 1.3: Vacuum configuration

When aluminum or titanium alloys are to be examined, the S1 TRACER should be used in vacuum mode. The vacuum pump attaches to the instrument with the provided tubing as shown in Figure 1.3. The slide vent valve vents the system when vacuum is not in use to prevent damage to the highly sensitive Si-Pin detector. The clip-on window protector must be removed when in vacuum mode to obtain accurate readings.

Note: When the user selects an aluminum or titanium method in the BrukerS1 program, the software prompts the user to connect the vacuum pump. Additional information on selection of vacuum mode is contained in sections 4.2 and 5.3.4.

The S1 TRACER analyzer and the vacuum pump are battery operated. They may also be operated from A/C power. Note that for bench top operation, the instrument can be used with battery or A/C (line voltage) power.

An optional PC can also be puchased with the S1 TRACER when it is used for special applications, such as Art & Conservation

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2. S1 TRACER Operator Radiation Safety Requirements

2.1 What is Radiation?

- The term radiation is used with all forms of energy—light, X-rays, radar, microwaves, and more. For the purpose of this manual, radiation refers to invisible waves or particles of energy from X-ray tubes.

- **High levels of radiation may pose a danger to living tissue because it has the potential to damage and/or alter the chemical structure of cells. This could result in various levels of illness (i.e. mild to severe).**

- This section of the manual provides a basic understanding of radiation characteristics. This should help in preventing unnecessary radiation exposure to S1 TRACER users and persons nearby. The concepts have been simplified to give a basic picture of what radiation is and how it applies to operators of the S1 TRACER XRF analyzer.

- Sections 2.2 - 2.4 characterize the S1 Tracer safety features and controls and provide specific radiation profiles for the S1 TRACER analyzer.

- The user of a S1 TRACER XRF analyzer should study Appendix A to better understand the nature of radiation and how to be safe using handheld XRF analyzers. Appendix A will also provide perspective as to the exposure levels associated with the equipment.

2.2 X-Ray Radiation from the S1 TRACER

X-rays are emitted at approximately a 53° angle from the aperture to the user's left (as viewed from the user's perspective), shown in figure 2.1.

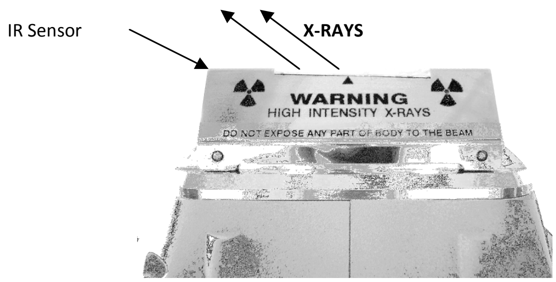


Figure 2.1: Emission of X-rays from the aperture

Radiation Scatter

Radiation scatter is produced whenever an absorbing material is directly irradiated from a nearby source. The atoms within the material become temporarily excited, producing X-rays before becoming stable again. This process, called X-ray fluorescence (XRF), is the principle of operation of the S1 TRACER XRF analyzer.

The X-ray tube within the S1 TRACER is used to irradiate a chosen material at very close range with a narrow, collimated beam. The X-rays from the tube excite the atoms of the material, which then produce secondary X-rays that scatter in random directions. Hence, the term ***radiation scatter***.

Backscatter

The S1 TRACER generates spectrum data by analyzing the specific secondary X-ray energies that travel from the sample under test to the instrument detector. Because X-rays travel in random directions, it is possible for an X-ray to miss the detector and be scattered in the direction of the operator. This is referred to as ***backscatter***.

Although the S1 TRACER is specifically designed to limit backscatter, there is always the possibility that a small number of X-rays may scatter beyond the detector. To ensure safe operation of the system, it is vital that the operator understands the radiation field. The radiation profiles provided in Figures 2.8 and 2.9 illustrate the radiation field intensity for the S1 TRACER. The Radiation Profile section contains the details on measurements of the radiation field. **The profiles should be studied carefully by anyone who operates the S1 TRACER, in order to better understand and apply the practices of ALARA using time, distance and shielding.**

2.3 Hand Held XRF Analyzer Safety Design

The Bruker S1 TRACER series XRF analyzers employ a miniature X-ray tube instead of a radioactive material to generate the X-rays. The general construction and the safety features described in this manual are the same for all S1 TRACER models.

Bruker AXS Handheld designed this hand held X-ray tube analyzer to conform to 21 CFR 1020.40 safety requirements for cabinet (i.e. closed beam) X-rays systems, with the exception of providing a totally enclosed beam.

Note: To prevent the operator from being directly exposed to the open X-ray beam, extensive safety circuit requirements including switches and failsafe lamps have been incorporated.

The S1 TRACER series portable XRF analyzers were tested by TUV SÜD against safety requirements of IEC 61010-1, "Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory User, Part I General Requirements." The S1 TRACER passed the ionizing radiation leakage requirements in IEC 61010-1, section 12.2.1 of <1 µSv/hr (<0.1 mrem/hr) at 100 mm. Since the instruments passed all of the safety requirements, the device was afforded the $_{C}$TUV$_{US}$ license, CB Global Scheme, and the general CE marks. The license requires periodic production audits by TUV SÜD. See the S1 TRACER Safety Logic Circuit section for discussion on the warning lamps, failsafe features, and labeling that has been incorporated to provide a high level of protection to the operator.

The S1 TRACER is a hand held (4 lb.) X-ray fluorescence (XRF) analyzer used as an analytical X-ray system. It employs a 4-watt, miniature (<15 mm diameter and <75 mm long) X-ray tube operated with an acceleration voltage range of 6 to 40 kV and a current range of 0.05-20 µA, (the maximum high-voltage available at 20 µA is 15 kV). In some cases, allowable ranges for X-ray tube voltage and current may be different to comply with local regulations. The tube target is dependent on the intended application and may contain target material such as Rh, Ag or Re.

The X-ray tube and high-voltage (HV) power supply are sealed in a fluid filled assembly. The X-ray tube is shielded by a variety of materials to minimize any stray X-ray radiation. This is mounted in the XRF housing and the XRF housing is closed using tamper-proof fasteners.

The S1 TRACER X-ray beam is collimated through an aperture that is approximately 0.14 inches (3.5 mm) in diameter. The aperture is part of the beam collimator assembly. The radiation profiles illustrated in Figures 2.8 and 2.9 illustrate the effectiveness of the design to limit X-ray emission to primarily that which passes through the aperture. See the Radiation Profile Section for discussion of the radiation profile measurements.

2.3.1 Safety Logic Circuit, Indicator Lamps and Warning Labels

The S1 TRACER analyzer is designed with a Failsafe Safety System to prevent inadvertent operation of the analyzer. The safety system for the S1 TRACER analyzer consists of a key switch, password protection, two (2) failsafe LED indicator lamps, a trigger to activate X-rays, an infrared proximity sensor to verify close proximity of a test sample, and a low count rate detection safety shutoff. The function of each of the S1 TRACER's safety features is described below:

- **Primary Power Safety Key Switch** – A keyed main power switch (Figure 2.3) is employed to control power to all components. The key switch must be turned on before any other actions can be initiated.

- **Software Password Protection** – BrukerS1 software on the companion PDA must be running for the analyzer to generate X-rays. Upon launching the BrukerS1 PDA software, a user password must be correctly entered to enable the analyzer to generate X-rays.

- **Software X-ray Radiation Warning** – Presuming that the correct password has been entered, the PDA software displays a black and yellow X-ray Radiation Warning symbol and a text warning for 15 seconds. No user input is accepted during the time the X-ray Radiation Warning is displayed.

- **Yellow Power On Indicator Lamp** – When the key switch is turned on, the yellow lamp (Figure 2.3) will illuminate, indicating that the analyzer is powered on. The lamp incorporates redundant LED elements for increased reliability.

If the instrument microprocessors detect a malfunction in the instrument, the yellow lamp flashes to alert the user. The redundant LED segments are incorporated in such a way that if either of the LED elements fails, generation of X-rays is disabled.

- **Operator Trigger Interlock**– When the trigger style switch is pulled, X-rays are generated if the rest of the safety circuit has been satisfied. The switch is spring-loaded and must be held in during measurements. If the switch is inadvertently released, the spring mechanism will return the switch to its idle position and stop X-ray generation.

- **Infrared (IR) Proximity Sensor** – The IR proximity sensor is used to confirm that the instrument has been placed against a sample. The sensor is located in the instrument nosepiece near the tube/detector opening. If the nosepiece is removed from the sample by a distance greater than 38mm (~1.5") the IR proximity sensor will stop X-ray generation. The exact distance is somewhat dependent on the sample material being tested.

- **Red X-ray On Indicator Lamp** – When the trigger is pulled and the infrared sensor is engaged, the red lamp (Figure 2.3) will illuminate, indicating the generation of X-rays. The lamp incorporates redundant LED elements for increased reliability. If either of the red LED elements fail, X-rays cannot not be generated.

- **Low Count Rate Detection Safety Shutoff** – While X-rays are being generated, the S1 TRACER microprocessor continually monitors raw count rate from the detector. If at any time during the measurement, the raw count rate falls below 500 counts per second, the microprocessor will stop X-ray generation since this indicates that no sample is in place. Should this occur, the operator must release the trigger and then re-start the test.

2.3.2 S1 TRACER XRF Safety Warning Labels

The S1 TRACER has safety warning labels to alert the user and/or identify the functions of the controls. These labels are described below.

- To the right of the power (key switch) part of the analyzer (Figure 2.2) is a sign as follows:

Figure 2.2: Caution radiation sign

- The control panel of the analyzer is labeled as illustrated in Figure 2.3

Figure 2.3: S1 TRACER control panel and indicator lamps

- The yellow lamp, when illuminated, indicates power is applied to the analyzer.
- The red lamp, when illuminated, indicates that X-rays are being generated.
- The power (key switch) is labeled with an international power On/Off symbol.

- The vacuum window over the examination window carries a label with an X-ray warning (Figure 2.4)

Figure 2.4: Vacuum window and X-ray warning label

- An X-ray warning label is located near the nosepiece of the analyzer (Figure 2.5)

Figure 2.5: X-ray warning label near nosepiece of analyzer

- On the clip-on window protector that covers the analyzer nose (Figure 2.6) are two signs:

Figure 2.6: Clip-on window protector warning sign

- A metal manufacturer's plate (Figure 2.7) is mounted under the analyzer housing near the handle. In countries other than the USA, this label may be different based on local regulatory requirements.

Figure 2.7: Instrument base caution sign

2.4 S1 TRACER Radiation Profile

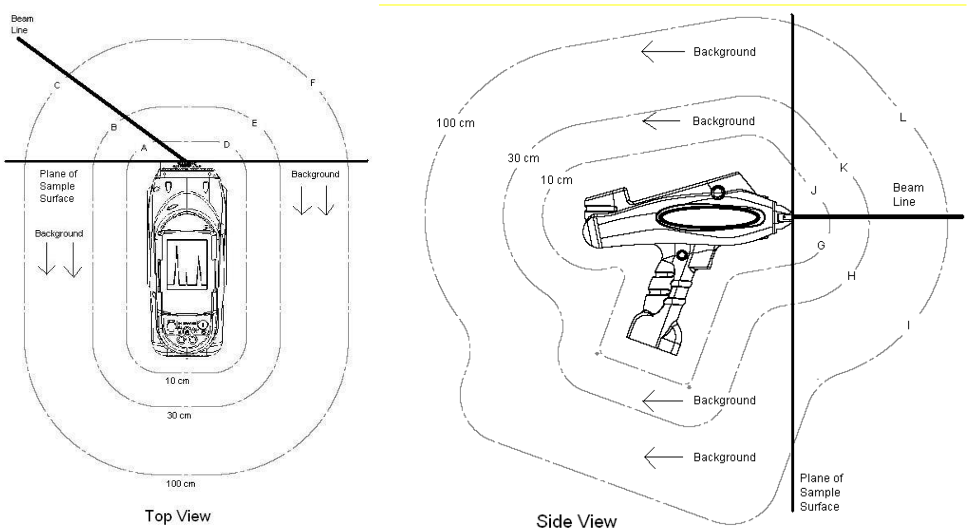
The radiation profile of the S1 TRACER shown in Figures 2.8 and 2.9 are for normal operating conditions. These readings show the radiation background around the instrument in all directions. These values were obtained using a Bicron Low Energy Micro Rem ion chamber. These measurements indicate that the dose rate at 10 cm from any accessible surface was lower than 5.0 µSv/hr (less than 50 µrem/hr).

In Figure 2.8, measurements were made at 40 kV and 10 µA (the maximum current/voltage permitted) with the Ti/Al filter in place.

In Figure 2.9, measurements were made at 15 kV and 20 µA without the Ti/Al filter.

Radiation Profile

(For 40 kV 10 µA, Duplex 2205 sample in beam)



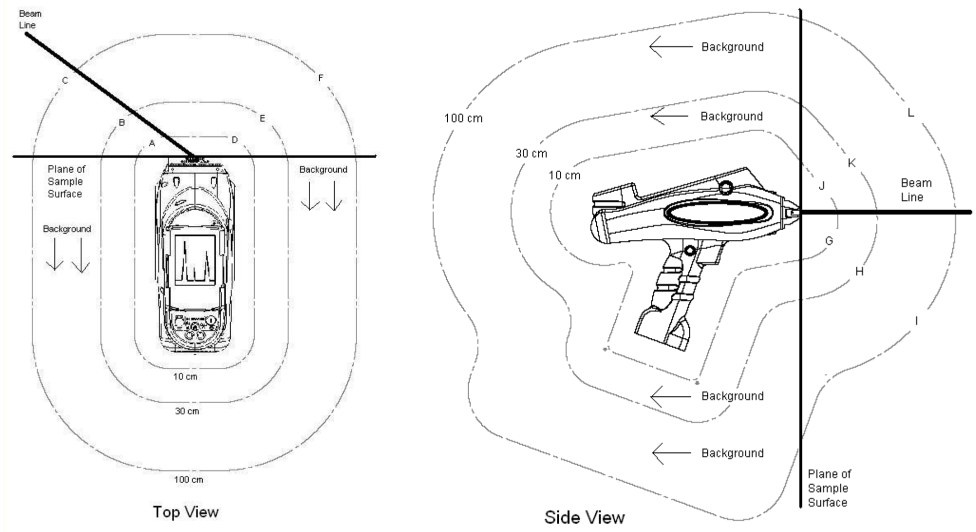
	Reading (µrem/hr)		Reading (µrem/hr)
A	2	G	1
B	bkgnd	H	bkgnd
C	bkgnd	I	bkgnd
D	2	J	1
E	bkgnd	K	bkgnd
F	bkgnd	L	bkgnd

Figure 2.8 Dose rates for the S1 TRACER normal operation configuration. Readings are in µrem/hr. All other locations on side, top, bottom and back of the analyzer are background (bkgd). Readings taken with a Bicron Model RSO-50 E low energy ion chamber survey instrument. Reference distances were measured from the effective center of the detector to the surface of the analyzer or sample. The indicated readings were the maximum noted for the distances and locations. Each reading was taken over a one minute period with the analyzer operating at approximately 10 µA and 40 kV, with a Ti/Al filter.

Note: dose rates will vary based on current, energy, sample, target, collimator and windows.

Radiation Profile

(For 15 kV / 20 µA, no filter, AL2014 sample in beam)



	Reading (µrem/hr)		Reading (µrem/hr)
A	7	G	2
B	bkgnd	H	bkgnd
C	bkgnd	I	bkgnd
D	2	J	2
E	bkgnd	K	bkgnd
F	bkgnd	L	bkgnd

Figure 2.9 Dose rates for the S1 TRACER normal operation configuration. Readings are in µrem/hr. All other locations on side, top, bottom and back of the analyzer are background (bkgd). Readings taken with a Bicron Model RSO-50 E low energy ion chamber survey instrument with the beta shield open. Reference distances were measured from the effective center of the detector to the surface of the analyzer or sample. The indicated readings were the maximum noted for the distances and locations. Each reading was taken over a one minute period with the analyzer operating at approximately 20 µA and 15 kV, without a filter.

Note: dose rates will vary based on current, energy, sample, target, collimator and windows.

2.5 Using the S1 TRACER Safely

When the S1 TRACER is used properly, X-ray radiation from the analyzer poses no potential for harm to the user, nearby persons, or objects.

A properly trained user will use the S1 TRACER in a manner that eliminates or minimizes the risk of unnecessary exposure to X-ray radiation.

Safe use of any XRF device is based on the principles of:

- Time – managing the amount of time during which X-rays are being produced by the analyzer
- Distance – keeping all parts of the user's body as far away from the X-ray producing nosepiece as possible, keeping the X-ray producing nosepiece pointed in a direction away from nearby persons, and keeping nearby persons away from the analyzer during use
- Shielding – ensuring that the S1 TRACER is mechanically intact and sound, and using the shielded sample cup accessory when measuring physically small or unknown samples which might permit unnecessary X-ray radiation to escape

Collectively, these practices are know by the phrase "**As Low As Reasonably Achievable**", or the acronym **ALARA**. User practice to implement ALARA will be further discussed in Appendix A, "Basic Radiation Safety Information", and during S1 TRACER user training.

2.6 Radiation Safety Tips for Using the XRF Analyzer

All S1 TRACER operators should follow minimum safety requirements discussed below. When handled properly, the amount of radiation exposure received from the analyzer will be negligible. The following safety procedures are provided to help ensure safe and responsible use:

- **Do not allow anyone** other than *trained and certified personnel* to operate the S1 TRACER XRF analyzer.
- Be aware of the direction that the X-rays travel when the red lamp is on and avoid placing any part of your body (especially the eyes or hands) near the X-ray port during operation (see the Radiation Profile Section for measurement information).

  ***WARNING**: No one but the operator(s) should be allowed to be closer than 1 meter (~3 feet) from the* S1 TRACER*, particularly the beam port. Ignoring this warning could result in unnecessary exposure.*

Figure 2.11: Safe use of the S1 TRACER

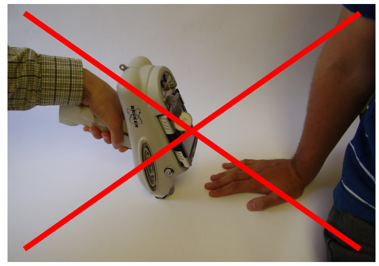


Figure 2.12: Unsafe Use of the S1 TRACER

WARNING: *Never hold a sample to the X-ray port for analysis by hand. Hold the instrument against the sample.*

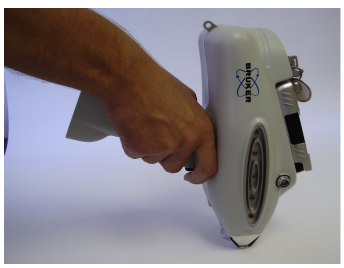


Figure 2.13: Safe use of the S1 TRACER

Figure 2.14: Unsafe use of the S1 TRACER

- The infrared (IR) sensor located on the nosepiece is designed to prevent the emission of X-rays from the X-ray port without a solid object being in direct contact with the nosepiece.

  WARNING: *The operator should never defeat the IR sensor in order to bypass this part of the safety circuit. Defeating this safety feature could result in unnecessary exposure of the operator. When using the bench top configuration, obtain a sample large enough to cover both the analyzer window and the IR sensor. If a sample is not sufficiently large to cover both the analyzer window and the IR sensor, then the optional safety shield accessory should be used for testing that sample.*

Figure 2.15: Safe use of the S1 TRACER

Figure 2.16: Unsafe use of the S1 TRACER

- Pregnant women who use the S1 TRACER should be aware that improper handling or improper use of the instrument could result in radiation exposure which may be harmful to a developing fetus.
- Wear an appropriate dosimeter if required by a regulatory agency when operating the S1 TRACER.
- The operator is responsible for the security of the analyzer. When in use, the device should be in the operator's possession at all times (i.e. either in direct sight or a secure area). The key should not be left in an unattended analyzer. Always store the instrument in a secure location when not in use; also store the key in a location separate from the analyzer to avoid unauthorized use.
- During transport to and from the field, store the instrument in a cool, dry location (i.e. in the trunk of a car rather than in the back seat.).

2.7 Correct S1 TRACER Positioning

Always place the analyzer on the sample, or when testing small parts, place the S1 TRACER in the stand and place the sample onto the nose of the analyzer.

When testing very small samples, use a clip-on sample holder and a radiation safety shield, and keep a safe distance from the nosepiece of the analyzer while X-rays are being generated.

Thin or Light Element Samples

A less obvious risk of excess radiation exposure occurs when testing thin samples. Part of the radiation coming from the X-ray tube is of a sufficiently high energy to penetrate thin samples, especially if the sample is composed of "lighter" (low atomic number) elements. The following tables illustrate relative intensities after the radiation has passed through aluminum/iron sheets of various thicknesses (the tube is operated at 40 kV and is filtered by a 1.27 mm thick aluminum sheet inside the instrument). **When testing thin samples, use of the radiation safety shield is recommended.**

Table 2-1: Intensity of X-ray Radiation after Sample Penetration

Aluminium Sheet Relative Intensities

Thickness	Relative Intensity
0 mm	100%
1 mm	46%
2 mm	26%
3 mm	16%
4 mm	11%
5 mm	7.5%
10 mm	1.5%

Iron Sheet Relative Intensities

Thickness	Relative Intensity
0.0 mm	100%
0.1 mm	23%
0.2 mm	9%
0.3 mm	4%
0.4 mm	2.1%
0.5 mm	1.1%
1.0 mm	0.08%

An aluminum sample must be quite thick before it absorbs a substantial amount of the radiation, while iron provides much better absorption. The transmission difference is very important and demonstrates why it is not a safe practice to measure samples while holding them in your hand.

2.8 In Case of Emergency

If a person without proper training attempts to operate the S1 TRACER analyzer, resulting X-ray emission from the X-ray tube could be harmful to the operator or others nearby. If an S1 TRACER is lost or stolen, notify the local law enforcement and regulatory authority as soon as possible.

In the event of an accident with, or damage to the S1 TRACER analyzer, immediately turn off the device, and remove the battery pack. Then follow the steps below.

2.9 Minor Damage

If any hardware item appears to be damaged, even if the analyzer remains operable, immediately contact Bruker AXS Handheld at (800) 466-5323 or (509) 783-9850 for assistance. Use of a damaged analyzer may lead to unnecessary radiation exposure and/or inaccurate measurements.

2.10 Major Damage

If the analyzer is severely damaged, immediately stop use of the analyzer and contact Bruker AXS Handheld and notify the appropriate regulatory agency in your state or country. Care must be taken to ensure that personnel near the device are not exposed to unshielded X-rays that may be generated (i.e. if the safety logic circuit has been damaged and is not functional). Immediate removal of the battery pack will stop all X-ray production.

2.11 Loss or Theft

Should an S1 TRACER be lost or stolen, immediately notify the appropriate regulatory agency in the state or country in which the device was located. Additionally, immediately notify local law enforcement authorities and Bruker AXS Handheld.

Take the following precautions to minimize the chance of loss or theft:

- Never leave the analyzer unattended when in use.
- When not in use, always keep the device in its shipping container and store it in a locked vehicle or in a secure area.

- When not in use, keep the key separate from the analyzer.
- Maintain records to keep track of all instruments owned and the operators assigned to use them and where they were used.
- Never share your BrukerS1 program password with another user.

2.12 License/Registration Requirements

The owner/operator of a S1 TRACER XRF analyzer may be subject to license and/or registration with the appropriate local agency. The owner/operator should:

- Contact the appropriate regulatory agency where the analyzer is to be used regarding specific requirements. In the U.S., this agency is generally the State Health Department.
- Never remove labels from the analyzer.
- Comply with all instructions and labels provided with the device.
- Store the analyzer in a safe place where it is unlikely to be stolen or removed accidentally.
- Keep the key separate from the analyzer.
- Maintain records of the storage, removal, and transport of the analyzer. Know its whereabouts at all times.
- Monitor operators’ compliance with safe use practices. Use dosimetry where required.
- Report to the local regulatory agency any damage to the shielding and any loss or theft of the analyzer.
- Only sell or transfer the analyzer to persons registered to receive it.
- Notify your regulatory agency upon the transfer or disposal of the X-ray unit.

2.13 Transportation Requirements

An owner/operator of a S1 TRACER may only transfer custody of the analyzer to authorized (licensed/registered) individuals. The user must notify the destination State's regulatory agency at least one week [typical] in advance of intent to transport and use the instrument in that state. When transferring control or ownership of the S1 TRACER, the owner must verify that the recipient is authorized to receive the analyzer. No verification is required when returning it to Bruker AXS Handheld, the original manufacturer.

Check with your local regulatory agency prior to transporting or shipping a S1 TRACER. For travel or shipment within the U.S., there are no special Department of Transportation (DOT) interstate travel and shipping regulations for the S1 TRACER. The analyzer may be shipped using any available means. If the user is flying, it is recommended that the device should be checked through due to possible concerns about the X-ray unit in the main cabin.

For international shipping, check with the transport company (DHL, FedEx) and the government regulatory agency.

The owner is responsible for ensuring that all requirements of the local jurisdiction where the X-ray tube XRF is to be used are followed. To prevent inadvertent exposure of a member of the public in case the X-ray tube XRF Analyzer is lost or stolen, the key should be maintained and shipped separately.

3. Principal Components of the S1 TRACER

3.1 Principal S1 TRACER Components

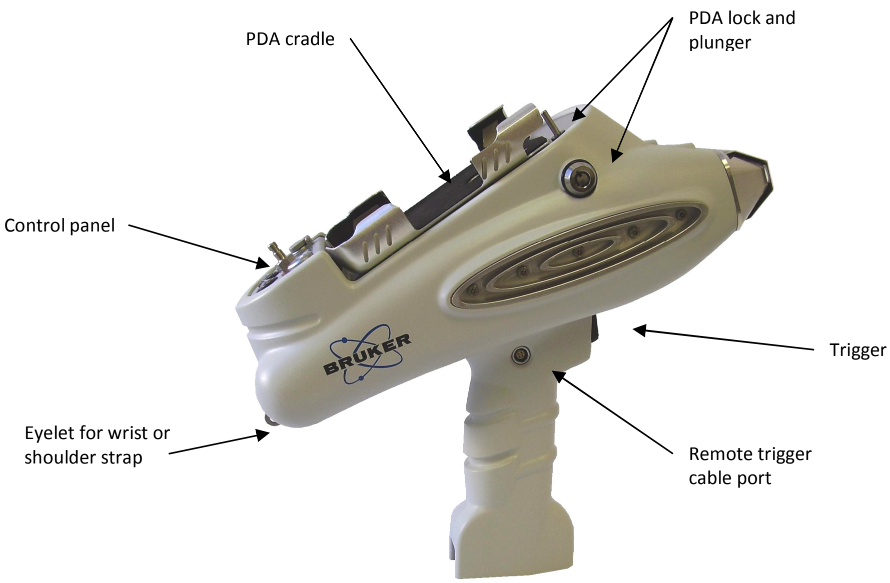


Figure 3.1: S1 TRACER right side profile

Figure 3.2: S1 TRACER control panel

3.2 Principal PDA Components

Figure 3.3: iPAQ PDA

3.3 Principal Vacuum Pump Components

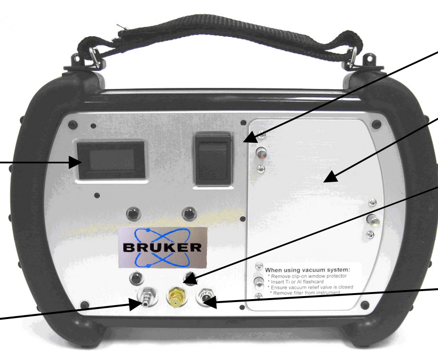
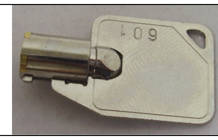
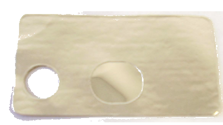
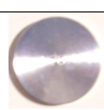
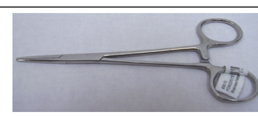
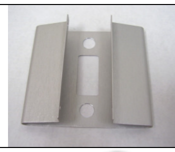


Figure 3.4: Vacuum Pump

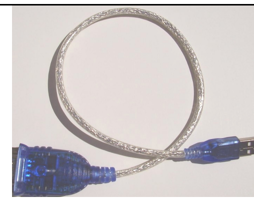
3.4 Included Accessories

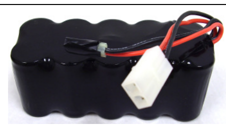
The following accessories are included with the S1 TRACER. For replacement parts, call Bruker AXS Handheld at (509) 783-9850.

S1 TRACER Accessories			
Power Interlock Keys (2)		PDA Release Keys (2)	
Li-Ion Battery Packs (3)		Battery Charger (AVT) and Power Cord	
Instrument Stand with PDA cradle		A/C Power Supply (Cincon)	
Clip-on Window Protector		Remote Trigger Cable	
Replacement Vacuum Windows (10)		Replacement Kapton Windows (5)	
Shoulder Strap		Wrist Strap	
AL7075 Calibration Check Standard		Forceps	

Duplex 2205 Calibration Check Standard		AL5083 Calibration Check Standard	
Clip-on Sample Holder		Safety Shield	
Shipping Case			

PDA Accessories			
Compact Flashcard		A/C Power Supply	
Null Modem Cable		Sync Cradle/Battery Charger	
Display Covers		Stylus	

Laptop Accessories			
PC Download Cable		USB to Serial Cable	

Vacuum Pump Accessories			
NiMH Battery Pack (2)		Universal Smart Battery Charger	
Vacuum Tubing (may be clear or black)		A/C Power Supply and Power Cord	
Shoulder Strap		Shipping Case	

3.5 Additional Available Accessories

These accessories are available to be used with the S1 TRACER. To order these parts, call Bruker AXS Handheld at (509) 783-9850.

Wire Adaptor	The wire adaptor attaches to the clip-on window protector and narrows the aperture to a thin slit that allows smaller diameter pieces to be examined.
Safety Shield	The safety shield is used in bench top operations to protect the user from accidental exposure to X-rays. For the case of small test samples, it can safely cover the IR sensor while the sample covers the aperture.
Replacement Windows	Additional replacement vacuum or Kapton windows are also available.

3.6 Operating Conditions of the S1 TRACER

Temperature	Instrument -10° to +50°C Charger +5° to +45°C
Humidity	Continuous operation at 20% to 95% RH, no condensation. Instrument should not be exposed to rain. The charger is designed for indoor use only.
Shock Resistance	During transportation and operation, the instrument must not be dropped or left in extreme conditions that might damage its sensitive components. To achieve optimum accuracy, avoid movement or vibration during measurements.

Charging Line Voltage	Instrument: 90 – 240 V, 50 – 60 Hz. iPAQ PDA: 100 – 240 V, 50 – 60 Hz Charger: 100 – 260 V, 45 – 70 Hz Vacuum Pump Charger: 100 – 240 VAC, 47 – 63 Hz

4. Preparing the S1 TRACER for Use

4.1 Powering the S1 TRACER and PDA

All of the S1 TRACER components may be operated using either battery or A/C power.

The batteries for the S1 TRACER and the vacuum pump should arrive fully charged. However, it will be necessary to fully charge the PDA batteries prior to using the analyzer for the first time. In addition, if the PDA has not been used for a week or more, it should be recharged prior to use.

4.1.1 S1 TRACER

4.1.1.1 Battery Power, Charging the Batteries

The S1 TRACER uses a Li-ion battery pack that is contained in the handle of the analyzer. Ensure that the analyzer is off prior to removing the battery pack. To change the battery, push the lever on the bottom of the handle, and then pull on the black base to remove.

Figure 4.1: Removing the battery from the S1 TRACER

To charge the battery pack, connect the pack to the AVT battery charger. Connect the battery charger and the power cord, and then plug the power cord into a standard wall outlet. The orange lamp on the charger indicates that the battery is charging, and the green lamp indicates that charging is complete. A totally depleted battery may take approximately 4 hours to fully charge.

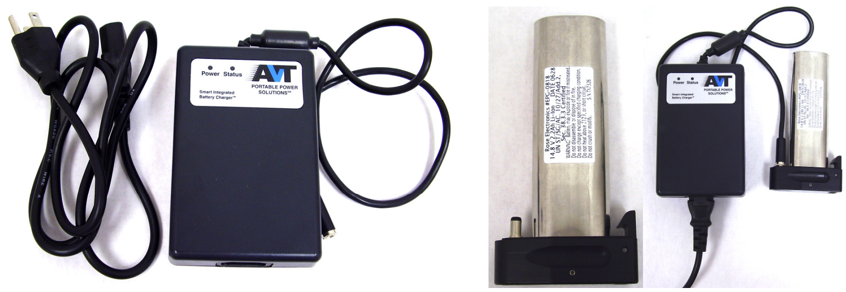


Figure 4.2: Charging the S1 TRACER batteries

> ● **NOTE**
> Lithium batteries should not be stored for long periods with a full charge. They should be stored with ~50% charge.

To reinstall the battery pack, insert the pack in the handle of the analyzer until a click is heard. A new, fully charged battery will operate the S1 TRACER for approximately 4-6 hours.

4.1.1.2 A/C Power

To operate the S1 TRACER on A/C power, ensure that the analyzer is off and remove the batteries. Plug the A/C power supply into the handle of the S1 TRACER, connect the power cord to the A/C power supply, and then plug the power cord into a standard wall outlet (see Figure 4.3 below).

Figure 4.3: Operating the S1 TRACER using AC power

4.1.2 PDA

4.1.2.1 Battery Power/Charging the Batteries

> ● **NOTE**
> If the PDA battery is sufficiently discharged and cannot be turned on, you must charge the PDA battery manually prior to using the S1 TRACER.

When the PDA is attached to the S1 TRACER and the analyzer is on with the BrukerS1 program running, the PDA battery charge level will be monitored. The S1 TRACER will automatically charge the PDA battery when its charge drops below 50%.

To charge the PDA battery manually, detach the PDA and connect it to A/C power using the cords and adapters provided. Before removing the PDA from the S1 TRACER, ensure that the PDA and S1 TRACER are powered off. Remove the PDA by using the PDA release barrel key to move the plunger downward, and then slide the PDA toward the nosepiece of the analyzer and out of the cradle. The plunger must be extended to remove the PDA release barrel key.

Figure 4.4: Insert PDA release barrel key into lock and turn key to move plunger

Either connect the PDA to the A/C adaptor and then plug it into a standard wall outlet or place the PDA in the cradle, connect the A/C adaptor to the cradle, and then plug it into a standard wall outlet. An orange LED on the top left of the PDA face will flash to indicate that the PDA battery is charging. When the PDA battery is fully charged the orange LED will be on continuously.

Figure 4.5: Charging the PDA with the wall charger

Figure 4.6: Charging the PDA with the cradle

For more information on the PDA, please refer to the iPAQ user manual.

4.1.2.2 A/C Power

To operate the PDA on A/C power, plug the A/C power supply into the PDA, and then plug the cord into a standard wall outlet.

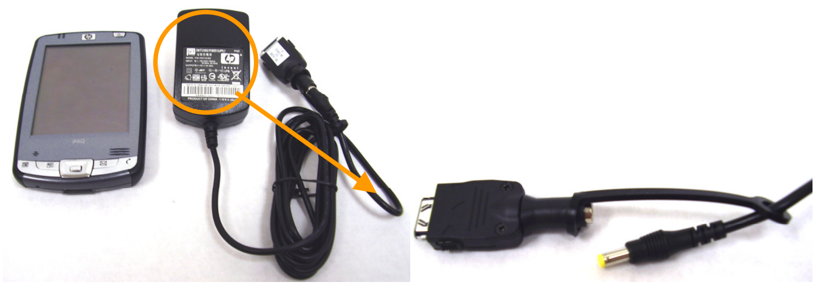


Figure 4.7: Hooking up A/C power to the PDA

4.1.3 Vacuum Pump

4.1.3.1 Battery Power/Charging the Batteries

The vacuum pump uses nickel metal hydride (NiMH) batteries. Ensure that the vacuum pump is off prior to removing the batteries. To change the battery, turn the three knobs one-quarter turn counter-clockwise to remove the battery cover. Unclip the white connector and remove the battery from the compartment.

Figure 4.8: Removing the battery from the vacuum pump

4.1.3.2 A/C Power

To operate the vacuum pump on A/C power, plug the A/C power supply into the port on the front of the vacuum pump, connect the power cord to the A/C power supply, and then plug the power cord into a standard wall outlet.

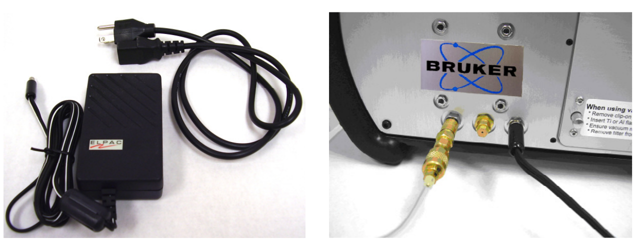


Figure 4.9: Hooking up A/C power to the vacuum pump

To charge the vacuum pump battery, first remove the battery from the vacuum pump, if necessary. Connect the battery to the universal smart battery charger. Ensure that the switch is set to 1.8A. Connect the battery charger and the power cord and then plug the power cord into a standard wall outlet. The orange LED on the charger indicates that the battery is charging, and the green LED indicates that the charge is complete. The vacuum pump batteries require 4 to 6 hours to completely recharge.

Figure 4.10: Charging the vacuum pump battery

To reinstall the battery, reattach the white connector and place the battery back into the compartment on the vacuum pump. Replace the battery cover and turn the three knobs clockwise to lock it in place. A new, fully charged battery will operate the vacuum pump for 2 to 4 hours.

4.1.4 A Note on NiMH Batteries

NiMH batteries do not have a memory and provide best performance and service life under *high* load conditions. To prolong the life of the batteries:

- Recharge the NiMH batteries frequently.
- Fully discharge the batteries (by using them in the analyzer) after every 30 charge cycles.
- Ensure that the ambient temperature during charging is between +5°C and +45°C (40°F to 115°F).
- If the vacuum pump or battery packs are to be stored for a prolonged period, the batteries should NOT be fully charged before storage. Rather, keep the battery charged to about 30% to 50% and store at room temperature. If the

battery is not used for extended periods of time, recharge about once per year to prevent over discharge.

GENERAL BATTERY WARNINGS

- Misusing the battery can cause the battery to get hot, ignite, or rupture and cause serious injury.
- Do not place the battery in a fire or heat the battery. Do not place the battery in direct sunlight or use or store batteries in a hot location. Do not place the battery in a microwave oven, high pressure container, or induction cookware.
- Do not puncture the battery with nails or other sharp objects, strike the battery with a hammer, step on the battery, or otherwise subject it to strong impacts or shocks.
- Do not expose the battery to water or saltwater or allow the battery to get wet.
- Do not disassemble the battery as this may disconnect its safety protection devices.
- Charge the battery only with the charger that is intended to charge the battery.
- Do not use any other devices to discharge the battery. The battery should be discharged only by using the analyzer.

4.2 Vacuum Configuration

> ● **NOTE**
> Analysis of aluminium or titanium alloys requires selection of a specific method in the Bruker S1 analysis program.

If possible before starting testing, make an initial determination of the material to be analyzed. Aluminum or titanium alloys should be measured using the vacuum system with the clip-on window protector *removed* from the nosepiece.

4.2.1 Inspecting the Vacuum Window

The vacuum window protects the sensitive instrumentation from dust and debris in normal operation and also provides a vacuum seal during light element analysis. The vacuum window needs to be replaced only if it has been damaged and can no longer hold a vacuum. Five (5) replacement vacuum windows are included with the S1 TRACER. Generally, a vacuum of 10 Torr or less, as indicated on the vacuum pump LCD display, is sufficient to achieve accurate measurement of light elements. Should the vacuum window require replacement, please refer to section 4.2.3.

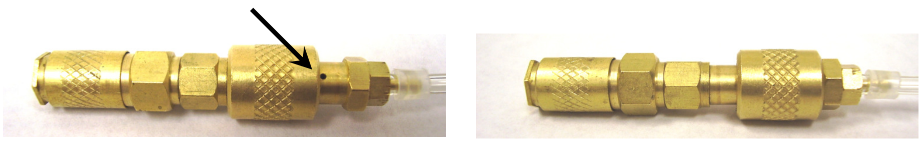
4.2.2 Connecting the Vacuum Pump

> ● **IMPORTANT**
> Before turning off or disconnecting the pump from the analyzer, open the vacuum release valve. Failure to open the vacuum release valve prior to removing the vacuum tubing from the vacuum pump or the analyzer will damage the highly sensitive Si-PIN detector.

To analyze aluminum and titanium alloys, attach the vacuum pump to the S1 TRACER. Connect the vacuum tubing between the vacuum pump and the S1 TRACER, ensuring that the connector with the vacuum release port (slide valve) is connected to the vacuum pump. Ensure that the vacuum release port (slide valve) is closed by being moved toward the analyzer (see Figure 4.12). Turn the vacuum pump on. The vacuum system is ready when the display reads 10 Torr or less (a pressure of 5 Torr or less is preferable for accurate readings.)

For best accuracy when measuring aluminum or titanium alloys, allow the vacuum pump to run for several minutes before beginning testing.

Figure 4.11: Attaching the vacuum tubing



Vacuum release port in open position *Vacuum release port in closed position*

← To vacuum pump → To TRACER

Figure 4.12: Opening/closing the vacuum release valve

When analyzing light alloys (such as aluminum or titanium alloys) in vacuum mode, remove the clip-on window protector as illustrated in Figure 4.13. Grip the clip-on window protector firmly on both sides and lift off of the analyzer. To reinstall, gently press the clip-on window protector over the nose of the analyzer, lining up the four holes on the window protector with the alignment pins on the nose that hold it in place.

Figure 4.13: Installing/removing the clip-on window protector

4.2.3 Replacing the Vacuum Window

To replace a damaged vacuum window, first ensure that the analyzer is turned off and the vacuum pump is properly disconnected (see section 4.2.2). Carefully peel the old window tape from the nose of the analyzer. Now that the nose is exposed, be careful not to allow dust and debris into the aperture as this debris may damage sensitive components and affect analysis results. Remove any resident adhesive on the nose with a soft lint-free cloth dampened with isopropyl alcohol. Peel the backing off of the replacement window and line up the aperture with the window. Press the tape such that there are no air bubbles, gaps, or creases to allow air to enter the nose. Carefully use a fingernail to press firmly around the aperture for a good seal.

Figure4.14: Changing the vacuum window

4.3 Testing Configuration

The S1 TRACER may be used as a handheld device or as a bench top instrument, depending on the testing requirements.

4.3.1 Hand Held Configuration

To use the S1 TRACER as a hand held device, be sure to secure the wrist strap. To attach the wrist strap, wind the ring through the eyelet on the back of the analyzer (see Figure 3.1).

4.3.2 Bench Top Configuration

To set up the instrument stand, lift the long side (screw may need to be loosened to lift the side fully) and tighten the screw to hold it in place. Lift the shorter side such that the legs swing down and fit into the grooves in the base of the instrument stand. Attach the PDA cradle with the Velcro dots.

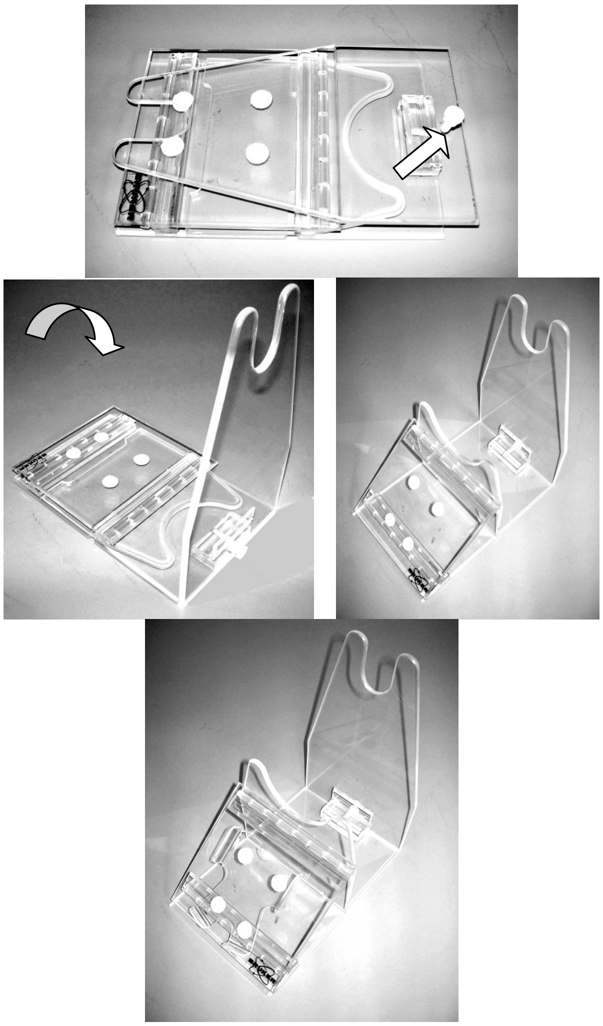


Figure 4.15: Setting up the instrument stand

> ● **NOTE**
> Ensure that the connector and the port are properly aligned (the red dot on the body of the cable connector should be aligned with the red dot and notch in the receptacle on the analyzer.) Do not force the null modem cable connector into the port receptacle.

To use the S1 TRACER in the bench top configuration, remove the PDA from the analyzer PDA cradle (see Figure 4.4). Place the analyzer into the stand by aligning the grooves in the body and handle and sliding it onto the stand so that the control panel of the analyzer is forward (see Figure 1.2). Connect the PDA to the S1 TRACER with the null modem cable and place the PDA in the PDA cradle on the instrument stand.

To analyze small samples or to have a flat surface on which to work, install the clip-on sample holder instead of the clip-on window protector. When testing very small samples, place the Safety Shield Accessory over the sample so that the end of the safety shield also covers the IR sensor. Figure 4.17 illustrates the safety shield being placed over the sample prior to testing. For actual testing, the safety shield must rest flush onto the surface of the sample holder, and the operator must not have their hand near the nosepiece of the analyzer.

Use care so that nothing punctures the window on the analyzer. If the window is damaged, see section 4.2.3 for instructions on how to replace the windows. Do not use the analyzer until the punctured window has been replaced.

Figure 4.16: Clip-on sample holder installed on the S1 TRACER

Figure 4.17 Preparing to use the safety shield when testing a very small sample. The safety shield must be completely flat against the sample holder with the instrument IR sensor covered for testing.

4.4 Starting the Analyzer

If using the analyzer and accessories in battery power mode, be sure to use fully charged batteries in the S1 TRACER, PDA, and vacuum pump. Otherwise, connect them to A/C power. See section 4.1.3.2 for more information.

Remember that for vacuum operation (examining light alloys such as aluminum and titanium) the clip-on window protector should be removed. If small samples are to be analyzed in bench top mode, install the clip-on sample holder.

● **IMPORTANT**
Before turning off or disconnecting the pump from the analyzer, open the vacuum release valve. Failure to open the vacuum release valve prior to removing the vacuum tubing from the vacuum pump or the analyzer will damage the highly sensitive Si-PIN detector.

● **NOTE**
Ensure that the cable connector and the receptacle are properly aligned (the red dot on the body of the cable connector should be aligned with the red dot and notch in the receptacle on the handle of the analyzer). Do not force the cable connector into the receptacle.

● **IMPORTANT**
Do not start the BrukerS1 program until the S1 TRACER is initialized. The BrukerS1 program is looking for communication with the S1 TRACER. If started in the wrong sequence, refer to section 7.1: *Error: Measurement will not start,* to correct the problem.

For typical operation, the steps to start the analyzer are:

- If the unit is to be used in vacuum mode, hook up the vacuum pump to the S1 TRACER. Start the pump and wait for the readout to display 10 Torr or less (an indication of 5 Torr or less is preferable).
- If desired, set up the analyzer in the bench top configuration.
- Install the remote trigger cable into the remote trigger port on the handle of the S1 TRACER, if desired.
- Remove the stylus from the PDA.
- Attach the PDA to the S1 TRACER:

Handheld Configuration	Bench Top Configuration
• Unlock the PDA plunger lock with the barrel key. • Place the PDA snugly into the cradle of the analyzer. **Be careful not to use too much force when installing the PDA.** This may damage the PDA connector at the base of the cradle and disable the analyzer. • Lock the PDA into place. The key cannot be removed until the plunger is raised.	• Insert the Null Modem cable into the serial port on the control panel on the S1 TRACER. **NOTE: Use caution inserting the connector on the null modem cable into the receptacle on the control panel of the S1 TRACER. Both are keyed and must be aligned for proper insertion.** • Insert the opposite end of the cable into the bottom of the PDA. • Rest the PDA in the cradle on the analyzer stand.

- Turn the S1 TRACER power interlock key to the ON position. This will activate the yellow power indicator lamp. Wait 1 minute for the Peltier cooler and X-ray tube to stabilize. The audible sound of the filter wheel will be heard. The sound is normal and means that the analyzer has initialized.
- Turn the PDA power on by the button on the top right side of the PDA.

4.5 Adjusting the PDA Backlight

Using the bright backlight on the PDA while running on battery power can substantially reduce battery runtime. To adjust the backlight on the PDA, do the following:

- Tap on the “Start” icon in the upper left corner of the main screen.
- Tap on the “Settings” icon.
- Tap on the “System” tab near the bottom of the screen.
- Tap on “Backlight” and adjust settings according to the need.
- The “Battery Power” tab enables the user to set the amount of time the PDA waits before turning off the backlight if the device is running on battery power.
- The “External Power” tab enables the user to set the amount of time the PDA waits before turning off the backlight if the device is running on external power.
- The “Brightness” tab will enable the user to adjust the brightness level on battery or external power.

NOTE
If the backlight has turned off because it has not been used for the specified period of time, simply press a button or tap on the screen to turn the backlight on again.

•

5. Operation/General Purpose Measure

The S1 TRACER is delivered fully calibrated for a variety of alloys. Therefore, it can be used for normal work without any preparation other than that described in Chapter 4.

The analyzer is operated through the BrukerS1 analytical program. This program is located in the PDA's **Start** menu.

5.1 Starting the BrukerS1 Program

Bruker AXS Handheld recommends using ONLY the stylus provided with the iPAQ PDA. Use of any other item in place of the provided stylus may void the PDA warranty.

The flash memory card containing the BrukerS1 program files for the PDA does NOT need to be installed into the PDA during normal operation. The flash card should be stored in a safe location for use in case reinstallation of the BrukerS1 program becomes necessary. If it appears that this action is required, see the section on troubleshooting, Section 7.3 for detailed instructions on reinstalling the BrukerS1 software onto the PDA.

To start the BrukerS1 Program:

- Tap on the "Start" icon in the upper left corner of the main screen.
- Tap on the "BrukerS1" icon to start the analytical program. It will take a few seconds to load the program.

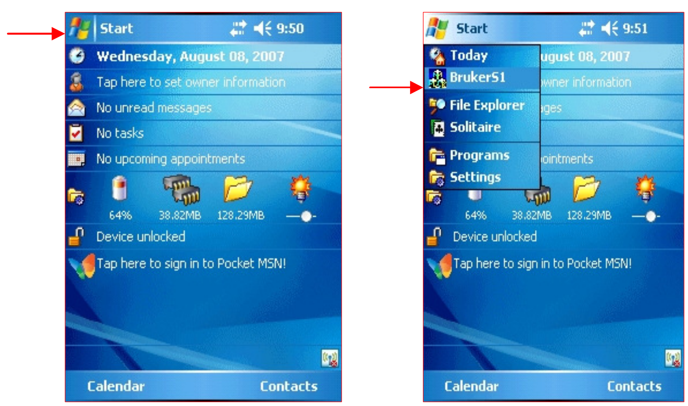


Figure 5.1: Starting the BrukerS1 program

> ● **NOTE**
> Immediately upon receipt of the analyzer, the password should be changed to a new password of your choice.

Starting the BrukerS1 program brings up the Login screen as shown in Figure 5.2. After tapping on the “Login” button, a login screen will appear as shown in Figure 5.3. Enter your personal password, and then tap “Continue”.

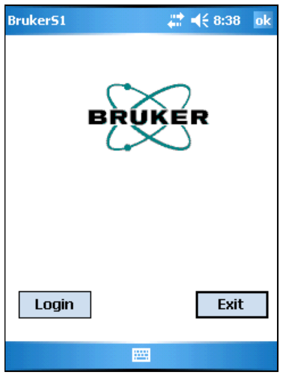


Figure 5.2: Main screen

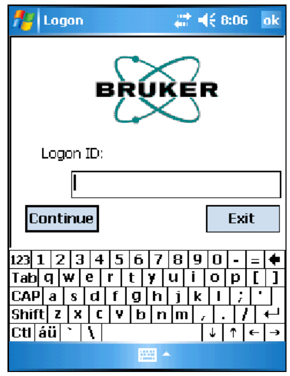


Figure 5.3: Login screen

When the software has verified the user password, a radiation warning will appear as illustrated in Figure 5.4, indicating that the BrukerS1 is for use by trained and authorized personnel only. This radiation warning screen will be displayed for approximately 15 seconds. No operator action is possible during the time while the radiation warning is displayed.

After the Radiation Warning is completed, the main *Mode Selection* screen illustrated in Figure 5.5 will appear.

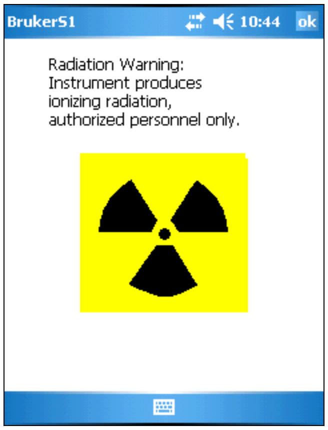


Figure 5.4: Radiation Warning screen

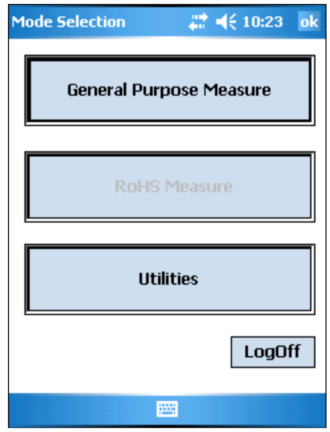


Figure 5.5: Main Mode Selection screen

Before beginning testing, the user should note that the PDA memory may "fill up" after a large number of tests have been run. If the PDA memory is full, the operator may continue testing but the results will not be stored. To prevent data loss, either install a flash memory card (Compact Flash or SD, available as an accessory) and set the BrukerS1 software to write results to the memory card (see section 6.4, System Setup) or periodically download the test results to a PC (see section 5.10, Viewing and Exporting Stored Data.) The PDA memory will store approximately 2000 readings, depending on the individual test results.

After logging on to the PDA, and when the main Mode Selection screen (Figure 5.5) is displayed, the user can begin testing by tapping on the "General Purpose Measure" button. The audible sound of the filter wheel will be heard. The second Mode Selection screen, shown in Figure 5.6, is displayed. The following options are located in the **General Purpose Measure** menu:

5.1.1 Metals Mode

Pass/Fail mode enables the user to determine whether or not the material being analyzed matches a specific alloy from the library.

Analyze is the default mode for obtaining the Grade ID (alloy name) and chemical composition of aluminum, titanium, iron, nickel, cobalt, and copper alloys.

> ● **NOTE**
> If you are unsure of the composition of the material to be analyzed, using the Fundamental Parameters (FP) method may provide results faster and more correctly than Empirical Method in determining the composition of the material. Please see section 5.3.1 for more information about selection of Fundamental Parameters or Empirical methods.

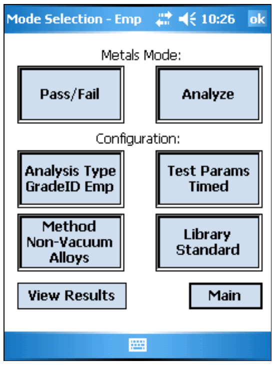


Figure 5.6: General Purpose Measure menu

5.1.2 Configuration

Select the *Analysis Type* (PMI-FP, GradeID-EMP, or Auto). Selection of *Analysis Type* will affect the accuracy of the results.

The *Test Parameters* option enables the user to adjust the length of time of the test and to activate or deactivate the auto trigger.

The *Method* can be changed to obtain more accurate results by using instrument settings optimized for measurement of certain alloy types. For instance, to assay aluminum alloys, change the setting to “Al Vacuum Alloys” and make sure to connect the vacuum pump properly (see section 4.2). For more information about the *Method* menu, see section 5.3.4.

The *Library* menu enables selection of the standard factory library and/or user-defined libraries to be used during testing and identification.

If the **Pass/Fail** and **Analyze** buttons in the *Metals Mode* screen appear to be "grayed out", the PDA software has not established communications with the S1 Tracer instrument. If this occurs, see Section 6.4, Systems Setup, and Section 7, Troubleshooting, for assistance.

5.2 Sample Preparation

The analyzer analyzes the sample surface to a small depth, so for most accurate assessment, the material must be homogeneous, i.e. the chemical composition must be uniform throughout the sample to be tested.

If the sample is flat and clean (no rust, oil, dirt, paint or other coating, etc.), no additional sample preparation is necessary.

Contamination on the sample surface will have the greatest effect during analysis of lighter elements. Dust, dirt, and oil can be simply cleaned from the surface with a cloth or soft brush. Rust, corrosion, paint, and coatings should be removed by sanding or grinding the sample surface.

When testing alloys based on lighter elements, particularly aluminum, use care when selecting the material to be used for cleaning the test surface. Abrasives based on silicon used in "sand-blasting" or "bead-blasting", or aluminum oxides used in "sandpaper" or "grinding wheels" may leave traces of those materials on, or even embedded in the sample surface. These traces can affect the accuracy of calculated concentrations and Grade ID.

5.3 Analyzer Settings Configuration

5.3.1 Analysis Type

● **NOTE**
Best results will be obtained if the general alloy type(s) of the material being tested are known prior to selecting *Analysis Type* and configuration *Method*.

The S1 TRACER may be configured to analyze a material in one of four different Analysis Types. Make the selection then tap "Continue" to save your settings in this menu.

Positive Material Identification - Fundamental Parameters (PMI-FP) uses a Fundamental Parameters method to analyze valid counts for each element and compute concentrations. In general, FP analysis should be selected if the general type of material to be tested is not certain. The FP method can analyze the composition of a broader range of materials, but will generally take longer to display results, and the results may not be as accurate as those obtained using the Empirical method.

Grade Identification - Empirical (GradeID-Emp) calculates elemental concentrations based upon an empirical calibration and analyzes valid counts for each element. In general, if the type of material is known (e.g., steel alloy, copper alloy, etc.) Empirical methods will identify the results more quickly than the FP method, and will often report slightly more accurate analytical results.

Auto - automatically switches from Empirical analysis to Fundamental Parameters analysis if a Grade ID cannot be determined within five seconds.

Dual - will be implemented in a future version of the BrukerS1 software.

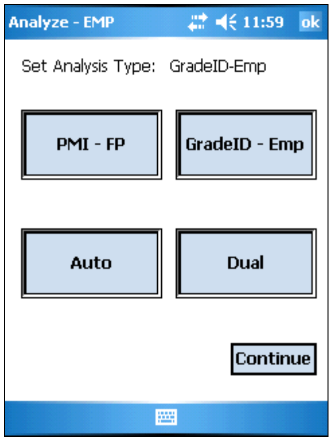


Figure 5.7: Analysis Type screen

5.3.2 Test Parameters

When testing several different materials, it may be desirable to test each material sample for a fixed amount of time. It may also be convenient to have the S1 TRACER automatically continue to generate X-rays after the trigger is pulled, rather than having to hold down the trigger for the entire duration of the test; this function is called the *Auto Trigger*. These settings can be adjusted in the **Test Parameters** menu as shown in Figure 5.8.

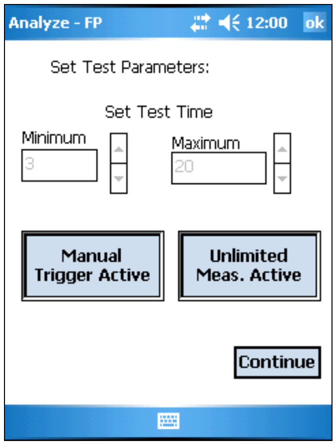


Figure 5.8: Test Parameters screen

To toggle between *Manual* and *Auto* trigger, tap on the "Trigger Active" button. The *Manual* trigger setting specifies that the trigger must be held down for the entire duration of the test; the *Auto* trigger setting specifies that the trigger needs to be pressed only once to start the test. **Due to local regulations, the *Auto Trigger* feature is not available in some countries.**

To toggle between *Timed Measurement* and *Unlimited Measurement*, tap on the "Measurement Active" Button. In *Timed Measurement* mode, the "Minimum" and "Maximum" boxes display the lower and upper timed limits for each test. The "Minimum" value specifies the number of seconds the test must run before test results will be saved. This helps prevent unwanted results from being saved when the trigger is accidentally pulled. The "Maximum" value specifies the maximum number of seconds the test will run. These values can be adjusted by tapping on the up and down arrows next to each box. They can also be entered using the keyboard; this can be done by tapping on the keyboard icon at the bottom of the screen.

When the *Unlimited Measurement* mode is enabled, the numbers in the "Minimum" and "Maximum" boxes are grayed and their values cannot be adjusted. In this mode, the test time is controlled entirely by holding the trigger. Tap "Continue" to save your settings in this menu.

5.3.3 Library

The **Library** option is for identifying and verifying alloys and grades that are not stored in the factory libraries.

The library to be used can be selected by entering the **Library** menu, selecting the library of interest, and tapping on “Continue”. An example of a **Library** menu screen with the standard and user libraries is shown in Figure 5.9.

In some cases, a User Library or Libraries may be required for testing. An example would include identification of non-standard specialized alloys. To create or edit your own user library, please refer to section 6.3 “Library Maintenance.”

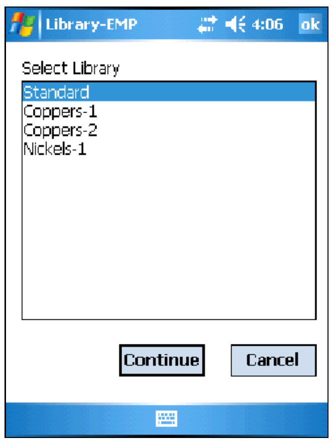


Figure 5.9: Library menu with Standard and User Libraries

5.3.4 Analysis Method

In the **Method** menu, the general category of materials being analyzed may be selected from the menu shown in Figure 5.10. **Method** settings establish different voltage, current, and filter settings for the S1 TRACER, optimized to provide the most accurate measurement and chemistry calculation for each of the different types of alloys included in the Reference Library.

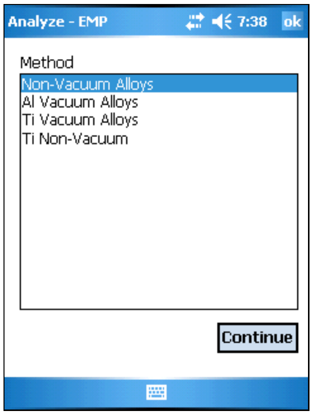


Figure 5.10: Analysis Method menu needs update

In the **Method** menu, there are six different menu options. Tap on the setting of interest and then tap “Continue”. There will be a momentary pause followed by the audible sound of the filter wheel. If selecting “Al Vacuum Alloys” or “Ti Vacuum Alloys”, you will be prompted to connect the S1 TRACER to the vacuum pump for accurate analysis of light elements. For a full description of how to correctly connect and use the vacuum pump, please see section 4.2.

5.4 Analysis Modes

5.4.1 Pass/Fail Mode

Pass/Fail mode enables the user to determine whether or not the material being analyzed matches a specific alloy from the library. Tapping on the “Pass/Fail” button opens a screen as seen in Figure 5.11.

To test for a specific alloy, scroll down the “Fail” list and highlight the alloy of interest. Tap the arrow button underneath to add the selected alloy to the “Pass” list. The “Pass” list indicates which alloys will pass the test. To remove an alloy from the “Pass” list, highlight the alloy on the “Pass” list and tap on the arrow button underneath to move the alloy into the “Fail” list.

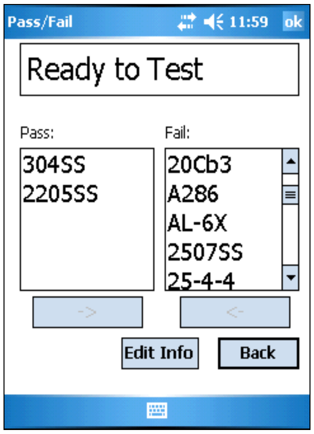


Figure 5.11: The Pass/Fail menu

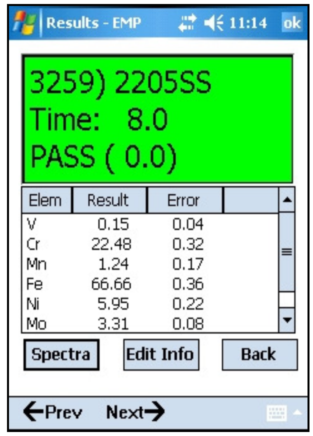


Figure 5.12: Example of a "Pass" Test screen

Once the "Pass" alloys have been selected, the analyzer is ready to start testing. After the trigger is pulled and testing is started, the screen will display results as shown in Figures 5.12, 5.13, and 5.14. This screen displays the "passable" alloy name, the chemistry of the tested material, and whether or not the material passes or fails. As the test progresses, the color of the upper screen will indicate the test status: green indicates that the material matches one of the Grade IDs selected, yellow indicates a possible match, and red indicates that the material does *not* match one of the selected Grade IDs. The display also includes a *Match Quality* value, displayed in parenthesis. The *Match Quality* number will range from 0.0 to 10, and is an indicator of how closely the measured chemistry for the material being tested matches the chemistry for the Grade ID found in the library. For *Match Quality*, higher numbers indicate a closer match to the library values. For most standard alloy Grades, a value of 8.0 or higher may be expected.

NOTE: If a material does not match one of the alloys in the PASS list, the S1 TRACER will still attempt to determine a Grade ID, but display a FAIL indication.

NOTE: If the chemistry of the alloy does not closely match the chemistry in a library, "**No Match**" will display for Grade ID. The *Match Quality* threshold below which "**No Match**" is displayed is set to a default value of 5.0. The *Match Quality* threshold may be changed from the System Setup Menu.

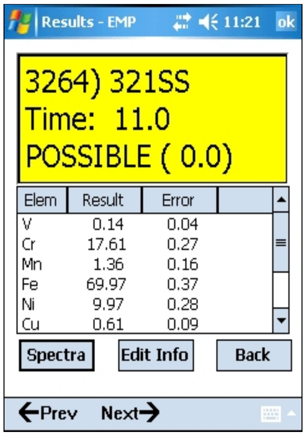


Figure 5.13: Example of a "Possible" Test screen

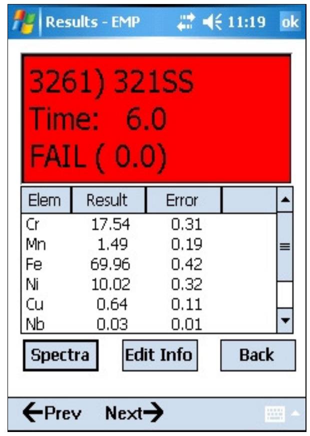


Figure 5.14: Example of a "Fail" Test screen

5.4.2 Analyze

The default measurement mode is *Analyze*. This mode is used for analysis of unknown materials. When testing in this mode, the PDA displays the alloy name along with the chemical composition of the material, as shown in Figure 5.16.

Upon starting a test, the PDA will alert the user and the calculated material composition will begin to display. If the material is an alloy contained in the S1 TRACER library, the alloy name will be displayed at the top of the screen. As the test progresses, the results will become more precise. The display also includes a *Match Quality* value, displayed to the right of the reported Grade ID. The *Match Quality* number will range from 0.0 to 10, and is an indicator of how closely the measured chemistry for the material being tested matches the chemistry for the Grade ID found in the library. For *Match Quality*, higher numbers indicate a closer match to the library values. For most standard alloy Grades, a value of 8.0 or higher may be expected.

The concentration for each element is recalculated with every data sample, and compared to the allowable range of concentrations for that element in the reported alloy Grade ID. Calculated concentrations which fall within the allowable range are displayed against a green background, those which are outside of, but within 3 sigma of a range threshold are displayed against a yellow background, and those falling outside the 3 sigma range are displayed against a red background. The color scheme for displaying calculated concentrations is illustrated in Figure5.16.

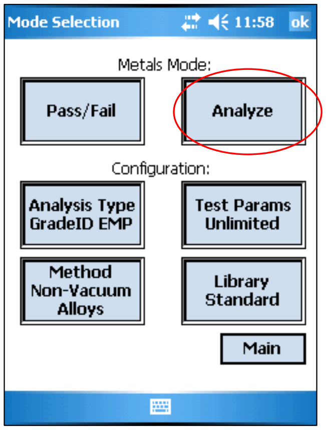


Figure 5.15: Analyze in the General Purpose Measure menu

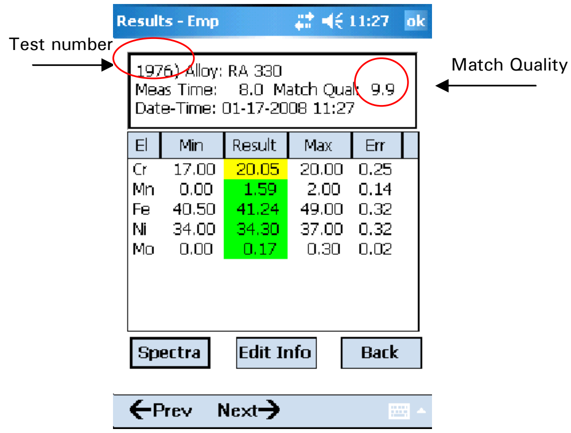


Figure 5.16: Example of the Analyze screen

When testing aluminum or titanium alloys using the vacuum system, the S1 TRACER continually monitors the vacuum within the analyzer. If the vacuum rises above the level required for accurate measurements, the analyzer (PDA) will sound a chime tone and display a “Vac Bad” visual alert in the bottom left of the analysis screen. See section 4.2 for additional information about use of the vacuum system.

5.5 Making Measurements

NOTE: The analyzer should be allowed to warm up for at least 1 minute after being turned on before starting a test. This allows the S1 TRACER internal microprocessor to initialize and for the Peltier cooler and the X-ray tube to stabilize. You will hear a slight whirring sound when the S1 TRACER is ready; this sound is normal and comes from the internal filter wheel.

To analyze a material, ensure that the BrukerS1 program is running on the PDA, and then place the S1 Tracer nose on the material and pull the trigger. (If “Timed Assay” was selected, pull and release the trigger to start the measurement.)

> **● IMPORTANT**
> **High intensity X-rays are generated when the trigger is pulled. Keep eyes and other body parts away from the nose of the analyzer. Only trained operators may use this analyzer.**

Be sure that the analyzer window is pressed firmly against the material. Ensure that the infrared (IR) sensor on the nose of the analyzer is covered by the material, or the measurement will not start. The infrared safety sensor on the analyzer nose operates by detecting light reflected from the material surface. In addition, the Backscatter Detection safety feature will shut off the X-rays when the detector does not sense an object in front of the nosepiece. Both safety features are incorporated to prevent accidental X-ray radiation exposure.

Figure 5.17: The nose of the analyzer

There are two indicator lamps on the control panel of the analyzer (see Figure 5.18). The yellow lamp indicates that the power is on, or, if it is blinking, that an error has occurred (see section 7. The red lamp indicates that the analyzer is generating X-rays (trigger is pulled). Note that if the red lamp looks uneven, one of the dual red LEDs may have failed and X-rays will not be generated (see section 7 for troubleshooting).

Figure 5:18: The control panel of the analyzer

A few seconds after the trigger is pulled, the analyzer displays the first calculated chemistry result on the PDA screen. The result is updated continuously as long as the trigger is held, and the elapsed measurement time is shown beneath the alloy name on the PDA screen. To stop the measurement, release the trigger. **NOTE:** Increasing the measurement time will improve the precision of the results.

When the measurement is complete and results are shown, a new measurement can be started simply by releasing the trigger and pulling it again.

5.6 Viewing Results and Spectra

After making a measurement in Analyze mode, the screen will display the finalized results of the test (previously illustrated in Figure 5.16). The same screen display appears when viewing previous test results from **View Readings** in the **Utilities** menu (see section 6.1). To view the spectrum from this screen, tap the "Spectra" button at the bottom of the screen. To return to the results screen, tap the "Results" button.

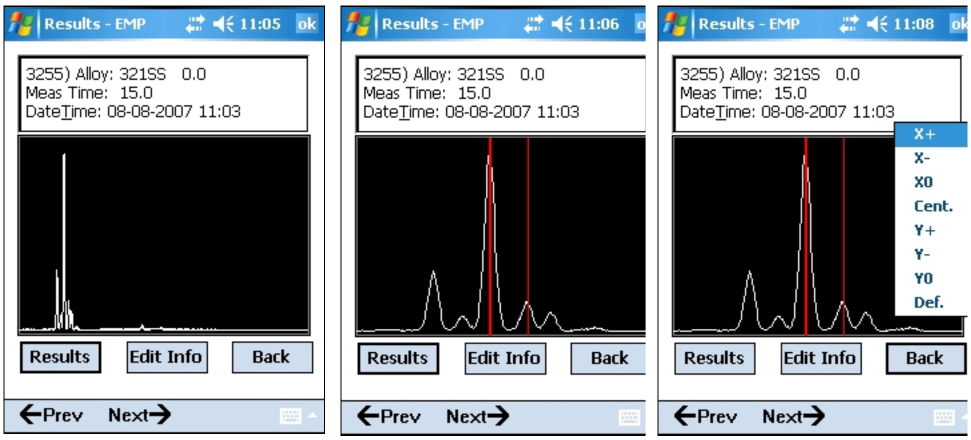


Figure 5.19: Examples of the spectra screen, spectra screen with the iron peaks indicated by the red lines, and the spectra axis menu

The spectra can be manipulated by dragging the stylus along the screen. Dragging the stylus up and down will stretch and compress the y-axis (count rate) scale. Dragging the stylus left and right will move the x-axis (keV) scale so that the entire spectrum can be viewed.

The spectrum can also be manipulated through the spectral menu. Press and hold the stylus anywhere on the spectrum to bring up the spectral menu (see the right-hand screen in Figure 5.19). The following options are available:

- **X+**: Stretches the x-axis (keV) scale to zoom in on the spectrum.
- **X-**: Compresses the x-axis (keV) scale to zoom out from the spectrum.
- **X0**: Re-centers and returns the spectrum to the original scale along the x-axis.
- **Cent.**: Re-centers the spectrum on both the x- and y-axes.
- **Y+**: Stretches the y-axis (count rate) scale.

- **Y-**: Compresses the y-axis (count rate) scale.
- **Y0**: Returns the spectrum to the original scale along the y-axis.
- **Def.**: Restores the spectrum back to its default setting; the spectrum is re-centered and the original scale along both axes is restored.

To highlight spectral peaks, tap anywhere on the screen to mark the area of interest with two red vertical lines. These lines correspond to the spectral energies of each element.

To identify which spectral energy lines correspond to a particular element, tap on the "Results" button to return to the results page. Highlight the element of interest by tapping on the element name. Tap on the "Spectra" button to return to the spectrum. The spectral energy lines associated with the element of interest will be displayed by two red lines (the K and L energy lines).

5.7 Editing Information

Information related to the test may be added to the test record and saved by use of the **Edit Information** screen. Tap on the "Edit Info" button in the **Analyze** screen. In the **Edit Information** screen, the user can enter the name of the test, the identification (ID) of the material being tested, and other information in the two provided fields. To enter information in any field, tap on the field to display the cursor, open the PDA "keyboard" by tapping the keyboard icon at the bottom of the PDA screen, and enter the desired information. When a particular field is complete, repeat the procedure for the other fields as needed. To save this information, tap "Continue" at the bottom of the screen. To cancel, tap "Back."

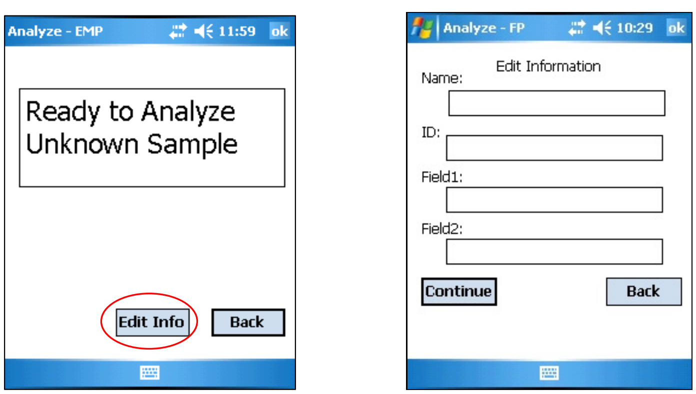


Figure 5.20: Accessing and Using the Edit Information screen

Entering or editing test information **must be done before making a measurement.** The **Edit Information** screen can also be accessed from the **View Readings** menu (see section 6.1).

If test information is added, that test information will be recorded for **ALL** measurements subsequent to the one for which the test information was recorded. To prevent this, after the measurement for which the test information was entered is completed, re-enter the **Edit Information** screen and delete the information.

5.8 Saving Results and Spectra

Results and chemistry for each test are automatically saved in individual rows in one file. On the PDA, this test data file name automatically defaults to “results”. In addition, spectra data for each test are saved as PDZ files in the “data” directory of the PDA. For more information on how to access this directory, see section 5.10. To change the settings on the PDA so that it saves results or spectra to a Compact Flash or SD memory card, see section 6.4.

5.9 Turning off the Analyzer

Tap the “Back” button on the Analyze or Pass/Fail results screen. Tap the “Main” button on the **General Purpose Measure** screen and then tap “LogOff” to return to the Login screen. Tap the “Exit” button to exit the BrukerS1 program.

Turn the PDA power off.

Turn the S1 TRACER power switch to the “OFF” position.

● **IMPORTANT**
Failure to open the vacuum release valve prior to removing the vacuum tubing from the vacuum pump or the analyzer will damage the highly sensitive Si-PIN detector.

If using the analyzer in vacuum mode, turn off the vacuum pump. Open the vacuum release valve and allow the pressure to stabilize prior to removing the pump or tubing from the S1 TRACER (see section 4.2.2).

5.10 Viewing and Exporting Stored Data

S1 TRACER test results may be viewed using the “Pocket Excel” program on the PDA or by exporting the stored results to a PC. Results can also be viewed individually on the PDA by accessing the **View Readings** screen in the **Utilities** menu. See section 6.1.

5.10.1 Viewing Results using "Pocket Excel"

To view stored results with the PDA using Pocket Excel, close the BrukerS1 program and open Pocket Excel. Pocket Excel automatically searches the PDA for any Excel files. Tap on the desired file to open and view it.

Result files are stored in the "Data" folder inside of the "My Device" folder.

5.10.2 Viewing Results using a PC

To view S1 TRACER test data on an external PC, you must first export the test data to the PC Using Microsoft ActiveSync. Transferring data from the PDA will be similar to transferring data from an external disk drive using Microsoft Windows Explorer.

ActiveSync must be used in order to convert the Pocket Excel files (.pxl) to Comma Separated Values files (.csv), which can be read by Microsoft Excel.

If test data was saved on a Compact Flash or SD memory card, data may be transferred directly to a PC by use of a card reader accessory. In this case, ActiveSync is not required.

5.10.3 Installing Microsoft ActiveSync (if required)

- Connect the PDA cradle's USB cable to the PC.
- If needed, turn on the PC and wait until Microsoft Windows is fully started.
- Insert the ActiveSync CD-ROM into the computer's disk drive.
- Follow the instructions that appear on the computer screen.

NOTE: ActiveSync may also be downloaded from the Microsoft website: http://www.microsoft.com/windowsmobile/activesync/activesync45.mspx

5.10.4 Exporting the Results and Spectra Files using ActiveSync

> ● **NOTE**
> The default file name for data being saved in this process is "results.csv". If more than one set of data is to be saved, use the "save as" function and rename the file to be saved to avoid writing over previous data.

- Remove the PDA from the S1 TRACER and install it into its cradle.
- Open the **"**ActiveSync**"** program on the PC.
- Connect as "Guest" (Do not create a "Partnership"; it is not needed for exporting files).
- Open "My Computer" and double-click the PDA (Mobile Device) icon (see Figure 5.21). The PDA directory is:
    - My Windows Mobile-Based Device\Data
- Select the files in the "Data" folder to be exported.
- Copy the files to your PC hard drive.

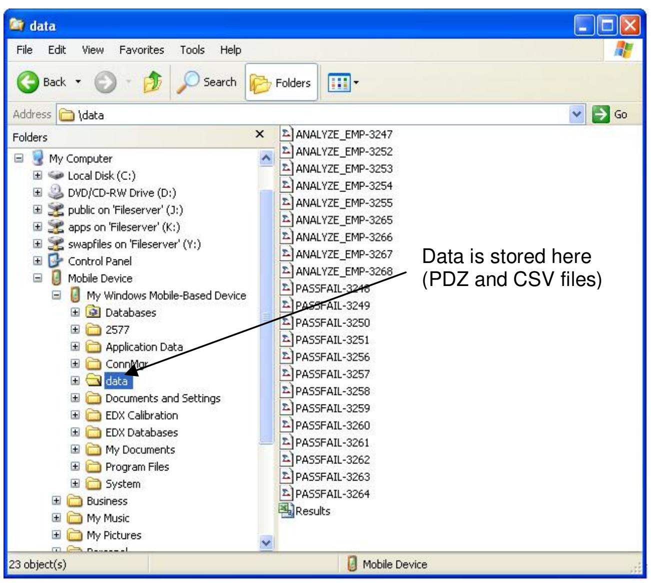
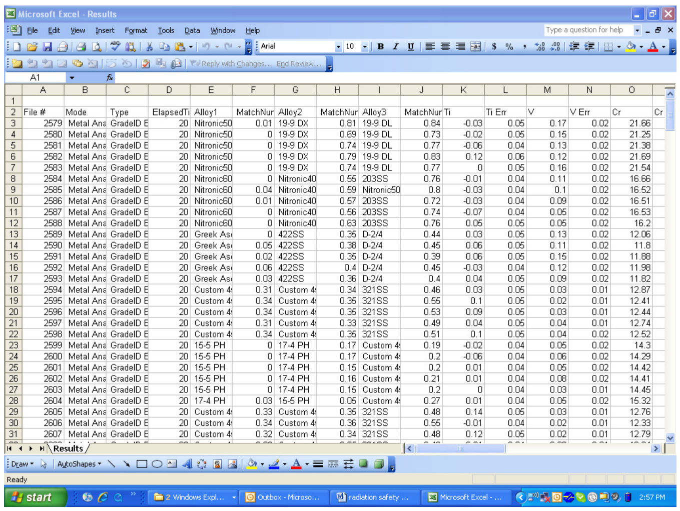


Figure 5.21: Example of File Explorer

5.10.5 Viewing and using Test Results Data Downloaded to the PC

- Open Excel on the PC.
- In Excel, select "File", "Open," and in the *Files of Type* drop down box, select "Text Files" or ".csv". Select the name of the file to be opened.



File #	Mode	Type	ElapsedTi	Alloy1	MatchNur	Alloy2	MatchNur	Alloy3	MatchNur	Ti	Ti Err	V	V Err	Cr	Cr
2579	Metal Ana	GradeID E	20	Nitronic50	0.01	19-9 DX	0.81	19-9 DL	0.84	-0.03	0.05	0.17	0.02	21.66	
2580	Metal Ana	GradeID E	20	Nitronic50	0	19-9 DX	0.69	19-9 DL	0.73	-0.02	0.05	0.15	0.02	21.25	
2581	Metal Ana	GradeID E	20	Nitronic50	0	19-9 DX	0.74	19-9 DL	0.77	-0.06	0.04	0.13	0.02	21.38	
2582	Metal Ana	GradeID E	20	Nitronic50	0	19-9 DX	0.79	19-9 DL	0.83	0.12	0.06	0.12	0.02	21.69	
2583	Metal Ana	GradeID E	20	Nitronic50	0	19-9 DX	0.74	19-9 DL	0.77	0	0.05	0.16	0.02	21.54	
2584	Metal Ana	GradeID E	20	Nitronic60	0	Nitronic40	0.55	203SS	0.76	-0.01	0.04	0.11	0.02	16.66	
2585	Metal Ana	GradeID E	20	Nitronic60	0.04	Nitronic40	0.59	Nitronic50	0.8	-0.03	0.04	0.1	0.02	16.52	
2586	Metal Ana	GradeID E	20	Nitronic60	0.01	Nitronic40	0.57	203SS	0.72	-0.03	0.04	0.09	0.02	16.51	
2587	Metal Ana	GradeID E	20	Nitronic60	0	Nitronic40	0.56	203SS	0.74	-0.07	0.04	0.05	0.02	16.53	
2588	Metal Ana	GradeID E	20	Nitronic60	0	Nitronic40	0.63	203SS	0.76	0.05	0.05	0.05	0.02	16.2	
2589	Metal Ana	GradeID E	20	Greek Asi	0	422SS	0.35	D-2/4	0.44	0.03	0.05	0.13	0.02	12.06	
2590	Metal Ana	GradeID E	20	Greek Asi	0.05	422SS	0.38	D-2/4	0.45	0.06	0.05	0.11	0.02	11.8	
2591	Metal Ana	GradeID E	20	Greek Asi	0.02	422SS	0.35	D-2/4	0.39	0.06	0.05	0.15	0.02	11.88	
2592	Metal Ana	GradeID E	20	Greek Asi	0.06	422SS	0.4	D-2/4	0.45	-0.03	0.04	0.12	0.02	11.98	
2593	Metal Ana	GradeID E	20	Greek Asi	0.03	422SS	0.36	D-2/4	0.4	0.04	0.05	0.09	0.02	11.82	
2594	Metal Ana	GradeID E	20	Custom 4!	0.31	Custom 4!	0.34	321SS	0.46	0.03	0.05	0.03	0.01	12.87	
2595	Metal Ana	GradeID E	20	Custom 4!	0.34	Custom 4!	0.35	321SS	0.55	0.1	0.05	0.02	0.01	12.41	
2596	Metal Ana	GradeID E	20	Custom 4!	0.34	Custom 4!	0.35	321SS	0.53	0.09	0.05	0.03	0.01	12.44	
2597	Metal Ana	GradeID E	20	Custom 4!	0.31	Custom 4!	0.33	321SS	0.49	0.04	0.05	0.04	0.01	12.74	
2598	Metal Ana	GradeID E	20	Custom 4!	0.34	Custom 4!	0.35	321SS	0.51	0.1	0.05	0.04	0.02	12.52	
2599	Metal Ana	GradeID E	20	15-5 PH	0	17-4 PH	0.17	Custom 4!	0.19	-0.02	0.04	0.05	0.02	14.3	
2600	Metal Ana	GradeID E	20	15-5 PH	0	17-4 PH	0.17	Custom 4!	0.2	-0.06	0.04	0.06	0.02	14.29	
2601	Metal Ana	GradeID E	20	15-5 PH	0	17-4 PH	0.15	Custom 4!	0.2	0.01	0.04	0.05	0.02	14.42	
2602	Metal Ana	GradeID E	20	15-5 PH	0	17-4 PH	0.16	Custom 4!	0.21	0.01	0.04	0.08	0.02	14.41	
2603	Metal Ana	GradeID E	20	15-5 PH	0	17-4 PH	0.15	Custom 4!	0.2	0	0.04	0.03	0.01	14.45	
2604	Metal Ana	GradeID E	20	17-4 PH	0.03	15-5 PH	0.05	Custom 4!	0.27	0.01	0.04	0.05	0.02	15.32	
2605	Metal Ana	GradeID E	20	Custom 4!	0.33	Custom 4!	0.35	321SS	0.48	0.14	0.05	0.03	0.01	12.76	
2606	Metal Ana	GradeID E	20	Custom 4!	0.34	Custom 4!	0.36	321SS	0.55	-0.01	0.04	0.02	0.01	12.33	
2607	Metal Ana	GradeID E	20	Custom 4!	0.32	Custom 4!	0.34	321SS	0.48	0.12	0.05	0.02	0.01	12.79	

Figure 5.22: Example of a "Results" file opened in Excel

5.11 Checking Calibrations

In the document envelope provided with the analyzer, there are the following items:

- A stainless steel duplex 2205 check sample (used to verify non-vacuum alloy calibration).
- An aluminum 5083 or 7075 check sample (used to verify the vacuum/aluminum calibration).
- A calibration sheet for stainless steel duplex 2205.
- A calibration sheet for aluminum 5083 or 7075.
- A CD-ROM with a copy of the calibration files.

All S1 TRACER XRF analyzers are calibrated with NIST traceable alloy standards unless the client's application is not intended for alloys.

To verify the calibration of the analyzer, set the analyzer up to operate and run five 30-second tests. Average the chemistry results. The results for each element should be within the tolerance range specified on the corresponding calibration sheet.

6. Utilities Menu

From the Main Mode Selection screen illustrated in Figure 6.1, the user may select the “Utilities” menu to access and change settings associated with the operation of the analyzer. From the Utilities screen, the following actions are possible:

- Review previously collected test results (readings).
- View a table of line energies for each element.
- View the standard library entries, and create and edit custom User Libraries.
- View and manage communications port settings used by the Bruker S1 program.
- Manage user passwords.

The Utilities screen is illustrated in Figure 6.2.

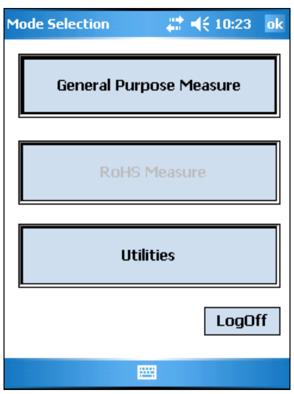


Figure 6.1: Main Mode Selection screen

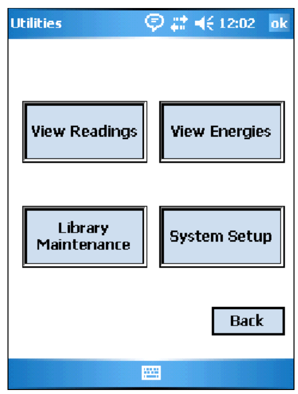


Figure 6.2 Utilities screen

6.1 View Readings

The **View Readings** screen, illustrated in Figure 6.3, enables the user to view all results taken from testing. Result files may be selected or sorted by checking the boxes on the left side of the screen corresponding to various test types. The result files are sorted by the selected test type first, and then by the test number.

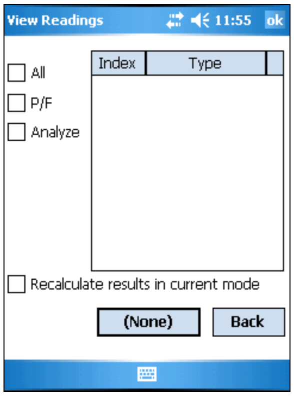


Figure 6.3: View Readings screen

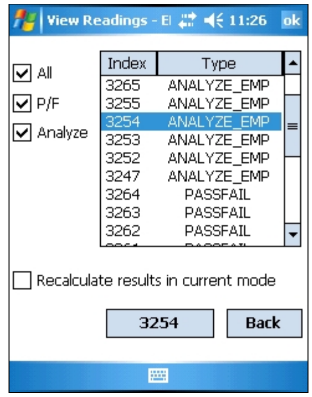


Figure 6.4: View Readings screen with list

Highlight a result file and then tap on the button containing the corresponding number; this will display the results screen as seen in Figures 5.12-5.14 or 5.16, depending on the mode in which the test data was taken. The spectrum and the edited information can also be viewed from this screen.

The check box labeled "Recalculate results in the current mode" enables the user to recalculate GradeID or Pass/Fail determination based upon the current library or mode selected, respectively. The chemistry and spectral data is reread and redisplayed in the current mode. The new results are displayed by tapping on each individual test. This option could be useful if several libraries are being compared, or if a Pass/Fail test was made when an Analyze test was desired or vice versa.

NOTE: Use caution when selecting the "Recalculate results…" feature as this permanently alters the calculated chemistry and/or pass-fail results for that test.

6.2 View Energies

The View Energies screen enables the user to view spectral line energies and intensities for all the elements. The other elemental information that is displayed includes the following:

- Atomic number
- Element symbol
- Element name
- Atomic weight

- Spectral line energies and intensities for each element (typically denoted by designations such as Kα1, Kα2, Kβ1, Kβ2, Kβ3, Lα1, Lα2, Lβ1, Lβ2, Lβ3, Lβ4, Lγ1, Lγ2, Lγ3, and Ll)

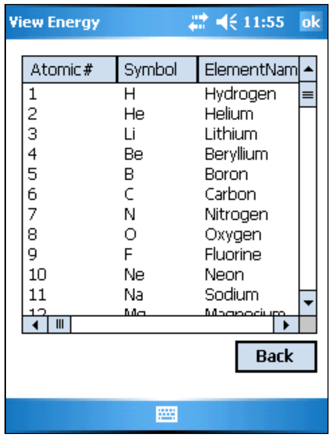


Figure 6.5: View Readings screen

Tap the "Back" button on the bottom of the screen to return to the **Utilities** menu. Spectral energy information can also be viewed in Appendix B.

Comment [s1]: Has it been verified that the numbers in the PDA match the numbers in Appendix B? I know that different charts can contain slightly different results and it would be nice if ours were consistent.

6.3 Library Maintenance

Selecting the Library Maintenance button opens a second Libraries screen illustrated in Figure 6.6.

NOTES:

- In the context of the Tracer S1, a ***library*** is a file within the PDA software which defines the names of the alloys to be identified during testing along with the allowable range of concentration for each element within a particular alloy.
- **Library Maintenance** functions will generally not be accessed during normal operation of the Tracer S1 unless a custom User Library is being created or used.
- The ***Standard Library*** contains a list of all alloys (also referred to as "Grade IDs") which will be identified by the S1 Tracer and the ranges of chemical concentrations for each element associated with a particular alloy.
- ***User Libraries*** are custom user-created libraries which enable:
  - Definition of alloys other than those contained in the Standard Library;

- Definition of custom naming conventions which may be useful in some applications.

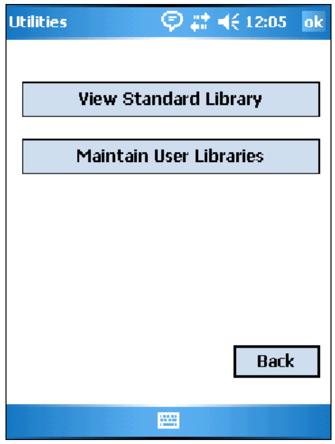


Figure 6.6: Libraries Screen

6.3.1 View Standard Library

The View Standard Library button opens the View Library screen as shown in Figure 6.7. From this screen, the user may view the library of all the standard alloys identified by the S1 TRACER and the allowable range of their composition by weight percent. The following data for each alloy is available:

- The alloy name
- The UNS (Unified Numbering System for Metals and Alloys) designation.
- The allowable range of concentrations of elements for each alloy as identified by the S1 TRACER. All detectable elements are listed with the corresponding allowable range of concentrations in weight percent is listed. These ranges of concentration are used by the analyzer in identifying the alloy

Tap the “Back” button on the bottom of the screen to return to the **Utilities** menu. The chemistry library of the S1 TRACER can also be viewed in Appendix B.

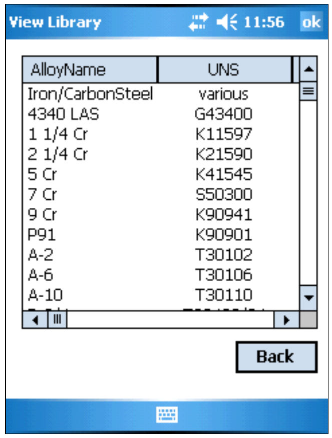


Figure 6.7: View Library screen

6.3.2 Maintain User Libraries

The **Maintain User Libraries** button (see Figure 6.6) opens the **User Library Maintenance** screen shown in Figure 6.8.

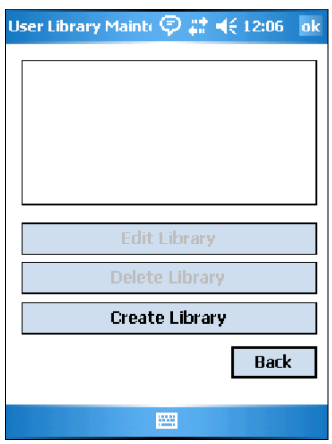


Figure 6.8: User Library Maintenance screen

From the User Library Maintenance screen, the user may create and manage user libraries to define special alloys and/or custom alloy names.

Figure 6.8 illustrates a User Library Maintenance screen before any user libraries have been defined or saved. After a User Library has been created and saved, the User Library Maintenance screen will appear similar to the illustration of Figure 6.9.

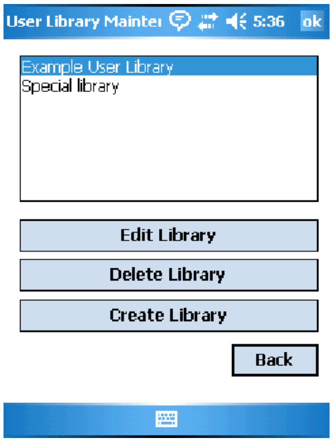


Figure 6.9: User Library Maintenance screen after user libraries have been added

6.3.3 Edit Library

To edit one of the existing User Libraries, select the name of the library to be edited, and then select the **Edit Library** button. A User Grade Entry screen (similar to that illustrated in Figure 6.11) will open.

To delete a user library, select the name of the library name to be deleted, and then select the **Delete Library** button. The system will open a dialog box on the PDA screen asking if the user is sure they want to delete the selected library. If the user selects **Yes** from the dialog box, the selected library will be deleted.

To create a new user library, select the **Create Library** button to open the New User Library naming screen illustrated in Figure 6.10. Enter the new User Library name using the keypad, then select the **OK** button to create the new library name. When the new library name has been created, User Grade Entry screen shown in Figure 6.11 will open.

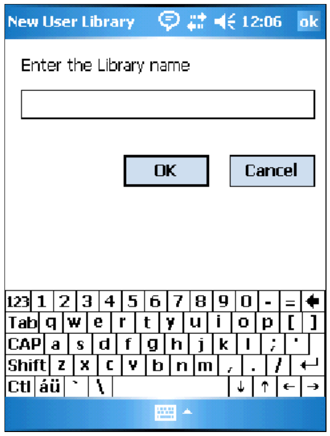


Figure 6.10: New User Library screen

6.3.4 Material Records

To add new material records or edit existing material records, the User Grade Entry screen (Figure 6.11) is used.

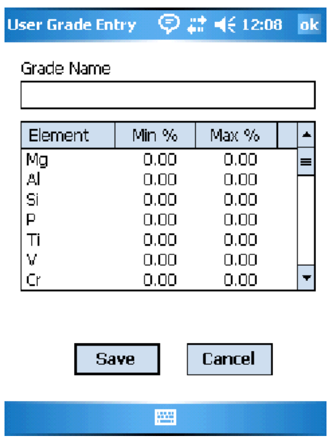


Figure 6.11: The User Grade Entry screen

When adding a new material record, begin by selecting the “Grade Name” field. The keyboard pop-up dialog box will appear. Enter the desired ID name for the new material.

To Enter or edit elemental concentration range values, select the appropriate element and percentage (minimum or maximum) by tapping on that value. Then use the keyboard to enter the new or edited value. Continue until all desired concentrations are entered, then close the keyboard pop-up and select the **Save** button.

NOTE: Determining or selecting the minimum and maximum concentration values for each user-defined material is beyond the scope of this document. Be particularly cautious when selecting a range of values for a particular element which overlap the range of values for that element in another material. When value ranges overlap, ambiguous Grade Identification may result.

Figure 6.12 illustrates a typical example of a concentration value being entered for a user library grade entry. Editing values for an existing grade uses the same screen and procedure as for a new grade entry.

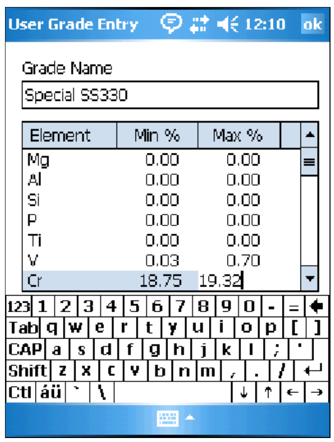


Figure 6.12: Entering values for a grade to be added into a User Library (or editing an existing User Library grade record)

6.4 System Setup

The **System Setup** screen, illustrated in Figure 6.13, enables the user to select various setting for use during subsequent testing. In summary, the user may select which data files to record, where the data files will be recorded, which COM port to use for communication with the S1 TRACER analyzer, and the threshold for Match Quality used in Pass/Fail testing. The user password may also be changed beginning from the "System Setup" screen.

To change the COM port, tap on the down arrow in the dialogue box. Scroll up and down the list until the desired COM port is found. In most cases, the default value, COM1, is applicable.

The user may choose which test data files to save. Check the boxes next to "Results" and "Spectra" to choose to save those files. Check the box next to "Save CSV" to save the results as a CSV file. When saving files, the default location is in a "Data" folder in the PDA memory structure. To save to a Compact Flash or SD memory card, check the box next to "Removable Media". Ensure that a memory card is installed in the PDA when selecting this storage method.

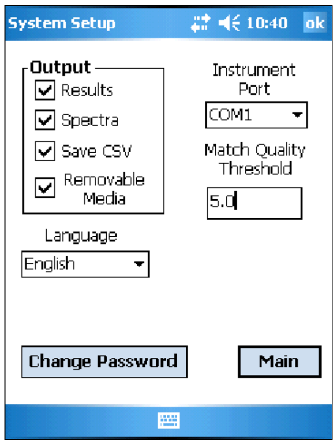


Figure 6.13: System Setup menu

To change the threshold for Match Quality used in Pass/Fail calculations, enter the new value in the Match Quality Threshold box. For most Pass/Fail measurements, the default value is applicable. It is recommended to NOT change the Match Quality Threshold when using the Standard Library. Generally, the Match Quality Threshold should be changed only if testing in Pass/Fail mode and using a User Library to define the materials that are being tested.

To change the user password, tap "Change Password" in the System Setup menu screen to display the Password Management dialogue box illustrated in Figure 6.14. Enter the current password, then the selected new password, then re-enter the new password. Select "OK" to activate the new password.

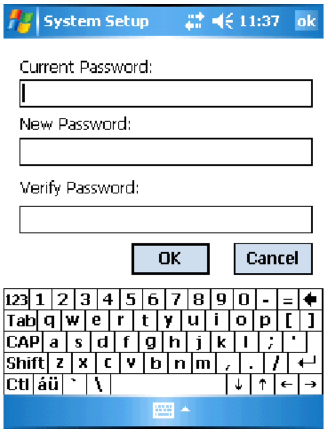


Figure 6.14 Password Management screen

When the new password has been successfully changed, a confirmation will appear as illustrated in Figure 6.15.

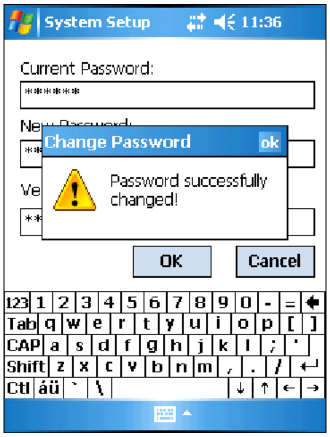


Figure 6.15: Password successfully changed banner

If the current password was entered incorrectly, the software will display a warning as illustrated in Figure 6.16.

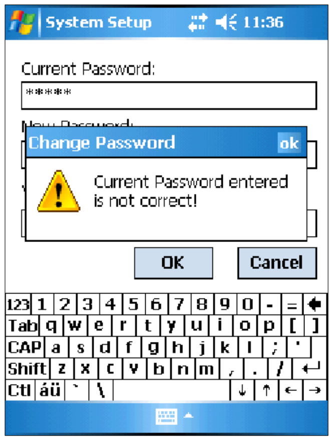


Figure 6.16 Current password entered incorrectly banner

NOTE: The password scheme in the BrukerS1 software is case-sensitive. Be sure you record your selected password in a safe place away from the analyzer, as Bruker AXS Handheld cannot recover a lost user password.

7. Troubleshooting

7.1 Measurement will not start

- Ensure that the IR sensor and the analyzer window are covered by the test material.

If the PDA program was started before the analyzer was turned on and initialized, the program may not respond when the trigger is pulled. Be sure to wait at least 60 seconds after the power key is turned on before starting the BrukerS1 Program. Should this condition occur, perform a "soft reset" on the PDA by performing the following steps:

- Exit the BrukerS1 program and turn off the PDA and the analyzer (section 5.9).
- Remove the PDA from the instrument or disconnect the null modem cable.
- Use the stylus to press the *reset* button recessed into the bottom left side of the PDA.
- Remount the PDA on the analyzer or reconnect the null modem cable.
- Make sure the analyzer power is on for at least one (1) minute before starting the BrukerS1 program.
- If a measurement still cannot be started, check that the BrukerS1 software is configured properly for communication with the S1 TRACER analyzer. See section 6.4 and figure 6.13. Ensure that the Instrument Port is set to "Comm 1."

To prevent this error, it is important to remember to exit the BrukerS1 program before turning off the analyzer.

7.2 Can't find the BrukerS1 program on the "Start" menu

Step 1

- Access the Start Menu on the PDA and tap on "Settings".
- Tap on "Menus" and ensure that the BrukerS1 program is checked. The BrukerS1 icon will now appear in the Start Menu. If the BrukerS1 program is not displayed in the "Menus" menu, proceed to Step 2.

Step 2

- Connect the Sync Cradle to your computer.
- Insert the PDA into the cradle.
- Ensure that ActiveSync is installed (see section 5.10.3).

- Access the PDA's files by clicking on "Explore" on the ActiveSync screen.
- Click on "Mobile Device" and then "My Windows Mobile-Based Device".
- On the top menu bar, access the "Tools" menu and then click "Folder Options". Click on the "View" tab, scroll down and ensure that "Show hidden files and folders" is selected.
- Locate the BrukerS1 program, right click on the icon, and select "Create Shortcut".
- Find the shortcut you just created (it should be labeled "Shortcut to BrukerS1"); right click on the icon and select "Cut".
- Click on the "Windows" folder and then on the "Start Menu" folder. Click on the "Programs" folder.
- Right click on an open area in the window and select "Paste".
- Remove the PDA from the cradle and access the Start menu on the PDA. If the BrukerS1 program did not appear, repeat Step 1.

7.3 The BrukerS1 program on the PDA will not start or "locks up"

Step 1

If other programs are running, the BrukerS1 program may "lock up" and fail to respond to commands. Closing other programs will free system memory and allow the BrukerS1 program to run more smoothly.

- Open the "Start" menu and tap on "Settings".
- Choose the "System" tab.
- Tap on the "Memory" icon and select "Running Programs" and close all running programs except "Menu".

If this procedure does not restore proper function of the BrukerS1 program, perform a "soft reset" of the PDA as described in section 7.1.

If a "soft reset" does not restore proper operation, the BrukerS1 program may need to be reinstalled.

Step 2

To reinstall the BrukerS1 software:

- Remove the PDA from the S1 TRACER (or if connected via the null modem cable, disconnect the cable from the PDA).

- Ensure that the flashcard is **NOT** inserted into the PDA.

NOTE: If a hard reset is performed on the PDA with a flashcard inserted, all files on the flashcard will be erased.

- Perform a hard reset on the PDA:
  - The following keys must be pressed and held while resetting the PDA by pushing the PDA Stylus into the reset hole located on the end of the PDA next to the PDA connector.
    - The “Mail” Key (showing the Envelope icon);
    - The Calendar Key (showing the Calendar icon); and
    - The Power Key
  - After the hard reset the PDA will display the screen alignment procedure. Perform the screen alignment as prompted. Continue the PDA setup as prompted until asked for a password. Press Skip. When the PDA displays the startup screen, turn the PDA power off.
- Insert the Restore Flashcard into the PDA
- If the PDA does not automatically power up, turn on the power. The Bruker.exe and supporting programs will automatically load.
- Remove the Restore Flashcard and keep it in a safe place.
- The PDA should be turned off and then may be reconnected to the S1 TRACER. The analyzer is now ready to operate.

7.4 The PDA is displaying an incorrect date and/or time

- To adjust the date and/or time displayed by the PDA, start from the main screen (illustrated in figure 5.1)
- Tap the Date/Time field once to open the Date/Time setting screen.
- In the Date/Time setting screen, use of the *Home* settings is recommended for S1 Tracer applications.
- Set the correct date and time by tapping on the up- and down-arrow icons with the stylus.
- When the correct date and time have been entered, close the Date/Time setting screen by tapping the *OK* icon in the upper right of the screen.

- If tests were performed while the date and/or time were set incorrectly, those test records in the *results.csv* file will be incorrectly time-stamped.

7.5 The vacuum pump will not reach 10 Torr or less

- Ensure that the fittings on the tubing are fully inserted on the vacuum pump and S1 TRACER and that the vacuum release port is in the closed position. See section 4.2.2 for instructions on proper installation of the vacuum pump.

  IMPORTANT: FAILURE TO OPEN THE VACUUM RELEASE VALVE PRIOR TO REMOVING THE VACUUM TUBING FROM THE VACUUM PUMP OR THE ANALYZER WILL DAMAGE THE HIGHLY SENSITIVE SI-PIN DETECTOR.

- If there continues to be a problem with the vacuum pressure level, ensure that the analyzer window is completely sealed and not punctured. See section 4.2.3 for instructions on replacing the vacuum window.

7.6 The yellow lamp on the control panel is blinking

The yellow light on the control panel may blink due to several errors including the following:

- Low Battery indicator
- Temperature warning

First, turn off the analyzer with the key switch and exchange the battery for a freshly charged one (see section 4.1.1).

- If the yellow light is still blinking after installing a freshly charged battery, there may be a high temperature error. Turn off the PDA and analyzer power (section 5.9). Allow the unit to cool to operating temperatures (-10ºC to +50ºC). Turn the analyzer on again and verify that the error has been reset (yellow light is no longer blinking). If the yellow light continues to blink, contact a Bruker AXS Handheld representative.

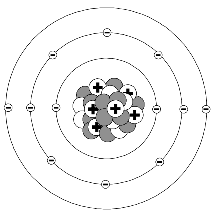
7.7 The red lamp on the control panel looks uneven

If the red light on the control panel looks uneven, it means that one of the two red LEDs inside the indicator is not functioning. As a safety measure, if one or both of the red LEDs is not functioning, X-rays will not be generated when the trigger is pulled and no results will be displayed. DO NOT attempt to look into the nose of the analyzer to see if X-rays are being generated. Contact a Bruker AXS Handheld representative for more information.

APPENDIX A: BASIC RADIATION SAFETY INFORMATION

A.1 What is Radiation?

- The term radiation is used with all forms of energy - light, X-rays, radar, microwaves, and more. For the purpose of this manual, however, radiation refers to invisible waves or particles of energy from radioactive sources or X-ray tubes.



- **High levels of radiation may pose a danger to living tissue because it has the potential to damage and/or alter the chemical structure of cells. This could result in various levels of illness (i.e. mild to severe).**

- This section of the manual provides a basic understanding of radiation characteristics. This should help in preventing unnecessary radiation exposure to S1 TRACER users and persons nearby. The concepts have been simplified to give a basic picture of what radiation is and how it applies to operators of the Bruker XRF Analyzer.

- Section 2.2, “Specific Bruker S1 TRACER User Requirements” characterizes the S1 Tracer safety features and controls and provides specific radiation profiles for the user’s S1 TRACER analyzer.

A.2 The Composition of Matter

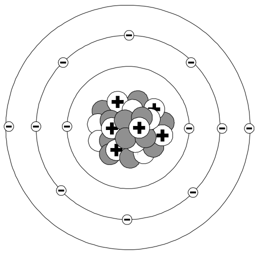


Figure A-1: An Atom

- To help understand radiation, we'll start by briefly discussing the composition of matter.
- The physical world is composed of key materials called ***elements***. The basic unit of every element is the ***atom***. Although microscopic, each atom has all the chemical characteristics of its element.

All substances or materials are made from atoms of different elements combined together in specific patterns. That is why atoms are called the basic building blocks of matter.

Example: Oxygen and hydrogen are two very common elements. If we combine one atom of oxygen and two atoms of hydrogen, the result is a molecule of H_2O, or water.

A.2.1 Parts of the Atom

Just as all things are composed of atoms, atoms are made up of three basic particles called ***protons***, ***neutrons***, and ***electrons***. Together, these particles determine the properties, electrical charge, and stability of an atom.

Protons

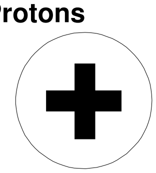


Figure A-2: A Proton

- Are found in the nucleus of the atom.
- Have a positive electrical charge.
- Determine the atomic number of the element, therefore, if the number of protons in the nucleus changes, the element changes.

Neutrons

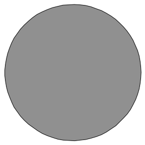


Figure A-3: A Neutron

- Are found in the nucleus of the atom.
- Have no electrical charge.
- Help determine the stability of the nucleus.
- Are in the nucleus of every atom except Hydrogen (H-1).
- Atoms of the same element have the same number of protons, but can have a different number of neutrons.

Electrons

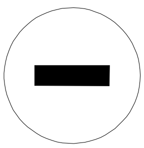


Figure A-4: An Electron

- Are found orbiting around the nucleus at set energy levels or shells (K and L shells are important in X-ray fluorescence).
- Have a negative electrical charge.
- Determine chemical properties of an atom.
- Have very little mass.

A.2.2 Structure of the Atom

The design or atomic structure of the atom has two main parts: The ***nucleus*** and the ***electron shells*** that surround the nucleus.

Nucleus

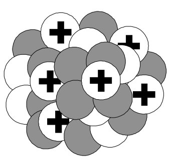
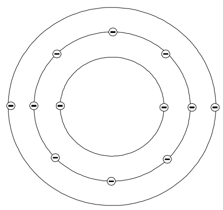


Figure A-5: The Nucleus

- Is the center of an atom.
- Is composed of protons and neutrons.
- Produces a positive electrical field.
- Makes up nearly the entire mass of the atom.

Electron Shells



- Circle the nucleus of an atom in a prescribed orbit.
- Have a specific number of electrons.
- Produce a negative electrical field.
- Are the principle controls in chemical reactions.

Figure 6: Electron Shells

The protons and neutrons that form the nucleus are bound tightly together by powerful nuclear forces. Electrons (-) are held in orbit by their electromagnetic attraction to the protons (+). When these ratios become unbalanced, the electrical charge and stability of the atom are affected.

A.3 Electrical Charge of the Atom

The ratio of protons and electrons determine whether the atom has a positive, negative, or neutral electrical charge. The term ion is used to define atoms or groups of atoms that have a positive or negative electrical charge.

- **Positive Charge (+)**—If an atom has **more protons** than electrons, the charge is positive.
- **Negative Charge (-)**—If an atom has **more electrons** than protons, the charge is negative.
- **Neutral (No Charge)**—If an atom has an **equal number** of protons and electrons, it is neutral, or has no net electrical charge.

An atom's charge is important because it determines whether the atom is capable of chemical reactions. The process of removing electrons from a neutral atom is called ***ionization***.

Atoms that develop a positive or negative charge (gain or lose electrons) are called ***ions***. When an electrically neutral atom loses an electron, that electron and the now positively charged atom are called an ***ion pair***.

A.4 The Stability of the Atom

The concept of stability of an atom is related to the structure and the behavior of the nucleus:

- Every stable atom has a nucleus with a specific combination of neutrons and protons.
- Any other combination results in a nucleus that has too much energy to remain stable.
- Unstable atoms try to become stable by releasing excess energy in the form of particles or waves (radiation).

The process of unstable atoms releasing excess energy is called ***radioactivity***.

A.5 Radiation Terminology

Before examining the subject of radiation in more detail, there are several important terms to be reviewed and understood.

Bremsstrahlung: The X-rays or "braking" radiation produced by the deceleration of electrons, namely in an X-ray tube.

Characteristic X-rays: X-rays emitted from electrons during electron shell transfers.

Fail-Safe Design: One in which all failures of indicator or safety components that can reasonably be anticipated cause the equipment to fail in a mode such that personnel are safe from exposure to radiation. For example, if the red lamp indicating "X-RAY ON" fails, the production of X-rays shall be prevented.

Ion: An atom that has lost or gained an electron.

Ion Pair: A free electron and positively charged atom.

Ionization: The process of removing electrons from the shells of neutral atoms.

Ionizing Radiation: Radiation that has enough energy to remove electrons from neutral atoms.

Isotope: Atoms of the same element that have a different number of neutrons in the nucleus.

Non-ionizing Radiation: Radiation that does not have enough energy to remove electrons from neutral atoms.

Normal Operation: Operation under conditions suitable for collecting data as recommended by manufacturer, including shielding and barriers.

Primary Beam: Ionizing radiation from an X-ray tube that is directed through an aperture in the radiation source housing for use in conducting X-ray fluorescence measurements.

Radiation: The energy in transit in form of electromagnetic waves or particles.

Radiation Generating Machine: A device that generates X-rays by accelerating electrons, which strike an anode.

Radiation Source: An X-ray tube or radioactive isotope.

Radiation Source Housing: That portion of an X-ray fluorescence (XRF) system, which contains the X-ray tube or radioactive isotope.

Radioactive Material: Any material or substance that has unstable atoms, which are emitting radiation.

System Barrier: That portion of an area, which clearly defines the transition from a controlled area to a radiation area and provides the necessary shielding to limit the dose rate in the controlled area during normal operation.

X-ray Generator: That portion of an X-ray system that provides the accelerating voltage and current for the X-ray tube.

X-ray System: Apparatus for generating and using ionizing radiation, including all X-ray accessory apparatus, such as accelerating voltage and current for the X-ray tube and any needed shielding.

A.6 Types of Radiation

As stated earlier, radiation consists of invisible waves or particles of energy that can have a health effect on humans if received in too large a quantity. There are two distinct types of radiation: ***non-ionizing*** and ***ionizing***.

Non-ionizing Radiation

Non-ionizing radiation does not have the energy needed to ionize an atom (i.e. to remove electrons from neutral atoms).

Sources of non-ionizing radiation include light, microwaves, power lines, and radar. Although this type of radiation can cause biological damage, like sunburn, it is generally considered less hazardous than ionizing radiation.

Ionizing Radiation

Ionizing radiation does have enough energy to remove electrons from neutral atoms. **Ionizing radiation is of concern due to its potential to alter the chemical structure of living cells.** These changes can alter or impair the normal functions of a cell. Sufficient amounts of ionizing radiation can cause hair loss, blood changes, and varying degrees of illness. These levels are approximately 1,000 times higher than levels that the public or workers are permitted to receive.

There are four basic types of ionizing radiation as shown below: These are emitted from different parts of an atom (Figure A-7).

- Alpha Particles
- Beta Particles
- Gamma rays or X-rays
- Neutron Particles

Note: S1 TRACER XRF devices only emit X-rays

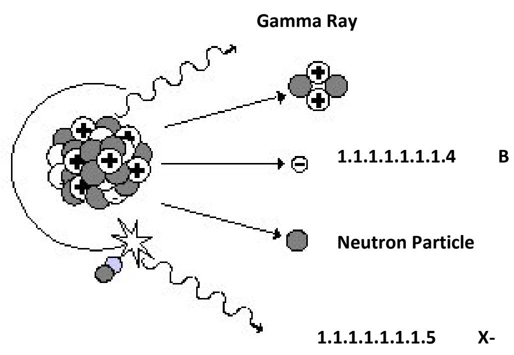


Figure A-7: Types of Ionizing Radiation

The penetrating power for each of the four basic radiations varies significantly (see Figure A-8).

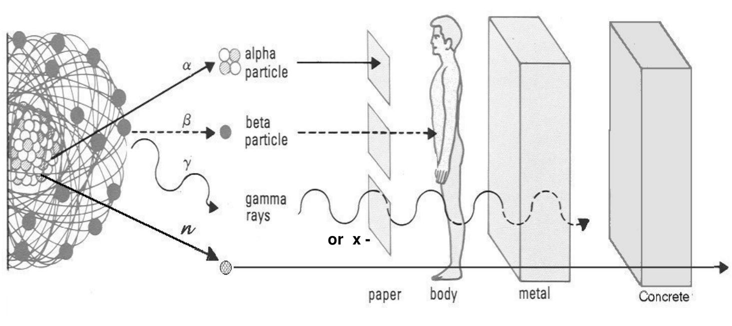


Figure A-8: The Penetrating Power of Various Types of Radiation

Alpha particles

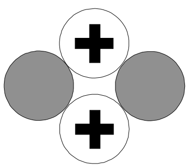


Figure 9:
Alpha Particle

- Have a large mass, consisting of two protons and two neutrons.
- Have a positive charge and are emitted from the nucleus.
- Ionize by stripping away electrons (-) from other atoms with its positive (+) charge.

Range: Due to the large mass and charge, alpha particles will only travel about one to two inches in air. This also limits its penetrating ability.

Shielding: Most alpha particles will be stopped by a piece of paper, several centimeters of air, or the outer layer (i.e. dead layer) of the skin.

Hazard: Due to limited range and penetration ability, alpha particles are not considered an external radiation hazard. However, if inhaled or ingested, alpha radiation is a potent internal hazard as it can deposit large amounts of concentrated energy in small volumes of body tissue.

Beta Particles

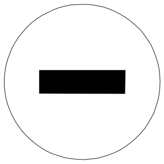


Figure 10: A Beta Particle

- Have a small mass and a negative charge (-), similar to an electron.
- Are emitted from the nucleus of an atom.
- Ionize other atoms by stripping electrons out of their orbits with their negative charge.

Range: Small mass and negative charge give the beta particle a range of about 10 feet in air. The negative charge limits penetrating ability.

Shielding: Most beta particles can be stopped by a few millimeters of plastic, glass, or metal foil, depending on the density of the material.

Hazard: Although beta particles have a fairly short range, they are still considered an external radiation hazard, particularly to the skin and eyes. If ingested or inhaled, beta radiation may pose a hazard to internal tissues.

Gamma Rays and X-rays

Gamma rays and X-rays are electromagnetic waves or photons of pure energy that have no mass or electrical charge. Gamma rays and X-rays:

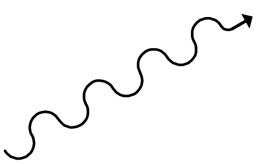


Figure 11:
A Gamma or X-ray

- Are identical except that gamma rays come from the nucleus, while X-rays come from the electron shells or from an X-ray generating machine
- Ionize atoms by interacting with electrons.

Range: Because gamma and X-rays have no charge or mass, they are highly penetrating and can travel quite far. Range in air can be easily several hundred feet.

Shielding: Gamma and X-rays are best shielded by use of dense materials, such as concrete, lead, or steel.

Hazard: Due to their range and penetrating ability, gamma and X-ray radiation are considered primarily an external hazard.

Neutron Particles

Neutron radiation consists of neutrons that are ejected from the nucleus of an atom. Neutron particles:

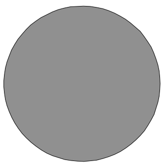


Figure 12: A Neutron

- Are produced during the normal operation of a nuclear reactor or particle accelerator, as well as the natural decay process of some radioactive elements.
- Can split atoms by colliding with their nuclei, forming two or more unstable atoms. This is called fission. These atoms then may cause ionization as they try to become stable.
- Neutrons can also be absorbed by some atoms (capture) without causing fission resulting in creation of a sometimes radioactive atom dependent on the absorber. This is called fusion.

Range: Since neutrons have no electrical charge, they have a high penetrating ability and require thick shielding material to stop. Range in air can be several hundred feet.

Shielding: The best materials to shield against neutron radiation are those with high hydrogen content (water, concrete or plastic).

Hazard: Neutron radiation is considered primarily an external hazard due to its range and penetrating ability.

A.7 Units for Measuring Radiation

The absorption of radiation into the body, or anything else, depends upon two things: the type of radiation involved and the amount of radiation energy received. The units for measuring radiation internationally are the ***Gray*** and ***Sievert*** and in the USA are the ***rad*** and ***rem***.

A.7.1 Rad (Radiation Absorbed Dose)

A rad is:

- A unit for measuring the amount of radiation energy absorbed by a material (i.e. dose).
    - Defined for any material (e.g. 100 ergs/gm).

- Applied to all types of radiation.
- Not related to biological effects of radiation in the body.
- 1 rad = 1000 millirad (mrad)
- The Gray (Gy) is the System International (SI) unit for absorbed energy.
- 1 rad = 0.01 Gray (Gy) and 1 Gray = 100 rad.

A.7.2 Rem

Actual biological damage depends upon the concentration as well as the amount of radiation energy deposited in the body. The rem is used to quantify overall doses of radiation, their ability to cause damage, and their dose equivalence (see below).

A rem is:

- Is a unit for measuring dose equivalence.
- Is the most commonly used unit of radiation exposure measure.
- Pertains directly to humans.
- Takes into account the energy absorbed (dose); the quality of radiation; the biological effect of different types of radiation in the body and any other factor. For gamma and X-ray radiation all of these factors are unity so that for these purposes a rad and a rem are equal.
- Sievert is the SI unit for dose equivalence.
- 1 rem = 1000 millirem (**mrem**)
- 1 rem = 0.01 Sievert (**Sv**) and 1Sv = 100 rem

A.7.3 Dose and Dose Rate

Dose is the amount of radiation you receive during any exposure.

Dose Rate is the rate at which you receive the dose.

Example: 1) Dose rate = dose/time = mrem/hr
2) Dose = dose rate x time = mrem

A.8 Sources of Radiation

We live in an environment which is and has always been subject to radiation. As human beings, we have evolved in the presence of ionizing radiation from natural background radiation.

No one can completely avoid exposure to radiation, whether working with radioactive materials or not. We are continually exposed to sources of radiation from our environment, both natural and man-made.

The average person in the U.S. receives about 3.6 mSv or 360 mrem of radiation per year. The average annual radiation dose in the state of Colorado is 4.5 – 5.0 mSv (450 – 500 mrem) per year.

A.8.1 Natural Sources

Most of our radiation exposure comes from natural sources (about 3.0 mSv or 300 mrem per year). In fact, most of the world's population will be exposed to more ionizing radiation from natural sources than they will ever receive on the job.

There are several sources of natural background radiation. The radiation from these sources is exactly the same as that from man-made sources.

The four major sources of natural radiation include:

- Cosmic Radiation
- Terrestrial Radiation (sources in the earth's crust)
- Sources (sources in the human body such as K-40 from, e.g., eating bananas) also referred to as internal sources.
- Radon, Uranium and Thorium.

Cosmic Radiation

- Comes from the sun and outer space.
- Is composed of positively charged particles and gamma radiation.
- Increases in intensity at higher altitudes because there is less atmospheric shielding.

> **Example:** The population of Denver, Colorado, receives twice the radiation exposure from cosmic rays as people living at sea level

The average dose received by the general public from cosmic radiation is approximately 280 µSv (28 mrem) per year.

Terrestrial Radiation

There are natural sources of radiation in the soil, rocks, building materials, and drinking water. Some of the contributors to these sources include naturally radioactive elements such as Radium, Uuranium, and Thorium. Many areas have elevated levels of terrestrial radiation due to increased concentrations of Uranium or Thorium in the soil. The average dose received by the general public from terrestrial radiation is about 280 µSv (28 mrem) per year.

Internal Sources

The food we eat and the water we drink all contain some trace amount of natural radioactive materials. These naturally occurring radioactive isotopes include Na-24, C-14, Ar-41 and K-40. Most of our internal exposure comes from K-40

There are four ways to receive internal exposure:

- Breathing
- Swallowing (ingestion)
- Absorption through the skin
- Wounds (breaks in the skin)

The average dose received by the general public from internal sources is about 400 µSv (40 mrem) per year.

Examples of Internal Exposure:

1) Inhalation of radon or dust from other radioactive materials
2) Potassium-40 in bananas
3) Water containing traces of uranium, radium, or thorium
4) Handling of a specified radioactive material without protective gear or with an unhealed cut

Radon

Radon comes from the radioactive decay of radium, which is naturally present in soil. Radon and its decay products are present in the air, and when inhaled can cause a dose to the lung.

- Is a gas, which can travel through soil and collect in basements or other areas of the home.
- Emits alpha radiation. Because alpha radiation cannot penetrate the **outer** layer of skin on a human body, it presents a hazard only if ingested into the body.
- Is the largest contributor of natural occurring radiation.

A.8.2 Man-made Sources

In addition to natural background radiation, some exposure comes from man-made sources that are part of our everyday lives. These sources account for the remaining approximately 65 mrem (650 µSv) per year of the average annual radiation dose.

The four major sources of man-made radiation exposures are:

- Medical radiation (approximately 53 mrem, or 530 µSv per year)
- Atmospheric testing of nuclear weapons (less than 1 mrem, or 10 µSv, per year)
- Consumer products (approximately 10 mrem, or 100 µSv, per year)
- Industrial uses (less than 3 mrem, or 30 µSv, per year)

Medical Radiation

Medical radiation involves exposure from medical procedures such as X-rays (chest, dental, etc.), CAT scans, and radiotherapy. The typical dose received from a single chest X-ray is about 10 mrem, or 100 µSv, per exposure.

Radioactive sources used in medicine for diagnosis and therapy result in an annual average dose to the general population of 14 mrem, or 140 µSv.

The average dose received by the general public from all medical procedures is about 53 mrem, or 530 µSv, per year.

Atmospheric Testing of Nuclear Weapons

Testing of nuclear weapons during the 1950s and early 1960s resulted in fallout of radioactive materials. This practice is now banned by most nations.

The average dose received by the general public from residual fallout is approximately 1 mrem, or 10 µSv, per year.

Consumer Products

These include such products as:

- Televisions
- Building materials
- Combustible fuels
- Smoke detectors
- Camera lenses
- Welding rods

The total average dose received by the general public from all these products is about 10 mrem, or 100 µSv, per year.

Industrial uses

Industrial uses include X-ray generating machines used to test all sorts of welds, material integrity, bore holes, and to perform microscopic analyses of materials.

The average dose received by the general public from industrial uses is less than 1 mrem, or 10 µSv, per year.

Table A-1: Example of Annual Radiation Doses from Selected Sources*

Exposure	µSv	mrem
Cigarette Smoking	13000	1300
Radon in homes	2000	200
Medical exposures	530	53
Terrestrial radiation	300	30
Cosmic radiation	300	30
Round trip US by air	50	5
Building materials	36	3.6
World wide fallout	<10	<1
Natural gas range	2	0.2
Smoke detectors	0.001	0.0001

Table A-2: Average Annual Occupational Doses*

Occupation	mSv	mrem
Airline flight crewmember	10	1000
Nuclear power plant worker	7	700
Grand central station worker	1.2	120
Medical personnel	0.7	70
DOE/DOE contractors	0.44	44

* Based on U.S. data only

Significant Doses

As stated previously, the general public is exposed daily to small amounts of radiation. However, there are four major groups of people that have been exposed in the past to significant levels of radiation. Because of this we know much about ionizing radiation and its biological effects on the body.

These four major groups of people who have been exposed to significant levels of radiation are:

- The earliest radiation workers, such as radiologists, who received large doses of radiation before biological effects were recognized. Since then, safety standards have been developed to protect such employees.
- The more than 100,000 people who survived the atomic bombs dropped on Hiroshima and Nagasaki.
- Those involved in radiation accidents, like Chernobyl.

- People who have received radiation therapy for cancer. This is the largest group of people to receive significant doses of radiation.

A.9 Biological Effects of Radiation

A.9.1 Cell Sensitivity

The human body is composed of billions of living cells. Groups of these cells make up tissues, which in turn make up the body's organs. Some cells are more resistant to viruses, poisons, and physical damage than others. The most sensitive cells are those that are rapidly dividing, that is why exposure to a fetus is so carefully controlled. Radiation damage may depend on both resistance and level of activity during exposure.

A.9.2 Acute and Chronic Doses of Radiation

All radiation, if received in sufficient quantities, can damage living tissue. The key lies in how much and how quickly a radiation dose is received. Doses of radiation fall into one of two categories: ***acute*** or ***chronic***.

Acute Dose

An acute dose is a large dose of radiation received in a short period of time that results in physical reactions due to massive cell damage (acute effects). The body can't replace or repair cells fast enough to undo the damage right away, so the individual may remain ill for a long period of time. Acute doses of radiation can result in reduced blood count and hair loss.

Recorded whole body doses of 100 - 250 mSv (10 - 25 rem) have resulted only in slight blood changes with no other apparent effects.

Radiation Sickness

Radiation sickness occurs at acute doses greater than 1 Sv (100 rem.) Radiation therapy patients often experience it as a side effect of high-level exposures to singular areas. Radiation sickness may cause nausea (from cell damage to the intestinal lining), and additional symptoms such as fatigue, vomiting, increased temperature, and reduced white blood cell count.

Acute Dose to the Whole Body

Recovery from an acute dose to the whole body may require a number of months. Whole body doses of 5 Sv (500 rem) or more may result in damage too great for the body to recover.

Example: 30 firefighters at the Chernobyl facility lost their lives as a result of severe burns and acute radiation doses exceeding 8 Sv (800 rem.)

Only extreme cases (as mentioned above) result in doses so high that recovery is unlikely.

Acute Dose to Part of the Body

Acute dose to a part of the body most commonly occur in industry (use of X-ray machines), and often involve exposure of extremities (hand, fingers, etc.). Sufficient radiation doses may result in loss of the exposed body part. The prevention of acute doses to part of the body is one of the most important reasons for proper training of personnel.

Chronic Dose

A chronic dose is a small amount of radiation received continually over a long period of time, such as the dose of radiation we receive from natural background sources every day.

Chronic Dose vs. Acute

The body tolerates chronic doses better than acute doses because:

- Only a small number of cells need repair at any one time.
- The body has more time to replace dead or non-working cells with new ones.
- Radical physical changes do not occur as with acute doses.

Genetic Effects

Genetic effects involve changes in chromosomes or direct irradiation of the fetus. Effects can be somatic (cancer, tumors, etc.) and may be heritable (passed on to offspring).

Somatic Effects

Somatic effects apply directly to the person exposed, where damage has occurred to the genetic material of a cell that could eventually change it to a cancer cell. It should be noted that the chance of this occurring at occupational doses is very low.

Heritable Effects

This effect applies to the offspring of the individual exposed, where damage has occurred to genetic material that doesn't affect the person exposed, but will be passed on to offspring.

To date, only plants and animals have exhibited signs of heritable effects from radiation. This data includes the 77,000 children born to the survivors of Hiroshima and Nagasaki. The studies performed followed three generations, which included these children, their children, and their grandchildren.

A.9.3 Biological Damage Factors

Biological damage factors are those factors, which directly determine how much damage living tissue receives from radiation exposure, and include:

- Total dose: the larger the dose, the greater the biological effects.
- Dose rate: the faster the dose is received, the less time for the cell to repair.
- Type of radiation: the more energy deposited the greater the effect.
- Area exposed: the more body area exposed, the greater the biological effects.
- Cell sensitivity: rapidly dividing cells are the most vulnerable.
- Individual sensitivity to ionizing radiation:
  a) developing embryo/fetus is the most sensitive.
  b) children are the second most vulnerable.
  c) the elderly are more sensitive than middle-aged adults.
  d) young to middle-aged adults are the least sensitive.

Prenatal Exposure

A developing embryo/fetus is the most sensitive to ionizing radiation because of its rapidly dividing cells. While no inheritable effects from radiation have yet been recorded, there have been effects seen in some children exposed to radiation while in the womb.

Possible effects include:

- Slower growth
- Impaired mental development
- Childhood cancer

Some of the children from Hiroshima and Nagasaki, exposed to radiation while in the womb, were born with low birth weights and mental retardation. While it has been suggested that such exposures may also increase the risk of childhood cancer, this has not yet been proven. It is believed that only doses exceeding 150 mSv (15 rem) increase this risk significantly.

It should be stressed that many different physical and chemical factors can harm an unborn child. Alcohol, exposure to lead, and prolonged exposure in hot tubs are just a few of the more publicized dangers to fetal development.

For more information, see Radiation Dose Limits: Declared Pregnant Worker, Section A.8.

Putting Risks in Perspective

Acceptance of any risk is a very personal matter and requires that a person make informed judgments, weighing benefits against potential hazards.

Risk Comparison

The following summarizes the risks of radiation exposure:

- The risks of low levels of radiation exposure are still unknown.
- Since ionizing radiation can damage chromosomes of a cell, incomplete repair may result in the development of cancerous cells.
- There have been no observed increases of cancer among individuals exposed to occupational levels of ionizing radiation.
- Using other occupational risks and hazards as guidelines, nearly all scientific studies have concluded the risks of occupational radiation doses are acceptable by comparison.

Table A3: Average Lifetime Estimated Days Lost Due to Daily Activities

Activity*	Estimated Days Lost
Cigarette smoking	2250
25% Overweight	1100
Accidents (all types)	435
Alcohol consumption	365
Driving a motor vehicle	207
Medical X-rays	6
10 mSv (1 rem) Occupational Exposure	1
10 mSv (1 rem) per year for 30 years	30

Table A4: Average Estimated Days Lost By Industrial Occupations

Occupation*	Estimated Days Lost
Mining/Quarrying	328
Construction	302
Agriculture	277
Transportation/Utilities	164
Radiation dose of 50 mSv (5 rem) per yr for 50 years	250
All industry	74
Government	55
Service	47
Manufacturing	43
Trade	30

The comparison of health and industrial risks illustrates the fact that no matter what you do there is always some associated risk. For every risk there is some benefit, so you as the worker must weigh these risks and determine if the risk is worth the benefit. Exposure to ionizing radiation is a consequence of the regular use of many beneficial materials, services, and products. By learning to respect and work safely around radiation, we can effectively manage our exposure.

Note: * based on US data only.

A.10 Radiation Dose Limits

To minimize risks from the potential biological effects of radiation, regulatory agencies and authorative bodies have established radiation dose limits for occupational workers. These limits apply to those working under the provisions of a specific license or registration.

The limits described below have been developed based on information and guidance from the International Commission on Radiological Protection (ICRP-1990), the Biological Effects of Ionizing Radiation (BEIR) Committee, the US Environmental Protection Agency (EPA} and the National Council of Radiation Protection (NCRP).

For an XRF analyzer using an X-ray tube as the source, any requirement on dose limits for the operators would be established by the appropriate regulatory agency.

In general, the larger the area of the body that is exposed, the greater the biological effects for a given dose. Extremities are less sensitive than internal organs because they do not contain critical organs. That is why the annual dose limit for extremities is higher than for a whole body exposure that irradiates the internal organs.

Your employer may have additional guidelines and set administrative control levels. Each employee should be aware of such additional requirements to do their job safely and efficiently.

The following table illustrates typical dose limits.

Table A-5: Annual Occupational Dose Limits:

	International	U.S.
Whole Body	20 mSv*	5 rem
Extremities	500 mSv	50 rem
Organs or Tissue (Excluding lens of the eye and skin)	500 mSv	50 rem
Lens of the Eye	150 mSv	15 rem

*Averaged over 5 years

Table A-6: Radiation Limits for Visitors and Public

International Limit	1 mSv (100 mrem) per year
United States Limit	1 mSv (100 mrem) per year

Declared Pregnant Worker

A female radiation worker may inform her supervisor, in writing of her pregnancy at which time, she becomes a Declared Pregnant Worker. The employer should then provide the option of a mutually agreeable assignment of work tasks, without loss of pay or promotional opportunity, such that further radiation exposure will not exceed the dose limits as shown below for the declared pregnant worker.

Table A-7: Dose to Pregnant Worker

International Limit 2 mSv (200 mrem) to abdomen during remainder of gestation period after declaration (ICRP 60)

United States Limit Declared Pregnant Worker (embryo/fetus) - 0.5 rem / 9 months (≈ 0.05 rem / month)

A.11 Measuring Radiation

Because we cannot detect radiation through our senses, special devices may be required by some jurisdictions for personnel operating an XRF to monitor and record the operator's exposure. These devices are commonly referred to as ***dosimeters***, and the use of them for monitoring is called ***dosimetry***.

The following information may apply to personnel using the S1 TRACER XRF analyzers in jurisdictions where dosimetry is required:

- Wear an appropriate dosimeter that can record low energy photon radiation.
- Dosimeters wear period of three months may be used, subject to local regulation.
- Each dosimeter will be assigned to a particular person and is not to be used by anyone else.

Measuring Devices

Several devices are employed for measurement of radiation doses: including ionization chambers, Geiger-Mueller tubes, pocket dosimeters, thermoluminescence devices (TLD's), optically stimulated luminescence dosimeters (OSL) and film badges. It is the responsibility of your Radiation Safety Officer (RSO) or Radiation Protection Officer (RPO) to specify and acquire the dosimetry device or devices specified by your local regulatory authority for each individual and to specify any other measuring devices to be used.

The Ionization Chamber

The Ionization Chamber is the simplest type of detector for measuring radiation.

It consists of a cylindrical chamber filled with air and an insulated wire running through its center length with a voltage applied between the wire and outside cylinder. When radiation passes through the chamber, ion pairs are extracted and build up a charge. This charge is used as a measure of the exposure received.

This measurement is not highly efficient (30-40% efficiency is typical), as some radiation may pass through the chamber without creating enough ion pairs for proper measurement.

The Geiger-Mueller Tube

The Geiger-Mueller (GM) Tube is very similar to the ion chamber, but is much more sensitive. The voltage of its static charge is so high that even a very small number of ion pairs will cause it to discharge.

A GM tube can detect and measure very small amounts of beta or gamma radiation.

The Pocket Dosimeter

The Pocket Dosimeter is also a specialized version of the ionization chamber. It is basically a quartz fiber electroscope. The chamber is given a single charge of static electricity, which it stores like a condenser. As radiation passes through the chamber, the charge is reduced in proportion to the amount of radiation received, and the indicator moves towards a neutral position.

A dosimeter that has been exposed to radiation must be periodically recharged, or zeroed.

Thermo luminescence Devices (TLDs) and Optically Simulated Luminescence Dosimeter (OSL)

TLDs and OSL are devices that use materials in the form of crystals, which can store free electrons when exposed to ionizing radiation. These electrons remain trapped until the crystals are read by a special reader or processor, using heat (TLD) or light (OSL). When this occurs, the electrons are released and the crystals produce light. The intensity of the light can be measured and related directly to the amount of radiation received.

Thermoluminescent materials, which are useful as dosimeters include: lithium fluoride, lithium borate, calcium fluoride, calcium sulfate, and aluminium oxide.

There are two common types of dosimeters: whole body and extremity.

Whole Body Dosimeter

A TLD or OSL whole body dosimeter is used to measure both shallow and deep penetrating radiation doses. It is normally worn between the neck and waist.

The measured dose recorded by this device may be used as an individual's legal occupational exposure.

Extremity

An extremity is a TLD in the shape of a ring, which is worn by workers to measure the radiation exposure to the extremities.

The measured dose recorded by this device may be used as the worker's legal occupational extremity exposure.

A.12 Reducing Exposure (ALARA Concept)

While dose limits and administrative control levels already ensure very low radiation doses, it is possible to reduce these exposures even more.

The main goal of the ALARA program is to reduce ionizing radiation doses to a level that is As Low As Reasonably Achievable (ALARA).

ALARA is designed to prevent unnecessary exposures to employees, the public, and to protect the environment. It is the responsibility of all workers, managers, and safety personnel alike to ensure that radiation doses are maintained ALARA.

There are three basic practices to maintain external radiation ALARA:

- Time
- Distance
- Shielding

A.12.1 Time

The first method of reducing exposure is to limit the amount of time spent in a radioactive area. The shorter the time, the lower the amount of exposure.

The effect of time on radiation could be stated as:

Dose = Dose Rate x Time

This means the less time you are exposed to ionizing radiation, the smaller the dose you will receive.

Example: If 1 hour of time in an area results in 1 mSv (100 mrem) of radiation, then 1/2 an hour results in 0.5 mSv (50 mrem), 1/4 an hour would result in 0.25 mSv (25 mrem), and so on.

A.12.2 Distance

The second method for reducing exposure is by maintaining the maximum possible distance from the radiation source to the operator or member of the public.

The principle of distance is that the exposure rate is reduced as the distance from the source is increased. The greater the distance, the amount of radiation received is reduced.

This method can best be expressed by the ***Inverse Square Law***. The inverse square law states that doubling the distance from a point source reduces the dose rate (intensity) to 1/4 of the original. Tripling the distance reduces the dose rate to 1/9 of its original value.

Expressed mathematically:

$$C \times \frac{D_1^2}{D_2^2} = I$$

Variables

C is the intensity (dose rate) of the radiation source
$\mathbf{D_1}$ is the distance at which C was measured
$\mathbf{D_2}$ is the distance from the source
I is the new level of intensity at distance $\mathbf{D_2}$ from the source

Example: If the intensity (C) of a point source is 1 mSv (100 mrem) per hr at one foot (D_1), then at two feet (D_2) it would be 0.25 mSv (25 mrem) perhr (I).

C = 1 mSv (100 mrem) per hr
D_1 = 1 foot D_2 = 2 feet
I = 0.25 mSV (25 mrem) per hr
$\mathbf{C \times (D_1)^2 / (D_2)^2}$ = $1 \text{ X } (1)^2/ (2)^2$ = 1/4 = 0.25 mSv/hr **OR** $100 \text{ X } (1)^2/ (2)^2$ = 25 mrem/hr. (I)

The inverse square law does not apply to sources of greater than a 10:1 (distance: source size) ratio, or to the radiation fields produced from multiple sources.

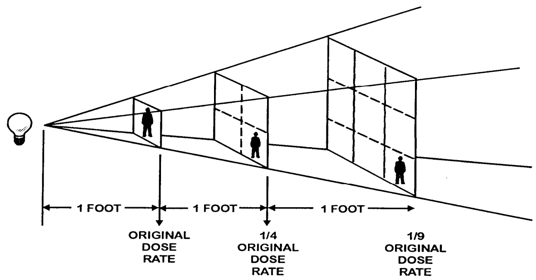


Figure A.13: The Inverse Square Law

A.12.3 Shielding

The third, and perhaps most important, method of reducing exposure is shielding.

Shielding is generally considered to be the most effective method of reducing radiation exposure, and consists of using a material to absorb or scatter the radiation emitted from a source before it reaches an individual.

As stated earlier, different materials are more effective against certain types of radiation than others. The shielding ability of a material also depends on its density, or the weight of a material per unit of volume.

Example: A cubic foot of lead is heavier than the same volume of concrete, and so it would also be a better shield.

Although shielding may provide the best protection from radiation exposure, there are still several precautions to keep in mind when using S1 TRACER XRF devices:

- Persons outside the shadow cast by the shield are not necessarily 100% protected. Note: All persons not directly involved in operating the XRF should be kept at least three feet away.
- A wall or partition may not be a safe shield for persons on the other side.
- Scattered radiation may bounce around corners and reach nearby individuals, whether or not they are directly in line with the test location.

Note: The operator should ensure that there is no one on the other side of the wall when using an XRF Analyzer.