Honeywell
measurex

6 October 1997

Mr. David Wesley
Senior Health Physicist
Radioactive Materials
Licensing
Department of Health Services
601 North Seventh Street
Mail Stop 178
Sacramento, CA 95814

Subject: Licenses 1856 and 1663; Notification of a New Customer Manual

Dear David:

Honeywell-Measurex presently distributes gauges with nuclear sources under License 1856 (generally licensed devices). We also are authorized to distribute devices to persons or firms with appropriate specific licenses under our License 1663.

Item 14 of License 1856 states that Honeywell-Measurex will provide a copy of an instruction manual with radiation safety information to licensees to whom we transfer a gauge. Other documents are also required by this license condition; this letter does not address those additional requirements.

In the past, Honeywell-Measurex had satisfied the requirement for an instruction manual by supplying customers with a copy of our Radiation Safety Training Manual. However, the Radiation Safety Training Manual also contains information that is specific to our operations within our Cupertino manufacturing facilities and which is irrelevant to customers.

We have now completed a manual specifically for customers. Effective immediately, we will start providing this new manual whenever we transfer gauges to general or specific licensees. Enclosed is a sample copy for your files. As usual, Honeywell-Measurex wishes to be able to update and modify this manual without being required to obtain a license amendment before using the updated version.

If you require additional information, please contact me. I can be reached at (408) 725-3127 or via e-mail at elsa.nimmo@hmx.honeywell.com.

Sincerely,
HONEYWELL-MEASUREX CORPORATION

Elsa Nimmo

Elsa Nimmo
Radiation Safety Officer

CC: Brendan Brady
Radiation Safety Committee

Honeywell
measurex

Radiation Safety Manual for Honeywell–Measurex Customers

August 1997

Confidentiality Statement

This manual is a product of Honeywell–Measurex Corporation. It is intended for use only by Honeywell–Measurex and customer personnel in connection with Honeywell–Measurex products. It is strictly prohibited to copy this manual or any part thereof or to transfer this manual or any part thereof to any non-Honeywell–Measurex person or entity, except customer personnel for use in connection with Honeywell–Measurex products. Persons employed by a third-party service company shall not have access to this manual.

Notice

All information and specifications contained in this manual have been carefully researched and prepared according to the best efforts of Honeywell–Measurex Corporation, and are believed to be true and correct as of the time of this printing. However, due to continued efforts in product improvement, we reserve the right to make changes at any time without notice.

To order additional or revised copies of this publication, contact Honeywell–Measurex Corporation, One Results Way, Cupertino, CA 95014-5991, U.S.A. Telephone (408) 255-1500.

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Contents

1. Introduction

1.1. Purpose

The purpose of this document is to provide the user with basic radiation safety information pertaining to X-ray or nuclear sensors manufactured by Honeywell–Measurex.

Please note that references in this manual to Honeywell–Measurex sources, Honeywell–Measurex sensors, and similar terms refer also to the corresponding items manufactured by Measurex Corporation prior to its merger with Honeywell in 1997.

Reference is made throughout this manual to "Honeywell–Measurex sensors." This term is descriptive only; it does not and it cannot imply that Honeywell–Measurex is responsible for the safe operation, maintenance, testing, or inspection of Honeywell–Measurex sensors.

> Note:
> By law in the U.S., radiation safety is the responsibility of the person or firm in possession of the sensor/radiation source. Even if an X-ray or nuclear sensor is held under a lease or a loan, **the customer is ultimately responsible for ensuring the safety of the sensor/radiation source.**

1.2. About This Manual

This manual contains 4 chapters and 2 appendices.

Chapter 1, **Introduction**, this chapter.

Chapter 2, **Radiation Source Regulations in the United States**, gives an overview of the regulations that govern the use of radiation sources by Honeywell–Measurex customers.

Chapter 3, **Procedures**, describes the steps to take in the event of a problem or emergency. It also provides information on authorized

maintenance procedures and instructions for safely performing those procedures.

Chapter 4, **Radiation Hazards and Dose Limits,** provides a detailed review of the biological effects of human radiation exposure and discusses under what circumstances these effects can be hazards to users of Honeywell–Measurex equipment.

Appendix A, **Information about Honeywell–Measurex Radioactive Sources**, contains information on the origin and types of radiation sources used in sensors manufactured by Honeywell–Measurex.

Appendix B, **Figures**, contains an illustration of the sensor head with shipping shield and samples of radioactive materials labels.

1.3. General Radiation Safety Procedures

The sensors manufactured by Honeywell–Measurex containing radioactive and X-ray sources are designed to be safe for use by both customers and persons responsible for calibration, testing, shipment and receipt, installation, and maintenance. All individuals who work near Honeywell–Measurex sensors should keep in mind the following general instructions:

- **Learn to recognize the radiation symbol** and the warning labels applied to shipping containers, storage areas, source holder assemblies, and sensor heads. Honeywell–Measurex recommends that you contact a member of your organization's radiation safety staff immediately if there is any question as to whether a source of radiation is present.

- **Minimize the amount of time** spent near radiation sources. Note the shutter position when approaching a sensor (observe the warning lights). If the shutter is open, do not spend unnecessary time near the sensor.

- **Maximize the distance** between the radiation source and location of people. In general, if the distance is doubled, the radiation level decreases to less than half the original level. Conversely, at half the original distance from a radiation source, the radiation level is generally more than double the original level.

- **Avoid direct exposure** to radiation. Never insert hands, fingers, or any part of the body into the measurement gap of a sensor unless the source shutter has been verified to be completely closed.

- **Make use of appropriate shielding.** In the case of radiation sources contained within Honeywell–Measurex sensors, appropriate shielding has been designed into the source container (either source holder assembly or X-ray tube holder) and/or the sensor head containing the source. Similarly, sources contained within standard shipping containers have been provided with adequate shielding. Keep this shielding intact and unmodified.

- **Think before acting.** Before doing any work that could affect radiation levels in any way (that is, anything that alters the time spent near a source, the distance from a source, or the shielding of a source), think through the possible consequences of the planned actions.

- **Ensure that all radiation safety interlocks are functional.**

- **Wear any required radiation badges.** If your organization requires the use of radiation badges, always wear them when working around sensors containing radioactive or X-ray sources.

> WARNING:
> **Never, under any circumstances, should you disassemble a source holder assembly or override interlocks in order to work inside a sensor head containing an energized X-ray tube. Exposure to radiation can result in serious injury.**

2. Radiation Source Regulations in the United States.

The information in this chapter is provided as a general outline. It is not a detailed list of regulations or a legal interpretation of regulations.

The use of any device that produces radiation is highly regulated throughout the world. Regardless of the country, there are usually four regulatory issues that directly affect Honeywell–Measurex customers:

- Licensing: Some type of licensing and/or registration is required for the customer facility that plans to possess sensors containing radiation sources
- Transportation: Transportation and/or importation of radiation sources is restricted.
- Testing: Some periodic testing of Honeywell–Measurex-distributed sensors is required to ensure that the integrity of the device is maintained.
- Enforcement and Compliance: Although the process varies from country to country, radiation safety regulations are generally strictly enforced throughout the world.

In the United States, the use of radioactive material in Honeywell–Measurex-distributed sensors is regulated either by the United States Nuclear Regulatory Commission (NRC) or by individual states, known as "Agreement States." Agreement States have regulations which are generally equivalent to the NRC requirements. Approximately half of the states are Agreement States.

States where radioactive material is regulated directly by the NRC are grouped into four regions, each with its own regulatory agency. States that are regulated directly by the NRC also have state agencies that have some responsibility for the use of radiation sources within their boundaries. These state agencies often have additional requirements that Honeywell–Measurex and its customers must observe.

Despite the many agencies involved, there is general uniformity in the requirements in the U.S. The sections below describe some of the requirements that apply regardless of location within the U.S.

2.1. Licensing

There are two types of radioactive materials licenses in the U.S. — Specific Licenses and General Licenses.

2.1.1. Specific License

A firm that wants a Specific License must make application to the appropriate regulatory authority, stating exactly what work involving radiation sources will be done, how it will be done, and why their personnel are qualified to do it. The regulatory authority then reviews the application and either grants or denies the Specific License.

The Specific License consists of one or more pages detailing the exact conditions of the license and the date of expiration for the license. The Specific License applicant is charged a fee for this license.

Most Honeywell–Measurex customers in the U.S. do **not** have a Specific License to cover their possession and use of Honeywell–Measurex sensors that contain radioactive sources. Most possess and use Honeywell–Measurex sensors under General Licenses, described later in this chapter.

2.1.2. General License

A General License is the permission, granted under U.S. regulations, to possess and operate a device containing radioactive material which has been designated as a "generally licensed device."

To be authorized for distribution as a generally licensed device, the equipment must be designed in such a way that it does not require extensive knowledge of radiation safety for its safe use. It must have fail-safe mechanisms and interlocks to prevent accidental exposures. Also, the levels of radiation around the device must be below a specified level. Standard Honeywell–Measurex sensors containing radioactive sources are generally licensed devices.

At the present time (1997), no action is required on the part of Honeywell–Measurex customers to obtain a General License. Honeywell–Measurex customers do not need to apply for the license and there is no document issued by any regulatory authorities. A General License is simply a right granted by Law.

A typical section of regulations granting a General License would read: "A general license is hereby issued to ... industrial firms ... to acquire, receive, possess and use ... by-product material contained in devices designed and manufactured for the purpose of ... gauging or controlling thickness ... . The general license ... applies only to by-product material contained in devices which have been manufactured ... in accordance with the specifications contained in a specific license."

Customers who possess Honeywell–Measurex sensors under a General License are limited in what they are permitted to do with the equipment. They also have certain responsibilities. These requirements appear on the radioactive material label on the sensor, and they are summarized below.

Under a General License, Honeywell–Measurex customers have the following obligations (note that additional requirements may be listed on or supplied with the equipment):

- Maintain the warning labels on the sensor heads and comply with the instructions printed on the labels.
- Have the radioactive source(s), except Kr-85, tested for leakage at 6-month intervals by a person who holds a Specific License to perform this test on Honeywell–Measurex sensors (for sensors

manufactured by the Ohmart Corporation and distributed by Honeywell–Measurex, see Section 3.3).

- Have the on-off mechanism (shutter) and warning lights tested at 6-month intervals by a person who holds a Specific License to perform this test on Honeywell–Measurex sensors (for sensors manufactured by the Ohmart Corporation and distributed by Honeywell–Measurex, see Section 3.3).

- Limit installation, servicing, or removal involving the radioactive source, its shielding or containment to persons who hold a Specific License to perform this work on Honeywell–Measurex sensors, except for those procedures described in Chapter 3 of this manual.

- Maintain records with dates and names of persons who perform the installation, testing, or servicing as described above.

- Suspend operation of the Honeywell–Measurex sensor immediately in the event of detection of removable radioactive material (leakage) or failure or damage which affects the shutter, warning lights, shielding, etc. Do not start the sensor until it is repaired or replaced by a person holding a Specific License for this work on Honeywell–Measurex sensors.

- Furnish a complete description of the event described in the above paragraph to the applicable regulatory agency.

- Transfer or dispose of the Honeywell–Measurex sensor only to a person or firm holding a Specific License that permits them to receive a Honeywell–Measurex sensor of this type.

- Maintain records of all receipts, transfers, or disposals of Honeywell–Measurex sensors that contain radioactive sources.

- Notify the applicable regulatory authorities of radiation incidents, theft, or loss of a Honeywell–Measurex sensor that contains a radioactive source.

2.2. Transportation

A customer with a General License may neither transport nor package for transportation any equipment if it involves the radioactive source in any way. These activities require obtaining a Specific License.

2.3. Testing

The type of testing Honeywell–Measurex customers are required to have performed on Honeywell–Measurex sensors depends on the type of license they possess.

Customer requirements for General Licenses are listed in the section immediately before this one. Customers with Honeywell–Measurex sensors under Specific Licenses must follow the requirements stated in that license.

2.4. Enforcement and Compliance

Holders of radioactive material licenses are inspected from time to time by regulatory agencies. Usually, inspections are conducted more frequently for Specific Licensees than for General Licensees. Honeywell–Measurex customers are inspected periodically. The customer has the final responsibility for compliance with the General or Specific License requirements.

In the event that a Honeywell–Measurex customer is inspected by a regulatory agency, the Honeywell–Measurex Radiation Safety Office will provide assistance to the extent possible. Records of each system are maintained in the Honeywell–Measurex Radiation Safety Office, and customers may request that copies be sent or faxed to them.

3. Procedures

Reference is made throughout this manual to "Honeywell–Measurex sensors." This term is descriptive only; it does not and it cannot imply that Honeywell–Measurex is responsible for the safe operation, maintenance, testing, or inspection of Honeywell–Measurex sensors.

Various design features and safety interlocks incorporated in Honeywell–Measurex sensors minimize hazardous situations involving radiation. Nonetheless, it is important for individuals working with Honeywell–Measurex sensors to be aware of the correct procedures in the event of a problem.

> Note:
> Honeywell–Measurex recommends that you notify your radiation safety officer and the Honeywell–Measurex Radiation Safety Office **IMMEDIATELY** if any problem involving radiation safety occurs.

If necessary, a member of the Honeywell–Measurex Radiation Safety Office can be reached 24 hours a day at Cupertino. IN AN EMERGENCY designated individuals can be reached by calling (408) 255-1500.

3.1. Summary of Safety and Emergency Instructions

3.1.1. Source Shutter Problem

Source shutters that do not open or close smoothly or that fail to close completely must be treated as a serious safety problem. Symptoms of shutter problems, such as high background counts, are discussed in the next section of this chapter. Failure of a shutter to close properly:

- May result in radiation exposure to personnel, particularly if the source holder assembly or X-ray source is moved from its normal position.
- Negates the effect of radiation safety interlocks.

WARNING:
If the shutter cannot be completely closed, Honeywell–Measurex recommends that you IMMEDIATELY notify your radiation safety officer and consult with the Honeywell–Measurex Radiation Safety Office. Do not attempt shutter repair.

Never wire or otherwise physically keep the source shutter in the open position. This could result in a serious accident.

3.1.2. Radioactive Source Rupture

The possibility of a radioactive source rupturing is very small. The source capsule (the metal case containing the radioactive material) has been designed to pass strenuous testing. In addition, the source holder assembly protects the capsule. However, if there is an inexplicable change in air counts, or any other reason to suspect that a source rupture has occurred, follow the steps given below:

- Honeywell–Measurex recommends that you contact your radiation safety officer **immediately** and notify the Honeywell–Measurex Radiation Safety Office. It is impossible to provide instructions in this manual appropriate for all situations. The information below gives some general guidelines, but it is not intended to substitute for detailed instructions.

- The instructions for immediate actions that you will be provided will depend on whether the source is Kr-85 or another radioactive source.

3.1.2.1. Kr-85 source rupture

In the event of a rupture of a Kr-85 source, it will normally be requested that ventilation be maximized in the area containing the sensor. This is because Kr-85 is a chemically and biologically inert gas which disperses rapidly. Prompt dilution with air minimizes the dose to personnel. Kr-85 does not constitute a hazard when well-diluted.

3.1.2.2. Rupture of sources other than Kr-85

Do nothing that could cause the material to dilute. Do **not** try to clean the area before consulting with your radiation safety officer. Your regulatory authorities and the Honeywell–Measurex Radiation Safety Office should be consulted for steps to minimize the spread of the radioactive material.

3.1.3. Accidental Sensor Head Separation or Misalignment

Accidental separation of the sensor heads causes a potentially hazardous condition since it could result in exposure to the radiation beam.

If heads are accidentally misaligned or separated, special precautions must be observed. Although the sensors are equipped with interlocks designed to cause the shutter to close in the event of head separation, it should be assumed that the interlocks have been damaged until proven otherwise. Perform the following steps:

- Press the OFF SHEET button. (Use the button on the scanner if possible.)
- Confirm that green SHUTTER CLOSED lamps are lighted for nuclear sources. If this is not the case, assume that the shutter is open. Stay 10 feet (3m) or more from sensor head and contact the your radiation safety officer immediately.
- If the sensor head includes an X-ray source, turn X-ray power off.

- If the green SHUTTER CLOSED lamps are lighted and all X-ray power is off, the head can be moved OFF SHEET and the safety / shipping shield carefully attached to cover the source window. Avoid placing hands or any part of the body in front of the source window(s). The safety / shipping shield is a metal shield used to cover the gap surface of the source head—see Figure B–1.

- If there is any possibility that someone received unusual radiation exposure, Honeywell–Measurex recommends that you notify your radiation safety officer and the Honeywell–Measurex Radiation Safety Office immediately.

- Do not operate the sensor until after the cause of the problem has been understood and corrected.

3.1.4. Fire

In the event of fire, observe the following safety precautions:

- If possible, send scanning heads to the OFF SHEET position and turn power off.

- The fire itself is the primary hazard and should be controlled using any appropriate means.

- If the sensor has been in any way involved in the fire, consult with the your radiation safety officer and the Honeywell–Measurex Radiation Safety Office before operating it.

- It is essential to verify that all interlocks are functional and that there has been no damage to the source holder assembly before the sensor is operated. Contact a licensed service technician to check the interlocks.

- In the case of Honeywell–Measurex-manufactured sensors, the source holder assemblies containing radioactive sources are equipped with a thermal safety nut. The thermal safety nut causes the shutter to close (and to remain locked) if the source holder assembly reaches a temperature limit.

3.1.5. Accumulation of Debris in Source Holder Assemblies

Honeywell–Measurex source holder assemblies are normally protected from any vapors or debris by the window in the sensor head. However, if the window is damaged and isn't immediately replaced, and the shutter is open, material may enter the source holder assembly.

> **WARNING:**
> **Do not attempt to clean the debris out of the shutter cavity.**

Methods that might seem reasonable can be hazardous and are not permitted to General Licensees. In particular, do not use a cotton-tipped swab, screwdriver, etc., to attempt to dislodge the debris. Do not use a stream of air, water, or other material to attempt to dislodge debris. Do not attempt to vacuum out the debris. Consult with the Honeywell–Measurex Radiation Safety Office regarding options for cleaning the source holder.

3.1.6. Tungsten Acetate

Tungsten acetate is a green or olive-gray coating, or corrosion, which sometimes appears on the surface of source holder assemblies. It is more common on older assemblies or on those which are in a moist environment.

Tungsten acetate is caused by a chemical reaction between the material (tungsten) that makes up some of the source holder assembly and chemicals such as acetic acid, which is found in many industrial environments. The presence of tungsten acetate does **not** mean that the radioactive source has leaked.

Tungsten acetate accumulation, if not caught in the early stages, can cause the source shutter to jam in either the open or closed position. Since shutters which jam open can be hazardous, it is very important to catch tungsten acetate before it becomes serious.

The semiannual radiation check performed by Honeywell–Measurex personnel includes an inspection of the source holder assembly for tungsten acetate.

There are a number of things you can do to minimize the risks from tungsten acetate:

- Never use corrosive types of RTV inside sensor heads containing source holder assemblies. Corrosive RTV gives off acetic acid which appears to promote tungsten acetate development. This type of RTV will be labeled "corrosive."
- Fix broken kapton windows promptly.
- Maintain the nitrogen or dry-air purge system in proper working order.
- Keep the inside of the source sensor head as dry as possible.

If you believe that tungsten acetate is present on your source holder, consult with the Honeywell–Measurex Radiation Safety Office.

3.1.7. Other Problems or Disasters

If other problems or disasters occur, do the following:

- If possible, send scanning heads to the OFF SHEET position and turn power off.
- Consult with the your radiation safety officer and the Honeywell–Measurex Radiation Safety Office before operating the sensor. Again, contact a licensed service technician to check the safety interlocks for correct function before the sensor is returned to use.

3.2. Maintaining Radiation Safety While Working on Sensors Manufactured by Honeywell–Measurex.

This section describes those operations which are either permitted or prohibited to holders of a General License in the United States for sensors manufactured by Honeywell–Measurex. Honeywell–Measurex also distributes sensors manufactured by the Ohmart Corporation. See Section 3.3 for instructions on working with these Ohmart sensors.

3.2.1. Summary of Operations on Honeywell–Measurex Sensors for U.S. General Licensees.

Refer to the numbered sections in Table 3–1 below for details of allowed operations. Operations which are not allowed are discussed in Section 3.2.3.

Table 3–1. Allowable and Not Allowable Operations

It Is Allowed to:	Section	It Is Forbidden to:
remove and replace the panels and covers on the sensor heads, perform diagnostic or repair work to electronics	3.2.2.1	install or remove the sensor remove the sensor head from the scanner remove the source holder from its mounting in the sensor head perform the required 6-month tests disable the interlocks or remove the labels or lights repair, modify or remove a source or its shielding ship or package for shipment the source or sensor with its source dispose of the source
do routine cleaning of the window and gap	3.2.2.2	
separate the sensor heads	3.2.2.3	
replace the kapton windows in the sensor	3.2.2.5	
replace the bulbs or LED's in the warning lights	3.2.2.6	

3.2.2. Operations which U.S. General Licensees Are Permitted

General Licensees in the United States are permitted to clean portions of the source or detector sensor heads which are in the measurement gap when the heads are in their normal configuration. General Licensees are also permitted to separate the sensor heads to perform a more thorough cleaning or to replace the kapton windows in the heads. The procedures for maintaining radiation safety while performing these operations are given in this section.

Some additional operations which do not directly involve the radiation source are also permitted and will be discussed below.

WARNING:
Under no conditions is a General Licensee allowed to repair, modify or remove a radiation source or its associated shielding.

3.2.2.1. Removal of access panels and head covers.

As part of these procedures, General Licensees are permitted to remove and replace the access panels and head covers on the detector head and the source head. These panels and covers may also be removed for other diagnostic or repair work, such as checking electronic test points in either the source head or detector head. Refer to the manual that was supplied with your sensor for diagrams of these panels and covers.

WARNING:
Under no conditions is a General Licensee allowed to remove the source holder from its mounting, or the sensor heads from the scanner or frame.

3.2.2.2. Cleaning the gap surfaces and windows

Follow these procedures to properly maintain radiation safety while cleaning the gap surfaces or windows with the heads in their normal configuration:

- If you have been assigned a radiation badge (or badges), be sure to wear the badge. Do not proceed if you are required to have a badge and the badge is unavailable.
- If the heads must be separated for effective cleaning, follow the instructions in Section 3.2.2.3, Separation of Sensor Head(s). Note that head removal is not permitted except for personnel authorized for that operation by a Specific License.
- Command the source shutter(s) to close by pressing the OFF SHEET button at the scanner end bell.
- Observe the warning lights and confirm that all red SHUTTER OPEN warning lights are off and that all green SHUTTER CLOSED lamps are lighted. **Do not proceed if the green lamps are not lighted!**
- Use a long-handled tool with an attached cleaning pad (modified flyswatter) to clean the head surfaces inside the measurement gap.
- Note that the dose rate through the closed shutter will exceed the natural background rate, although it will be just a small fraction of the shutter open rate. This is normal and unavoidable, and is not a sign of shutter malfunction or shutter design failure.

WARNING:
If air counts or shutter closed counts are unusual, do not proceed. Honeywell–Measurex recommends that you contact your radiation safety officer promptly and notify the Honeywell–Measurex Radiation Safety Office.

3.2.2.3. Separation of sensor heads

In order to perform a more thorough cleaning or to replace the kapton windows in the sensor, follow these procedures to ensure radiation safety while separating the sensor heads:

- If you have been assigned a radiation badge (or badges), be sure to wear the badge. Do not proceed if the assigned badge is unavailable.
- If the sensor head contains X-ray source(s) only, turn off power to X-ray tube(s) and remove the key. Do not return the key or reapply power until sensor heads are returned to their normal configuration.
- Confirm that all source shutters are completely closed. **Regardless of the method used to close shutter(s), take time to verify that the shutter(s) are actually fully closed by following each of the three steps listed below.** This is very important due to the high radiation levels that exist when the shutter is open and the possibility of serious injury, particularly to the skin, within a period of seconds or minutes.

  1. If possible, request background counts and verify that they are within the normal range for shutter closed.
  2. Observe warning lights if the system is powered up; only green lamps should be lighted.

     WARNING:
     Do not proceed if the green lamps are not lighted!

     WARNING:
     If <u>both</u> green and red lamps are lighted, do not proceed!

  3. Open access panel to the head, if applicable. Manually verify that all shutters are completely closed using the shutter position indicators attached to the shutter solenoids.

     WARNING:
     If there is any doubt as to whether any shutter is closed, DO NOT PROCEED.
     Honeywell–Measurex recommends that you contact your radiation safety officer promptly

and notify the Honeywell–Measurex Radiation Safety Office.

- For Scanners with an Interlocked Clutch

  After confirming that the shutters are closed, turn off power to the sensor heads in the end bell or disconnect the power supply in the Scanner Control Cabinet. Follow the procedures described in the manual that came with your scanner to disengage the interlocked clutch. Place Danger Tags at the power switch and at the Clutch Release Switch to warn others not to reconnect head power until the heads have been returned to their normal configuration.

- For Scanners without an Interlocked Clutch

  After confirming that the shutters are closed, turn off power to the sensor heads in the end bell (2010 scanners) or disconnect the power supply in the Scanner Control Cabinet. Place a Danger Tag at the appropriate location to warn others not to reconnect head power until the heads have been returned to their normal configuration.

During and after sensor head separation, keep the source window directed away from personnel.

Following head separation, attach the sensor head safety / shipping shield over the source window unless immediate access to the window is required. See the Sensor Head Safety / Shipping Shield illustration in Appendix B, Diagrams.

3.2.2.4. Cleaning the gap

Although the heads are now separated, you should still use a long-handled tool with an attached cleaning pad (modified flyswatter) to clean the head surfaces inside the measurement gap. Observe the precautions noted in Section 3.2.2.2.

3.2.2.5. Source or detector head window replacement

The following information describes the procedures for maintaining radiation safety while replacing the kapton window in the source or detector sensor head:

> **WARNING:**
> **If air counts or shutter closed counts are unusual, do not proceed. Honeywell–Measurex recommends that you contact your radiation safety officer promptly and notify the Honeywell–Measurex Radiation Safety Office.**

- It is important to replace the kapton windows on the source and detector heads promptly if they are damaged. The windows protect the source holder assembly and ion chamber from accumulating debris. Debris can cause problems, including a drop in detected signal, an erratic signal, or interference with smooth shutter operation.

- To verify shutter closure and separate the sensor heads, follow the steps described in Section 3.2.2.3 on "Separation of Sensor Head(s)." **It is very important to follow each of the steps given in these instructions in order to avoid the possibility of direct exposure to the radiation beam.**

- If the window to be replaced is on the source sensor head, **keep hands out of the area directly above or below the kapton window during the entire replacement process.**

- If the window to be replaced is on the detector head, attach the safety / shipping shield to the source sensor head before replacing the window on the detector head. See Appendix B, Diagrams, for a diagram of a safety / shipping shield.

3.2.2.6. Other permitted operations

General Licensees are permitted to perform operations involving the sensors that do not involve the shielding for the radioactive source, the sensor heads, or their mounting on the scanner. Examples of such operations include replacing the radiation warning lights, or the static verification of samples.

3.3. Maintaining Radiation Safety while Working on Ohmart Sensors Distributed by Honeywell–Measurex.

Certain sensor systems sold by Honeywell–Measurex contain radioactive sources in sensor models manufactured by the Ohmart Corporation. The radioactive materials identification label for these sensors includes the following information:

- The standard radiation symbol
- Words: "**CAUTION RADIOACTIVE MATERIAL**"
- Isotope type
- Serial number of sealed source
- Activity of sealed source
- The date
- Ohmart order number
- Honeywell–Measurex system number
- Ohmart order number
- The following labeling:

  OHMART SOURCE HOLDER MODEL BAL
  Manufactured by: THE OHMART CORP, CINCINNATI, OHIO
  Distributed by: HONEYWELL–MEASUREX CORP.,
  CUPERTINO, CALIFORNIA
  REMOVAL OF THIS LABEL IS PROHIBITED

  An additional text label may also be present. It provides a summary of requirements and restrictions for firms who possess such sensors under a U.S. general license.

  The radiation safety procedures for working with these sensors are described in this section.

3.2.3. Operations which U.S. General Licensees Are NOT Permitted

The following list is a summary of some of the procedures that require a Specific License:

- Any work on the source holder not described in the procedures in this chapter
- Removal of the source holder from its mounting in the sensor head or the scanner
- Performing the leak testing or the other tests mandated for 6-month intervals,
- Installation or removal of the sensor.
- Removal of sensor head from the scanner.
- Packaging the source holder or sensor with its source for shipment.
- Shipping or disposing of the source.
- Measuring radiation profiles.
- Performing modifications that affect radiation safety, including but not limited to the following:

  1. changes in the gap for the heads.
  2. disabling safety interlocks, even temporarily and with another individual in attendance.
  3. removal of radiation labels or warning lights (not referring to replacement).
  4. removal of sheet guide extenders, or of other sensors that are external to but adjacent to heads containing a source sensor.

3.3.1. Summary of Operations on Ohmart Sensors for U.S. General Licensees.

Refer to the numbered sections in Table 3–2 below for details of allowed operations for Ohmart sensors. Operations which are not allowed are discussed in Section 3.3.3.

Table 3–2. Allowable and Not Allowable Operations

It Is Allowed to:	Section	It Is Forbidden to:
mount the sensor	3.3.2.1	start up the sensor, including:
perform the mandated 6-month tests	3.3.2.2	remove safety / shipping shield
including:		confirm sensor function
source shutter testing	3.3.2.2.1	initial leak test or radiation measurements
leak tests	3.3.2.2.2	
remove sensor head window plates for routine maintenance	3.3.2.3	repair components inside source sensor head
replace warning lights	3.3.2.4	disable the interlocks or remove the labels or lights
		repair, modify or remove a source or its shielding
		ship or package for shipment the source or sensor with its source
		dispose of the source

3.3.2. Operations that Are Permitted on Ohmart Sensors

General Licensees in the United States in possession of a Model BAL Ohmart sensor distributed by Honeywell–Measurex are permitted to perform the operations described in this section. The procedures for maintaining radiation safety while performing these operations are given in this section.

Some additional operations which do not directly involve the radiation source are also permitted and will be discussed below.

> **WARNING:**
> **Under no condition is a General Licensee allowed to repair, modify or remove a radiation source or its associated shielding.**

3.3.2.1. Mounting the sensor heads

Provided that the safety / shipping shield is not removed, any person is permitted to mount the Ohmart BAL sensor in position on the process line, do the electrical wiring, and turn the power switch on.

Care must be exercised when uncrating the sensor. If there is any indication of sensor shipment damage, contact Honeywell–Measurex.

After mounting the sensor heads in position, initially **only a person with an appropriate specific license may start up the sensor**. This includes:

- Removal of the shipping safety / shield
- Confirming the correct function of the source shutter and the source shutter indicators
- Measuring and recording the radiation dose rates in areas adjacent to the sensor
- For Sr-90 or Am-241 sensors, testing for leakage of radioactive material

3.3.2.2. Periodic testing required at 6-month intervals

U.S. General Licensees are required to have source shutter indicators and the "On-Off" mechanism checked and documented at intervals of no longer than six months. Leak testing for sensors that contain Sr-90 and Am-241 is also required at six-month intervals. Honeywell–Measurex will provide such service under contract. Alternatively, these required tests, **with the exception of those done at the time of sensor installation**, may be conducted by the General Licensee on Ohmart sensors distributed by Honeywell–Measurex using the procedures given below.

3.3.2.2.1. Source Shutter Indicator and "On-Off" Mechanism testing:

- For a sensor with keylock shutter switch:

Turn the keylock from the OFF to ON position several times. Confirm that the red shutter indicator light turns on and the green indicator light turns off when the key is turned to ON. Confirm that the green shutter indicator light turns on and the red indicator light turns off when the key is turned to OFF.

If the indicators do not illuminate, check and replace the lamps. If the lamps are good, but fail to illuminate properly, contact Honeywell–Measurex for assistance. Note that any repairs involving components inside the source head must be performed by personnel with a Specific License.

Be sure to document and file the results of the test, including the date and the name of the person who performed the test.

- For a sensor with a microcomputer:

Using the console, command the shutter to open (generally "scan" or "SinglePoint"). Confirm that the red shutter indicator light turns on and the green indicator light turns off. Command the shutter to close (generally "Standby" or "OffSheet Mode"). Confirm that the green shutter indicator light turns on and the red indicator light turns off.

If the indicators do not illuminate, check and replace the lamps. If the lamps are good, but fail to illuminate properly, contact Honeywell–Measurex for assistance.

> Note:
> Any repairs involving components inside the source head must be performed by personnel with a Specific License.

Be sure to document and file the results of the test, including the date and the name of the person who did the test.

3.3.2.2.2. Leak testing for Sr-90 and Am-241:

General Licensees with Ohmart model BAL sensors may elect to collect leak test samples themselves. The customer may make arrangements with the Ohmart Corporation or another firm licensed to supply leak test kits and analyze the collected samples. The procedures for collecting leak test sample are described below.

The initial leak test required at sensor installation **must** be performed by a person with a Specific License as follows:

- Confirm that the green shutter indictors are lighted and the red indicators are off.

  WARNING:
  Do not proceed if the green lamps are not lighted!

  WARNING:
  If <u>both</u> green and red lamps are lighted, do not proceed!

- Take the leak test kit to the source sensor head. If the kit includes gloves, put them on.

- Remove the swab from the plastic bag, grasping it by the end opposite the fiber tip.

- Wipe the external surface of the source sensor head with the fiber-tipped end of the swab.

  1. Wipe around the top cover joint of the source sensor head mounted on a scanner.

  2. Wipe very carefully around the outside edge of the source window in the measurement gap surface of the source sensor head. AVOID wiping the window surface itself.

  3. Wipe around the end cover joint of the source sensor head mounted on the scanner.

- Without touching the fiber-tipped swab or allowing it to touch other objects, place it back in the leak test kit bag and seal the bag. Complete any required paperwork and send the swab in for analysis. Be sure to confirm that you receive the results of the analysis; keep them on file for inspection.

3.3.2.3. Removal of sensor head window plates

Ohmart Concept One sensors have window plates on the upper and lower sensor heads that are easily removable. These may be removed for maintenance and cleaning, using the following procedures:

- Close the shutter. Confirm that the red "shutter-open" lights are off and the green "shutter-closed" lights are on.

- Loosen the window plates using the clip fasteners. Remove the plates from the heads.

- Be sure to re-install the plates with the plate windows correctly positioned over the source and ion chamber windows on the heads. Note that the smaller diameter window is in the plate which must go on the source sensor head.

3.3.2.4. Other permitted operations

General Licensees are permitted to perform operations involving the sensors that do not involve the shielding for the radioactive source, the sensor heads, or their mounting on the scanner. Examples of such operations include replacement of the radiation warning lights, or the static verification of samples.

3.3.3. Operations that Are NOT Permitted on Ohmart Sensors

The following list is a summary of some of the procedures that require a Special License:

- Removing the safety / shipping shield at sensor start-up
- Performing the initial radiation safety tests and leak testing
- Performing repairs on components inside the sensor head
- Performing repairs on the BAL source holder
- Shipping or packaging for shipment the Ohmart sensor or its source
- Performing modifications that affect radiation safety, including but not limited to:
    - disabling safety interlocks, even temporarily and with another individual in attendance.
    - removal of radiation labels or warning lights (not referring to replacement).

3.4. Required Recordkeeping for All Sensors

Requirements will depend on the conditions of the customer's radioactive material license and/or the regulations. Honeywell–Measurex recommends that at least the following documents be kept available for use by employees and for inspection by regulatory authorities:

- Safety and Emergency Instructions for Nuclear and X-ray Sensors (e.g., RS51)
- Copies of the radiation profiles provided by Honeywell–Measurex and copies of any additional radiation surveys that may have been made on-site
- A copy of the radioactive materials license for possession and use of the sensor, for example RS70 and associated documents for U.S. General Licensees
- A copy of the applicable radiation safety regulations for the location of use
- Copies of the periodic radiation safety tests on Honeywell–Measurex sensors
- Documentation of any radioactive source exchanges, transfer, or disposal that may have taken place
- Records documenting fulfillment of any other license or regulatory requirements that apply (e.g., dosimetry records)

4. Radiation Hazards and Dose Limits

4.1. Introduction

Radiation exposure is perhaps the most thoroughly studied and understood of all human health hazards. However, much misunderstanding exists about the dose and the types of radiation associated with the various biological effects. This section will discuss these effects and when they occur.

In addition to the information in this chapter, Appendix A presents in "question-and-answer" format some specific information about the most common radiation source found in the sensors manufactured by Honeywell–Measurex.

Note that in the following information, doses that are designated as "acute" are single doses received within a brief time period rather than cumulative doses received over a period of days, weeks, or months.

Exposure to the radiation sources used by Honeywell–Measurex can produce some of the biological effects listed below. Other effects cannot be caused by exposure to Honeywell–Measurex sources and are included for general information only.

4.1.1. Radiation Protection Quantities and Units

The discussion of radiation exposure and hazards must make use of specialized units of measurement. For the purposes of this discussion, these radiation protection quantities and units are shown in Table 4–1, and are included here for reference purposes only.

Table 4–1. Radiation Protection Quantities and Units

Quantity (Symbol)	Special Unit (Symbol)	SI Unit (Symbol)
Absorbed dose (D): energy absorbed per unit mass of material in presence of ionizing radiation.	rad 1 rad = 100 ergs/g = 0.01 J/kg in air 1 rad = 1.15 R	gray (Gy) 1 Gy = 1 J/kg 1 Gy = 100 rads
Activity (A): the number of radioactive disintegrations per unit time.	curie (Ci) 1 Ci = 3.7×10^{10} sec^{-1}	bequerel (Bq) 1 Bq = 1 sec^{-1} 1 Bq = 2.7×10^{-11} Ci
Dose equivalent (H): quantity that expresses all kinds of radiation on a common scale for biological effect.	rem 1 rem = 1 rad x QF where QF is a quality factor accounting for relative biological effects due to radiation of interest	sievert (Sv) 1 Sv = 100 rems
Exposure (X): amount of ionization produced per unit mass of air by photons (gammas or X-rays).	roentgen (R) 1 R = 2.58×10^{-4}C/kg = 1 esu/cm^3 air (at STP) = 1.6×10^{12} ip/ -air	C/kg
Half-life: the time required for half the radioactive atoms of a particular radionuclide to decay. Example: Kr-85 has a half life of about 11 years. A Kr-85 source with activity of 1 Ci in 1994 will have activity of about 0.5 Ci in 2005.	seconds, minutes, days, weeks, years	seconds, minutes, days, weeks, years

4.2. Prompt Effects

Biological effects classified as "prompt effects" are those that occur within a relatively short time (immediate to several months) after exposure to radiation. Prompt health effects are described below in these subsections.

Each subsection also describes any hazards in these categories which may be posed by exposure to the radiation sources used in Honeywell–Measurex sensors

4.2.1. Skin Damage and Hair Loss

Skin damage and hair loss resulting from exposure to radiation occur at the site of irradiation. Thus, a large dose to the skin of the hand does not cause rashes or hair loss on the face or scalp.

Radiation-induced skin damage can be divided into three categories like the classifications used to indicate severity of thermal burns. It should be noted that it is not possible to distinguish radiation burns from thermal burns on the basis of skin symptoms alone. The categories are:

- First Degree

  A radiation burn equivalent to a first degree thermal burn, similar to a mild sunburn, occurs following acute skin doses of 200 rem (2 Sv) or more. Although some temporary reddening, sensations of warmth and/or itchiness may be present within hours of the exposure, the major skin reddening occurs two or three weeks after exposure followed by tanning of the irradiated skin. Temporary hair loss may occur on exposed portions of the skin within two or three weeks of the radiation exposure. There may be permanent hair loss with acute doses in excess of 700 rem (7 Sv).

- Second Degree

  Radiation burns equivalent to second degree thermal burns occur at acute skin doses of 1000 rem (10 Sv) or more. These burns are characterized by major skin reddening, permanent hair loss, and blistering within one to two weeks of the exposure.

- Third Degree

  Severe burns similar to scalding or chemical burns occur at acute skin doses of 5000 rem (50 Sv) or more. Such burns result in immediate and intense pain followed by the appearance of raw lesions and permanent hair loss. The time it takes to develop lesions is dose-dependent. Skin grafts may be required.

4.2.2. Honeywell–Measurex Radiation Sources and Hazards to Skin or Hair

The radiation sources used by Honeywell–Measurex in sensors can present a hazard to the skin. For example, skin burns could occur for the following reasons:

- If a person inserted a hand in the measurement gap of a sensor with the source shutter open.
- If a person separated the heads with the source shutter open.
- If a person disassembled a shielded assembly containing a radiation source.

Of the sources used by Honeywell–Measurex, a 30 kV, 0.2 mA X-ray tube presents the greatest skin hazard, followed by a 1 curie Kr-85 source. Theoretically, an unshielded exposure for about one minute at a distance of approximately 2 cm from either of these sources could cause a third-degree burn and permanent hair loss on the exposed areas. Sr-90 and Am-241, **in the quantities used in Honeywell–Measurex sensors**, emit less radiation per unit time than the Honeywell–Measurex 30 kV X-ray sources or Kr-85 sources and thus pose a slightly smaller hazard to the skin.

4.2.3. Sterility, Impaired Fertility, or Impotency

The following describes amounts of radiation which can cause variations in fertility:

- Brief Decrease in Fertility

  An acute dose of 150 rem (1.5 Sv) or more to the gonads in males or females may result in a brief decrease in fertility.

- Temporary Sterility

  Sterility of a 1– to 2-year duration may result from acute doses of 250 rem (2.5 Sv) or more to the gonads in males or females.

- Permanent Sterility

  Permanent sterility may result from acute doses of 500 rem (5 Sv) or more to the gonads in males or females.

- Hormonal Changes, Impotency

  In males, there is no association between radiation exposure and hormonal changes which result in impotency. If the dose is large enough to induce premature sterility in females, menopause is accompanied by all the usual hormonal changes.

4.2.4. Honeywell–Measurex Radiation Sources and the Risk to Fertility

In order to affect fertility, radiation doses of the magnitude listed above must reach the portion of the gonads where sperm or egg cells are produced or stored. The radiation sources most commonly used by Honeywell–Measurex (Kr-85, Pm-147, and Sr-90) emit radiation which is not sufficiently penetrating to affect fertility.

Furthermore, the doses required to affect fertility are very large. A penetrating acute dose of 450 rem (4.5 Sv), if received uniformly by the trunk of the body, results in death for approximately half the people exposed. At such doses, survival becomes the overriding concern rather than fertility.

4.2.5. Effects on the Unborn Child

There are a number of women who have received large radiation doses while pregnant. They include women who survived the atomic bomb in Japan and women who had abdominal X-rays for medical purposes. Studies of their offspring indicate that unborn children are more sensitive to radiation than are adults. These studies further show a link between childhood cancer, especially leukemia, mental or growth retardation and prenatal radiation exposure.

According to the National Academy of Sciences, subtle cell changes may result from acute doses to the unborn child in the range of 10 to 20 rem

(0.1 to 0.2 Sv). For this reason, regulatory agencies in the U.S. have suggested a voluntary dose limit for women who work around sources of radiation and who may be pregnant. This limit is 0.5 rem (0.005 Sv) of penetrating radiation to the trunk of the body during nine months. This limit is 10% of the annual limit for occupational exposure to penetrating radiation.

4.2.6. Honeywell–Measurex Radiation Sources and Prenatal Radiation Exposure

With two possible exceptions, the radiation sources used by Honeywell–Measurex do not constitute a radiation hazard to the embryo and fetus even under the worst imaginable accident conditions. This is because the radiation emitted is not sufficiently penetrating to reach the unborn child.

The two possible exceptions are situations involving X-ray exposure or accidental intake of radioactive material. While most of the X-ray sources used by Honeywell–Measurex are low energy and a potential hazard only to the skin, 30 kV and other more energetic sources **could** pose a risk to the unborn child under accident conditions involving direct abdominal exposure to the expectant mother. Accidents of this type are improbable. The nature of the radioactive sources used and the design of the sensors make accidental ingestion, inhalation, or absorption of radioactive material improbable.

It would be exceedingly unusual for a Honeywell–Measurex customer to receive a penetrating radiation dose as large as the 0.5 rem (0.005 Sv) voluntary dose limit for a 9-month period. Most of the approximately 1,000 employees who are monitored at Honeywell–Measurex receive no measurable penetrating radiation doses during an entire year. Nonetheless, women who are pregnant (or think they might be) should contact their company's radiation safety officer to review particular situations if they have concerns about radiation exposure.

4.2.7. Acute Radiation Syndrome

Symptoms resulting from large acute penetrating doses to the trunk of the body (or a major portions of it) are collectively known as the "acute radiation syndrome." The symptoms and outcome depend on the dose and the dosage rate. These may include nausea, fatigue, fever, anemia, hemorrhaging, infection, and death. Based on accident and atomic bomb studies, without medical intervention, an acute penetrating dose of

450 rem (4.5 Sv) to the trunk of the body of the average adult will result in death within one month in about 50 percent of those irradiated.

4.2.8. Honeywell–Measurex Radiation Sources and the Acute Radiation Syndrome

The probability of a Honeywell–Measurex customer receiving a dose which could result in any stage of the acute radiation syndrome is exceedingly small. This is due to the basically non-penetrating nature of the radiation emitted by the sources used and the physically small beam size.

4.3. Delayed Effects

Biological effects classified as "delayed effects" are those which occur several months or years after exposure to radiation. Delayed health effects are described below in these subsections.

Each subsection also describes any hazards in these categories which may be posed by exposure to the radiation sources used by Honeywell–Measurex.

4.3.1. Cataracts

In a group of 8,000 survivors from Hiroshima and Nagasaki, 10 cases of full cataracts were found 11 years after the bombing. Studies indicate a threshold for cataract induction of 200 to 500 rem (2 to 5 Sv) for acute exposures to the lens of the eye.

4.3.2. Honeywell–Measurex Radiation Sources and Cataract Induction

The sources most commonly used in Honeywell–Measurex sensors, Kr-85 and Pm-147, do not pose a risk to the lens of the eye because the range of the most energetic beta ray emitted is less than the depth of the lens below the surface of the eye. Although Kr-85 does emit a small number of more penetrating photons (gammas), their contribution to the radiation dose is negligible compared to the dose from beta rays. The other sources, particularly X-ray and Sr-90, can pose a risk to the eye. Damage can be prevented by avoiding exposing the eye to the primary beam of the radiation source.

4.3.3. Cancer

Based primarily on studies of the exposed populations in Hiroshima and Nagasaki, there appears to be a relationship between cancer induction and radiation exposure. The available data correlating radiation dose and increase in cancer rate are for relatively large doses. These data indicate a linear relationship between increase in cancer rate and radiation dose.

Estimates of cancer risk at lower doses, such as those received by occupationally exposed persons, are extrapolations of this linear relationship. This is generally thought to be a very conservative approach assuming the worst possible risk. It is entirely possible that there is actually a threshold; that is, a dose below which the risk of cancer is not

increased. In the absence of proof, we assume that there is no threshold and that any increase in radiation exposure carries with it some increase in the risk of cancer.

According to the American Cancer Society, approximately 25 percent of all adults between the ages of 20 and 65 who are not occupationally exposed to radiation will develop cancer at some time. About one third of all cancers are fatal. In a group of 10,000 workers, one would expect about 2,500 to develop some sort of cancer at some time. Based on the extrapolations described above, if every person in another group of 10,000 workers received a radiation dose of 1 rem (0.01 Sv), one would expect approximately 2,503 to develop some sort of cancer. This is an increased cancer risk of 0.03 percent per rem of radiation dose where the cancer frequency in the absence of radiation exposure (above natural background) is 25 percent.

4.3.4. Honeywell–Measurex Radiation Sources and Cancer

As noted previously, the vast majority of Honeywell–Measurex employees who are monitored for radiation exposure receive no measurable dose during an entire year. This low dose, combined with the nonpenetrating nature of the radiation emitted by most sources used by Honeywell–Measurex, results in a minuscule to nonexistent cancer risk to both Honeywell–Measurex and customer employees due to occupational radiation exposure.

Even so, no one should be casual about working with radiation sources. It is important to remain aware that the risk involved will be very, very small if appropriate safety precautions are observed.

4.3.5. Nonspecific Life Shortening Effects

If cancer induction is not included, there is no conclusive evidence that chronic radiation exposure causes premature aging. In fact, there are some animal studies which appear to indicate that the opposite is true—that continuous exposure to low doses of radiation promotes health and longevity. At this time, however, the prudent approach is to assume that radiation exposure carries risk and that it should be minimized in any reasonable manner.

4.3.6. Genetic Effects

Genetic radiation effects refer to health effects which appear in offspring **conceived after** one or both parents are exposed to radiation. Genetic radiation effects are transmitted by sperm or egg cells which are altered by radiation exposure. (Note that this is different from prenatal radiation exposure—radiation exposure received by an unborn child—discussed earlier in this chapter.)

Genetic radiation effects have been observed in studies of animals exposed to high doses of penetrating radiation. However, genetic radiation effects have not been observed in humans. Studies of 30,000 offspring of irradiated Hiroshima/Nagasaki survivors plus a control group of 30,000 offspring of comparable, but unexposed, parents showed no difference in the incidence of stillbirths, infant deaths, birth weights, or malformations.

Although conclusive proof of radiation-induced genetic effects in humans does not exist, it would be reckless to assume there is no genetic risk to humans.

About 10.7 percent of all children born to parents who receive no occupational radiation exposure have a genetic disorder of some sort. Animal studies **suggest** that an exposure of both parents to 1 rem (0.01 Sv) prior to a child's conception increases the risk of a genetic disorder to about 10.707 percent. This means that out of a group of 100,000 children born to parents who received no radiation exposure—beyond normal "background" radiation from living on earth—an average of 10,700 are expected to have some genetic change. From the animal studies, one would expect to see 10,707 children with a genetic variant if their 200,000 parents each had received a penetrating dose of 1 rem (0.01 Sv).

For the reasons discussed under Section 4.3.4., "Honeywell–Measurex Radiation Sources and Cancer," personnel who follow radiation safety procedures need not be overly concerned with increasing the risk of genetic disorders in their offspring.

4.4. Regulatory Limits for Radiation Exposure

The sections that follow discuss the basis for the radiation dose limits and what those limits are for different groups within the population.

4.4.1. Establishment of Dose Limits

In the U.S., the Nuclear Regulatory Commission (NRC) and state agencies base their radiation dose limits on recommendations from the Environmental Protection Agency (EPA), the National Council on Radiation Protection (NCRP), and the International Commission on Radiological Protection (ICRP). The limits are such that the predicted risk to a worker who receives the maximum permissible dose (MPD) each year for 50 years is approximately the same as the occupational risks to workers in mining or heavy construction. Most other countries have adopted identical or very similar limits.

4.4.2. Dose Limits

A summary of applicable U.S. dose limits for occupationally exposed persons at least 18 years of age is given below. These limits apply to external radiation received while at work and do not include medical exposures. (External radiation means radiation from sources outside the body.)

- Penetrating radiation dose to whole body:
  the annual limit is 5 rem (0.05 Sv)
- Radiation dose to extremities (hands, feet, and skin):
  the annual limit is 50 rem (0.5 Sv)
- Radiation dose to the lens of the eye:
  the annual limit is 15 rem (0.15 Sv)

Occupational dose limits for persons under 18 years of age are 10 percent of the limits given above.

4.5. Average Annual Exposure Levels

The previous section discussed radiation dose limits. This section will provide information on the **average** radiation doses actually received by radiation workers and by members of the general population.

4.5.1. Radiation Workers

A worker in the U.S. radiation industry who wears a radiation badge receives on the average a penetrating dose of approximately 0.5 rem (0.005 Sv) above background per year. As noted previously, the average annual dose received by monitored employees at Honeywell–Measurex is very close to zero—that is, no increase above the exposure to natural background radiation.

4.5.2. Average Background Radiation for All Persons

The average radiation exposure received by individuals who do **not** work with or near sources of radiation is from several sources. These are described below.

1. Natural background due to cosmic radiation, radioactive materials naturally present in the earth's atmosphere, in the soil, and in our bodies is:

   0.1 rem/yr (0.001 Sv/yr)

2. Radiation due to mining, weapons development, nuclear energy, consumer products:

   0.01 rem/yr (0.0001 Sv/yr)

3. Radiation due to diagnostic and therapeutic medical uses:

   0.09 rem/yr (0.0009 Sv/yr)

4. This provides a total of:

   0.2 rem/yr (0.002 Sv/yr)

Note:
The levels given above are averages. Persons who do not undergo medical procedures involving radiation may have annual background doses of closer to 0.1 rem (0.001 Sv). The background radiation level also varies with altitude and with proximity to deposits of naturally occurring radioactive minerals. The atmosphere screens out cosmic radiation with the result that the background radiation level decreases with decreasing altitude.

4.6. Typical Dose Rates from Honeywell–Measurex Sensors

Honeywell–Measurex sensors in the U.S. are generally sold to customers who are not required to obtain a Specific License for radioactive materials. Therefore, they must meet strict requirements regarding external radiation level. Most Honeywell–Measurex sensors satisfy the following limits at a distance of 1 foot (30 cm) from the edge of the measurement gap (in the plane of the gap) with the source shutter open:

- Penetrating radiation 0.005 rem/hr (0.00005 Sv/hr)
- Nonpenetrating radiation 0.030 rem/hr (0.00030 Sv/hr)

The actual radiation levels near a sensor decrease as distance from the edge of the gap increases. At customer sites, the presence of the product being measured usually prevents close proximity to the sensor when the source shutter is open. In any case, the radiation levels surrounding the sensor (in its normal configuration) are low enough that a person need not be concerned if it is necessary to work nearby.

With the source shutter closed, the radiation levels adjacent to a radioactive source sensor head will be considerably lower than with the source shutter open. The radiation levels will, however, exceed the average background level that would be observed if no radioactive source were present. The fact that the radiation levels with the source shutter closed exceed the background level is normal and should not be a cause for alarm.

A. Information about Honeywell–Measurex Radioactive Sources

Honeywell–Measurex basis weight sensors contain one of 5 different radioactive materials. The following sections will describe these materials and their source capsules, and answer some frequently asked questions about radiation and safety.

A.1. What are the Radioactive Materials Used In Honeywell–Measurex Sources?

The source materials in Honeywell–Measurex sensors are radioactive elements. In order to describe them, we first need to review some things about elements and radioactivity.

Everything in nature is made of combinations of the 92 naturally-occurring elements. How these elements can combine in countless variations is determined by their chemical properties, that is, by the number and arrangement of each element's electrons. Typically an element has the same number of electrons and oppositely-charged protons. Electrons can readily come and go, however, so it is really the number of protons which determines an element's identity.

The elements are listed by scientists in the Periodic Table according to their proton number ("atomic number"). The abbreviation used in the Periodic Table for the name of an element is called the element's atomic symbol. Krypton, for example, which is the most common source material in Honeywell–Measurex sensors, is listed as Kr and element #36 because it contains 36 protons.

The five elements used by Honeywell–Measurex in its basis weight sensors are listed in Table A–1 below:

Table A–1. Radionuclides Used in Sensors (up to 1997)

Element	Symbol	Atomic Number
Krypton	Kr	36
Strontium	Sr	38
Ruthenium	Ru	44
Promethium	Pm	61
Americium	Am	95

A.2. Why Are These Elements Radioactive?

Every element comes in different varieties called isotopes. The isotopes of a given element are all chemically identical—they each have the identical number of electrons (and protons). Isotopes are different because they have different numbers of neutrons. These neutrons determine if an isotope is radioactive.

Radioactive Isotopes
Neutrons are non-electrical particles that are present along with the protons in the atom's nucleus. Isotopes of the same element are difficult to tell apart, except when enough neutrons are either missing or added to the nucleus so that the atom becomes unstable. The isotope of the element is then said to be radioactive.

Radioactive Decay
A radioactive isotope, being unstable, will decay into other elements. Radiation is emitted from the nucleus when it decays. Isotopes differ widely in their stability, and some will take thousands of years to decay substantially, while highly radioactive isotopes may decay almost completely in days or less. The time it takes for a radioactive isotope to decay to one-half of its initial quantity is called its half-life.

Atomic Weight
Isotopes are identified by their atomic weight. This number is essentially the number of protons and neutrons combined in the nucleus. Since the number of protons for a given element is always the same, the atomic weight really indicates the number of neutrons in the isotope.

Let's consider krypton as an example. The most common isotope of krypton has 36 protons and 48 neutrons in its nucleus, so it is referred to as Kr-84. The radioactive isotope of krypton used by Honeywell–Measurex has one more neutron in the nucleus, so it is referred to as Kr-85. It has a half-life of about 11 years—in other words, in about 11 years, half of the Kr-85 initially present will decay and half will remain radioactive. Half of the remaining radioactive krypton will decay in the following 11 years, and so on.

A.3. What is Radiation ?

When the nucleus of a radioactive isotope decays or breaks up, it will eventually change into one or more non-radioactive elements. To do this, the nucleus must shed some of its energy—in other words, it must emit radiation. There are four kinds of radiation we need to consider, called alpha, beta, gamma, and X-rays by the scientists who first investigated them.

Alpha Rays
Alpha rays are chunks of the nucleus ejected from the decaying isotope. They are the least penetrating form of radiation. If a source of alpha rays is somehow swallowed or inhaled, the alpha rays can be very harmful to living tissue. Outside of the body, however, alpha rays are easily blocked from causing harm by clothing, paper, etc. Americium is the only source presently (1997) used in Honeywell–Measurex sensors that produces alpha rays.

Beta Rays
Beta rays are electrons that are shot out of the nucleus of the isotope in a range of energies. This is the radiation used by most of the basis weight sensors, such as those with krypton sources, for making their measurements. The ability of beta rays to penetrate material depends on their energy. Honeywell–Measurex beta ray sources range in energy from relatively low (Pm-147) to high (Sr-90).

Gamma Rays
Gamma radiation is an extremely energetic form of light, a million times more energetic than the light we can see. Gamma rays are the most penetrating form of radiation. When it is interacts with matter, light, acts as though it is made of particles. The word "photon" is often used for light when describing how it interacts with matter as if a particle rather than a wave. (Photons may be gamma rays, X-rays, or other forms of light.) The source holders provide protection from photons that are either emitted by the source directly or that exist as a result of the source's presence.

X-Rays
X-rays are produced by all radioactive beta decay as a secondary effect. Like gamma rays, X-rays are an energetic form of light. They typically pass through soft tissue in the body, and are absorbed by bone.

A.4. The Source Capsules Used in Honeywell–Measurex Sensors

Each source capsule used by Honeywell–Measurex contains a very small amount of one radioactive isotope. The capsules are small metal cylinders, usually with a circular flange used for mounting in basis weight assemblies. The capsules are a few centimeters in height, and the top of each capsule is etched to identify its contents.

The source capsule must **never** be accessed except by persons specifically licensed to disassemble source holder assemblies.

The capsule window in the source holder assemblies is located immediately behind the shutter. The window is a thin metal foil which allows much of the radiation which strikes it to pass through. The capsule walls block a large fraction of the radiation which strikes them.

The likelihood that a source capsule will leak or rupture is very small for the capsules containing solid isotopes (that is, all of the isotopes except krypton). It is unusual for a source capsule containing krypton gas to develop a leak, but it has happened. This situation will be discussed extensively in the section below which deals with krypton.

A.4.1. What types of radiation come from the sensors?

The radiation from each source that is used for making measurements is summarized in Table A–2 below. Other radiation emitted by the source is also listed. Please note that other radiation may be emitted than just what is listed here. For example, it was mentioned above that all beta radiation produces X-rays as a secondary kind of emission.

Table A–2. Radiation From Sensors

Isotope	Radiation Used for Measurement	Additional Emissions
Kr-85	beta	gamma
Sr-90	beta	beta
Ru-106	beta	gamma
Pm-147	beta	beta
Am-241	gamma	alpha

A.4.2. How high are the radiation levels close to the sensors?

The radiation levels adjacent to Honeywell–Measurex sensors are low when the heads are in their normal position. All sensors shipped routinely by Honeywell–Measurex in Cupertino satisfy the following shutter-open dose rate limits:

non-penetrating or skin dose rate	0.03 rem/hr
penetrating dose rate—capable of penetrating to the depth of the lens of the eye or deeper	0.005 rem/hr

These dose rates apply at a distance of 30 cm (12 inches) from the edges of the heads or sheet guide extenders. A small percentage of systems which are built for customers with specific radioactive materials licenses may exceed these limits.

In reality, the shutter-open **penetrating** dose rate 30 cm from Honeywell–Measurex sensor heads is rarely more than 10 percent of the above limit. The **non-penetrating** dose rate approaches the 0.03 rem/hr limit for some sensors.

A.4.3. What does that mean?

This means that the dose rate outside the measurement gap of the sensors is quite low. In order to exceed the U.S. limits for occupational exposure to the skin, a person would have to spend more than 1600 hours in one year at 30 cm or less from a sensor. The source shutter would have to be open and contain no product in the measurement gap. The probability of this occurring is negligible.

In essence, this means that a person can work around a sensor without being concerned about receiving a large radiation exposure. At the same time, we assume that all radiation exposure carries some risk. The reasonable approach is to avoid all unnecessary exposure and to spend no more time than necessary near sensors when the source shutter is open.

A.4.4. What causes radiation to be present outside the gap?

Radiation present outside the measurement gap is primarily due to particles and X-rays which scatter out of the primary beam. The maximum energy of these scattered particles is approximately the same as the energy of the particles in the primary beam. However only 0.1% or fewer of the particles in the primary beam scatter to a distance outside of the gap.

It is important to keep in mind that the level of the scattered radiation is below the dose rate limits described above.

A.4.5. What would happen if my hand were exposed to an unshielded source?

The measurement gap for sensors with isotopic sources is typically 1 cm (0.4 in) wide, and the primary radiation beam emitted by the sources is less than 2 cm (less than 1 in.) in diameter. It is difficult for an average adult to place his or her hand between this gap and into the primary beam when the heads are together. Some systems do have significantly wider measurement gaps, however, so it is worth considering the consequences of placing one's hand into the beam.

If a hand were exposed to an unshielded source, it could produce serious damage. The type and extent of the damage depends on the type and energy of the radiation in the primary beam, and on the time of exposure.

The krypton and promethium sources produce beta rays that penetrate only to the depth of the skin. The beta rays from strontium and ruthenium sources are more energetic, and will penetrate into the tissue and bones of the hand.

The primary beam of americium sources is composed of gamma rays, and krypton and ruthenium also produce gamma rays. Gamma rays can be extremely penetrating and capable of passing through a human hand.

The possibility of cancer is a long term health concern from exposure to penetrating radiation. The risks are very difficult to estimate in the abstract, but certainly increase with exposure time. The more immediate consequences of exposure to a penetrating beta beam would be burn-type injuries both to the skin and to the deeper tissues of the hand. Again, the severity of the injuries would depend on the exposure time.

Kr-85 is the most common source in Honeywell–Measurex sensors, and it is useful to consider the specifics of exposing a hand to the Kr-85 beam.

None of the emitted beta particles can penetrate deeper than 1/4 cm (1/10 in.) below the surface of the skin. The gamma rays emitted by Kr-85 are much more penetrating—50 percent of them can penetrate to a depth of 7 cm (2.8 in.) or more below the skin surface, thicker than the width of the hand. However, because gamma rays from Kr-85 are emitted in much smaller quantities than beta particles, their contribution to the radiation hazard is relatively small.

Exposure to the beam of an unshielded Kr-85 source of the type used by Honeywell–Measurex can produce serious damage to the skin. At short distances, the source output is sufficient to cause the equivalent of a third-degree burn to the exposed skin in a matter of minutes. Burns of lesser severity, equivalent to second- or first-degree thermal burns, can occur from shorter exposure time.

In addition, any increase in skin dose increases the risk of skin cancer. Therefore, it is very important to avoid the possibility of direct exposure to a Kr-85 source.

A.5. What is Krypton?

Krypton is the substance most often used as a radiation source in Honeywell–Measurex sensors. Krypton is called an inert gas since it does not react readily with other substances.

The word "krypton" comes from the Greek word meaning "hidden." Krypton makes up about one part per million of the earth's atmosphere. Both radioactive and stable isotopes of krypton are also produced in nuclear reactors. This krypton can be recovered from the used fuel rods of fission reactors. Such fuel reprocessing is the source of commercially available Kr-85 used in Honeywell–Measurex sensors.

A.5.1. What type of radiation does Kr-85 emit?

Each time a Kr-85 nucleus undergoes a decay, it emits a beta particle. In about one out of every 244 nuclear decays, Kr-85 also emits a high-energy photon.

A.5.2. Can a krypton capsule develop a leak?

Krypton source capsules contain a very small amount of pressurized gas. The source window is a thin metal foil which permits more of the radiation to be transmitted than do the thicker capsule walls. A leak can develop in the foil window or in the weld between the foil and the capsule wall. When that happens, the capsule may slowly leak its contents over a period of weeks or months. Alternatively, the source may vent most of the krypton it contains within a very short period of time.

A.5.3. What are the symptoms of a source capsule leak?

A slow leak may not be immediately obvious since Kr-85 sources normally decrease in output by about 0.5 percent per month due to radioactive decay. More rapid leaks may cause large drops in reference counts and increased sensor instability. However, these same symptoms can caused by other conditions, such as debris buildup in the basis weight assembly.

A.5.4. What should I do if I think a krypton capsule may be leaking?

If possible, maximize the ventilation in the area containing the Kr-85 source. Honeywell–Measurex recommends that you contact your radiation safety office and the Honeywell–Measurex Radiation Safety Office promptly.

A.5.5. Is there a hazard to me or other employees due to a Kr-85 capsule leak?

In the mill environment, there is no reasonable way that a Kr-85 capsule leak could pose a hazard to you or others. This is because:

- Krypton is an inert gas, which does not contaminate objects or accumulate in body tissue.
- Krypton gas dilutes and disperses very rapidly.
- Except when in a fairly concentrated form, the quantity of Kr-85 is not sufficient to result in hazardous radiation levels.

Kr-85 leaks are infrequent events. They are a subject of concern, but should not be a cause of alarm.

A.6. What is Strontium?

Strontium is element #38 on the Periodic Table. It occurs naturally in a variety of minerals in the Earth's crust. Strontium is named after the town in Scotland where it was discovered. In its pure form, strontium is a somewhat soft, yellowish solid similar to calcium in many of its properties.

Both radioactive and stable strontium are produced as fission products in nuclear reactors. This strontium can be recovered from the used fuel rods of fission reactors. Such fuel reprocessing is the source of commercially available Sr-90 used in Honeywell–Measurex sensors.

A.6.1. What type of radiation does Sr-90 emit?

When a Sr-90 atom decays it emits a beta particle with a range of energies similar to Kr-85. After this decay, Sr-90 briefly becomes another radioactive isotope, which emits one more beta particle of much higher, penetrating energy. Unlike Kr-85, the decay of Sr-90 results in no gamma radiation. As mentioned above however, photons with X-ray energies accompany all radioactive decay.

A.7. What is Ruthenium?

Ruthenium is element #44 on the Periodic Table. It is a hard, silvery metal that can be refined from ores. Commercially, ruthenium is mixed with other metals to make the resulting alloy harder.

Like krypton and strontium, a radioactive isotope of ruthenium is produced in nuclear reactors. The recovered isotope is the source of Ru-106 that was used in the past in some Measurex sensors.

A.7.1. What type of radiation does Ru-106 emit?

The decay of ruthenium 106 itself provides only low energy beta rays. However when Ru-106 decays it briefly becomes another radioactive isotope which produces high energy radiation. Every 100 decays of Ru-106 produce 79 high energy beta particles and 31 energetic gamma rays.

A.8. What is Promethium?

Promethium is a somewhat unusual element. All of its isotopes are radioactive, and it is the only element of its kind that has not been detected on earth. It is element #61 on the Periodic Table, and is produced in nuclear reactors as a byproduct of uranium fission. It is named after a mythical Greek figure who brought the gift of fire to mankind.

A.8.1. What type of radiation does Pm-147 emit?

Every Pm-147 decay produces one beta particle at a non-penetrating energy (less than 0.1 cm of skin). No gamma particles result from Pm-147 decay. Like all radioactive decay, however, X-rays are produced as a secondary effect.

A.9. What is Americium?

Americium is a synthetic element. It has never been found in nature, and was first made by American scientists (who gave it its name) in 1944. It is created by bombarding plutonium with neutrons to produce the silvery-white metal. Americium was the fourth new element to be created in this manner. It is used as the source element in many home smoke detectors.

A.9.1. What type of radiation does Am-241 emit?

Americium is used in Honeywell–Measurex sensors as a source of gamma rays. About 86% of Am-241 decays produce a relatively low energy gamma ray. A more energetic gamma photon is produced in about 13% of decays.

Am-241 primarily decays by emitting alpha ray particles. These particles are not used by the sensor and they cannot penetrate the walls or the window of the source capsule. They would be effectively blocked by a few centimeters of air.

A.10. How Much Radioactive Material is in the Sources?

Each Honeywell–Measurex sensor containing a radioactive source is labeled to tell, among other things, the type and quantity of radioactive material and the assay date. The quantity listed on the label is a nominal value. In no case will the actual quantity exceed the nominal value. Nominal values for radioactive sources presently used in Honeywell–Measurex sensors are listed in Table A–3 below:

Table A–3. Nominal Values for Radioactive Sources (1997)

Isotope	Activity
Kr-85	1 curie
Sr-90	0.05 curie
Pm-147	0.54 curie
Am-241	0.50 curie

A.10.1. What is a curie?

An amount of radioactive material is usually measured in terms of "activity" (instead of weight or volume). The activity tells how many times a radioactive decay process occurs in a radioactive source within a given time. Activity is measured in special units called curies. Another unit, the bequerel, is also used.

One curie corresponds to a quantity of material which undergoes 37 billion nuclear disintegrations per second. The activity of a radioactive source isn't necessarily related to the size or mass of the source. The activity of a source also does not necessarily correspond directly to the radiation level it produces. For example, a 10,000 curie source of one material might produce a much smaller radiation level than a 0.05 curie source of another material.

However, the activity does say something about the radiation produced when comparing two sources that are identical in all other respects. For example, for a 1 curie Sr-90 source and a 0.1 curie Sr-90 source that are otherwise identical, the 1 curie source will produce 10 times the radiation level that the 0.1 curie source will produce at the same distance.

A.10.2. What does the half life have to do with the source activity?

The activity listed for the source is for a particular date which is usually called the "assay date." Because the source is radioactive, the source is transforming into another substance. For example, in a 1 curie Kr-85 source, Kr-85 nuclei are disintegrating and becoming Rb-85 nuclei—a stable, non-radioactive substance—at the rate of 37 billion nuclei per second. Since there are less and less Kr-85 nuclei left, the number of disintegrations per unit time gradually decreases.

When the disintegration rate, or activity, falls to half the original activity (that is, activity on the date of the assay), we say that one half-life has passed. The half-lives of the radioactive sources used by Honeywell–Measurex are listed in Table A–4 below:

Table A–4. Half-Live of Radioactive Sources

Isotope	Half-Life (in Yrs)	Approximate Decrease in Activity per Year
Kr-85	10.7	6%
Sr-90	27.7	2%
Ru-106	1.02	49%
Pm-147	2.62	23%
Am-241	432	0.2%

Notice the approximate annual decrease in source activity. The source activity listed for a sensor is meaningful only when given with the assay date.

Depending on the source type, the product type and customer requirements, the decrease in the rate of radiation emission may or may not be significant.

B. Figures

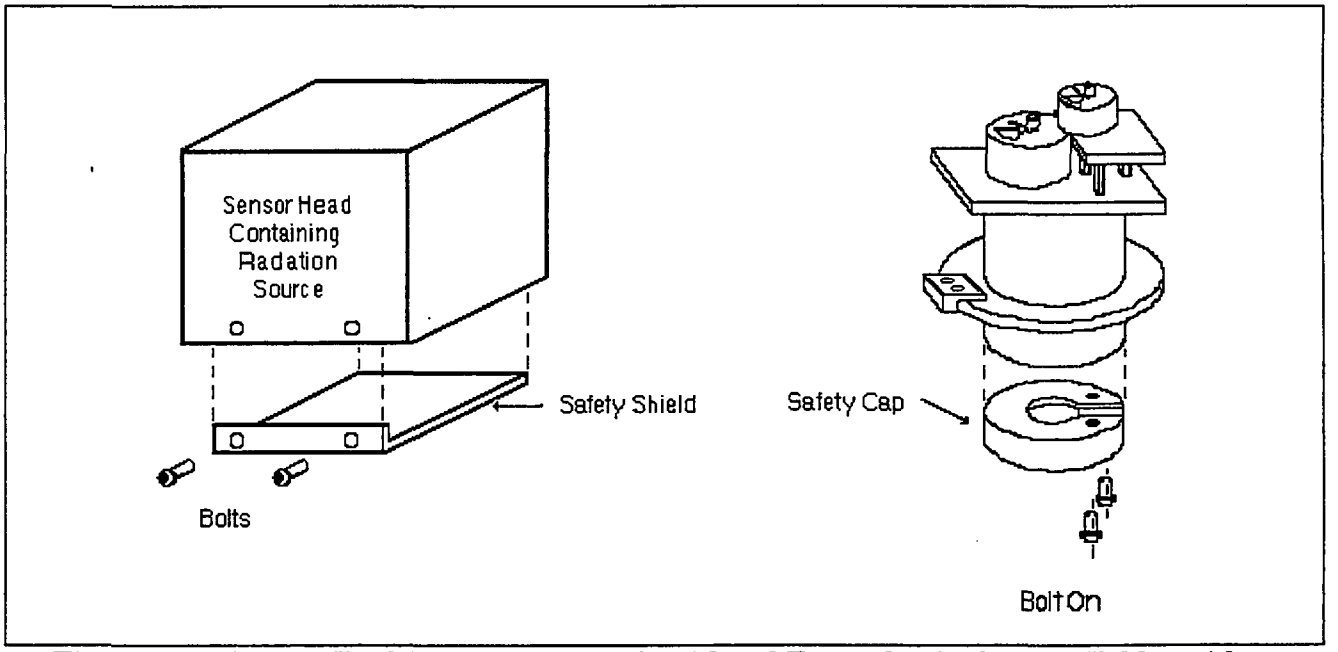

Figure B–1. Sensor Head Safety/Shipping Shield and Example of a Source Holder with a Safety Cap

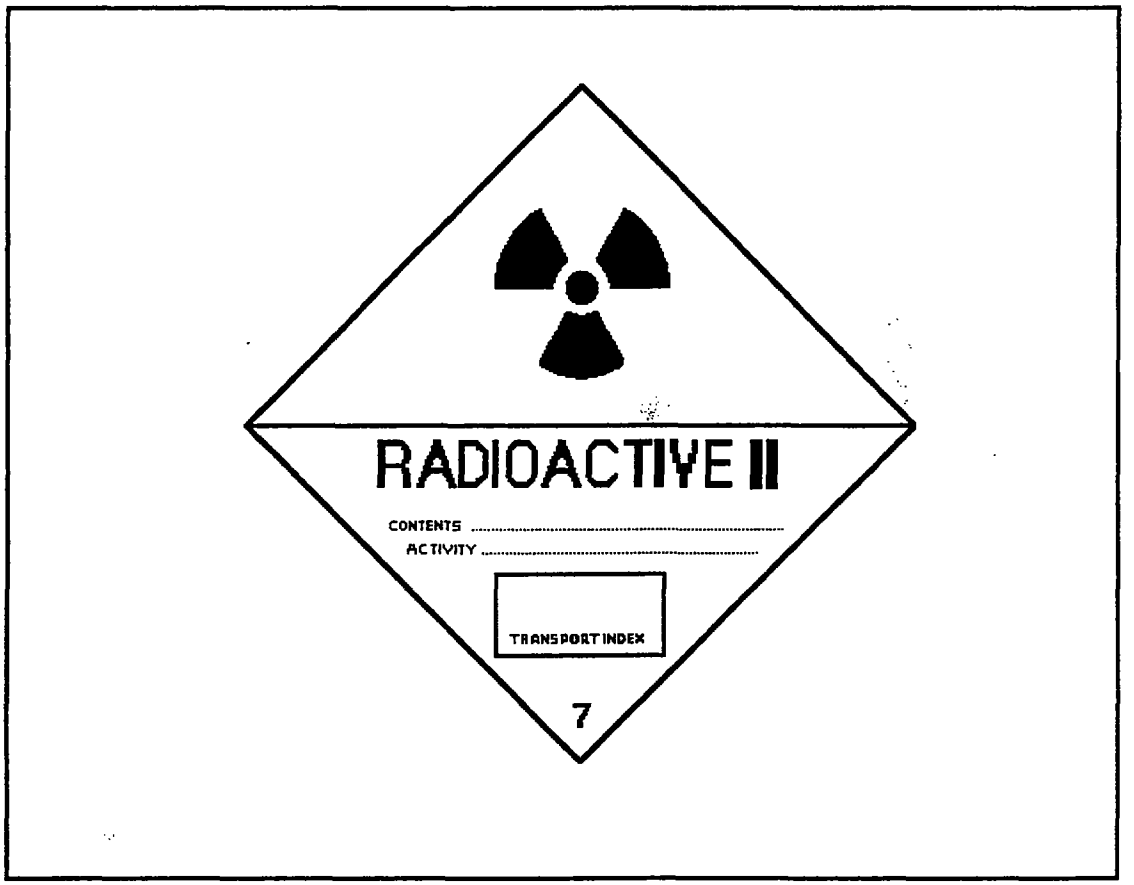

Figure B–2. Sample Radioactive Material Shipping Label (not actual size)

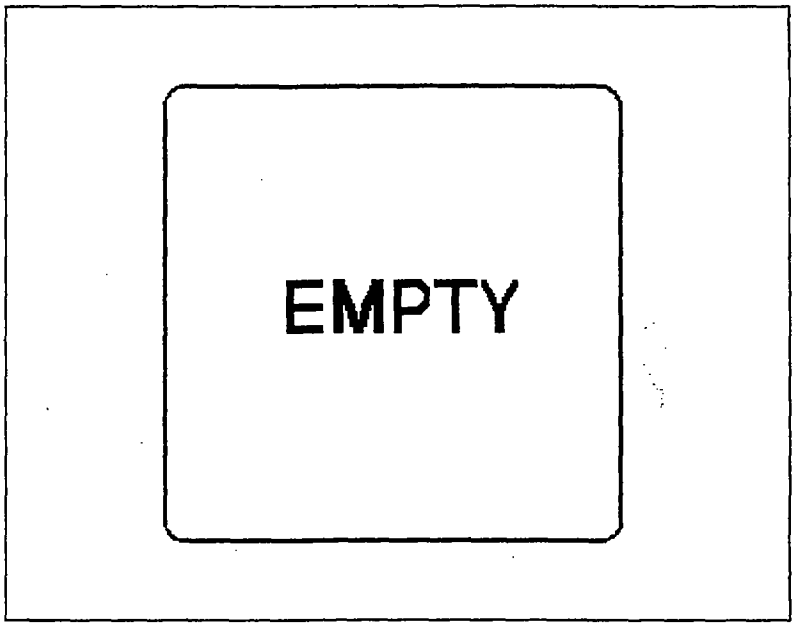

Figure B–3. Sample Empty Label

This label is used to indicate that shipping containers or sensor heads do **not** contain a radioactive source. The label shown in this diagram is smaller than its actual size.