Radiological Survey Instruments and Dosimetry Devices

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INTRODUCTION

This module provides general information about radiological survey instruments. Basic functions and limitations are discussed. Because there are many models of survey instruments available, this discussion provides only a general description of survey instrument types and uses. For participants wanting more detailed descriptions of specific devices and their functions, information on several commonly available instruments is included in the appendix to this module.

PURPOSE

The purpose of this module is to provide you with a general awareness and understanding of radiological survey instruments and how they can be used to survey for radiation exposure and contamination. Proper use of radiological survey instruments will provide you with more information on the hazards present at the scene.

MODULE OBJECTIVES

Upon completion of this module, you will be able to:

1. Identify two categories of radiological survey instruments.
2. State the proper application and limitation of contamination survey instruments.
3. Identify a method for checking for the presence of removable contamination
4. State the proper application and limitation of radiation exposure survey instruments.
5. Identify the maximum radiation levels expected on shipping packages and/or transport vehicles.
6. Identify commonly used dosimetry devices.

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RADIOLOGICAL SURVEYS AND INSTRUMENTATION

The use of radiological survey instrumentation by responders at an incident scene is optional. The Emergency Response Guidebook does not specifically recommend the use of radiological survey instruments during the initial response phase of the incident. Use of these instruments will give you more detailed information about the radiological hazards present at the scene.

Radiation cannot be detected by our senses. By using radiological survey instruments, properly trained responders can easily and accurately detect radiation. There are two general categories of radiological survey instruments available. One category of instruments is designed to measure radiation, while the other is designed to measure contamination. Some instruments are designed to measure both radiation and contamination.

Basic Theory

Similar to the way a radio converts radio waves to sound, a radiological survey instrument converts radiation energy to a meter reading. In a radiological survey instrument, ionizing radiation interacts with material in the detector to produce ions. The detector collects these ions and sends them to the instrument which produces an audible and/or visual response. Some radiological survey instruments combine the detector and meter in one unit, while others may have the detector attached to the meter by a cable (See examples below).

There are many different models and types of radiological survey instruments with a variety of features and controls1. Because they have different operating characteristics, you should know how to operate those used in your jurisdiction.

CONTAMINATION SURVEY INSTRUMENTS

Contamination survey instruments are very sensitive and measure the presence of radioactive material in terms of counts per minute (CPM). Instruments that measure effects in CPM are useful for detecting contamination on personnel and equipment. A limitation of contamination survey instruments is that they should not be used to measure radiation exposure. Contamination surveys should always be reported in CPM.

Application of Contamination Survey Instruments

The purpose of a contamination survey is to locate radioactive material in unwanted locations. Contamination surveys are useful for the following:

- Locating contamination on personnel and equipment
- Determining the effectiveness of decontamination
- Verifying contamination control boundaries
- Determining the extent and magnitude of a contaminated area

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Because the difference between measurements of background radiation and that produced by contamination may be slight, it is important to determine the background (naturally-occurring) radiation level prior to performing a survey. Determine background radiation levels by observing the meter reading in the cold zone. Contamination surveys should be preformed in areas with low background radiation. The higher the background radiation level, the harder it is to determine contamination levels.

Begin by following your local procedures or manufacturer's recommendations for instrument pre-operational checks and instrument calibration frequency.

- Verify that the instrument is on, set to the lowest scale, the audio can be heard, and there is visual response
- The probe/detector should be held within 1/2 inch of the surface being surveyed
- Move the probe slowly, approximately 1 to 2 inches per second
- If the count rate increases while surveying, pause for 5-10 seconds over the area to provide adequate time for instrument response

Assessing Packages for External Contamination

If a package appears to be breached or you suspect it may be breached, you can check for the presence of removable contamination by taking a smear of the package. Removable contamination is defined as the radioactive material that can be transferred from a surface by rubbing with moderate pressure. The smear (or wipe/swipe test) is the universal method of assessing removable contamination. A small cloth, filter paper, or fiberglass disk is used to “wipe” an area or object suspected of being contaminated. A smear should cover a minimum surface area of 100 cm^2 (approximately equal to a square measuring 4” by 4”). Smears should be dry and taken using moderate pressure. Protective clothing should always be worn when taking smear samples to minimize the chance of personnel contamination.

Individual smear samples should be kept separate to avoid cross contamination. Smear packets (similar to the one pictured at right) make this easy and available from a variety of vendors. If pieces of cloth or paper towel are used, they can be kept separate by using plastic storage bags. Data should be maintained indicating the date and location of each smear sample.

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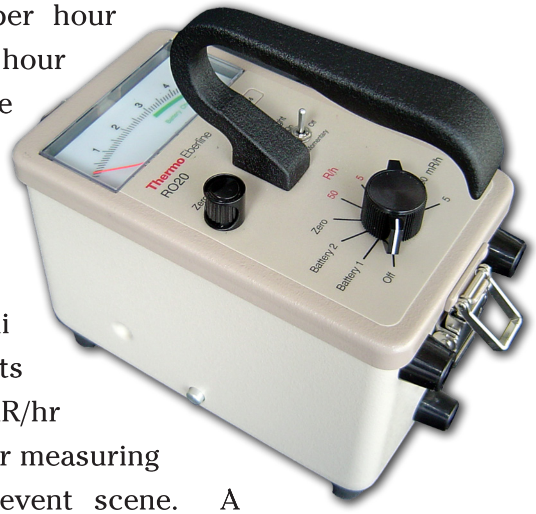
Smears can be counted (surveyed) in the field using a contamination survey meter. The smear(s) should be counted in a low background area by properly trained personnel. Count the smears by holding the probe approximately ½" from the surface of the smear. Pause for 5-10 seconds over the area to provide adequate time for instrument response. Become familiar with your jurisdiction's or state's guidelines for when an object is considered contaminated. For example, some jurisdictions use twice background or 100 CPM above background as a positive indication of contamination. Field counting techniques, like those described here, can be used to check for removable contamination, but may not be appropriate for releasing material as "clean." Release surveys should be conducted under the direction of the state or local Radiation Authority.

RADIATION EXPOSURE SURVEY INSTRUMENTS

Exposure rate survey instruments usually measure radiation in terms of milliroentgen per hour (mR/hr) or roentgen per hour (R/hr). These effects are typically recorded in the biological equivalent of mrem/hour or rem/hour or, if the instrument uses the SI units, micro or milli sieverts/hour. Instruments that measure effects in mR/hr or R/hr are most useful for measuring radiation fields at the event scene. A limitation of radiation exposure survey instruments is that they are generally not as sensitive as contamination survey instruments and may not efficiently detect some types of contamination.



Application of Radiation Exposure Survey Instruments
The purpose of a radiation exposure survey is to locate and measure sources of radiation. Radiation exposure surveys are useful for the following:

- Establishing control zone boundaries
- Controlling personnel exposure
- Assessing package integrity
- Locating sources of radiation

Follow your local procedures or manufacturer's recommendations on instrument pre-operational checks and instrument calibration frequency. Prior to performing a radiation survey, verify that the instrument is on, the range selector switch is on the lowest scale, the audio can be heard (if applicable), and a visual response registers on the meter.

Many radiation exposure rate survey instruments are designed to detect both beta and gamma radiation. These instruments

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typically employ some type of rotating or movable beta shield that can be opened to admit beta radiation (see photos below). With the detector shield closed, beta radiation is blocked out and only gamma radiation is detected. With the beta shield open, both beta and gamma radiation are detected. The beta dose contribution from a measurement can be determined by subtracting the reading taken with the beta shield closed from the reading taken with the beta shield open (open window reading – closed window reading).

When surveying for beta and gamma radiation, radiation measurements should be made by approaching the

area or object to be surveyed with the detector extended in front of you and the beta shield, if applicable, in the open position. With the shield in the open position, the instrument will simultaneously detect gamma and beta radiation.

Periodically monitor in a 360 degree circle to ensure that you have not walked by a source of radiation. Monitor for radiation with the detector at waist level and periodically check above and below this level. When a source of radiation is discovered, survey as necessary to determine its approximate location.

When performing a radiation survey, it is useful to listen to the audio response so that even if you are temporarily distracted, the response to a radiation field can be heard.

The following table can be used to assist you in converting the SI units (sieverts) to the traditional units (millirem).

Reading in sieverts	Equals	Reading in mrem &rem
1 microsievert	=	0.1 millirem
1 millisievert	=	100 millirem
1 sievert	=	100 rem

ASSESSING PACKAGE AND VEHICLE RADIATION LIMITS

Radiation Limits on Packages in Non-exclusive Use Shipments

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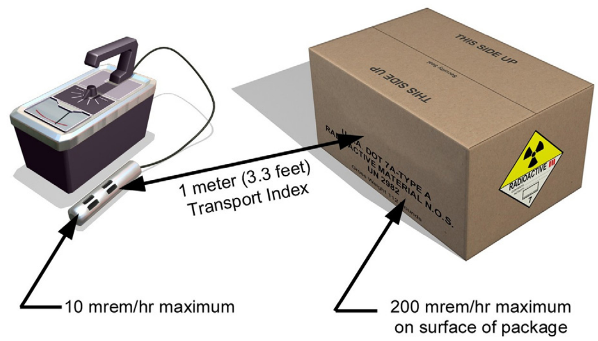
When radioactive material is transported under normal conditions (non-exclusive use), each package must be designed and prepared or shipment so that the maximum radiation level does not exceed 200 mrem/hour at any point on the external surface of the package and the transport index does not exceed 10. When assessing a package's integrity at an accident scene, you can use this information as a baseline for determining if damage has occurred to the package. For example, a dose rate reading of 250 mrem/hour on contact with the exterior of a package could indicate potential damage.



Additionally, you should not expect to see radiation dose rates on the surface of the vehicle transporting the material that are greater

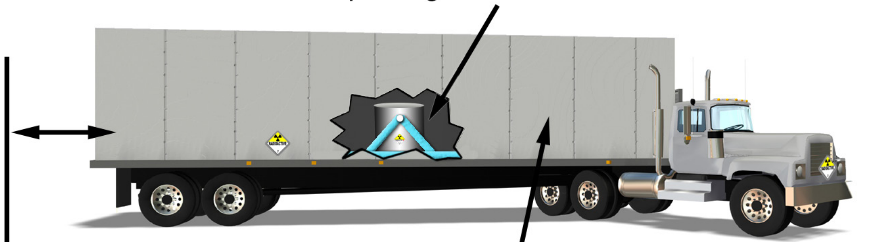
than the limits allowed for the packages inside the vehicle. An exception might occur if several packages with dose rates close to 200 mrem/hour were located near the exterior surface of a vehicle; in such a case, you may see a dose rate reading on the exterior of the vehicle somewhat above 200 mrem/hour.

Radiation Limits for Exclusive Use Vehicles

Packages that exceed the radiation levels previously mentioned must be transported by exclusive use[1]. Packages in exclusive use vehicles may have radiation levels up to 1,000 mrem/hour on their exterior surface provided that:

a) the shipment is made in a Closed Transport Vehicle[2];
b) the package is secured within the vehicle so that its position remains fixed during transportation, and
c) there are no loading or unloading operations between the beginning and end of the transportation.

No point on the outer surfaces, or outer plane, of the vehicle may exceed 200 mrem/hour. Radiation levels at 2 meters from the vehicle



cannot exceed 10 mrem/hour. Drivers of exclusive shipments are required to have specific written instructions for the shipment. These instructions must be included with the shipping papers.

Note: To determine if a shipment is being transported under the exclusive use provisions, you can look at the shipping papers, ask the driver, and/or contact the shipper.

READING THE METER FACE

Many of the newer survey instruments have a digital display and

[1] "Exclusive use" means a single shipper transports the material and all initial, intermediate, and final loading and unloading are carried out in accordance with the direction of the shipper or receiver.

[2] Closed Transport Vehicle means a transport vehicle or conveyance equipped with a securely attached exterior enclosure that, during normal transportation, restricts the access of unauthorized persons to the cargo space.

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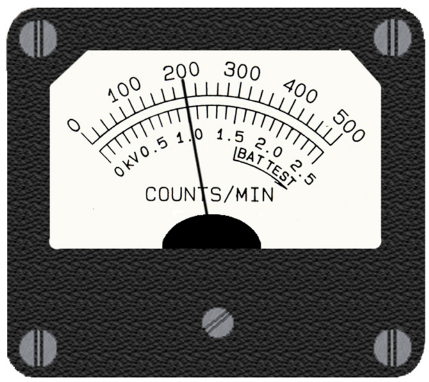
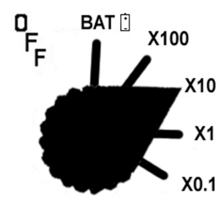
will automatically adjust the range from microrem to millirem to rem per hour or from counts per minute (CPM) to kilo counts per minute (kCPM). The traditional analog instruments can be more difficult to read than digital instruments. Often it requires that the user multiply the reading displayed on the meter face by a multiplier, depending on which scale the instrument range multiplier switch is set to. For example, in the illustration below, the reading on the meter face shows a reading of 200 CPM; since the range multiplier switch is set to X10, the 200 is multiplied by 10 so that the actual reading is 2,000 CPM.

As discussed earlier, contamination survey results are usually



200 CPM on the meter face times 10 on the range multiplier switch equals 2,000 CPM



recorded in CPM and radiation survey results are usually recorded in mR/hr. For those instruments that display in both CPM and mR/hr, the user should determine which units to record their reading in based upon the type of survey (radiation or contamination) being performed. Contamination surveys are best performed with pancake style detectors and radiation surveys are best performed with side window GM or “hotdog” style detectors. An example of each type is shown below:

In the case of the CD V-700 (pictured at right), the meter face reads

Pancake Style Probe

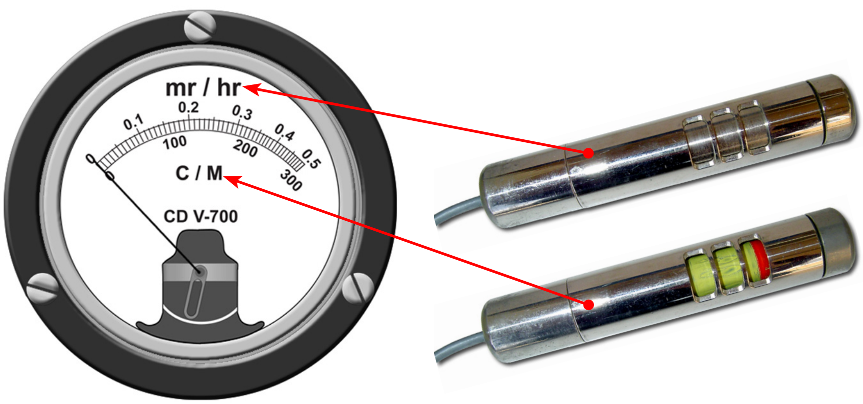
Hotdog Style Probe

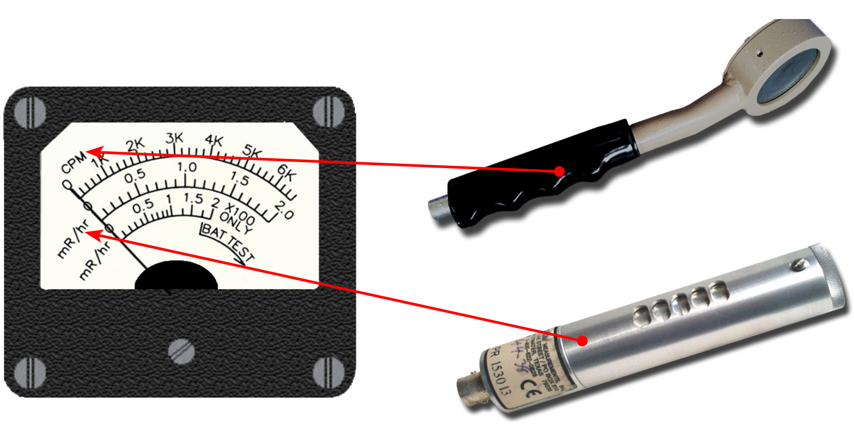
with the standard side window GM or "hotdog" probe (as seen in the photo to the right), readings should be recorded in mR/hr when the probe window is closed and in CPM when the probe window is open.

With the Ludlum style instruments, readings should be recorded in CPM with the pancake style probe attached and in mR/hr with the hotdog probe attached. The graphics below illustrate these points.

Personal Radiation Detectors

Another type of radiation detection instrument now available is a small, pocket sized device that alerts the user to the presence of





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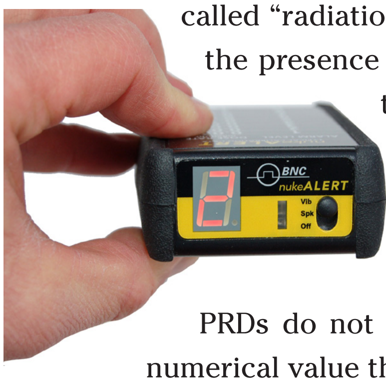
Radioisotope Identifiers

Another type of radiation survey instrument sometimes employed by advanced HazMat teams and state and federal personnel is called a Radioisotope Identifier. These units are commonly referred to as a RID (Radioisotope IDentifer) or RIID (Radioactive Isotope IDentifer or Radiation Isotope Identification Device). RIDs are capable of identifying gamma-emitting isotopes and typically include a dose rate measurement feature. Many are also are equipped with neutron detection capability. In addition to giving the user the name of the gamma-emitting isotope (e.g., Co-60, Ir-192, etc.), many RID devices will tell the user what the material is commonly used for (e.g., medical, industrial, natural, etc.). These instruments do provide additional information to the responder but require additional training to understand the operational limitations and capabilities.

RID devices are often used to identify illicit trafficking of radioactive materials. Often a two step process is employed whereby the radioactive material is first located—often using a common radiation survey instrument—and then a RID device is used to identify the isotope. The purpose of isotope identification is to determine if the material setting off a radiation detector or monitor is from a legitimate source. For example, it is common for shipments of materials containing naturally occurring radioactive materials (e.g., bananas, cat litter, fertilizer, ceramics, etc.) to set off a radiation monitor. If someone were trying to smuggle illicit radioactive material inside one of these shipments, a RID device could be used to identify a man-made radioisotope present inside a shipment containing naturally occurring radioactive material.

elevated radiation levels and possible radioactive material. Often called "radiation pagers," they can be used to detect the presence of illicit nuclear materials. Be aware that many of these instruments are not designed to measure accumulated dose. They are extremely sensitive to low levels of gamma radiation and have a fast response time. Many PRDs do not display dose rates but rather give a numerical value that ranges from 0 to 9. This numerical value corresponds to a relative level of elevated radiation above background, where "9" represents the highest.



DOSIMETRY DEVICES

Although not required at an incident scene, dosimetry devices are useful for keeping track of your total accumulated radiation dose. A dosimeter is like the odometer on your car. For example, where the odometer measures total miles traveled, the dosimeter measures the total amount of dose you have received. There are several different types of dosimeters available. Some commonly used examples are discussed here.

Self Reading Dosimeters

A self reading dosimeter (SRD) measures the radiation dose in roentgens (R) or milliroentgens (mR). Generally, SRDs only measure gamma and X-ray radiation.

SRDs are called by many names: direct reading dosimeter (DRD), pocket ion chamber (PIC), and pencil dosimeters are a few common names.

To read the dosimeter, hold it up to a light source and look through the eyepiece. You should always record the SRD reading before you enter a radiation field (hot zone). Periodically, (at 15 to 30 minute intervals) read your SRD while working in the hot zone and upon exit from the hot zone. If a higher-than-expected reading is indicated, or if the SRD reading is off-scale,

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you should:

- Notify others in the hot zone
- Have them check their SRDs
- Exit the hot zone immediately
- Follow local reporting procedures

If you are using a low range dosimeter (e.g., 0 to 200 mR), you should consider exiting the hot zone if the dosimeter reads greater than 75% of full scale. The reason for this is to prevent your dosimeter from going off scale; if your dosimeter goes off scale, it will no longer keep a record of the dose you received. A dosimeter can be recharged or "zeroed" after each use. Record the final reading upon leaving the hot zone. Exercise care when using a SRD, they are sensitive instruments. Rough handling, static electricity, or dropping a dosimeter may result in erroneous or off-scale readings.

Electronic Dosimeters

The electronic dosimeter serves the same basic function as the SRD, except that it has a digital readout that displays the total dose received by the wearer in milliroentgens (mR) or millirem (mrem). Electronic dosimeters are available from various manufacturers in a variety of sizes and shapes. There are many options available, depending on the required or desired response.

Many electronic dosimeters have an audible response that indicates the exposure rate through a series of chirping noises. The frequency of the chirping increases and decreases in relation to the dose rate. These "chirpers" provide the advantage of an audible warning when dose rates increase.

Thermoluminescent Dosimeters

Thermoluminescent dosimeters (TLDs) do not provide an "on-the-spot" indication of accumulated dose as the previously mentioned dosimeters do. Specialized equipment is needed to retrieve the radiological exposure data stored by the TLD. TLDs are not usually available for use by individual fire departments or local agencies. Specialized hazardous material response teams and state and federal radiological response organizations usually wear TLDs.

1. Radiation itself (can/cannot) be detected by our senses (circle the correct answer).

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Check Your Understanding

2. Radiation (can/cannot) be measured easily and accurately (circle the correct answer).

3. Some radiological survey instruments are used to survey for __________, and others are used to detect and/or measure _________ exposure.

4. If a radiological survey instrument measures effects in counts per minute (CPM), it is going to be most useful as a contamination survey instrument. True/False.

5. A limitation of contamination survey instruments is that they are not designed to measure __________ exposure.

6. The purpose of a contamination survey is to locate radioactive material in unwanted locations. True/False.

7. Taking a ________ is the universal method of assessing removable contamination.

8. The maximum radiation level on packages in non-exclusive use vehicles is _____ mrem/hour.

9. The maximum contact radiation level allowed on packages transported inside exclusive use closed transport vehicles is _____ mrem/hour.

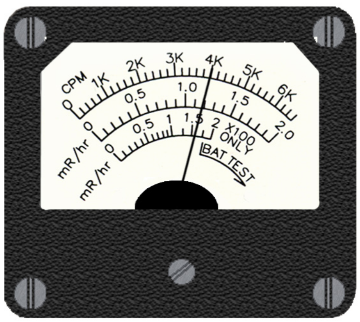
10. A self reading dosimeter (SRD) keeps track of accumulated (radiation/ contamination) dose while in a field of radiation. (Circle the correct answer).

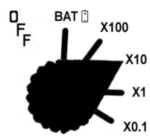
ANSWERS

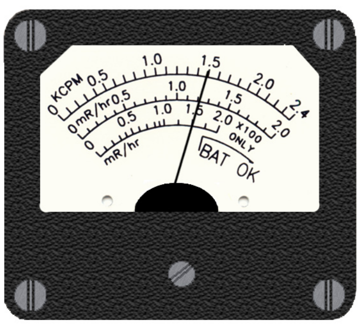
1. cannot
2. can
3. contamination
   radiation
4. True
5. radiation
6. True
7. smear
8. 200
9. 1,000
10. Radiation

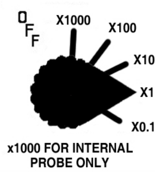
Ludlum Instrument

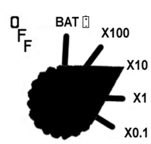
Meter Reading | **Range Selector** | **Probe Used** | **Results**

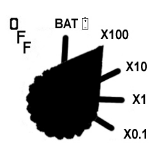




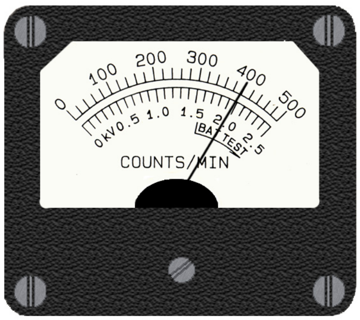
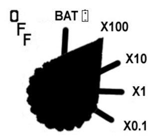
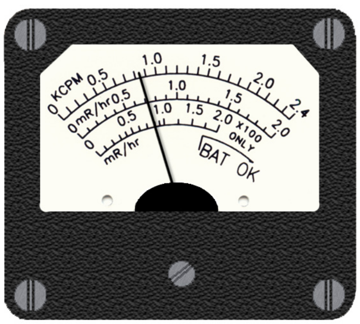
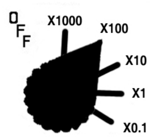
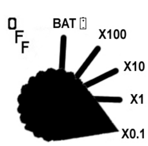
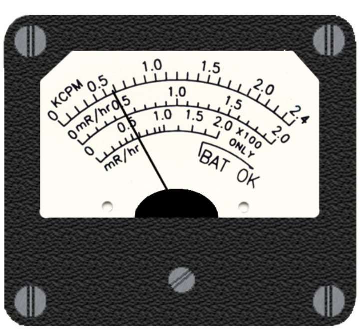
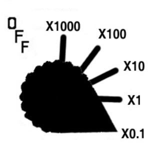






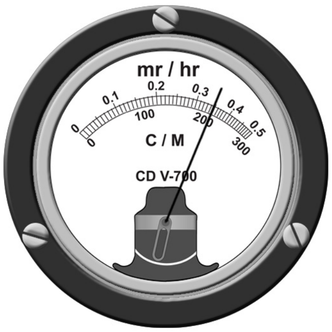


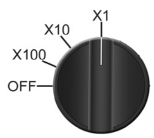
Ludlum Instrument

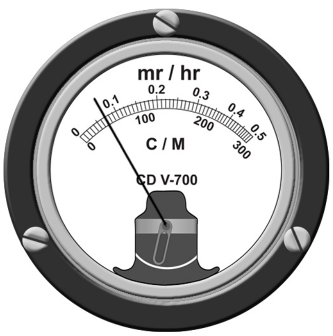
Meter Reading	Range Selector	Probe Used	Results
			________________
	 x1000 FOR INTERNAL PROBE ONLY		________________
			________________
	 x1000 FOR INTERNAL PROBE ONLY		________________

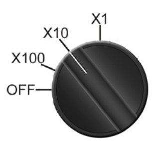
CD V-700 Instrument

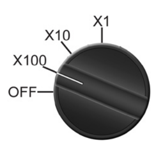
Meter Reading	Range Selector	Probe Used	Results

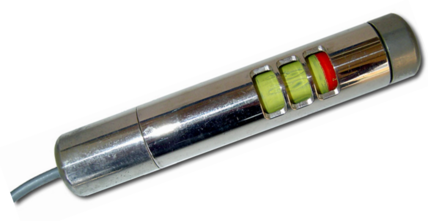


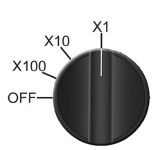






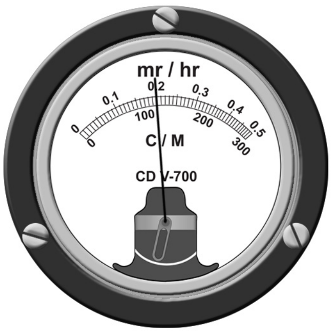


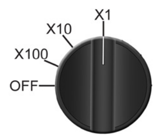




CD V-700 Instrument

Meter Reading | **Range Selector** | **Probe Used** | **Results**





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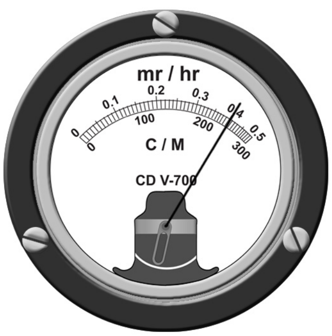

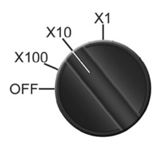

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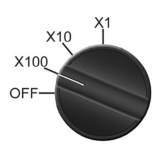

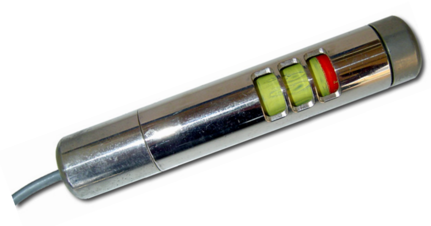

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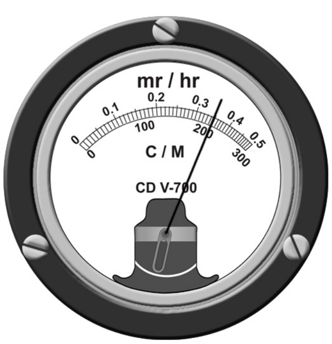

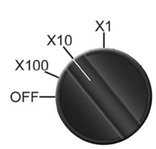

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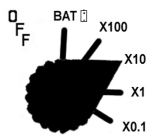
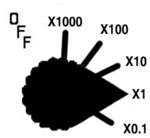
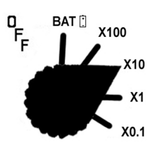
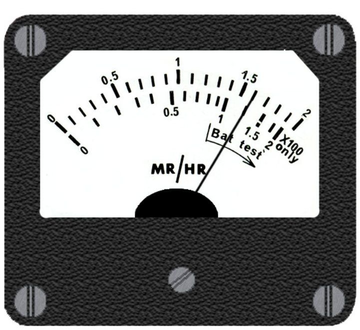
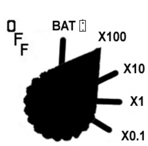
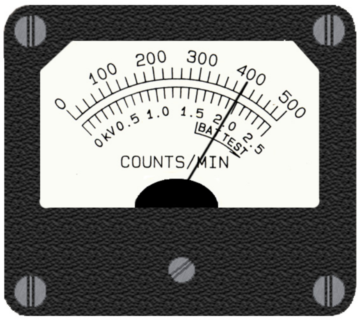
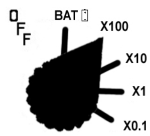
Ludlum Instrument Answers

Meter Reading	Range Selector	Probe Used	Results
			40,000 CPM
	 x1000 FOR INTERNAL PROBE ONLY		1.2 mR/h
			16,000 CPM
			125 mR/h

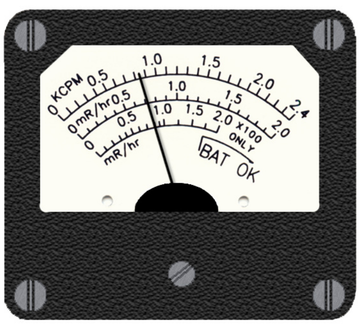
Ludlum Instrument Answers

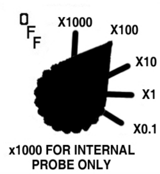
Meter Reading	Range Selector	Probe Used	Results



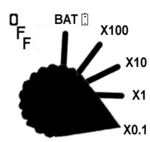


40,000 CPM

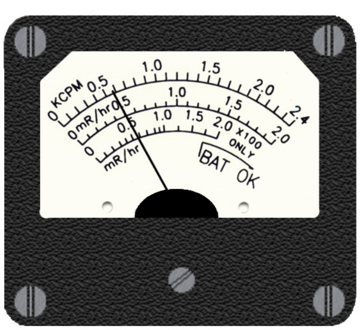


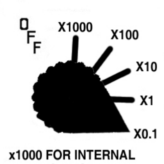


80 mR/h



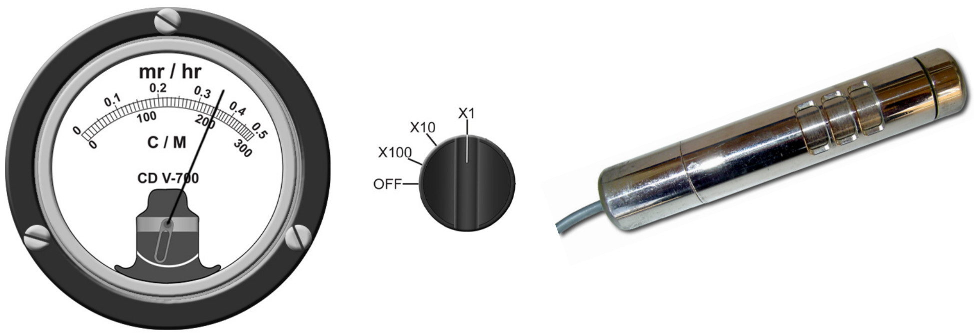
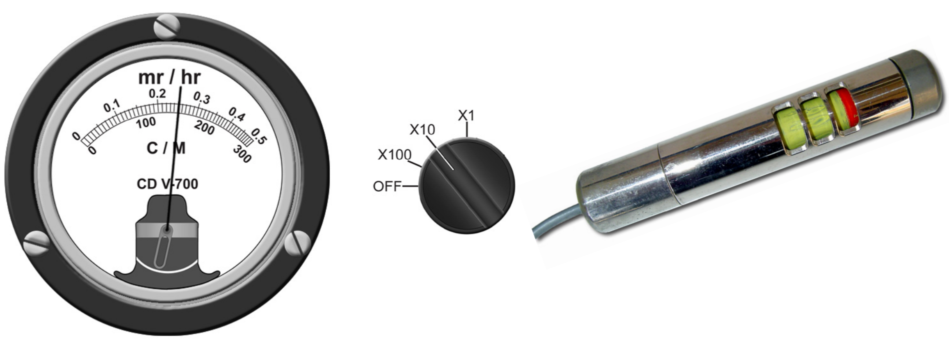
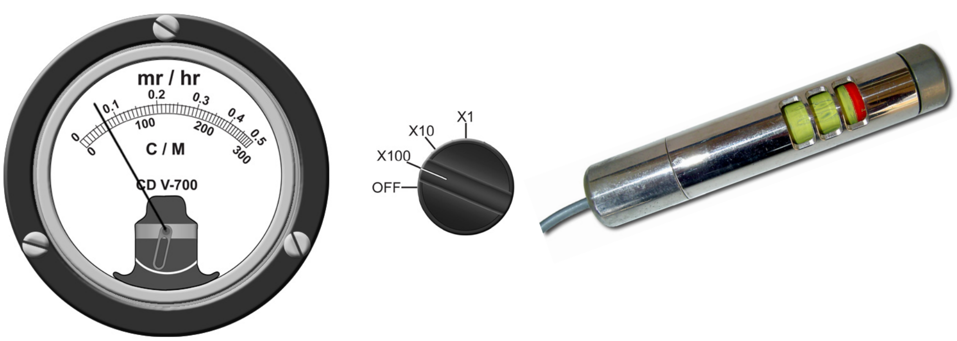
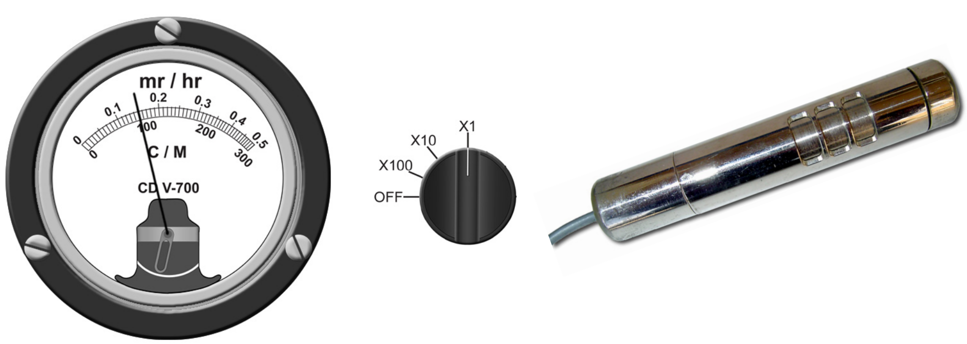
500 CPM



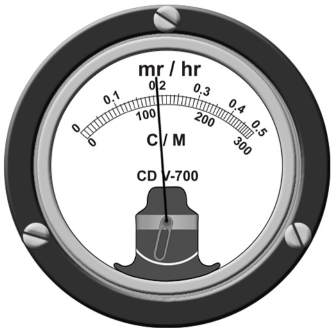
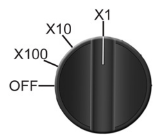
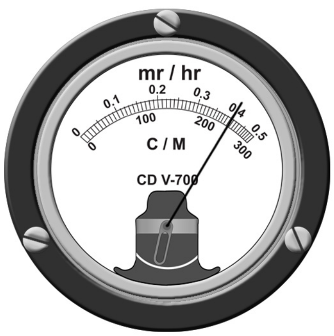
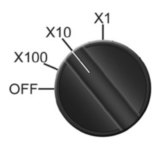
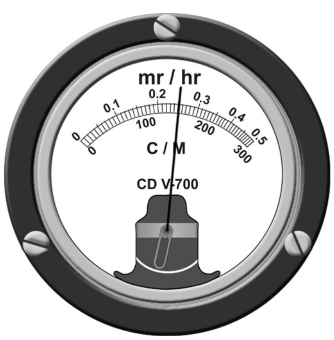
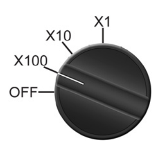
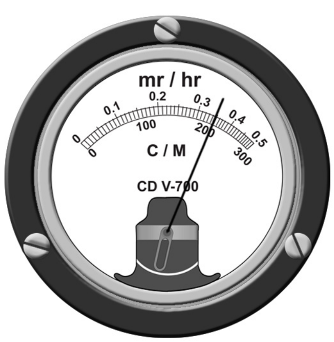
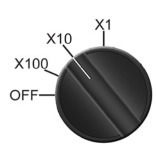
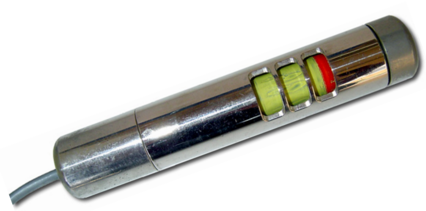


.05 mR/h

CD V-700 Instrument Answers

Meter Reading / Range Selector / Probe Used	Results
	0.35 mR/h
	1,500 CPM
	5,000 CPM
	0.15 mR/h

CD V-700 Instrument Answers

Meter Reading	Range Selector	Probe Used	Results
			0.2 mR/h
			4.0 mR/h
			15,000 CPM
			2,000 CPM