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	REVISION FINAL rev2
INDUSTRIAL HYGIENE GROUP Standard Operating Procedure: Field Procedure	DATE 01/10/07
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SUBJECT: INSTRUMENT OPERATION: THM 7025 3-Axis Hall Magnetometer	

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1.0 Purpose/Scope

This procedure provides a standardized method for the operation of the THM 7025 3-Axis Hall Magnetometer. It should be used in conjunction with the SBMS Subject Area Static Magnetic Fields and IH SOP IH 99110 *Static Magnetic Field Measurement Principles: Area Surveys*.

The THM 7025 provides a method for easy and accurate surveys of workplace static magnetic fields. This area survey meter should be used to determine the baseline static magnetic field levels and area SMF levels. It is designed for conducting SMF surveys to determine the need for area warning posting, estimation of personnel exposure, locate problem-SMF sources, and measuring the effectiveness of engineering controls. It should be used on conjunction with a string with paperclips to map magnetic force fields that may affect an object. The types of items that can be surveyed with this instrument include static sources such as permanent magnets, Magnetic Resonance Imaging (MRI) equipment, Nuclear Magnetic Resonance (NMR) equipment, superconducting coils, accelerator magnets, detector magnets, dc magnets in radio frequency and microwave tubes, ion pumps, electron microscopes, beam transport magnets, and electromagnetic lifting devices.

The THM 7025 can be used as a screening tool to determine the need for personal monitoring and to sketch isometric lines for control area delineation. Generally, employee exposure assessments close to exposure limits should be made with a Static magnetic field dosimeter (such as the Holiday Instrument HI-3550 Magnetic Field Monitor). However, this area survey meter can be used to conduct baseline exposure assessments, determine the need for further dosimetry, and measure exposure in operations that are of short duration and involve limited employee movement. This

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information can only be used for projects that are at fixed field strengths and for static magnetic fields (DC). If the strength is changed, or experiment is modified, then resurveying is necessary or the worst exposure scenario should be assessed. If the meter reading is to be used to measure the actual employee exposure, then the entire procedure should be observed and information regarding the length of the duration in the field and a description of the procedure including number of times the procedure was performed in the area if it is a repetitive procedure must be documented.

2.0 Responsibilities

- 2.1 **Program Administration:** This procedure is administered through the SHSD Industrial Hygiene Group.
- 2.2 Members of the SHSD Industrial Hygiene Group are required to follow this procedure. Other BNL organizations that provide BNL with field monitoring or other hazard assessment services are required to follow this SOP.
- 2.3 **Industrial Hygiene Professional:** The *Industrial Hygiene Professional* of SHSD and other BNL organizations are to be qualified by the SHSD Program Administrator. These individuals will conduct or supervise industrial hygiene hazard assessments and personal exposure monitoring using this procedure. These *IH Professionals* are responsible for:
 - Interpreting, reporting, and documenting personal exposure monitoring in accordance with the requirements of this procedure, other appropriate SOPs, and generally accepted professional standards and practices.
 - Ensuring a quality report is prepared that documents the exposure, evaluates the relevance to exposure standards, and recommends protective and corrective actions.
 - Ensuring the final report is provided in a timely manner to all appropriate parties.
 - Ensuring that the appropriate data is correctly and completely entered into the BNL IH exposure monitoring database (i.e. *Compliance Suite*[®]).
 - Ensuring that original records of sampling and analysis enter the SHSD *Record Custodian* filing system.
- 2.4 **Industrial Hygiene Technician (Sampler):** The industrial hygiene technician is to be qualified to conduct industrial hygiene personal exposure monitoring under the direction of his/her organization's *IH Professional*. The sampler is responsible for collecting personal exposure monitoring samples in accordance with the guidance of the *IH Professional* and the requirements of all SOP's pertinent to the particular monitoring requirements (i.e. Chain of custody, equipment check in/out, equipment operation, recordkeeping, etc.).

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2.5 **Compliance Suite[®] data entry:** The management of the person conducting the sampling is responsible for entering complete and correct data into the BNL IH exposure monitoring database (i.e. *Compliance Suite*). This task may be assigned to one or more individuals who act as the data entry person for an organization, however, it remains the responsibility of the line management of the *Sampler* to ensure this task is fulfilled within 21 calendar days of the end of the sampling event.

3.0 Definitions

Gauss (G) – in the CGS system, this the unit for one flux line passing through one square centimeter.

Magnetic Field – for static magnetic fields and extremely low frequencies, this is generally used for the magnetic flux density. When referring to RF and microwaves, the term usually means magnetic field strength (H field).

Magnetic field strength –(H) vector field () with units of amps per meter.

Magnetic Flux Density (B) Gauss: The number of magnetic flux lines per area that is induced by an applied magnetic field intensity H. The B results from an applied H is given by $B = \mu H$, where μ is the permeability (sometimes referred to as the *absolute permeability*) of the magnetic material in which the flux is contained. Where U is zero then $B=H$.

Magnetic Field Strength or magnetizing force (H) - The force within the magnet that produces the flux lines.

Flux density and magnetic field strength are related but not equal. The intrinsic characteristics of the magnetic material must be considered. Only in free space (air) are flux density and field strength considered equal.

Occupational Exposure Limit: The maximum time weighted average (TWA) or ceiling value exposure permitted for employee exposure, based on the less of the OSHA Permissible Exposure Limits (PEL) or ACGIH Threshold Limit Value (TLV). OSHA does not have a static magnetic field standard. BNL has adopted OELs are cited in the Static Magnetic Field subject area.

Tesla (T)- In the SI system this is 10,000 lines per square centimeter. Unit of magnetic induction or magnetic flux density (B field) in the meter-kilogram-second system (SI) of physical units. One Tesla equals one Weber per square meter (or magnetic flux per unit area), corresponding to 10^4 gauss .

4.0 Prerequisites

4.1 **Training prior to using this meter:**

- 4.1.1 Demonstration of proper operation of the instrument to the satisfaction of the requirements in Section 7.
- 4.1.2 Other appropriate training for the area to be entered (check with ESH coordinator or FR Representative for the facility).
- 4.1.3 Static Magnetic Field Training and review of the subject area Static Magnetic Fields.

4.2 **Area Access:**

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- 4.2.1 Contact the appropriate Facility Support Representative or Technician to obtain approval to enter radiological areas.
- 4.2.2 Verify with the appropriate Facility Support Representative or Technician if a Work Permit or Radiological Permit is needed or is in effect. If so, review and sign the permit.
- 4.2.3 Use appropriate PPE for area

5.0 Precautions

5.1 Hazard Determination:

- 5.1.1 The operation of this meter does not create any chemical, physical, or radiological hazards. The meter design does not cause significant ergonomic concerns in routine use.
- 5.1.2 If individuals using the meter wear pacemakers, or other medical electronic devices, they may not be exposed to fields greater than or equal to 0.5 mT (5 Gauss). Also, individuals with ferromagnetic implants should not be exposed to levels greater than or equal to 60 mT (600 G) without clearance from the Occupational Medicine Clinic.
- 5.1.3 Protection of the meter: The THM 7025 can theoretically measure magnetic fields up to 2 T. However strong magnetic fields effect the test instrument:
 - 5.1.3.1 With the battery inside, the main unit should not be exposed to magnetic fields stronger than 0.1 T as it might be pulled away from the hands of the user.
 - 5.1.3.2 Even when the battery is removed, the main unit should not be exposed to magnetic fields stronger than 1.5 T. Permanent damage can occur to the instrument.
 - 5.1.3.3 The transformer of the power supply contains a mass of iron. The plug-in power supply should never be exposed to magnetic fields stronger than 0.1 T as permanent damage can occur to the instrument.
 - 5.1.3.4 Storage temperature of equipment: -20 C to +60 C.
 - 5.1.3.5 Operating temperature of equipment: 0 C to 40 C.

5.2 Personal Protective Equipment/Other Precautions:

- 5.2.1 Check area for warning signs and instructions to the area before entering. Follow recommendations. Additional PPE: Other appropriate PPE may be

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needed for the area being entered. Check with your ES&H Coordinator or Facility Support Representative.

5.2.2 Exposure levels as low as 1 mT (10 Gauss) have been reported to cause deletion of information on magnetic memory materials, such as found on credit cards, identification badges, computer disks, and video tapes. Watches may be stopped. Use nonmagnetic objects or tools when working with or around magnetic fields above 60 mT. These objects may be drawn into the magnet and pose a flying object hazard. Metal-toed safety shoes may also be affected.

5.3 **Job Risk Assessment:** Consult the *Job Risk Assessment* [SHSD-JRA-05](#) for the risk analysis of this operation based on the hazards and controls of this SOP.

5.4 **Radiation Contamination:** It is possible that some surfaces in areas to be tested may have radiation contamination. In these cases, personal protective equipment and administrative controls must be implemented for the radiation contaminant hazard in addition to the chemical hazard.

5.5 **Work Planning:** All requirements of work permits and work planning system reviews must be met in performing this procedure.

5.6 **Environmental Impact and Waste Disposal:** This sampling does not have adverse impact on the environment or create waste for disposal.

6.0 Procedure

Operation of the THM 7025 (picture of meter and description of controls and displays is contained in Appendix 9.1.) These instructions are only for manual use: and do not describe use with a serial interface cable and a computer. (Consult manufacturer instruction for details on remote operation.)

6.1 Equipment: (Illustrations in Appendix 8).

- Meter Body
- Sensor 3-axis sensor (model THS7025-10) with its 1.5 meters shielded cable
- One 9 Volt Lithium battery. Life – 22 hours.
- 110V or 220V plug-in power supply (model HPS7015-10). Pictured in Appendix 8.2
- Zero-field chamber (model ZFC7015-16).
- 3-meter serial interface cable with Sub-D 9 poles IBM-PC type connector (model SC7015-13).

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- Non- magnetic measuring stick

6.2 Battery installation

- 6.2.1 Check the battery before installation with a voltmeter. The life of the battery is 22 hours.
- 6.2.2 Slide the battery door at the back of the unit.
- 6.2.3** Install the 9V battery and replace the battery door.
- 6.2.4** Plug the sensor into the connector at the top of the unit.
- 6.2.5** Turn on the THM 7025 by pressing the ON/OFF switch for at least 1 second.
 Note: There is no way to check the battery during operation. When the battery is too low, the display indicates “BAT” and a few minutes later, the THM 7015 switches off by itself. Maintain a spare battery in the case.

6.3 ON/Off Switch

- 6.3.1 Press once for at least 1 sec: Instrument is On.
- 6.3.2 Press again: Instrument is Off.
- 6.3.3 The THM 7025 switches off automatically after ~3 minutes, if the on/off switch has not being used or if no RS 232c command is sent. To disable the automatic switch OFF, press the button <HOLD>, hold it and then press <ON/OFF>. The display shows “ON” for about 0.4s to indicate that the instrument is now ON until you turn it Off by using the <ON/OFF> button.

6.4 **Warm-up:** A warm-up is not required for this meter.

6.5 **Range:** The values of measurement are displayed in three ranges: 19.99 mT, 199.9 mT, 1999 mT. When the THM 7025 is switched ON, it is set on autoranging mode and it displays the measurements in the most appropriate range. This feature can be turned off and a specific range can be selected by pressing the <RANGE> button a series of times.

Press <Range>button	Range of measurement	Range indication in the display
None. Default machine status	Autoranging	
1 st	Up to 1999	0
2 nd	Up to 199.9	0.0
3 rd	Up to 19.99	0.00
4 th	Autoranging	Auto

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6.6 Reading Hold

- 6.6.1 As long as the button <HOLD> is pressed down, the display of the measured value is held. The sign \blacktriangle comes in the display. By releasing <HOLD> the THM 7025 continues its measurement and gives new valued.
- 6.6.2 The normal operation of the Hold function is.
 - 6.6.2.1 When meter is powered: Meter operates in the running mode
 - 6.6.2.2 Depress <HOLD>: Meter displayed value as long is button depressed
 - 6.6.2.3 Release<HOLD>: Meter returns to the running mode

6.7 Calibration:

- 6.7.1 Check the display to determine if the meter is reading zero prior to each survey. The offsets of the Hall sensors are calibrated at the factory. This is called System Offset.
- 6.7.2 If the display does not read zero, place the probe in the zero field chamber in an area without a magnetic field. **DO NOT REZERO WHEN SENSOR IS IN A MAGNETIC FIELD** otherwise the measurements will be dependent on the sensor orientation.
- 6.7.3 Press and hold the <ZERO> button, the press the <HOLD> button. The new offset is measured and memorized. The machine retains this measurement even after switching off the THM 7025. Record re-zeroing on data sheet.
- 6.7.4 To restore the factory System Offset, press and hold the <ZERO> and press<ON/OFF>. This action resets the default parameters.

6.8 Operation:

- 6.8.1 **Operator Position:** Preferably the operator should be further from the magnetic source than the probe. Use a non-metallic extender if necessary. Note the distance from the source, and location of the measurements.
- 6.8.2 Use the default auto range or select the desired display range (see 6.5).
- 6.8.3 Point the meter at the source. If you do not know the strength of the magnet, approach source slowly from a distance so that you are not beyond the capabilities of the meter, and there is no potential for the meter being pulled out of your hand.
- 6.8.4 Observe and record the readings shown on the display in a running mode or hold mode.

6.9 Use of Bz Button (B on Z axis)

- 6.9.1 For survey purposes, this feature is not used, the default **3 axis feature** is used. Pressing the Bz button toggles between the 3 and single axis measurements.

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6.9.2 To distinguish between the modes, the sign “+” or “-” will appear with the magnetic field value in single axis mode. Otherwise no sign is displayed.

6.10 Recording readings:

Plan and conduct hazard assessments and exposure monitoring using the procedure outlined in *IH 60500 Reporting Personnel Exposure Monitoring Results* for:

- Exposure Assessment Sampling Strategy,
- Initial Notification of Employee Monitoring Results, and
- Preparation of a formal report on the exposure monitoring or hazard assessment.

6.10.1 See the Subject Area *Static Magnetic Fields* for the most recent version *SMF Use form*.

6.10.2 Return meter and original sampling form to the SHSD IH Laboratory daily or at the end of each project as agreed to by the IH Laboratory Technician.

6.10.3 Send a copy of any hazard evaluation report written on the survey to the IH Laboratory.

6.10.4 If this survey determines that employees are potentially exposed at or above the 0.5 (5 gauss level) for pacemaker users, or above any of the other BNL exposure levels, then identify the employees on the Static Magnetic Field form Part C, Employee Exposure Record, and forward a copy to the IH laboratory and the Occupational Medicine Clinic.

7.0 Implementation and Training

Prior to using this procedure, the user:

- 7.1 Demonstrates proper operation of this instrument to the satisfaction of the SHSD IH Program Administrator.
- 7.2 Completes other appropriate training for the area to be entered (check with ESH coordinator or FS representative for the facility).
- 7.3 Completes OT&Q Training and a medical surveillance required for any PPE used on the job or for other hazards encountered in the work area.
- 7.4 Completes qualification on this procedure on at least a 3 year basis, providing the professional uses the equipment several times per year.
- 7.5 Personnel are to document their training using the Attachment 9.4 with its *Job Performance Measure Completion Certificate* for this meter.

8.0 References

- 8.1 THM 7025 User's Manual.

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8.2 BNL SBMS Subject Area – Static Magnetic Fields.

9.0 Attachments

- 9.1 Photo of meter and parts
- 9.2 Short Operating Instructions
- 9.3 Theory of Operation
- 9.4 *Job Performance Measure Completion Certificate.*

10.0 Documentation

Document Development and Revision Control Tracking		
PREPARED BY: <i>(Signature and date on file)</i> N. Bernholz Author Date 07/02/01	REVIEWED BY: <i>(Signature and date on file)</i> J. Peters SHSD IH Group Date 07/02/01	APPROVED BY: <i>(Signature and date on file)</i> R. Selvey SHSD IH Group Leader Date 07/05/01
ESH Coordinator/ Date: <i>none</i>	Work Coordinator/ Date: <i>none</i>	SHSD Manager / Date <i>none</i>
QA Representative / Date: <i>none</i>	Training Coordinator / Date: <i>none</i>	Filing Code: IH52
Facility Support Rep. / Date: <i>none</i>	Environ. Compliance Rep. / Date: <i>none</i>	Effective Date: 07/06/01
ISM Review - Hazard Categorization <input type="checkbox"/> High <input checked="" type="checkbox"/> Moderate <input type="checkbox"/> Low/Skill of the craft	Validation: <input type="checkbox"/> Formal Walkthrough <input type="checkbox"/> Desk Top Review <input type="checkbox"/> SME Review Name / Date:	Implementation: Training Completed: Tracked in BTMS Procedure posted on Web: 01/02/07 Hard Copy files updated: 01/02/07 Document Control on forms: n/a

Revision Log

Purpose: <input type="checkbox"/> Temporary Change <input type="checkbox"/> Change in Scope <input type="checkbox"/> Periodic review <input type="checkbox"/> Clarify/enhance procedural controls		
Changed resulting from: <input type="checkbox"/> Environmental impacts <input type="checkbox"/> Federal, State and/or Local requirements <input type="checkbox"/> Corrective/preventive actions to non-conformances <input checked="" type="checkbox"/> none of the above		
Section/page and Description of change: Revised to include Section 7 Implementation and Training. Text added to Section 2, 4, 5, 6, and 7. JRA added to Section 5.		
R. Selvey 03/29/05 <i>(Signature and date on file)</i> SME Reviewer/Date:	Reviewer/Date:	Reviewer/Date:

The only official copy is on-line at the SHSD IH Group website.
Before using a printed copy, verify that it is current by checking the document issue date on the website.

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Purpose: <input type="checkbox"/> Temporary Change <input type="checkbox"/> Change in Scope <input type="checkbox"/> Periodic review <input type="checkbox"/> Clarify/enhance procedural controls		
Changed resulting from: <input type="checkbox"/> Environmental impacts <input type="checkbox"/> Federal, State and/or Local requirements <input type="checkbox"/> Corrective/preventive actions to non-conformances <input checked="" type="checkbox"/> none of the above		
Section/page and Description of change: Section 2.2, 2.3, 4.1, 7.1, and 7.5 revised to reflect qualification requirements. Section 5 revised to remove JRA table and link to OHSAS web site and add/update the description of radiation contamination, environmental waste, and work planning. Attachment 9.4 Job Performance Measure was added.		
R. Selvey 01/10/07 (signature/date on file) SME Reviewer/Date:	SME Reviewer/Date:	SME Reviewer/Date:

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Attachment 9.1 Photo of Meter



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Attachment 9.2

Short List of Operating Instructions/Trouble shooting messages

Step	User Action	Digital Display
1	Battery Check Battery must be checked before installation	If the battery is low the display reads <i>bat</i>
2	Calibration <ul style="list-style-type: none"> • Power button ON • Connect probe • In static magnetic field free area (0.1 mT) place probe in zero field chamber • Press button <ZERO>, hold it and press button <HOLD>. 	
3	Operation Point probe at source	Reading digital displayed
4	Operator Position Stand behind the meter. It is acceptable to extend the probe towards the source. Note: the body of the instrument cannot exceed 0.1 Tesla (100 mT) .	

ACTION/SCREEN DISPLAY	DESIRED ACTION	BUTTON SEQUENCE	RESULT
Display reads "Er.n" where 'N' is the error number (see list in section)	Clear error	Press <ZERO> once	Clears the error
Error Number= " 1 "			Return to factory
Error Number= " 2 "	Clear the error	Press <ZERO> once	Clears the error
Error Number= " 3 " (Occurs when residual background field is too high to be nulled)	Clear the error	Press <ZERO> once	Clears the error
Machine does not read zero in non magnetic field, or when the internal memory is saturated	Reset system offset	Place probe in zero field chamber Press <ZERO>, hold it, press <HOLD>	Zero is reset. (User's Offset established)
Restore factory defined System Offset		Press <ZERO>, hold it, press <ON/OFF>	Factory System Offset is restored.

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Attachment 9.3 Theory of Operation

The METROLAB 3-axis Hall Teslameter “THM 7025” is an instrument using Hall elements to measure magnetic fields. The main feature of the THM 7025 is the simultaneous measurement of the 3 axis, X, Y, Z, which are set at 90 degree angle, allowing a direct measurement of the magnetic field intensity, without a particular orientation of the sensor (isotropic).

In the 19th century, Edwin Hall placed a gold film in a magnetic field, passed a current through the film and measured the voltage across the foil. He found that there is a proportional relationship between the voltage detected and the magnetic flux density as well as the incident angle of the flux lines. The polarity of the voltage is dependent upon the direction of the flux lines.

The THM 7025 is a modern hall effect device, commonly called a Hall Generator, comprised of three Gallium Arsenide or Indium Arsenide films at right angles to detect the flux lines in three dimensional space. The films are located in the probe and are supported on ceramic substrates for physical and thermal stability as well as locations for wiring nodes. The readout is displayed in mT and can detect both direct current (DC) and alternating current (AC) fields.

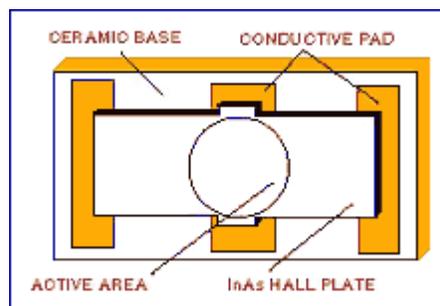
All the functions of the THM 7-25 (controls and measurements) can be accessible to a computer via a RS 232c serial interface.

The THM 7025 calculates and displays the modulus of the magnetic field as per the equation

$$B = \text{square root of } (\sqrt{B_x^2 + B_y^2 + B_z^2})$$

Hall discovered that the voltage, now called the *Hall voltage*, V_h , is directly proportional to the number of flux lines passing through the foil, the angle at which they pass through it, and the amount of current used. He also found that the polarity of the voltage reverses when the direction of the flux travel reverses.

A modern Hall effect device (see Photo 1), commonly called a *Hall generator*, consists of a thin square or rectangular plate or film of GaAs or InAs to which four electrical contacts are made (see Figure 3).



A "bulk" Hall generator is constructed by soldering a thin slice of a III-V compound such as InAs to conductors on a ceramic substrate. Thin film devices are made by depositing the vaporized compound directly on the ceramic circuit plate.

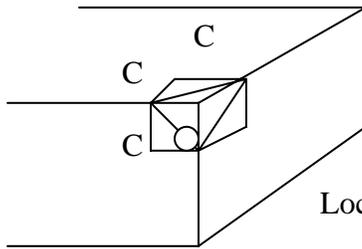
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The plate or film is often affixed to a ceramic substrate that provides mechanical support, thermal stability, and wiring nodes. Other devices are wire bonded to a nonmagnetic lead frame and encapsulated in a dielectric material.

The output of a Hall device is greatest when the flux lines are perpendicular to the surface of the material. When the angle is held constant, and a constant current is provided through the material, the Hall voltage is directly proportional to flux density. Conversely, holding the flux density and current constant allows the device to respond to the angle of the flux lines.

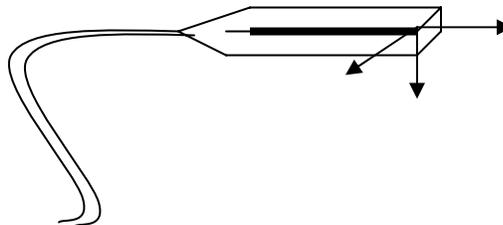
C= 3.7 mm side of the probe is 12mm x 12mm

The three sensor probe are located inside a 3 mm diameter sphere centered on the corner of a 3.7 mm side cube.



Location of the 3-axis hall sensor

Probe



**Non-ionizing Radiation – THM 7025 Operation
Job Performance Measure (JPM) Completion Certificate**

Candidate's Name	Life Number:
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Practical Skill Evaluation: Demonstration of Evaluation Methodology by Oral Exam

Criteria	Qualifying Performance Standard	Unsat.	Recov.	Satisf.
1. Hazard Analysis	Understands the need to perform a hazard analysis of the area and potential exposure to the self as sampler and workers in the area.			
2. Personal Protective Equipment	Understands the need to be aware of the potential surface contamination, airborne levels of contaminants, radiological hazards, and noise hazard. Knows how to determine the need for PPE.			
3. Sampling Equipment	Knows where equipment needed for the procedure is located and how to properly sign it out.			
4. Pre-Testing Inspection	Verifies the system to be monitored is operational and represents typical operation. Makes notation in sampling record if the operating conditions are atypical.			
5. Operating Parameters	Knows the theory to establish operating parameters (safety envelope) for the equipment. Make drawing or photo. Measure.			
6. Documentation-Technician	Demonstrates correctly filling out IH monitoring forms.			
7. IH Professional Documentation	Demonstrates correctly filling out IH forms, transfers appropriate info to IH databases, prepares an evaluation assessment report (including an evaluation of the relationship of the exposure to occupational exposure limits), and notify workers and management of the results.			

Meter Operation Practical Skill Evaluation: Demonstration of Methodology

Criteria	Qualifying Performance Standard	Unsat.	Recov.	Satisf.
Turning on the meter	Demonstrates how to correctly operate the meter. Describes appropriate warm-up time.			
Zeroing	Demonstrates how to correctly operate the meter to eliminate background, previous stored readings, stray fields not to be measured.			
Probe placement during measurements.	Demonstrates how to correctly operate and align the meter.			
Spatial Averaging	Demonstrates how to correctly align and locate the meter probe relative to source(s)			
Time Averaging	Demonstrates how to correctly calculate exposure relative to occupational exposure limits.			

I accept the responsibility for performing this task as demonstrated within this JPM and the corresponding SOP.

Candidate Signature:	Date:
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I certify the candidate has satisfactorily performed each of the above listed steps and is capable of performing the task unsupervised.

Evaluator Signature:	Date:
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