ENGINEER COURSE

PACKET

2

Introduction to Magnetic Silencing

SS

WB

SELF-STUDY WORKBOOK

M A G N E T I C

S I L E N C I N G

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RECORD OF CHANGES			
Correction or Change No.	Date of Change	Date Entered	By Whom Entered

PACKET 2

INTRODUCTION TO MAGNETIC SILENCING

SECTION I

A. OBJECTIVES: Unless otherwise specified, the following objectives will be accomplished with the conditions and standards as described in Packet 1.

1. Understand the history of mine warfare.

2. List the types of mines, principles of operation, and defensive measures.

3. List the types of magnetism, their properties and characteristics.

4. Define the terms used in magnetic silencing, and units of magnetic measurement.

5. Understand the earth's magnetic field and its effect.

B. REFERENCES

- NAVSEA S9086-KC-STM-000/CH-300 RI, Technical Manual Electrical Plant, Section 2, Safety (Reference No. 1)

- NAVSEA 0901-LP-400-0000/CH-400, Technical Manual Electronics, Section 2, Safety (Reference No. 2)

- NAVSEA 0967-0100, EIMB General Handbook (Reference No. 3)

- NAVSEA S5475-AF-GTP-010/INT HIST MSIL, Introduction and History of Magnetic Silencing (Reference No. 4)

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SECTION I

C. PREREQUISITES

1. Completion of Packet 1.

D. OVERVIEW

NOTE: Review the SAFETY NOTES contained in References 1, 2, and 3.

1. This packet provides a brief history of mine warfare, the mine's impact on shipping, and methods developed to counter the effect of mines. The fundamentals of magnetism, the keystone to magnetic silencing, will be described.

2. Information Sheet No. 2-1 describes the development of mine warfare, its effect on shipping, and the ways and means developed to counter its effect.

3. Information Sheet No. 2-2 explains the fundamentals of magnetism, including permanent, induced, and electromagnetism. The earth's magnetic field and its magnetic influence are discussed. Units of measurement used in magnetic silencing are given and defined.

4. For this packet you will need only references and the materials contained herein.

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SECTION II

INFORMATION SHEET NO. 2-1
TITLE: Basic Information

Introduction

Recent naval history has proven that mines can be an extremely effective weapon. Initially, mines were developed to sink or damage enemy ships. They were planted in sea lanes to stop or hinder ship movements. To cause destructive damage to a ship, a mine must explode at or near a ship's hull. In World War II, mines were highly successful in disrupting shipping. Over 600 Japanese ships were sunk by mines during "Operation Starvation" alone. Mines, both Allied and enemy, sank more ships than any other weapon during World War II. In future conflicts, mines can be expected to play a prominent role. Additional information regarding mines and mine warfare is available in paragraphs 1-2, 1-3, and Appendices A-1 and A-2 of reference 4.

Types of Mines

1. Contact Mines. The first mine to be used extensively was the contact mine. This mine was designed to be moored below the water surface in shipping lanes where it would be in the path of enemy ships. Horns or appendages from the mine served as firing mechanisms. When struck by a ship, the effect on the horns caused the mine to detonate and sink or damage the ship. Contact mines were effectively used in World War I. Diagram 1 shows a typical contact mine.

   A technique of using cutting wires towed by ships was developed to sweep the mines from their moorings. Once the mines were cut from their moorings they floated to the surface where they could be destroyed by gunfire. In this manner safe channels through minefields could be made.

2. Influence Mines. The next step in mine warfare was the development of the influence mine. Influence mines were designed to rest on the bottom and be exploded by the

environmental disturbances which surround ships. Mooring cables are not used and direct contact with a ship is not required to detonate an influence mine. The cutting wire technique used to sweep contact mines is useless against influence mines.

The first and most important influence mine was the magnetic mine which was designed to sense the magnetic fields that surround all ships with steel hulls or equipment. Another type of influence mine is the acoustic mine, which senses sounds in the water caused by ship's noises. This type of mine can be swept or detonated by underwater acoustic devices that generate sounds to simulate those of passing ships. Another type of influence mine is the pressure mine, which reacts to changes in hydrostatic pressure caused by a ship's passage through the water. The combining of various influences in mine sensing devices has led to increased difficulty of minesweeping operations. The term "magnetic silencing" is used to describe methods used to reduce the magnetic fields of all ships that might be exposed to magnetic mines.

Magnetic mine warfare began in September, 1939, with the outbreak of World War II in Europe. At that time, Germany began laying magnetic influence mines in shipping lanes off the east coast of England. This new weapon rendered all countermine and sweeping techniques developed during World War I obsolete. This weapon was so effective that within three months, 44 ships lay at the bottom of the English Channel. Continued use of magnetic mines by Germany soon became a problem for the U.S. Navy, but England's proximity to Germany, and the earlier hostilities between the two countries, forced England to take the first steps in counteracting this extraordinarily effective weapon. The worst feature of the new weapon was that the usual sweeping procedure, cutting the mines loose from their cables and destroying them by gunfire, was useless. Obviously, this procedure could not be used with mines placed on the sea bottom; some entirely new method of sweeping and of protecting ships had to be devised. Virtually nothing was known about the new mine or its firing circuit. Examination of an actual mine was needed. During the first weeks of World War II, the new magnetic mines were laid by submarines. But laying mines by submarines was a slow and restricted process because of inherent limitations in the number of mines carried and the lack of submerged maneuverability in shallow and narrow waters. By November 1939, the mines were being laid at night by low-flying aircraft. While the use of planes increased the power of the enemy attack, it also speeded the development of countermeasures by aiding the British search for a mine to use for analysis. Mines were seen dropping by parachutes and one was spotted at a point uncovered at low tide. On November 23, 1939, the British brought the uncovered magnetic bottom mine ashore and rendered it safe for study in detail. Examination disclosed a magnetic firing mechanism consisting of a gimbaled dip needle balanced horizontally by a spring mechanism. The spring mechanism was designed to adjust itself automatically to the proper tension for any field in which it was laid.

As a ship passes over a magnetic influence mine, the dip needle is deflected by the increased vertical component of the ship's magnetic field. Should the magnetic field strength of the ship be strong enough, the mine's firing circuit could be closed. There was nothing fundamentally new in the device; its success was due rather to clever designing and first-rate engineering. Diagram 2 shows the basic principle of a dip needle firing circuit.

Countermeasures

1. Passive Countermeasures. Once the firing circuitry of the magnetic mine was understood, measures to counteract it, as well as techniques to sweep it from the shipping lanes, were rapidly developed. A method to reduce the magnetic field strength of ships was developed and referred to as "degaussing," a word derived from the magnetic unit "gauss."

Degaussing techniques will be discussed in detail in subsequent chapters of this course. Briefly, degaussing techniques produce magnetic fields that counteract the ship's field through the use of loops or coils and dc currents reducing its "magnetic signature." Diagram 3 shows the relative effect of degaussing. Degaussing proved successful, and by the summer of 1940 more than 2,000 merchant ships had been fitted with degaussing coils.

From this beginning, a science called "magnetic silencing" was developed. This science deals with the methods and techniques of reducing a ship's magnetic field so that the possibility of detection by magnetic mines and other magnetic influence detection devices is minimized.

2. Active Countermeasures. New techniques of minesweeping had to be developed to sweep the shipping lanes free of magnetic mines. Specially constructed ships with nonferrous hulls and low levels of magnetic field strength were introduced. Degaussing coils were used to further reduce ship magnetic fields. When properly equipped and operated, these new minesweepers could safely pass directly over magnetic mines without activating the firing mechanism. Special sweep gear designed to safely detonate the mines far behind the minesweeper was towed over the minefields. The sweep gear or "tail" consists of a special, two sectional electrical cable about 480 meters long. In use, this cable streams astern while the minesweeper is underway. In order not to endanger the minesweeper with any part of the magnetic minesweeping field, the sweep gear cable is made up of two sections. The first section is quadded and does not produce a magnetic field; the second is single cable and produces the sweeping field. Diagram 4 shows electromagnetic minesweeping.

a. Quadded Section. The quadded section (called "short leg") is designed to float and consists of four insulated electrical conductors, two for each polarity, extending aft about 205 meters from the stern. A particular arrangement of the four conductors called "quadding" prevents this section from producing a magnetic field. The conductors are bound tightly together, with the plus and minus conductors placed in an X arrangement. As a result, the opposing magnetic fields from large dc currents in the conductors are neutralized. Having this section of cable between the stern and the second section provides a zone of protection against mines exploding too close astern.

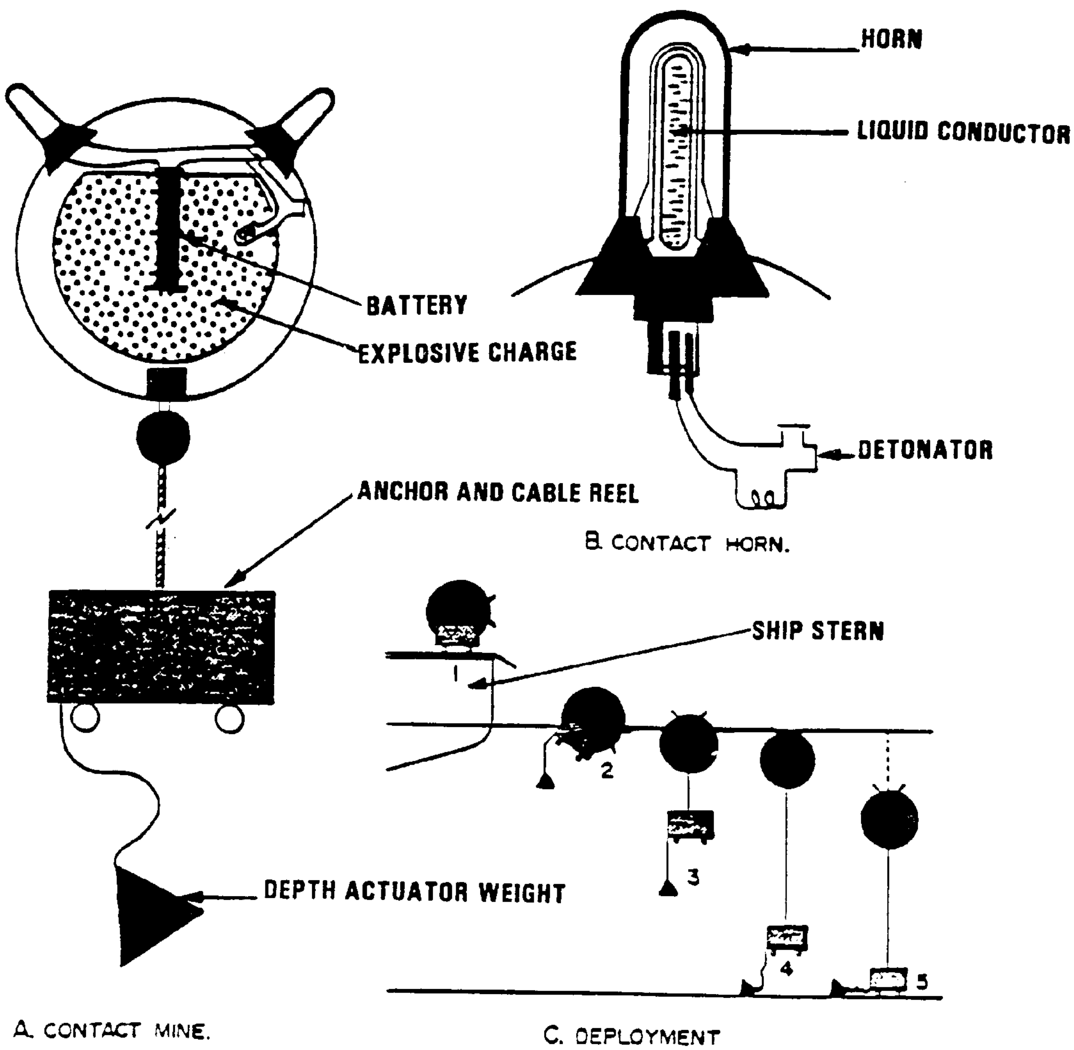
b. Single Cable Section. The single cable section (called "long leg") provides the sweeping field. This single electrical cable contains materials for buoyancy, extends about 275 meters, and connects to the end of the quadded tail. Current in this section creates the magnetic field required for sweeping (detonating) magnetic mines. Various arrangements consisting of submerged electrodes (open loop) or a closed loop are used for the return current.

c. Magnetic Minesweeping Generator. An onboard generator supplies the necessary electrical current. The generator is pulsed (positive, zero, negative, zero, etc.) during minesweeping.

d. Pulsing. The primary purpose of applying sweep current in pulses is to maximize the effectiveness of sweeping mines. This effectiveness is a result of three basic factors: the higher intensity of magnetic sweep fields from high current pulses, the pulsing of alternating plus and minus field polarities, and the repetition of magnetic sweep fields. Higher intensity fields extend the effective range of the sweep field. The alternating polarities extend the sweeping to include mines that may be sensitive only to one or both polarities. Repetition of sweep fields is particularly effective in sweeping mines with counters in the firing mechanism. Counters are used to increase the difficulty in sweeping and give a false sense of security if shipping and/or minesweeping experience a period when no detonations occur. Pulsing generally operates a counter once for each pulse until a preset condition results in detonation. Repeated pulses expedite the minesweeping operation.

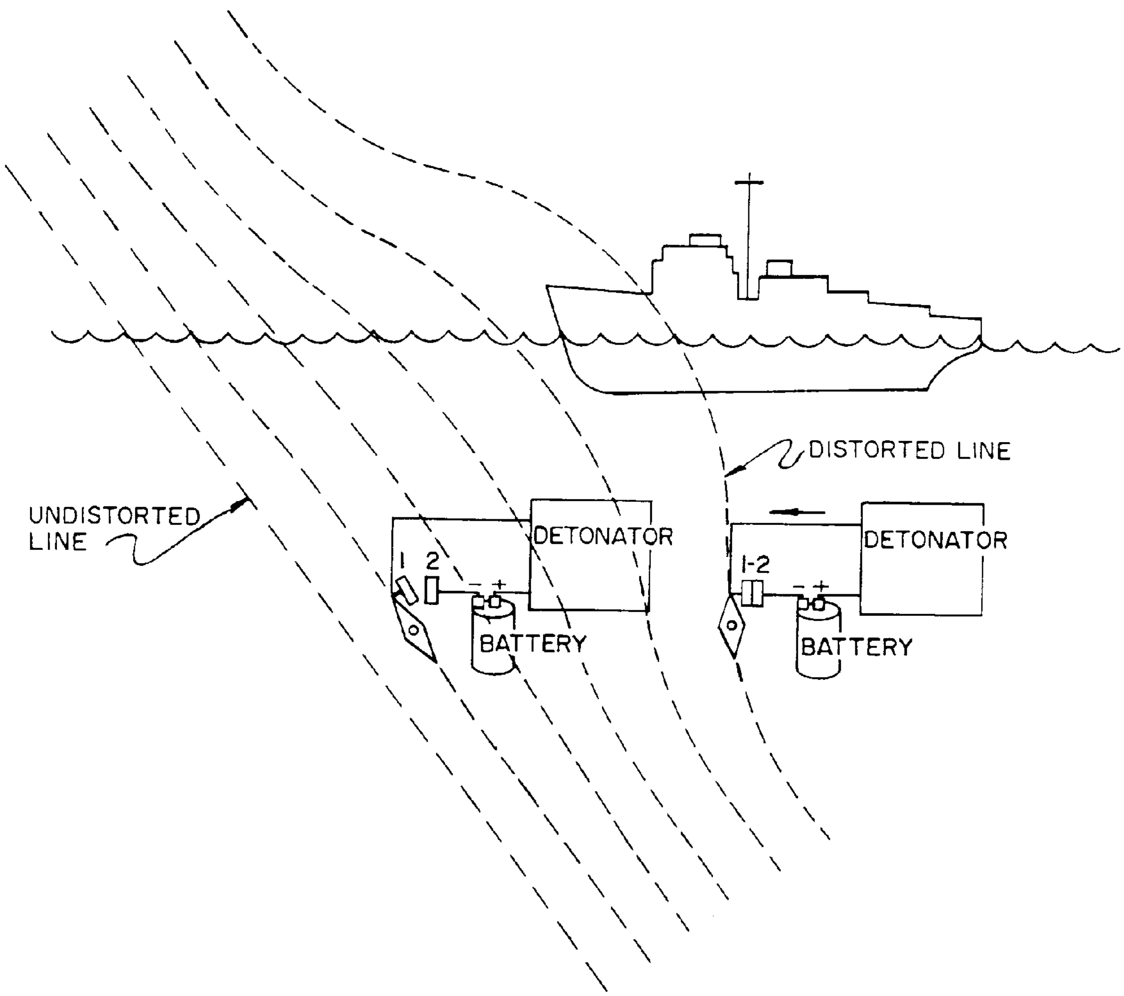
Magnetic Measurement

Magnetic mines create the necessity for continuously monitoring the magnetic status of all the ships and minesweepers affected by the magnetic silencing program. The effectiveness of equipment installed aboard shipsand minesweepers to reduce their magnetic environment must be measured periodically and corrected when necessary. Navy authorities have established magnetic criteria which the ships and minesweepers must meet. Ships and minesweepers are tested at degaussing ranges for compliance with magnetic field criteria, and calibrations are conducted when the criteria are exceeded. Service at the ranges is provided by personnel specialized in analyzing ranging data.



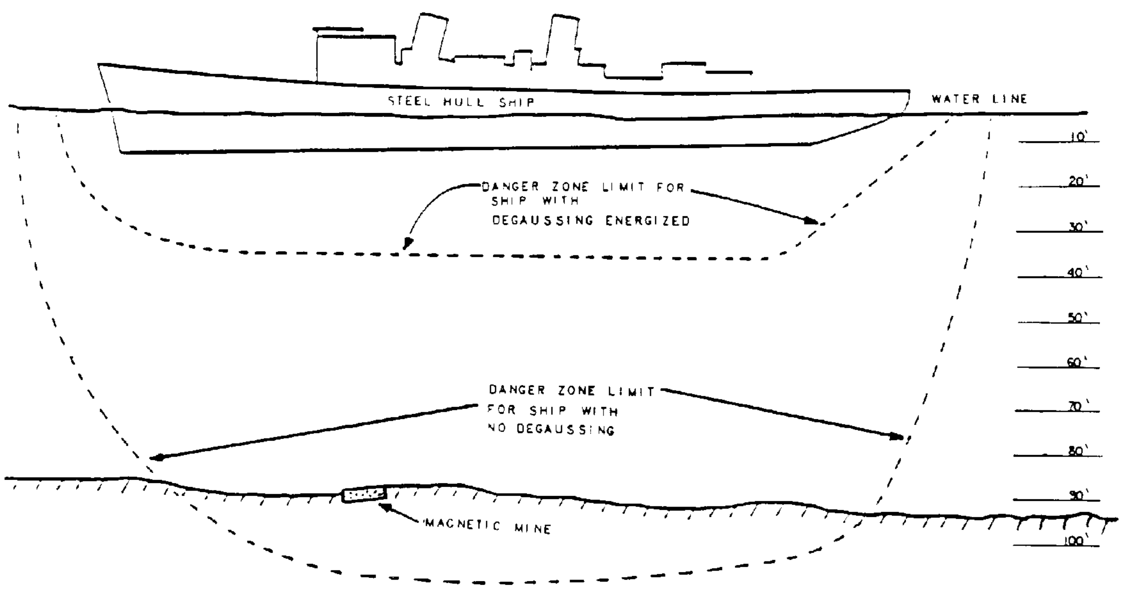
Typical Contact Mine

Diagram 2



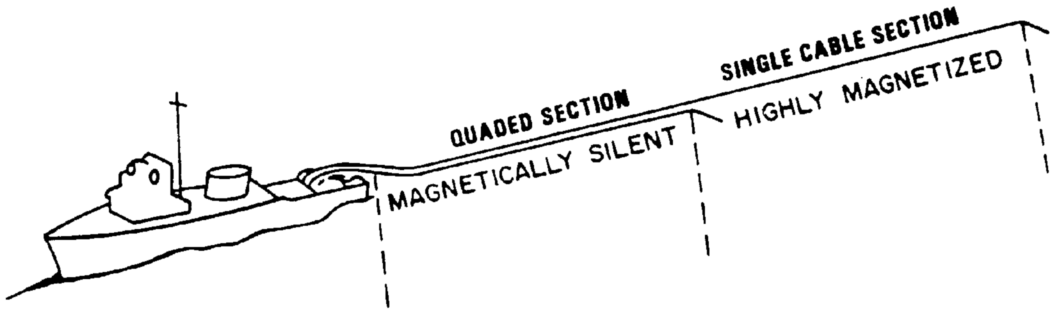
Dip Needle Mine Firing Circuit

Diagram 3



Relative Effect of Degassing of Steel Hull Ships

Diagram 4



Electromagnetic Minesweeping

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SECTION II

ASSIGNMENT 1: Basic Information

DIRECTIONS: Choose the word(s) which best completes each sentence below. Print those words in the space provided. When you finish, your supervisor will correct this assignment.

1-1. Allied and enemy ________________________________ sank more ships than any other weapon during World War II.

1-2. Contact mines must make __________________________________ to detonate.

1-3. Contact mines are swept using ____________________________.

1-4. ___________________________________ were first used during World War II.

1-5. Influence mines are detonated by the ______________________ which surround ships.

1-6. A pressure mine senses changes in _________________________.

1-7. Acoustic mines sense _____________________________________ in the water caused by ___________________________________.

1-8. Acoustic mines are swept by using _________________________.

1-9. Magnetic mines sense the ________________________________ that surround ships.

1-10. The reduction of the strength of a ship's magnetic field is known as ____________________________________.

1-11. Early German magnetic mines used a gimbaled _______________ ____ in their firing mechanisms.

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ASSIGNMENT 1: Basic Information

1-12. A passive measure against magnetic mines is ________________.

1-13. Minesweepers designed to sweep magnetic mines have ____ hulls.

1-14. Minesweepers use special gear or a ________________________ streamed astern to detonate magnetic mines.

1-15. The first section of the sweep tail consists of electrical conductors, is nonmagnetic, and is called the ______________ _____________.

1-16. The last section of the sweep tail is a ____________________ cable and creates the __________________________________ for sweeping (detonating) magnetic mines.

1-17. Large dc currents are applied to the sweep tail in _____________________________________.

1-18. It is necessary to ___________________________________ the magnetic status of all ships.

1-19. Navy authorities have established _________________________ which ships and minesweepers must meet.

1-20. Ships and minesweepers are tested for compliance with the criteria at _____________________________________.

INFORMATION SHEET NO. 2-2
TITLE: Fundamentals of Magnetism

Magnetism

Magnetic fields are all around us. Early sailors and travelers discovered that certain materials tended to always point in the same direction. From this knowledge they developed the magnetic compass--even though, at first, they did not know why it worked. Today we know a great deal more about magnetism. This knowledge is essential if we are to understand magnetic silencing. Chapter 2 of reference 4 provides additional information on the fundamentals of magnetism.

1. Magnetic Field. The simplest and most common type of magnet is the bar magnet. A bar magnet is a length of steel or iron which will pick up nails, tacks, and other small magnetic objects. Surrounding this simple magnet is an area of influence called a magnetic field.

2. Lines of Force. If a bar magnet is placed under a piece of glass and iron filings are sprinkled over the glass, the iron filings will tend to align themselves in a distinctive pattern in relation to the magnet. This pattern corresponds to invisible magnetic lines of force that surround the bar magnet. The magnetic lines of force of the field are arranged in loops. A compass needle, if held close to the magnet, will also align itself with these lines. The relative concentration of the apparent lines in any given area represents the magnetic flux density of the magnetic field at that point. See Diagram 1.

3. Magnetic Poles. Those portions of the magnet toward which or from which the external lines of force appear to converge or diverge are called the magnetic poles. The bar magnet has one at each end. With the magnet suspended so that it is free to turn, one end will swing to the north. This end is the north-seeking, or simply the "north" pole. The other end is the south-seeking or "south" pole.

4. Magnetic Field Polarity. For convenience, a direction must be assumed for the magnetic field. By convention, the plus

direction of the external magnetic field of a bar magnet is the direction from the north to the south pole. This is shown by the arrows in Diagram 1. Thus, the direction of a line of force (external to the magnet) from a north to a south pole is positive or plus.

5. Flux Density. Flux density is an important characteristic of a magnetic field. The denser the flux lines, the stronger the field. Flux density refers to the number of lines of force (webers) per square meter. The SI (System International d'Unites) unit for flux density is the Tesla, the most commonly used unit in magnetic silencing.

Nonmagnetic and Magnetic Materials

Nonmagnetic materials are those materials that cannot be magnetized. Examples of nonmagnetic materials are wood, plastic, glass, copper, brass, and aluminum. Magnetic materials can be magnetized. Iron, steel, and alloys containing cobalt, nickel, or some of the rare earths are examples of magnetic materials. Magnetic material is classed as "hard" or "soft", depending on the degree to which it retain its magnetization (retentivity). A "hard" magnetic material will have a high retentivity while a "soft" magnetic material will have a low retentivity.

Permanent Magnets

A magnet is a body with its own (inherent) magnetism and usually has high magnetic strength. Natural magnets consist of certain ores such as magnetite (loadstone). Artificial permanent magnets are made of magnetically hard material. Permanent magnets can be made from almost any kind of steel that is capable of being hardened by heat treatment. Commercially produced magnets are made from special materials such as carbon steel, tungsten steel, and platinum-cobalt steel, which possess the characteristics of very high magnetic retentivity.

INFORMATION SHEET NO. 2-2
TITLE: Fundamentals of Magnetism

Domains

A bar of steel or iron consists of a great number of tiny, elementary magnets called domains. These domains always exist irrespective of the magnetic state of the metal. Within any one domain, all atoms are aligned with parallel axes. Domains are large enough to be seen under an electron microscope. In an unmagnetized bar of metal, the domains are oriented in random directions, as shown in Diagram 2(A). As a magnetic field is applied to the bar, the domains tend to align themselves in the direction of the magnetic field. Diagram 2(B) shows a bar of metal with the domains predominantly aligned in the same direction. As the magnetic field intensity of the field applied to the bar increases, domains in the bar align themselves in one direction (the same direction as that of the magnetizing force). In this condition, the bar is magnetized completely (saturated), as shown in Diagram 2(C). No external magnetizing force, regardless of the strength, can increase the bar magnetization further.

Permanent Magnetism

The source of the magnetic field of a bar magnet is self-contained within the bar; i.e., the field arises from the fixed orientation of magnetic domains. Self-contained magnetism, being inherent to the bar material itself, is called intrinsic induction. When there is no external magnetizing force acting on the magnet, any residual intrinsic induction is called permanent magnetism. Magnetic materials used in the hull and internal structures of steel hull ships normally have permanent magnetism to some degree. Mechanical shock and internal stress during the time that an external magnetizing force is applied to ferrous materials tend to make the magnetic induction more permanent. Because of this phenomenon, a ship tends to become a permanent magnet due to pounding and stresses during the course of its construction.

Induced Magnetism

1. Magnetizing Force. Magnetic materials of ships are normally exposed to a magnetizing force such as the Earth's field and fields from other sources. This magnetizing force places a

stress on the magnetic domains of the material, and by this stress, aligns them with the direction of the magnetizing force. The domains are restrained, however, according to the hardness of material and types of alloys.

Moreover, the movement of the domains is elastic; alignment of domains may exist only while the magnetizing force is present. When the magnetizing force is no longer present, the domains may return to the alignment that existed prior to application of the magnetizing force. The magnetic field (induction) from the magnetic material that exists only with an applied magnetizing force is called induced magnetism.

Electromagnetism

1. Electromagnetism. When an electric current flows through a wire, a magnetic field, such as the one shown in Diagram 3, surrounds the wire and is called electromagnetism. Electromagnetism plays an important role in the science of degaussing because the strength and direction of the magnetic field can be controlled and varied easily by changing the amount and direction of the current in a closed circuit.

   a. Electromagnetic Polarity. Note that the electromagnetic field surrounding the conductor in Diagram 3 is shown in a clockwise direction. The direction of this field is related to the direction of current flow. In this example, the current is represented as flowing from the right-hand to the left-hand terminal. If the direction of current flow were reversed, the magnetic field would assume a counterclockwise direction. The magnitude or strength of the field increases as the current through the conductor is increased, and it collapses immediately when current flow ceases.

   b. Magnetic Field from a Loop. To make use of a magnetic field created by electric current in a wire, the wire must be bent into particular shapes, such as a circular loop. When the wire encloses an area such as a circle, the direction of the field surrounding the wire lies in one direction inside the area and the opposite direction outside the area. See Diagram 3. Observe that the magnetic field from the wire is concentrated in the small area inside the loop. A square or rectangular loop is often used aboard ships for the degaussing system. Degaussing loops are discussed in detail in later packet lessons.

c. Magnetic Field from a Solenoid. Another useful design of wiring arrangement is the solenoid. In effect, the solenoid is composed of many circular loops wound along a common axis. The primary purpose of solenoids is to create fields of very high intensity.

Earth's Magnetic Field

1. Magnetic Characteristics.

a. Lines of Force on the Earth's Surface. The Earth has magnetic fields as if a huge permanent magnet were located within the Earth, extending from the Arctic to the Antarctic polar regions. See Diagram 4. Lines of force from this magnet cover the earth's surface, and they exert a magnetic influence on all ferrous materials on or near the surface. Since many of these ferrous materials themselves become magnetized, they distort the background field into irregular contours. Thus, the lines of force at the earth's surface do not run in straight, converging lines like the meridians on a globe, but they appear more like the isobar lines on a weather map.

b. Direction of Lines of Force. Earlier in this packet it was noted that, by convention, the external direction of the magnetic field of a bar magnet is from its north pole to its south pole. Lines of force for the Earth's field, however, leave the earth in the Antarctic regions and re-enter in the Arctic regions. For this reason, it is necessary to realize that the magnetic south pole is located in the north geographic region.

Magnetic Silencing Terms, Units, and Symbols

Terms for quantities and units presently used in magnetic silencing are derived from the SI (System International d' Unites) units. The following terms will be used in the course:

Weber (Wb)--unit of flux, which corresponds with the concept of lines of force. The weber is the magnetic flux whose decrease to zero when linked with a single turn induces in the turn a voltage whose time integral is one volt-second. One weber equals 10^8 maxwells.

Tesla (T)--unit of flux density or magnetic induction. One tesla is equal to 1 Wb/m^2.

Maxwell--the unit of magnetic flux in the cgs electromagnetic system. One maxwell equals 10^{-8} weber.

Amperes per meter (A/m)--the unit of field strength, or magnetizing force.

More information on these units can be found in reference 4, paragraph 1-4.

INFORMATION SHEET NO. 2-2
TITLE: Fundamentals of Magnetism

Definitions of three common terms used in magnetic silencing are:

Term	Unit Quantity	Symbol	Definition
Flux	weber	Wb	Quantity of magnetic field. (One Wb within a single turn will induce one volt for one second, when created from zero or reduced to zero.)
Flux Density	tesla	T	Density of magnetic field. (1 Wb/sq meter)
Field Strength (Magnetizing force)	amperes per meter	A/m	Magnetizing force (H) produced by a current (I) flowing through a solenoid of n turns per meter.

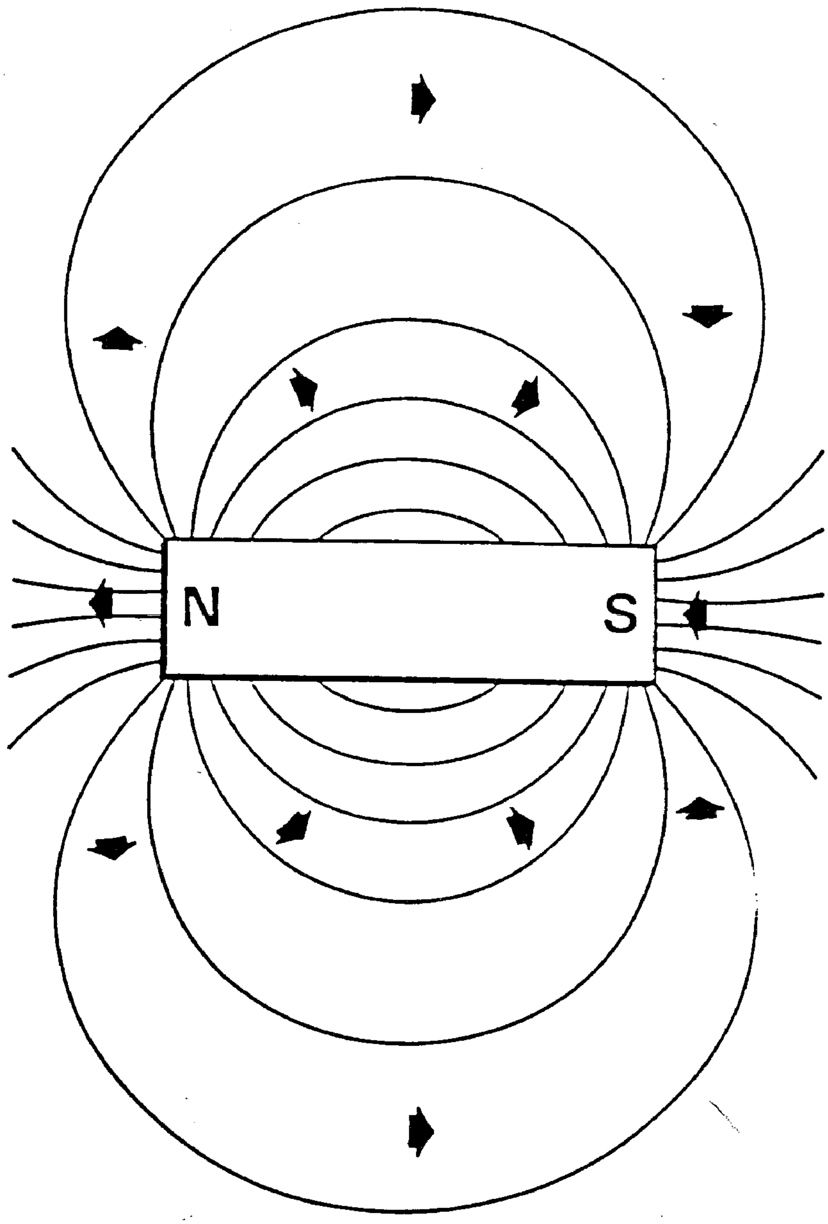
Formula:

$$H = nI \text{ A/m}$$

$$H = \frac{I}{S} \text{ A/m}$$

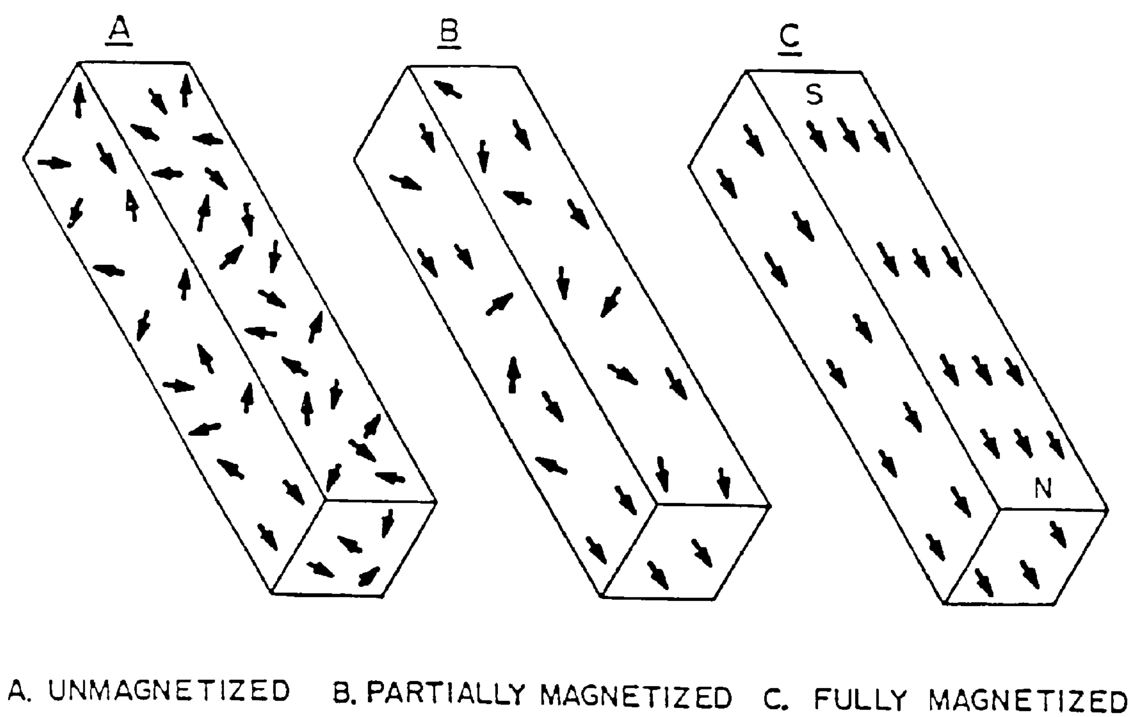
Where S = space between turns in meters

Diagram 1



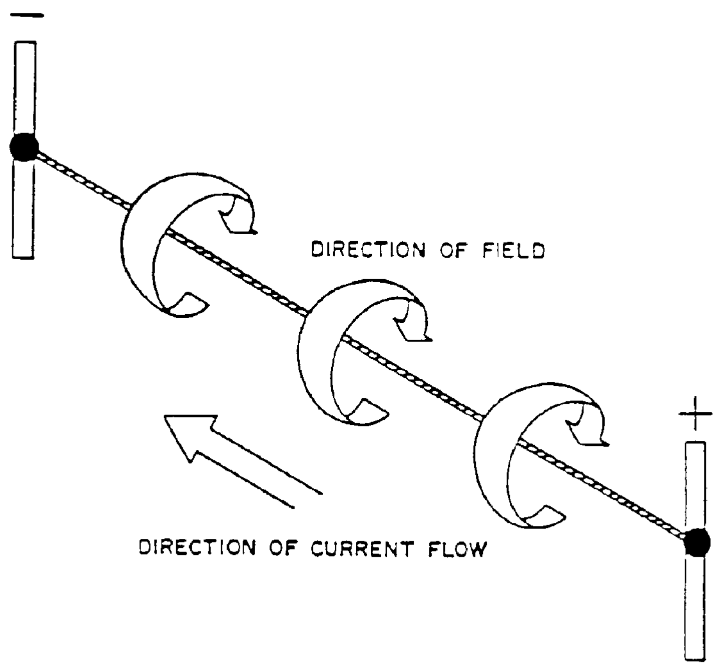
Field Surrounding a Bar Magnet

Diagram 2

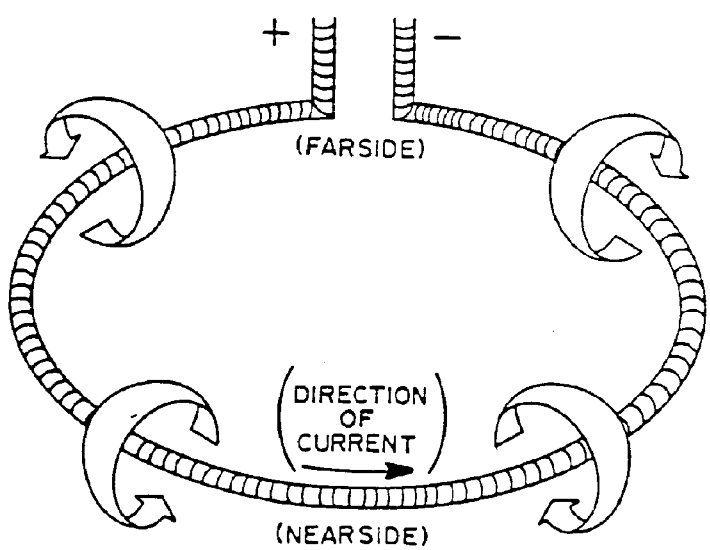


Magnetization by Domains in an Iron Bar

 Diagram 3

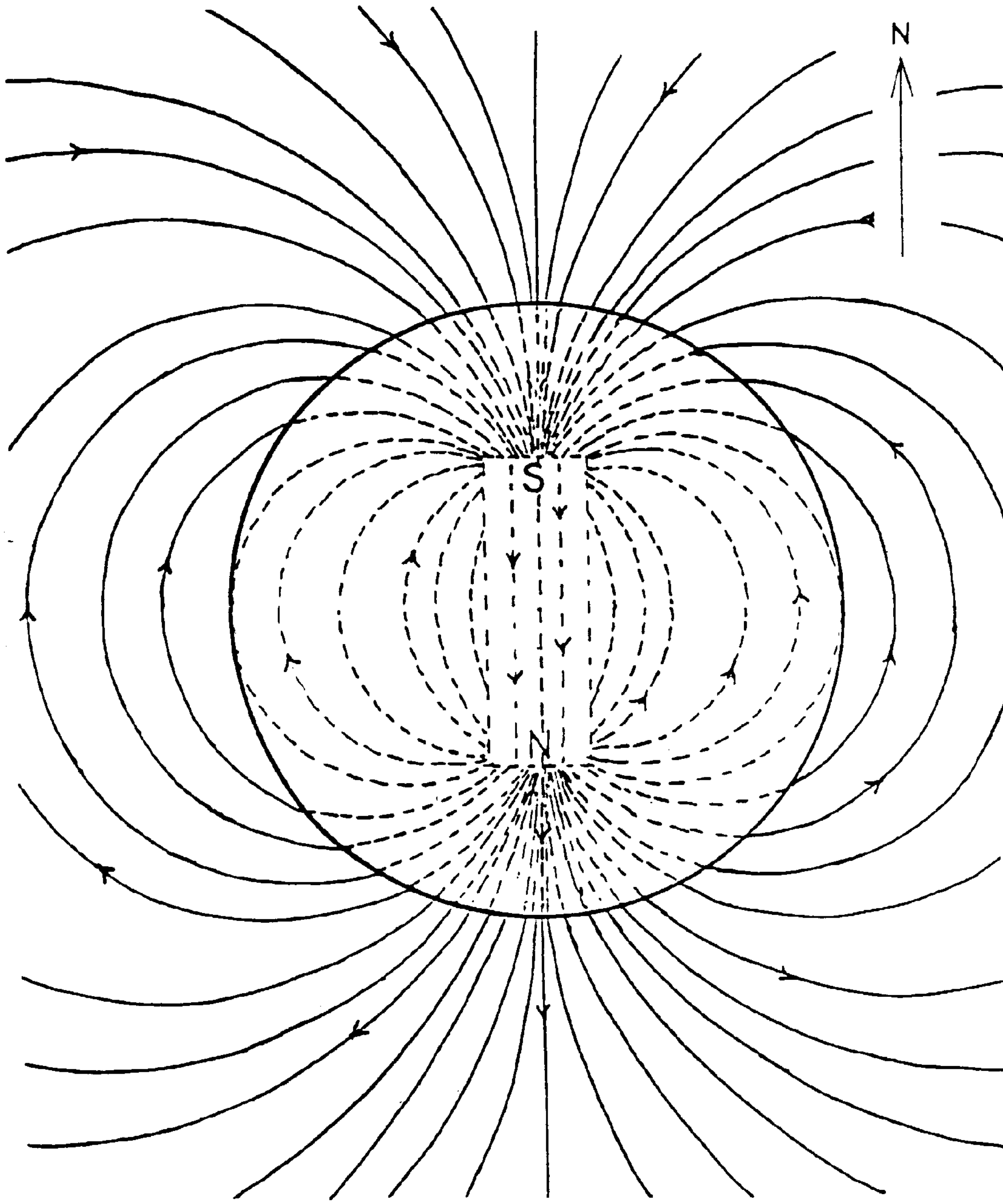


Surrounding a Conductor.



Surrounding a Loop of Wire.

Electromagnetic Field



Earth as a Magnet

PACKET 2

SECTION II

ASSIGNMENT 2: Fundamentals of Magnetism

DIRECTIONS: Choose the word(s) which best completes each statement below. Print those words in the spaces provided. When you finish, have your supervisor correct this assignment.

2-1. Magnetic fields exist in the area surrounding a magnet, and appear to contain loops called ______________________________.

2-2. Magnetic poles are areas in a magnet where the lines of force seem to converge or ____.

2-3. The direction of the external lines of force of a magnet is defined as ____________________________________ from a north pole to a south pole.

2-4. A north magnetic pole will attract a _______________________ magnetic pole.

2-5. The geographic north pole is by definition a magnetic ______ ___________________________________ pole.

2-6. Aluminum, copper, glass, etc., are classed as ______________ ____ materials.

2-7. Magnetic materials are made up of microscopic elementary magnets called ____________________________________.

2-8. A steel bar in which the domains are permanently aligned in the same direction is an example of ________________________ magnetism.

2-9. Magnetism that exists only in the presence of an external magnetizing force is called ___________________________.

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ASSIGNMENT 2: Fundamentals of Magnetism

2-10. An electromagnetic field is an important form of ______________________________.

2-11. The earth's LOF leave the earth in the _____________________ hemisphere and re-enter in the _____________________________ hemisphere.

2-12. The earth's field will cause slow changes to occur in the ship's ____________________________________ magnetism.

2-13. The tesla is the unit of ___________________________________ or magnetic induction.

2-14. Ampere turns per meter is the unit of field strength, or __________________________.

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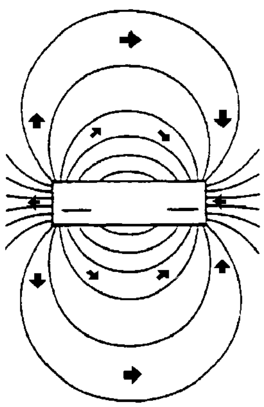
SECTION II

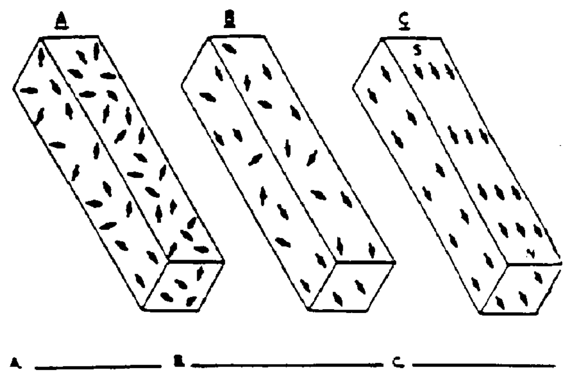
ASSIGNMENT 3: Fundamentals of Magnetism

<u>DIRECTIONS</u>: Mark your answer in the following exercises.

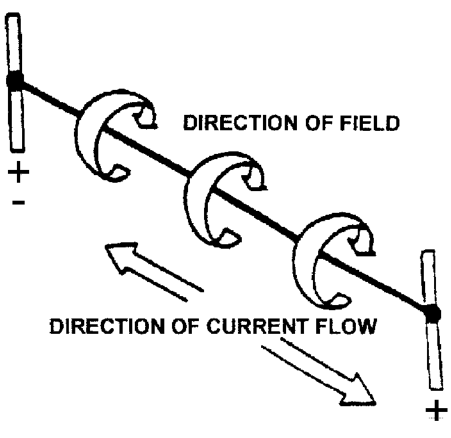
1. Label the poles of the magnet correctly as N or S.



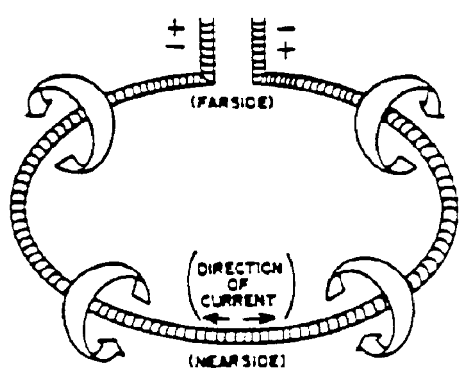
2. Label each bar with its degree of magnetism (unmagnetized, fully magnetized, partially magnetized).



3. Indicate the direction of current flow by circling the correct arrow (<-- or -->). Indicate the correct polarity by circling the correct charge (+ or -).



4. Indicate the direction of current flow by circling the arrow (<-- or -->). Indicate the correct polarity by circling the correct charge (+ or -).



PACKET 2

SECTION III

A. ASSIGNMENT:

1. This completes the material in Packet 2. If you have any questions, ask your supervisor for assistance.

2. When you feel you have mastered the material in this packet, ask your supervisor to give you Progress Test 2.

3. Upon successful completion of the test, your supervisor will give you Packet 3, "Basics of Magnetic Silencing".

NOTES:

______________________________ Supervisor's Signature

____________________ Date Completed