

MAG PRO II
Magnetic Gradiometer
User's Guide



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QUICK START INSTRUCTIONS

1. Make yourself magnetically clean.
2. Turn the Volume Switch clockwise to activate the instrument and set the volume to a comfortable level.
3. Set the Range Switch to 200 milligauss.
4. Sweep the unit back and forth in front of you as you walk along and search the area. With no magnetic (ferrous) targets present the unit will idle at approximately 20 hertz. As you approach a ferrous target, the frequency will increase and peak directly over the target.
5. For strong or shallow targets raise the unit about a foot above the ground or select the 2,000 milligauss range. Conversely, for weak or deep targets you may wish to increase the sensitivity by selecting the 20 milligauss Range.
6. If you intend to use the data logger output option, hold the Mag Pro II vertically and walk parallel traverses. With the aid of a GPS unit and by holding a steady pace, you should be able to prepare a good plot of the vertical magnetic field in your search area.

Remember the MAG PRO II is a precision instrument and should be treated accordingly.

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Introduction

The state-of-the-art Mag Pro II magnetic Gradiometer packs all of its sophisticated electronics in an incredibly light 2 pound package. The instrument is waterproof from the base of the electronics to the tip of the sensor, while the electronics is water resistant. The Mag Pro II has three full-scale operating ranges and they are: 2,000 milligauss, 200 milligauss, and 20 milligauss. Normal surveys are performed on the 200 milligauss range. The instrument audio output idles at a nominal 20 Hz when no magnetic objects are present and increases whenever the Mag Pro II approaches a ferromagnetic anomaly.

When the Mag Pro II detects a magnetic anomaly, rotate the instrument to the vertical position and use an “X” or crossing pattern to pinpoint the maximum vertical field. Then you can tilt the instrument as required to align it precisely with the target’s magnetic field vector, thus giving you the field value, polarity and angle of inclination.

Not only is the Mag Pro II a laboratory quality instrument designed for field use, but it is unequalled as a magnetic locator where it can be used to pinpoint buried iron or steel pipe, survey markers, water valves, water meters and any other ferrous object covered by dirt, pavement, water, snow or ice.

If you hear a warble output from the instrument: BEWARE! A strong warble output from the instrument means you are probably over an energized power line, whereas a weak warble output often indicates the presence of a telephone or communications cable. The capabilities of this instrument are limitless and an experienced operator will find many uses for the Mag Pro II.

There is no need to worry about the instrument battery level since a built-in Low Battery indicator begins flashing whenever the operator has 2 to 3 hours of normal operation remaining. Typically the Mag Pro II will provide in excess of 40 hours of normal operation from standard alkaline batteries.

Theory of Operation

The primary sensing elements used by the Mag Pro II magnetic gradiometer are fluxgate magnetometers. Fluxgate magnetometers are vector magnetic field sensors that measure the average magnetic field component along their sensitive axis, i.e. the magnetic field component along the longitudinal axis of the sensor tube.

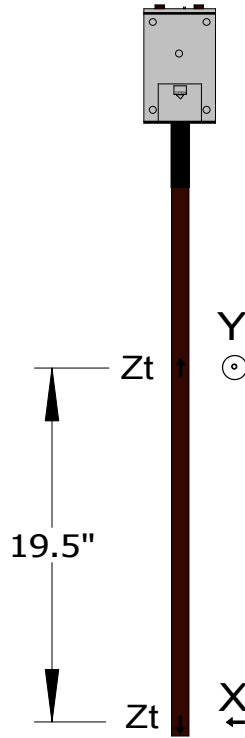


Figure 1, Sensor Location

For the magnetic gradiometer to work properly, the magnetometer sensors are aligned opposing so that the magnetic field measured by one sensor is the negative of the magnetic field measured by the other. The instrument then electrically sums the output of the two sensors. By summing the two output signals, you cancel any field common to both sensors, such as the Earth's Magnetic Field, and leave only the differential magnetic field. The differential magnetic field (the magnetic field detected by one sensor and not the other) is the magnetic field of interest and hopefully represents the magnetic field of your target and not the field of your pocketknife, watch or the magnetic field of the steel arch support in your shoe. The instrument's audio output idles at approximately 20 Hertz when no magnetic objects are present, and increases in frequency as you approach a ferromagnetic target.

Magnetic Cleanliness

The importance of the operator's magnetic cleanliness prior to beginning a search cannot be over-emphasized. Some of the more common sources of local magnetic interference are watches, steel arch supports or toe protectors in shoes, key chains, and pocketknives.

Field Operation

Turn the gradiometer on and then adjust the Volume Control to a comfortable setting and set the Range Switch to 200 Milligauss.

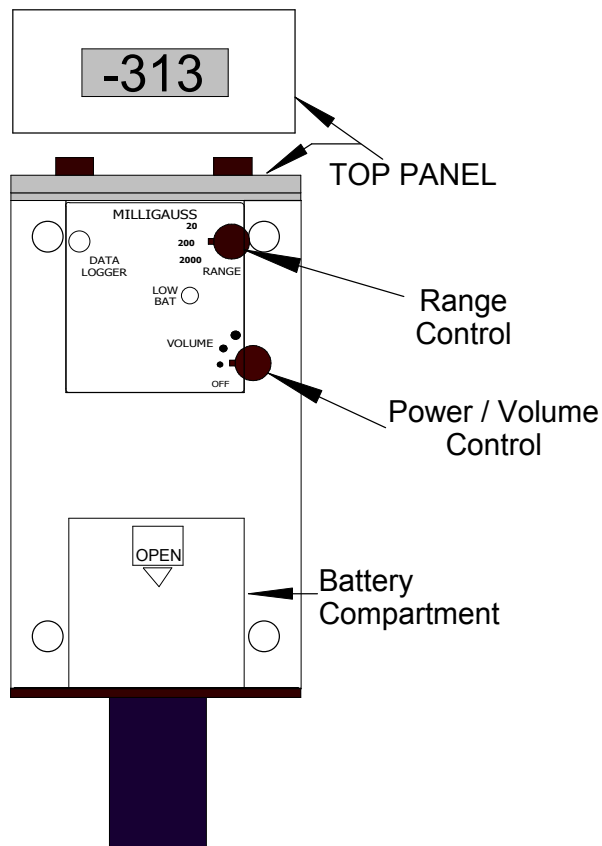


Figure 2, Instrument Controls

Range Settings

Most search operations work well with the Range Switch set to 200 milligauss full scale. For small and relatively weak magnetic targets, the 20 milligauss range may be desirable; conversely when the operator is searching for large, relatively strong magnetic targets, the 2,000 milligauss range may be desirable.

Frequency Output

The instrument's audio output idles at approximately 20 Hertz when no magnetic objects are present. The speaker output tone then increases in frequency whenever the Mag Pro II approaches a magnetic object.

Pinpointing your Target

You may hold the instrument at an angle to maximize your search area, however when you want to pinpoint your target's location, it is advisable to hold the gradiometer vertically and use an "X" or crossing pattern.

Panel Meter

The Mag Pro II magnetic gradiometer has an easily readable Liquid Crystal Display (LCD) panel meter. The 3½ digit (0 to ± 1999) Digital Panel Meter provides a resolution of 1 nanotesla or 0.01 milligauss on the 20 milligauss range. The digital display provides an exact numeric readout of the local magnetic field gradient, and with a sensor separation of nearly 20 inches, the displayed field, is in many cases, the total field of the target.

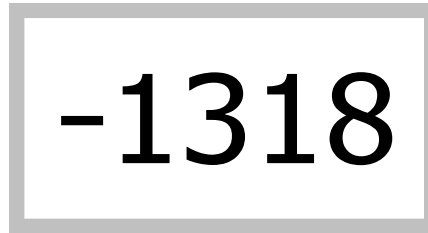


Figure 3, Meter Option

The highly-visible LCD panel meter is also helpful if high background noise begins to overwhelm the speaker. At that time, the operator can frequently continue his search operation simply by referring to the LCD display. The LCD panel meter displays the strength of the local magnetic field while the audio output varies according to the output signal strength making it easy to precisely locate the source of this magnetic anomaly.

Data Loggers

The Mag Pro II comes equipped with an output jack that is designed to interface directly with one of two data loggers. Serial numbers 915001 through 915004 come equipped with a 3mm mono output jack that can be used with the TandD model VR-71 Voltage Recorder. All other Mag Pro II gradiometers have a 3mm stereo output jack that can be used with either the TandD model VR-71 voltage recorder or the Lascar model EL-USB-3 data logger.



Figure 4, TandD model VR-71 Data Logger

Magnetic Signatures of common buried objects

Most common underground targets have a predictable magnetic pattern and consequently produce a predictable output frequency change in the magnetic locator. In the figures that follow, the bold line above ground indicates the relative output frequency level of the Mag Pro II as it moves across the indicated target: the higher the line; the higher the instrument output frequency.

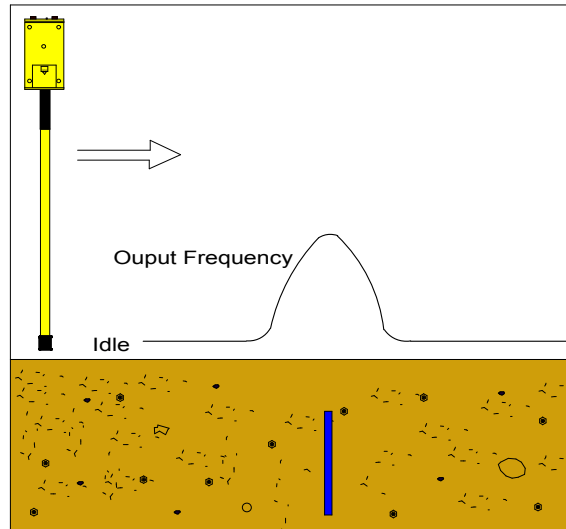


Figure 5, Survey Marker or Well Casing

The peaking of the Mag Pro II output frequency normally indicates that you are over the top center of a vertical dipole (survey marker or well casing).

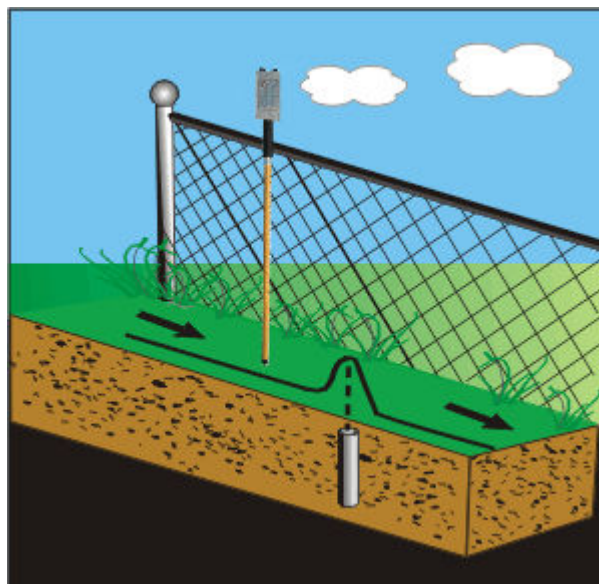


Figure 5, Chain-Link or “Cyclone” Fences

When working around chain-link fences, set the sensitivity control to 3 or 4, hold the instrument vertically and walk along parallel to the fence approximately 8 inches to 1 foot away. You will hear the magnetic field of the fence as you walk along including the field from the posts. However; if your target is near to or under the fence, there will be a dramatic increase in the instrument frequency as you approach the target and you will have no difficulty distinguishing your target from the fence.

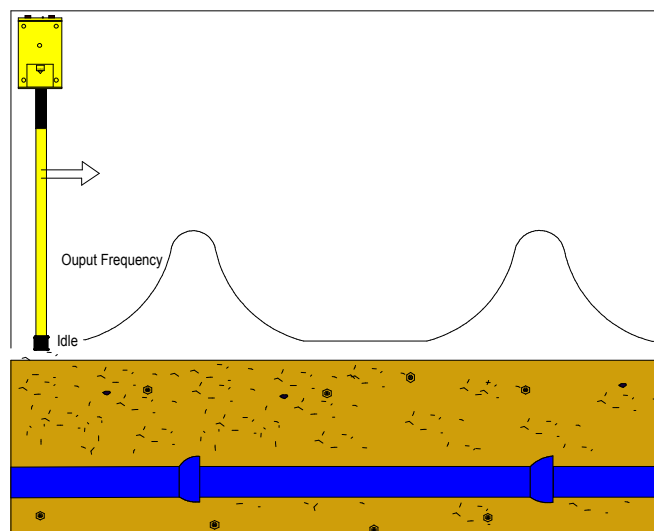


Figure 6, Horizontal Pipe

The peaking of the DML2000 output frequency normally indicates that you are over the end of that pipe section; which can be either a weld or a “Bell” joint, as shown above. When searching for horizontal gas and water lines, look for a polarity change on the digital panel meter (model DML2000-M only). A polarity change that occurs when the output frequency is low; means you are nominally over the midpoint of the pipe section. A polarity change when the output frequency is high; typically indicates a pipe joint or weld.

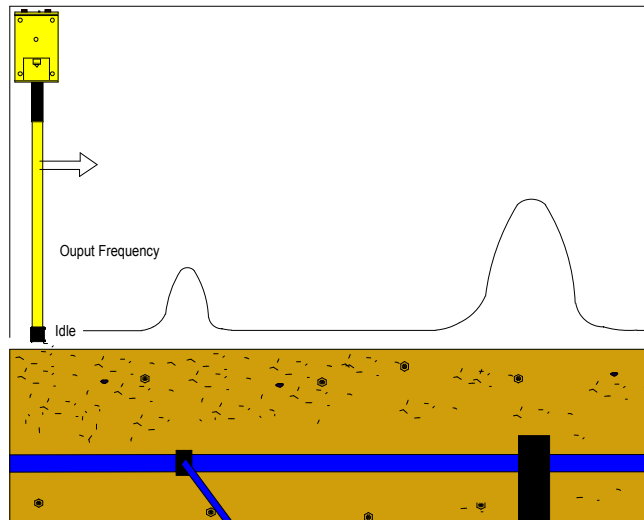


Figure 7, Service Connections and Valve boxes

Frequency peaking occurs over service connections and valve boxes, any place the pipe has been cut and a service connection or other magnetic anomaly inserted.

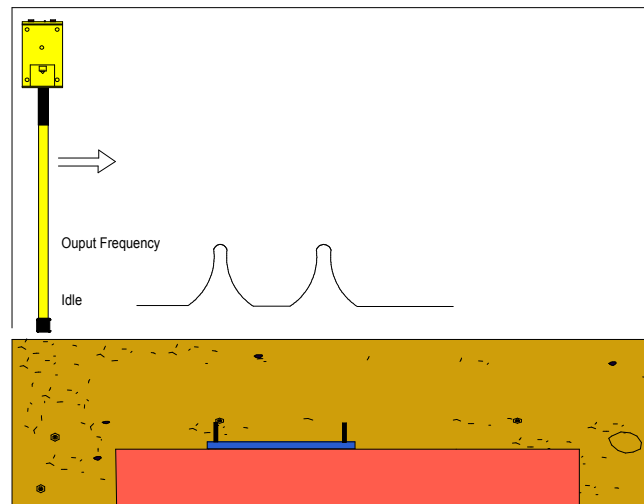


Figure 8, Septic Tank

Most concrete septic tanks have a cover with two handles. The handles are inverted, U-shaped pieces of rebar which are highly magnetic. In most cases, the audio output of the Mag Pro II will reach its peak directly over the handles, which makes it easy for the operator to identify the correct place to dig. In other cases, the Mag Pro II will detect not only the handles on the cover but the magnetic field of the wire mesh or rebar in the concrete. This allows you to not only pinpoint the location of the cover but to also outline the tank and determine precisely its orientation.

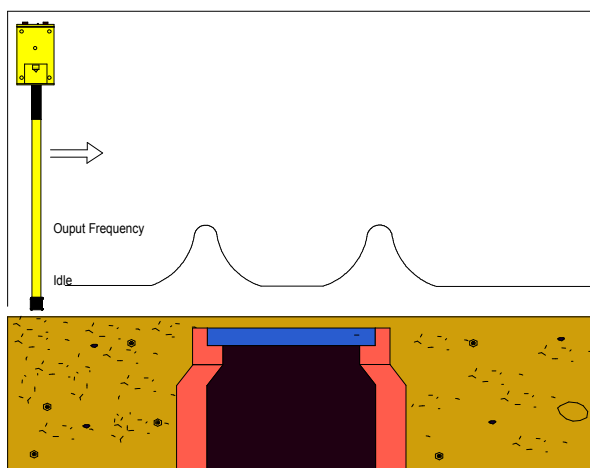


Figure 9, Manhole Cover

A typical manhole cover is highly magnetized and easily detected by the Mag Pro II magnetic locator. However in some cases where the manhole cover has recently been removed and reinstalled but not in its original orientation, another situation can exist. The magnetic field of a manhole is a combination of two magnetic fields, the magnetic field of the cover itself and the magnetic field of the steel support ring. When both fields are aligned they add and are easy to detect, this is the most common situation. However, when a manhole cover has been recently removed and the cover reinstalled but rotated 180°, then the two magnetic fields tend to cancel each other and detection becomes more difficult.

Target Depth Detection Information

So you think depth detection is easy? Once you read this article you may change your mind.

To get credible information on buried targets in your area (Country), the best advice I can give you is to use your locator or gradiometer on known targets first and once you are comfortable with how the instrument performs, then you can search for similar targets where the depth is unknown.

Remember: It is not only inadvisable but in most areas illegal to dig a hole without first contacting your local “Miss Utilities” contractor. They have trained individuals who can survey your area of interest and identify and mark all of your underground utilities before you dig.

The depths outlined here are typical responses. There have, however, been numerous instances where targets have been located at far greater depths. In almost every case, the magnetic locator operator used his instrument almost daily and knew how to get the maximum out of his instrument. He was magnetically clean, his search area was well defined and contained a minimum amount of trash metal, he held his instrument in a vertical position and he used the maximum sensitivity setting.

Target	Depth
Iron Marker (3/4" x 18")	8 – 11 feet
Cast-Iron Pipe (4" Pipe)	6 – 9 feet
Manhole Cover	5 – 7 feet
Well Casing	12 – 16 feet
PK Nail (1½")	10 – 13 inches
Iron Valve	6 – 9 feet
55 Gallon drum	7 – 10 feet
Septic Tank (Handles)	6 - 9 feet

The chart above is based upon data collected from actual measurements of buried targets in North America. The depth information contained herein is based upon many readings taken independently over many years. This information is typical depth readings where the target is well-known, the magnetic environment of the target area is well known and the instrument operator has had many years of experience and knows his instrument well. When operating in the field, always remember that the depth of any target is a function of your target orientation, the magnetic properties of your target, the presence of any nearby magnetic anomalies and how long the target has been buried.

In 1973, Geometrics published an Applications Manual for Portable Magnetometers. The following figures are from the manual and show the relative magnetic field strength of some very common objects.

Table of Anomalies of Common Objects
Typical Maximum Anomaly

Object	Near Distance	Far Distance
Automobile (1 ton)	30 feet 40 gammas	100 feet 1 gamma
Ship (1000 tons)	100 feet 300 to 700 gammas	1000 feet 0.3 to 0.7 gammas
Light Aircraft	20 feet 10 to 30 gammas	50 feet 0.5 to 2 gammas
File (10 inch)	5 feet 50 to 100 gammas	10 feet 5 to 10 gammas
Screwdriver (5 inch)	5 feet 5 to 10 gammas	10 feet 0.5 to 1 gamma
Revolver (38 special or 45 automatic) (induced approximately equal to permanent, see text)	5 feet 10 to 20 gammas	10 feet 1 to 2 gammas
Rifle	5 feet 10 to 50 gammas	10 feet 2 to 10 gammas
Ball Bearing (2mm)	3 inches 4 gammas	6 inches (0.5 feet) 0.5 gamma
Fenceline	10 feet 15 gammas	25 feet 1 to 2 gammas
Pipeline (12 inch diameter)	25 feet 50 to 200 gammas	50 feet 12 to 50 gammas
DC Train	500 feet 5 to 200 gammas	1000 feet 1 to 50 gammas
'Cow' magnet (½" W, 3" L)	10 feet 20 gammas	20 feet 2 gammas
Well casing and wellhead	50 feet 200 to 500 gammas	500 feet 2 to 5 gammas

(Note: anomalies are only representative and may vary by a factor of 5 or even 10 depending upon the many factors described herein)

The instrument of choice for any serious magnetic search is the Dunham & Morrow, Mag Pro II. The first units will be on the market in August of 2010. The Mag Pro II has three full-scale output ranges: 2,000 milligauss, 200.0 mG and 20.00 mG. The Mag Pro II features a 3½ digit LCD panel meter, and the corresponding instrument resolution for each range is therefore 1mG, 0.1mG and 0.01mG. Which means; that on the 20 mG range the last digit on the right represents 1 gamma or 1 nanotesla.

MAGNETIC FIELD CONVERSION FACTORS:

The local magnetic field for the Washington DC area is **513 milligauss** at an angle of **67.6°**.

A single-axis magnetometer with its sensor aligned along the axis of the Earth's magnetic field will therefore read **513 milligauss** on the 2,000 milligauss range.

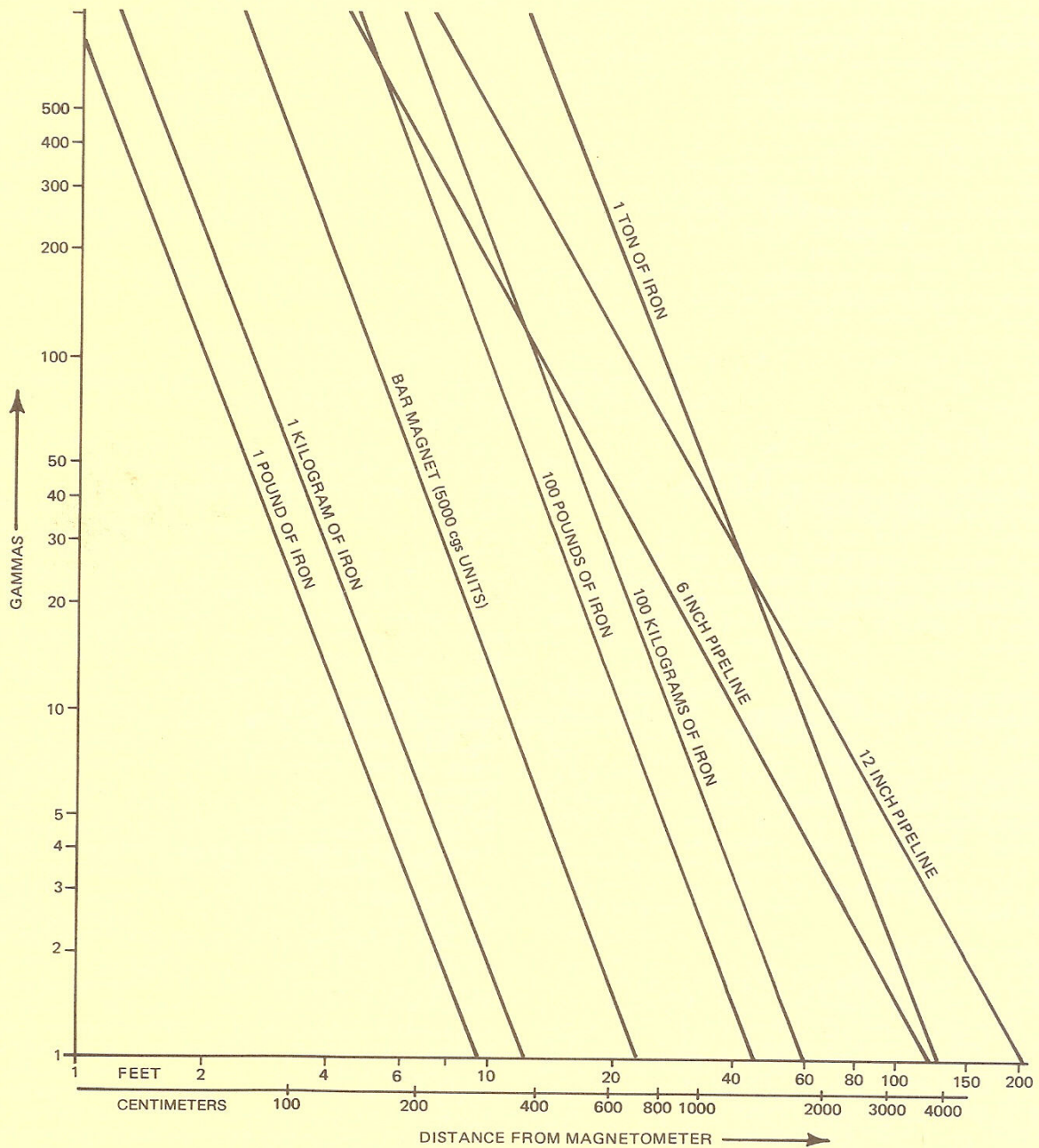
$$1 \text{ gamma } (\Gamma) = 1 \text{ nanotesla (nT)}$$

$$0.01 \text{ milligauss (mG)} = 1 \text{ gamma } (\Gamma) = 1 \text{ nanotesla (nT)}$$

To convert from gamma or nanotesla to milligauss, multiply by 100

$$\text{i.e. } 513 \text{ milligauss} = 51,300 \text{ nanotesla} = 51,300 \text{ gamma}$$

Figure 46. Nomogram for Estimating Anomalies from Typical Objects (assuming dipole moment $M = 5 \times 10^5$ cgs/ton, i.e., $k = 8$ cgs. Estimates valid only within order of magnitude)



INSTRUCTIONS FOR USE:

To use the nomogram, select a given weight or type of object from among the diagonal labeled lines. Then choose a distance along the bottom line (abscissa) of the graph and follow a vertical line upwards from that distance until it intersects the diagonal line of the selected object. At that point, move horizontally to the left to a value on the vertical axis (ordinate) of the graph and read the intensity in gammas.

At a given distance, the intensity is proportional to the weight of the object. Therefore, for an object whose weight is not precisely that of the labeled lines, simply multiply the intensity in gammas by the ratio of the desired weight to the labeled weight on the graph. If the distance desired does not appear on the graph, remember that for a typical object the intensity is inversely proportional to the cube of the distance and for a long pipeline the intensity is inversely proportional to the square of the distance between magnetometer sensor and object. Due to the many uncertainties described herein, the estimates derived from this nomogram may be larger or smaller by a factor of 2 to 5 or perhaps more.

In summary, the detection depth has nothing to do with the soil content or whether your target is buried under asphalt, water, ice or snow. The best way to determine the detection depth of any target is to place the Mag Pro II on a horizontal table or surface, and then bring the target toward the end sensor and measure the distance from the instrument tip to your target. Then reverse the target 180 degrees and record the new distance. The average of these two distances is the detection “depth”. For other targets, you will need to determine the detection depth in place and then average the results to obtain a typical “depth” figure. Repeat with other similar targets as often as possible to build-up your numbers and confidence that you have developed a statistical average. The numbers you end up with can be useful to others, so we encourage you to publish and to share you results with us so we can include them on website.

Historical Notes:

Some of the earliest work on Fluxgate magnetometer design took place at Bell Labs prior to and during World War II. Much of that work was later transferred to the Naval Ordnance Laboratory where they perfected the magnetic torpedo. The magnetometer sensors detected and measured the magnetic field of a target and detonated the torpedo when the signal polarity changed, just as it passed under the keel of the boat. The first practical use of two coaxial, fluxgate magnetometers arranged in the typical magnetic locator design occurred during the Vietnam War where they were used to detect Vietcong tunnels. Today, fluxgate magnetometers are used to monitor solar flare activity, control the attitude of satellites, and guide cruise missiles to their target. They are also used in earthquake prediction instruments, in underwater Search & Salvage operations and in solid-state heading sensors on boats, cars, and airplanes.

The engineers at Dunham & Morrow have been active in the US Space Program since the early 1970's. In addition, they have produced numerous specialty magnetometers for the US Military and the US intelligence community. Some of their more notable programs include: Hubble Space Telescope, the GOES series of weather satellites, the IRAS satellite for the European Space Administration, and magnetometers for the Italian San Marco series of satellites.

General Specifications

Meter:	3½ digit, LCD (0 to ± 1,999)	Audio Output:	Variable Frequency audio output proportional to the differential magnetic field. (20 – 3200 Hertz)
Full Scale Ranges:	2000 milligauss 200 mg 20 mg	Temperature:	(32 – 90) F (0 – 33) C
Resolution:	1 mg (2000) 0.1 mg (200) 0.01 mg (20)	Weight:	2.0 lbs. (0.9 kg)
Accuracy:	± 1 % of FS	Dimensions:	42 ½” x 3 ¾” x 1 ¾” (108 cm x 9.5 cm x 4.4 cm)
Linearity error:	≤ 0.02 %	Waterproof:	36” (91.4 cm) base of electronics to tip of sensor.
Sensor misalignment:	≤ 0.1 °	Operating time:	40 hrs, 4-AA alkaline batteries (80 hrs with lithium batteries)
Output Signal Noise:	≤ 0.002 mg	Warranty:	Lifetime
Low Battery Indicator:	RED flashing LED		

Analog Output / Data Logger Output

With an external 4½ digit, Voltmeter attached

METER RESOLUTION (Milligauss)

Range (milligauss)	Scale Factor (unbiased output)	Scale Factor (2.5 V biased)	Resolution
2000	2.0 V / gauss	1.0 V / gauss	0.1 mg
200	2.0 V / 100 mg	1.0 V / 100 mg	0.01 mg
20	2.0 V / 10 mg	1.0 V / 10 mg	0.001 mg

Electrical Connector:	3 Conductor Stereo Phone Jack 1/8” (3 mm)
Mating Connector:	3 Conductor Stereo Phone Plug
Wiring:	Base Ground
	Center 2.5 V Biased, ± 2.0 VDC
	Tip 0 to ± 4.0 VDC

Note: The Mag Pro II has numerous capabilities including measuring AC magnetic field signatures. Contact the factory for additional information about the instrument frequency response (warren@magneticlocator.com).

Calibration

Your Mag Pro II has been factory calibrated and with proper handling the calibration should remain unchanged. However, if at anytime re-calibration is required or desired, a charge of \$250 plus shipping will be assessed.

Service

If your Mag Pro II ever needs service:

1. Return the instrument to:

Dunham & Morrow, Inc.
43676 Trade Center Place, Suite 145
Dulles, VA 20166

2. Include a brief description of the defect and a daytime telephone number or email address, should a DMI service technician or representative require additional information.
3. Warranty repairs will be completed at no charge. For non-warranty repairs an estimate will be prepared and either emailed or faxed to the customer for approval before any work is started.

Warranty

Lifetime Warranty - All Dunham & Morrow magnetic locators and gradiometers are warranted to the original purchaser to perform failure free for the life of the product, which is no less than 25 years from the date of purchase. Dunham & Morrow will repair or replace any defective magnetic locator, provided that such magnetic locator has not been subject to abuse, misuse, neglect, modification, nor been repaired by anyone other than DMI or its authorized representative. The batteries are specifically excluded from this warranty, as is exposure of the electronics to battery acid corrosion.