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of Engineers**

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Engineering Laboratory

Locating buried utilities

Susan R. Bigl

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes, in basic language, how to operate buried-utility locators and what the locators' uses and limitations are. Its scope is limited to locators using the principles of magnetometry, induction balance, magnetic induction and radio-frequency tracking. Magnetometry and induction balance work best for near-surface isolated targets such as valve boxes and manhole covers. Magnetic induction will locate all types of metallic utilities, including cast iron and steel pipe, power cables and communication lines. Radio-frequency tracking traces unpressurized non-metallic lines that have available-		

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20. Abstract (cont'd).

* access for introducing a floating transmitter into the line (e.g., sewer or storm drains made of plastic or vitreous tile pipe). *1001 10*

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PREFACE

This report was prepared by Susan R. Bigl, Research Physical Scientist, Geotechnical Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

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CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

These conversion factors include all the significant digits given in the conversion tables in the ASTM Metric Practice Guide (E 380), which has been approved for use by the Department of Defense. Converted values should be rounded to have the same precision as the original (see E 380).

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
inches	25.4	millimetres
feet	0.3048	metres

LOCATING BURIED UTILITIES

Susan R. Bigl

1. INTRODUCTION

1.1 Purpose

This report describes the features and operating procedures of the most common devices that are used for locating buried utilities from the ground surface.

1.2 Scope

The function of the devices described in this report is to locate the utilities themselves; they do not locate leaks in buried lines. The locators included here are also limited to relatively simple and less expensive models that operate using magnetometry, induction balance, magnetic induction and radio-frequency tracking. Downward-looking radar has been excluded because currently available models are quite expensive and require considerable training for the operator to correctly interpret their output.

Rather than attempt to cover all existing models of buried-utility locators in detail, this report will describe the locators in general terms. The following subsection is a guide for selecting the proper locator for a particular locating task. The remaining sections briefly explain how each locator works and then describe the common features and basic operating procedures for that locator. A few suggestions on how to avoid improper practices and perform difficult locating tasks are included. Appendix A lists source information for various buried-utility locators and Appendix B discusses the effects of the winter environment on the operation of utility locators.

1.3 Locator selection

Several factors should be examined when you are deciding what locator to use for the task at hand. Table 1 will help you in this selection

Table 1. Locator types to be used for particular location needs.

Utility		Depth of burial	Locators
Description	Examples		
Isolated iron or steel object	Valve box Manhole cover Storage tank Pedestal	Less than 2 ft	Ferromagnetic Induction-balance Dipping-needle
		Greater than 2 ft and less than 6 ft	Ferromagnetic
Linear metallic utility capable of conducting a current	Cast iron } Steel } Copper }	Up to 15 ft	Magnetic-induction
	pipe { water sewage drainage steam gas		
	Metal cable { power telephone cable TV		
	Metal tracer tape buried with nonmetallic line		
	Power transmission line	Up to 15 ft	Power-cable locator
Linear nonmetallic utility (unpressurized)	Plastic } Tile }	Up to 25 ft	Radio-frequency tracking
	pipe { drainage sewage		
	Brick or stone sewer		

process. First, consider whether the item to be located is an isolated object near the surface (e.g., valve box) or a linear utility (a long buried line, e.g., pipe or cable).

Isolated objects, if they are massive and are made of iron or steel, can be detected by three types of locator. Two of these, dipping-needle locators and ferromagnetic locators, operate using the principle of magnetometry; the third type uses induction balance. How deep the target is buried is the next factor to consider. All three of these locators are able to find objects buried fairly shallowly (less than 2 ft), while only the ferromagnetic locator can detect targets buried up to 6 ft deep.

In the case of locating long buried lines, it is important to know the physical characteristics of the line being sought. Devices for locating metallic pipes or cables (magnetic-induction locators) are quite different from those that locate nonmetallic lines (radio-frequency tracking locators). A locator designed to detect nonmetallic lines cannot be used to

search for metallic lines. On the other hand, metallic-line locators can be used to find nonmetallic lines, but only if a metal tracer tape was buried with the nonmetallic line or if a metal cable of some sort is inserted into the line. Magnetic-induction locators can detect all types of buried metallic lines that are capable of conducting an electric current. Examples include cast iron, steel or copper pipe, and cables or wires used for power transmission, telephone or TV signals. Depth capability ranges up to 15 ft.

The radio-frequency tracking method can only be used to locate non-metallic lines that are unpressurized and that have available access. Examples of these include sewers or storm drains constructed of plastic or vitreous tile pipe. The most powerful models are able to locate pipes buried up to 25 ft below the surface.

Table 1 lists one other type of locator that is designed specifically for locating power lines. These devices, often referred to as power-cable locators, are a specialized version of a magnetic-induction locator.

Each type of locator listed in Table 1 is available commercially in several models that vary widely in their shape and operating features. Although most locators operate using only one of the basic principles, some models allow the operator to choose from more than one principle, thus increasing the instrument's versatility.

2. DIPPING-NEEDLE LOCATORS

2.1 Components and principle of operation

The dipping-needle locator is a very simple device that operates on the principle of magnetometry. It senses deviations from the earth's normal magnetic field such as changes occurring close to objects that contain iron or steel. The dipping-needle locator consists of a small case with a magnetized needle (like a compass needle) that aligns itself with the local magnetic field direction (Fig. 1). When this device is moved near a buried iron object, where the local field is distorted towards the vertical, the needle will "dip" from a shallow angle to a vertical orientation (Fig. 2). By locating places where the needle dips, it is possible to find fairly massive objects that are buried near the surface.

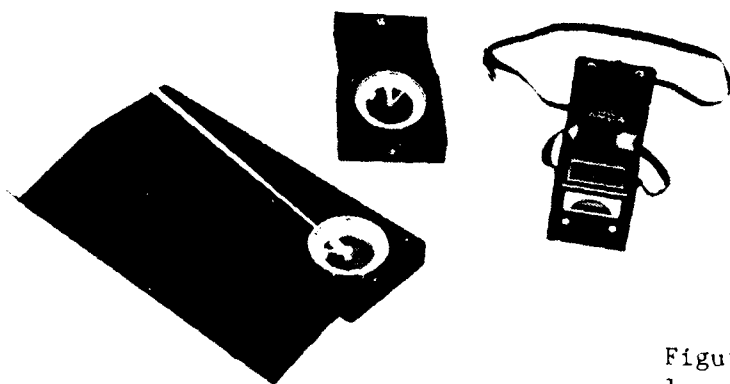


Figure 1. Typical dipping-needle locators.

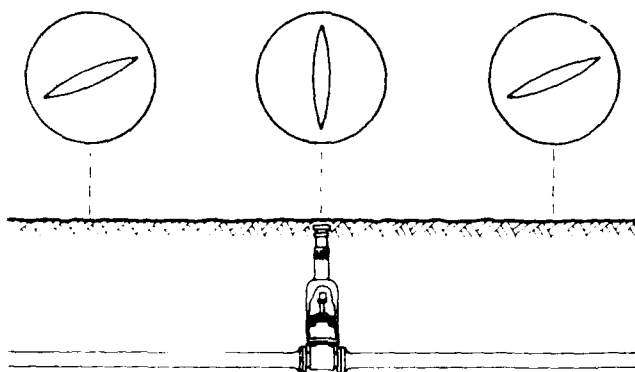


Figure 2. Needle dips to vertical position when located directly over buried magnetic object.

2.2 Uses and limitations

A dipping-needle device is able to locate only isolated, massive objects that will cause strong distortions of the earth's magnetic field (i.e., those that are constructed of iron or steel). Two common examples are manhole covers and valve boxes. The dipping-needle locator is further restricted to locating objects buried near the surface (less than 2 ft). Objects buried at greater depths will cause the needle to move only slightly, and these indications are very difficult to interpret. This device is also limited in that it cannot provide an estimate of burial depth.

2.3 Operating procedures

2.3.1 Find north

The first thing to do when searching for a target with the dipping needle is to find magnetic north. Hold the device horizontally at waist height, operating it like a compass, and note what direction the needle is pointing.

2.3.2 Orient case

Always hold the long axis of the case in line with the north-south plane during your search. Some cases have an arrow labeled north to remind you of this.

2.3.3 Note average dip

In a location where there are no nearby metallic objects, notice the normal resting position of the needle. This is the average dip of the earth's magnetic field. While searching, look for changes from this normal position.

2.3.4 Conduct search

Hold the case a few inches above the ground surface and move it over the area where you suspect to find your target, tracing a grid pattern in lines about 1-2 ft apart. When the needle dips to a steeper angle, decrease the grid spacing in order to find the position of maximum dip. Where the maximum dip is located relative to the buried target will depend on the shape and orientation of the target in the ground (see next section).

2.4 Magnetic fields of buried objects

2.4.1 Iron valve boxes

Relative narrow, vertically oriented masses such as valve boxes (or well casings) have magnetic fields that will produce a maximum dip directly above the center of the mass (Fig. 3).

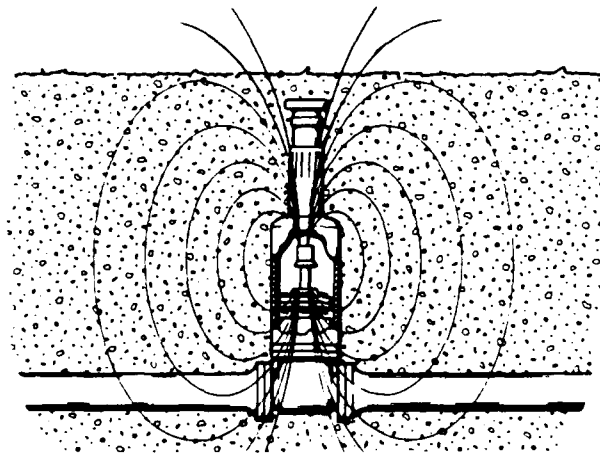


Figure 3. Magnetic field of vertically oriented object (c.g., valve box). Needle will dip directly above center.

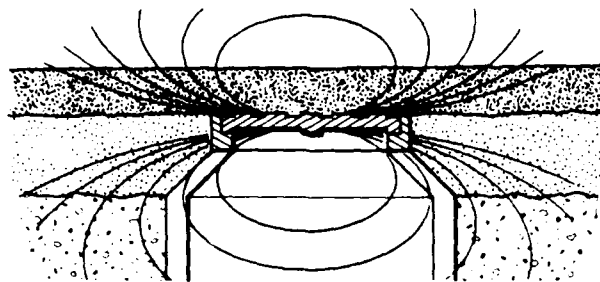


Figure 4. Magnetic field of horizontally oriented object (e.g., manhole cover). Needle will dip over edges.

2.4.2 Manhole covers

The magnetic fields of long, flat, horizontally oriented objects will cause the needle to dip the maximum amount at the ends of the object (Fig. 4). When a manhole cover is located very close to the surface, the needle will dip the most around its entire outer edge.

2.5 Features

The main thing to consider when you select a dipping-needle locator is how easy is it to use. Because the needle operates best if kept close to the ground, some units include a long strap or a telescoping handle that can be held at waist height. This allows you to avoid stooping or bending over during a search. Another convenient feature is a reflector that allows the operator to view the position of the needle from above, rather than looking from the side.

3. FERROMAGNETIC LOCATORS

3.1 Components and principle of operation

The ferromagnetic locator, which is also called a flux-gate magnetometer, operates on the principle of magnetometry. Like the dipping-needle locator, it senses any local changes in the earth's normal magnetic field, as would occur near iron-containing objects.

The ferromagnetic locator consists of a long, narrow probe that is attached at the top to a box containing the necessary electronics, control knobs for adjusting sensitivity and volume, a jack for headphones, and sometimes a response meter (Fig. 5). The shaft contains two sensors, one at the base and one in the upper section, that measure the magnetic field

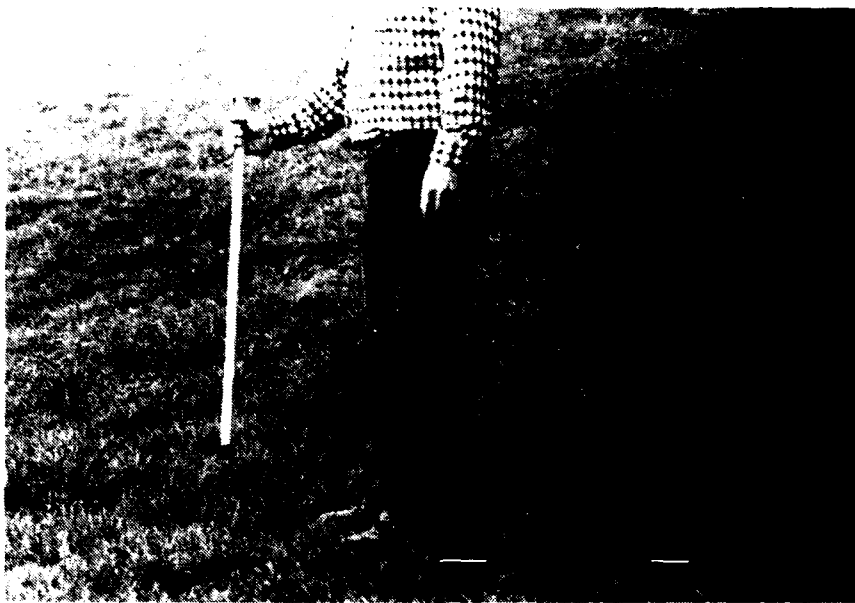


Figure 5. Typical ferromagnetic locator (flux-gate magnetometer).

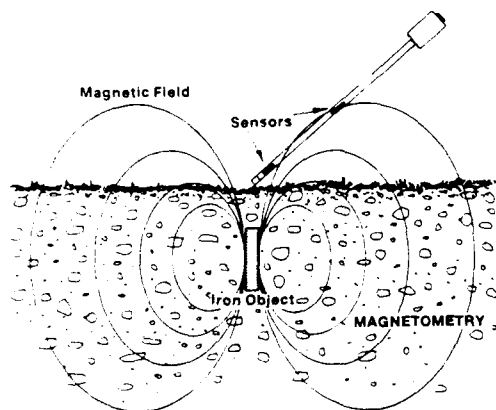


Figure 6. Position of magnetic field sensors in ferromagnetic locator.

strength (Fig. 6). When one sensor detects a higher strength than the other, the locator responds by raising the pitch of the audio signal or showing a higher reading on the response meter. The greater the difference between the two sensors, the greater the response level. This produces a maximum indication at locations of interest.

3.2 Uses and limitations

The highly sensitive ferromagnetic locator will detect a variety of buried targets, provided they are constructed of iron, steel or any ferrous

metal. Targets can range from large objects such as valve boxes, manhole covers, storage tanks, and cast iron or steel pipe, to smaller items such as surveyor's stakes and marking nails, tools and barbed wire. Large objects can be located to depths of 6 to 8 ft, while small objects can be located only if they are near the surface. This instrument, however, is not capable of estimating the depth to the buried target.

Because ferromagnetic locators will indicate all existing variations in the magnetic field, it is difficult to locate buried targets in areas where large metallic objects (e.g., vehicles, buildings) are present at the surface or where steel bars have been used to reinforce concrete.

3.3 Operating procedures

While operating a ferromagnetic locator, keep in mind that it is also sensitive to metal objects on your person. It may be necessary to remove your watch during use. The probe should also be kept away from boots or shoes with steel safety toes.

3.3.1 Adjust sensitivity

After turning on the instrument, adjust the sensitivity knob to about mid-range. This is a good setting for most searches, although the exact setting needed to detect a given target will depend on its size and shape, its orientation, its depth and its relationship to nearby magnetic materials. Practicing over familiar or visible targets will help you to learn what setting works well in a given situation. In general, higher sensitivities will be necessary for small or very deep objects, while lower settings are needed for large objects or when a large magnetic object (such as a building or fence) is near the search area.

3.3.2 Conduct search

To search for an object with the sensitivity set at mid-range, sweep the tip of the probe from side to side in a systematic pattern, while keeping it close to the ground. When the probe approaches a magnetic target, you will either hear a rise in pitch of the output tone or see a deflection on the meter. If there is no response throughout the search area, increase the sensitivity and repeat the search.

An instrument set for high sensitivity should remain in a vertical position. To conduct a search in this case, hold the locator upright and walk in a grid pattern.

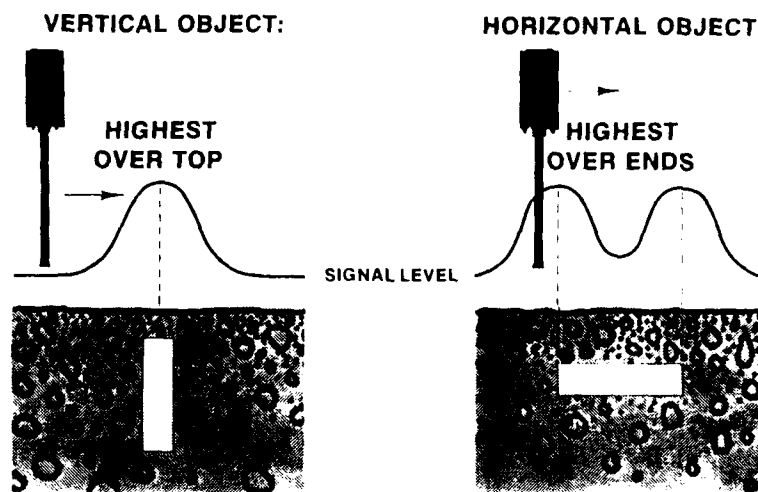


Figure 7. Signal level over vertically and horizontally oriented targets, with locator held vertically. Signal is highest directly over a vertical target and at the ends of a horizontal target.

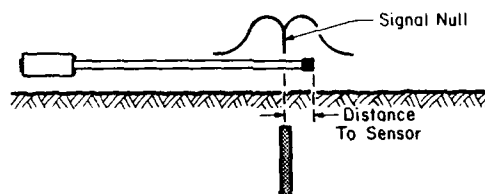


Figure 8. Signal level over vertical object, locator held horizontally. Signal nulls when sensor at tip is directly above target.

3.3.3 Pinpoint target

When the locator indicates a response, decrease the spacing of your search grid. Find the point of maximum response in one direction. Then, starting at that maximum, move the locator along a perpendicular line until you find another peak. By making a series of these "+" patterns, you can pinpoint the spot that returns the highest signal. In general, the highest signal occurs directly over a vertical target, and over the ends of a horizontal target (Fig. 7).

Alternatively, the target can be pinpointed by holding the locator in a horizontal position. If the probe is moved over the target as shown in Figure 8, the signal level will decrease when the sensor at the tip is directly over the target. This method is useful when you are attempting to

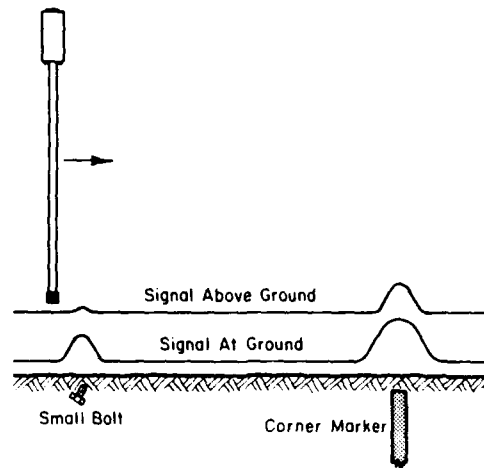


Figure 9. Raising the probe height changes the signal level such that small objects can be distinguished from large objects.

locate targets close to metal buildings or fences. The probe should be held perpendicular to the building (fence) and a constant distance from it.

3.3.4 Multiple signals

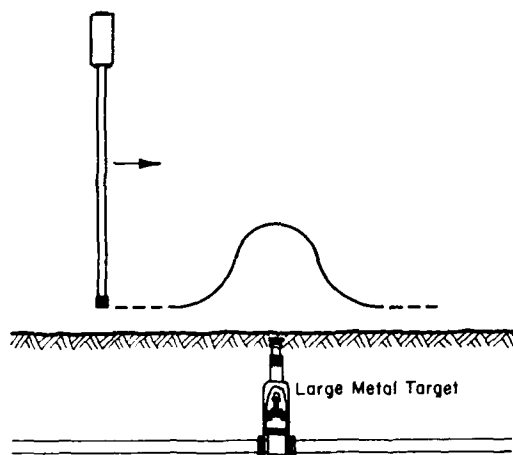
In searching an area, you may discover more than one high response where you expect to find only one. In this case, try raising the locator a few inches and check the two points again. If a small item produced the extra response, its signal level at the higher position will decrease much more than the signal from a large target (Fig. 9).

3.4 Typical signatures

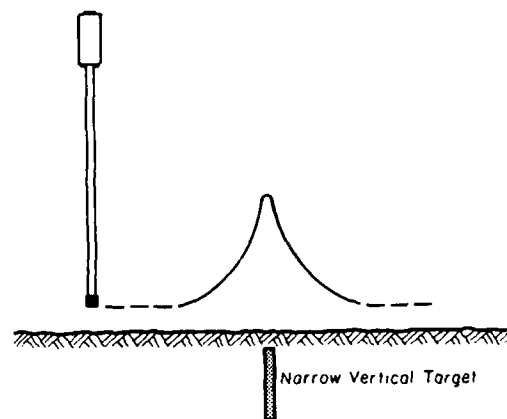
The variation in signal level produced by a locator as it passes over a buried target is commonly referred to as the target's "signature." The size, shape, depth and orientation of a target all have an influence on its signature. However, typical signatures can be described in general terms.

A vertically oriented target will produce a signature with the highest signal level occurring directly over its center. Signatures from large, massive objects have a wide area of high response (Fig. 10a), while those from narrow, vertical objects have a sharp peak (Fig. 10b). If the target is highly magnetized, the signature may include a small rise in signal surrounding the main peak (Fig. 10c).

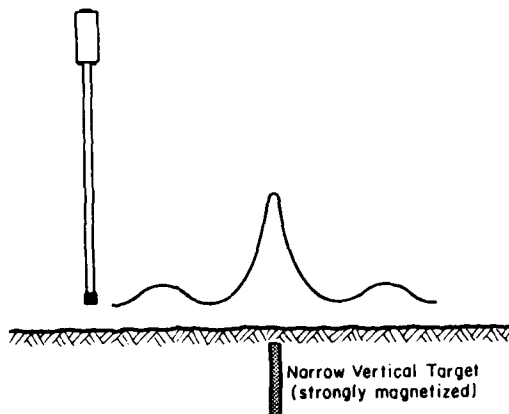
Medium- and larger-sized horizontal objects will give their highest response at the ends (Fig. 7). If narrow horizontal targets are slightly



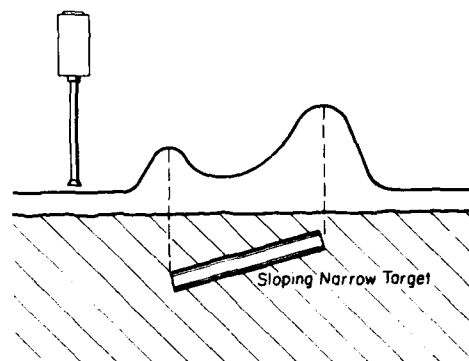
a. Signature has broad curve over large metal target.



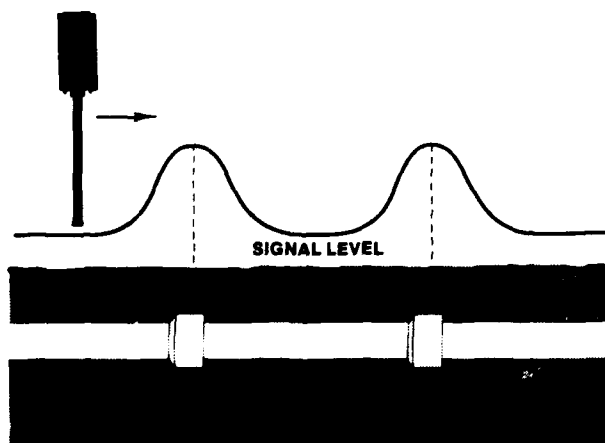
b. Signature has sharp peak over narrow, vertical object that is not strongly magnetized.



c. Signature has small rise surrounding sharp peak over narrow, strongly magnetized object.



d. Signature has unequal peaks over sloping, narrow target. The end closer to the surface has the higher peak.



e. Signature from cast iron pipe has peaks over location of joints.

Figure 10. Typical signatures produced by a ferromagnetic locator.

tilted, a higher response will be returned from the end that is closer to the surface (Fig. 10d). Manhole covers will also give their strongest signal at the edges. With the sensitivity turned way down, it should be possible to trace the outline of covers located near the surface. Cast iron pipes produce the strongest signal from their joints (Fig. 10e).

3.5 Features

The feature of interest with ferromagnetic locators is how their responses are indicated. As stated elsewhere, they generally do this with a meter or with a higher pitch of the audio signal. Models without a meter require the operator to have a keen sense of hearing to distinguish between different pitch levels. Tone-deaf people would not be able to operate such an instrument.

4. INDUCTION-BALANCE LOCATORS

4.1 Components and principle of operation

Devices based on the principle of induction balance, which are used for locating near-surface metallic objects, usually have a box containing the electronics at the top, below which is a telescoping rod and a circular plate, or detection head, at the bottom (Fig. 11).



Figure 11. Typical induction-balance locators.

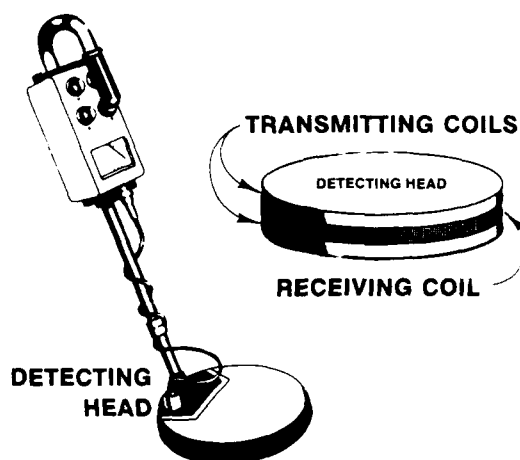


Figure 12. Simplified view of detection head.

Inside the detection head are three layers: the middle one is a receiving coil and the outer two are transmitting coils (Fig. 12). The transmitting coils have magnetic fields that oppose each other. As long as these are balanced, the receiving coil will produce no response. However, when the instrument is moved near a metallic object, the balance between the transmitting coils is disturbed. This is detected by the receiving coil, and its response is indicated as an increase in output volume or as a higher deflection of a meter in the electronics box.

In addition to the audio speaker and response meter, the electronics box may include controls for sensitivity and volume, a knob for tuning the electronic balance between the two radiating coils, and a "ground rejection" knob for tuning out the return from highly conductive soil. As in most locators, there is a method for checking the battery power level.

4.2 Uses and limitations

Induction-balance locators are designed to locate near-surface metallic objects, and are often used as coin detectors. They can detect objects made of any type of metal including silver, aluminum and copper. This ability contrasts with dipping-needle and ferromagnetic locators that sense only ferrous objects such as iron or steel.

In buried utility applications, induction-balance locators can locate manhole covers, telephone pedestals and valve boxes, as well as lost tools. Special detection heads are available for locating reinforcing bar in concrete roads or foundations. These can also be used to locate wires or pipes within nonmetallic walls of buildings.

The depth range of induction-balance locators is limited to only a few feet for larger targets and to less than 1 ft for smaller items such as nails or tools. In general, the detection range depends on the type of soil or other surrounding material, and on the size, shape and surface area of the buried metal object.

4.3 Operating procedures

4.3.1 Adjust rod length

The first step in operating an induction-balance locator is to adjust the length of the telescoping rod. When the handle is held in a comfortable position, the detection head should be just above and parallel with the ground surface. A height of about 2 in. is correct for most instruments. However, some manufacturers suggest operating at a height of 4 in. when you are looking for larger targets only.

4.3.2 Tune response level

The next step is to tune the instrument for a proper response to buried metal objects. This tuning process should be done in a place where the soil conditions are the same as in the area to be surveyed, and where there is no metal nearby to influence the instrument. Available models have varying degrees of sophistication, but most quality instruments include knobs to balance the electronics of the detection coils, to set the sensitivity of detection, to eliminate ground effects of highly mineralized soil and to adjust the volume of output.

The knobs for controlling ground effects and the electronic balance should be adjusted so that raising and lowering the detection head has no effect on the level of output. The exact procedure to achieve this varies with the particular locator model, so refer to its individual manual for specific instructions.

The level at which to set the sensitivity depends on the particular locating task to be done. High sensitivity is necessary for maximum depth penetration and for locating very small objects. Low sensitivity is useful for selectively locating large objects.

Using induction-balance locators for buried utility applications can be frustrating if they respond to all the small "junk" items in the search area (e.g. coins, bottle caps or nails). To eliminate this problem, hold the detection head several inches above the ground surface and turn the

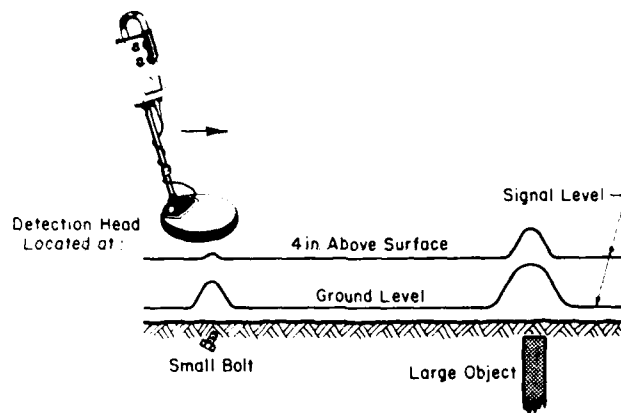


Figure 13. Discriminating small and large objects by raising height of detection head.

sensitivity to its minimum setting. Adjusted in this manner, small objects will return a very weak signal that is barely noticeable, while large objects will give peak signals (Fig. 13). A good way to test this procedure is to line up a series of small coins about 1 ft apart, ending the line with a large metal object. Then, pass the detection head over the row, noting the response given by the locator.

4.3.3 Conduct search and pinpoint target

The search procedure itself is fairly straightforward. Walk in a grid pattern, holding the detection head at a constant height above the ground surface, and notice any increasing audio and meter indications. When a high signal is received, decrease the grid spacing and move the locator in perpendicular directions until you find the point of maximum response.

4.4 Typical signatures

The "signature" of a buried target is the response level produced by a locator as it passes over the target. In contrast to ferromagnetic locators, induction-balance locators emit a constant high response over the entire area of a large metal object (Fig. 14). Note that this happens when the sensitivity is set at its minimum level. Large objects may overload the systems of locators that are set at higher sensitivity levels, and these will emit confusing, "blanked out" signals.

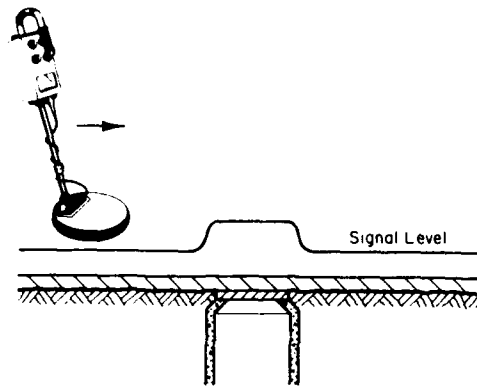


Figure 14. Typical signature over large metal object (manhole cover).

4.5 Features

An essential feature that induction-balance locators should have for utility location is a control to vary the sensitivity level (see section 4.3). Another useful feature, referred to by some manufacturers as "ground rejection," is the ability to compensate for different soil or background conditions. Without this ability, soils that are iron-rich will cause the locator to respond even when no metallic objects are present.

An optional feature available with some models allows the locator to be carried for longer periods without tiring the operator. The box containing the response meter and controls is detached from the rest of the locator and worn close to the body, suspended from a shoulder strap. With this system, the detection head and telescoping rod are the only parts that need to be carried by hand (Fig. 15).

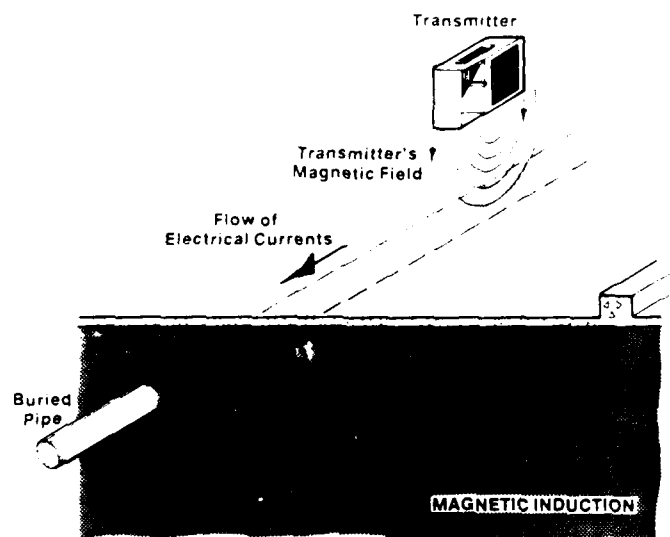


Figure 15. Optional body mount for prolonged use.

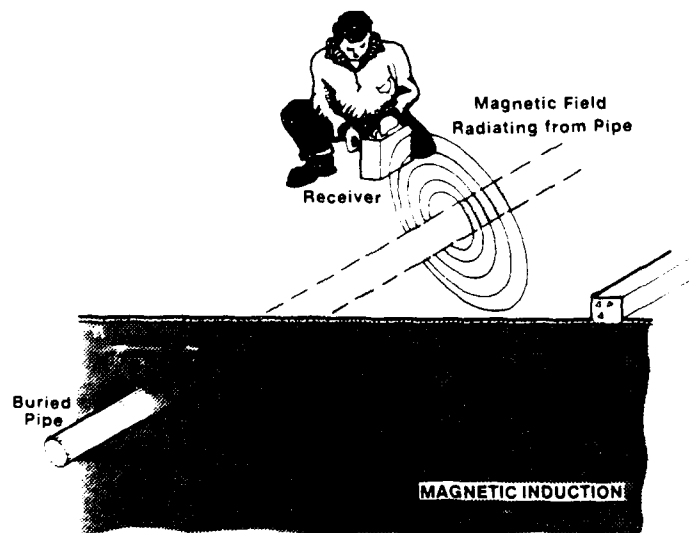
5. MAGNETIC-INDUCTION LOCATORS

5.1 Components and principle of operation

Magnetic-induction locators are designed to locate buried metallic utilities (e.g., pipe, cable). They include separate transmitter and receiver units that operate at a low frequency. The purpose of the transmitter is to generate a magnetic field, which propagates through the ground



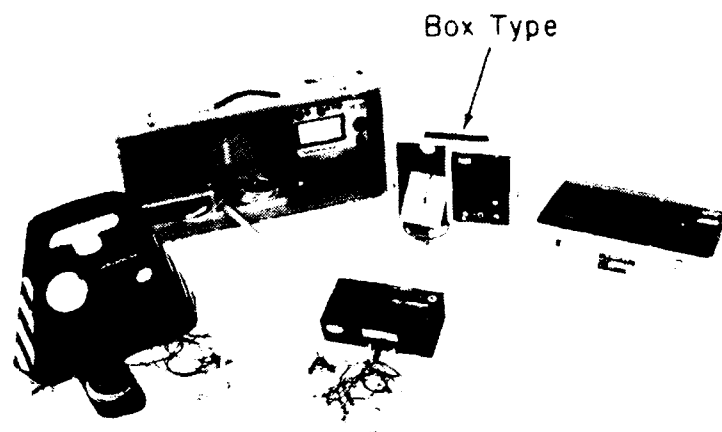
a. Magnetic field generated from transmitter travels to pipe.



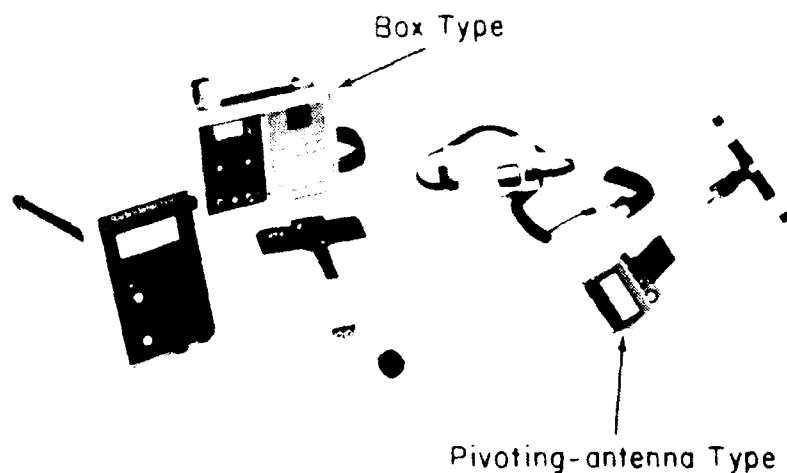
b. Magnetic field radiating from pipe is detected by receiver.

Figure 16. Magnetic induction, principle of operation.

and surrounding air to reach the buried pipe or cable below (Fig. 16a). The magnetic field causes electrical currents to flow within the utility. Because the currents travel in a circulating fashion, they create another magnetic field that radiates outward from the utility in concentric circles. The receiver detects this second magnetic field and, using its circular geometry, the operator can pinpoint the location of the pipe (Fig. 16b).



a. Transmitters.



b. Receivers.

Figure 17. Typical magnetic-induction locators.

The transmitter is a small case that holds the antenna, batteries and electronics package (Fig. 17a). It may have switches or knobs to select the frequency range or power output. There are input jacks for connecting various attachments and the grounding wire. Included also is a method to test the batteries and perhaps a meter to indicate the output achieved.

Receiver units come in various shapes and sizes, but all can be hand-held and are easily portable (Fig. 17b). Most receivers fall into two groups: 1) a small rectangular case (box type), or 2) a unit that includes a grip and a console with the electronics at the top and a vertical rod, which holds at its base an antenna that can be pivoted into several positions (pivoting-antenna type). The electronics package may have a response meter, an audio output, a sensitivity control, a volume control, a battery test switch and a jack for headphones.

5.2 Uses and limitations

Magnetic-induction locators can detect only those buried linear utilities that are capable of conducting an electric current. Thus, they are limited to locating buried pipes and cables made of metals such as cast iron, steel, copper and aluminum. It is possible to detect nonmetallic utilities with this type of locator, but only if a metallic tracer tape was buried with the nonmetallic line or if a metal cable is placed within the line. In this case, you locate the metallic tape in order to find the desired line. A feature that increases the versatility of magnetic-induction locators is that most models permit the operator to estimate the approximate depth to the utility.

The depth to which magnetic-induction instruments can locate utilities ranges up to 15 ft, depending on the several factors that affect the strength of the signal applied to the line. In general, utilities that carry stronger signals can be located at greater depths. Cables can often be located deeper than can pipe because they are designed to carry strong signals. Pipe with a larger diameter also carries a stronger signal than small pipe. The strength of the signal applied is also affected by the method of energizing the utility with the transmitter (section 5.5.1), the frequency of operation (section 5.3.1) and the output power (section 5.3.2). A final influence on the depth at which utilities might possibly be located is the surrounding soil type and its moisture content. Dry, sandy soils allow greater penetration than wet, clay-rich soils.

Magnetic-induction locators work well in simple situations where a line is buried alone. Surface indications are generally less than 1 ft from the imaginary line directly above the actual utility location (Bigl et al. 1984). Under certain circumstances, these instruments can also selectively locate an individual line that is buried near several other lines.

In order to successfully single out a particular line, it must have a much stronger signal than the adjacent lines. When all lines are energized to similar levels, their magnetic fields greatly influence each other. This may cause the surface indications to be offset from the actual locations of the utilities or modified such that only one line is indicated where several are actually present. Methods to energize one line more strongly than the others include setting up the transmitter using direct connection or a coupling clamp (section 5.5.1), using a lower transmitter frequency (section 5.3.1), using a lower output power (section 5.3.2) or tilting the transmitter (section 5.5.1).

5.3 Operating procedures -- general

Refer to section 5.5 for the most direct explanation of commonly used operating procedures for magnetic-induction locators. This section presents general comments about the relative advantages of certain levels of operating frequency and output power.

5.3.1 Operating frequency

Most magnetic induction models operate at a single frequency in the range from 1 kHz to about 500 kHz. In general, higher frequencies will induce stronger signals on a given buried line, allowing it to be located at greater distances and depths. It is advantageous to use a very high frequency when you are locating a utility such as a cast iron line, which has insulating seals at its joints that block the continuous travel of the signal down the line. Energizing this type of line with a high frequency helps the signal to jump from one pipe section to the next. On the other hand, where several lines are buried close together, a high frequency signal has a tendency to jump from one line to another. Therefore, it is best to use a model that operates on a low frequency (1-10 kHz) when you need to single out a particular line from several that are buried in a group.

5.3.2 Output power

Many transmitter units give the operator a choice of output power settings. This may be either in the form of a switch that varies between low and high power or a knob that allows continuous variation within a wide range. In general, you should use low power settings when operating the transmitter with the direct connection method (see section 5.5.1, Direct Connection). While using the induction transmitter set-up (section 5.5.1, Induction), high power levels are preferable in some situations and low power levels are preferable in others. High power ensures a greater tracing distance and provides more energy for overcoming unfavorable soil conditions. However, high power increases the possibility of coupling energy on any adjacent lines that you are not looking for. Using lower power settings will decrease the chances of this. Energizing with low power also lessens the chances of confusing a signal that is radiated directly through the air with a signal radiated from the energized pipe. Receiving the signal directly through the air is called "air lock" (see section 5.4.1).

5.4 Search mode operating procedures

The search mode is used when you suspect that a buried line is in an area, but you don't know exactly where it is.

5.4.1 Two-person search

The simplest search procedure uses two operators. After setting the controls on the transmitter for induction (section 5.5.1, Induction), simultaneously move the transmitter and receiver across the area where the line may be buried until the receiver responds (Fig. 18). At this time, keep the receiver stationary and move the transmitter to the position that produces the highest response by the receiver. Set the transmitter on the ground at that position (which should be approximately above the buried

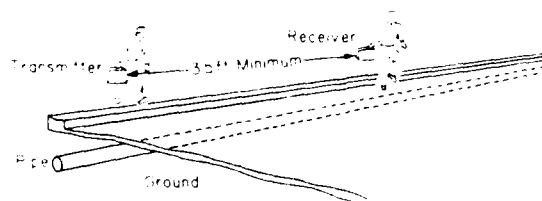


Figure 18. Two-person search procedure.

line). Next, use the receiver to trace the path of the line following the procedures described in section 5.5.2.

When operated in the way described above, the magnetic field of the transmitter travels through the ground to reach the utility, but it also travels through the air. You must therefore be careful not to get the receiver too close to the transmitter. Otherwise, it will pick up the signal directly through the air, rather than from the pipe below. This false response is called air lock or direct air coupling. The separation distance at which air lock starts generally ranges between 25 and 100 ft for different models, depending on the output power of the transmitter.

To help avoid accidental air lock when conducting a two-person search, tie a rope between the two units with a length equal to the correct separation distance. By keeping the rope taut during the search process, you won't allow the units to get too close together.

5.4.2 One-person search

Searching for a buried line can be done with a single person using a procedure similar to the two-person search. First, adjust the transmitter for operation using induction (section 5.5.1, Induction), and place it on the ground in a position central to the search area. Connect the transmitter and receiver with a rope that has a length equal to their correct separation distance. Keeping the rope taut, walk with the receiver in a circle until it returns a response. (If you get no response, move the transmitter and try again.) When you find a response, locate the point where the receiver's signal reaches a maximum. Move the transmitter to that position and proceed with the techniques for tracing the line (section 5.5.2).

An alternate one-person search can be conducted using a locator that has transmitter and receiver units in two small boxes. A bar or handle provided with the instrument allows you to connect the two units and carry them simultaneously. Grasp the handle so that the receiver is in front of you and the transmitter follows behind (Fig. 19). Next, adjust the knobs on the receiver to tune its response as described in the manufacturer's instruction manual. To search, walk at right angles to the path where you suspect the utility is located. Indications from the receiver will reach a maximum when you cross over the utility. To determine the position of the utility more exactly, approach it from either side and place a mark on the

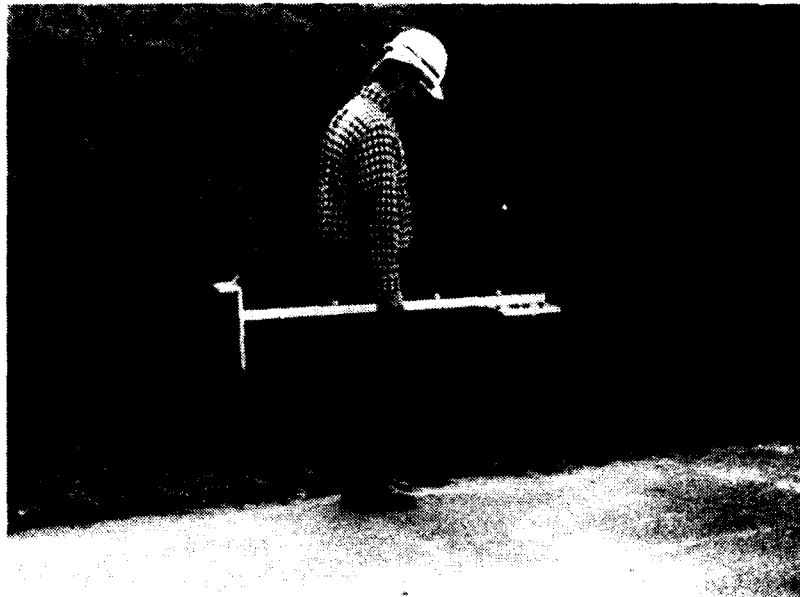


Figure 19. One-person search using two-box locator with handle.

ground next to your feet at the point where the receiver returns the highest signal. The utility is located midway between the two marks.

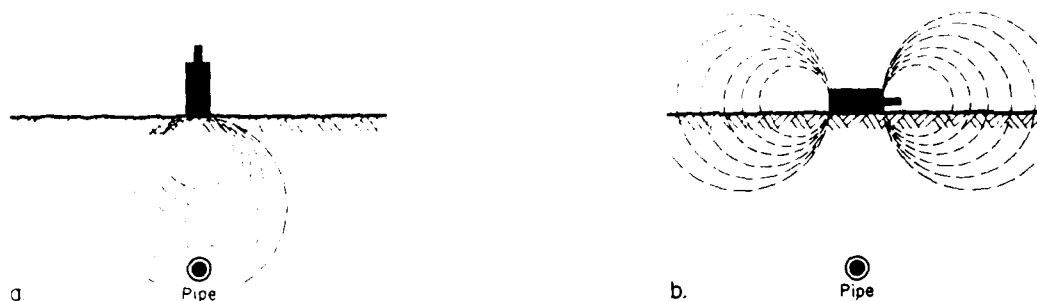
5.5 Tracing mode operating procedures

The tracing mode is used when you know an actual location of the desired utility and you want to either trace its course from there or locate it at a site nearby.

5.5.1 Activate transmitter

The first step is to set up the transmitter so that it induces the flow of electrical currents in the utility. Most models have three possible methods of doing this. They are used for particular situations as outlined below.

<u>Method</u>	<u>Situation</u>
• Induction	An exact location of a buried line is known, but it is necessary to follow this line to an area where its location is only vaguely known.
• Direct connection	Access to the line of interest is available at a manhole, valve box, building connection, etc; a clean metal contact point can be exposed.
• Coupling clamp	Access to the line of interest is available; insulation around line prevents direct connection.



a. CORRECT: transmitter upright and parallel to pipe.

b. WRONG: transmitter lying flat.

Figure 20. Positioning of transmitter for induction method.

Induction. To set up using the induction method, simply place the transmitter on the ground so that it stands upright at a point directly above the known location of the utility (Fig. 20). Set the controls to the proper position for operation by induction. Remember also to turn on the power and check that the battery level is adequate. Orienting the long axis of the transmitter parallel with the suspected path of the line will generally induce the strongest possible signal.

When operating the transmitter using this method, be careful that the receiver does not get too close to the transmitter, or you will have problems with air lock (see section 5.4.1). Having to maintain this minimum separation distance limits the use of the induction method in congested areas where buildings are close together.

Another disadvantage of the induction method is that the propagation of the magnetic field through the ground causes all the lines within its path to be energized. Since each line then generates a magnetic field that is detected at the receiver, it is difficult to determine which response is coming from the desired target. (Other problems with multiple lines becoming energized are discussed in sections 5.2 and 5.5.3.) In some cases, it may be possible to remedy this problem by positioning the transmitter at an angle, as shown in Figure 21, thus placing a stronger signal on the line of interest.

The induction method has a final disadvantage. A relatively weak magnetic field reaches the utility, because a portion of the energy given off by the transmitter is lost as it travels through the ground. As a result, the pipe also returns a weak magnetic field, decreasing the possibility that the locator will be able to detect it.

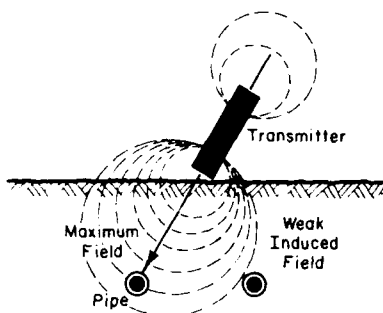


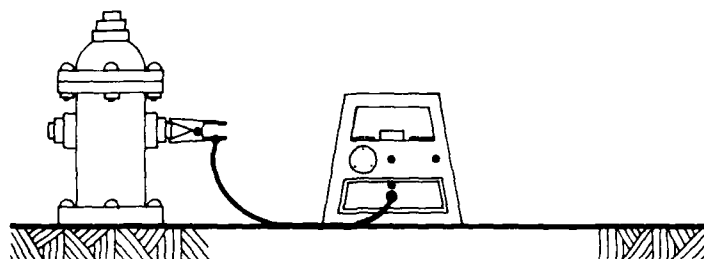
Figure 21. Selectively energizing a single buried line. Suggested position of transmitter when a second line is closely parallel.

Direct connection. The method called "direct connection" or "conduction" establishes a strong signal on the line of interest, but it requires that direct access to the line be available at some point, such as a man-hole or a building connection.

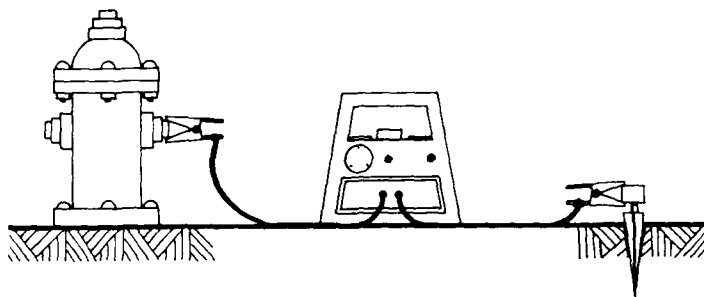
To set up the transmitter using this method, the manufacturer will supply a cable that has a connecting plug at one end and an alligator clip or some other type of clamping device at the other. Insert the plug into the appropriate jack on the transmitter and connect the clip to a clean metal surface on the utility (Fig. 22). (A small magnet attached to the clip will help you to connect the cable to iron or steel utilities in places where there is nothing for the clip to grab.)

To complete the direct connection set-up, the transmitter must also be grounded. Some models provide a separate cable for this. Plug one end of it into the transmitter and connect the opposite end to a metal stake (or rod) that you drive into the ground with a hammer (Fig. 22). Other models have a system in which the ground cable and the live cable are both connected to the transmitter with a single plug. The opposite end of the live cable has a clip that you connect to the utility; the ground cable has a metal plate for inserting into the ground (Fig. 23).

For the signal to be correctly transmitted to the utility line, there are two cautions regarding procedures that cannot be overstressed: 1) The connection between the live cable and the utility must be made to a point where clean, bare metal has been exposed (all rust and paint removed). 2) A good quality ground must be established. Connecting clamps and wires should be tightly secured. The ground plate or rod should be pushed vertically into the ground, preferably at a damp location, and as deeply as



a. Live cable attaches directly between transmitter and utility.



b. Second cable is used to ground transmitter.

Figure 22. Direct connection transmitter set-up (two-cable type).

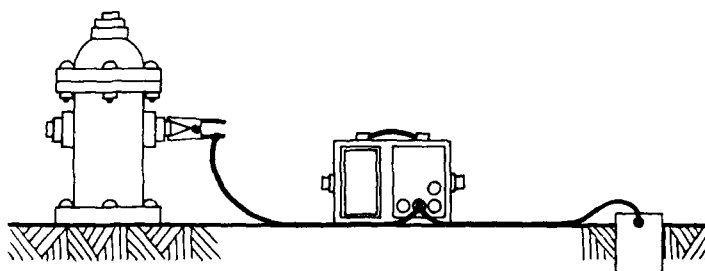


Figure 23. Direct connection transmitter set-up (alternate type). Live cable and ground cable plug into a single jack.

possible. If the soil is very dry, pouring salty water over the ground plate or rod may help to create better contact with the soil.

If the search area is paved, first try connecting to an established ground nearby or extending the ground wire length to reach the closest exposed soil. As a last resort, you may try laying the ground plate (rod) flat on the pavement surface.

The proper distance to the grounding location depends on the situation. If the utility line to be located is isolated (i.e., no other utilities nearby), it is best to place the transmitter as far from its connection point as the cable will permit. You should also position the ground at right angles to the utility to establish the strongest possible signal on the line. Where several utilities are located close together, the ground should be positioned close to the particular line you're interest in (or further away in the opposite direction from the other lines). If the ground is located beyond a second utility line, that line will also become energized.

Coupling clamp. A strong signal can also be established on the line of interest using an attachment called an "inductive coupling clamp" or "coupler." Coupling clamps usually have curved jaws that allow you to secure them around any insulated cable or metal pipe that has a diameter smaller than the inside dimension of the clamp (Fig. 24). To properly energize the line, the jaws of the clamp must be closed tightly.

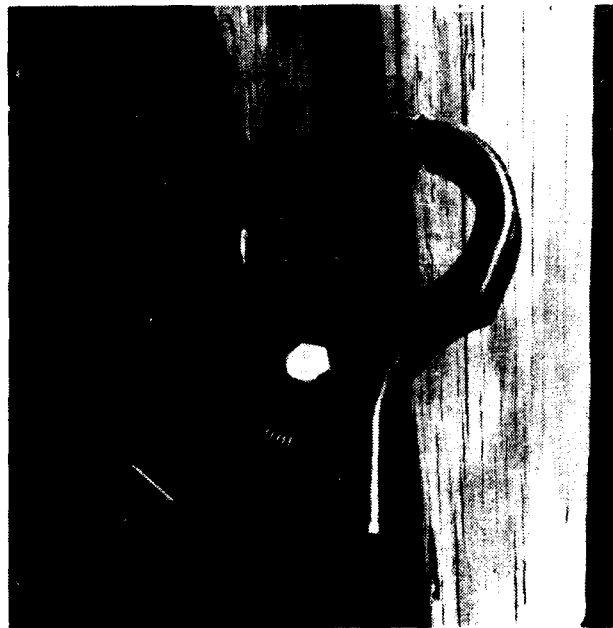
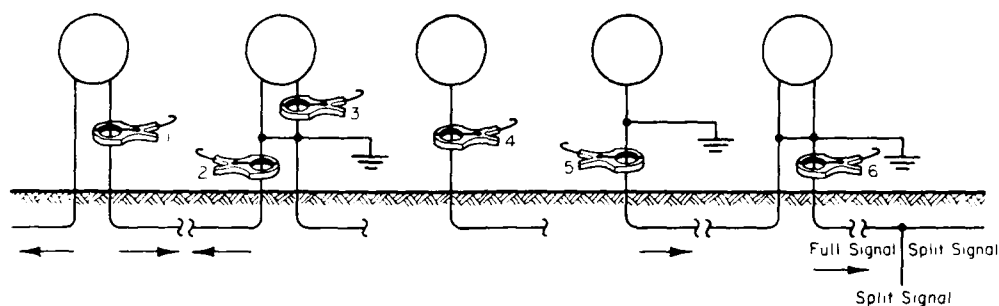


Figure 24. Energizing utility with coupling clamp.



1. Coupling clamp is used for all tracing applications where conductors are exposed. When clamp is attached midway along a conductor, signal will be transmitted in both directions.
2. Clamp should be placed between a ground and the point where the conductor enters the earth.
3. When clamp is positioned incorrectly, the trace signal will return to ground.
4. If clamp is attached at a terminating point that is an open circuit, trace signal will not be transmitted.
5. You will need to provide a ground at a terminating point to provide proper current flow through the ground.
6. When coupling to a conductor with drop lines or laterals, the full trace signal is transmitted up to the junction, then it is divided in half down each line beyond that point.

Figure 25. Applications of the inductive coupling clamp.

The set-up procedure is fairly simple. First, clamp the jaws around the line to be energized; then attach a cable from the clamp to the correct output jack on the transmitter. With some models, the knobs regulating the output of the transmitter will have to be adjusted so that power will travel to the clamp.

For best tracing results, the utility you attach to must be a closed loop, or circuit, or be grounded. To provide your own ground, it is useful to carry with you a short metal rod and a cable with clips at each end. The coupling clamp should be hooked up between the electrical ground and the point where the utility enters the ground. Figure 25 illustrates alternate applications of the coupling clamp.

5.5.2 Locate line with receiver

Once the transmitter has been set up to energize the line, the next step is to carry the receiver over the suspected path of the utility. As the receiver approaches the line, it will respond either by a deflection of the needle on a meter or by changing the volume of its audio output, or both.

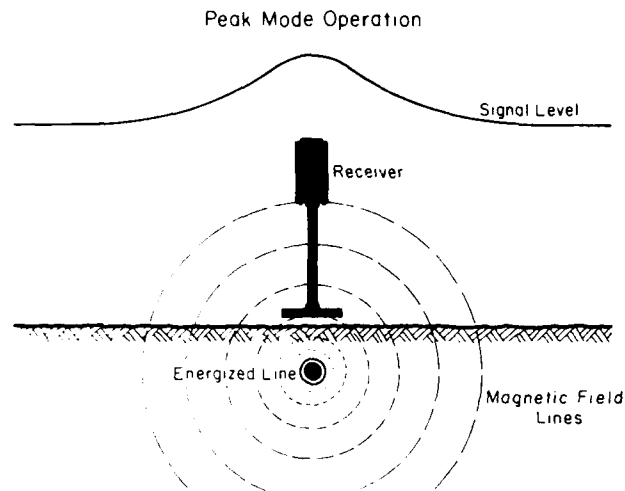


Figure 26. Theory of peak mode operation -- horizontal antenna. Response level is highest directly over pipe because antenna is tangent to magnetic field lines.

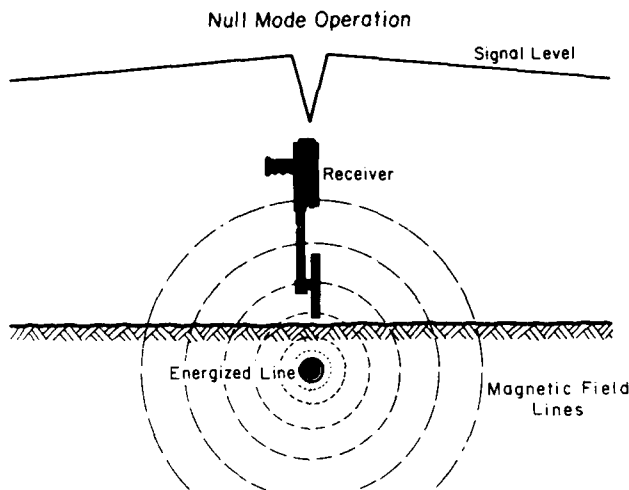


Figure 27. Theory of null mode operation -- vertical antenna. Response level drops sharply directly over pipe because antenna is perpendicular to magnetic field lines.

Most receivers have two operating procedures such that their response will either rise to a peak or fall rapidly to zero when directly over an energized utility line. These procedures are called "peak mode" and "null mode" operation respectively (Fig. 26 and 27). Because peak mode operation has a gradually changing response, it is best to use it for finding the

general position of the buried line. On the other hand, null mode operation results in responses with sharp contrasts. There will be a narrow area with no response (called a "null") directly above the pipe, but on either side, the response level will be very high. Null mode should be used for pinpointing the exact location of the pipe after its general position has been determined using the peak mode.

Background explanation. Peak and null mode operation are made possible by changing the relative orientation between the antenna within the receiver and the circular magnetic field that radiates outward from an energized utility (Fig. 26). When operated using peak mode, the receiver's antenna is exactly tangential to the magnetic field lines at the position directly over the utility. This tangential relationship causes the receiver to give a maximum response directly above the utility. While operating in the null mode, the opposite case is true. The antenna is oriented so that it will be at a right angle to the field lines directly above the utility. The receiver's response drops rapidly to zero in a narrow area at that position (Fig. 27).

Because this geometry is so important to the correct functioning of magnetic-induction locators, it is critical that you hold the receiver in a horizontal or vertical position at all times. Do not wave the receiver back and forth as you trace the path of the utility.

The geometry of magnetic field lines also explains why you will receive broader and lower-amplitude responses as the pipe depth increases (Fig. 28). The magnetic field lines reaching the surface from a deep pipe

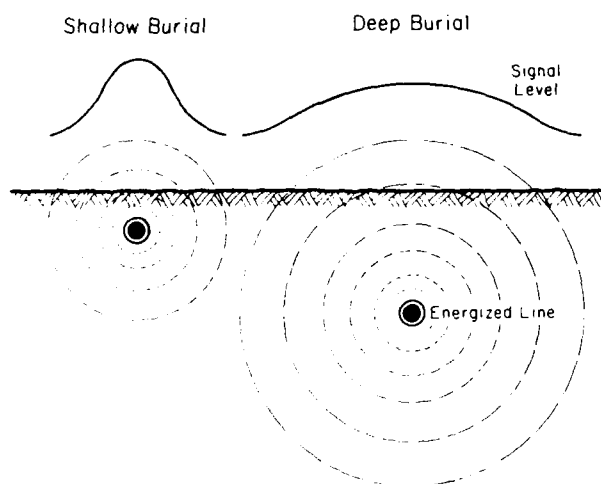


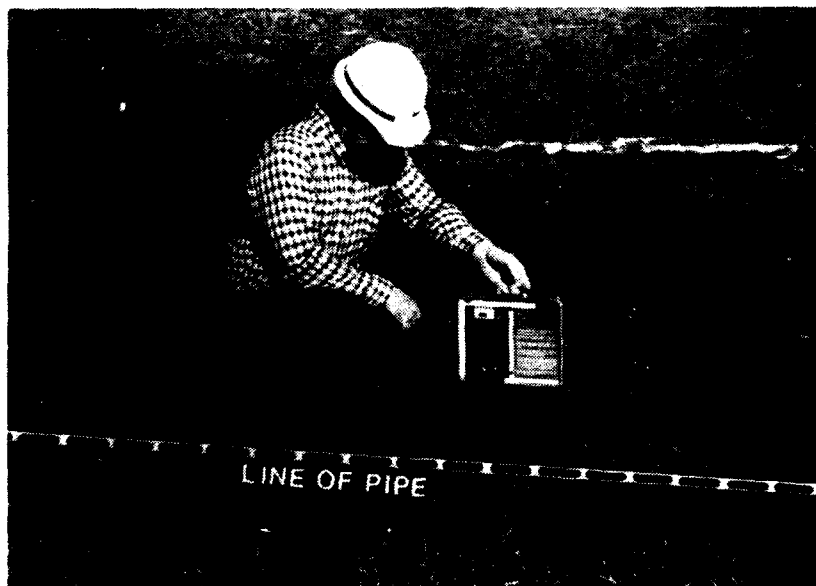
Figure 28. Response level variations due to change in pipe depth.

have a greater radius of curvature and weaker intensity than those from a shallow pipe. The broader field lines result in a broader response detected by the receiver.

General procedures. The exact procedures for operating the receiver unit of magnetic-induction locators are unique to any particular model and the instructions in the manual for that model should be followed above all others. However, instructions can be described in general terms by separating the receivers into two basic styles -- box type and pivoting-antenna type.

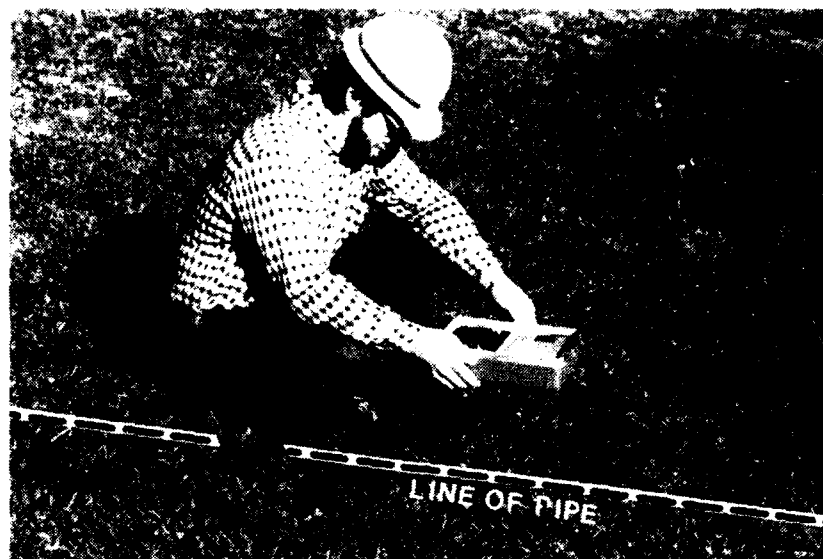
To operate the box type receiver in the peak mode, hold it vertically and carry it close to the ground, keeping its long axis parallel with the suspected path of the pipe (Fig. 29a). Slowly walk perpendicular to the path of the line until the indication reaches its highest level. At the point of maximum response, the buried line is located directly below the receiver. By following the line of maximum response, you will be tracing the path of the buried utility.

To operate the box type receiver in the null mode, hold it horizontally as shown in Figure 29b. Scan the area where you expect to find the pipe, keeping the receiver close to the ground surface. It will respond at



a. Peak mode.

Figure 29. Correct operation of box-type receiver.



b. Null mode.

Figure 29 (cont'd). Correct operation of box-type receiver.



a. Peak mode (antenna horizontal). b. Null mode (antenna vertical).

Figure 30. Correct operation of pivoting-antenna type receiver.

a high level to either side of the pipe, but directly over the pipe, its response will drop to zero or to a very low level. To trace the path of the pipe, walk down the line and move the receiver back and forth to locate the places with this null response.

The pivoting-antenna type receivers have a hand grip that you should hold with your arm extended downward, keeping the shaft of the receiver exactly vertical for both operating modes (Fig. 30). To operate using peak mode, orient the lower antenna horizontally with its long dimension perpendicular to the suspected line of the pipe; for null mode operation, rotate the antenna so that it is in a vertical position. The response levels given by this type of receiver will follow the patterns described above for the box type receiver.

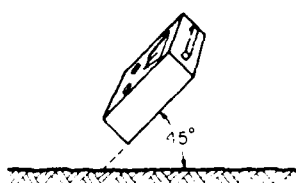
Adjusting the sensitivity control is a very important factor in getting accurate readings from the receiver unit. Usually, in peak mode operation, very low sensitivity levels will give the best results. Your aim should be to have the maximum reading stay within the range of the meter and peak at the upper part of the scale. If the receiver is the type that only changes volume, adjust the sensitivity so that it sounds a response within only a narrow area just above the pipe. Higher sensitivity settings will be necessary if you are attempting to trace a particular line over long distances.

The sensitivity levels that most often give the best results in null mode operation are settings close to the maximum range (high end) of the control. This will usually produce a very narrow area of null response (less than 1 ft wide). If the sensitivity is not turned up high enough, either no response will be received or the null response will cover a wide area. If the sensitivity is set too high, the response will not drop as you cross over the pipe.

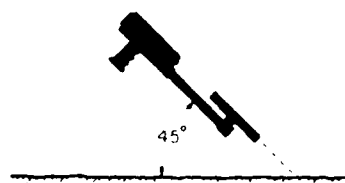
Be sure that the receiver does not get too close to the transmitter during operation or air lock will result (see section 5.4.1). This is especially critical for operation with induction or during search procedures. However, a small separation distance is also required when using direct connection or a coupling clamp.

5.5.3. Estimate depth

45° triangulation. Models of magnetic-induction instruments that have null mode operation are capable of estimating the depth to an energized



a. Box receiver



b. Pivoting-antenna receiver.

Figure 31. Receiver position for depth estimation using 45° triangulation.

utility line using a technique called "45° triangulation." Before estimating depth, you must have previously located a point that is directly above the utility. Starting at that point, hold the receiver perpendicular to the utility, oriented at a 45° angle as shown in Figure 31. (Many models include a leveling bubble to help you position the receiver at exactly 45° from horizontal.) Then, walk away from the pipe until the receiver produces a null response. The distance from the point where you obtained this null response to the point directly above the pipe equals the depth to the center of the pipe (Fig. 32). Subtract the pipe's radius to find the depth to the top of the pipe. Measure this distance on both sides of the pipe and use an average of the two readings for your estimate of the pipe depth.

If the depth readings taken to either side of the pipe differ significantly, don't trust either reading. This situation is probably the result of other nearby conductors radiating their own magnetic fields that overlap the field of the utility you are looking for. Its magnetic field will then deviate from the circular geometry produced when only a single line is

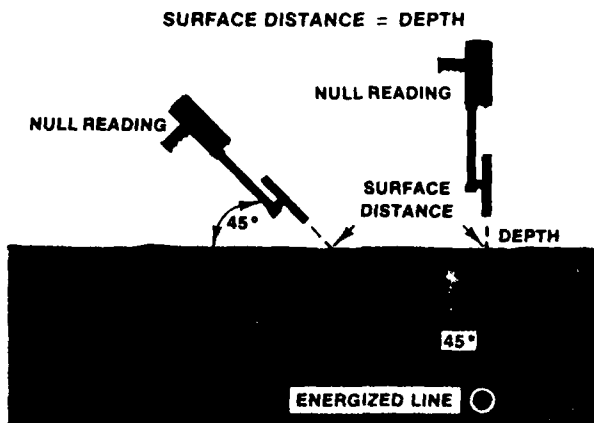


Figure 32. Theory of depth estimation using 45° triangulation.

present. This situation causes the receiver to incorrectly indicate the position of the utility and results in inconsistent depth readings. To get more reliable readings, try using an alternate method of energizing the line you want to locate, as described at the end of section 5.2.

Other methods. Some magnetic-induction locators have alternate methods of determining the depth to the energized utility. Because the exact techniques vary considerably from one model to another, it is impossible to describe them in detail. An example of a very simple technique is to hold the receiver directly over the utility, push a button, and read the depth from a scale on the response meter. Another technique involves placing the receiver on the ground directly above the utility and adjusting the controls to set the needle at a particular spot on the meter. You then change one switch and raise the receiver until the needle returns to that spot. The height needed to raise the receiver is equal to the burial depth of the utility.

5.6 Features

Since many features of magnetic induction locators have been described previously in detail, this section will summarize them briefly and discuss additional useful features.

5.6.1 Transmitter.

An important aspect of the transmitter is the type of grounding system it employs. A ground rod is often sturdier than a thin metal plate for pounding into highly compacted soils. Several models have a permanent connection between the ground plate and connecting cable, which will often loosen and result in incomplete transmission of the transmitter's signal to the line of interest. The cables used for operation with direct connection should have a sturdy clamp or clip for connecting to the utility. It is often helpful to attach a magnet to the clip for use in awkward connections. Locators that include an inductive coupling clamp definitely have greater versatility than those that do not. Units that have variable output power allow both operation in close quarters and tracing over long distances.

Two other useful, but less essential, features for transmitters include bright safety coloring on the sides of the case to avoid accidental damage and a light or quiet hum to indicate when the power is on. This

last feature may remind an operator to turn the power off when the unit is not in use.

5.6.2 Receiver

An essential feature on the receiver is a sensitivity control, which is a standard feature on all locator models. Having a response meter in addition to audible output is a big help for easily distinguishing slight changes in response level. It is also convenient to have a volume control, because a constant loud response can become very annoying. Other features of interest are the style (e.g., box vs pivoting-antenna) and weight of the receiver. The box style tends to be more tiring for the operator because it requires bending or squatting for the best results. A heavy or bulky receiver is also tiring to use.

Most receivers have peak mode operation as a standard feature. The addition of null mode operation allows the operator to estimate a line's location more quickly and accurately. Null mode also gives the locator the capability of estimating burial depth using 45° triangulation. A leveling bubble that indicates when the receiver is being held exactly at the 45° position will increase the accuracy of depth estimates.

5.6.3 General

A well padded case in which to pack away magnetic-induction locators is helpful to protect their delicate electronics during transport. Another feature that will save on battery life is a system that automatically shuts off the transmitter and receiver units when they are packed away. Also, to avoid "down time" while batteries are being ordered, an instrument that uses commonly available battery types is suggested.

Another desirable feature is a rejection filter to eliminate alternating current interference when tracing buried utilities under power lines. This may be incorporated into the electronics of the unit or activated with a manual switch. The interference can also be eliminated by having a receiver that is responsive only to the transmitter frequency (not a harmonic of the alternating current line frequency).

6. POWER-CABLE LOCATORS

6.1 Components and principle of operation

Devices called power-cable locators operate on the same basic principle as magnetic-induction locators, except that they are tuned to detect

the 60-Hz frequency of electrical power transmission rather than the frequency generated by a transmitter. Some of the more sophisticated models of magnetic-induction equipment can also detect this frequency in addition to their normal operating frequency.

Cable locators consist of a unit that is identical to a magnetic-induction receiver, most commonly the pivoting-antenna type (see section 5.1). When the unit is carried over a buried power line, it will emit a maximum response directly above the line.

6.2 Uses and limitations

As is evident from their design, cable locators are used for (and limited to) locating power transmission lines or other conductors that may have picked up a signal at the same frequency.

6.3 Operating procedures

Because power-cable locators are so similar to magnetic-induction receivers, the instructions in section 5.5.2 are entirely applicable to their operating procedures. Section 5.5.3 should be consulted regarding depth estimation techniques.

6.4 Features

Likewise, features available on cable locators are the same as those discussed in section 5.6.2, which describes the features of magnetic-induction receivers.

7. RADIO-FREQUENCY TRACKING LOCATORS

7.1 Components and principle of operation

Radio-frequency tracking locators are designed to locate unpressurized nonmetallic lines that have available access. They are similar to magnetic-induction units in that they consist of a transmitter and a receiver unit tuned to a low frequency (3.5 to 100 kHz). The transmitter, which is snaked or floated inside the pipe, emits a directional signal that is detected at the surface by the receiver (Fig. 33).

The battery-operated transmitters, sometimes called "probes," are available in several sizes and output strengths for use in different depth ranges and applications (Fig. 34). The most powerful are tube-shaped canisters (2 to 3 in. diameter, 6 to 12 in. long) that may have attachable

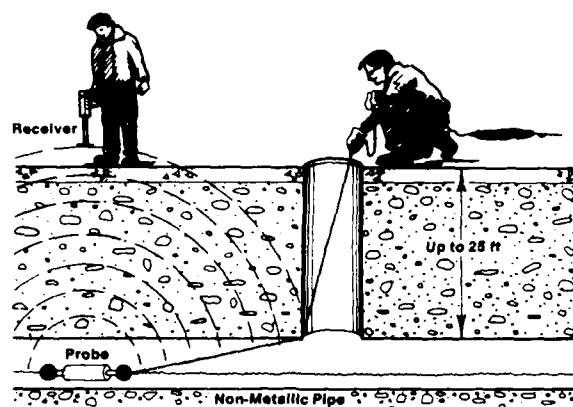


Figure 33. Theory of radio-frequency tracking. Radio-frequency signal from transmitter inserted into line is detected at surface by the receiver.

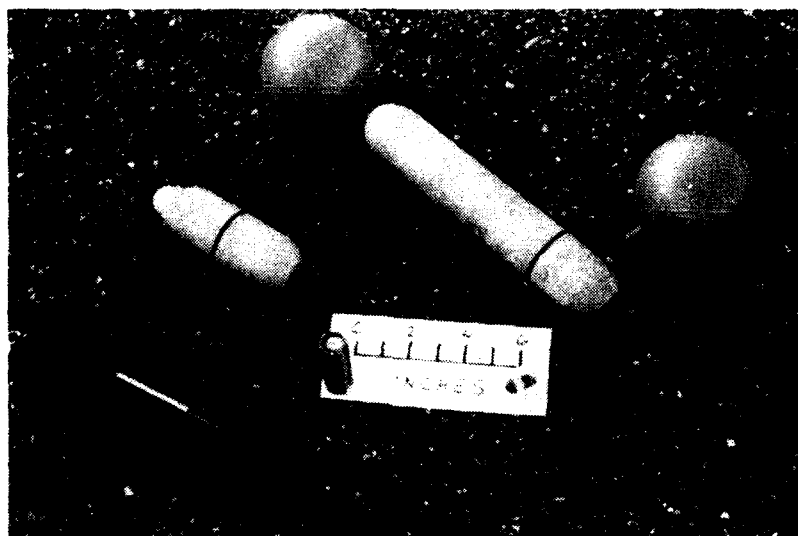


Figure 34. Typical radio-frequency tracking transmitters.

plastic floats for added buoyancy. Some are sized so they can be easily taped onto the end of a sewer snake (1 by 1 by 3 in.). Other probes are as small as a 1/2-in. cube and can be flushed into a sewer system while attached to a string.

The receivers are similar to the pivoting-antenna type of magnetic-induction receivers (see Fig. 30). They consist of a box, which includes the response meter, a sensitivity control, a volume control, an audio out-

put, a battery check switch and a hand grip. A rod comes out of the box and at the end is the rotating antenna.

7.2 Uses and limitations

Radio-frequency tracking locators are used for nonmetallic utilities such as pipes made of plastic, asbestos cement, concrete or vitrified clay (tile), and conduits constructed of wood, brick or stone. However, the lines must be unpressurized and have available access, because the location procedure involves inserting a probe directly into the line.

The depth range of operation depends on the strength of the probe's output, but lines can be located up to 25 ft deep. This increase in detection depth over the previously described methods is helped by the battery being placed in the probe, which allows a strong signal to be continuously generated from within the pipe.

With this method, it is also possible to pinpoint the blockage in a line by propelling a snake with an attached probe through the line until it reaches the obstruction. By locating the probe's signal with the receiver, you have also located the blockage.

7.3 Operating procedures

7.3.1 Activate probe

The first thing to do in the radio-frequency tracking method is to activate the probe. This is usually done by connecting the battery to the appropriate leads or inserting it into a designated slot within the probe.

7.3.2 Insert probe in line

The next procedure is to insert the probe into the line to be located. Choosing the most appropriate method will depend on the size of the probe and the rate of flow within the line. Very small capsules are easily tied to a string and flushed into the sewer system. Larger probes can either be tied to a rope or bolted to a metal sewer snake or cable by a special coupling. Small probes can be secured to a rope or snake by wrapping them with electrical tape.

Ropes will work well when there is enough flow to propel the probe down the line. However, if the line is dry and the probe must be pushed along it, the use of a stiffer metal snake will be necessary. To help change a downward push on the snake into a horizontal motion along the

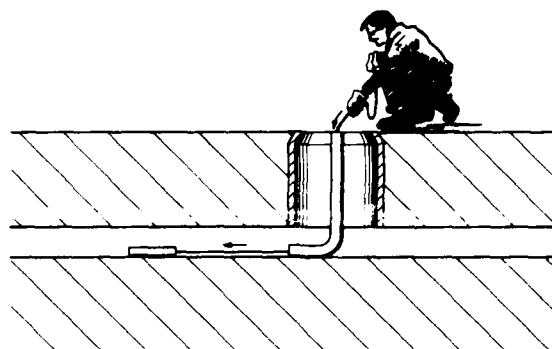


Figure 35. Pushing a sewer snake with attached probe through a pipe with a 90° bend helps to move the probe horizontally in a dry line.

line, insert the snake through a pipe with a 90° bend that is positioned at the access manhole (Fig. 35).

Once the probe is in the line, move it a few yards downstream, then hold it stationary by some method such as tying the rope to a rung of the manhole ladder. After you have located the probe (using techniques described below), allow it to travel a few yards further down the line and locate it again. By repeating this procedure, the path of the line can be traced at the surface.

7.3.3 Locate probe with receiver

To locate the probe with the receiver, procedures are generally similar to those for magnetic-induction receivers (see section 5.5.2). You carry the receiver over the area where you suspect the probe is located, and as the receiver approaches the probe, it will respond by showing a deflection on a meter or by changing its audio output. Radio-frequency tracking differs from magnetic induction in that a maximum response from the probe must be found along two perpendicular directions in order to pinpoint its location. Most models allow this to be done using either peak or null mode operation.

More specifically, to locate the probe, first walk along the suspected path of the buried line. When you receive a response from the probe, find the point at which it reaches a maximum in that direction. Then, starting at that point, search back and forth in the perpendicular direction until you find another maximum. The exact location of this second maximum should be directly above the position of the probe.

7.3.4 Estimate depth

Depth estimation is usually possible with radio-frequency tracking units, but methods differ widely among various models. The instruction manual of any particular unit will specify the recommended procedures.

During your estimation of the burial depth, keep in mind that the reading indicated by the receiver is to the position of the probe. The diameter of the pipe should be subtracted from this reading to determine the depth to the top of the pipe. This is especially critical when the sewer is quite large and the probe is floating along the bottom.

7.4 Features

7.4.1 Probes

There are several features that are included in well-designed radio-frequency probes. Watertight joints where pieces connect assure that the probe will function properly. These joints usually have o-rings or similar sealing devices to keep water out. The overall size of the unit will determine if it can move through bends or corners in the line. A convenient means of connecting the probe to a rope or sewer snake makes its use much easier. The probe can also have added buoyancy in float-through operations if it has a way of having hollow plastic or Styrofoam floats attached to either end. As with all battery-operated devices, models that use easily available batteries will reduce down time while special batteries are on order.

7.4.2 Receivers

Since receivers of radio-frequency tracking units are nearly identical to magnetic-induction receivers, refer to section 5.6.2 for a discussion of their recommended features.

8. LITERATURE CITED

- Bigl, S.R., K.E. Henry and S.A. Arcone (1984) Detection of buried utilities - review of available methods and a comparative field study. USA Cold Regions Research and Engineering Laboratory, CRREL Report 84-31.
- Sellmann, P.V., A.J. Delaney and S.A. Arcone (1984) Conductive backfill for improving electrical grounding in frozen soils. USA Cold Regions Research and Engineering Laboratory, CRREL Special Report 84-17.

APPENDIX A. SOURCE DIRECTORY FOR BURIED-UTILITY LOCATORS

The following directory lists source information for buried-utility locators and includes 19 manufacturers and two distributors of European equipment. Individual models and their approximate prices (December 1984) are given along with remarks about the equipment. Many of the sources handle a broader range of subsurface equipment than is shown, so the model information is in no sense exhaustive.

This alphabetical listing was compiled from advertisements in trade journals and displays at equipment shows; it may be neither complete nor error free. The appearance of either a manufacturer or a model in no way implies endorsement or promotion of a particular product. Conversely, omission is the result of oversight and does not imply a negative judgment.

The directory is included to demonstrate the wide variety of equipment that is available and to help prospective buyers concerned with utility detection in selecting equipment that is suitable for their needs. Buyers are urged to evaluate their needs, obtain descriptive literature, request a demonstration of candidate devices, and investigate warranty and service considerations before making any purchase commitment.

Source	Model	Price	Remarks
Aqua Survey & Instrument Co. 141 W. Xenia Ave. Cedarville, OH 45314 (513) 766-2451	Aqua locator	\$ 72.00	Dipping-needle locator
Aqua-Tronics, Inc. 3021 Industrial N.E. Salem, OR 97303 (503) 363-4378	A6 A7 AT-9	\$ 450.00 550.00 280.00	Magnetic-induction locator (TB*) Magnetic-induction locator (PA**) Power-cable locator
Associated Research, Inc. 8221 N. Kimball Ave. Skokie, IL 60076 (312) 647-7850	8500A 8700	\$ 825.00 1460.00	Magnetic-induction locator (modified PA) Mag.-ind. † locator with fault finding ability
Biddle Instruments 510 Township Line Rd. Blue Bell, PA 19422 (215) 646-9200	Cable tracer Tone generator	\$ 355.00 755.00	Power-cable locator or mag.-ind. receiver (PA) Mag.-ind. transmitter for use with above
Chicago Steel Tape P.O. Box 359 Watseka, IL 60970 (815) 432-5237	FT-60	\$ 520.00	Ferromagnetic locator
Communications Technology 2237 Colby Ave. Los Angeles, CA 90054-1592 (213) 473-5024	C-4904A	\$2500.00	Mag.-ind. locator (modified PA); has fault locating ability. (Previously manufactured by Hewlett Packard)
Detectron Division Tinker and Rasor 417 Agostino Road P.O. Box 281 San Gabriel, CA 91778-0281 (818) 287-5259	505 7-T Mark V	\$ 500.00 250.00 700-750.00	Magnetic-induction locator (TB) Induction-balance locator Mag.-ind. locator (TB) with optional holiday detector or short locator
Electro-Alarm Safety Devices 745 N. Pleasant Ave. Fresno, CA 93728 (209) 264-6894	UIT	\$ 250.00	Power-cable locator
Fisher Research Laboratory 1005 I Street Los Banos, CA 93635-4398 (209) 826-3292	TW-5 65 90 FF-16 FX-3	\$ 420.00 260.00 300.00 1395.00 450.00	Magnetic-induction locator (TB) Induction-balance locator Induction-balance locator Cable tracer and fault locator Ferromagnetic locator
Goldak/UDSEC P.O. Box 1988 Glendale, CA 91209 (818) 240-2666	TR-5A 720 PB-44 600 6800	\$ 485.00 370.00 900-1730.00 320.00 930.00	Magnetic-induction locator (TB) Induction-balance locator Mag.-ind. and radio-frequency tracking locator (PA) (1 receiver with various transmitters) Power-cable locator Mag.-ind. locator; high powered (PA)

* TB - Two-box type; ** PA - pivoting antenna receiver; † Mag.-ind. - magnetic induction

Source	Model	Price	Remarks
Heath Consultants, Inc. P.O. Box 456 100 Tosca Drive Stoughton, MA 02072 (617) 344-1400	TSI	\$3950.00	Mag.-ind. locator (PA); transmitter has adjustable power and frequency. (Heath distributes TSI, which is manufactured in Europe, and various other locators).
Metrotech 670 National Ave. Mountain View, CA 94043 (415) 965-9208	810	\$1440.00	Models 810, 850 are sophisticated mag.-ind. locators with fully automatic receivers; 850 has a choice of two transmitters with low and high power output Magnetic-induction locator (TB) Ferromagnetic locator Induction-balance locator
	350	1995.00	
	480	495.00	
	880	625.00	
	220	350.00	
Metro Tel Corp. 15 Burke Lane Syosset, NY 11791 (516) 364-3377	71-620-10 "Cable Hound"	\$ 170.00	Magnetic-induction locator (modified PA)
Nilsson Electrical Lab., Inc. 111 Eighth Ave. New York, NY 10011-5287 (212) 675-7944	715	\$ 475.00	Magnetic-induction locator (PA)
Joseph G. Pollard Co., Inc. New Hyde Park, NY 11040 (516) 746-0642	P515	\$ 50.00	Dipping needle with loop handle
	P516	60.00	Dipping needle with extension handle (Pollard is distributor for a wide variety of locating and utility equipment).
Progressive Electronics, Inc. 325 South El Dorado Mesa, AZ 85202 (602) 966-2931	501	\$ 400.00	Magnetic-induction locator (modified PA)
	521	650.00	Magnetic-induction locator (modified PA)
	508	170.00	Extremely lightweight mag.-induction locator
Radar Engineers 9535 N.E. Colfax St. Portland, OR 97220 (503) 256-3417	167	\$ 260.00	Tone generator for unloaded energized cables
	208A	270.00	Power-cable locator
	210A	495.00	Magnetic-induction locator (modified PA)
	420A	1800.00	Mag.-ind. locator with fault finding ability
Radiodetection Corp. 615 Franklin Turnpike P.O. Box 623 Ridgewood, NJ 07451 (201) 455-7710	C.A.T.	\$ 485.00	Power-cable locator or mag. ind. receiver
	Genny	435.00	Mag.-ind. transmitter for use with C.A.T.
	GPR 106	1500.00	Radio-frequency tracking locator
	GPR 107	1900.00	Radio-frequency tracking locator
	GPR 404	2550.00	All purpose locator: power cable, mag. ind., induction balance, radio-frequency tracking (U.S. Outlet for Electrolocation Ltd., Bristol, England)
Schonstedt Instrument Co. 1775 Wiehle Ave. Reston, VA 22090-5199 (703) 471-1050	GA-22	\$ 600.00	Ferromagnetic locators. Pipe location capability claimed for the GA-52B
	GA-52B	675.00	

Source	Model	Price	Remarks
Test and Measurement Systems/3M	APC EMS Test Set	\$1425.00	Magnetic-induction locator (TB)
2111 West Braker Lane	APC EMS-II Marker	650.00	Selectively locates EMS Markers
P.O. Box 2963	Locator		
Austin, TX 78769-2963	APC EMS Full Range	9.00	Coil antenna encased in polyethylene shell
(512) 834-1800	Marker		
(formed by merger of Dynatel	APC EMS Mini Marker	6.00	Smaller coil antenna
Dept. and APC Industries Inc.)	Dynatel 500A	1242.00	Magnetic-induction locator
	Dynatel 573A	2047.00	Mag.-ind. locator with fault finding ability
Utility Tool Company	100	\$ 460.00	Magnetic-induction locator (modified PA);
2900 Commerce Blvd.	"Pipe Horn"		operates using induction only
P.O. Box 66305			
Birmingham, AL 35210			
(205) 956-3710			

APPENDIX B. WINTER OPERATION OF BURIED-UTILITY LOCATORS

B.1 Introduction

Two basic environmental differences exist during the winter that may influence the operation of equipment designed for locating buried utilities. These are lower air temperatures and frozen soil in the upper layer of the ground.

B.2 Hand-held locators

For the most part, hand-held locators that do not touch the ground during normal operation will be unaffected by the winter environment. A slight change from summer operation may be that lower temperatures can reduce the performance of batteries and very low temperatures can affect the performance of electronic components. The locator's response to buried targets should be unchanged by the presence of frozen ground.

B.3 Electrically grounded transmitters

There is one case in which frozen ground has an effect on the operation of magnetic-induction locators. Electrically grounding the transmitter for the direct connection method (section 5.5.1) can be very difficult because of the resistive nature of frozen soil.

When it is necessary to ground a transmitter during the winter, first consider alternatives to establishing a ground in frozen soil. It may be possible to connect to an established ground using a long wire with alligator clips attached on either end. Another alternative might be to ground the transmitter at a location where the soil is not frozen (e.g. over a heated utilidor, near the south side of a building or under a deep snow cover). A third possibility would be to pound a long grounding rod through the frost layer and into the unfrozen ground below. A pipe with a sharpened tip may be easier to drive into the ground than a solid rod. If the bottom tip of the pipe is tapered, the soil particles will be forced into tighter contact with the outside of the pipe.

To establish a ground in frozen soil, drill a hole that has a larger diameter than the grounding rod (e.g., 6 to 10 in.), insert the rod, and backfill the hole with a conductive material such as a water-saturated salt-soil mixture (Sellmann et al. 1984). The backfill can be prepared

either by mixing the salt and the local soil or by saturating the soil backfill with a salt-water solution. A salt-soil mixture that contains 5% salt by weight produces very conductive material. If an insufficient amount of local soil is recovered to refill the hole, other fine-grained soil (e.g., silt) can be added. In desperation, absorbent paper saturated with salt water can be compacted with the soil as a filler.

Using more than one ground also decreases the resistance to ground in frozen soil (Sellmann et al. 1984). It may be worthwhile to establish two or three grounds and connect them in series to the transmitter. (This technique may also be used when the ground is not frozen.)