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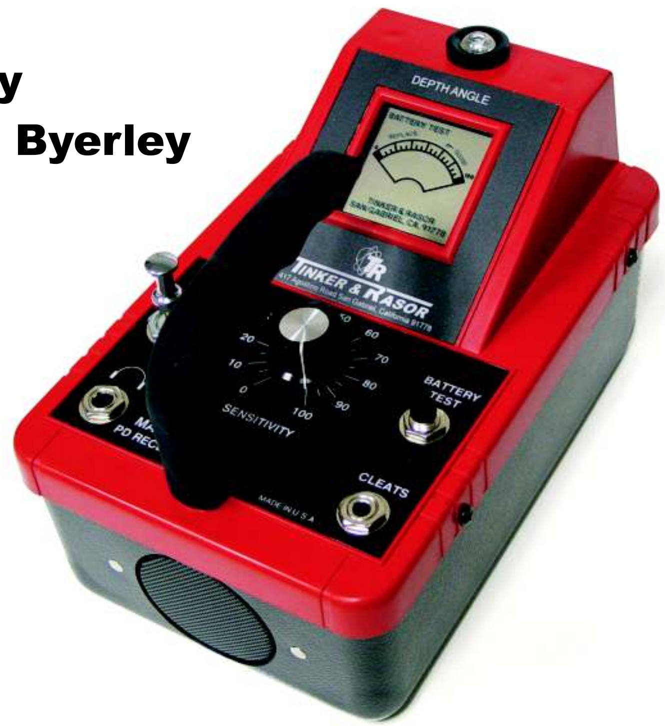
ELECTRICAL SURVEY METHODS OF UNDERGROUND COATED PIPELINES

(Locating and Identifying Holidays and Cable Breaks)



By
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ELECTRICAL SURVEY METHODS OF UNDERGROUND COATED PIPELINES

Improved methods of locating coating faults, insulating joints, foreign line contacts and pipe locations are to be discussed. The improved method involves the use of relatively large flow of stable AC audio frequency current through the pipeline and a surface traverse with inductor and amplifier to locate the desired point or item by using the “NULL” method.

LOCATING COATING FAULTS ON AN UNDERGROUND PIPELINE

This type of survey is commonly referred to as Pearson survey, based on the original method of Mr. J. M. Pearson (1). The original concept of his operating techniques are still in use today and this article is designed to inform the industry of improvements both in methods and equipment.

The original technique was to apply from 5 to 10 milliamperes of AC current at approximately 1,000 c.p.s. between a coated pipeline and an earth ground. The AC energy is passed from the pipe metal to the soil through the faults in the coating. The location of the “electrical leaks” can be detected with suitable indicating apparatus and marked for excavation. The measurement of such electrical leaks is conducted across short spans of earth directly above the coated pipeline. Under good conditions, two thousand feet of pipeline coatings can be tested in either direction from the input AC power source.

Relatively small amounts of AC energy have heretofore been available to apply to a coated pipeline system. The operational distances of a survey of this type that can be performed away from the AC energy source is rather limited, plus the fact that the survey must be conducted directly over the coated pipeline. When a relatively small amount of AC audio energy is used, the signal receiving instrument must be of high gain. Although the high gain receiver has merit with relationship to distances away from the AC input source, it becomes increasingly susceptible to unwanted signals and cleat noise.

One of the greatest drawbacks in the use of relatively small amounts of AC audio energy in an unfiltered high gain receiver has been to observe a rather broad difference in the amounts of current flowing to the earth via coating faults. This broad difference in signal can well mean the unnecessary excavation of larger areas than needed to make repairs to the coating.

IMPROVED EQUIPMENT

The oscillator desirable for the improved method should be capable of developing 5 to 10 watts of stable AC audio frequency energy. It should be equipped with output voltage taps to obtain proper impedance match to the coated piping system and a signal interrupter so that the audio signal can be distinguished from unwanted signals. To obtain maximum current flow on a coated piping system, the placement of the grounding system is of the utmost importance. The ground system of the oscillator should be made to the best ground available at a given location, preferably grounded to another underground system which is foreign to the one under surveillance. After proper grounding of oscillator is assured, the driving voltage switch on the oscillator should be advanced so as to give proper impedance match to the coated piping system. For best results, it is highly advantageous to have a receiver with a low input impedance such as a transistor type. The low impedance input material decreases cleat contact noise and also make it unnecessary to use shielded cable between the two ground reference points. The audio amplifier should be equipped with filters that are resonate to the frequency of the oscillator. This resonate filtering will eliminate most of the unwanted signals.

IMPROVED METHODS

There are two ways AC audio frequency energy can return to the earth ground system of the audio oscillator when audio current is caused to flow in a coated pipeline. One way is through the good portion of the high electrical resistant coating by electrical capacity to the earth and the other path of return is through coating faults where the metal pipe is making good contact with the earth. To what percentage the audio current divides, is dependent entirely upon the electrical resistance of the coating, and resistance of the soil adjacent to the coating fault. Most coatings are of relatively high electrical resistant material and the voltage potential that is present at a coating fault can be intercepted and pin-pointed. To measure the difference in potential of the applied AC audio current between the coated piping system and the earth ground, it is necessary to have two mobile ground reference points. The ground reference points usually consist of two men, both of whom wear electrical conductive type shoe cleats, which in turn are connected electrically to the audio receiver, borne by one of the operators. The electrical connection between the two ground reference points is made by means of an insulated single conductor wire approximately 25 feet in length. This 25 foot separation of the ground reference points should be maintained during the original traverse over the coated piping system to assure detection of all signal responses due to the potential differences between the piping system and the soil. The signal response observed by the operator will vary considerably due only to changes in soil resistance that are usually present during a survey of this type. Soil resistance vary greatly, making the "NULL METHOD" of operation invaluable. The "NULL METHOD" eliminates unnecessary investigations due to changes in signal level.

LOCATING ISOLATED HOLE AND INVESTIGATION

When audio current is applied between a coated pipe and a good earth ground, the NULL can be obtained at any single coating fault. It is of the utmost importance that the ground reference points continue their traverse through the complete NULL. After the complete NULL effect of the signal is observed by the operator, the two ground reference points should be shortened to approximately 5 feet, and a slow reverse traverse be made over the point of NULL indication. By shortening the distance between the two reference points, the point of NULL can be pin-pointed and the coating fault is assumed to lie at this point. The complete investigation of each point of indication can be conducted in the following manner. Place one ground reference contact at the point of NULL indication and with the other ground reference contact, make a 360 traverse, the audio tone level remains nearly constant, it can be assumed that the original indication was created by a coating fault. However, if, during the 360 traverse , there is a point where a substantial change in the audio tone level is noted, it can be assumed a foreign system is lying at right angles, and in close proximity to the coated pipeline under surveillance. An indication of this type may not warrant the excavation but would not necessarily rule out the possibility of a coating fault at this point.

INSPECTION OF POOR COATING

The original traverse is conducted in the pre-described manner, that is, with two ground reference points spaced at 20-25 feet over the pipeline. When the first ground reference contact approaches the area of poor coating, there will be a sharp rise in the audio tone level. Where the area of poor coatings begins and is directly between the two ground reference points, the audio tone will drop below normal background level and will remain at this level until the second ground reference contact arrives at a point of good coating. At this point, the audio tone will rise sharply and, as the two ground reference points proceed, the audio tone will taper off to normal background level. It can then be assumed that the area , where the audio signal is below normal background level, is in generally poor condition.

INVESTIGATION

There are two testing procedures that can be carried out in a minimum of time to determine whether the poor coating indication consists of a continuous discontinuity or a series of coating faults. Again, place the first ground reference point over the pipeline at any point between the broad NULL. The second ground reference point makes a 360 traverse around the stationary contact point. If the audio tone drops sharply as the traverse is made directly over the pipeline in each direction of the stationary ground reference point, it can be assumed that the coating is in generally poor condition. To distinguish between a continuous discontinuity of a series of coating faults, place one ground reference contact directly over the pipeline and the second ground reference contact at a 20 to 25 foot right angle to the pipeline. A continuous coating discontinuity produces an almost symmertrical circular field of potential gradient so the audio tone would rise slightly above normal background level and remain constant throughout the area of indication. In the case of numerous coating faults, all of the potential gradients appear on the ground's surface at right angles to the pipeline. These potential differences can be recognized by the sharp increase in audio signal strength at the larger coating faults and marked for excavation.

LOCATING COATING FAULTS BY ELECTRICAL CAPACITANCE

The latest innovation of locating coating faults on underground pipelines is by electrical capacitance. The survey is conducted with substantially the same equipment, enabling the operator to locate coating faults under adverse soil conditions and paved areas, The method eliminates the direct electrical ground contacts (shoe cleats). The reference points consist of two men whose bodies are electrically connected to the audio receiver. This electrical connection causes a capacitance effect of each operator between the audio receiver and the pipeline. the method of operation using the capacitance technique is conducted in he same manner as when using ground contact (shoe cleats). However, the capacitance method should only be used when it is impractical to make good electrical contact with the soil.

PRELIMINARY PROCEDURES

Prior to the actual electrical survey, there are several steps to follow:

1. The locating and marking of the pipeline. (When using relatively large amounts (5-10 watts) of AC audio frequency energy, it is not necessary to conduct the survey directly over the pipeline, but it should be conducted within 10-15 feet either side).

2. Pipeline should be insulated at the point from which the survey is to start and well grounded at the opposite end.

3. All rectifier connections and bonding to foreign systems should be removed.

A survey of this type should be conducted only when soil compaction around the pipe is assured and moisture content is present in the surface soil. This type of inspection is most effective on well coated pipelines when there are very few electrical connections to the surrounding earth. The ideal time for this type survey would be on newly constructed coated piping systems after soil compaction is assured. When conducting this type survey on older coated piping systems, it is often found that areas which were once anodic have become inactive and energy will not flow to the soil at these areas. Consequently, when active anodic areas are located and repaired, it is often found the inactive anodic area becomes active and another survey would be necessary. This would indicate a number of electrical surveys would be necessary to assure the pipeline coating holiday free.

OPERATING DISTANCES

Under ideal conditions, using 5-10 watts of stable AC audio current with proper impedance match to the coated pipeline, and suitable low impedance, resonate filtered audio receiver, surveys have been conducted on seven miles of coated pipe without advancing the AC input power source. On a 10 year old coated pipe, distances of approximately 2 miles have been inspected without advancing the AC input oscillator. This line has mastic type coating.

1 J. M. Pearson, Petroleum Engineer, 12 (10) 82 (1941).

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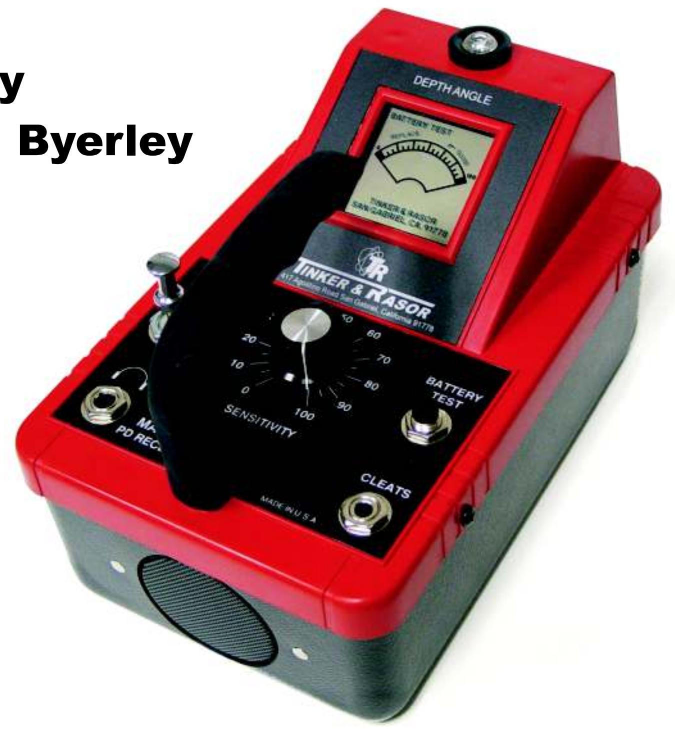
METHOD AND EQUIPMENT USED IN LOCATING PIPELINES THAT ARE BURIED OR SUBMERGED AT EXCESSIVE DEPTHS

By
Darrel D. Byerley



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LOCATING SUBMERGED PIPELINES

This paper describes an improved method and apparatus used in accurately locating buried pipelines that lie below the practical depth range of standard type locators.

The usual method in locating underground pipelines is with the use of a locator which develops radio frequency energy of very low power. This type of locator applies a radio frequency signal to the pipeline under study by radiation from the radio transmitter through both air and soil or less frequently by direct coupling to the pipe. The practical depth range of a radio frequency type locator is 15 to 20 feet, depending upon the size of pipe and the soil conditions.

Where a pipeline lies below the depth range of the standard locators, it has been a practice to expose the pipeline at various points in order to map the true course. On offshore pipelines, the practice has been to employ marine survey personnel to probe for their true location. Where offshore pipelines have an overburden greater than 6 to 8 feet, the usual method has been to jet off the overburden and attach buoys to the pipelines so final plotting could be noted on a site map. These methods are both time consuming and expensive, particularly where divers must be employed for underwater locating surveys.

The apparatus used in the pipe locating method to be described consists of an audio oscillator and receiver.

OSCILLATOR:

The transistorized oscillator converts low voltage (12 volts) d.c. to stable audio frequency a.c. directly by a highly efficient method. The input current to the oscillator is only 1.7 amperes for a full output of 15 watts. In order that a maximum of the audio energy can be transferred from the oscillator to the pipe, the output circuit is provided with a selector switch so that voltages of 2.5 - 5.0 - 7.5 - 15 - 50 and 100 volts are available to match the impedance load of the pipe. An interrupter makes the 750 cycle signal more easily recognized.

RECEIVER:

The receiver employs a high gain, five transistor amplifier and a sharply tuned 750 cycle filter. Silicon transistors and modern circuit design insure maximum circuit stability even when operated at ambient temperature extremes. The filter attenuates a.c. and d.c. interference. The search coil is contained within the receiver and has low impedance of 2,000 ohms. Although earphones are furnished for operator's optional use, the loudspeaker offers advantages related to safety, convenience and comfort. Built-in battery test and signal intensity meter of modern full-face design for ease of observation. Multi-directional depth level gauge for accurate (within 1 inch) depth determination.

APPLICATION and METHOD

When alternating current of audio frequency is caused to flow in a conductor, such as a pipeline, an electrical field exists around the pipeline in a plane at right angles to the pipeline (See Fig. 1).

The intensity of the electrical field depends upon the amount of audio current flowing in the pipeline. This electrical field can be intercepted and measured by placing an inductance coil in the same plane as the pipeline. As the coil is moved back and forth at right angles to the pipeline, the electrical field is cancelled directly over the pipeline and a null will be noted as long as a relatively large amount of audio current is flowing in the pipeline. Using this null method, it is possible to follow the pipeline while a large amount of audio current is flowing in it. When rather large amounts of audio signal can be applied to a pipeline, and a suitable receiver is used, the practical depth of pipe locating can be extended to much greater depths. Pipelines

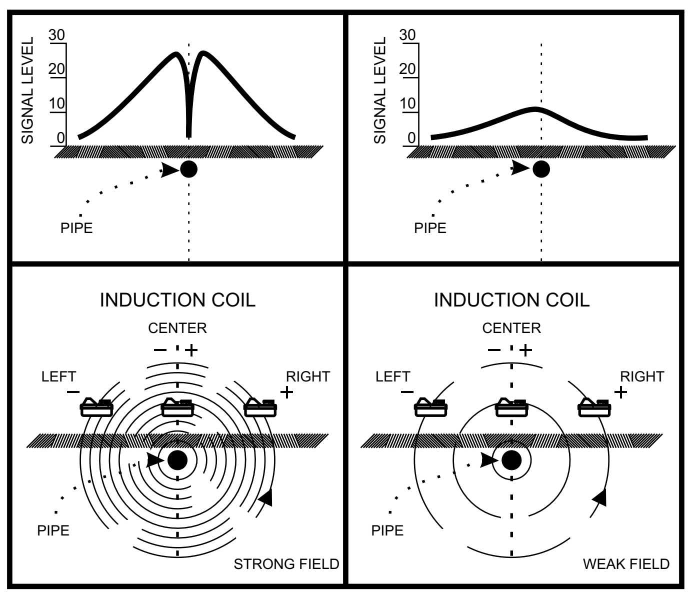

FIGURE 1

at depths exceeding 35 feet have been accurately located by this equipment and method, and depths greatly exceeding this may be possible, depending on the condition of the protective coating.

To locate deeply buried or submerged pipelines, the audio oscillator is electrically connected to the pipeline at a convenient location at either end of the line, but preferably at a terminus so the audio current will flow in one direction only. If the pipeline is well coated, the audio oscillator ground may be made through the water in the immediate vicinity of the pipeline terminus. If the pipeline is poorly coated or has no protective coating, the audio oscillator ground should be made through a well insulated cable to a point several hundred feet away from the oscillator and at right angles to the pipeline.

After the audio frequency current is properly applied to the pipeline, the locating survey is conducted from a boat. The operator places the inductance coil in a horizontal position with reference to the pipeline and as the boat makes oblique traverses over the pipeline, a sharp null effect will be noted. By audible observation the operator will notice a gradual rise in tone as he approaches the location of the pipeline and the null effect occurs when directly over the pipeline (See Fig. 1). As the exact null occurs, the operator gives a visual signal, or an audible signal if two-way radio is used, to two survey units with transits (Fee Fig. 2). The transits are located on shore and several hundred feet to each side of the pipeline. The surveyors take fixes at the signal command of the operator and these fixes are then plotted on a site map. It is recommended that a thorough investigation be made by making several oblique traverses over short distances. This can be accomplished in a very reasonable period of time and will better substantiate the true course of the pipeline.

This method and equipment can be used on the locating of most all pipelines. The fact that on well coated pipelines the operator can advance away

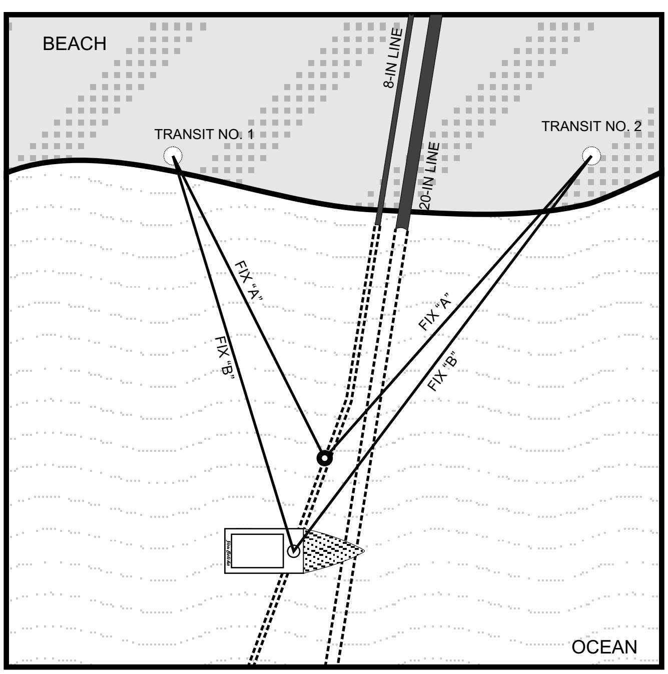

FIGURE 2

from the audio oscillator for several miles is worthy of mention. Another aspect is the tracing of an

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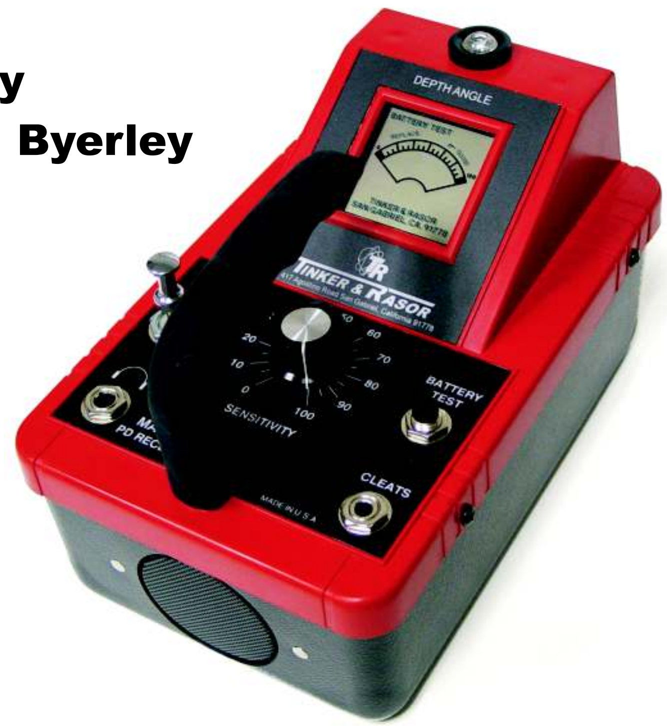

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NULL METHOD FOR LOCATING ELECTRICAL SHORTS AND OPEN COUPLINGS ON UNDERGROUND PIPELINES

This paper describes an improved method and apparatus used in locating electrical shorts and open couplings on underground pipelines.

Locating underground electrical contacts and open couplings on coated pipelines forms one of the major field problems in the installation and maintenance of a cathodic protection system.

Locating and removing these contacts or open couplings is often very time consuming and expensive, particularly in urban areas where a considerable amount of the system lies under paving and in close proximity with other underground structures. Another hindrance is AC interference from overhead power lines or where the AC ground neutral is connected to the system.

The usual technique in locating major contacts or open couplings on coated pipeline systems is to apply an audio frequency signal between the coated pipeline and a good earth ground. A traverse over the pipeline away from the audio frequency generator is made by walking over the pipeline with an inductor in the form of a coil, a suitable audio receiver and earphones. Audio current flowing through the coated pipe will cause an electrical field around the pipe and by placing the inductance coil in a vertical position with reference to the pipeline, a strong signal is received. As departure is made away from the audio generator, the audio signal in the ear phones will diminish gradually depending on the condition of the coating and amount of audio energy that is being applied into the coated pipeline. These conditions also have a bearing on the distance from the audio frequency generator the operator can travel without advancing the generator. While traverse is made away from the audio generator and a rapid drop in audio is noted, an electrical contact is assumed to be at this point. This method means that a rather broad difference in audio signal level has to be observed. Further differences in audio signal can occur from interference of other pipelines in close proximity to the coated system. All of which can contribute to inaccuracies in locating the electrical contacts or open couplings.

An improvement in the method just described can be made with substantially the same equipment and which enables the operator to locate the actual point of contact with a greater degree of accuracy and a considerable saving of time. This method does, however, require that audio energy of from 5 to 10 watts be available to apply to the coated pipe system.

When alternating current of audio frequency is caused to flow in a conductor, such as a pipeline, an electrical field exists around this conductor in a plane at right angles to the conductor. (See Fig. 1.)

The intensity of the electrical field depends upon the amount of the audio current flowing in the pipe. This electrical field can be intercepted and measured by placing an inductance coil in the same plane as the coated pipe. As the coil is moved back and forth at right angles to the pipe, the field is cancelled directly over the pipe and a null effect will be noted as long as a large amount of audio current is flowing in the coated pipeline.

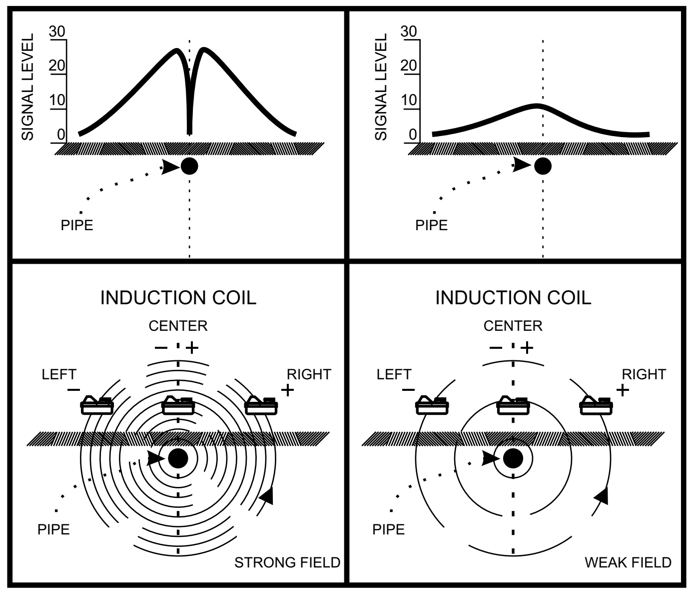

FIGURE 1

Using this null method, it is possible to follow the pipeline while a relatively large amount of audio current is flowing in it. The new method looks for the disturbance of the null rather than maximum signal strength and, therefore, give a sharper indication of the location of the electrical contact.

If the coated pipe is in contact with a foreign system that is grounded, the audio current will flow in the foreign system. The same null effect will then be present on the foreign system as on the coated pipe from audio oscillator to point of contact.

As illustrated in Fig. 2, when the null is disturbed at a given point, a square traverse is made around this point to determine in which direction the audio current is leaving the system. If, in the course of this square traverse, a point is reached

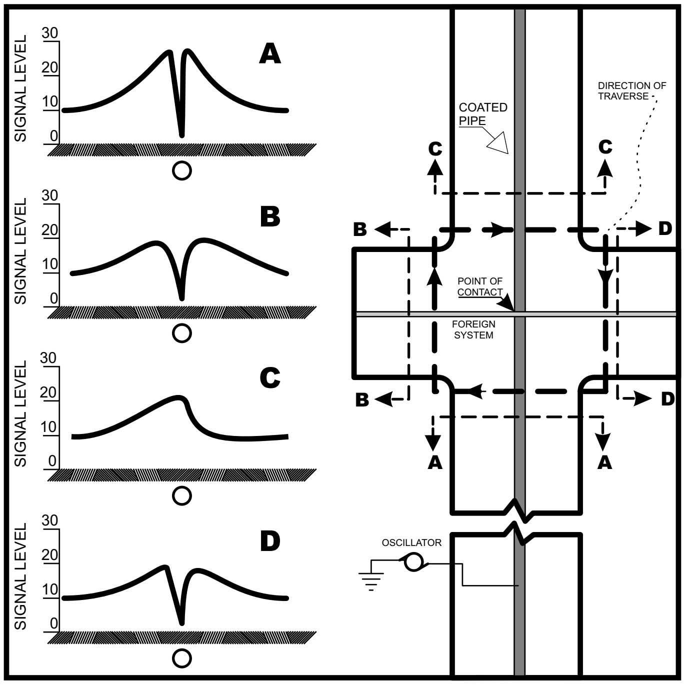

FIGURE 2

where a null occurs, it is assumed that audio current is flowing through a member below this point. If no null effect is noted in the course of the square traverse, it can then be assumed a foreign member is lying parallel above or below the coated pipe and making contact with the coated pipe. Note in Fig. 2 that no high current flows beyond the point of contact in the coated pipe.

In many gas distribution systems, insulating couplings are installed at each meter set. Many of these systems are sectionalized by means of insulators in the gas main. It is possible to check the function of the insulators at the meter set with use of the null method. By placing the audio oscillator across an insulated meter set, an excellent ground is assured since most gas systems on the dwelling side of the meter set are interconnected to a steel water system. A traverse is then made by crossing the service lines at right angles while remaining a few feet off the gas main. During this traverse the audio signal level will remain constant until a member conducting the audio current is crossed. At this point of crossing a null will occur. By following the current flow in this member using the null method, it is easily determined if audio current is flowing past the meter set. Current flow beyond meter set indicates the insulator is not functioning properly (See Fig. 3.).

This method is also extremely successful in determining the insulating qualities of buried insulators (See Fig. 4). It has been observed where potentials were measured on each side of an insulated coupling, several hundred millivolts

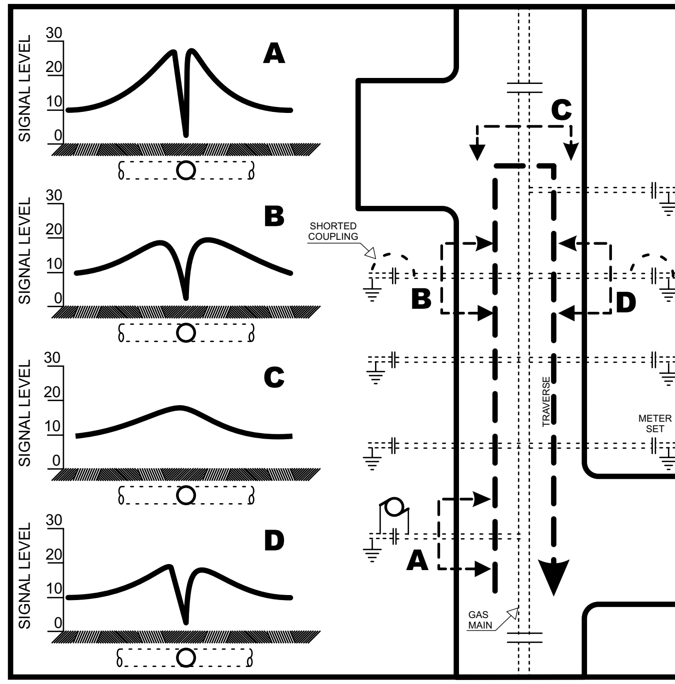

FIGURE 3

+/- difference was noted. However, when an audio current of 5 to 10 watts was applied to the coated system, it was noted that audio current was flowing through this insulated flange. With tests conducted, it can be understood that this

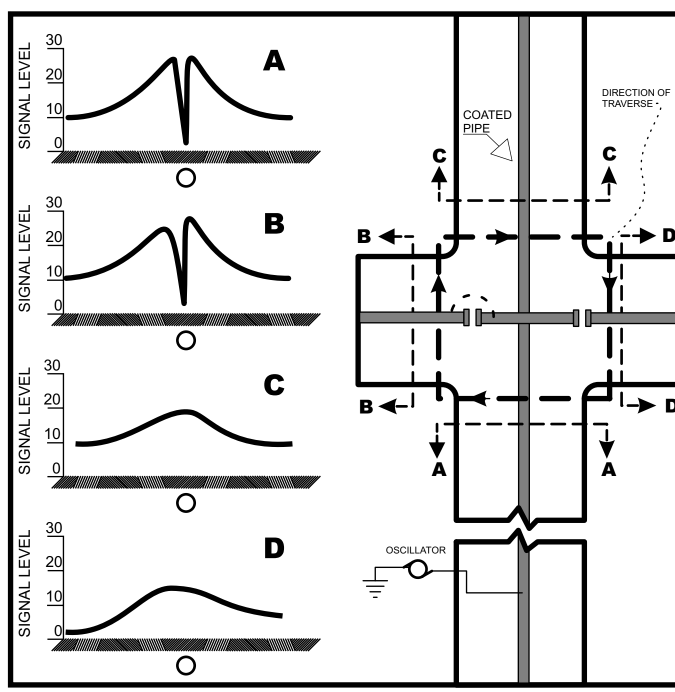

FIGURE 4

insulated coupling was considered a relatively high resistance open coupling. Potential measurement alone might indicate that this insulator was satisfactory. At a frequency of 750 cycles only a small amount of current flows through an insulator by capacitance, so that when a sharp null is obtained on the opposite side of the insulated flange, low resistance or a short is indicated.

If many electrical contacts or open couplings are present on a coated piping system, they may have to be corrected in sequence or the audio oscillator must be advanced to another location since the audio current will follow the path of least resistance back to the ground system of the audio oscillator.

It is recommended that all suspected points of electrical contact or open couplings be investigated thoroughly. This can be accomplished by advancing the audio oscillator beyond the point of null disturbance and tracing the audio current flow in the coated pipe back to the original point of null disturbance. If the null disturbance lies at the same point after traverse from both directions, it can be assumed that the fault lies beneath this point. If the point of null disturbance appears to be caused from contact with a foreign underground system (which is indicated by the square traverse around the point of disturbance, Fig. 2), the audio current can then be applied to the foreign system and traced back to the coated pipe. If audio current is flowing from the foreign system to the coated pipe, a null disturbance will be noted at the point of electrical contact. A thorough investigation can be made in a reasonable period of time and will substantiate each point to null disturbance.

It might be well to note that many electrical contacts and open couplings are located above ground. Usually the contacts are located where the coated pipe enters a building or is in contact with metal straps at bridge crossings which in turn are connected to reinforcing steel in the concrete. In either case, whether these faults lie above or below ground, the audio current flowing in the conductor can be followed.

In brief, the null method follows the flow of audio frequency current in a coated pipe, determines where it leaves and indicates where it contacts a foreign line. The point of discharge is determined by a sharp disturbance of the null itself rather than the signal level of the audio frequency.

This method is quite practical, particularly as competent corrosion field personnel can interpret their findings quickly and accurately.

When audio current of 5 to 10 watts is applied to a coated pipe, the distance between the coated pipe and the induction coil has little effect on the null method. This method has been used and proven to depths of thirty-five feet in surveys locating offshore fuel lines.

There are several primary features that are desirable to the apparatus used for locating electrical contacts or open couplings accurately with minimum time.

1. Audio generator capable of applying 5 to 10 watts of stable audio frequency.
2. Output voltage selector switch for proper impedance match to the pipe load.
3. Interrupter.
4. Receiver equipped with filters resonate to the frequency of the oscillator.

TYPICAL CONNECTION ACROSS INSULATED METER

TRUCK BATTERY USED TO POWER OSCILLATOR