Locating Gas Pipelines with Radioactive Sources

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Introduction

The increasing cost of excavation work is of concern to every utility that operates buried equipment. It has been estimated that the use of improved pipe locators could result in significant savings.

The location of buried pipes is based on several different principles. A radar-based pipe locator [Hale 1983, Young 1983] sends out a short pulse, which is reflected by the pipe and received by an antenna. The technique of inductive pipe location uses a low-frequency transmitter working in the 10–120 kHz range, and a receiver [Blears and Daniels 1984, Garnett 1983].

These locators can achieve a good success rate in locating the buried pipes, but they exhibit a high signal loss in some parts of the country because of the combination of moisture, clay, and salt in certain soils [Young 1983]. Difficulties arise also when a pipe is buried under an iron-reinforced concrete floor, or when there are many pipes present in close proximity.

With a different physical approach, it may be possible to overcome these problems. The practicability of using radioactivity to locate buried pipes has been evaluated.

Experimental Work

Research work in the laboratory was started by building a test 'gas pipe' consisting of a 2 m long tube covered by concrete blocks, which simulated the soil cover. Weak (20 MBq) radioactive sources containing ^{24}Na and ^{56}Mn were inserted in the middle of the tube. These sources were produced by irradiating $NaNO_3$ and $KMnO_4$ in our nuclear reactor, SLOWPOKE. The layers of concrete blocks covered a 4 m^2 area and varied in thickness from 40 to 80 cm. In the laboratory, the transmitted radiation was measured by a collimated 7.5 cm cylindrical NaI(Tl) crystal, which was shielded on all sides, except its face, by 3 cm of lead, and was coupled to a scaler. In the field, the transmitted radiation was measured by a 5 cm cylindrical (NaI(Tl) detector, which was collimated with a lead ring 2 cm thick, and coupled to a ratemeter.

In the laboratory, readings were taken directly above the source and every 10 cm along a straight line crossing this point.

After obtaining good results in the laboratory, we proceeded with tests on an unused section of real gas main, which was made available to us by Gaz Metropolitain Inc. This pipe is buried 120 cm in the ground, it is 15 cm in diameter and 60 metres long. A valve was installed by Gaz Metropolitain Inc., in order to provide an opening to the pipe. For the tests, 400 MBq of Na-24 and Br-82 were used. The sources were prepared by mixing an epoxy resin with $NaNO_3$, $KMnO_4$, and NaBr, in a ratio of 1:3. The mixture was then irradiated in a SLOWPOKE reactor to obtain the desired activity. The use of radioactive powders, therefore, was avoided. The solid sources were attached to a steel cable and inserted into the gas pipe.

Results and Discussion

The results obtained in the laboratory are listed in Table 1. With these results, the resolution of the location was calculated. This was defined as the distance at which the net count rate decreases to 50 per cent of the maximum count rate obtained when the detector is located directly above the radioactive source. These values indicate the degree of precision that can be achieved in locating a gas pipe by means of this method. An average value of 36 $\pm$ 3 cm was obtained in the laboratory. The resolution appears to be independent of the thickness of the material covering the gas pipe. The shape of the curve formed by the readings was also evaluated. In fitting the measured values to the normal distribution function [Spiegel 1975] quite a good fit was obtained, as shown by the values of the chi-square test. The means and the standard deviations of the hypothetical normal distribution functions were calculated by the standard formulas found in all basic books on statistics.

The method was then tested in the field. Using the

Table 1: Variation of Net Count Rates (in Counts / s) with the Position of the Detector (Tests in the Laboratory)

Isotope Thickness (cm)	*Na-24* 40	60	80	*Mn-56* 40	60	80
−80	67	23	5.2	6.5	2.4	1.7
−70	88	26	5.6	8.3	4.9	2.8
−60	112	34	7.4	14	7.0	4.4
−50	156	44	7.6	23	9.9	6.0
−40	181	63	9.9	27	15	6.4
−30	318	95	15	66	23	8.0
−20	572	147	21	96	34	8.1
−10	1002	202	30	130	45	9.0
0	1138	225	40	166	47	9.1
+10	922	215	39	129	44	8.0
+20	527	160	35	63	40	7.6
+30	268	101	27	61	26	7.5
+40	165	63	19	21	21	6.9
+50	116	44	7.8	18	15	5.8
+60	100	30	5.2	11	13	5.6
+70	79	23	5.2	9.7	12	4.3
+80	64	21	6.2	7.6	9.5	2.1
Resolution	33	37	40	32	36	38
Chi-square	15.6	6.7	7.7	18.4	7.1	13.7

Table 2: Variation of Net Count Rates (in Counts / s) with the Position of the Detector (Tests in the Field)

RI	*Distance from the opening (m)*	*Direction perpendicular to the gas-main (cm)* 100	40	20	0	−20	−40	−100
	0	15	65	150	320	180	85	13
	2	12	50	140	310	170	65	11
Na-24	4	10	45	120	250	150	50	10
	6	13	55	110	280	170	60	12
	10	14	60	170	310	160	80	14
	20	13	55	160	300	170	85	15
	0	16	130	250	650	280	150	16
Na-24	2	14	120	240	640	250	130	13
&	4	12	100	180	620	220	100	9
Br-82	6	10	90	220	610	230	120	11
	10	11	110	240	650	270	140	12
	20	16	130	230	640	260	130	11
	30	13	120	250	630	270	130	12

steel cable the 400 MBq source of Na-24 and Na-24, combined with Br-82, was inserted into the gas main. The count rates obtained are shown in Table 2.

As clearly indicated, the signal is strongest when the detector is directly above the radioactive source, and it decreases rapidly when the detector is moved away from the source. It was possible to cover the full length of the gas pipe.

The obvious limitation of this pipe-locating method is the need for an opening through which the radioactive source can be introduced into the canalization; consequently, this technique can be used only near the points where gas is consumed. However, the nuclear method described in this paper gives unambiguous results, and it is impossible, for example, to confuse a gas pipe with a water main.

With an activity level of 400 MBq, it is quite easy to locate a gas pipe up to 1.2 m in depth. A weaker radioactive source can be used when the canalization is buried closer to the surface.

The method described should be especially advantageous when a gas pipe under a concrete floor needs to be modified. In this case, an exact location is feasible, and the cost of breaking through the concrete would be minimized.

Another advantage of this method is that it can be used in pipes made of any type of material, some of which (for example plastics) may be difficult to detect with other techniques. This method should also be effective in locating pipes buried under iron-reinforced concrete, because the radioactivity would be only slightly attenuated by the presence of the iron grid. The whole operation takes about 10 minutes and the basic equipment (counter and ratemeter) can be bought for a few thousand dollars.

Conclusions

Radioactive sources containing Na-24 and / or Br-82 make it possible efficiently and accurately to locate buried gas pipes, provided an opening to the pipe is available. The use of radioactivity gives non-ambiguous results and can be used with gas pipes made of any type of material. The technique is fast and cost-effective.

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