CONDITION ASSESSMENT OF WATER MAINS USING REMOTE FIELD TECHNOLOGY

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SUMMARY

The principles of Remote Field Technique (RFT) for Non-Destructive Evaluation (NDE) of water pipelines are briefly described. The performance of an RFT tool is also described, along with an evaluation from Australian field trials. A total of three sections of pipelines were examined in Sydney and Adelaide, and there is an excellent agreement between the RFT analyses and the exhumation results. Furthermore, the RFT analysis indicates that not all sections of a pipeline, earmarked for replacement, need replacing in the immediate future. Consequently, the technique provides an opportunity for the Water Industry to reduce costs for renewal projects and to ascertain the condition of critically located assets.

Keywords : Nondestructive Testing, Water Pipes, Asset Management, Condition Assessment.

AUSTRALIA'S WATER PIPELINE NETWORK

In 1995 Australia's water pipeline network is estimated to be longer than 107,000 km and conservatively valued at 16 billion Australian dollars. Of this, approximately 72,000 km is metallic pipe - principally grey cast iron, ductile iron and steel. The remainder consists of non-metallic pipe, almost exclusively asbestos cement and unplasticised polyvinyl chloride. .

More than 16,800 km of sand cast iron pipe is still in operation in Australia, some of it more than 150 years old with the average age of this "type" of grey cast iron estimated at 85 years. Spun grey cast iron was introduced in the 1920's and its average age is estimated at 35-40 years. Initially, all sand cast iron pipelines were installed without internal or external corrosion protection, with cement lining being applied in-situ to most of these pipelines after the Second World War. Factory spun linings were introduced in the 1920's, and the majority of spun cast iron pipe is lined with the better performed factory-applied lining. However, external corrosion protection was not commonplace until the early 1970's.

Although grey cast iron pipe enjoys a good record of performance in Australia (two major water authorities define the "life" of grey cast iron pipes as 120 and 150 years for their asset value calculations), its average age will increase and so will the number of failures.

Traditional techniques, such as soil testing, pipe sampling and statistical failure modelling, employed to ascertain the condition of existing mains provide some information but are unable to precisely locate positions of corrosion defects along a pipe/pipeline.

REMOTE FIELD TECHNIQUE

In simple terms, the remote field technique (RFT) uses the principles of Remote Field Eddy Current to measure the wall thickness of a pipe by sensing the attenuation and phase delay of an electromagnetic signal which has passed through the pipe wall. The signal is induced into the pipe by an internally placed solenoidal coil which is energised by a low frequency alternating (a.c.) current . This generates eddy currents and a magnetic field which radiates from the exciter. The electromagnetic field attenuates with distance and shifts in phase as it travels away from the exciter. At a distance of about three pipe diameters, the field in the pipe wall is stronger than the field within the pipe, and can be detected by sensors positioned in the pipe in this "remote field region". (See Figure I)

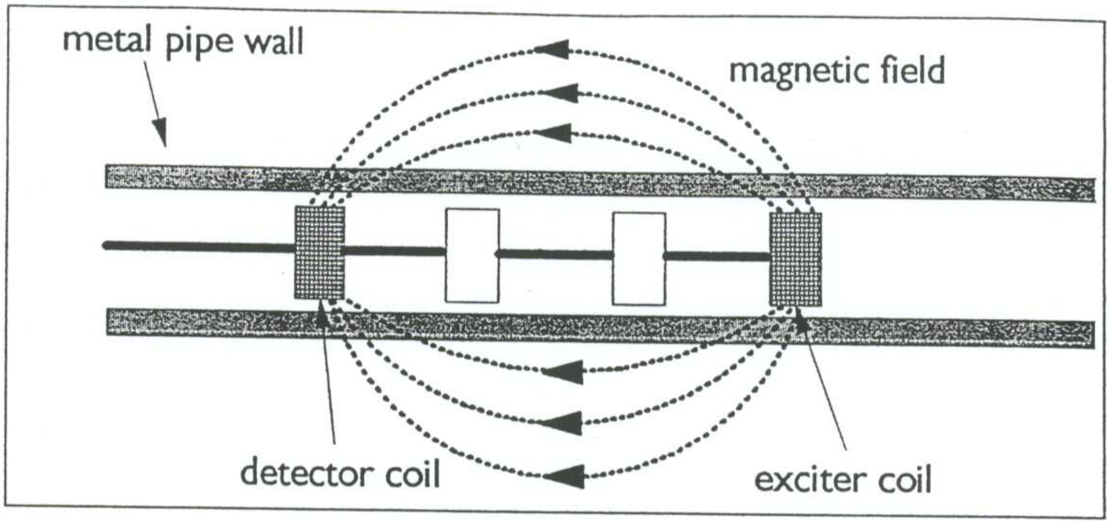

Figure I. Remote Field Technique for Inspection of Metal Tube

In effect, the electromagnetic energy has made a double transit through the pipe wall, and measurements of its attenuation and "time of flight" can be directly related to the pipe wall thickness. The signal arriving at the detector is typically very small (only a few microvolts) and very sensitive electronics are required for its measurement.

HISTORY OF DEVELOPMENT OF REMOTE FIELD TECHNIQUE

The technique has been in existence as a non-destructive inspection tool for more than 40 years , and indeed a "remote field tool" was patented in 1951. Early development of the technique was performed by Shell Development for inspecting oil well casings and small diameter oil pipelines. However, early instruments lacked sensitivity to small pits and further development stalled until digital electronics and fast computers became readily available.

Additional investigatory work was performed by Shell Development in 1978, based largely on theoretical considerations, and a large proportion of this research was verified by Colorado State University in 1986 using Finite Element Analysis (1).

In more recent applications, the Remote Field Technique has been used in the Water Industry, and in 1992 an American Water Works Association Research Foundation report summarised available Non-Destructive Evaluation (NDE) methods with possible application for evaluation of the condition of water mains. A conclusion reached from the survey was "the remote-field eddy current inspection by Russell Technologies (RTI) was the most successful method evaluated in this study" (2). Following this report, RTI conducted field trials on 6" cast iron pipe, firstly in Calgary, then in Edmonton, and in 1995, Sydney and Adelaide.

RFT NDE TOOL

Non-Destructive Evaluation (NDE) tools such as Hydroscope 201™ (shown in Figure II), uses the principles of Remote Field Eddy Current to detect thickness variations in ferrous pipes.

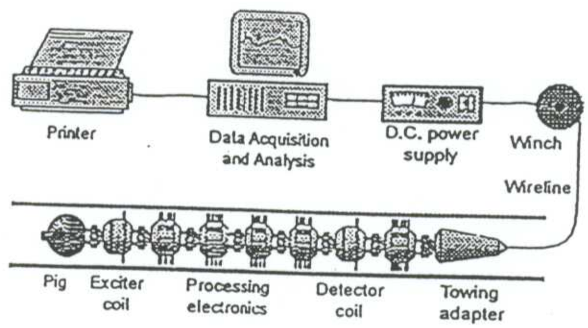

Figure II. An example of an RFT NDE Tool - RTI's Hydroscope 201™

The RFT NDE tool as shown in Figure II consists of a train of sealed modules containing excitation and detection coils, processing and data transmission electronics. Each individual pressure module is connected to the next by U-joints. The train of pressure modules are connected via a 1000 metre wireline to a host computer above ground.

The tool is designed to traverse 90° bends and tees and is currently sized to fit 150mm and 200mm pipe. It is propelled through the pipe either by water pressure or by winching, at a speed up to 12 metres/minute. The tool records data only when moving which is logged to the hard drive at the rate of 660 samples per metre. This translates to one sample per 1.5mm, which sets the axial resolution. At speeds greater than 12m/min, some data points may be lost. Each module of the tool is equipped with brushes which are designed for centralisation in the pipe, which may be cement mortar lined (in-situ or centrifugally applied) or unlined (with small amount of tuberculation). The total tool clearance in clean unlined 150mm pipe is 50mm.

Phase and amplitude readings are measured by the detector coil. The readings are then amplified, filtered and digitised for transmission to the above ground computer. The function of the computer is to gather, store, process, display and print data. Data can be displayed in chart form as shown in FigureIII, where phase and amplitude changes are shown as individual traces, or in polar form (as shown in Figure IV), where phase changes are displayed as changing vector angles, and amplitude as change in vector distance.

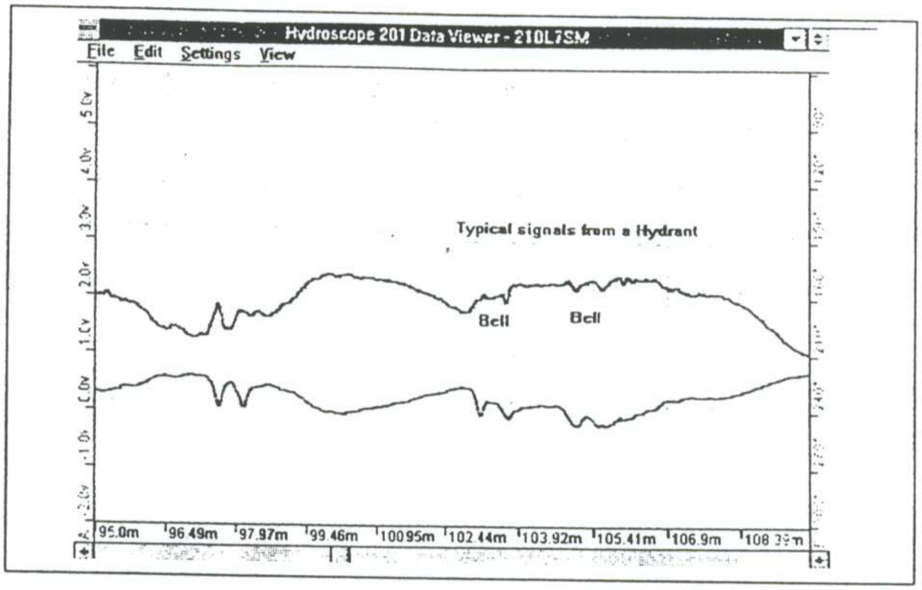

Figure III. Run-Chart Format of Data from RFT NDE Tool

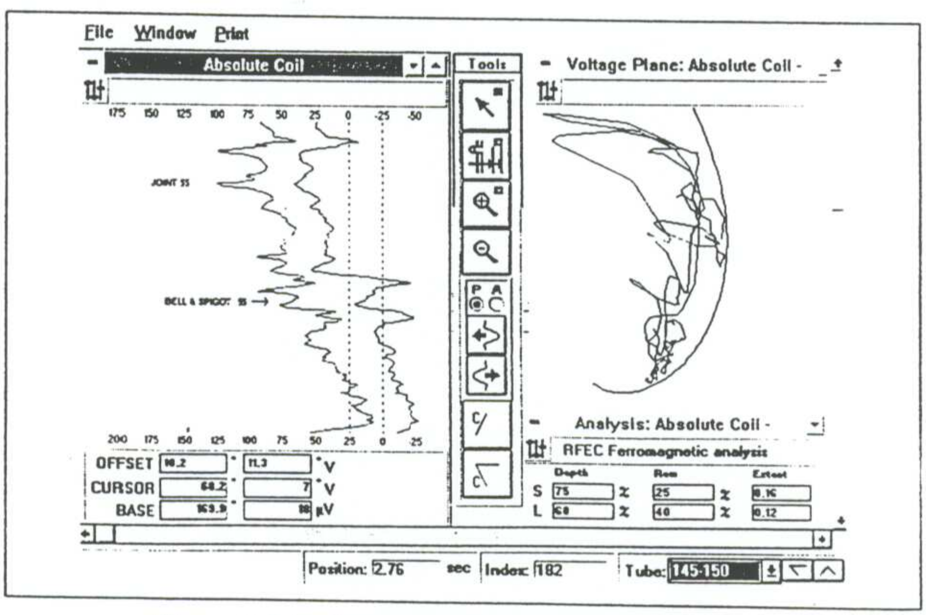

Figure IV. Polar Plot Format of Data from RFT NDE Tool

PERFORMANCE OF RFT NDE TOOL

Under ideal conditions the Hydroscope 201™ has a resolution for "general" corrosion of 5% of nominal wall thickness, and for "pitting" corrosion, 20% of wall thickness over an area of 50mm in diameter. The presence of appurtenances such as property service connections, other large defects and fittings can in some situations "mask" the detection of small defects.

Field trials were conducted in the summers of 1994 and 1995 in Canada, through a partnering arrangement between RTI and the City of Edmonton. Several mains were tested with the first prototype tool, and subsequently excavated, cleaned and visually inspected. The results obtained by the RFT analysis provided good correlation with those obtained from the visual examination. (3)

In order to ascertain the performance of the RFT technique, three 150mm cast iron pipelines were inspected in Australia in April 1995. Details of the150mm pipelines are given in Table 1.

LOCATION	PIPE TYPE	AGE yr	LENGTH ANALYSED m	LENGTH EXHUMED m
1. South Strathfield, Sydney, N.S.W.	Vertically Cast Iron (native soil backfill, c.m.l. in-situ & lead joint)	84	50	36
2. Merrylands, Sydney, N.S.W.	Spun Cast Iron (native soil backfill, spun c.m.l. .& lead joint)	45	59	59
3. Ottoway, Adelaide, SA	Vertically Cast Iron (native soil backfill, spun c.m.l. & lead joint)	55	123	24

Table 1. Australian RFT NDE Field Evaluation Locations

From the detailed RFT analyses (example shown in Figure V) the probability of short term failure for individual pipe length in each of the three lines was assessed, and assigned a value from 20 to 100 (100 representing a high probability of failure). The assessment was based on consideration of both minimum residual wall thickness and area of corrosion.

Following the exhumation and subsequent grit blasting of 37 "pipe lengths" from the three sites (10 from Dean Street, 21 from Chester Street, and 6 from Ottoway) each pipe length was assessed independently from the RFT results, but by using a similar assessment criteria. In the case of assessment of exhumed pipe however, only wall losses due to effects of external corrosion were considered as it was difficult to grit blast the bore of each pipe. The comparison of results obtained from the RFT analysis with that of the exhumations is depicted in Figure VI.

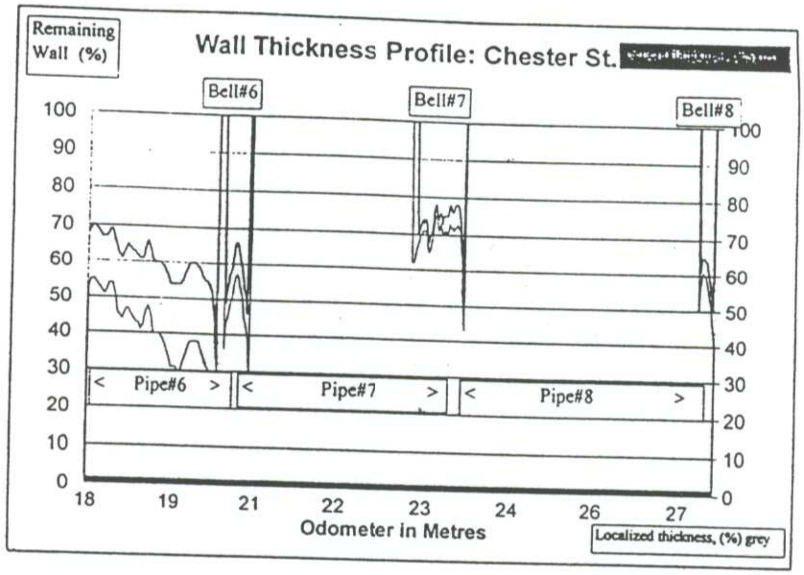

Figure V. An example of the Detailed RFT Analysis

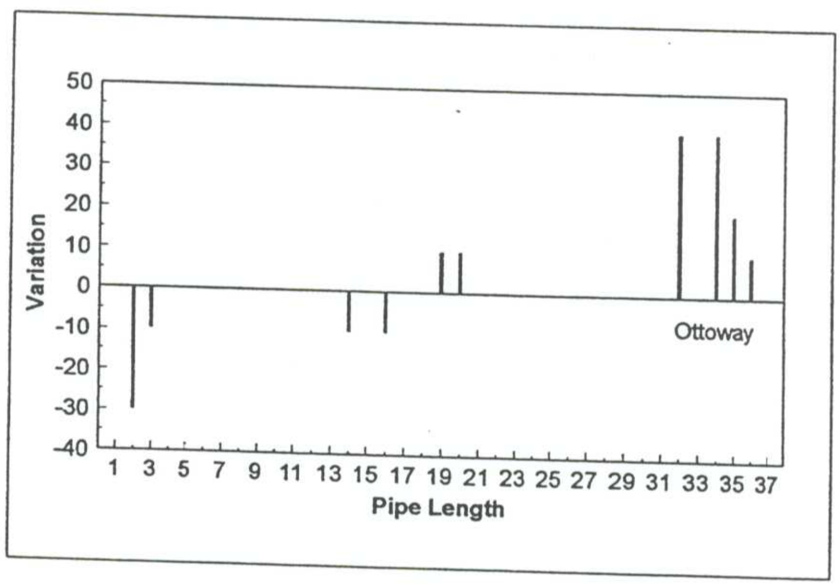

Figure VI. Variation of RFT Analysis to Observed Condition

There is very good agreement (less than 10% variation) between the RFT analysis and exhumation results for 89.2% of the pipe lengths. Some difficulty existed with the RFT analysis of the Ottoway pipeline, but this is most likely due to the peculiar structure of the statically cast iron pipe. In simple terms, the structure consisted of a region containing a large amount of non-metallic material "sandwiched" between two outer layers (external surface and pipe bore) of cast iron. Accordingly, the RFT analysis has underestimated wall thickness. The results of the RFT analysis and observed condition from exhumation for the Ottoway pipeline is shown in Figure VII.

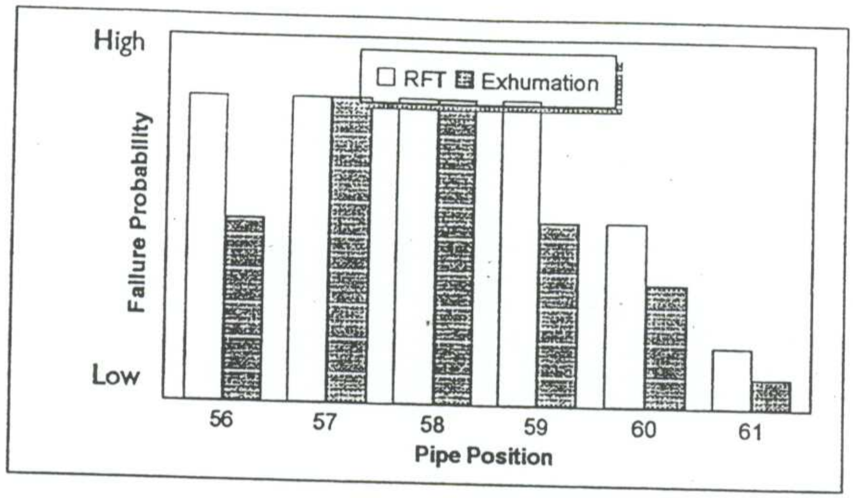

Figure VII. Results of RFT Analysis and Pipe Exhumation for Ottoway Pipeline (statically cast grey iron pipe containing internal defects and lead joints)

PRACTICAL OUTCOME OF RFT ANALYSIS OF A PIPELINE

One practical outcome of an RFT analysis is to provide guidance on when and where to replace sections of a pipeline. Individual pipe lengths can be categorised into those which should be replaced immediately (within **1** year), those which should be replaced in **10** years, and those which will not need to be replaced for at least **20** years. This consideration involves the use of RFT data (depth and extent of corrosion) and operational factors (e.g. maximum operating pressures, likelihood and magnitude of surge pressures, soil conditions, traffic loading). From the RFT analysis of the Chester Street, Merrylands main (and subsequently verified by exhumation observations), only 30% of the existing section of pipeline earmarked for replacement using 'main break data', needed to be replaced immediately, and the remaining 70% could have remained in service for at least 10 years. This modified "replacement schedule" represents a cost saving of approximately **40%** (based on discount rate of 10% and taking into account RFT analysis costs) compared with the traditional approach.

Another practical outcome is the ability of an RFT analysis to ascertain the condition of mains which are classified as "critical". In these mains, no failure is tolerable, and every effort is employed to minimise the probability of failure. Examples of critical mains include those operating beneath major roadways, railways and shopping malls and centres.

CONCLUSIONS

The RFT technique is an **accurate** and **practical method** to ascertain the condition of buried small diameter pipelines such as cement mortar lined grey cast iron . It offers the Water Industry an opportunity to **reduce costs** by replacing only those sections of pipelines that have a high probability of failure in the near future.

REFERENCES

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3 Staples, L.B., (1994), Proc. Seminar on Trenchless Technologies, Montreal