North American Society for Trenchless Technology (NASTT)
NASTT's 2016 No-Dig Show

Dallas, Texas
March 20-24, 2016

TM1-T1-05

Detection of internal pitting on pipes suspended under bridges

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ABSTRACT

Steel, cast-iron and ductile-iron water and waste water pipelines which span ravines or are suspended under bridges pose some unique inspection challenges. Accessing the pipeline is the first, and usually the most difficult challenge; however, manipulating a NDT technique in confined spaces and at height can be just as daunting.

Where internal Tools are used, the pipeline can easily be inspected; however, sometimes it is not possible to insert internal Tools, and an external inspection is necessary. This paper presents a new, low-frequency AC technique that has been successfully used to inspect such pipelines from the outside. A case study is presented on a large potable water pipe crossing the Mississippi River, slung under a highway bridge. The technique is described and some of the results of the inspection. Difficulties such as access and pipe supports, as well as safety constraints are also discussed. The advantages and disadvantages of electromagnetic techniques compared to other NDT techniques are presented.

Key words: Pipeline Condition Analysis; External pipeline inspection tools; Non-destructive testing.

INTRODUCTION

This paper presents a case study of two inspections that were performed in Minneapolis in 2014. The pipes were slung below two highway bridges that cross a major river. The 48" steel pipe has been in service since 1952 and the 54" steel line was built in 1948.

Franklin Avenue Bridge

The Minneapolis Water Treatment and Distribution Services ("MWTD", est 1867) owns and operates approximately 1000 miles of water distribution pipelines. It is the largest distribution system in the upper Midwest and the source water is taken from the Mississippi River. The Franklin Avenue Bridge (officially the F.W. Cappelen Memorial Bridge) spans the Mississippi River for a length of 1043 feet. It was built in 1923 and is 55' high above the water. In 1952 a water main was installed under the bridge together with a planked man-walk and safety wires.
Periodic inspections noticed degradation of the coating, so the pipe was cleaned and re-coated in 2002 with a thin coating of special paint.

Figure 1. Franklin Avenue Bridge, from above and street view (Google Earth)

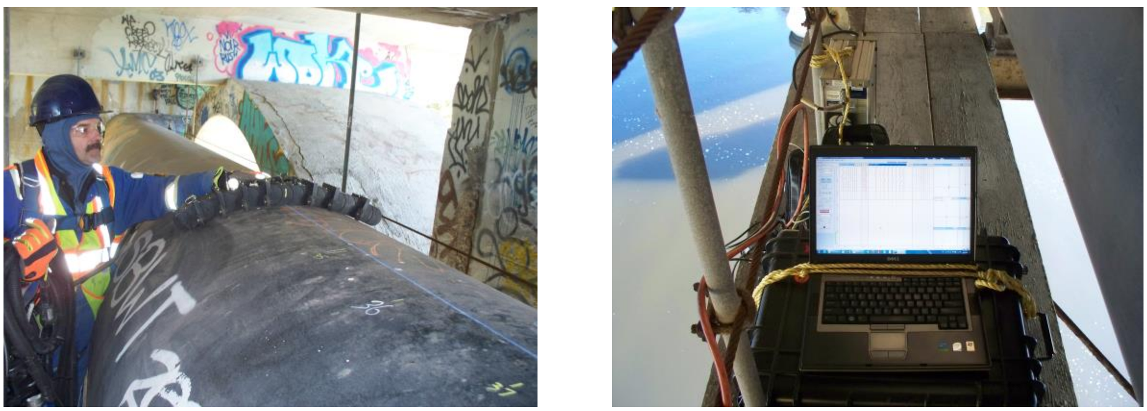

Figure 2. 48" pipe underneath bridge with inspection tool being used to scan it (left) and plank walkway (right).

The 48" steel pipe has a wall thickness of 0.375" and consists of longitudinally welded pipe and girth welds between pipes. MWTD inspectors had noted degradation of the coating and surface rusting and they hired Brown and Caldwell Engineering ("BCE") as consultants to evaluate the pipe for external and internal degradation, and to recommend remedial steps. BCE searched the market for technologies to inspect the pipe from the outside, with capabilities to detect internal pitting as well. The inspection contract was awarded to PICA Corporation who used an inspection technique known as "Through Transmission", housed in a flexible, wheeled bracelet probe to perform a partial inspection of the pipe.

10th Avenue Bridge

The 10th Avenue Bridge is an open-spandrel arch bridge also across the Mississippi River in Minneapolis. It is listed on the National Register of Historic Places and opened in 1929. It is scheduled for major rehabilitation in 2017-2018 to repair deteriorated concrete. In 1948 a 54" steel water main was installed under the bridge.

The pipe wall thickness is 0.437" and the pipe is internally lined. The thick external coating is quite degraded and external rusted areas are visible. MWTD was interested in knowing if there is any internal degradation going on as well. If the pipeline had extensive internal pitting as well as the visible external pitting, they may lean towards a replacement of the pipe rather than rehabilitate the coating and repair any badly pitted areas.

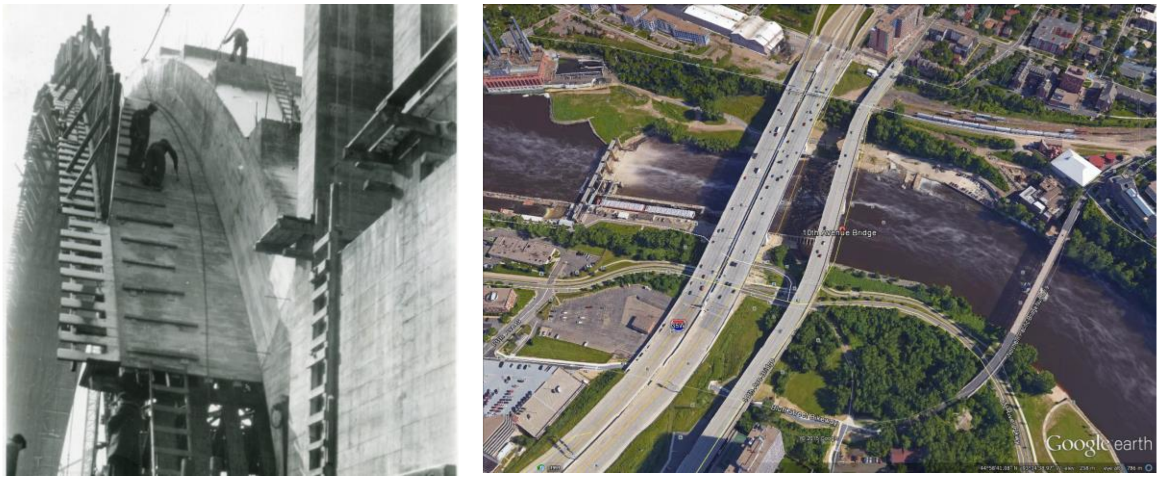

Figure 3. 10th Avenue Bridge under construction (left) and aerial view today (right: at centre of photo)

Figure 4. Street view of 10th Avenue Bridge (left) and scanning of 54” pipe under bridge (right)

Inspection Technique Description

The Bracelet Probe (“BP”) uses a “Through-Transmission” electromagnetic inspection technique. In simple terms a low frequency EM field is generated by one or more exciter coils. This field couples to the pipe and is detected by an array of detectors. Variations in the pipe wall thickness cause perturbations in the field that are sensed by the detectors and displayed on a connected lap-top. As the BP is scanned along the pipe, the data are recorded and saved on the lap-top. Data can be assessed real-time; however, it is more common to analyze the data after each scan. In Fig 4 (right) the BP can be seen on the top of the pipe scanning over the degraded coating and bare pipe.

Interesting side note: the crew not only had to chase away pigeons that were living under the bridge, but also had to work around a homeless person who had adopted the bridge as his temporary house! This catwalk was fairly easy for the public to access so there was also an interesting array of graffiti.

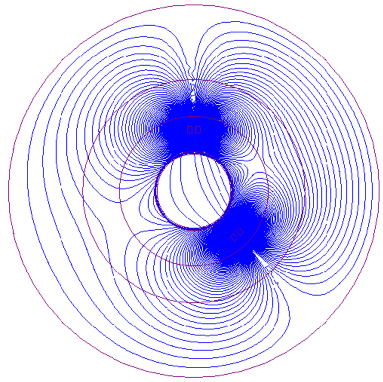

Fig 5. The magnetic field is shown around a Bracelet Probe

In Fig 5 the circle in the middle of the view is the pipe. If you look closely, you can see that there are many flux lines concentrated in the pipe wall. There are also flux lines that penetrate right through the wall and exist on the inside of the pipe ("through transmission"). It is the perturbations in the flux that is concentrated in the pipe wall that provides information of the remaining wall thickness.

Two elements of the through transmission (TT) field are measured: Signal phase (or "time of flight") and signal amplitude. For internal defects, like corrosion pits, the amount of phase shift can be used to tell the depth of the pits. For external pits, there is very little phase shift, so the signal amplitude is relied on to tell the extent of the corrosion.

The BP system is calibrated against pits of known dimension in a calibration pipe (eg: 25%, 50%. 75% and 100% deep, flat bottom holes). The Threshold of Detection (TOD) for ID wall loss is approximately 25% and the Probability of Detection (POD) varies with scan speed and defect dimensions. For the 54" pipe, using 0.5" FBH's, and a scan speed of 2m/min, the POD is approximately 80% for a 25% deep FBH. This improves to over 90% for defects with larger volume (eg, 75% deep, POD = >95%)

Scope of work for 54" pipe was to scan a 10" scan width for the full length of the horizontal pipe at the following clock positions: 10, 12 and 2 o'clock. Additional scans were taken at the 8 and 4 o'clock positions.
For the vertical portions of the pipes at either end, One BP scan was taken plus a number of ultrasonic thickness readings.

Scope of work for the 48" pipe was to scan the BP at clock locations: 3, 9, 10:45, 10:55 and 12 o'clock for various distances ranging from 14' to 839' (predicated by access).

Advantages of electromagnetic over other NDT techniques

NDT techniques are compared in the table below

Ability	**Electromagnetic**	**Radiography**	**Ultrasonic**	**Flux Leakage**
Read through scale	Yes	Yes	No	No
Large rapid scan area	Yes (10" wide)	Yes (14" x 17" film) One shot at a time	Only with AUT and then only if surface is sand blasted	Yes, if surface is clean and smooth
Detects internal and external pitting	Yes	Yes	Yes if surface prep is good	Yes if surface prep is good
Speed of inspection	2m/min	14" x 17"= 0.5 to 1 hr	With good surface prep: 6"/sec	With good surface prep: 6"/sec
Cost of inspection	Reasonable	Costly due to speed	Costly due to surface prep	Costly due to surface prep

Table 1. Comparing other common NDT techniques to electromagnetic

Challenges

There were a number of challenges that the inspection crew had to face, including:

- Wind. It was windy and cold under the bridge (hard on batteries and fingers)
- Working at height. Fall-arrest harnesses were tied off to the wires that act as guard rails.
- Access to the work platform: a “Snooper Truck” was used to get the crew and equipment to the planked walkway (see Fig 7 below)
- Access to the bottom of the pipe: The bottom of the pipe was inaccessible due to the planked walkway being close to the pipe (see Fig 4)
- Tying off lap-top and other equipment: The laptop and other equipment had to be tied down due to the windy conditions. To move down the pipe it had to be untied, moved and re-tied.
- River rescue: MWTD policy was to have a rescue boat in the river during all working hours in case of personnel or equipment falling into the river.

Results

The inspection technique proved to be very effective at delivering a good quality condition assessment of both pipes. The detailed results are confidential, but we can say that the information provided has allowed MWTD to make an informed decision of rehab vs replacement. Examples of some of the defects detected are shown below:

Fig 6 Local external pitting examples. The right hand photo is directly under an expansion joint of the bridge deck

Fig 7. Snooper truck used for access to the planked walkway.

Acknowledgements:

We would like to thank Brown and Caldwell for their management and assistance on the project and MWTD for adopting a relatively new technology to assess the condition of their pipelines.
Information regarding the construction of the 10th Avenue Bridge came via Google Earth and the City of Minneapolis Public Works website.