Guide to Pipe Condition Survey (PCS)

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FOREWORD

After the disastrous landslip of 1994 occurred in Kwun Lung Lau on Hong Kong Island, the Government has paid more attention on utility maintenance with particular emphasis on leakage detection of buried water carrying services on both slopes and roads. The Government has increased resources and imposed additional legislation on the detection of underground utilities. As a direct result, the utility profession has been developing rapidly, and over the last decade, the number of "Utility Specialists" (管綫專業監理師) has grown as the Government's requirements for Competent Persons to carry out the investigations has been implemented, in addition, Recognized Professional Utility Specialist (RPUS) (管綫專業監察師) has been recognized in recent years. However, lack of standard surveying methods, centralized monitoring systems and organized management, have lead to unsatisfactory investigation results.

In order to address these issues, Hong Kong Institute of Utility Specialists (HKIUS) (香港管綫專業學會), targeting the promotion of knowledge and good practice in the utility profession, collaborated with Hong Kong Utility Research Centre (HKURC) and supported by the funding from the Professional Services Development Assistance Scheme (PSDAS) of HKSAR, published a series of guide books and pamphlets in 12 disciplines of the utility profession in order to set standards for the practitioners to follow. As part of HKIUS continual effort to enhance the professionalism of the utility profession, it is the intention of the series that the quality of the survey can be raised and that utility related incidents can be avoided by performing high quality utility practices. Hopefully, the resulting benefits can extend to the general public.

This issue provides good practice of Pipe Condition Survey (PCS) (金屬管道狀況評價). It states the whole process and specification of conducting PCS from planning to finishing stages and intended to be used by all personnel involved in the works.

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President, HKIUS (2010-11)
April, 2011

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1. INTRODUCTION

Most of the pipes buried in the older urban areas in Hong Kong are installed in early years. They have already depreciated in a certain extent and maintenance works are inevitable. Otherwise, an increasing number of pipes will fail to achieve its function in terms of quantity and quality. Water may be lost due to physical defects and the quality of the water may deteriorate. Pipe bursting and other utility-related incidents may happen in higher frequency.

To maintain a healthy utility system in older areas, from 2000, the Government has been launching a large-scale pipe replacement and rehabilitation program to rejuvenate the water supply network. However, replacement and rehabilitation of the whole area involves very high cost. In fact the need for rehabilitation or replacement varies from pipe to pipe. In order to identify which main shall receive rehabilitation and the extent of the rehabilitation work, pipe condition survey can be carried out beforehand. Pipe condition survey involves a series of survey investigating the integrity of the pipe and external factors affecting the pipes.

An accurate detection helps Engineers to make a better decision for the rehabilitation works for different mains. Therefore, standardized requirements and sufficient information are needed for Pipe Condition Survey. Hong Kong Institute of Utility Specialists (HKIUS) (香港管綫專業學會), aiming at maintaining a healthy underground drainage system and safe working environment, has prepared guidelines to provide a standardized process of conducting pipe condition survey in order to promote a good practice for the practitioners. Note that such standards are for reference only, other standards or requirements are acceptable as long as stated in the contract or there are mutual agreements between the Contractor and the Engineer/ Client.

2. OBJECTIVE AND SCOPE

Pipe condition survey is a method to assess the condition of the pipes buried underground. Different techniques are employed in the survey. The techniques used shall be determined according to the situation. In this document, some non-destructive methods are introduced.

Common surveys used include Visual Inspection, Wall thickness measurement, Conduit Condition Evaluation (CCTV and ME Survey), Coating Defects Survey, Water Leakage Detection, Soil Sampling and Testing, Utility Survey, Stray Current Measurement. The surveys provide information on different aspects of the pipe, and thus the extent of deterioration of the pipes and their probability of failure can be estimated.

The purpose of this guide is to provide recommendations on good practice of the methods and specification of pipe condition survey to enhance the quality of the survey. As the detection techniques can be complex, reasonable procedures shall be carried out. This document provides a standardized process. It aims at providing guidelines for the practitioners to follow and to improve the quality of surveys.

This guide provides information on the process and specification of conducting Pipe Condition Survey from planning to finishing stages. Nevertheless, users of this guide shall refer to relevant documents for further information on safety that are not covered in details. It must be stressed that the guidelines given in this guide are in no way exhaustive, and professional judgment must be employed in all cases.

This guide is intended to be used by all personnel who are involved in the planning, commencement and supervision of pipe condition survey, including contractors, utility companies, consultants, government departments and other parties concerned.

3. Preparation

3.1 Planning of survey

Desktop evaluation which includes the following shall be carried our before other surveys.

Pipe material
Pipe diameter
Pipe age
Pipe failure record (historical)
Lining
Coating
Joint Type
Valves
Other fittings
Depth (range)
Prescribed bedding and backfill material
Location

The above details shall be collected from existing information provided in the contract document and if possible, during preliminary site visits. In case no detail can be found from the contract document and during site visit, utility surveys and judgements will be made based on the relevant information on hand.

3.2 Statutory requirement

Both employers and employees shall comply with relevant occupational health and safety legislations and obligations to ensure a safe working environment and minimize disturbance to the public caused by the work.

The Workplace Health and Safety Regulations of Hong Kong specifies several requirements for personnel involved in works, some of the requirements are stated in relevant ordinance or regulations such as working in a confined space, road traffic control, excavation safety, dangerous substance, noise at work, etc. It is important to follow relevant ordinances stated on the Occupational Safety and Health Council (http://www.oshc.org.hk) before commencement of work.

Also, operators shall use Personal Protective Equipment (PPE) and shall have sufficient knowledge in both usage and maintenance of the equipment. PPE shall include:

Steel toe cap, rubber safety boots
Safety helmet
Safety vest (reflective at night)
Safety goggles/Anti-glare glasses
Breathing apparatus/Disposable respirator
Harness and Fall arrester
Gloves
Ear muffs / ear plugs
Handy gas detector
Audio-visual alarm
Resuscitator

In works for the Water Supplies, the Drainage Services or other government departments, appropriate steps shall be taken to minimize or even eliminate any potential risks for injuring the public. In case where excavations are required, the access around the work area has to be properly supervised by a Competent Person (CP) (合資格人士), under Cap. 406H, the Electricity Supply Lines (Protection) Regulation, at all times. The access for "essential services", e.g., police, fire service and ambulance, has to be retained. Access to other public services, such as bus stops, footpaths, etc, shall also be maintained and supervised.

If excavations are required, no dirt, excess spoil or other material shall be left in the water channel and polluting the drainage system. Sediment control procedures can be referred to the Environmental Protection Department (http://www.epd.gov.hk).

Confined space is potentially hazardous. Safety measures for confined Space Entry shall include:

1) Operation of a permit to enter system
2) A Competent Person (as defined under Cap 59 of the HKSAR safety legislation) must first issue a permit to enter before any work begins. This shall define the period of time that works may last, as well as the safety measures that are to be in place.
3) Only workers who have been currently trained and approved as Certified Workers in confined spaces may be permitted to enter the confined space. The Competent Person must be able to cite evidence of such training before any worker is allowed to enter a confined space.

4) Installation of an appropriate ventilation system such as tubed blowers.

5) Thorough testing of atmosphere including oxygen levels as well as levels of toxic and explosive gases, using a properly calibrated gas monitor.

6) The use of appropriate retrieval equipment such as a tripod and harness for entries.

7) Continual monitoring of the atmosphere including oxygen levels as well as levels of toxic and explosive gases, using a properly calibrated gas monitor for the duration of works being conducted in the confined space.

8) Constant communication with the surface using two way radios where required.

3.3 Personnel requirements

In order to maintain the Utility Profession's requirements for the consistency, reliability and accuracy of reports, pipe condition survey shall be performed by properly trained and accredited personnel. Accredited personnel shall hold a certified qualification issued by a Registered Training Organisation (RTO), such as Utility Training Institute or The Hong Kong Polytechnic University or equivalent.

All works carried out within sewers, manholes or other confined spaces shall hold a Certificate of Confined Space Certified Worker and shall be performed in accordance with the requirements for works in the vicinity of Confined Space and Occupational Health & Safety Legislations, as well as any additional precaution that may be specified by the asset owner.

Table of personnel requirement

Training and Experience Requirements for Personnel Carrying Out Inspection (HKIUS standard, 2011)				
Title	Role	Minimum Training Requirement	Minimum Years of Practical Experience	Qualification
Project Leader	Responsible for contract administration and preparation, checking and certifying of reports for compliance with the technical specification.	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ Has attended training courses for relevant survey/detection methods, and Possesses a valid training certificate for relevant survey/detection methods used	10 years in contract administration, preferably in works related to the inspection, survey and in data management.	Either: M/FHKIUS, RPUS plus CP, CW or MHKIE/ R.P.E. plus CP, CW and relevant training in RTO (e.g. PolyU, UTI) for surveys and data management
Deputy Project Leader	Responsible for assisting project leader and acting the post of project leader when project leader temporary not with the team	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ Has attended training courses for relevant survey/detection methods, and Possesses a valid training certificate for relevant survey/detection methods used	10 years in contract administration, preferably in works related to the inspection, survey and in data management.	Either: M/FHKIUS, RPUS plus CP, CW or MHKIE/ R.P.E. plus CP, CW and relevant training in RTO (e.g. PolyU, UTI) for surveys and data management
Team Leader	Responsible for works arrangement and data processing including checking of raw data for quality and consistency.	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ Has attended training courses for relevant survey/detection methods, and Possesses a valid training certificate for relevant survey/detection methods used	5 years in works related to the inspection, survey and in data management.	M/FHKIUS, RPUS, CP, CW
Crew Leader	Responsible for supervising the field works and site safety.	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ Has attended training courses for relevant survey/detection methods, and Possesses a valid training certificate for relevant survey/detection methods used	3 years in works related to the inspection, survey and in data collection	O/MHKIUS, CP, CW
Operators	Responsible for operating equipment and carrying out inspection and survey.	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ Has attended training courses for relevant survey/detection methods, and Possesses a valid training certificate for relevant survey/detection methods used	2 years in works related to the inspection, survey and in data collection.	AMHKIUS, CP, CW

4. INSPECTION

4.1 Visual Inspection

A visual inspection in the form of a walkover survey of the alignment, surface condition, locations of connection and earthing of exposed pipe sections in chambers will be conducted (including any fittings in the chambers). These visual inspections will include an assessment of the extent of corrosion of the fittings, possibly including pit/ thickness measurements, using UT and direct physical measurement, if necessary.

Entering into chambers for these inspections may be conducted concurrently with other activities conducted during the shutdown, and will be managed in such a way so as to avoid any interference by these works.

Shutdown is not required in visual inspections. The valve chambers, however, may require pumping of water to enable easier inspection. In the event that it is difficult to provide a safe working environment at a particular location, valves and fittings at this location will not be inspected.

Since Coating Defect Survey cannot be carried out on the non-buried mains due to unavailability of electrical signal path, visual inspections shall be conducted to examine the pipe coating condition, pipe joint condition and the extent of external corrosion to the non-buried mains.

Category	Coating	Pipe	General Comments	Wall thickness/ pit depth measurement
1	Good condition, little or no crazing, no bare metal	No corrosion	Very good condition, coating affording corrosion protection	Not required
2	Some lose coating/ disbonding	No corrosion	Good condition. Some potential loss of corrosion protection of coating for underlying metal	Not required
3	Some small area of exposure	Some surface corrosion (minor pitting)	Poor condition of coating	Not required
4	Large area of exposure	General surface corrosion (minor pitting)	Very poor condition of coating	Optional
5	Large area of exposure	Significant corrosion	Significant level of pitting	Required

Survey Outputs:

- Visual observations
- Pit depth measurements
- Wall thickness measurements (if any)
- Locations of connection and earthing
- Photographic records
- Details to be submitted in Walk over Survey/Site visit Report.

4.2 Coating Defects Survey

This is performed essentially along electrically continuous mains by impressing an electrical signal into the pipeline (at a fitting or exposed pipe section), and measuring the diminution of the signal from above the pipeline at regular short distances (say 5-10m) intervals along the length of main investigated. This is shown schematically in the following diagram.

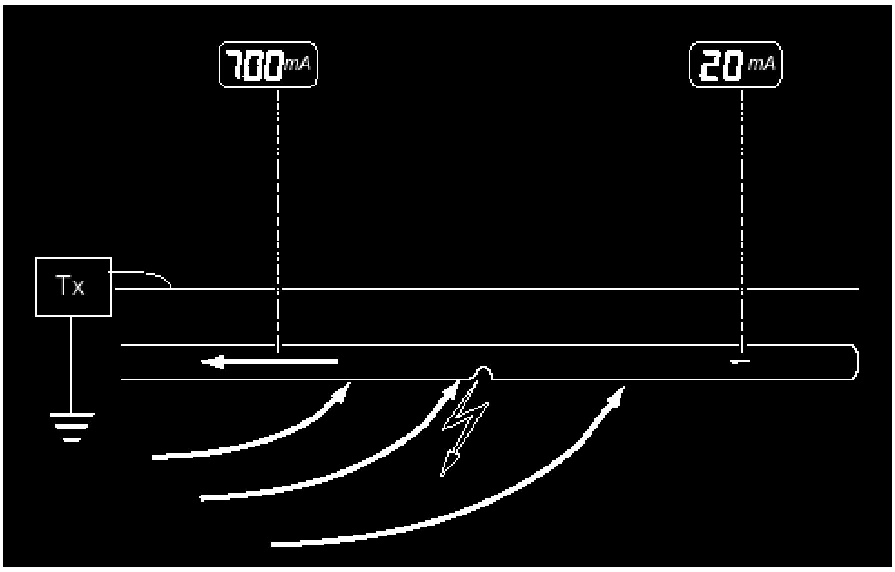


Fig. 4.1: Schematic of coating defect survey

In case of significant current loss identified during the CDS, defect(s) are to be suspected. The crew will return to the point of suspect of defect and perform a confirmation survey by CDS and may also with the A-Frame for lost current measurement.

Electrical continuity is verified by the input of a signal at a proposed access point. The receiver of the CDS Pipe Current Mapper detects this signal. The main is then said to be electrically continuous for this section and measurements can be taken within it.

CDS testing requires the following:

1) Distance between defect and attachment location shall be greater than 20m;

2) Ideally no other off-take/connection or congested utility within the testing distance.

3) When off-takes/connections or congested utilities present, the signal may be interfered and the result may be affected. In such case, data from nearby areas will be interpreted and likelihood will be constructed based on the available data.

Survey output:

- General condition of coating along survey length.

- Estimation of average soil contact area.

- Location of large defects (where practical).

Note: Expected life expectancy may be provided only when there is sufficient data collected by various methods including CDS, soil sampling, stray current, etc.

Limitation of the survey:
The pipeline needs to be

1) Electrically continuous (welded joints);

2) Buried;

3) Coated with insulated material;

4) Physically/electrically separated from other pipelines or metal objects.

If the metal pipeline is not coated with insulated coating, but encased in concrete, the signal will also “flow” into the surrounding environment. This commonly occurs at bends. Also, the technique may not be capable of differentiating the conditions of two parallel pipelines which are interconnected and in close proximity to each other.

Further limitations include lack of reliable information at bends, due to signal distortion and absence of insulated coating.

There may be some areas/sections of mains which are difficult to obtain an electrical signal due to many other more conductive paths.

4.3 Soil Sampling and testing

Soil samples of approximately 250g will be obtained from convenient areas as close as practicable to the pipelines. These will be obtained by hand augering (if possible) or by opportunistic procurement at close-by excavation sites. Samples will be taken with minimum disturbance from surrounding areas.

The soil will then be sent to laboratory for experiment. One of the techniques for soil sampling is Linear Polarisation Resistance (LPR) technique. The polarisation resistance is determined by calculating the change of potential of a working electrode with respect to the impressed current (dV/dI). In general terms, the higher the polarisation resistance; the less corrosive the soil is.

A 1m x 1m x 1-1.5m pit will usually be excavated. A pit depth greater than 1.5m requires a temporary work design. This will be created and checked by the Independent Checking Engineer (ICE).

Linear Polarisation Resistance

Linear Polarisation Resistance (LPR) soil testing is an electrochemical laboratory technique that analyses soil samples obtained from place as close as practicable to the buried main. It is cost-effective and non-invasive and is utilised to determine the overall external condition of the pipeline. The original output of an LPR analysis is the estimated pitting rate of a length of pipe in close proximity to the soil samples site. In the case of coated mains, the results need to be used in combine with a measurement/estimation of the condition of the external coating.

Soil samples will be acquired from place as close to the main as possible (this is particularly important when introduced backfill is used). All sampling locations shall be recorded at the time of extraction.

Soil obtained at pipe depth is specially prepared, and then put into a cell between two electrodes. Direct current is applied at an increasing magnitude in both the positive and negative directions, and the resulting change in potential is measured against a reference electrode. The greater the "resistance", the less corrosive is the soil. A strong correlation exists between the polarisation resistance and the maximum pitting corrosion rate of bare pipe. Initial results obtained are polarisation resistance values, Rp, a measure of soil corrosivity, expressed as ohms per square centimetre. These are then transformed into pitting rates. The value of maximum pit depth exhibited by a pipe is obtained from a combination of the empirical relationship between the pitting rate of unprotected cast iron and Rp, age of main, original pipe wall thickness, and area of bare pipe on coated main.

Survey output:

- Polarisation resistance, Rp, in ohms/sq.cm;
- Pitting rate in mm/yr

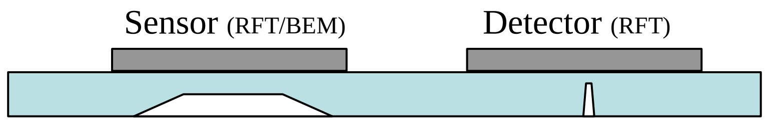
4.4 Pipe Wall Thickness Measurement

Ultra Sonic Testing, Remote Field Technique and Broadband Electromagnetic are methods to measure the pipe wall thickness.

The resolution of UT is better than BEM or RFTM electromagnetic techniques. Essentially, EM techniques determine the extent of general corrosion over a larger area. In case of coated and lined steel fresh water mains, this information is considered to be of limited value, due to the scarcity of internal corrosion, and obvious occurrence of external corrosion, which is more appropriately measured using direct measurement techniques. However, in case of salt water mains, the failure data strongly suggests that internal pitting corrosion has caused a substantial proportion of failures, and therefore needs to be investigated in a more focused and intensive manner.

In order to acquire data over a segment of pipe wall, it is proposed to measure the wall thickness of individual 50mmx50mm squares for a grid arrangement to the whole circumference of a pipe body with an approximate length of 1m under normal circumstance. This data can then be successfully extrapolated over much longer length in order to determine the maximum pit depth and the thinnest pipe wall for the length of pipe. In turn, this data can be used in conjunction with other readings (minimum of 3 per main for salt water mains or at a distance of 2-3km per point for salt water mains) to determine the pitting distribution over longer lengths of pipe. For fresh water mains it is proposed to ascertain wall thickness measurements at a minimum rate of 1 per main, or 1 per 2-3km for fresh water mains.

E-M



E-M will measure the average % change of wall thickness over the area measured. Will not measure the small deep defect

Fig. 4.4.1 Schematic of RFTM and BEM Inspection Techniques showing resolution of internal defects/corrosion

UT

With internal defects

UT will measure the time for the wave to be reflected as 0.000001961 s ; this in turn will be transformed to a distance by using the speed of sound in steel of 5100m/s to give 5mm. It's capable of determining the actual profile

UT will measure the time for the wave to be reflected as 0.000001961 s ; this in turn will be transformed to a distance by using the speed of sound in steel of 5100m/s to give 2mm. It's capable of determining the actual profile

Fig. 4.4.2 Schematic of UT Inspection Techniques showing resolution of internal defects/corrosion

Pipe Preparation and Repair

In order for the measurements to take place, the coating needs to be removed from the pipe for an area slightly greater than which is to be inspected. Then measurements are conducted and recorded for each 50mm square in a systematic grid like pattern – as shown below.

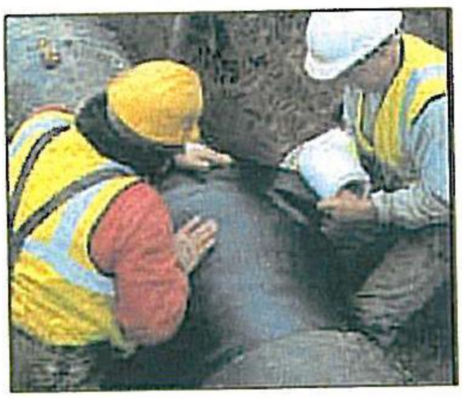
	1	2	3	4	5	6	7	8
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Fig. 4.4.3 Grid pattern for IUT Measurements

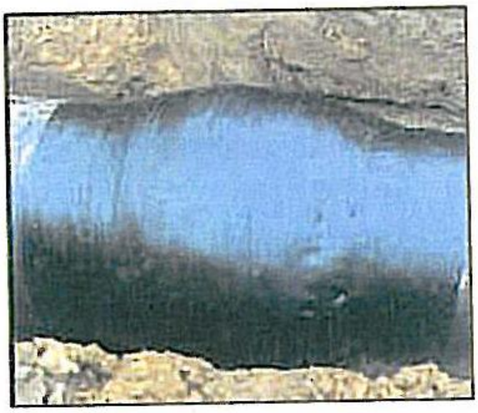
Repairing by Coating Tape

Following the completion of the measurements, the pipe surface will be restored/ repaired according to the following categories:

When a section of pipe originally coated with bitumen is completely removed from the whole body of its circumference, coating tape will be used.



Picture 1: Wrapping in process



Picture 2: completed wrapping

Repairing by Bitumen

When a section of the pipe originally coated with bitumen and being partially removed coating, bitumen will be used with details as shown in the following steps:

1) Trim off bare area with hand tools

2) Check again the extent of coating removed/ bare metal. Remove all lining or rust at the area using grinder or wire brush until bare-metal surface.

3) Apply bitumen primer. Ensure there is no gap between the repaired portion and the existing lining.

4) Apply bitumen to the affected area. Ensure there is no gap between the repaired portion and the existing lining. Make good (smooth) the surface and allow to dry.

5) Backfill the pit for re-instatement.

Note: The bitumen will be heated using LPG until it is relatively soft to be applied using scraper to evenly spread out. As the quantity of the bitumen material to be used for local repair purpose is minimal, the process will have no significant adverse effect on the environment.

Limitations

- UT has the best resolution, but needs direct contact. The condition of the other parts needs to be interpolated by the point measurements.

- UT measurements occur in real time, whereas RFTM measurements need to be determined by extensive special analysis techniques.

All NDT techniques are comparative techniques – whether it is UT (ultra Sonic), RFT (Remote Field Technique) or BEM (Broadband Electromagnetic). In case of UT, if the material structure is constant – mild steel – then the machine can be calibrated using a small sample of the same material – as it relies on the speed of sound in steel. This is much more difficult for the Electromagnetic techniques – RFT/BEM. Essentially, they measure relative wall thickness – presumably 100% original wall thickness. UT requires direct access to surface, whilst BEM/RFT can be used over coating/lining. Both BEM and Mainscan require the original wall thickness to process data. They each need to be calibrated for increased accuracy. The method of operation, stationery vs. moving, has nothing to do with the accuracy.

UT has the best resolution so far – but a smaller inspection area. Ideally, if EM techniques are used without access to a free surface (which will normally be the case with in-situ mains) then 100% of wall thickness needs to be either estimated or measured using UT.

Survey output:

- Wall thickness in mm
- Percentage of remaining pipe wall. (100% when a pipe is relatively new)

4.5 Stray Current Monitoring

Stray current corrosion is one of the major causes for failures of water mains. Stray current corrosion is caused by uncontrolled electrical current from extraneous sources through unintended paths. If current passes in and out from a metal pipe, an electrolysis cell is set up. As a result, the area where positive current exist is forced to react as an anodic site. This may lead to rapid consumption of the metal and causes the local corrosion reaction on the pipe wall. The amount of metal lost from corrosion is directly proportional to the amount of current discharged from the affected pipeline. [4] In Hong Kong, the common sources of stray currents include electric railway system, catholic protection of nearby pipelines and DC-driven elevators, etc. The stray current measurements were performed by measuring pipe-to-soil potential, using a high capacity digital Data Taker data logger and copper-copper sulphate electrode according to BS EN 50162:2004.

This is to be performed at a number of locations by measuring pipe-to-soil potential, using a data logger and copper-copper sulphate electrode.

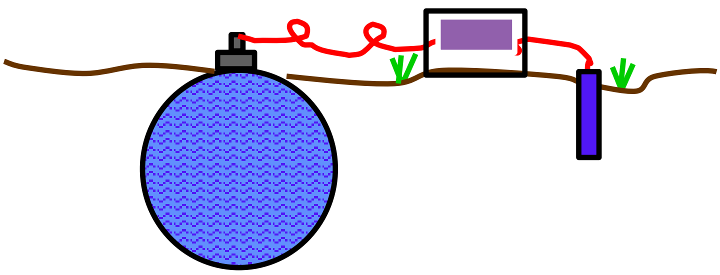


Fig. 4.5.1: Schematic of stray current monitoring

Limitations of the technique include inability to quantify the level of current passing through the pipe. To determine this, it is necessary to modify the testing procedure. If present, interfering catholic protection systems will need to be turned on and off during the period of testing.

Survey Outputs:

- Pipe to soil potentials in a certain period of time
- Qualitative assessment of likelihood of stray currents.

4.6 Utility Survey (US)

Utility mapping can be done by Electromagnetic Utility Detection or Ground Penetrating Radar (GPR).

Electromagnetic Induct Utility Detection

The method of electromagnetic induct utility detection involves the use of a hand-held detector (pipe and cable locator), which detects the magnetic fields of the buried utilities, and a portable signal generator. The locator can only detect metallic cable or pipes with wires laid along as the detection bases on the signals generated by the alternating current. For non-metallic pipes, a transmitter such as a sonde can be inserted in the pipes for detection.

Passive detection involves only the receiver (locator). It detects passive signals that naturally present on the conductors. This method is fast and convenient but inaccurate because the passive signals may be weak and may change without notice.

Active detection involves the use of both receiver and transmitter. The transmitter produces active signals to the pipeline so that the receiver can trace the pipeline. There are basically three methods for conducting active detection, direct connection, signal clamping and induction.

Direct connection is one of the most effective methods to trace the pipes. Pipes can be traced by completing a circuit. The transmitter shall contain two leads, the red lead and the black lead. The red lead is connected to the pipe directly or to an access point such as a valve or meter. The circuit is completed by connecting the black lead to the ground. Ground rod placement (the black lead) shall be as far away from the trace path as possible and at right angle to the path. The pipe alignment and depth can then be located. The method of signal clamping is clamping a signal clamp round the pipe. The signal from the transmitter is applied to the pipeline so that it can be detected on either side. This method requires excavation to reach the pipe. The method of induction requires no access to the pipes. The transmitter broadcasts signal into an area so that the receiver can locate the pipe. The transmitter shall be placed on the ground over the cable to be located and in line with the cable path. Adjust the frequency of the transmitter until the receiver detects the pipe. However, this method is used when the area has no other buried conductors or when all buried conductive services are to be located.

Methods mentioned above are applicable to metallic pipes and non-metallic pipes with tracer wires. For non-metallic pipes, a sonde transmitter can be employed. Sonde is a small self-contained signal transmitter designed for inserting into a non-metallic ducts, drains or sewers so that it can be located and traced with a receiver. Further information can refer to Guide to Utility Survey (UTI).

After the receiver has located the pipeline, the operator shall identify the pipe alignment with temporary markings.

Ground Penetrating Radar (GPR)

GPR is a trenchless method for locating pipes. The GPR transmits pulse into the ground and the pulse is reflected if there are buried utilities. It detects the features and depth of the utilities and is capable of distinguishing different services in congested areas. Different frequencies shall be used to detect different services. Normally, conduits of all materials can be detected. Higher frequency shall be used in the detection of cable while lower frequency shall be used in the detection of sewers and water mains. Details concerning the principle and use of GPR can be referred to Guide to Ground Penetrating Radar Survey (UTI).

By using the above methods, the accuracies given below shall be achieved. Underground services shall be located continuously and recorded in three dimensions not exceeding 5 meters in discrete areas or at intervals not exceeding 10 meters for survey along the road, and at each surface feature, change of direction and bifurcation.

The position and level of locatable services, at the recorded points and intervals defined above, shall be related to grid control points and bench marks to better than ±100mm root mean square error on the ground. 90% of a representative sample of points on locatable services shall be within ±165mm or 0.1d (depth) whichever is bigger. For any known underground service that cannot be investigated to such accuracies, except by excavation, they shall be defined as "unreliable". "Specification for Utility Mapping by Non-destructive Methods" proposed by HKIUS provides detailed requirements regarding the survey works.

Opened manholes/pits will be fenced off from pedestrians for works both on the foot paths and on the carriageway. Locations and depths of utilities identified on site will be marked by spray paint and be recorded by total station by a land survey officer.

Survey output:

- Drawing in DWG/DGN/IDMS format.

- Text report describing the site condition, findings and special issues related to the site.

- Report and drawing will be checked and endorsed by M/FHKIUS (US(PCL)).

4.7 Water Leakage Detection

WLD will be carried out by trained personnel (A/O/M/FHKIUS). Leak Noise Correlation (LNC) will be used to localize the suspect leak location and Electronic or Mechanical Listening Devices (ELD/MLD) will be used for confirming the position of the suspected leak.

LNC will be set up between two contact points (valves, exposed pipe sections). Each point is connected to a transmitter. These points shall usually be less than 1000m apart. A signal receiver as well as sampling machine will be used to collect data regularly and a leak will be suspected when a peak is found by the machine. Peaks may be due to any constant frequency which may be a leak or a regular signal from a nearby source such as a transformer room or pump room. Background noise usually will not affect the result.

Mechanic Leak Detectors are passive devices including listening stick and geophone. Manual listening of leak noise is involved in these methods. The accuracy highly depends on the experience of the operators. Therefore, qualified and experienced personnel shall be employed. Sometimes contractors may too rely on LNC Survey, MLD is employed to pinpoint the leak location based on the result of the LNC Survey.

Survey Outputs:

- Location plan showing the survey extent and any suspected leak.

- Text report with progress photographs describing the site condition, findings and any special issues occurring on site.

4.8 Conduit Condition Evaluation (CCTV &/or ME)

A CCTV inspection is designed to ascertain the condition of the water main to provide data assessing:

1) The structural integrity of the pipeline system

2) The service condition of the pipeline system

3) The possible cause and effect of any extraneous water infiltration/ exfiltration to/ from the pipeline system

4) The location and extent of the expedient connections to the pipe line systems

In normal circumstances, CCTV inspection is used for pipe diameters up to and including 2100mm. We may use the pull-in for pipe diameter up to and including 150mm, use 4-wheel tractor for pipe diameter bigger than 150mm and up to 450mm, use big tractor for pipe diameter bigger than 450mm.

If there are sediments or grease that obstruct the pipe and so investigation, drain cleaning may be required. Usually, better result can be yielded after cleaning the drain. However, it is not a must unless instructed by the Client or Engineer after the initial survey.

The crew will place the camera cable drum at the start point and connect the cables. Whilst this is under way, the Crew Leader (O/MHKIUS) will be inputting the inspection header information onto the monitor screen and loading the videotape into the video recorder. The following information will be displayed:

a. Customer name
b. Location of inspection (Street Name etc.,)
c. Date of inspection
d. ST No. to FH No.
e. Pipe Size
f. Pipe Material
g. Pipe Duty
h. Direction of Survey i.e., up stream/ down stream
i. Date
j. Tape No.
k. Page 1 information will be at the beginning of the tape only.
l. Page 2 information will be at the beginning of each survey. No mixed information will be on any one tape unless specified by the customer. This means that foul water and storm water will be on separate tapes.

The crew will connect the camera unit to the main cable and mount the camera on the skid / tractor. The Crew Leader will then test the camera, camera lights, camera focus and the tractor unit to ensure all things are in working order, and also undertake the relevant tests.

The information obtained in a CCTV inspection very much depends on the quality of image captured, thus the machine has to be checked everyday to ensure they are working in good condition. The checking includes monitor test, camera test and cable calibration. The image's quality check can be performed with a Marconi Resolution Chart Number 1. For cable calibration, a minimum of 30m of cable shall be checked.

If the camera is to be winched through the pipeline, the crew will have passed the towing line through the pipe from the U/S, D/S access point and connected this to the camera skid. The pipe diameter will have been measured and the camera height adjusted on its mount to ensure that the camera lens is in the centre of the pipe axis. When all tests have been completed, the camera is inserted into the pipe run and the slack is taken out of the main cable.

The CCTV monitor shall comprise an automatically updated record in meters and tenths of meter of the meterage of the camera position from the cable calibration point, which is also called "adjusted zero". Normally, the zero position is set in the manhole, so that the pipe end connecting the manhole is captured to identify the exact physical location of the zero position. The accuracy of the measurement shall be within 1% of total length or 0.3 m whichever is greater.

The camera shall be positioned in the correct position to avoid image distortion. In circular or regular shaped sewers/drains, the camera lens shall be positioned at the centre. In oval/oviform sewers the camera lens shall be positioned at a distance two thirds of the height or the vertical dimension of the sewer/drain and vertically above the invert. A positioning tolerance of ±10% of vertical pipeline dimension shall be allowed. Normally, the camera lens shall be positioned looking along the axis of the pipeline. In case when the pipeline is very large, camera will be elevated on a tractor. The travel speed of the camera in the drain shall not exceed:

- m/s for sewers/drains of less than 225 mm in internal diameter (ID);

- 0.15 m/s for sewers/drains greater or equal to 225 mm ID but less than or equal to 300 mm ID;m/s for sewers/drains greater than 300 mm ID; or

- Other agreed traveling speed as long as it will enable all details to be extracted from the video tape recording

The Crew Leader will note all defects and will take photographs of major faults by utilizing digital "Video print" photography and each photograph is numbered consecutively for each survey.

At the end of each survey, the Crew Leader will end the survey by entering information that shall be entered on page 3, stating the IDS manhole number and the total drainage measured on the counter. This procedure is used for each survey, a survey being from MH to MH. At the commencement the next survey the meter counter is reset to zero.

On completion of the full survey, the videotapes are brought back to the office where the information is compiled into a report using either computerised operations or the standard report format. The format is defined in the Conduct Condition Evaluation Codes, HKCCEC, 2009 of UTI and compatible with Manual of Sewer Condition Classification published by the UK Water Research Council. The computer version displays the same information but in a different layout.

For pipelines over this size or under abnormal circumstances, In Conduit Photography (ICP) by Man-Entry Survey will be introduced, leading to a higher risk. More qualified operators are needed and so it will be higher in cost.

Survey output:

- The general condition of lining (if any) for the lengths inspected
- Qualitative estimate of extent of tuberculation/internal corrosion
- Assessment of pitting beneath tuberculation
- Conduit Condition Evaluation (CCE) in accordance with HKCCEC 2009, UTI.
- On site coding sheets by trained operators (A/O/M/FHKIUS)
- CCE report to be drafted by IDMS and be checked by M/FHKIUS(CCE(CCTV&ME)).

5. POST-SURVEY DATA PROCESSING

5.1 Analysis and Evaluation

The data obtained from the NDT testing will be used to determine the Probability of Failure and "Life" of each of the two mains. This will be achieved through utilisation of proprietary deterministic algorithms – Envirostat and PipeFail. This analysis considers the effects of pressure, age, soil environment, presence of stray currents, and coating condition.

A pipeline is exposed to a highly variable environment, and it is usually inappropriate to utilise a single or limited number of measurements without spatial extrapolation along the entire length. However, such an extrapolation can only be conducted within the same stratum or sample space. For example, a measurement or assessment conducted on an above ground pipeline cannot be meaningfully extrapolated to buried sections.

As a consequence, Envirostat is the spatial extrapolation of a physical quantitative measurement, such as remaining wall thickness, pit depth, or polarisation resistance (Rp) from a relatively small number of measurements to along an entire stratum, to obtain the minimum wall thickness or maximum pit depth, or minimum Rp.

The output from this process is an extreme value, plus a distribution of pitting rates or wall thicknesses for the entire stratum. The extrapolation also takes into account the lengths of individual pipes, the sampling distance, total length of pipeline stratum and coating condition.

PipeFail is a series of algorithms that are deterministic models to estimate the time to failure or probability of failure from a physical measurement (primarily using remaining wall thickness). In simple terms, the probability of failure of a pipe is a function of remaining wall thickness, internal loading and external loading.

The algorithm takes into account the type of pipeline material (e.g. mild steel, ductile iron, grey iron) and models the behaviour of this material when subjected to internal loads (hydrodynamic and hydrostatic) as a function of age, remaining wall thickness and pipe diameter. It primarily estimates the thickness at which failure will occur for the various pipe materials. This relationship is shown schematically in the Fig. below.

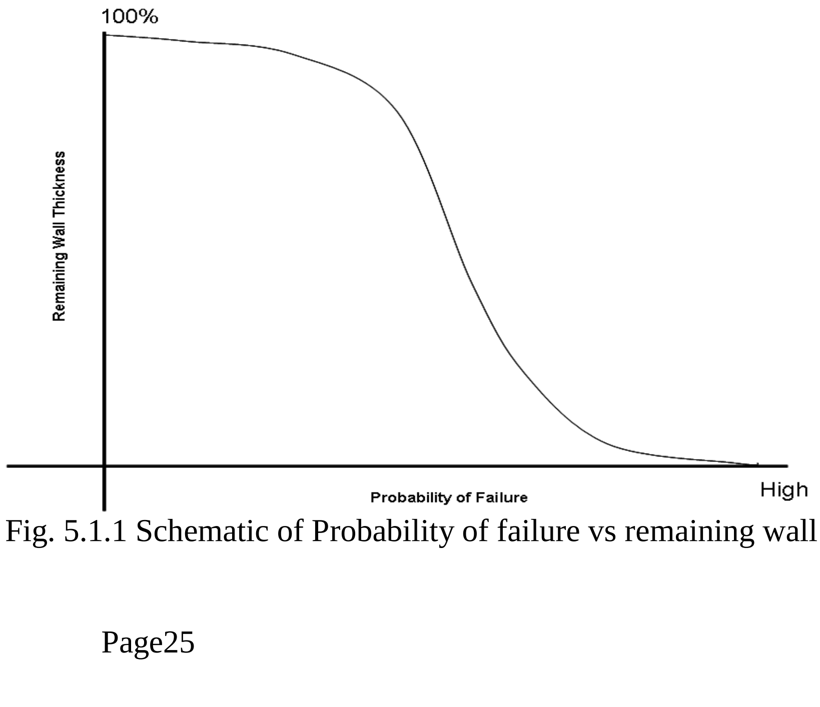


Fig. 5.1.1 Schematic of Probability of failure vs remaining wall thickness

PipeFail is invariably used in combination with Envirostat results.

The combination LPR-Envirostat-PipeFail technique has been tested in South East Water in Melbourne by comparing actual failure data with predicted failure data for 31 rising mains. The prediction of failures to date was correct in 24 cases, representing a successful prediction rate of 77%. Factors contributing to the variation include insufficient number of samples (e.g. 1 sample per 500 m, or only 2 samples per pipeline).

The PipeFail algorithm has undergone substantial development since conducting these studies. In 2001, a detailed comparison was performed between predicted failures using combination LPR-Envirostat-PipeFail technique and actual recorded failures for six DN500 cast iron mains in the Hunter Water region. Excellent agreement was obtained for all pipelines.

PipeFail is a series of algorithms developed by PCA that estimates the most likely time to failure of a pipeline or individual pipeline element as a function of:

- Material type
- Remaining wall thickness;
- Age of main;
- Original wall thickness of main;
- Pressure regimes - maximum and variability.

Envirostat utilises Extreme Value Statistics (EVS) to allow extrapolation of wall thickness (pit depth) values beyond individual results to the entire length of main or section of main. It takes into account:

- Sample spacing;
- Length of stratum/main;
- Condition of coating;
- Utilisation of selected backfill.

Utilisation of both PipeFail and Envirostat is depicted schematically in the following Fig..

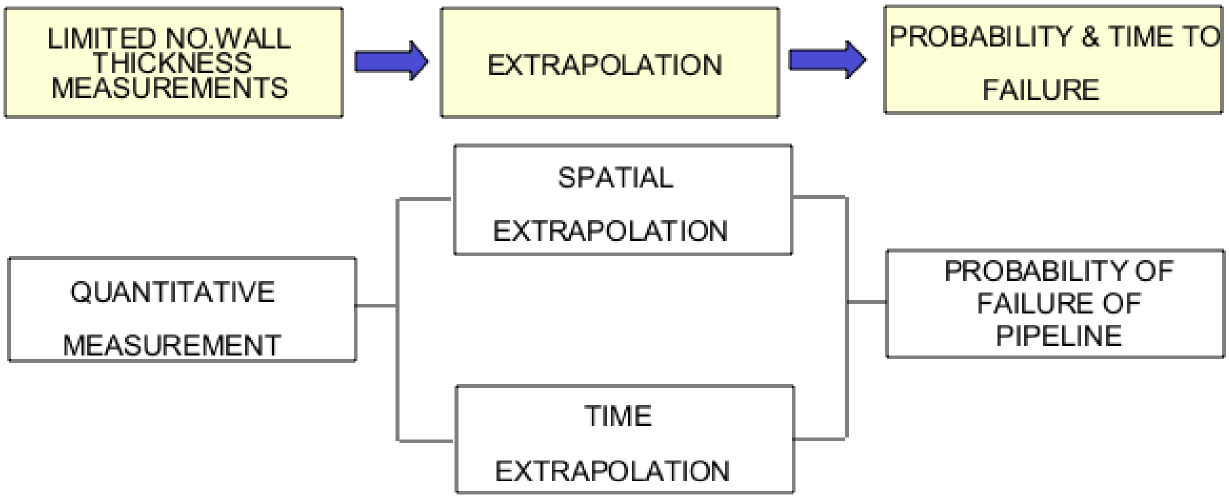


Fig. 5.1.2. Utilisation of the combination of PipeFail and Envirostat.

Probability of failure values are generated using the PipeFail algorithm on the basis of the empirical condition data and the Envirostat spatial extrapolation of condition. Probability is reported for a main or section of main, as "annual probability of failure" and is the likelihood of at least one individual pipe length belonging to that section of pipeline failing in a 12-month period. Failure is defined in this report as occurring when the pipe is no longer capable of sustaining its normal operating pressure. It does not include leaking lead joints, or failures due to externally applied mechanical loads, such as soil stress, or traffic loading.
The probability of failure is directly related to the expected time between failures by the relation:

$$T = \frac{1}{P}$$

where
T is expected time between failures
P is annual probability of at least one failure.

Graphical outcomes from this process include Probability of Failure as a function of age, and expected Failure Regime, also as a function of age.

The probability of failure data depicts the likelihood of failure of a pipe length within the entire main or section of main. Values greater than 0.1 or 10% can be considered as very high, with an expected failure within 10 years. The probability of failure is determined by considering the extent of corrosion through the wall of the pipe (remaining wall thickness), type of material, and pressure regime. Different failure algorithms exist for grey cast iron, ductile cast iron and mild steel.

Failure regimes are formulated when failures are likely to occur, and shall be used only as a guide to compare performance of pipelines.

It is intended to produce a series of Preliminary Reports for each main as inspections and analyses are completed. For instance, initially an estimation of soil conditions will be imposed with the results from CDS inspections to provide an initial estimation of condition of the pipeline. This estimation will possibly change as a consequence of new additional data from soil corrosivity.

In summary, the CDS survey determines the condition of the coating, and an estimate of the extent to which the pipe is exposed to the surrounding soil. In order to estimate the performance of the pipe from this survey, it is required that the following estimates are incorporated into the analysis:

1) Original pipe wall thickness (in absence of measurement assume BS value);

2) Distribution of soil conditions (into 3 possible categories – non-corrosive, moderately corrosive and corrosive);

3) Pressure regimes into 3 categories (high, medium and low);

4) Extent of internal corrosion – can be estimated with fresh water mains, but probably needs to be determined with salt water mains;

5) Effects of stray currents (assumed negligible in absence of data); and

6) Age of main

Based on the findings of the desktop evaluation and field survey measurement(s) as described in sub-clauses (a) to (e), the Specialist Contractor shall complete a report, which shall cover the following:

a) Assessment and analysis of the survey and testing results;

b) Interpretation of the results as graphics and text;

c) Assessment and analysis of pipeline condition;

d) Determination of reasons for defects, bursting, leakage and any other failures;

e) Assessment of corrosion rates, and prediction of the remaining life of the pipes, and the probability of failure by use of statistical models;

f) Provision of necessary assessments, analyses and predictions to facilitate development of a rehabilitation and replacement plan for the pipeline.

g) Presentation of the findings in the Final Condition Survey Report.

REFERENCES

1) Water Service Department, Report on condition survey, Agreement No. CE 25/2006(WS) Replacement and Rehabilitation of Water Mains Stages Mains in Kowloon Investigation, Design and Construction, Atkins China Ltd, 2008.

2) W. Peabody, Control of pipeline corrosion, National Association of Corrosion Engineers, Houston, Texas, 1978.

3) Balvant Rajani and Jon Makar, A methodology to estimate remaining service life of grey cast iron water mains. Canadian Journal of Civil Engineering Vol.27:1259-1272, 2000.

4) Fergusion, P.H. and Nicholas D.M.F., External Corrosion of Buried Iron and Steel water mains, Corrosion Australasia, Vol. 17. No. 4, Australasian Corrosion Association Inc. Melbourne Victoria. 1992.

5) Hay, L, The Influence of Soil Properties on the Performance of Underground Pipelines. Department of Soil Science University of Sydney

6) Ian Vickridge, Stephanus Shou, and Phil Ferguson. Pipeline Condition Assessment in Hong Kong, 24th International No Dig Conference, Brisbane, 2006.

7) P. Cheung, K. Moody and D. Wong, Design of Stray Current Corrosion Control System for the Lan Tau and Airport Railway, Annual Conference of Institute of Corrosion, Gatwick, United Kingdom. 1997.

8) Richard W. Bonds, Stray current effects on ductile iron pipe, Ductile Iron Pipe Research Association, 1997.

9) Water Supplies Department of HKSAR, Replacement and Rehabilitation Programme of Water Mains [online]. Available: http://www.wsd.gov.hk/tc/html/edu/rehab/index.htm [accessed 10 December 2008]

Appendix A: Abbreviations

Company/ Organization	
Code	Description
BD	Buildings Department, HKSARG
CEDD	Civil Engineering and Development, HKSARG
DSD	Drainage Services Department, HKSARG
EMSD	Electrical and Mechanical Services Department, HKSARG
EPD	Environmental Protection Department, HKSARG
HA	Hong Kong Housing Authority, HKSARG
HKIUS	Hong Kong Institute of Utility Specialists
HKURC	Hong Kong Utility Research Centre
HyD	Highways Department, HKSARG
LandsD	Lands Department, HKSARG
LD	Labour Department, HKSARG
PolyU	The Hong Kong Polytechnic University
UTI	Utility Training Institute
WRc	Water Research Centre
WSAA	Water Services Association Australia
WSD	Water Supplies Department, HKSARG
WTI	Water Training Institute
Others	
Code	Description
%	Percentage
BMP	Bitmap (Picture Format)
BWCS	Buried Water Carrying Service
CCE	Conduit Condition Evaluation
CCE(CCTV & ME)	Conduit Condition Evaluation(Closed Circuit Television & Man- Entry)

Company/ Organization	
CCES	Conduit Condition Evaluation Specialists
CCTV	Closed Circuit Television
CD	Compact Disc
CL	Cover Level
COP	Code of practice
CP	Competent Person
DN	Nominal Diameter
DP	Design Pressure
DVD	Digital Versatile Disc
e.g.	Exempli Gratia
GIS	Geo-Information System
EPR	Environmental Protection Requirements
etc.	et cetera
GL	Ground Level
H	Height
HKCCEC	Hong Kong Conduit Condition Evaluation Codes
HPWJ	High Pressure Water Jetting
hr	Hour
Hz	Hertz
ICG	Internal Condition Grade
ID	Internal Diameter
IDMS	Integrated Data Management System
IL	Invert Level
ISO	International Standards Organization
JPEG	Joint Photographic Experts Group (Picture Format)
kHz	Kilo- Hertz
kPa	Kilopascal

Company/ Organization	
m	Meter(s)
ME	Man Entry
MHICS	Manhole Internal Condition Survey
mm	Millimetre(s)
Mpa	Megapascal
MPEG	Motion Picture Experts Group (Video Format)
MS	Method Statement
MSCC	Manual of Sewer Condition Classification, UK
OHSAS	Occupational Health and Safety Assessment Series
PPE	Personal Protective Equipment
ppm	Parts per million
PS	Particular Specification
PSI	Pound Per Square Inch
QA/ QC	Quality Assurance/ Quality Control
Ref.	Reference
RMSE	Root Mean Square Error
RPUS	Recognized Professional Utility Specialist
RTO	Recognized Training Organization
SCG	Service Condition Grades
SOPs	Safe Operator Procedures
SPF	Sun Protection Factor
SPG	Structural Performance Grade
SRM	Sewer Rehabilitation Manual
STP	System Test Pressure
TTA	Temporary Traffic Arrangement
US	Utility Specialist
VHS	Video High Speed

Company/ Organization	
W	Width
WLD	Water Leakage Detection
WO	Works Order
WP	Work Procedure

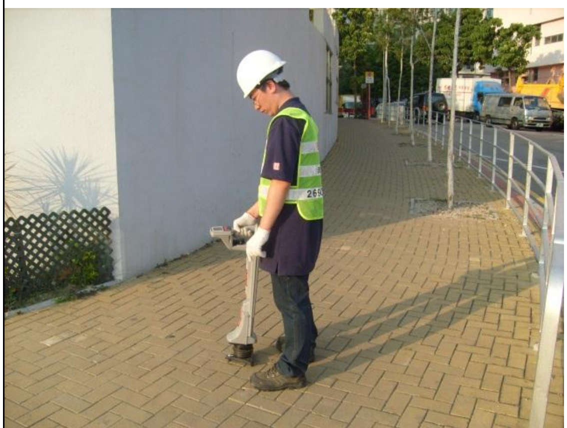
Appendix B: Related Photos

A: Large bare area at joint.

B: Ultrasonic thickness measurement at bare joint area


C: Pipe Wall Thickness Measurement in progress.

D: Coating defect survey set up.


E: Coating defect survey in progress.


F: Soil samples.

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Guideline Amendment Form

Please fill in the following form if any error or mistake is found in this manual. We thank for your support and appreciate your continuous help in improving this manual.

Discipline*	Page No.	Description of Existing Content	Suggested Amendment

* A. Conduit Condition Evaluation (CCTV and ME Survey)
B. Manhole Internal Condition Survey
C. Utility Survey (Pipe Cable Locator Survey, PCL)
D. Water Leakage Detection and Control
E. Advanced Leakage Detection of Buried Water Carrying Services Affecting Slopes
F. Pipe Rehabilitation by Trenchless Technology
G. GPR(Ground Penetrating Radar) Survey
H. Flow Study in Drainage Conduit (流量監控)
I. Pipe Condition Surveys by other non-destructive methods
J. Data Management for Utility Records
K. Utility Management
L. Safety

Please fill in your contact information in case follow up is needed.

First Name: ________________ Second Name: ________________ Last Name: ________________

Title: ______________________

Organization: ____

#Telephone No.: ______________________ #Email Adress: ____________________________________

#Address: ____

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\# Please fill in one or more contact information in the blanks provided
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P C S

Professional Service Development Assistance Scheme (PSDAS)
Professional Guide Notes and Pamphlet for utility professionals in Hong Kong
Project ref: Y09-HKIUS-P02-PSDAS